Integration Of Smart Techniques For Achieving Energy Efficiency At Campuses

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ABSTRACT

The integration of design techniques and technology in creating smart campuses has gained traction due to its potential to improve services, decision-making, and sustainability. As commercial buildings strive for net-zero energy to reduce reliance on fossil fuels, the Internet of Things (IoT) has emerged as a popular technology in various sectors, including logistics, transportation, healthcare, connected cars, and smart cities within educational institutions. A literature review on smart buildings and campuses analysed energy consumption and efficiency, focusing on 2015–2022 studies. The review identifies smart campus technology, its contribution, and energy efficiency measures. Despite its Need, there exists a knowledge gap in effectively applying IoT in the built environment to achieve energy efficiency. To address the gap, this study presents a systematic review of IoT concepts, models, applications, trends, and challenges within the built environment. The review reveals limitations in developing effective IoT strategies and highlights indefinite implementation constraints. Understanding these challenges is crucial for the successful integration of IoT technologies and smart campus initiatives, contributing to the development of net-zero campuses in the future.

Keywords: smart campus, energy efficiency, renewable energy, sustainable technology, IOT(internet of things), IBMS, smart grid, energy management system

1. INTRODUCTION: -

In an era where sustainability and technological advancement are paramount, the integration of design techniques and cutting-edge technologies within the framework of smart campuses has emerged as a pivotal strategy in the pursuit of net zero energy goals. (Avisha Gita Prafitasiwi, 2023) This synthesis endeavors to explore the symbiotic relationship between architectural innovation and technology's transformative potential, particularly focusing on the role of the Internet of Things (IoT), Data Analytics, Integrated Building Management Systems (IBMS), Smart Grids, and Intelligent Energy Management Systems (IEMS) (Addanki Anirudh, 2017).

IoT, with its capacity to interconnect myriad sensors and devices, forms the backbone of a networked campus ecosystem. Coupled with data analytics, this synergy enables informed decision-making through insights into energy consumption patterns, occupant behaviours, and environmental conditions (Addanki Anirudh, 2017).

Meanwhile, IBMS consolidates diverse building subsystems into a centralized control platform, optimizing energyintensive operations based on real-time monitoring and occupant trends while ensuring comfort and efficiency (Christensen, 2019). The deployment of Smart Grids facilitates dynamic communication between energy providers, users, and renewable energy sources. This interaction enables agile demand-response mechanisms, peak load management, and seamless integration of sustainable energy, aligning seamlessly with the drive for net zero energy campuses (Nasro Min-Allah, 2020). Furthermore, Intelligent Energy Management Systems leverage IoT-derived data to predict, adapt, and optimize energy distribution, minimizing waste and maximizing renewable energy utilization (Christensen, 2019).

2. METHODOLOGY: -

The study employed a comprehensive literature review, covering only technologies utilized in smart buildings and smart campuses. In this review, the study used a search technique that targeted journals in Web of Science (WoS), Energies, Science Direct, SCOPUS, government documents, and selected books. However, some helpful material was discovered on the websites of several conferences and charitable organizations. To achieve Net Zero Campuses, the study employed a mix of keywords linked to Smart Campuses and Net Zero Energies, with an emphasis on energy consumption and energy efficiency. The review identified and included recent studies from 2015 to 2022 in particular tables in targeted parts to present up-to-date research for built environment professionals. The search only looked at publications published in journals having an impact factor of at least Maintaining the received content's quality.

The study was divided into four stages: Identification, screening, eligibility, and inclusion. Finally, the review was prepared based on two primary directions. The very first smart campus and its technology. Second, the contribution of

smart technology such as IoT to energy consumption reduction and net zero energy campus development via (1) Techniques used in Smart Buildings (2) Internet of Things in Building Monitoring and Data Monitoring, and (3) Energy efficiency Measures at in Smart Campuses

3. ENERGY EFFICIENCY: -

Energy efficiency on campus is a top priority in today's sustainable landscape. With increased environmental concerns and the need to optimize resource utilization, campuses are increasingly focusing on decreasing energy consumption while maintaining or improving operational effectiveness. Energy efficiency projects cover a wide range of tactics, technology, and behavioural changes aimed at reducing energy waste, cutting greenhouse gas emissions, and conserving important resources. Campuses may greatly contribute to a more sustainable future while saving money, enhancing occupant comfort, and setting a progressive example for their communities by incorporating new solutions and establishing a culture of responsible energy management (Gregory Raffio, 2015).

3.1 Smart Campuses & Energy Efficiency: -

A smart campus for energy efficiency is a technologically integrated and data-driven environment in which advanced technologies such as the Internet of Things (IoT), data analytics, sensors, and automation are used to optimize energy consumption, reduce waste, and improve overall sustainability on campus. This all-encompassing strategy combines real-time data insights, intelligent technology, and educated decision-making to create an environment that balances occupant requirements with responsible energy management (Addanki Anirudh, 2017).

3.2 Techniques Used in Smart Campus For Energy Efficiency: -

A wide range of modern techniques and technology aid in the accomplishment of energy efficiency on smart campuses. These novel techniques optimize energy usage patterns by leveraging data-driven insights, automation, and intelligent control systems. Here are some techniques which were used at smart campuses For Energy Efficiency

3.2.1 Role Of Internet of Things (IoT) & Data Analytics in Energy Efficiency: -

The Internet of Things (IoT) and Data Analytics play a transformative role in energy efficiency, providing innovative solutions for monitoring, analysing, and optimizing energy consumption. Their synergy enables informed decision-making, proactive management, and significant reductions in energy wastage. IoT-enabled sensors and devices gather real-time data on energy consumption, occupancy patterns, environmental conditions, and equipment performance, providing a comprehensive view of energy usage. Data analytics processes this data to identify patterns, trends, and anomalies, uncovering hidden insights that help identify energy-saving opportunities and operational inefficiencies. (Karam M. Al-Obaidi, 2023)

Data analytics, powered by machine learning and artificial intelligence, enables predictive analysis, allowing organizations to optimize energy distribution, adjust usage patterns, and minimize energy spikes. Proactive energy management strategies are enabled by real-time data alerts, demand response and load shedding, equipment performance optimization, user behavior insights, energy usage visualization and reporting, and continuous improvement. These tools enable organizations to make informed decisions and adjust behavior to align with energy-saving goals, ultimately reducing energy wastage and improving overall efficiency (Karam M. Al-Obaidi, 2023).

3.2.2 Role Of Integrated Building Management Systems (IBMS)In Energy Efficiency: -

IBMS is a centralized platform that integrates various building systems, such as HVAC, lighting, security, and fire safety, ensuring optimal energy use and preventing overlapping operations. It offers real-time energy monitoring, occupancy and usage-based control, demand-driven HVAC and lighting optimization, peak load management, adaptive climate control, maintenance, and energy optimization, data-driven insights and reporting, integration with renewable energy sources, and continuous improvement (Gregory Raffio, 2015).

IBMS enables facility managers to track equipment performance, inform maintenance staff about potential issues, and generate data-driven insights and reports on energy consumption, system performance, and trends. It also integrates renewable energy sources, such as solar panels and wind turbines, into the building's energy mix, optimizing energy distribution and storage. Continuous improvement is achieved by capturing data and feedback over time, allowing for adjustments and refinements to energy management strategies based on historical data and changing building requirements (Gregory Raffio, 2015).

3.2.3 Role Of Smart Grid Integration in Energy Efficiency: -

Smart Grid integration revolutionizes energy efficiency by introducing advanced communication, control, and monitoring technologies to the traditional power grid. It enables real-time demand response and load management, seamless integration of renewable energy sources, real-time monitoring and control, microgrid management, voltage optimization,

power quality enhancement, grid analytics and predictive maintenance, electric vehicle integration, grid flexibility and resilience, and consumer engagement and awareness (Nasro Min-Allah, 2020).

Smart Grids enable real-time communication between utilities and consumers, enabling load management, renewable energy integration, real-time monitoring and control, microgrid management, voltage optimization, power quality enhancement, grid analytics and predictive maintenance, electric vehicle integration, grid flexibility and resilience, consumer engagement and awareness. These technologies enable utilities and consumers to monitor energy consumption, optimize distribution, and reduce energy costs, ultimately improving energy efficiency and reducing costs (Nasro Min-Allah, 2020).

3.2.4. Role Of Intelligent Energy Management in Energy Efficiency: -

Intelligent Energy Management Systems (IEMS) are crucial in enhancing energy efficiency by utilizing advanced technologies and data-driven strategies to optimize energy consumption, distribution, and utilization. These systems utilize real-time data, predictive analytics, and automation to ensure efficient energy usage across various applications. Key features of IEMS include real-time monitoring and analysis, predictive energy demand and consumption, adaptive energy distribution, load shedding and demand response, energy-efficient scheduling, integration of renewable energy sources, equipment performance optimization, peak demand management, energy consumption visualization, and continuous improvement and learning (Christensen, 2019).

Real-time monitoring and analysis enable informed decision-making and proactive energy management. Predictive analytics anticipate future energy demand based on historical data, usage patterns, and external factors, allowing for effective load management and optimizing energy distribution. Adaptive energy distribution adjusts energy allocation based on real-time data and demand forecasts, ensuring efficient utilization and preventing the overloading of specific components. Load shedding and demand response enable load shedding during peak demand times, while intelligent scheduling optimizes energy-consuming processes. Integrating renewable energy sources, optimizing equipment performance, and providing intuitive dashboards and reports enable stakeholders to make informed decisions and adjust behaviours to align with energy-saving goals. (Christensen, 2019)

3.3 Integration Of Techniques For Increasing Energy Efficiency: -

IoT connects objects, sensors, and systems to a network, enabling real-time monitoring of energy use and environmental factors in energy management. It enables educated decision-making and the identification of energy-saving potential. IoT-enabled sensors can detect occupancy levels and adjust lighting and HVAC systems accordingly to avoid energy waste. Data analytics helps detect patterns, trends, and anomalies in energy usage, predicting consumption patterns and recommending optimization measures. IBMS combines building systems into a centralized control platform, ensuring energy-efficient operation and occupant comfort (Addanki Anirudh, 2017).

Smart grids enable bidirectional communication between energy suppliers, users, and distributed resources, enabling realtime monitoring of energy demand and supply, demand-response systems, and effective load control. IEMS predicts and manages energy consumption using data from IoT and other sources, analysing historical data and real-time inputs. It may also optimize renewable energy usage and reduce energy waste, helping achieve net-zero energy goals (Nasro Min-Allah, 2020).

3.4 Challenges During the Integration of The Techniques: -

Interoperability, data security, and privacy are crucial for seamless communication and compatibility among diverse technologies. Integration requires careful planning and coordination, with initial investment, data management, skill gaps, change management, energy infrastructure compatibility, regulatory and policy barriers, maintenance, scalability, stakeholder engagement, and perception and awareness being key challenges (Addanki Anirudh, 2017).

Institutions may face budget constraints and uncertainties about long-term return on investment while overcoming resistance to change and adapting to dynamic energy distribution and demand-response mechanisms. Addressing regulatory and policy barriers, maintaining and updating IoT devices, sensors, and systems, and scalability are also essential for successful implementation. Stakeholder engagement, perception, and awareness are crucial for successful implementation and adoption (Addanki Anirudh, 2017).

4. CONCLUSION: -

The integration of IoT, Data Analytics, Integrated Building Management Systems (IBMS), Smart grids, and Intelligent Energy Management Systems (IEMS) offers a transformative approach to achieving substantial energy savings and increasing energy efficiency in various contexts, from individual buildings to entire campuses. These technologies collectively contribute to a more sustainable future by enabling data-driven decision-making, precise resource allocation and consumption optimisation, and streamlining operations. Integrated Building Management Systems streamline

operations by centralising control and real-time monitoring of energy-intensive subsystems, ensuring energy efficiency without compromising occupant comfort.

Smart Grid technology revolutionises energy distribution and management by enabling demand response, renewable energy integration, and real-time grid optimisation. This dynamic approach reduces energy waste and enhances grid stability and resilience. Intelligent Energy Management Systems further enhance energy efficiency by employing predictive analytics and Real-Time Adjustments, Leading To Significant Energy Savings.

However, Challenges Such As Interoperability, Data Security, And Initial Implementation Costs Must Be Addressed. This Research Emphasises The Importance Of Interdisciplinary Collaboration, Technological Innovation, And Supportive Policy Frameworks To Overcome These Hurdles And Fully Harness The Potential Of IoT, Data Analytics, IBMs, Smart grids, And Iems. As Society Prioritises Sustainability And Energy Conservation, The Integration Of These Advanced Technologies Becomes Paramount. By Effectively Utilising IoT, Data Analytics, Ibms, Smart Grid, And IEMS, We Can Pave The Way Towards A Future Marked By Reduced Energy Consumption, Increased Energy Efficiency, And A Greener, More Environmentally Conscious World.

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