Occupant Satisfaction with Certified Green Office Buildings in Chile

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Abstract Contemporary office buildings have primarily adopted environmental sustainability criteria through the guidelines and requirements of domestic or international green building rating systems. These systems incorporate criteria aimed at reducing resource consumption and the building's impact on the environment into their design, as well as criteria to improve indoor environmental quality (IEQ). However, doubts remain about the ability of green rating systems to guarantee occupant satisfaction with the building and its indoor environment in contrast with their counterparts. This research is based on a field study comparing occupant satisfaction in certified green office buildings with conventional buildings in Chile, from a sample of 176 occupants of green buildings and 175 occupants of buildings (N = 351). The study included a survey of occupants and the monitoring of thermal conditions in workspaces. The results showed that there are no significant differences in satisfaction and comfort between green buildings and their conventional counterparts. The occupants of conventional buildings showed trends of higher overall satisfaction for the winter and summer months, as well as for winter and summer temperatures. The other criteria, such as air in winter and summer, showed fairly similar results in both building types.

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1 Introduction

The main objective of green building rating systems is to reduce the environmental impact of buildings through energy performance optimization and resource use efficiency criteria, among others. Issues related to occupant well-being play an important role in these systems, generally as a dimension known as indoor environment quality or IEQ [1] which complements criteria related to energy and environmental impact [2]. In recent years, many countries around the world have developed their own green building assessment systems or methods, responding to the specific needs of their cultural and climatological context [3]. In 2014, Chile developed CES (Sustainable Building Certification in Spanish), which is applicable for both new and existing buildings. Despite the diversity among different systems, several authors note that all benefit occupants in physical, social, and/or psychological ways [4], which could have implications on health and well-being in the medium or long term. However, occupant well-being and comfort may be in conflict with building performance. For example, the energy efficiency of a building is positively affected by a compact building envelope and reduced ventilation rates, but for occupant well-being, the ventilation rate must be higher to dissipate particulate matter. In this conflict, sometimes efficiency is prioritized over occupant wellbeing [5].

For this reason, some authors have examined the ability of these methods to predict occupant satisfaction. Of note are [6] and [7] studies, which conclude that the LEED method does not affect occupant satisfaction with the building or with their workspace, in addition to finding that the positive influence of LEED certification on occupant satisfaction decreases over time. More recent research indicates that there is no complete and consistent conclusion regarding whether occupants are indeed more satisfied with their indoor environment in certified green buildings in contrast to conventional buildings [8–12]. Previous studies by Elnaklah et al. [13] grouped findings regarding the differential impact that certified sustainable buildings have on occupant satisfaction compared to conventional buildings or national benchmarks for indoor environmental quality. Studies suggesting higher occupant satisfaction in certified sustainable buildings for both thermal comfort and indoor air quality (IAQ) accounted for 56.25% of the universe [1, 14], while those showing lower satisfaction with certified sustainable buildings when compared to conventional buildings accounted for 31.25% [6, 14], and 12.5% found no difference between the two [15].

Some authors argue that the diversity of occupant characteristics conflicts with how certification systems are designed to target an average standard user, without considering habits, personal factors, or multivariate behaviors. For example, Almeida et al. [16] observed that people tend to feel a moral obligation towards specific behavior in a green building, such as energy saving, which, therefore, has a positive impact in these terms, but an unknown effect on satisfaction. Context is an important factor

in these studies. A review made by Khoshbakht et al. [10] found that research in the UK and US showed negligible differences in occupant satisfaction between sustainable buildings and their conventional counterparts regarding indoor environmental quality, while studies in China and South Korea discovered significantly higher satisfaction in sustainable buildings. The authors argue that the two contexts, western and eastern, result in different characteristics in the quality of design and maintenance of office buildings in general, which influences the baseline of occupant comfort and satisfaction. This suggests that occupant satisfaction in certified sustainable buildings is not universal, as there are local factors that influence this problem and merit further investigation at the contextual level [9].

In Latin America, 2066 buildings had been LEED certified by 2021. Similarly, in Chile, the LEED certification system has had a great impact, with more than 233 buildings certified. Additionally, 55 buildings are certified under the national CES system. Little research has been made on occupant satisfaction in sustainable buildings located in Latin American contexts. More specifically, the Chilean context has two characteristics that make this study particularly interesting: on one hand, the significant number of certified green buildings considering the size of the country, and on the other, the absence of mandatory regulations on energy and indoor environmental quality for office buildings. The latter would suggest that there may be a significant gap between conventional and green buildings. In any case, considerable progress has been made in Latin America regarding the creation of standards and regulations to promote green buildings in the coming years [17]. The objective of this article is to compare the satisfaction of occupants of LEED and CES certified sustainable office buildings with occupants of conventional office buildings located in Chilean cities, taking into consideration dimensions of thermal environment and air quality, in order to expand world knowledge on the subject.

2 Methodology

The methodology was based on fieldwork consisting of a survey of 351 occupants of 9 office buildings, together with measurements of the indoor thermal environment. 176 occupants of 3 certified green buildings and 175 occupants of 6 conventional buildings were studied in the cities of Concepción and Santiago. The survey was conducted in spring 2017 to reveal the occupants' perception of comfort in both winter and summer. A hard copy of the questionnaire was delivered to the occupants early in the morning and collected at the end of working hours in the early evening. It comprised closed-ended questions organized into sections on comfort and satisfaction in the workspace, ability to control the indoor environment, and prioritization of IEQ dimensions. Comfort and satisfaction for winter and summer were evaluated on a scale from 1 to 7 (See Fig. 1). In addition, the thermal environment (operative temperature and relative humidity) of the same offices was monitored on winter, summer, and spring days, using DELTA OHM HD 32.3 equipment, which was placed near the participants.

1. Comfort in the workspace

How would you describe the typical conditions of your usual work area in winter and summer?

Temperature	Uncomfortable	1	2	3	4	5	6	7	Comfortable
	Too hot	1	2	3	4	5	6	7	Too cold
	Constant	1	2	3	4	5	6	7	Varies during the day
Air	Still	1	2	3	4	5	6	7	Draughty
	Dry	1	2	3	4	5	6	7	Humid
	Fresh	1	2	3	4	5	6	7	Stuffy
	Odorless	1	2	3	4	5	6	7	Smelly
General conditions	Unsatisfactory	1	2	3	4	5	6	7	Satisfactory

2. Interaction with the indoor environment

In general, how satisfied are you with your ability to control the indoor environment in your office?

	Very unsatisfied	1	2	3	4	5	6	7 Very satisfied

3. Comfort and productivity

Do you consider that the influence of the following parameters on its productivity is

	Very High	High	Average	Low	Very Low	None
Temperature						
Noise						
Air quality						
Glare						
Lighting levels						

Fig. 1 Questionnaire design

The buildings were selected using comparability criteria in terms of geographic location and year of construction. The buildings are located in the two largest Chilean cities, Concepción (3 buildings) and Santiago (6 buildings), and are distributed equally, green buildings and conventional buildings, in each city. Table 1 shows the year of construction, window-to-wall ratio, and climate control mode for the case studies. Regarding climate control mode (Mode): Heating only (HT) corresponds to those buildings that only have a heating system, but are naturally ventilated by opening windows in summer; Mixed Mode (MM) corresponds to those cases that have an air-conditioning system but also operable windows, which enables natural ventilation through the opening of windows during mild periods; and Heated Ventilated and Air-Conditioned buildings (HVAC) correspond to all those sealed and air-conditioned buildings with no operable windows. As can be seen, all certified green buildings have HVAC systems, while conventional buildings varied between HT, MM, and HVAC. This also relates to window opening options, since green buildings are all sealed, with no option to open windows, unlike conventional buildings where most allow window opening.

Of the 9 case studies, two are LEED certified and one has both LEED and CES certifications. Table 2 shows the LEED credits for the following case studies: Case F, Core and Shell (v2009); Case K, Commercial Interiors (v2009); and Case O, Core and Shell (v2009). Case K is also nationally CES certified as "Outstanding Certification", with a score of 56 out of 59. Thus, Case K could be considered the greenest building in terms of certification, since it holds a double certification, Gold level in LEED, and "Outstanding" in CES. This case also has the highest number

Table 1 Characteristics of the case studies

Group	Case study code	N part.	Year	Built area (m^2)	City	WWR (%)	Mode	Operable windows
Conventional buildings	A	25	2016	4395	Concepción	70	HT	Yes
	H	29	2009	3100	Concepción	50	HT	Yes
	J	24	2009	12000	Santiago	70	MM	Yes
	L	33	2015	5947	Santiago	70	MM	Yes
	M	36	2016	15931	Santiago	40	HVAC	Some
	Q	28	2006	59000	Santiago	>80	HVAC	No
	Subtotal	175						
Green buildings	F	42	2013	8702	Concepción	70	HVAC	No
	K	38	2016	20150	Santiago	>80	HVAC	No
	O	96	2016	18630	Santiago	40	HVAC	No
	Subtotal	176						
Total		351						

N part: Number of participants; WWR: Window-to-Wall Ratio; HT: Heating only; MM: Mixed Mode; HVAC: Heated, Ventilated, and Air-Conditioned building

Table 2 LEED credits obtained by cases F, K, and O

LEED credits	Case F	Case K	Case O
Subtotal Sustainable Sites	20/28	21/21	22/28
Subtotal Water Efficiency	6/10	11/11	8/10
Subtotal Energy and Atmosphere	11/37	13/37	11/37
Subtotal Materials and Resources	2/13	3/14	4/13
Subtotal Indoor Environmental Quality	3/12	8/17	4/12
Subtotal Innovation	5/6	4/6	6/6
Subtotal Regional Priority	4/6	4/6	4/5
Total	51/110	64/110	59/110
Certification	Silver	Gold	Silver

Table 3 Operative temperature and relative humidity of the case studies

Group	Case study code	Winter		Spring		Summer	
		RH (%)	OT (°C)	RH (%)	OT (°C)	RH (%)	OT (°C)
Conventional buildings	A	60.2	20.3	47.6	21.1	57.0	21.5
	H	44.6	22.5	49.8	22.6	56.4	23.4
	J	41.9	21.7	41.9	21.9	49.0	23.9
	L	34.9	23.4	33.4	23.1	47.2	23.7
	M	43.4	21.0	34.4	22.8	44.3	23.3
	Q	41.8	21.7	38.0	22.5	48.2	23.3
	Average	44.5	21.8	40.9	22.3	50.4	23.2
Green buildings	F	46.2	22.8	48.3	23.1	51.7	23.5
	K	39.7	22.1	34.0	23.3	40.0	24.4
	O	39.8	22.8	47.7	22.9	48.9	24.1
	Average	41.9	22.6	43.3	23.1	46.9	24.0

RH: Relative Humidity; OT: Operative Temperature

of credits of the 3 cases in the IEQ category, which should be reflected in occupant satisfaction (Table 2).

3 Results and Discussion

This study has analyzed a set of data extracted from the comfort survey, comparing the results according to the type of certification that the buildings have, either green (LEED or CES) or conventional (without certification). The results are divided by the climatic seasons. Table 3 shows operating temperature and relative humidity, where green buildings are 0.8K higher in temperature than conventional buildings across all seasons.

Table 4 Characterization of occupants, office type, and building type

		Occupants		
		Conventional building	Green building	Total
Sex	Male	93 (53%)	93 (53%)	186 (53%)
	Female	82 (47%)	83 (47%)	165 (47%)
Age	18 to 25	14 (8%)	6 (3%)	20 (6%)
	26 to 35	73 (42%)	82 (47%)	155 (44%)
	36 to 45	35 (20%)	56 (32%)	91 (26%)
	46 to 55	37 (21%)	18 (10%)	55 (16%)
	56 to 65	15 (9%)	11 (6%)	26 (7%)
	Over 65	1 (1%)	3 (2%)	4 (1%)
Office type	Open plan	134 (77%)	167 (95%)	301 (86%)
	Enclosed, shared space	35 (20%)	2 (1%)	37 (11%)
	Enclosed, private space	6 (3%)	7 (4%)	13 (4%)

The characterization data by building type for the 351 occupants of the 9 buildings are displayed in Table 4. The male/female ratio is equal in both groups of buildings, as well as the number of occupants under 45 years of age, although the age distribution differs slightly between the two groups. Also, the most predominant age group is in the range of 26–35 years, averaging 44% between both groups of buildings. The greatest difference is in office type: green buildings are 95% open plan offices, compared to 77% in conventional buildings.

3.1 Responses to the Survey

The average results for each question for the green and conventional buildings groups are graphed in Figs. 2 and 3.

The results show that occupants' perceptions in both winter and summer are very similar in both groups of buildings. Conventional buildings are better evaluated in terms of thermal comfort than green buildings in both winter and summer, with a greater difference in winter.

However, green buildings are better evaluated in terms of temperature in both winter and summer, as demonstrated by the fact that the average occupant response remains around 4, between too hot and too cold, while in conventional buildings this figure moves slightly towards too cold in winter and too hot in summer. The biggest gap is in air quality, where green buildings are better evaluated in both winter and summer in terms of odors and freshness. Concerning overall satisfaction, conventional buildings are rated slightly higher than green buildings.

Figure 4 shows the boxplot analysis of all 351 occupants' responses for satisfaction under general conditions in winter and summer. It can be seen that, on average,

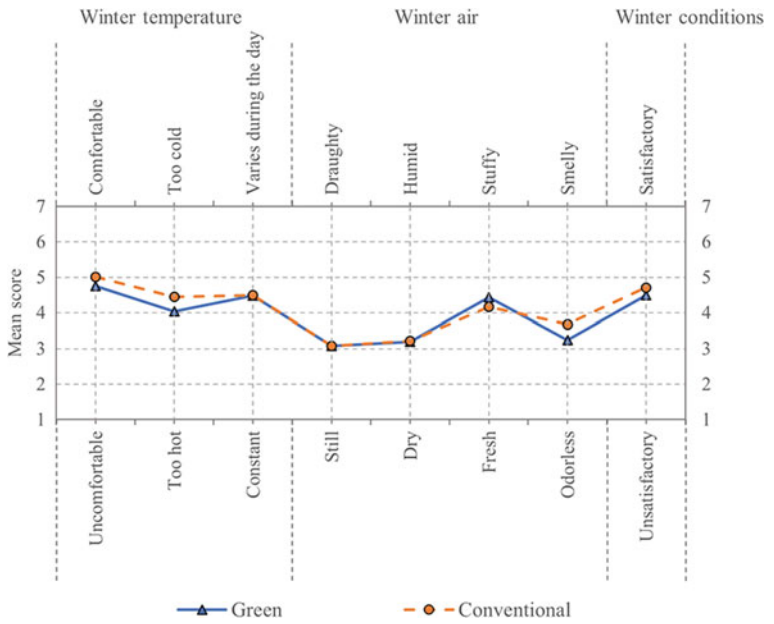

Fig. 2 Occupants' responses comparing green versus conventional buildings in winter

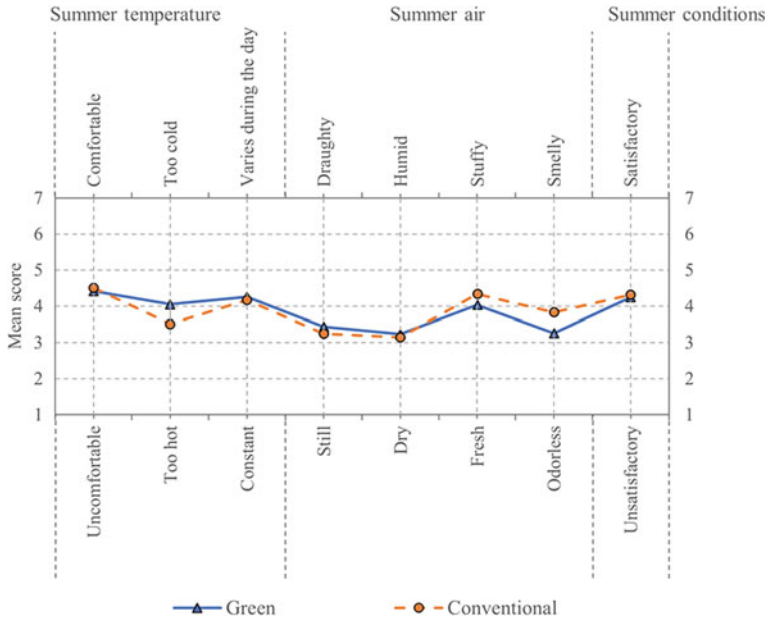

Fig. 3 Occupants' responses comparing green versus conventional buildings in summer

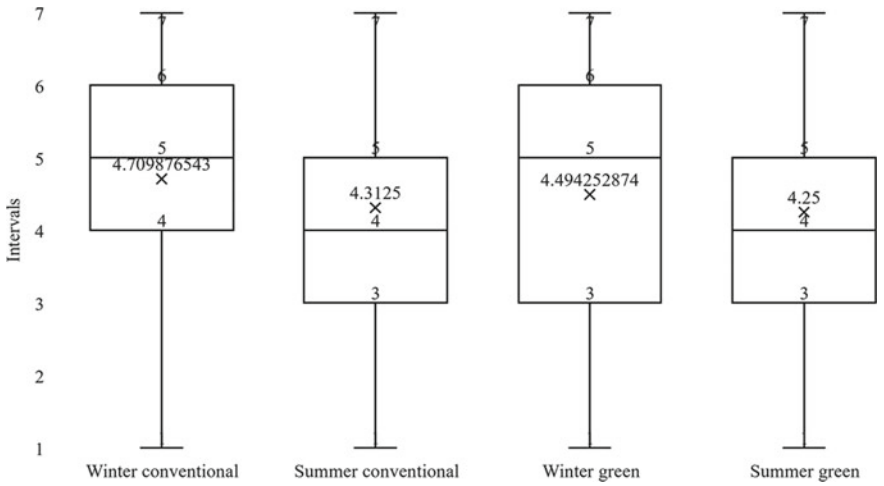

Fig. 4 Boxplot of satisfaction with general conditions in winter and summer for green and conventional buildings

conventional buildings present higher occupant satisfaction than green buildings in both seasons. In summer, satisfaction is lower and has less variation than in winter for both building groups. This can also be verified by comparing the averages of each building type, which demonstrate greater satisfaction for the winter months, especially in the case of conventional buildings.

Occupant satisfaction with general conditions in winter and summer, along with winter and summer temperatures for each case study are shown in Fig. 5. The analysis demonstrates that the maximum and minimum limits of the standard deviation are 4.94 and 4.05 respectively, the overall average of all responses is 4.50, and the standard deviation is 0.44. Case J (conventional) was the best-evaluated building, with an average response of 5.5 in winter and 5.4 in summer.

On the contrary, cases A, H, and F have the lowest average satisfaction of the study, 4.1 and 3.9 respectively, which is interesting considering that case F is certified LEED Silver. As can be seen, most of the cases are within the standard deviation limits except for case J, which has both winter and summer averages above the maximum limits, thus making it the best-evaluated case study for this question on general conditions. In an overview of all cases, most of the responses would seem to indicate that the general conditions are more unsatisfactory for the summer months.

Occupants' perception of how much each indoor environmental factor affects productivity is shown in Fig. 6. It can be observed that, in general, green building occupants perceive factors such as temperature, noise, and air quality, while lighting levels affect their productivity more than conventional building occupants.

There is a more marked difference in the noise factor, which highly and very highly affects the productivity of green building occupants. This may be related to the fact that green buildings have predominantly open plan layouts, where intrusive noise

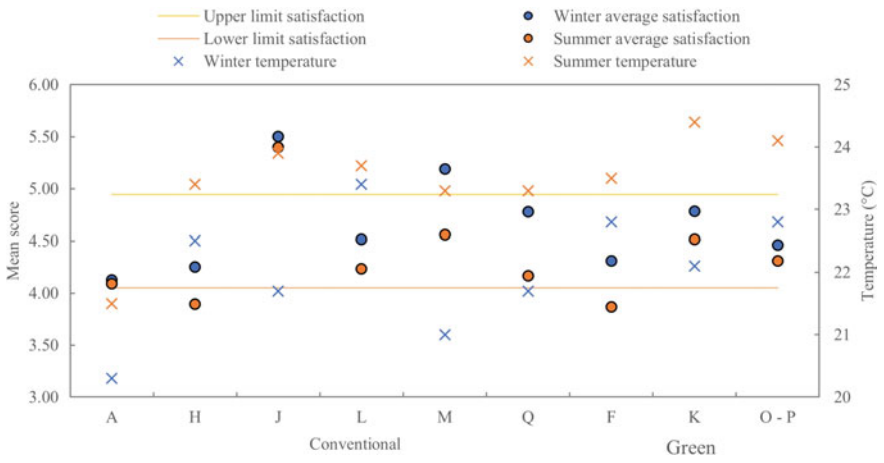

Fig. 5 Satisfaction and average temperatures for each case study

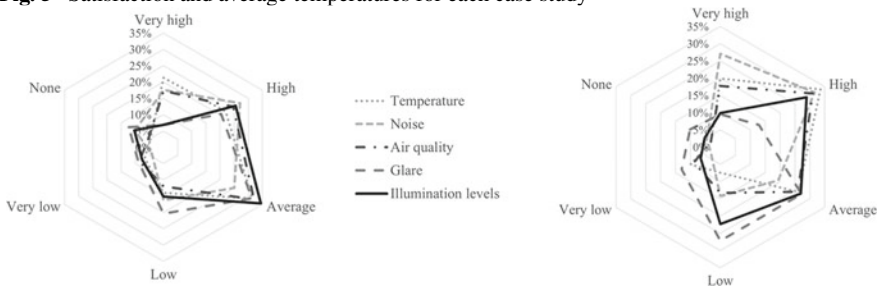

Fig. 6 Indoor environmental factors that affect productivity. Left: conventional buildings. Right: green buildings

can be greater. Glare is the only factor that affects the productivity of conventional occupants more.

Table 5 shows that the occupants of conventional buildings are more satisfied with their opportunity to control the indoor environment. The green buildings that are part of this study do not have operable windows, unlike conventional buildings that generally possess some operable windows, thereby allowing for natural ventilation. This could explain the greater satisfaction with indoor environmental control, which is in line with other studies that conclude that personal control of certain aspects of the environment can result in greater comfort and satisfaction, and sometimes better energy performance [11]. Bluyssen et al. [18] infer that limiting the use of personal controls has a negative impact and causes more symptoms associated with Sick Building Syndrome, and conversely, providing proximity to a window with an outdoor view will favor the occupant's mood and thus their mental health [19]. The variable of window opening may have a significant influence on the results, as it seems important to have control over window openings for the perception of satisfaction and additional control of the user inside the building.

Table 5 Satisfaction with the opportunity to control the indoor environment

Building type	Very dissatisfied						Very satisfied	Average
	1	2	3	4	5	6	7	
Conventional	4%	9%	12%	27%	18%	22%	8%	4.45
Green	17%	12%	19%	26%	12%	12%	4%	3.54

4 Conclusions

This research is based on a field study comparing the satisfaction of occupants of certified office buildings with conventional buildings in Chile, based on a sample of 176 occupants from 3 certified green buildings and 175 occupants from 6 conventional buildings (N = 351).

The main conclusions of this study are that from the data set analyzed of 351 survey responses from 9 office buildings, it can be concluded that there are no significant differences in satisfaction and comfort between green buildings and their conventional counterparts. The occupants of conventional buildings showed trends of higher overall satisfaction for the winter and summer months, as well as for winter and summer temperatures. The other criteria, such as air in winter and summer, showed fairly similar results in both building types.

Green buildings predominantly have an open plan layout and non-operable windows, which could explain why occupants express more sensitivity to noise and less satisfaction with the opportunities to control the indoor environment than occupants of conventional buildings. The best-evaluated building was a conventional building located in Santiago, built in 2009, making it the oldest building in the group. The building has a mixed mode operation system and allows for natural ventilation through the opening of windows.

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