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Assessment of the Implementation of Building Energy Management Systems in Residential Buildings: Property Managers' Viewpoint

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Abstract

The purpose of the study is to assess the implementation of BEMS in residential buildings from the perspective of property managers employing quantitative research methodology and descriptive data analysis. Findings show that adoption of energy management systems is very low. The study found that energy management systems are not really implemented; however, the most implemented energy management system is LED lighting system, which was followed by the home energy management system and energy monitoring tools. Furthermore, energy management systems consisting of smart thermostats, renewable energy management systems, and distributed energy management systems shown are relatively very low in implementation, indicating that most residential buildings holistically are not adopting energy management systems in mitigating high energy consumption. Therefore, these results indicate that there is still a significant gap in energy management knowledge among property managers, as well as an implementation gap. Therefore, this study suggests the need for awareness initiatives, enhanced technical capacity, and policy support to promote the adoption of BEMs in residential buildings.

Keywords
Building Energy Management Systems (BEMS); Residential Buildings; Energy Management Technologies; Property Managers; Technology Adoption

1. Introduction
In the face of rising energy sector demand driven by the rapid rise of the population, there is also a significant rise in emissions; thus, BEMS have emerged as a practical solution in mitigating high energy consumption in the residential sector through monitoring, analytics, and automation, which influences low energy consumption (Ridayati et al. 2026). Raimi et al. (2026) state that buildings globally consume 30% of the global energy consumption, which also

contributes to a quarter of the global greenhouse gas emissions. Furthermore, residential buildings consume one-third of the global energy, which also causes CO_2 emissions, which is problematic for the environment. Global energy frameworks advocate for innovation and automation in residential buildings as a remedy for high energy consumption, which will potentially reduce energy consumption and automatically reduce CO_2 emissions (Karamoozian et al. 2026). ISO 52120 states that digitalization in the residential sector, which can consist of smart thermostats and automated lighting systems, can reduce total building energy consumption and commercial buildings holistically by about 10% between 2017 and 2040 (Walczyk and Ożadowicz 2026). Yet there have been evident benefits of the implementation of BEMS, which consist of lower operating costs, improved comfort and responsiveness, and enhanced demand flexibility (Khafiso et al. 2023; Khafiso, 2024). There have been consistent barriers that affect their adoption, which include perceived complexity and limited user acceptance, privacy and cybersecurity risks, and technical frictions such as interoperability and vendor lock-in that threaten long-term operability (Khafiso et al. 2023; khafiso et al. 2024).

In South Africa, these global issues are refracted through a unique energy and regulatory context: residential energy use is shaped by unequal access and fuel stacking, while policy continues to frame efficiency and controllable demand as complements to generation development. According to South African energy statistics, the residential sector accounts for 19% of the country's total energy consumption as of 2021. Energy in residential buildings is utilized for cooking, heating, and cooling due to dynamic South African seasonal changes in the country, which necessitate heating initiatives during the winter season (khafiso et al. 2025). Therefore this high energy consumption in South Africa contributed to high energy consumption which contributed to high energy demand in South Africa and this contributed to high energy demand that surpasses energy supply in South Africa which contributed to loadshedding to balance demand and supply(Wiese et al. 2024). Thus, this initiative tries to balance demand and supply. This necessitates the implementation of BEMS in residential buildings to address the South African energy challenges. At the same time, Khafiso et al (2024) state that implementation conditions reflect local barriers identified in South African scholarship awareness and skills gaps, funding constraints, and limited incentives alongside governance and compliance issues such as POPIA-aligned data management for smart metering/control solutions and the broader institutional push towards building energy disclosure (EPC enforcement deadlines for large buildings). Against this backdrop, the present study's focus on property managers provides an empirically grounded route to assessing how BEMS is being implemented in South African residential buildings, why adoption succeeds or stalls in practice, and which operational, regulatory, and stakeholder conditions most strongly shape performance outcomes.

2. Literature Review

2.1. Overview of Building Energy Management Systems

The adoption of BEMS in residential buildings has become vital in enhancing energy efficiency and mitigating high energy costs due to high demand. BEMS enable real-time monitoring, control, and optimisation of energy consumption through the integration of sensors, smart meters, and automated control systems (Akbulut et al. 2025). In residential settings, these systems provide homeowners and property managers with detailed insights into energy usage patterns, allowing for informed decision-making regarding energy conservation strategies. Studies have shown that BEMS can significantly reduce energy consumption by optimising heating, ventilation, and air conditioning (HVAC), lighting, and appliance usage, thereby contributing to both economic savings and environmental sustainability (Khafiso et al. 2023; khafiso et al. 2024). BEMS play a crucial role in enhancing the adoption of smart residential technologies and innovation transformation in residential settings through the utilisation of Internet of Things (IoT), artificial intelligence, and data analytics, which enable advanced intelligent energy management systems in residential buildings(Akbulut et al. 2025). For instance, smart thermostats, occupancy sensors, and mobile-based feedback systems enable adaptive control of energy systems based on user behaviour and environmental conditions. This enhances user comfort while simultaneously reducing energy wastage. Furthermore, BEMS facilitates demand-side management by enabling users to shift energy consumption to off-peak periods, thereby reducing strain on the power grid and improving energy reliability (Bakare et al. 2023). Moreover, the application of BEMS in residential buildings supports broader sustainability and environmental goals. By promoting efficient energy use and integrating renewable energy sources such as solar photovoltaic systems, BEMS contribute to the reduction of greenhouse gas emissions and reliance on fossil fuels. In developing countries, including South Africa, the adoption of BEMS also offers solutions to energy challenges such as load shedding and rising electricity costs. Although implementation remains limited, the growing availability of affordable smart technologies and increasing awareness of energy conservation are expected to enhance the uptake of BEMS in residential buildings, positioning them as a key component of sustainable urban development.

2.2. Benefits of Building Energy Management Systems in Residential Buildings

BEMS provide significant energy efficiency benefits in residential buildings by enabling continuous monitoring and optimization of energy consumption. By gathering real-time data and managing systems such as HVAC, lighting, and appliances through computerized controls, BEMS help detect inefficiencies and reduce excessive energy use (Sayed and Gabbar 2017). This contributes to significant declines in electricity usage and utility fees for residential buildings. By regulating energy consumption based on occupancy patterns and environmental conditions, BEMS ensure energy is used only when needed, thereby promoting sustainable living and reducing carbon footprints. Another key benefit of BEMS is enhanced occupant comfort and convenience (Kozlovska et al. 2023). These systems allow residents to maintain optimal indoor conditions by automatically regulating temperature, lighting, and air quality. Advanced BEMS integrated with smart technologies enable remote access and control through mobile devices, allowing users to adjust settings from anywhere (Vermesan and Friess 2013). This level of automation not only improves living conditions but also simplifies daily routines, making homes more responsive to individual preferences and lifestyles. Furthermore, BEMS contribute to improved building performance and long-term asset management. By incorporating features such as fault detection and predictive maintenance, BEMS can identify system failures early and reduce maintenance costs. The integration of technologies like IoT and artificial intelligence enhances decision-making by providing insights into energy usage patterns and system performance. In the long term, this leads to increased property values, extended lifespans of building systems, and better alignment with sustainability regulations and energy-efficiency standards, particularly in modern residential developments.

3. Methods

The study employed a quantitative research methodology and used a questionnaire as the research design. According to Cresswell and Cresswell (2017), quantitative research methodology is a systematic approach to collecting and analyzing numerical data, enabling 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). The questionnaire used a five-point Likert scale to assess the implementation of BEMS, where 1=Never; 2=Rarely; 3=Sometimes; 4=Always; 5=Often. The questionnaire consisted of 26 Building Energy Management Systems, Questions 1 to 3, measuring the demographic background of the respondents. The closed-ended questionnaire was emailed to all property managers managing residential buildings in Bloemfontein, Free State, South Africa. A total of 80 property managers received the questionnaire, but only 43 responded. 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) states that for all practical purposes, if the sample size is relatively large, 30 or more is the standard rule of thumb. The 43 responses also reflect the fact that most managers manage multiple buildings in Bloemfontein; for instance, they manage 4 properties with more than 60 residences in each. Data gathered was descriptively analyzed and

4. Results

4.1. Demographic Data of the respondents

4.1.1. Number of years managing the property

Figure 1 shows that many respondents have relatively limited property management experience, with 58.1% having 1-5 years. 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 to 10 years and 11 to 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.

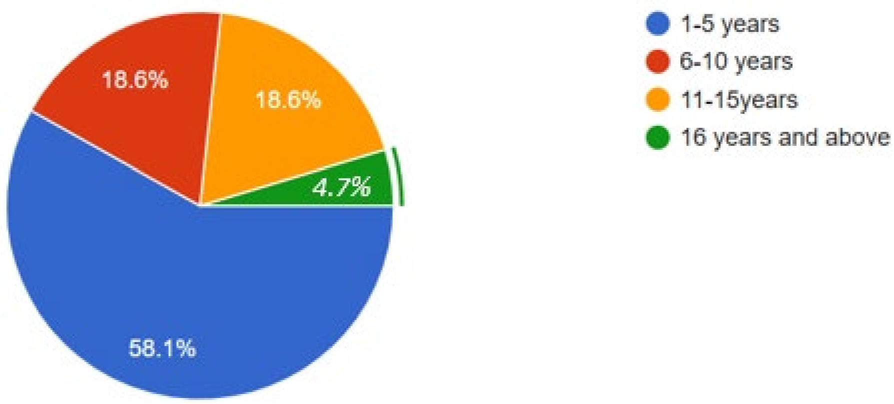

Figure 1. Number of Years of Managing Property (source: Authors)

4.1.2. Energy backup strategies during loadshedding

Figure 2 indicates that most 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.

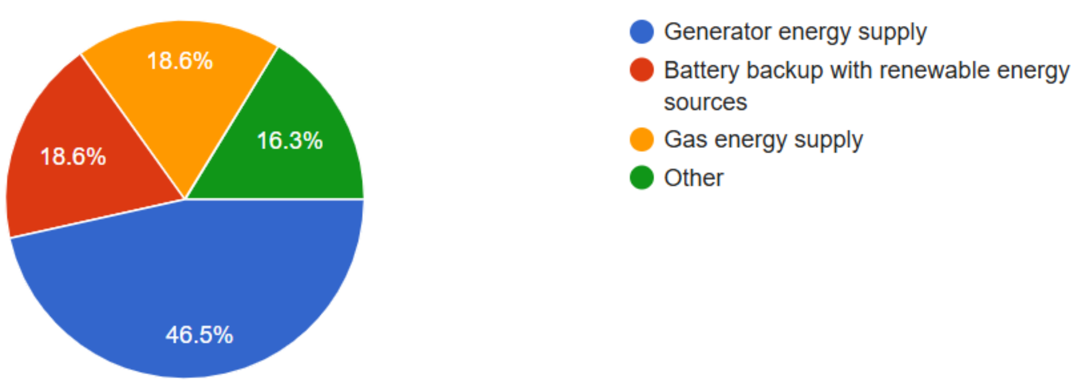

Figure 2. Backup Energy Sources During Power Cuts (source: Authors)

4.1.3. Occupancy Size of the Building Being Managed

Figure 3 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.

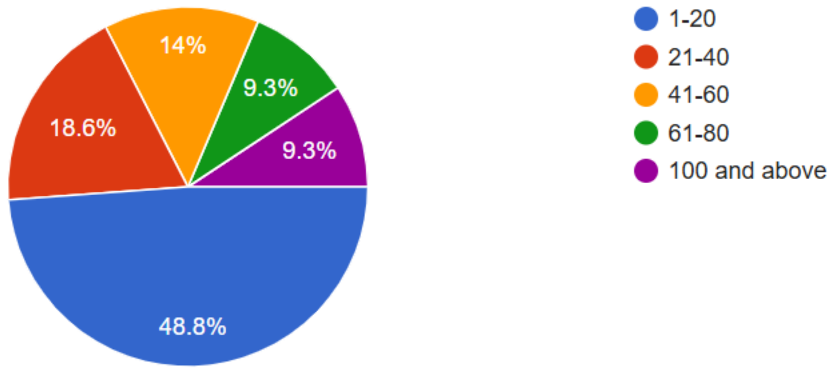

Figure 3. Occupancy Size of the Building Being Managed (source: Authors)

5.2 Building Energy Management Systems

Table 1 lists the BEMS applicable in the residential sector. The study's findings illustrated very low adoption of BEMS in the residential sector in Bloemfontein. BEMS implemented are simple technologies like LED lighting (Mean=2.60; SD=1.348) that are not complex and require few resources. This BEMS is closely followed by Home Energy Management System (mean = 2.16, standard deviation = 1.233) and energy monitors and meters (mean = 2.05, standard deviation = 1.272), indicating steady adoption of these energy management systems. The table further shows low adoption of energy management systems, with means ranging from 1.93 to 1.30, suggesting strong consensus among respondents about their minimal use.

Table 1. Building Energy Management Systems (source: Authors)

Building Energy Management Systems	**Mean**	**Std. Deviation**	**Skewness**		**Kurtosis**		**Rank**
	Statistic	**Statistic**	**Statistic**	**Std. Error**	**Statistic**	**Std. Error**	
LED Lighting Systems	2.60	1.348	0.103	0.361	-1.308	0.709	1.
Home energy management system (residential energy management system)	2.16	1.233	0.714	0.361	-0.567	0.709	2.
Energy Monitors and Meters	2.05	1.272	0.929	0.361	-0.402	0.709	3.
Solar Panel Systems	1.93	1.280	0.994	0.361	-0.337	0.709	4.
HVAC Control Systems	1.86	1.246	1.362	0.361	0.849	0.709	5.
Battery Energy Storage Systems	1.84	1.252	1.238	0.361	0.257	0.709	6.
Building Energy Management System	1.77	0.947	0.847	0.361	-0.548	0.709	7.
Smart Plugs and Outlets	1.74	1.093	1.572	0.361	2.030	0.709	8.
Load Controllers	1.70	1.103	1.425	0.361	0.993	0.709	9.
Mobile-based Feedback System	1.65	1.044	1.684	0.361	2.140	0.709	10.
Smart Thermostats	1.63	1.196	1.742	0.361	1.783	0.709	11.
Renewable Energy Management Systems	1.63	1.070	1.548	0.361	1.436	0.709	12.

Distributed Energy Resource Management Systems	1.63	0.846	1.311	0.361	1.146	0.709	13.
Watt Depot	1.56	1.076	2.069	0.361	3.679	0.709	14.
Energy Efficient Management System	1.56	0.934	1.756	0.361	3.052	0.709	15.
Digital Home energy management system	1.53	1.032	1.881	0.361	2.686	0.709	16.
Hybrid power system	1.51	1.077	2.185	0.361	4.044	0.709	17.
Smart Grid Energy Management Systems	1.47	0.797	1.597	0.361	1.601	0.709	18.
Viridi Scope	1.44	0.881	2.047	0.361	3.248	0.709	19.
Industrial Energy Management Systems	1.42	0.932	2.378	0.361	5.348	0.709	20.
Enterprise Energy Management Systems (EEMS	1.40	0.760	1.565	0.361	0.687	0.709	21.
Pervasive Service-Oriented Networks	1.40	0.849	2.547	0.361	7.175	0.709	22.
Adaptive Living Interface system	1.37	0.725	2.047	0.361	3.797	0.709	23.
Energy Wiz	1.37	0.725	1.653	0.361	1.099	0.709	24.
such as smart home hubs	1.37	0.787	1.979	0.361	2.767	0.709	25.
Microgrid Energy Management Systems	1.30	0.638	1.959	0.361	2.543	0.709	26.

5.3 Statistical Tests

The results indicate statistically significant differences in the level of implementation across the various BEMS, as evidenced by the Friedman test ($\chi^2(25) = 136.818$, $p = 0.000$). This shows that the implementation of BEM systems is not even present in all BEM assessments by the property managers, since most are more commonly used than others. Kendall's coefficient of concordance ($W=0.127$), on the other hand, indicates low consensus among property managers regarding the ranking of BEMS, suggesting that they hold different viewpoints based on their implementation. Apart from this discrepancy, the reliability analysis shows high consistency, with Cronbach's alpha of 0.957, indicating that the measured energy management system data is reliable (Table 2).

Table 2. Statistical tests (source: Authors)

Test Statistics				**Reliability Statistics**	
No. of respondents	43	No. of respondents	43	No of BEMSs	26
Chi-Square	136.818	Kendall's W[a]	0.127	Cronbach's Alpha	0.957
df	25	Chi-Square	136.818		
Asymp. Sig.	0.000	df	25		
		Asymp. Sig.	0.000		
Friedman Test		**Kendall's Coefficient of Concordance**		**Cronbach's Alpha**	

5. Discussion

The findings indicate that relatively basic and widely accessible energy technologies are the most implemented in residential buildings. LED lighting systems ranked highest (Mean = 2.60), followed by home energy management systems and energy monitors/meters. This suggests that property managers prioritise solutions that are cost-effective, easy to install, and deliver immediate energy savings. The relatively moderate standard deviations, coupled with near-normal skewness values, indicate a reasonable level of agreement among respondents regarding the prevalence of these technologies. These findings are consistent with existing literature, which identifies LED lighting and smart metering as entry-level energy efficiency measures due to their affordability and quick return on investment (IEA, 2021; U.S. Department of Energy, 2020; Ramantswana et al., 2026). Furthermore, the adoption of basic home energy management systems reflects the gradual transition toward smart residential environments, where users increasingly seek real-time feedback and control over energy consumption (Darby, 2018).

The second tier of technologies, including solar panel systems, HVAC control systems, and battery energy storage systems, shows moderate adoption. Although these systems offer substantial long-term benefits, their uptake appears constrained by higher capital costs and technical complexity. The positive skewness observed across these variables indicates that responses are concentrated toward lower agreement, suggesting that many respondents perceive these technologies as less prevalent. This aligns with studies showing that renewable energy systems and advanced control technologies, while beneficial, often face adoption barriers related to upfront costs, policy uncertainty, and limited technical capacity, particularly in developing countries (Pérez-Lombard et al., 2008; International Renewable Energy Agency, 2022). Nonetheless, their presence in the mid-ranking positions indicates growing awareness and gradual integration into residential energy systems.

In contrast, advanced and large-scale energy management systems, such as smart grids, microgrids, enterprise, and industrial-oriented platforms, ranked lowest, with mean scores below 1.50. The high positive skewness and kurtosis values in this category indicate strong consensus that these systems are rarely implemented in residential contexts. This is expected, as such technologies are typically designed for commercial or industrial applications rather than individual households. The findings support literature that emphasizes that complex, infrastructure-intensive systems require significant investment, regulatory support, and technical expertise, making them less feasible for residential deployment (Siano, 2014; Lund et al., 2017).

6. Conclusion

In conclusion, the study has shown that the adoption and use of BEMS in residential buildings are very low, which is a major concern, as the resulting high energy consumption is not mitigated. There was low indication of the adoption of LED lighting, energy monitors, and basic home energy management systems, although, when compared to others, which were prevalent, this is a major concern, which may be driven by lack of knowledge, lack of funds, or even unavailability of these BEMS systems locally. Solar energy, HVAC controls, and battery storage have seen increased adoption, but it remains relatively low. Therefore, there is holistically low utilization of the BEMS in residential buildings. Due to South Africa's energy generation being mostly coal-dependent, CO_2 emissions will continue to rise as energy consumption increases, leading to greater coal burning. The study recommends that the government initiate an initiative to upskill property managers and users in Building Energy Management Systems, as the findings indicate that implementation remains limited. There is a significant gap in knowledge of BEMS and actual implementation of BEMS in residential buildings, which needs to be addressed through campaigns and policy frameworks.

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