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A post-occupancy evaluation of a green rated and conventional on-campus residence hall

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Abstract

Green buildings increasingly attract attention in the real estate sector, and the United States is no exception. Studies indicate that green rated buildings may bring higher rents and sales prices. One reason for this inequity is that the indoor environment of these buildings may outperform conventional buildings. The main objective of this paper is to conduct a post-occupancy evaluation (POE) to compare the indoor environment in a LEED certified, on-campus residence hall with a similar, non-green rated residence hall. Results are evaluated to determine if green buildings really outperform. The results suggest that the green rated building outperformed the conventional building in the majority of the indoor environmental aspects, but not all. These results can inform a cost-benefit analysis of green features for new construction and refurbishments.

Keywords: POE; Post-occupancy evaluation; Residence halls; Green building; Perceived indoor environment

1. Introduction

In the last decade, an interest in green, or environmentally preferred, building design has increased dramatically. The US Green Business Council's (USGBC) Leadership in Energy and Environmental Design (LEED) certification program reports that in 2005, only 2% of all non-residential building starts were green. By 2012, that number grew to 41% (Katz, 2012). As for residential buildings, the usage of the LEED for Homes scheme has also increased during the last couple of years. In 2007, the program was used to certify 392 housing units; this figure increased to more than 17000 housing units by 2013, and there are more than 82000 housing units seeking LEED certification (Kriss, 2014). However, in order for this positive trend to continue, these buildings need to be evaluated to determine if actual performance is in line with the predicted outcome. Such evaluations should include technical and economic performance, but also the experiences of occupants.

One way to study these questions is to perform a post-occupancy evaluation (POE), which is defined as "the examination of the effectiveness for human users of occupied designed environments" (Zimring and Reizenstein, 1980, p. 1). A POE assesses client satisfaction as well as

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the functional "fit" of a specific space, with focus on the occupants' needs (Zimmerman and Martin, 2001). Such investigations can clarify occupants' perceptions of the indoor environment as well as the building design, potentially leading to performance benchmarks. Further, each case study brings about a learning opportunity for all involved stakeholders (Turpin-Brooks and Viccars, 2006).

POEs have been conducted in both residential and commercial buildings, using various baselines and comparisons. Some studies focus on occupant satisfaction in and/or perception of green buildings (Armitage et al., 2011; Gou et al., 2012a; Wilkinson et al., 2013). Other studies emphasize the differences (if any) in the occupants' satisfaction in and/or perception of green and conventional buildings (Abbaszadeh et al., 2006; Gou et al., 2012b; Paul and Taylor, 2008; Zalejska-Jonsson, 2012). Still others examine a move from a conventional building/refurbishment of a conventional building to a green building (Agha-Hossein et al., 2013; Thatcher and Milner, 2012; Sustainability Victoria and Kador Group, n.d.).

Specific research into air quality and indoor temperature has varied results. Some studies find that the occupants of green buildings have an overall greater satisfaction with both air quality (Abbaszadeh et al., 2006; Gou et al., 2012a; Zalejska-Jonsson, 2012) and, under certain conditions, thermal comfort (Abbaszadeh et al., 2006; Gou et al., 2012a,b; Thatcher and Milner, 2012). On the other hand, some research indicates that for various reasons and at different times of the year, there is more dissatisfaction with the temperature in green buildings (Gou et al., 2012a,b; Paul and Taylor, 2008).

Satisfaction with lighting also varies across different studies. In some instances, there is no discernable difference in perceived lighting quality when comparing green and conventional buildings (Abbaszadeh et al., 2006; Paul and Taylor, 2008). However, other studies indicate less satisfaction with lighting in green buildings (Gou et al., 2012b; Thatcher and Milner, 2012).

It is important to note that an individual's beliefs about environmental sustainability and its' importance can impact the view of building performance. Paul and Taylor (2008) employ environmental psychology to discuss "place identity," which predicts that individuals with pro-environment beliefs are more likely to identify with green buildings. As a result, they are more likely to give high satisfaction ratings when occupying environmentally friendly structures. Similar findings indicate that individuals with an ethic of sustainability report higher overall satisfaction with green buildings (Monfared and Sharples, 2011) and are more likely to overlook shortages in green designs (Deuble and de Dear, 2012; Leaman and Bordass, 2007).

Some studies also discuss the building's influence on pro-environment beliefs and behavior. Armitage et al. (2011) notice a difference between managers' and employees' opinions of a green work place. While managers believe that working in a green rated building has a positive impact on the employees' behavior and attitudes from an environmental point of view, the employees' report that they do not believe that the work environment has any impact on their environmental awareness. When looking into the residential sector, Zalejska-Jonsson (2012) results indicate that green residential buildings have a positive impact on the residents environmental awareness and behavior. However, Wilkinson et al. (2013) could not find such a relationship in their study.

2. Sustainable residence halls

In 1990, college and university leaders from around the world convened in Talloires, France to discuss the intersections between higher education and sustainability. Their public declaration outlined that "universities educate most of the people who develop and manage society's institutions. For this reason, universities bear profound responsibilities to increase the awareness, knowledge, technologies and tools to create an environmentally sustainable future" (Talloires Declaration, 1990). These university leaders were the first to collectively articulate the importance of addressing sustainability at institutions of higher education.

Since the Talloires Declaration, a rapidly increasing number of colleges and universities are working to infuse sustainability into policies and practices. Given their popularity, residence halls are one obvious conduit for greening a campus. The Association of College and University Housing Officers International estimates that over 2000 higher education institutions provide housing for over 2 million students (Torres-Antonini and Park, 2008).

2.1. University of Arizona Residence Life

As of June, 2014, there are 6546 permanent bed spaces and 174 extended housing spaces on the University of Arizona (UA) campus, spread between 22 undergraduate halls. The buildings were first occupied between 1921 and 2011, with five residence halls listed on the National Register of Historic Places and six built since 1990.

The most recent of these new buildings came from the Sixth Street Housing Project, which developed the Arbol de la Vida and Likins residence halls. UA policy dictates that new construction should seek at least LEED Silver certification. This project exceeded that expectation by producing two LEED for New Construction (v2.2) Platinum certified buildings.

After interviewing several UA employees intimately involved with this project, it is clear that the original intent was not to seek Platinum certification. Rather, the goal was to build structures that would provide the best possible environments and be durable enough to withstand the test of time and undergraduates. The team pursued all appropriate LEED credits, leading to the first LEED Platinum residence halls in Arizona.

In addition to new construction, UA Residence Life takes on regular renovation projects. Beginning in 2009,

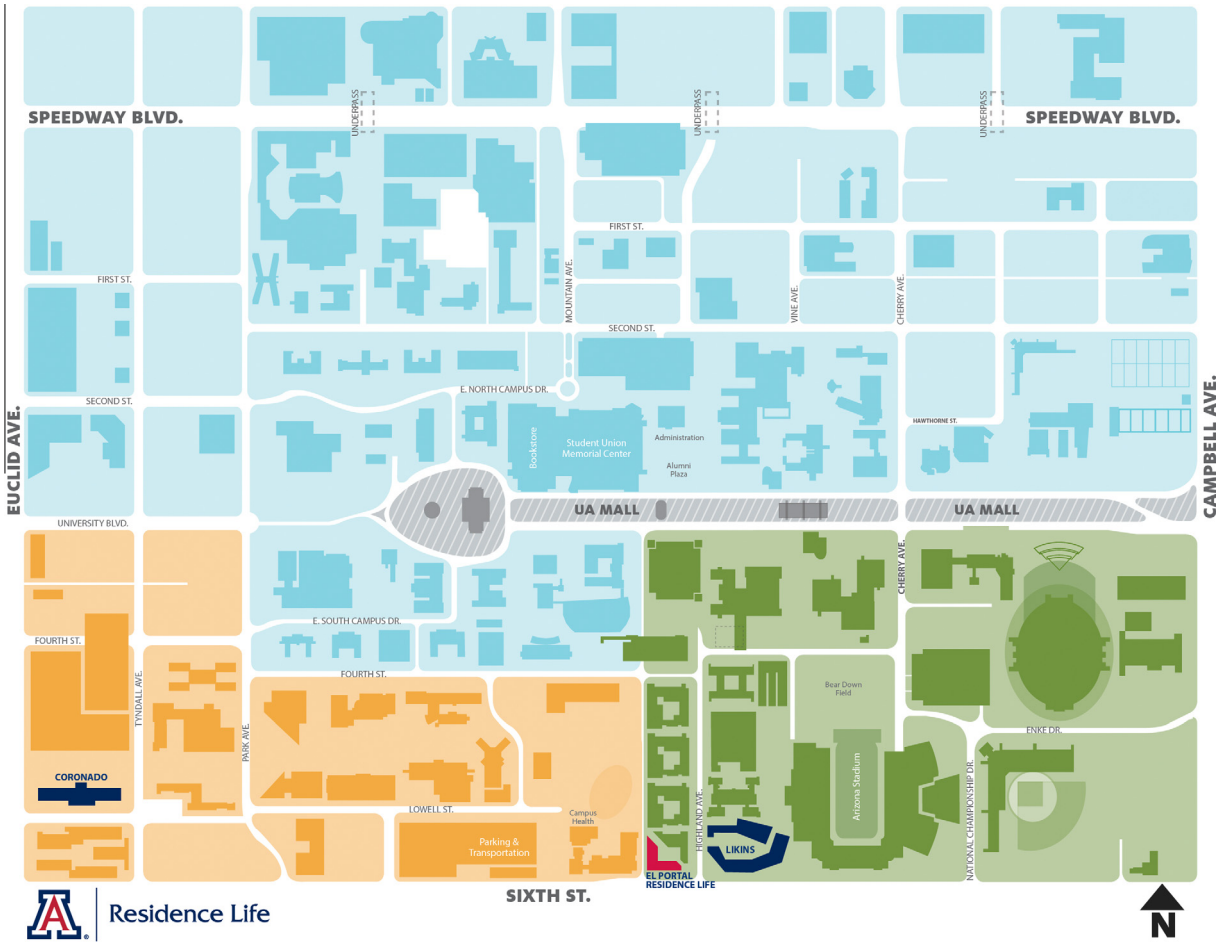

Figure 1. Campus Map (Source: Santander, A., 2014, Residence Life – Marketing, The University of Arizona).

the department began upgrading the windows in Coronado hall from single pane to double pane. Then, the hall was closed for major renovations for the entire 2011–2012 academic year. During the update, a number of building features were modernized, including: Student room décor and lighting, corridor lighting, the building exhaust system, and components of the electrical system. In addition, the building's waste and supply plumbing were also replaced.

The position of the two selected buildings (Likins and Coronado hall) is shown in the map of the campus area as presented in Fig. 1.

2.2. Description of Likins hall

Likins (pronounced "lye-kyns"), named after the UA President Emeritus Peter Likins, is a four to six story building first occupied in August, 2011. The building, which received a LEED for New Construction (v2.2) Platinum certificate, is designed around a large hacienda-style interior courtyard and its residential layout is a double loaded corridor with gang restrooms.

The building is equipped with green features such as solar thermal hot water, specially designed window shading, occupancy sensors for lights/AC, green plugs, recycled concrete roof coverings and an enhanced ventilation scheme. All of this ensued the LEED Platinum rating, which included a high score in the category Indoor Environmental Quality (IEQ).

The resident rooms have carpeted flooring, with the exception of the ADA[1] rooms which have sheet goods floors. The restrooms feature a poured-in-place seamless epoxy floor.

The student rooms' ceilings are exposed concrete, while the common areas ceilings are either exposed concrete, acoustic lay-in or specialty ceiling. The load-bearing walls are made of poured-in-place concrete while the interior walls are typically steel studs and drywall. An illustration of the student room floor plan is illustrated in Fig. 2.

In all, the building has a total gross area of 117 599 sq. f. (10 925 sq. m) with 17′6" by 11′6" feet (5.4 by 3.5 m) double rooms and some smaller, single occupancy, rooms. There are 171 student rooms, and the rent for a double room is $7870 per year. Floors two through six are all a combination of resident rooms, bathrooms and recreation/study spaces. The first floor includes offices, meeting rooms, storage spaces, a kitchen, as well as media and Great

[1] Americans with Disabilities Act.

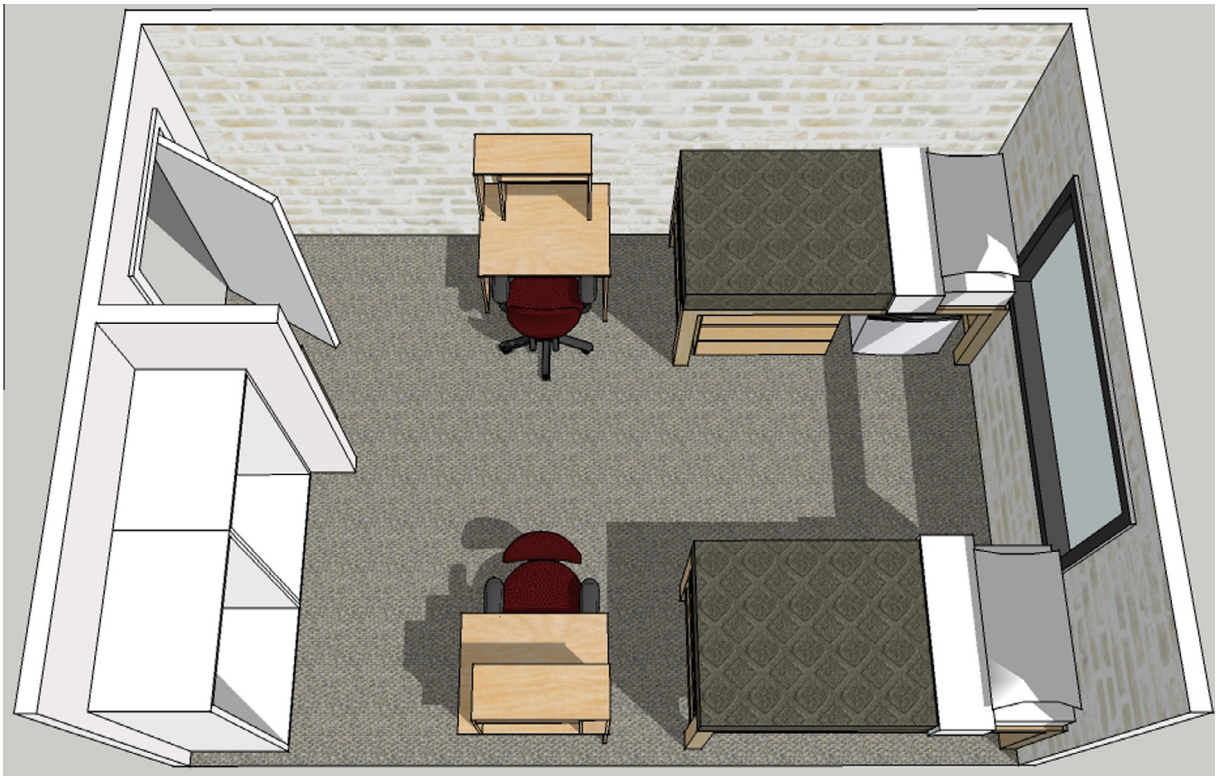

Figure 2. Likins room floor plan (Source: Residence Life, The University of Arizona, http://www.life.arizona.edu/images/floorplans/pueblo-de-la-cienega.jpg?sfvrsn=2).

Figure 3. Likins Residence Hall (Source: ROBBINS-MURRAY, D., 2014, Residence Life – Marketing, The University of Arizona).

rooms. A picture of the facade facing the south is presented in Fig. 3.

All UA residents are responsible for taking personal trash to a specially designated location at each building. In Likins, the trash room is accessible from the first floor courtyard. Recycling collection is also located inside the trash room, mere feet (about 1 m) from the garbage bins. There are two other recycling receptacles available on the main floor, but no other trash locations.

2.3. Description of Coronado hall

Coronado is a nine-story residence built in 1966 and refurbished in 2011–2012. The first floor consists of office spaces, lobby, a gym and common areas. The 400 student rooms are located on stories two through nine, and the rent for a double room is $7870 per year. In addition to resident rooms, these floors have two common spaces/study rooms, with various closets, storage spaces and mechanical rooms scattered throughout the building. The double rooms are 10′ by 20′ feet (3 by 6.1 m), with a total building area of 145 850 sq. f. (13 550 sq. m).

The building skeleton is steel post and beam, with poured-in-place reinforced concrete floors and roof. The student rooms have a suite-style design, where two rooms share an adjoining bathroom. This means that, typically, four students share one bathroom. The flooring in the student rooms is carpet, with ceramic tile in the restrooms. An illustration of the room layout is illustrated in Fig. 4.

In the common areas the flooring is vinyl composition tile (VCT), carpet or ceramic tile. The interior walls are wire stud with plasterboard and ceilings are textured structural concrete or upgraded acoustic ceilings.

During the renovation, occupancy sensors were added to both student and study rooms. Garbage is taken to a trash compactor located immediately adjacent to the building's main floor. To reach the recycling bins from the compactor, occupants must descend half a flight of stairs and walk approximately five yards (4.6 m). There are no indoor recycling receptacles. A picture of the facade facing the north is presented in Fig. 5.

3. Purpose and method

The purpose of this study is to examine the experienced differences in the indoor environment between a LEED Platinum certified residence hall (Likins hall) and a conventional residence hall (Coronado hall). It is predicted that the perceived indoor environment is better in the LEED certified building, as the building scored very well in the LEED IEQ (Indoor Environmental Quality) category. In order to evaluate this, a "two-case" case study is conducted, following a case study design outlined by Yin (2009). The cases are strategically chosen to be as similar as possible, considering construction/redevelopment dates and rent.

The project started with a walk through of both buildings and a total of six resident interviews of about 30 min each in Likins hall. The purpose was to get a general sense of how the occupants regarded the building's indoor

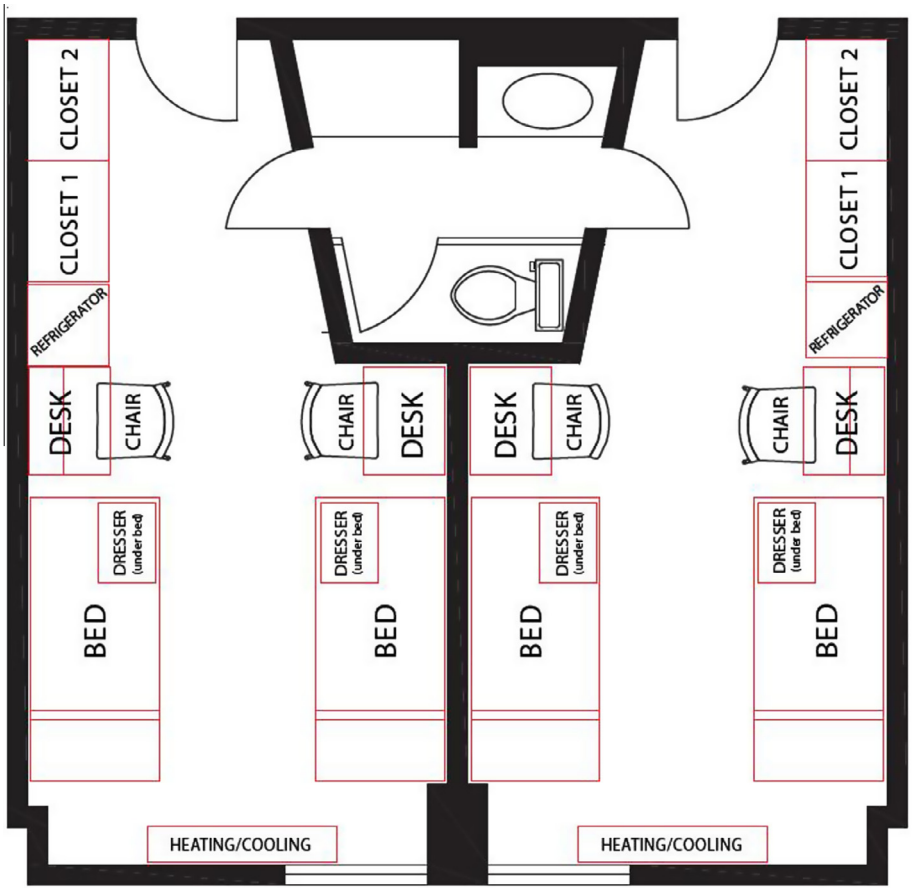

Figure 4. Coronado room floor plan (Source: Residence Life, The University of Arizona, (http://www.life.arizona.edu/images/floorplans/coro-floorplan.PNG?sfvrsn=2).

Figure 5. Coronado Residence Hall (Source: Robbins-Murray, D., 2014, Residence Life – Marketing, The University of Arizona).

environment in general, and the green features in particular. The interviews had a semi-structured context, enabling us to ask clarifying follow-up questions (Kajornboon, 2005). With the interviews in mind, an online survey was created to be sent to all residents of both buildings. The survey asked about the experience of indoor environmental aspects (room air temperature, room air quality and lighting conditions), and how the residents regarded green features (motion sensors, recycling behavior etc.).

The questionnaire was sent to the approximately 360 Likins residents on April 1, 2014 and was open for responses until April 18, 2014. At the same time, an identical survey was sent to the approximately 770 residents of Coronado hall. All residents were e-mailed a link to the survey by the buildings' Community Directors, professional staff members who manage the site. Students were informed that by participating they were eligible to win one of six $20 UA Bookstore gift cards.

The questions in the survey was outlined as either closed-ended, semi-closed ended or open-ended questions (Survio, 2013). The responses were formatted as either dichotomous response, nominal response, interval-level response or continuous response (Bhattacherjee, 2012). Chi-square tests were used to analyze the differences.

Reporting ones behaviors/opinions in an interview or survey in an unbiased manner is, however, not such an easy task as it may seem. As pointed out by Schwarz and Oyserman (2001) and Scheffer (2013), the structure (open ended, closed ended etc.) and the wording of the question itself will to some extent affect the answer (if you get any). Furthermore, the order of the alternative answers in the (semi-)close ended questions can affect the responses. Also, reporting past events is difficult due to the highly selective nature of human memory and recall. Therefore, questions regarding the past were kept to a minimum.

4. Results

In all, 85 students responded to the survey (1 incomplete), an overall response rate of around 7%. Out of these, 37 lived in Likins and 48 lived in Coronado. This gives us a response rate of about 10% in Likins and 6% in Coronado. Woman respondents are in majority (65 female and 19 male, 1 no response) as well as freshmen (first year) students (64 freshmen, 11 sophomore, 5 junior and 3 in year 4 or higher).

The following section presents the part of the study which considers the respondents perception of the indoor environment.[2]

Q: How is the temperature in your room during the...?

Answer choices Likins	Fall semester	Spring semester
Always too hot:	0 (0.00%)	0 (0.00%)
Mostly too hot:	2 (5.41%)	1 (2.70%)
Typically at a comfortable temperature:	30 (81.08%)	31 (83.78%)
Mostly too cold:	3 (8.11%)	5 (13.51%)
Always too cold:	2 (5.41%)	0 (0.00%)
Don't know:	0 (0.00%)	0 (0.00%)
Total:	37 (100.00%)	37 (100.00%)

Answer choices Coronado	Fall semester	Spring semester
Always too hot:	2 (4.26%)	0 (0.00%)
Mostly too hot:	12 (25.53%)	6 (13.04%)
Typically at a comfortable temperature:	24 (51.06%)	28 (60.87%)
Mostly too cold:	2 (4.26%)	9 (19.57%)
Always too cold:	6 (12.77%)	3 (6.52%)
Don't know:	1 (2.13%)	0 (0.00%)
Total:	47 (100.00%)	46 (100.00%)

[2] Please see Appendix A for the complete list of questions. The interested reader is encouraged to contact the corresponding author for further results.

As noted, the Likins respondents are to a greater extent more satisfied with the indoor room air temperature, during fall as well as spring semester. As for the fall semester, this difference is significant at a 5% level. However, for the spring semester the difference is only significant at a 10% level.

Q: "Were the thermostat or fan controls in your room easy to...?"

Answer choices Likins	Yes, very	Yes, quite	No	Don't know	Total
Find	35 (94.59%)	2 (5.41%)	0 (0.00%)	0 (0.00%)	37 (100.00%)
Use	31 (86.11%)	4 (11.11%)	0 (0.00%)	1 (2.78%)	36 (100.00%)

Answer Choices Coronado	Yes, very	Yes, quite	No	Don't know	Total
Find	32 (68.09%)	13 (27.66%)	2 (4.26%)	0 (0.00%)	47 (100.00%)
Use	23 (51.11%)	18 (40.00%)	4 (8.89%)	0 (0.00%)	45 (100.00%)

As for the room thermostats/fan controls, a significant difference ($\alpha = 5\%$) in favor of the Likins hall is also found, both regarding how easy they are to find and how easy they are to use.

Q: "How is the air quality in your room?"

Answer choices Likins	Responses
Good	24 (64.86%)
Acceptable	10 (27.03%)
Could be better	3 (8.11%)
Bad	0 (0.00%)
Don't know	0 (0.00%)
Total	37 (100.00%)

Answer choices Coronado	Responses
Good	15 (31.91%)
Acceptable	20 (42.55%)
Could be better	11 (23.40%)
Bad	1 (2.13%)
Don't know	0 (0.00%)
Total	47 (100.00%)

The Likins respondents are to a greater extent more satisfied with the room air quality. This difference is significant on a 5% level.

The respondents who answered "Could be better" or "Bad" (in the question regarding room air quality) are given a follow up question about what bothered them with the room air quality.

Q: "What bothers you about the air quality (multiple choices OK)?"

Answer choices Likins	Responses
Smoke (e.g. tobacco smoke)	0 (0.00%)
Garbage smell	1 (33.33%)
Mold odor	0 (0.00%)
Stuffy air	2 (66.67%)
Dusty air	1 (33.33%)
Other	1 (33.33%)
Total respondents:	3 (100.00%)

Answer choices Coronado	Responses
Smoke (e.g. tobacco smoke)	2 (18.18%)
Garbage smell	5 (45.45%)
Mold odor	2 (18.18%)
Stuffy air	7 (63.64%)
Dusty air	5 (45.45%)
Other	0 (0.00%)
Total respondents:	11 (100.00%)

Issues with the room air quality in Likins is stuffy air, garbage smell, dusty air and other (musty smell). In Coronado, the issues mainly considered stuffy air, garbage smell, dusty air, smoke and mold odor.

Q: "During the daytime, is there enough natural light in the room without turning on artificial lights?"

Answer choices Likins	Responses
Yes	30 (85.71%)
No	5 (14.29%)
Don't know	0 (0.00%)
Total	35 (100.00%)

Answer choices Coronado	Responses
Yes	34 (72.34%)
No	11 (23.40%)
Don't know	2 (4.26%)
Total	47 (100.00%)

As for the natural light in the rooms, the responses from both buildings are mostly positive. There is no significant difference between the two buildings.

Q: "How is the artificial lighting for studying in…?"

Answer choices Likins	Your room	Study rooms	Common spaces
Very good	10 (28.57%)	19 (55.88%)	13 (39.39%)
Good	8 (22.86%)	12 (35.29%)	15 (45.45%)
Acceptable	11 (31.43%)	3 (8.82%)	5 (15.15%)
Bad	4 (11.43%)	0 (0.00%)	0 (0.00%)
Very Bad	2 (5.71%)	0 (0.00%)	0 (0.00%)
Total	35 (100.00%)	34 (100.00%)	33 (100.00%)

Answer choices Coronado	Your room	Study rooms	Common spaces
Very good	15 (31.91%)	18 (38.30%)	10 (21.28%)
Good	20 (42.55%)	18 (38.30%)	25 (53.19%)
Acceptable	9 (19.15%)	8 (17.02%)	12 (25.53%)
Bad	1 (2.13%)	2 (4.26%)	0 (0.00%)
Very Bad	2 (4.26%)	1 (2.13%)	0 (0.00%)
Total	47 (100.00%)	47 (100.00%)	47 (100.00%)

Regarding the artificial lighting for studying in the students individual rooms, study room and common areas; we notice that almost all students find the artificial light in the study/common areas at least acceptable. As for the individual room, some respondents are not pleased with the artificial lighting for study purpose. There is no significant difference between the two buildings regarding the artificial lighting for study purpose in the individual room, study rooms or common spaces.

5. Discussion

Our initial assumption was that the green rated building would outperform the conventional building. This holds true for indoor comfort indicators such as indoor room air temperature and air quality, but falls short regarding lighting qualities. The greater satisfaction with the indoor air temperature in Likins could be due to the specially designed window shadings, which shade to a greater extent during the sunnier parts of the year. It could also be that the thermostats are easier to find and use, resulting in a more comfortable room air temperature. Regarding the room air quality, the difference could be due to the increased ventilation, the air flush-out prior to occupancy and usage of low emitting materials in the green rated building. However, as for natural and artificial lighting, no significant difference is found between the two buildings. Especially regarding the natural lighting, this is a bit of a surprise, as the room windows in Likins are considerably larger, in order to comply with the requirements for "Daylight and views" in the LEED IEQ category.

6. Conclusion

This study shows that the LEED rated Likins building outperforms the conventional Coronado dorm in categories such as indoor air quality and indoor air temperature, features that usually have an effect on the overall indoor comfort. It is, however, noteworthy that when considering daylight and artificial light, no significant difference is found. This begs the question: Relative to cost, which green features are the most beneficial?

This study is a small step in evaluating the performance of green rated buildings. Future studies within this field could go further by actually measuring lighting, air pollutants, indoor temperature, and the like, in order to more accurately assess a buildings indoor environment. Furthermore, future research could also encompass technical and economic aspects of the building performance, such as energy usage and maintenance costs. This would give an even broader view of how the building is performing, complementing POE data from tenants' reports of their experiences.

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Appendix A. Complete list of survey questions

Q: "On which floor is your room located?"
Q: "Do you live alone in your room or do you have a roommate?"
Q: "What year are you in the university?"
Q: "What gender are you?"
Q: "Do you live in Likins or Coronado?"
Q: "Do you use the "green" plugs in your room?"
Q: "Was it easy to find the stairs in the building?"
Q: "Was it easy to find the elevators in the building?"
Q: "Do you mainly use the stairs or elevators?"
Q: "Why do you mainly use the stairs (multiple choices OK)?"
Q: "Why do you mainly use the elevators (multiple choices OK)?"
Q: "How is the temperature in your room during the fall semester/spring semester?"
Q: "Do you ever open your window in order to adjust temperature (make it cooler/warmer) or refresh the air?"

Q: "Were the thermostat or fan controls in your room easy to find/use?"
Q: "How is the air quality in your room?"
Q: "What bothers you about the air quality (multiple choices OK)?
Q: "During the daytime, is there enough natural light in the room without turning on artificial lights?"
Q: "How is the artificial lighting for studying in your room/study rooms/common spaces?"
Q: "Do you ever leave the blinds down during the daytime for privacy?"
Q: "Are you ever bothered by the presence Sensors (which make the lights/AC etc. go off when there is no movement in the room) in your room/common rooms?"
Q: "Is it too far to carry and dispose of recycling/trash?"
Q: "Do you recycle?"
Q: "Why do you recycle (multiple answers OK)?"
Q: "What stops you from recycling (multiple answers OK)?"
Q: "How would you describe your general beliefs about sustainability?"
Q: "Do you use a bike here in Tucson?"
Q: "Do you have a secure place to park you bike in adjacent to your residence hall?"
Q: "Are there places you frequently visit that are too far to use a bike?"
Q: "How would you describe the style of your residence hall (multiple answers OK)?"
Q: "Can you name any of the sustainable features in your hall? If so, list them here"

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