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INFLUENCES OF GREEN BUILDING DESIGN ON ENERGY SAVING BEHAVIOUR: SYSTEMATIC LITERATURE REVIEW

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Abstract

Although green buildings are designed to reduce energy consumption, prolonged experience shows that their total actual savings are significantly smaller since their occupants are not engaged in energy-conscious behaviour. This behaviour, however, is significantly affected by the design of the building itself. As a result, many questions arise concerning the design features with the most substantial influence on the choices that the building's occupants make. The following study offers a review of the existing literature on the subject and clarifies the existing gaps. This research hopes to offer valuable information on the topic, leading to more informed future green building design decisions. The design of the study is in congruence with the PRIMSA requirements. The literature was analysed using Scopus and Web of Science. The current research on the topic presents which design elements open within green buildings can be proven to have an impact on the occupant's behaviour and offer suggestions for future research. The results of this review include a list of design factors that could shape the occupant's actions concerning energy-saving. A significant takeaway is the difficulty of implementing behavioural interventions during the building's operational phase. This information helps existing green buildings' facility managers to improve their energy performance. Designers may use these findings to further optimize the energy savings of future green buildings. As such, it contributes to the theoretical field by identifying and clarifying the correlation between features of a green building and its occupants' actions.

Keywords: Energy-saving behaviour, Green building design, Occupant behaviour, Sustainable architecture, Sustainable practices.

1. Introduction

Energy efficiency and long-term sustainability are greatly aided by green building design. Sustainable architecture prioritizes the comfort and health of its occupants and the health of their environment. One major issue that needs fixing is people needing to try to save energy by changing their habits to conserve energy and live healthy and comfortable lives [1].

Occupants often need help to embrace energy-efficient devices and behaviours despite the availability of such options for buildings with sustainable energy sources, reuse, energy conservation, and safe materials used to construct the buildings. Therefore, it is crucial to the success of energy-saving efforts to get insight into the elements that affect occupant behaviour and participation [2]. This article investigates the connection between green building design and user behaviour to pinpoint tactics for encouraging reduced energy use.

1.1. Research question

The following research question motivated the investigation: how do specific green building design features affect the ways consumers and tenants participate in energy-conservation practices? The purpose of carrying out a systematic literature review is as follows:

- Identify and evaluate the variety of green building design features that demonstrably have a sizeable positive or negative impact on the degree to which consumers and tenants are conserving energy.
- Investigate and classify the potential modulators and demodulators of consumer and tenant behaviour relative to energy conservation potential that are particular to green building contexts.
- Develop synthesis information on design and planning interventions that could be included in the design of green buildings to most effectively incentivize and support pro-consumption energy conservation behaviour among consumers and tenants.

This report will serve as a guide for the study by detailing the research plan. The information provided in the paragraph above forms the basis for understanding the building designs to accommodate behavioural differences. Firstly, cooling and heating needs among residents should be through 3D designs for simulation [2]. Additive manufacturing and 3D printable concrete are new advancements in green buildings and construction and provide a broad spectrum of advantages to cope with the behaviour disparities observed in buildings [3]. Additive manufacturing reduces construction material and labour, greenhouse gas emissions, material waste, and human error [4]. This will provide favourable heating and cooling effects in the different thermal zones of the whole building. Therefore, depending on the direction that each side of the building faces, a significant model design should be constructed to accommodate the presumed microclimate differences.

On that note, the floors known to be hot during weather conditions or seasons should have an interior design and equipment that makes it favourable for anyone to live in. This design could help residents lack the living conditions' disparities, hence making everyone present similar behaviours [4]. Nonetheless, energy behaviour and thermal comfort of buildings constructed using 3D printable concrete positively impact insulation due to the surface reflectivity, exterior environment, and thermal insulation; hence, building green buildings requires considering these factors to ensure the behaviours of the residents are considered from a positive perspective.

Moreover, the building floors earmarked with people experiencing different microclimates in the green buildings could be fit with external thermal insulation composite systems to reduce energy needs [5]. This involves using expanded polystyrene, primers, and adhesives [2]. This is significant in controlling cooling and heating conditions and could help people dwelling in the houses showcase similar behaviours. Green building design improves energy efficiency and the environment. Global energy-related CO_2 emissions are roughly 40% from buildings, according to the World Economic Forum [6]. Greenery, ventilation, and insulation may reduce energy use and carbon emissions dramatically. Green buildings employ renewable energy sources like solar panels and geothermal systems to reduce fossil fuel usage [7]. Building energy efficiency improves indoor air quality, thermal comfort, and occupant well-being. Green building design is vital for energy efficiency, climate change mitigation, and healthier, more sustainable built environments.

The current study aims to analyse the various factors influencing the behaviour change towards energy saving showcased among persons residing in green buildings. This research gap is evident from previous studies that focused on the importance of green buildings in saving energy. Very few studies concentrate on factors influencing the showcased change of behaviours and the connection between behaviour change and green buildings' design. This will help answer the research question of the available designs and construction resources that could help remove the behaviour differences among people residing in green buildings. Although green buildings will save energy through conservation of water, resources, energy, provision of liveable communities, and provision of indoor air quality, there is a need to understand how these advantageous components of green buildings could be experienced with similar leverage of all building residents through the accommodation of designs while constructing the buildings.

1.2. Research objectives

The analysis presented in the paragraphs above justifies the existence of the research gap. The motive is two objectives, which are: to summarize the findings concerning the connection between green building design and tenant energy-saving behaviour and develop a clearer vision of how this behaviour has and has not changed. to conduct a review of the existing literature on design-based interventions to diminish disparities of behaviour and stimulate stronger uniformity among tenants in their efforts to save energy at green buildings.

These objectives are derived from rational thinking about change since the green buildings will provide all-inclusive living communities and environments; hence, they will directly impact social behaviours if the differences are not corrected using designs. Also, due to market values, there is a need to address the various designs to use when building green buildings for every person, regardless of gender or other sociocultural differences, to feel comfortable.

2. Literature Review

Green building design is a critical strategy that prioritizes human safety, resource conservation, and environmental concerns. Green buildings lessen their environmental impact by including sustainable practices and technologies from the beginning of the design process. These tactics limit the impact of climate change and primary energy use by prioritizing waste reduction, renewable energy sources, and energy efficiency optimization. To lessen the environmental impact of Smart Houses, it is necessary to achieve 6% annual heating energy savings over predetermined periods [8]. This emphasizes the need for more research by underlining the importance of user behaviour and life cycle assessments in understanding the environmental consequences of smart homes [9]. Additionally, the study emphasizes the difficulty of achieving true environmental sustainability in smart home systems, especially regarding issues like ecotoxicity and abiotic depletion that could not result in net savings. The main goals of this work are emphasized by this comprehensive literature review, which synthesizes the body of knowledge and highlights research gaps on the interaction between energy-saving behaviour and green building design.

The problem of energy inefficiency in historic communal structures, especially within a European setting, is well-described [10]. Green building design solutions attempt to counteract this through thermal insulation, green roofs, LED lighting, window replacements, and on-site renewable energy generation [11]. However, occupant behaviour is a significant factor in determining how well these measures will perform [12]. In fact, in many cases, inadequate lighting, thermal discomfort, and ventilation issues are the unintended consequences of energy-efficient building design and occupant behaviour. Fortuitously, innovative software for energy monitoring and AC system tracking is available, improving efficiency further. Green design solutions are intended to encourage responsible use of energy, but the savings provided are highly dependent on the occupants. As a result, the best practice often requires raising awareness and facilitating this kind of behaviour change through educational initiatives [13].

Many different studies confirm the energy-saving efficacy of the thermal insulation, green roofs, LED lighting, and windows replacements. For optimal energy performance, campus buildings will also benefit from geo-exchange heat pumps, shower drain energy recovery, improved lighting efficiency, enhanced insulation and glazing, external shading, and renewable energy sources [11]. Some of these building systems have already been put in place, and it appears that they may not be sufficient for avoiding energy inefficiencies. Additionally, software for energy monitoring and tracking the functioning of AC systems is in use. This makes campuses a convenient choice for this line of research due to the possibilities and need for action. For instance, a study shows that student behaviour made a 20% energy consumption difference in a university setting [14].

Given this opportunity, it is essential to understand that even with advanced building systems in play, a significant portion of the energy savings opportunities is being lost due to occupants' behaviour. In buildings consumption, understanding of occupants and their impact on energy use would require the integration of agent-based modelling. In systems management, agent-based modelling is defined as a computational approach that models the interactions between autonomous agents in an environment [2]. In this context, these agents can represent individual occupants or groups of occupants with their own characteristics, decision-making processes, and behaviours. By simulating them, the impact their behaviour has on the energy consumption of electrical appliances can be assessed. lack of behaviour change. A similar recommendation is the examination of such weather types as pain and open window mode and snowing and outside temperature to check the preference for air conditioning unit and potentially shut down computers [2].

Understanding occupants and their impact on energy consumption in buildings necessitates the integration of agent-based modelling [11]. ABM is a computational approach that simulates the interactions between autonomous agents within an environment [12]. In buildings and energy use, these agents can represent individual or group occupants with their own characteristics, decision-making processes, and behaviours. By simulating these interactions, ABM can provide valuable insights into how occupant behaviour influences electrical appliances' energy consumption. Guattari et al. [15] and He et al. [16] all for behaviour change in such settings, including an investigation on students' preference for air conditioning units in specific weather patterns and shutting off computers when not using them to reduce the standby energy consumption.

It has been noted by Guattari et al. [15] and Heerwagen [17] that energy consumption is typically higher in mixed dorms with students of varying grades, in dorms hosting higher-grade students who spend more time in their accommodations, and during hot-humid seasons when air conditioning is required. Research on homes' air conditioning preferences throughout different weather conditions and efforts to reduce computer standby energy use by turning them off highlights the importance of changing people's habits. Homes' energy conservation can be encouraged through education and information initiatives [2].

Home-based appliances that integrate designs that accommodate green energy saving and consumption, including Du and Pan [14] and He et al. [16] are supported by the Howarth and Roberts [18] article that analyses how the lifecycle of a smart home system requires behavioural change since it is a design to save energy with adverse environmental side effects. SHS may contribute to saving energy due to innovative heating of homes, but they directly impact the environment. Occupants should change the latter behaviour as they produce unintended side effects when in operation. Smart home systems are installed to reduce energy use [19]. However, , Howarth and Roberts [18] warn that they may have unintended environmental consequences. In order to reduce negative environmental impacts, residents must take the initiative to alter their behaviour.

He et al. [16] agree that it is vital for home appliances to incorporate green energy-saving design. A contrary viewpoint is presented by Howarth and Roberts [18] who stress the significance of SHS's intelligent heating systems and the relevance of inhabitants selecting ecologically appropriate SHS. Electrochromic windows are discussed by He et al. [16] or their energy efficiency and impact on occupant behaviour by regulating solar heat gains. Installing these devices reduces the amount of solar heat entering a building.

Occupants should develop the behaviour of switching the devices for long to attain lower transmittances of solar radiation [18, 20]. Khoo et al. [20] target the behaviour change by occupants working or living in areas that use access points as smart terminals during peak user demands. The article calls upon the buildings with APs to consider putting them off when idle or during off-peak periods. This could help save the energy wasted when they are not in total operational capacity [21]. Li et al. [22] suggest that to save energy, buildings' access points should be turned off during idle or off-peak hours. Energy-efficient techniques, including maximizing the use of different appliances and implementing energy-saving building designs, are promoted by Li et al. [22]. According to Lu et al. [23], excessive energy consumption in green buildings relative to conventional ones is frequently caused by occupant behaviours. They recommend altering one's habits, like reducing waste, recycling, taking shorter showers, and using computers more energy-efficiently.

Lu et al. [23] noted the potential for higher energy consumption in green buildings compared to conventional ones, emphasizing the need for occupant behaviour changes. These changes include reducing waste, recycling, using appliances efficiently, and adopting energy-conscious computer usage habits [24]. Azizi et al. [8] and Howarth and Roberts [18] support this perspective, advocating for behavioural modifications within green buildings. Howarth and Roberts [18] further explore the importance of psychological factors and rational behaviour, drawing on the Theory of Planned Behaviour. According to Heerwagen [17], formal education significantly fosters the knowledge and motivation necessary for sustained energy-saving behaviours.

Passive and active green building designs

Although occupant behaviour is essential in the green building energy use optimization, the design of the building itself is also critical [25]. Green building designs often use an array of active and passive strategies that limit the reliance on traditional types of energy while making occupant conditions more comfortable [26]. Passive design strategies ensure that the building can operate at maximum efficiency using natural resources – that is, without the expenditure of additional energy [27]. Their primary goal is to ensure that the building will have sufficient thermal comfort and lighting inside without relying on additional heat or light sources. Good insulation and airtightness combined with the proper building orientation relative to the sun and prevailing winds can help avoid at least some of the heating and cooling needs [28].

Active design strategies are the strategies that do utilize energy but do so efficiently. They are usually necessary to maintain the levels of comfort provided by passive strategies while compensating for the limitations of the environment [27]. An example of a system like this is the HVAC system combined with sensors to gauge the occupancy of the building and smart controls [27].

Active strategies for building designs that work include efficient heating and cooling systems – they can lower the use of energy for heating and cooling the building if they are efficient enough. Renewable energy systems provide buildings with on-site sources of electricity, also lowering the amount of power from the grid used by the building. Lighting can also be automated and set up to turn itself off, and building management can be linked to the heating, ventilation, and air conditioning schedule as well as to the systems monitoring the energy use in real time [27]. The assessment has allowed concluding that more research is needed to understand the role of occupant behaviours in optimizing the energy use of green buildings.

3. Methods

The study employs a systematic literature review approach to synthesize and analyse existing research on the relationship between green building design and occupant energy-saving behaviour. Guided by the thematic insights derived from the literature review, the study focuses on two key areas:

- Building Occupants: The review will explore how green building features such as smart home systems, LED bulbs, electrochromic windows, and building access points influence building occupants.
- Policymakers and Builders: The focus will be on design and technological decisions made by policymakers and builders that impact energy use, such as solar air heaters, green building coverings, large-scale concrete 3D printing, and sustainable building practices.

3.1. Data checking

This study follows the PRISMA framework; Scopus and Web of Science databases were selected due to broad coverage of articles on a variety of subjects. Since variability of terms is characteristic of the focus area, keywords that would capture main trends and features of construction or design of energy-efficient buildings were extended. "Sustainable building design", "energy-efficient building design", and "low-impact building design" were added; it was done to minimize biases emerging from the use of narrow terms and increase the probability of developing a search focused on the bulk of existing research on green building design and occupant behaviour leading to energy savings. At the same time, over the review, the selection of keywords is subject to change as conclusions about existing literature are made.

Keywords should convey design elements affecting occupants that were known or expected, as well as a variety of behavioural terms for sustainability. The terms "green building", "sustainable building design", and "green technology" are essential. However, not all relevant articles may be captured simultaneously: there are studies that use other terms for green technologies, and their bulk is not included in the search as a result. Another categorical limitation of focusing on the term "behaviour" is that this term is interpretable too broadly. Some texts that will turn up will focus on behaviour in some misunderstandable way not focused on energy use; with an incorrect just-pushed not operable attitude. To remedy these potential limitations, further research will adjust the keywords as part of the search strategy and implement a bibliographic search by the reference lists of the articles considered.

3.2. Statistical review

This research used automation and human knowledge to identify studies. It started with a systematic review of each document to determine its relevance to the study issue. This first step involves carefully reviewing titles and abstracts to find papers that fulfil study goals. The entire texts of the chosen articles were rigorously evaluated after screening. This thorough review followed the carefully stated inclusion criteria to ensure that the papers included in the analysis satisfied the requirements for comprehensive and well-founded research synthesis. This research has numerous critical inclusion criteria. First, only English-language articles were used to improve understanding and permit complete study analysis. Again, ten-Q1 and four-Q2 journals were considered for their high impact and thorough peer-review procedures.

3.3. Data collection

Figure 1 describes the PRISMA framework used in the systematic literature review. The initial step of the process involved the identification of titles within two academic databases: Scopus and Web of Science. Duplicate entries were eliminated, whereas the retained articles' titles and abstracts were screened against the corresponding inclusion and exclusion criteria. The second stage comprised the retrieval of the full text of the qualified articles. In the third step, a QA of the studies was run, which, in the context of the present review, is equivalent to a qualitative synthesis. In the present review, the inclusion criteria were. In contrast, articles focusing on conventional buildings, only discussing energy policy, or not focusing on occupants' behaviour throughout the study period were excluded from the review.

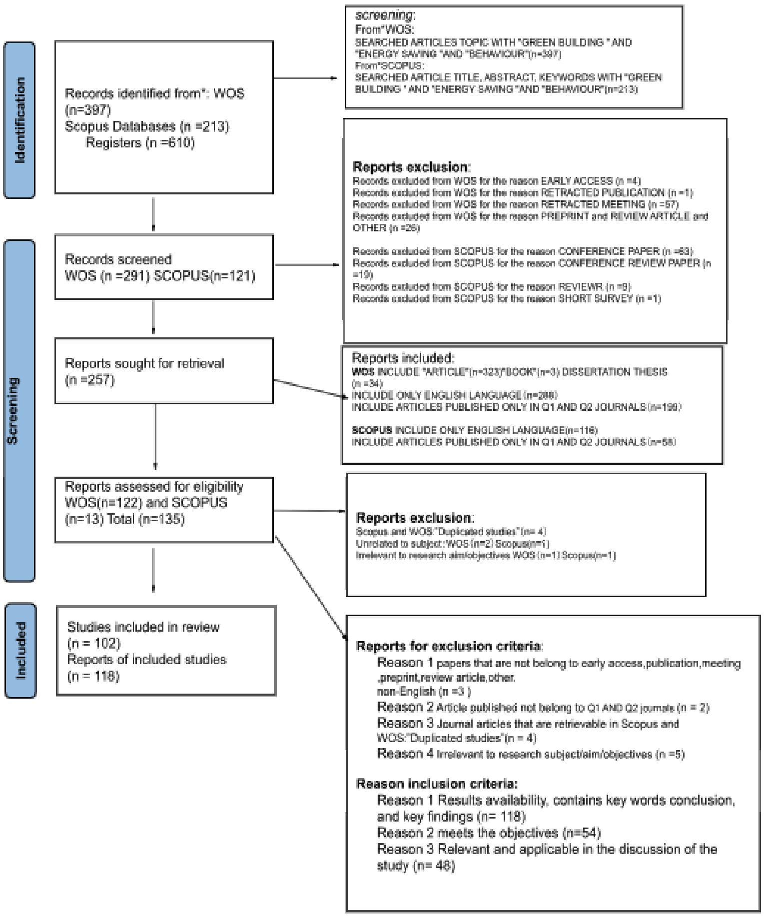

Fig. 1. PRISMA flowchart of the systematic literature review process.

3.4. Exclusion of articles

Thirty-six sources contained unrelated information about the topic, including 29 sources from WOS and seven from SCOPUS. The sources were classified as unrelated because their information did not discuss green designs. If they did, they failed to connect the designs with occupant behaviours, which are significant variables in the current study. On that note, sources containing behavioural change targeting building developers and policymakers were categorized as unrelated sources.

Petidis et al. [29] and Piccolo et al. [19] took a different perspective on addressing behavioural change by focusing on the policymakers and builders rather than the green building occupants. According to Howarth and Roberts [18], green roofs reduce carbon in a subtropical metropolis. Green roofs may reduce urban heat islands and save energy. Extensive green roofs and intensive green roofs ensure a cooling effect and energy savings in the buildings. Green roofs reduce air temperature, air-conditioning energy consumption, and carbon emissions, especially on low-rise structures. Green roofs may mitigate urban UHI and should be integrated into urban planning and building design to enhance thermal conditions, decrease energy consumption, and minimize carbon emissions [6]. Petidis et al. [29] call upon urban planners and politicians to change their behaviours of using materials that cause greenhouse gas emissions and use green roofs as a mainstream cooling solution in subtropical cities due to their climate change mitigation and urban sustainability advantages.

Petidis et al. [29] call for policymakers to change their construction behaviour, urging policymakers and builders to incorporate greening the building envelope as an energy-saving method. Leaving dense urban areas' buildings with low albedo without covering is a behaviour that ought to change since the lack of natural vegetation causes the urban heat island effect [30]. The microclimate created by the paved surfaces of buildings in dense urban areas could be avoided by using vertical greening to cool the building surfaces [31]. Nonetheless, Khoo et al. [20], in advocating for behavioural change by builders and policymakers and the inclusion of large-scale 3D printed vertical concrete, which is a green wall system to prevent a microclimate of urban buildings and enhance the energy efficiency of buildings. Energy conservation could help during the energy crisis that has intensified around the world [32]. Policymakers and builders should change their construction behaviours, combining traditional earth-to-air heat exchange systems with a solar air heater and phase change material for geothermal and solar energy to complement [33].

Policymakers and builders are urged to integrate sustainable and eco-friendly buildings to save energy by reducing energy consumption and gas emissions. According to McCoy et al. [24], builders should change their behaviour when making construction decisions independently and consider all stakeholders when building sustainable buildings.

Markedly, some articles addressing green roof and vertical greenery systems on building surfaces promote energy saving, grey water treatment, sound transmission reduction, and envelope longevity [23, 26, 34]. On that note, policymakers and builders should change their construction behaviour and adopt urban green infrastructures to reshape the urban environment. Behavioural changes among policymakers and builders are needed to address the willingness of people to pay for green office buildings if they provide comfort and indoor health. Environmentally conscious workers are more inclined to buy residences in green buildings. Sharing environmental ideas, such as development limitations and eco-crisis awareness, explains this uniformity in conduct. Therefore, builders and policymakers should incorporate pro-environmental behaviours and attitudes into green construction rules, guidelines, and tools to accommodate diverse customer preferences [35].

Lu et al. [23] discuss how creating awareness could ensure occupants save energy while residing in green buildings. The article proposes using posters, e-mails, and pamphlets distributed by building managers to emphasize the necessity of energy conservation [36]. This form of awareness creation is an evidence-based practice that helps conserve energy. However, the article was excluded from the study as it did not align with the research topic, given its failure to address significant designs to manage energy in green buildings. Some analyses address how materialistic customers residing in and owning green buildings contribute to environmental waste, while others discuss how behaviour change could mitigate waste [28]. Nonetheless, these articles were excluded as they focus on topics outside the scope of green building designs.

Wang et al. [37] focused more on behavioural changes among builders and policymakers, particularly through integrating green building certification. According to Lu et al. [23], while green building certification can partially induce energy-saving behaviours, occupants often disregard waste recycling and water-saving efforts. Xie et al. [38] also mentioned that green buildings may actually consume more energy than non-green buildings due to users' practices.

Lu et al. [23] was excluded from the study as it does not engage with designs used in green buildings, instead focusing on green building certification, which falls outside the research scope. Similarly, Khoo et al. [20] was excluded as it examines policymakers' investments in green buildings without addressing designs or occupant behaviours, which are critical elements of the study.

Furthermore, Lu et al. [23] was excluded as it did not provide information relevant to the research topic. Instead, it explored various rating systems for green buildings and technologies, including simulated annealing and the Technique for Order Preference by Similarity to an Ideal Solution [39]. Su et al. [40] and Xu et al. [41] were also excluded as they do not discuss green designs in buildings that require occupants to change their behaviour to reduce energy consumption. While these articles touch on occupant behaviour changes to manage energy, their focus on organizational culture influencing energy consumption in office settings is outside the study's scope.

According to Su et al. [40], the surroundings of office buildings influence employees' energy consumption. This includes sharing office rooms, environmental awareness, behaviours, and attitudes, which are infectious and have a high chance of influencing colleagues [39]. Xu et al. [41] emphasize the importance of communication and workplace dynamics in shaping energy-saving behaviours, highlighting how collective attitudes can create a ripple effect.

Hu et al. [42] joins the study's excluded sources as it discusses the policy efficacy of green buildings' energy performance in low-income housing units. According to Hu et al. [42], the construction type, occupant type, technology level, and apartment size affect energy use and consistency.

Zhang et al. [43] suggest that agent-based modelling (ABM) provides a useful framework for understanding and predicting how shared office environments influence energy use. Such models are valuable in designing interventions to address behavioural variations in energy consumption.

Markedly, Ofek et al. [44] discussed environmentally friendly buildings or green builds, and the significant stakeholders involved, including building developers, consumers, and architects. The article's failure to involve occupant behaviours and designs in green buildings was the significant reason for its exclusion from the study. Ausiello et al. [6] were excluded from the study since they did not engage in green designs or occupant behaviour change. The article discusses raw earth, wind, and sun as natural materials used in green energy sources.

McCoy et al. [24] were excluded from the study as the information it contains is irrelevant to the research topic. The article discussed how real-world observations and energy modelling could be used to assess actual home energy performance. Hu et al. [42] contains information about the need for more data to track changes in cooling patterns of green buildings; hence, it was excluded from the study. Notably, Kong et al. [21] were excluded from the study as the article analyses green spaces between green buildings that moderate the urban heat island effects; hence, the information is not relevant to the research topic [26].

Moreover, eight sources under WOS were excluded and categorized as irrelevant as the information they had was contained in other articles or published by the same authors. The eight sources included [1, 11, 20, 27-29, 39, 45]. The information available in these eight articles has already been discussed in other articles in this paper.

3.5. Data Analysis

Based on the literature review discussed in the paragraphs above, it is evident that occupant behaviour is a significant determinant in energy-saving efforts through regulated consumption. Various designs to create awareness of the need to save energy necessitated by designs, including LED bulbs, the substitution of windows, thermal insulation, and green roof installation, were addressed in the literature review that could influence occupants to change behaviour through maximization of energy-saving efforts [1], as shown in Table 1. Nonetheless, smart home systems Azizi et al. [8] should be used only with intelligent heating systems, as using the SHS without innovative heating systems has adverse environmental effects [9]. Also, electrochromic windows should be switched for a long time to achieve lower transmittances of solar radiation [46].

According to Li et al. [22] access points used as smart terminals in buildings during peak user demand periods should be turned off when idle and during off-peak periods to save energy. Notably, energy-sufficient lights and appliances, including TVs, refrigerators, and computers, should be optimized for usage [47]. Ding et al. [13] consider insulated windows and automated dynamic shading and glazing as the design to be incorporated in green buildings. However, occupants should change their behaviour by turning off lights and shutting down computers when not in use.

Table 1. Correlation between design elements and influence on occupant behaviour.

Design Elements	Influence on Occupant Behaviour	Reference
Led Bulbs	Encourage energy-efficient lighting usage	Sharma et al. [30]
Substitution of windows	Enhance thermal insulation and reduce energy loss	Petidis et al. [29]
Thermal insulation	Promote energy-efficient heating and cooling	Kong et al. [21]
Green roof installation	Encourage eco-friendly building practices	Petidis et al [29]
Smart terminals in buildings	Turn off during idle and off-peak periods	Li et al. [22]
Energy-efficient appliances	Optimize usage of lights, TVs, Refrigerators, and computers	Umoh and Bande [35]
Insulated windows	Enhance building energy efficiency	Ding et al. [13]
Automated dynamic shading and glazing	Improve energy management in green buildings	Ding et al. [13]

4. Discussion

A systematic analysis of the selected publications illuminates key relationships between green building design elements and occupant energy-saving behaviour. This review emphasizes the importance of physical design features and occupant actions in achieving energy efficiency goals. Design choices, particularly effective thermal insulation and advanced window technology, significantly enhance occupant thermal comfort. This reduces reliance on heating and cooling, resulting in measurable energy savings. Accordingly, occupants in such environments are more likely to exhibit energy-conscious behaviours, like avoiding simultaneous air conditioning use with open windows or setting temperatures above unnecessarily low levels.

While green design promotes positive behaviours, the research highlights the persistent need for behavioural interventions to address the complexities of tenant actions and maximize efficiency. The findings reinforce the value of green building design and nature-based solutions for energy reduction and occupant well-being. These results echo earlier studies on the importance of awareness campaigns and personalized communication in cultivating sustainable habits [4].

Facility managers are pivotal in successful green building operations. Understanding the interplay between design and behaviour empowers informed energy efficiency and occupant comfort choices. Focusing on insulation, window technology, and green solutions is key [14]. Additionally, targeted awareness initiatives can encourage sustainable behaviours. Appreciating individual behavioural variations allows facility managers to tailor energy-saving approaches.

5. Recommendations

Citing the results of the literature review, while thermal comfort was the most common driver of occupant behaviour, green building design should be focused on passive strategies, e.g. optimal building orientation, thermal insulation, and natural ventilation. The above should be combined with high-efficiency HVAC systems and localized control interventions that include operable windows and thermostats. Hence, a combination of passive and active strategies is likely to be maximizing both energy efficiency and occupant satisfaction. In this way, the strategies implemented would help minimize the risk of occupants engaging in behaviour patterns aimed at compensating for the lack of comfort, which is extremely wasteful in terms of energy use.

The systematic analysis of the publications selected for this review demonstrates the key relationships between the elements of green building design and occupant behaviour with regards to energy-saving. From the review, it becomes obvious that both physical design and occupant's behaviour are essential with regards to the energy efficiency of the building.

Thus, design interventions, particularly those related to thermal insulation and advanced window technology, are likely to enhance the thermal comfort of structures, thus reducing the dependence on heating and cooling systems and generating measurable energy savings. As a result, the occupants are less likely to engage in wasteful behaviour, for example, use air conditioning when the windows are open or set the temperature below the levels essential for maintaining inner thermal comfort.

6. Conclusion

This study provides a comprehensive analysis of how green building design features influence occupant behaviour, ultimately contributing to developing effective energy-saving strategies. A systematic literature review illuminates the complex interplay between physical design elements and occupant actions, with both playing pivotal roles in maximizing energy efficiency and building performance. The key findings prominently align with advanced window technology and thermal insulation, promoting natural ventilation and comfortable temperatures and reducing reliance on energy-intensive heating and cooling systems. Also, well-designed windows maximize natural light, encourage occupants to turn off artificial lights, and minimize energy use. This leads to the conclusion that green design fosters a connection to the environment, potentially inspiring energy-conscious behaviours throughout daily activities.

In conclusion, this study emphasizes the crucial role of green building design in promoting sustainable occupant behaviour. Targeted design choices around thermal comfort, lighting, and nature integration significantly impact a building's energy performance. Architects, designers, and builders can leverage these insights to create buildings that conserve energy and subtly guide occupants toward eco-friendly practices. This knowledge is essential in progressing towards a built environment that prioritizes sustainability and energy efficiency.

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