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Innovations and Opportunities in Commercial Building Energy Efficiency

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Abstract

Energy efficiency is essential for reducing costs and promoting sustainability in commercial buildings. Commercial buildings face many challenges while making their building energy efficient. These buildings often use a large amount of energy, leading to high costs and increased greenhouse gas emissions. As concerns about climate change grow, there is a need to find better ways to save energy in commercial buildings. The research is about how energy-efficient appliances, like LED lights, smart thermostats and motion sensors can help reduce energy use. Also, the behaviour of people working in these buildings affects energy consumption. Even with modern technology, energy can be wasted if people are not aware of how to use these systems properly. Many commercial buildings still struggle with high energy use because of outdated systems, lack of awareness, and inefficient behavior by occupants. One major challenge in commercial buildings is the high initial cost of upgrading to energy-efficient systems. Many businesses hesitate to invest in smart appliances and renewable energy solutions due to budget constraints, even though these technologies offer long-term savings. Better insulation, proper ventilation, and open spaces that allow natural light can reduce the need for artificial lighting and air conditioning. Integrating energy-efficient design from the beginning can lower long-term operational costs.

Introduction and Methodology

Introduction

Energy efficiency is smart use of energy wise, getting the same results while cutting down on waste, costs, and environmental impact. In commercial buildings, high energy consumption leads to rising operational expenses and increased greenhouse gas emissions. This makes energy-saving measures not just a cost-cutting strategy but also a necessity for sustainability. As concerns about climate change and energy shortages continue to grow commercial buildings are increasingly focused on finding ways to reduce energy consumption. While advancements in energy-efficient appliances and smart building technologies have made significant progress, many commercial buildings still struggle with inefficiency. Lack of awareness, and inconsistent occupant behavior often limit the effectiveness of these solutions, preventing them from reaching their full potential.

This study explores the challenges that commercial buildings face in becoming energy efficient, the effectiveness of sustainable appliances, and the role of innovative solutions that combine technology with behavioral changes. By understanding how occupant behavior affects energy consumption, we can

identify practical and cost-effective ways to enhance efficiency without compromising comfort or productivity. Many energy-saving initiatives fall short due to a lack of awareness, inadequate training, or resistance to change. That's why a combination of advanced technology, policy interventions, and behavioral strategies is essential to maximize energy efficiency in commercial buildings.

Statement of the Problem

Commercial buildings use a lot of energy, leading to high costs and greenhouse gas emissions. While sustainable appliances help reduce energy use, their impact is often not understood by many building owners or managers. This study explores how occupant actions affect energy consumption, evaluates the effectiveness of sustainable appliances, and identifies ways to combine technology and behavior change for better energy efficiency. The goal is to find cost-effective solutions, improve occupant awareness, and create strategies that promote energy-saving practices in commercial buildings

Objectives of the Study

- To evaluate the effectiveness of sustainable appliances in reducing energy consumption in commercial buildings.
- To identify the primary challenges faced by the commercial building to make their buildings energy efficient.
- To Evaluate innovative solutions and technologies aimed at improving energy efficiency in commercial buildings.
- To know the relationship between the demographic factors and the factors influencing energy consumption in commercial buildings.

Scope of the Study

This study focuses on identifying the challenges and innovations related to energy efficiency in commercial buildings, with a focus on sustainability, occupant behavior, and the role of energy-efficient appliances. It aims to provide insights into how commercial buildings can optimize energy consumption while maintaining operational efficiency and reducing costs.

Research Methodology

Research methodology refers to the systematic approach and set of methods used to conduct research. Sample size of the study is 58 respondents. Purposive sampling technique is used for the purpose of the study. The Primary data in this study by use of surveys, interviews and observations through structured questionnaire. Secondary data used for this study from books, research papers, online database and previous reviews. The tools used for the analysis are Percentage Analysis, Rank Analysis, Weighted Average Score Method and Chi-Square Analysis.

Limitations Of The Study

- The size of the study was limited to 58.
- The geographical area was within Coimbatore city.

Knowledge Gap of the Previous Study

Author name	Year	Title	Result
Anarene, B.	2024	Revolutionizing Energy Efficiency in Commercial and Institutional Buildings	Improving energy efficiency in HVAC systems, lighting, and building structures is crucial, as they account for high energy use and emissions in commercial buildings, with human behavior.
Shanzah Nazir, N.S.Thakur & Neetu	2024	Optimizing Energy Efficiency in Commercial Buildings through Advanced Building Strategies	Optimizing energy efficiency through advanced design strategies to maximize performance, ensure comfort, and enhance cost-effectiveness.
Iwuanyanwu, O., Gil- Ozoudeh, I., Okwandu, A., & Ike, C	2024	Retrofitting existing buildings for sustainability: Challenges and innovations	Challenges like technical and financial barriers, while emphasizing the benefits of energy-efficient technologies, renewable energy, and smart systems to reduce energy use and emissions.

Olatunde, T., Okwandu, A., Akande, D., & Sikhakhane, Z.	2024	Review of energy- efficient HVAC technologies for sustainable buildings.	Role of energy-efficient HVAC technologies in reducing energy costs, and environmental impact, while addressing challenges like high upfront costs.
Rajat Nainwal, Aniket Sharma	2023	Energy efficiency initiatives and regulations for commercial buildings in India	Compares energy regulations for commercial buildings and highlights the need for better enforcement to improve energy efficiency, especially in India.

Existing literature primarily focuses on technological advancements such as energy-efficient appliances, HVAC systems, and smart building solutions, but often overlooks the inconsistencies in occupant behavior that impact their effectiveness. While some studies highlight the influence of occupant actions on energy consumption, there is limited understanding of how to effectively modify these behaviors. This study aims to bridge these gaps by evaluating the combined effect of sustainable appliances and occupant behavior, proposing cost-effective, integrated strategies for improving energy efficiency in commercial buildings.

Energy Efficiency in Commercial Building – An Overview

Energy efficiency in commercial building is reducing operational costs, minimizing environmental impact, and using technologies that use less energy. This is important as commercial buildings consume a large amount of electricity for lighting, heating, cooling, and operating various devices and appliances. When energy is used efficiently, it helps lower electricity bills, reduces carbon emissions, and supports environmental sustainability. Smart appliances such as motion sensor lighting, automated heating, ventilating and air conditioning, smart power strips and plugs prevent unnecessary power consumption in the building by shutting down the devices that are not in use. Not just high technology appliances even simple energy saving methods would have a significant impact such as LED lights, proper maintenance of appliances. Energy efficient appliances contribute largely to energy efficiency and occupant behavior plays a crucial role in its efficiency. Ways employees, tenants, and visitors interact with lighting, heating, cooling, and office equipment significantly impacts a building's energy performance. Even with the most energy-efficient systems in place, inefficient usage patterns, or lack of awareness, resistance to adopting energy-saving practices can lead to unnecessary energy waste.

Analysis And Interpretation Of Data

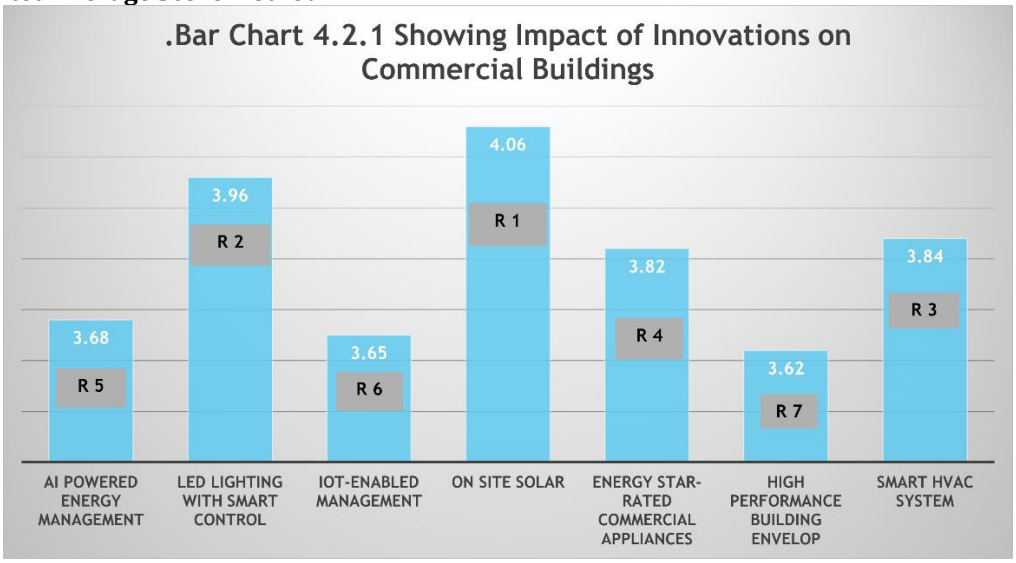
1. Percentage Analysis

Table showing the Characteristics of Sample

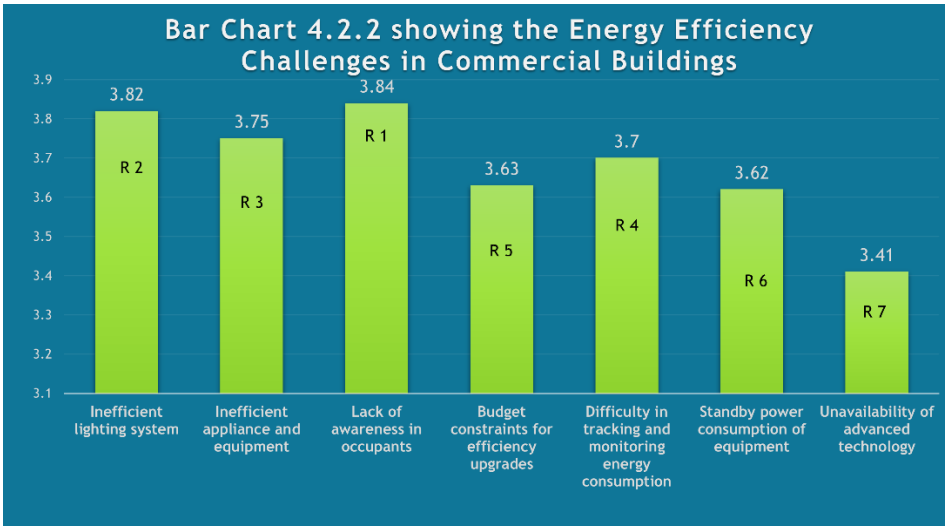
S.No.	Characteristics of Sample	Category	Frequency	Percentage
1	**Type of Commercial Building**	Office Buildings	30	26
		Retail Buildings	32	28
		Hospitality Buildings	4	3
		Hospitals	10	9
		Standalone stores	22	19
		Others	18	16
2	**Size of the Building**	Small(Less than 5,000 sq.ft.)	56	49
		Medium (5,000-50,000 sq. ft.)	48	41
		Large (More than 50,000 sq. ft.)	12	10
3	**Factors for High Energy Consumption**	Inefficient lighting and HVAC system	14	12
		Poor insulation and building design	10	10
		High occupancy and usage level	46	40
		Lack of monitoring and control system	34	29
		Others	12	9
4		Reduce Electricity	50	54

	Reason for Adopting Energy Saving Measure at Work Place	Environmental responsibility	46	40
		Workplace policy and rules	20	17
5	**Factor they Prioritize while Selecting an Appliance**	Energy Efficiency and Sustainability	24	21
		Cost and Affordability	44	38
		Performance	30	26
		Convenience and ease of use	18	16
6	**Factors Making it Convenient to Follow Energy Efficient Habits**	Automated Systems	20	17
		More awareness Program	34	29
		Better designed workplace that naturally reduce energy use	62	53

2. Weighted Average Score Method



The weighted average score has been taken in the study to know the impact of the innovations on energy efficiency in commercial buildings where on site solar panel ranked first with the score of 4.06, LED lighting with smart control ranked second with the score of 3.96, smart HVAC system ranked third first with the score of 3.84, energy star-rated commercial appliances ranked fourth first with the score of 3.82, AI powered energy management ranked fifth first with the score of 3.68, IoT-enabled management ranked sixth first with the score of 3.65 and high performance building envelop ranked seventh first with the score of 3.62.

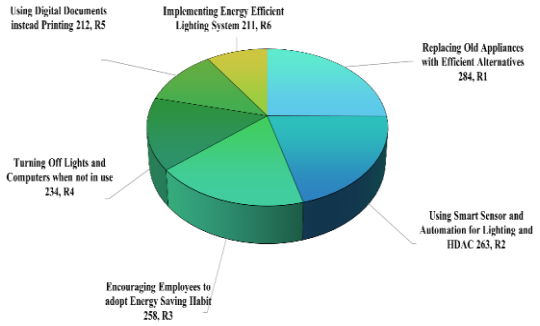


The weighted average score has been taken in the study to know the major challenges in commercial buildings the lack of awareness among occupants has been ranked first with the score of 3.84, inefficient lighting system ranked second with the score of 3.82, inefficient appliance and equipment ranked third with the score of 3.75, difficulty in tracking and monitoring energy consumption ranked fourth with the score of 3.70, budget constraints for energy efficiency upgrades ranked fifth with the score of 3.63, standby power consumption of equipment ranked sixth with the score of 3.62 and unavailability of advanced technology ranked seventh with the score of 3.41.

3. Rank Analysis

Rank analysis is a technique used to evaluate and prioritize factors based on their significance or preference.

Pie Chart Showing ranking of most Effective ways to Reduce Energy Consumption



The rank analysis shows that replacing old appliance with energy efficient alternatives has been ranked first with 284, using smart sensors and automation for lighting and HVAC ranked second with 263, encouraging employees to adopt energy saving habit ranked third with 258, turning off lights and computers when not in use ranked fourth with 234, using digital documents instead of printing and paperwork ranked fifth with 212, implementing energy efficient lighting system ranked sixth with 211 and motion sensor and automation ranked seventh with 162.

4. Chi-Square Analysis

Chi-square test is the non-parametric test of significant difference between the observed distribution of data among categories and the expected distribution based on the null hypothesis. This test is widely used to identify the relationship between multiple variables.

Null Hypothesis:

1. There is no significant relationship between the year of construction and types of lights used.
2. There is no significant relationship between type of commercial building and major energy consumption factor.
3. There is no significant relationship between type of commercial building and major challenges in implementing energy efficient solutions.
4. There is no significant relationship between sizes of the building and how office lighting is managed.
5. There is no significant relationship between sizes of the building and type of office appliance that consumes most energy.

Table No. 4.4 Showing the Relationship Between Variables

S.No.	Relationship Variables	Calculated Value	Table Value	Hypothesis Accepted/ Rejected	Result
1.	Relationships between Year of Construction and Type of Lights Used	0.8843	16.92	Accepted	No Significant Relationship
2.	Relationship between Types of Commercial Building and major Energy Consumption factors	0.965	31.41	Accepted	No Significant Relationship
3.	Relationship between Types of Commercial Building and Major Challenges in Implementing Energy Efficient Solutions	0.967	31.41	Accepted	No Significant Relationship
4.	Relationship between size of the building and how is office lighting managed	0.46	9.49	Accepted	No Significant Relationship
5	Relationship between Size of the Building and Type of Office Appliance that Consume most Energy.	0.325	15.51	Accepted	No Significant Relationship

Findings

The objective of the study is to analyze the energy efficiency challenges and innovations in commercial buildings. The study has been analyzed using percentage analysis, rank analysis, weighted average score method and Chi-Square analysis, this chapter summarizes the findings of the study.

Percentage Analysis

- Majority (28%) of the respondents are from retail buildings.
- Majority (49%) of the respondents has small building less than 5,000 square feet.
- Majority (40%) of the respondents thinks high occupancy and usage level is a reason for high energy consumption.
- Majority (43%) of the respondent's primary reason to be energy efficient is to reduce electricity.
- Majority (38%) of the respondents prioritize cost and affordability selecting an appliance.
- Majority (53%) of the respondents feel better designed work place is convenient to follow energy efficient habits.

Weighted Average Score Method

1. The respondents strongly agree that lack of awareness among occupants is a major reason for energy efficiency challenge in commercial buildings with the highest score, inefficient lighting system has been ranked the second, inefficient appliance and equipment has been ranked third, difficulty in tracking and monitoring energy consumption has been ranked fourth, budget constrains for energy efficient upgrades has been ranked fifth, standby power consumption of equipment ranked sixth and unavailability of advance technology ranked seventh with a least score.
2. The respondents feel that on site solar panel is highly effective with the highest score, LED lighting with smart control ranked second, smart HVAC system has been ranked third, energy star rated commercial appliances has been rated fourth, AI powered energy management has been ranked fifth, IoT enabled management has been ranked sixth and high performance building envelop ranked seventh with the least score.

Rank Analysis

The respondents prefer replacing old appliances with energy efficient alternatives which has been ranked first, using smart sensors and automation for lighting and HVAC has been ranked second, Encouraging employees to adopt energy saving habit has been ranked third, Turning off lights and computers when not in use has been ranked fourth, Using digital documents instead of printing and paperwork ranked fifth, Implementing energy efficient lighting system ranked sixth and Motion sensor and automation ranked seventh with the least score.

Chi Square Analysis

- The factors such as year of construction and types of lights used have insignificant relationship between them.
- The factors such as types of commercial buildings and major energy consumption factors have insignificant relationship between them.
- The factors such as types of commercial buildings and major challenges implementing energy efficient innovations have insignificant relationship between them.
- The factors size of the commercial building and how is office lighting managed has insignificant relationship between them.
- The factors sizes of the commercial building and type of office appliance that consume the most energy have insignificant relationship between them.

Suggestions

- LED lights and motion sensors lights can be used to reduce energy when not in use.
- Regular tracking of energy can be done to identify areas for reducing energy.
- Penalty can be imposed on those who leave lights and appliances when not in use
- Old and outdated appliances can be replaced with energy efficient appliances can be used to reduce energy.
- Building occupants can be offered incentives or rewards for adopting energy saving measures, encouraging them to turn off unused devices and follow energy efficient practices.
- Use smart power strips to automatically cut off power of unused devices, preventing energy wastage.

Conclusion

High energy usage is mainly due to outdated appliances, inefficient lighting and heating, ventilating and air conditioning systems and a lack of awareness among building occupants. Many businesses choose appliances based on cost rather than energy efficiency, which leads to higher electricity consumption over time. Despite these challenges, energy-efficient practices such as using LED lighting, smart heating, ventilating and air conditioning systems, and renewable energy sources like solar panels

have proven to be effective in reducing energy use. Businesses that monitor their energy consumption regularly and invest in modern, efficient appliances can save costs in the long run. The high initial cost of energy-efficient upgrades remains a major concern for many. Adopting smart energy management systems, automatic controls and promoting energy saving awareness among employees can helps to overcome these barriers.

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