

Do green buildings drive a better living experience? A systematic literature review of occupant-centred aspects in green building certification

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Abstract. Studies on the impacts of green building certification from the perspective of building occupants have not yet comprehensively ascertained: how certification might drive the perception of well-being; to what extent certification may encourage pro-environmental behaviours; whether such behaviours may be sustained by positively-perceived settings in green buildings. To consolidate existing knowledge, a systematic literature review was conducted using two databases, Scopus and the Web of Science. The PICOC (Population, Intervention, Comparison, Outcome, and Context) criteria guided keyword selection and search string definition, leading to retrieve 303 articles published between 2014 and 2024. After excluding irrelevant records following the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) flowchart, 107 papers were retained using Quality Assessment checklist. Finally, 16 studies were included in this review. The findings highlight a general positive impact of green building certification on occupants' perceptual and behavioural experiences. However, this positive impact is not consistently sustained, owing to multiple contextual factors, individual characteristics, and other influencing variables. Furthermore, due to the complexity of the relationships at play, particularly regarding subjective well-being and related concepts such as comfort and satisfaction, there is still a lack of clarity in definitions and implementation scopes. No conclusive evidence was found on how pro-environmental behaviours might effectively be enhanced among building users. The results of this paper represent the initial steps of a broader research effort aiming to support rating bodies and accredited professionals towards more effectively integrating occupant-centred aspects into the design and implementation of green building certification systems.

1. Introduction

To mitigate the compounding impacts of human activities on the environment (e.g., global warming, air pollution, etc.), considerations of sustainable development are now being integrated into all sectors [1]. As a major resource consumer and greenhouse gas emitter, the building sector has for long introduced the concept of green building rating to certify and promote leadership in sustainability [2]. Rating tools such as BREEAM (Building Research Establishment Environmental Assessment Method, UK), and LEED (Leadership in Energy and Environmental Design, U.S.) were launched already in the early 1990's. Although these rating systems paved the way for many other certifications systems that have followed in different countries worldwide (e.g., Green Star in Australia, Green Mark in Singapore, etc.),

their initial scope was mostly focused towards addressing buildings' environmental and energy-related challenges, while giving less relevance to the need to comprehensively address occupant-centric factors. Over recent years, consideration of human health and well-being has gained substantial prevalence, in the public debate as in the scientific discourse, this leading to the emergence of more "occupant-centred" rating systems such as, among others, the WELL Building Standard (U.S., 2014).

A green-certified building is generally assumed to offer a more comfortable, satisfactory and healthier environment. However, many questions remain on how to effectively drive better occupant experience through green rating, and how the building industry can keep pace with advances in scientific research. Well-being is a multifaceted construct that encompasses physical, physiological, and psychological aspects. Designing for well-being is therefore complex, often requiring adaptable settings that can foster dynamic positive experiences [3]. While many green-certified buildings have been found to improve energy efficiency and promote sustainable design solutions, studies have shown that they may not foster pro-environmental behaviours unless their 'green features' are actively communicated and embraced by occupants [4]. Here, pro-environmental behaviours can be defined as the individuals' conscious engagement in sustainable practices [5]. These considerations are key, since user behaviours might significantly impact on energy demands for both variable (e.g., lighting, heating) and fixed loads (e.g., office equipment). An appropriate consideration of occupant behaviour can, therefore, help reduce the gap between predicted and actual energy (and environmental) performance of buildings.

Recent global events (e.g., the COVID-19 pandemic) have raised awareness of a new set of values and priorities: redefining how we live and work; how we relate to others and to our habitats; how we understand and defend human health. To better respond to these challenges, this study presents a systematic literature review focused on the occupant-centred impacts of green-rated buildings. This review is guided by three research questions: (i) how green certification drives the perception of well-being among users; (ii) whether positively perceived settings promote pro-environmental behaviours; and (iii) whether such pro-environmental behaviours can be sustained outside the certified building.

2. Methods

2.1. Query string

The digital libraries for the literature review were sourced from the Web of Science and Scopus databases. The starting year was set to 2014, since this year marks the launch of the WELL Building Standard that, for the first time, formally integrated the concept of well-being within green certification. Only peer-reviewed articles published in English between 2014 and 2024 were included in this review.

The PICOC criteria were used to transform the key research questions into searchable keywords, while retaining focus on the three key concepts: *green certification*, *well-being*, and *pro-environmental behaviour*. Synonyms identified through the PICOC were also included in the search strings (Table 1), while subject areas were limited to 'environment', 'energy', 'psychology', 'engineering', and 'society'.

Table 1. Query string.

Database	Query string
Scopus	TITLE-ABS-KEY (certification OR "green building standard*" OR "rating system*" OR "rating tool*" OR "rating scheme*" OR "green building*" OR green-certified) AND TITLE-ABS-KEY (wellness OR well-being OR wellbeing OR satisfaction OR comfort OR health OR perception) AND TITLE-ABS-KEY (behaviour* OR action* OR behavior*) AND TITLE-ABS-KEY (building)
Web of Science	TS=(certification OR "green building standard*" OR "rating system*" OR "rating tool*" OR "rating scheme*" OR "green building*" OR green-certified) AND TS=(wellness OR well-being OR wellbeing OR satisfaction OR comfort OR health OR perception) AND TS=(behaviour* OR action* OR behavior*) AND TS=(building)

2.2. Literature screening

The PRISMA 2020 flowchart diagram was applied throughout the screening process. After removing duplicates, the bibliometric search yielded a total of 303 papers, of which 107 were retrieved for evaluation of their level of *relevance*, *consistency*, and *contribution* by means of a Quality Assessment (QA) checklist. Following the assessment framework described in Table 2, each paper was assigned one point for each sub-item addressed within each criterion. Ultimately, 16 papers, which had a high score and matched our eligibility criteria, were selected for this study. The individual relevance assessment scores for the selected papers are included in Table 3.

Table 2. QA checklist.

Category	Criteria	Score assignment
Relevance	Does this study address any of the three key concepts?	1 concept – Score : 1
	a) Green building certification (GBC)	2 concepts – Score : 2
	b) Well-being (WB)	3 concepts – Score : 3
	c) Pro-environmental behaviour (PEB)	
Consistency	Does this study investigate any of the defined relationships?	1 relation – Score : 1
	a) GBC and WB	2 relations – Score : 2
	b) GBC and PEB	3 relations – Score : 3
	c) WB and PEB	
Contribution	Does this study contribute to any research phase?	1 phase – Score: 1
	a) Background/theory description	2 phases – Score: 2
	b) Data collection	3 phases – Score: 3
	c) Data analysis and data extraction	

Table 3. Relevance assessment scores

Ref. N.	Relevance	Consistency	Contribution	Score
[6]	a) Green building	a) GBC—WB	a) Indicators of well-being	9
	b) Well-being	b) GBC—PEB	b) Method to address the sample selection bias	
	c) Pro-environmental behaviour	c) WB—PEB	c) GSEM framework	
[7]	a) IEQ in green buildings	a) GBC—WB	a) Introduction	9
	b) Occupant perception	b) GBC—PEB	b) Survey	
	c) Behavioural impact	c) WB—PEB	c) DID method, Paired sample t-test	
[8]	a) Green building	a) GBC—WB	a) Definition of well-being	8
	b) Hedonic, eudaimonic and negative wellbeing (NWB)	b) GBC—PEB	b) Survey (to well-being, the Scale of Positive and Negative Experiences (SPANE), assessment of PEB	
	c) Pro-environmental behaviours		c) SPSS, Mplus-path analysis	
[9]	a) Green building	a) GBC—WB	a) Literature review	8
	b) Satisfaction	b) GBC—PEB	b) Occupant behaviour simulation	
	c) Energy-related occupant behaviours	c) WB—PEB	c) SPSS	
[10]	a) Green buildings	a) GBC—WB	a) Description of Activity-based working (ABW)	8
	b) Satisfaction	b) GBC—PEB	b) BOSSA POE surveys, spot measurements, step-count monitoring	
	c) Physical activity	c) WB—PEB	c) Multilevel linear models (MLMs), SPSS	
[11]	a) Green building certification	a) GBC—WB	a) Description of Green awareness, behaviour, satisfaction	8
	b) Satisfaction	b) GBC—PEB	b) Survey, natural experiment	
	c) Green behaviour	c) WB—PEB	c) ANOVA tests and OLS regression models	
[12]	a) Green building certification	a) GBC—WB	a) Survey	8
	b) Comfort	b) GBC—PEB	b) Survey	
	c) Energy-related adaptive behaviour	c) WB—PEB	c) SPSS	
[13]	a) Green building certification	a) GBC—WB	b) Self-administered questionnaire and field measurement	7
	b) Occupancy symptoms/satisfaction,	c) WB—PEB	c) SPSS, MATLAB	

	c) Occupants' lifestyle and behaviour			
[14]	a) Green buildings c) Environmentally responsible behaviours (ERBs)	b) GBC—PEB c) WB—PEB	a) Description of ERB, PEB promotion strategies b) Photograph documentation of building characteristics, The Positive Sustainable Built Environments (PSBE) model c) Regression	7
[15]	b) Thermal comfort c) Behavioral variables	a) GBC—WB b) GBC—PEB	a) Introduction on BETSI survey b) Occupant-Related/building-related variables selection c) Analytical statistical analysis, logistic regression models	7
[16]	b) Thermal comfort c) Adaptive behaviours	a) GBC—WB b) GBC—PEB c) WB—PEB	b) Interview, field visit, sensor documenting, behaviour measurements c) Pearson correlations and panel regressions	7
[17]	a) Healthy buildings c) Healthy behaviour.	a) GBC—WB b) GBC—PEB c) WB—PEB	a) Introduction on office health behaviour promotion strategies b) Survey, Theory of planned behaviour (TPB)	7
[18]	a) Green buildings b) Discomfort c) Occupant behaviour	a) GBC—WB c) WB—PEB	a) Survey b) Simulation model	7
[19]	a) Green buildings b) Satisfaction	a) GBC—WB	a) Literature review b) Survey c) Gap analysis, Importance-Performance Analysis (IPA)	6
[20]	a) Green building c) Occupant behaviour	c) WB—PEB	b) Simulation	4
[21]	c) Energy saving behaviours	b) GBC—PEB	b) Survey, TPB c) Structural Equation Modelling	4

3. Results: Interplay between certification, perception and behaviour

The contents of these 16 papers were clustered based on the associations between the three key concepts: green building certification, occupant perception, and behaviour as shown in Figure 1[6-21]. It must be noted that, within these associations, reference to other occupant-centred factors beyond well-being – e.g., comfort, satisfaction, health – were also considered, while the concept of *pro-environmental behaviour* was expanded to *occupant behaviour* so as to also include consideration of healthy living habits (physically, physiologically and socially).

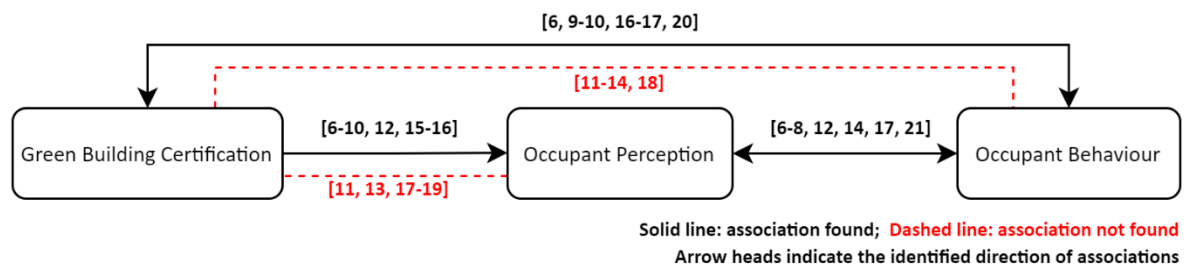


Figure 1. Syntheses of literature based on associations (Source: author).

3.1. Green Building Certification and Occupant perception

Green building certification has been reported to be closely associated with improved perception of occupant well-being, particularly through environmental features. For example, a Singapore-based study reported that tangible design features (such as the presence of greenery, enhanced ventilation, controls of the indoor environment, waste facilities, etc.) significantly enhanced users' well-being, whereas intangible features, such as water and energy efficiency, were found to be less impactful [6]. Similarly, a Canada-based study reported significant correlations between all aspects of well-being (i.e. hedonic, eudaimonic) and several environmental features (physical and social connections, views, etc.) [8].

Among aspects of occupant perception, satisfaction and comfort were the most extensively studied outcomes, with several studies showing higher occupant satisfaction in green-certified buildings as

compared to their non-rated counterparts. Investigations across Australia, Hong Kong, Sweden, and the U.S. have linked improved indoor environmental quality (IEQ) to enhanced satisfaction [7, 9, 10, 12]. Studies on residential buildings in Sweden and the U.S. have reported positive impacts of green building features on occupants' evaluations of thermal comfort [15, 16]. Conversely, an Australian simulation-based study revealed that occupants in Green Mark-rated buildings could experience higher *discomfort* than those in non-rated ones [18]. A U.S. study using Importance-Performance Analysis also reported that perceived performance of IEQ in LEED-certified homes fell short of its effectiveness, suggesting a room for improvement in the IEQ-related criteria in the LEED rating system [19]. Other studies have also reported a lack of direct association between green certification and enhanced occupant IEQ satisfaction. A Switzerland-based study comparing a Minergie-labelled residential building with a newly renovated non-green building reported that despite differences in IEQ between the buildings, they could not find significant differences in occupants' satisfaction between the two [13]. Similarly, studies conducted in China indicated that technological solutions may not always improve occupant experience, or affect their awareness of green features and technologies [11, 17]. Among commercial buildings, various studies have also questioned the effectiveness of green rating (e.g., LEED, BREEAM) from the perspective of occupants, positing the relevance of certification credits on occupant outcomes [22, 23].

3.2. Green Building certification and Occupant Behaviour

Various studies have identified an association between green building certification and their role in shaping occupant attitudes and actions, particularly towards encouraging pro-environmental behaviours (PEBs). A Singapore-based study reported that the tangibility of features significantly influenced residents' PEBs [6]. Additionally, healthier workplace behaviours, such as the promotion of physical activity, was also found to be linked to spatial design and strategic interventions of green buildings [10, 17]. A reciprocal relationship, where the performance of buildings (i.e. influencing the effectiveness of certification) was shaped by the behaviour of occupants, has also been reported. A U.S.-based study examining seniors' apartments during summertime showed that variations in the built environment by the residents' behaviours could significantly improve indoor thermal conditions [16].

However, despite the generally significant bidirectional associations between these two concepts, some studies also reported that obtaining green certification did not guarantee positive changes in occupant behaviour. Studies by Almeida et al., conducted in Australia, have reported an *inverse* association between certification and user responses, showing that occupants in green buildings exhibited more inefficient energy-use behaviours compared to those in non-rated buildings, this suggesting that green certification alone does not necessarily lead to more sustainable occupant actions [9, 20]. Studies investigating energy saving behaviours in green and conventional residential buildings also found no significant difference between the two groups [11, 13, 14, 18]. Instead of being linked to green building certification, energy-related behaviours (e.g., such as interacting with lighting system) were suggested to be more strongly related to spatial and use-based characteristics of the built environment, including workplace location, size of workplace, daytime or off-work time, etc. [12].

3.3. Occupant Perception and Occupant Behaviour

The association between occupant perception and behaviour has been investigated by fewer studies, yet the findings still reveal complex influences. Some studies showed that occupants in green-certified buildings more frequently adjusted settings to maintain their perception of comfort, for example for interactions with air conditioning, ventilation, and window or door operations [7, 12]. Studies in a LEED-certified residential building in Hong Kong showed that enhanced awareness (e.g., biospheric values and climate change concerns) significantly shaped energy conservation behaviours [14]. In this context, the use of the Theory of Planned Behaviour (TPB) revealed that occupants' attitudes, subjective norms, and perceived control might strongly drive their corresponding behaviours [17]. Du et al. proposed an expanded TPB model with a new variable, i.e. personal moral norm, to better explain energy-saving behaviours in students' dormitories, although their study could not detect a significant influence of subjective norms on energy-saving behaviour [21].

Occupant behaviour has also been reported to affect occupants' subjective perception of their indoor environment. For example, green behaviour was reported to improve the quality of life, and enhance the subjective well-being, for occupants of a Singapore Green Mark-certified residential building [6]. Additionally, instances where occupant behaviour mediated the association between green building performance and occupant perception have also been identified. A study conducted in Canadian green office buildings demonstrated that environmental features significantly encouraged pro-environmental behaviours, which in turn enhanced the overall perception of well-being [8].

4. Discussion

Our study could not find conclusive evidence of consistent relationships between *green building certification* and *occupant perception*, suggesting that green certification alone does not ensure improvement in occupant perception. Similar conclusions could be drawn regarding the association between green building certification and *pro-environmental* and *health-related behaviours*. While relatively few studies have explored the link between *occupant perception* and *behaviour*, diverse associations have emerged between these factors, underscoring the need for more thorough investigation of occupant behaviour in green buildings and its impact on daily decisions. Effectively, it is essential to motivate occupants to become active participants in building operations, thereby promoting pro-environmental behaviours while ensuring that their needs, preferences and aspirations are met.

Our study has certain limitations. The data retrieval in this study only relied on two databases, Web of Science and Scopus, potentially omitting relevant publications listed in other data sources. Future research could expand this database coverage. Secondly, the distinctions between aspects of occupant perception (e.g., comfort, satisfaction, health and well-being) require deeper analysis, as they are often addressed by scientific studies without clear and consistent definitions. Lastly, the use of the Quality Assessment Checklist for screening literature could have excluded some important studies due to the rigid scoring criteria adopted, while supplementary manual additions could be considered in follow-up studies for expanding the literature base.

5. Conclusion

To explore the questions set by this research from a bibliographic perspective, this study sought to conduct a systematic literature review using PICOC, PRISMA and Quality Assessment methodologies. Due to a scarcity of available resources, the review revealed limited evidence of the interplays between *green certification*, *occupant perception*, and *behavioural responses*. While the initial emphasis was placed on subjective well-being, the lack of literature references specifically focusing on this human outcome led to a broader consideration of "occupant perception" to encompass a wider spectrum of personal experiences. Despite this adjustment, no consistent indication of a *perception-behavior* correlation was detected across the reviewed studies, although occupants' actions and controls were regularly identified as potential mediators of the effectiveness of green building strategies.

In essence, the existing literature does not offer conclusive evidence of the associations under investigation, particularly within the green building context, highlighting the need for further research to improve the performance of green building certifications through occupant-centred strategies towards a better living experience.

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