'GREEN' BUILDINGS: WHAT AUSTRALIAN BUILDING USERS ARE SAYING

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Abstract

A comparative post-occupancy evaluation, based on occupant surveys of 22 'green design intent' buildings and 23 conventional buildings in Australia has been undertaken by Leaman, Thomas and Vandenberg. The study shows that while the best green buildings consistently outperformed the best conventional buildings from the occupants' perspective, the first generation of Australian green buildings may be underperforming on some indoor environment variables. Green buildings that are designed and operated properly and are user responsive achieve positive environmental outcomes and simultaneously deliver positive feedback for comfort and productivity. On the other hand, green buildings that do not perform well, as a consequence of poor realisation of design intent and little attention to user needs, run the risk of greater user dissatisfaction than many conventional buildings.

Across the buildings studied, the researchers identified significant associations between perceived productivity and overall comfort (lighting, ventilation, thermal comfort, and noise) and between perceived productivity and thermal comfort in particular. The findings presented in the paper highlight the importance of learning from post occupancy evaluations by using occupant feedback towards further development of successful green buildings.

Keywords: post-occupancy evaluation, indoor environment quality, perceived productivity

Introduction

Are 'green' buildings working from the building users' perspective? This paper presents initial findings from 45 Australian buildings [4] with a view to highlighting lessons towards developing successful green buildings.

By 'green' we mean buildings that have been created with explicit intent to include environmentally sustainable design (ESD) features and principles. Although the objective may be to create buildings with less environmental impact, they may not necessarily achieve this in reality. While the relative performance of buildings can be measured in terms of aspects such as water and energy efficiency, it is vital to understand the experience of the buildings from the users' point of view. Not only can a poorly performing building affect users' well being and productivity, in addition, subsequent measures needed to alleviate users' discomfort can result in great expense and in the building failing to achieve its efficiency targets. Our discussion here deals with end-user responses. A more complete picture would require study of both technical performance, including detailed energy assessment using measured data over a period of time, in conjunction with occupant surveys. This is not attempted within the present study, which is limited to building users' experiences and feedback.

Our findings come from occupant surveys in 22 'green' buildings and 23 'conventional' buildings in Australia, most of them carried out between 2003 and 2006 [5]. The 45 buildings are not a random sample. They are all the buildings that have been benchmarked using the Building Use Study survey [6]. The majority of the green buildings in the study have been built between 1998-2002 and are often referred to as "first generation green buildings". The term 'conventional' as used here refers to those buildings in the dataset where attention to ESD was not articulated as part of the design intent. Nearly all the conventional buildings are older, although a few have been completed as recently as 2005. Some of the conventional buildings included are those where 'pre-occupancy' surveys were undertaken, prior to the occupants move to new premises with a green design intent. It is also worth noting that the conventional dataset presented here is likely to be better than the norm, given several of the occupant studies in the conventional category have been prompted by owners and designers, partly to gauge the impact of positive interventions. As well as offices, the buildings in both categories include a range of educational buildings and libraries.

The Building Use Studies survey method has the capacity to provide feedback for over 60 variables covering aspects of overall comfort, temperature, air movement and quality, lighting, noise, productivity, health, design, image and workplace needs. At this stage we have examined the key summary variables, with some additional detail for the environmental variables - temperature, air, lighting and noise. It is anticipated that further analysis with a larger dataset will be undertaken to cover the full range of variables.

Our analysis is drawn from the raw scores for individual variables for each the building that we are studying. We do not 'normalise' (weight) the scores to give different emphasis to particular variables, or for number of occupants in each building or time that occupants spend in the building, as we find that weighting raises more problems than it solves, and can be misleading.

Users and green buildings

From the users' perspective green buildings have much going for them, because they seem to put back into buildings features which occupants like. These features, such as natural light, views and natural ventilation, have been disappearing from non-residential buildings over the past two to three decades. This applies especially to people who have workstations in deep-plan, air conditioned offices who often have less access to natural light and views, and lack individual control over heating, cooling, ventilation, lighting and noise.

Green buildings typically have:

- More natural ventilation, or, at least, a mixture of natural ventilation and air conditioning, and/or increased fresh air via the mechanical ventilation system.

- Narrow plan forms, often within the 15m limits of natural ventilation and daylight access, the corollary of which is less 'deep' space in the middle, which users dislike.
- Better utilisation of daylight.
- More user controls for windows, blinds, lights and ventilators. This can mean that needs (like thermal comfort) are met more quickly even though the conditions may only be 'good enough'. Users like rapid response when things go wrong or need changing, and will tolerate conditions which are reasonable.
- Higher floor to ceiling heights, which helps, eg, with daylight penetration.
- More open plan workspaces (usually desks) close to or next to windows.
- More care taken in design of achieving comfortable conditions, especially in summertime.

The above are features of buildings which occupants like and request when missing. Our experience is that successful green buildings often have:

- A more explicit design brief, so that targets are set.
- An integrated multidisciplinary team approach to design that is mindful of user needs.
- Extra consideration given to the reduction of energy use, water use and greenhouse gas emissions, with more efficient and better controlled fabric and equipment, site sensitive design and the selection of materials with less environmental impact.
- Responsive building management during commissioning and operation.
- Greater monitoring, so that performance outcomes are more likely to be assessed, more willingness to share findings, make them public and learn from mistakes.
- A more involved client, who may often also be the building's main tenant or user, and usually also committed to ESD principles.[7]
- Experience shows that green buildings can:
- Be more complex, with technologies which are difficult to manage or understand adequately. This follows trends in the 1980s and 1990s when buildings became harder to manage.[8]
- Include experimental features which may not be robust or tried-and-tested (although this can also be catch-22 because it is part of the much needed development and learning cycle which enables learning from experience).
- Incorporate token gestures, with not enough attention given to the basics of good design and construction, usability, manageability and ease of maintenance.
- Place too much emphasis on good intentions at the design stage, rather than the practical reality of their management and use. For example, to find that energy consumption estimates at design stage are grossly exceeded in reality.[9]

Our evaluation of green buildings through the BUS methodology has shown that the best green buildings can be a step-change improvement from what has gone before.

These buildings are still relatively few, but are growing in numbers. Green buildings tend to be riskier, in the sense that their performance varies more widely across the sample. The bigger they get (for example, in depth and height), the harder it becomes to resolve all the requirements to produce good all-round performance.

Users are often more tolerant of green buildings because, as previously discussed, green buildings have many of the features which users like. While it could be argued that their liking these has little to do with the 'greenness' of the features, the crucial thing is that the building satisfies the majority of the users' perceived needs quickly and effectively with the least environmental impact.

Comparisons

How well do 'green' buildings compare with 'conventional' buildings within Australian dataset? Provisional findings are shown in Figures 1 to 9.

Figures 1 to 5 have comparisons for a range of variables: summary variables can be found in Figure 1, while Figures 2 to 5 provide more detail for temperature, ventilation, lighting and noise. Figure 6 has comparisons for summary variables on box and whisker plots. Figure 7 has plots for the overall comfort variable showing all buildings studied. Plots for the remaining summary variables are available online.[10]

Summary variables ask for occupants' responses overall to a particular topic. For example, in addition to asking occupants to rate whether it is too hot or cold in summer, and whether temperatures are too stable or too varied, we also ask occupants what the temperature comfort conditions are like in summer overall – the summary variable. We find that using only summary questions can produce an apparently more optimistic response than with the more detailed questions, so we consider both (see Figures 2-5).[11]

The summary charts in Figures 1-5 have mean scores for green and conventional datasets across the studied variables. They are an indication of the average performances of the green dataset compared with the conventional dataset. In addition, their graphic location on the graduated scale makes it possible to assess how the mean scores compare to the scale properties (eg. the scale midpoint). For example, for the variable 'Health' in Figure 1, green buildings are appreciably better than conventional buildings (closer to satisfactory at the right-hand end of the scale) but the score for green is still only at the scale midpoint, which is only a reasonable performance. The benchmark for Australia (not shown in Figures 1-5) falls between the green and conventional scores.

Figure 1 highlights:

- Users perceptions of the 'physical' variables (temperature, air/ventilation, lighting, noise) with the exception of 'lighting overall' were, on average, lower in green buildings.
- Green building scores for 'soft' variables (design, image, needs, health, and perceived productivity, are on average generally better or about the same.

Summary findings from Figure 1 include:

- Poorer perceived thermal comfort performance for green buildings overall, especially in summer, but also the tendency for green buildings to be too cold in winter.

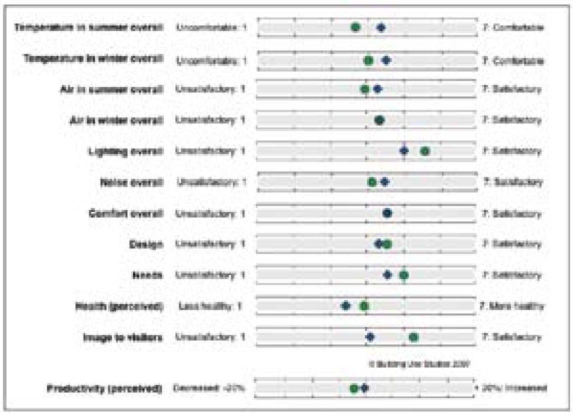

Figure 1 – summary variables
Circles = green intent (n=22); Diamonds = conventional (n=23); Building Use Studies Australian dataset 2007.

- Improvements in lighting ratings, especially in dealing with the problems of artificial lights and glare, which may also be connected with better lighting technology and new types of flat computer screen.
- Marginally lower perceived productivity scores on average, which, as discussed later, are strongly influenced by the experience of thermal comfort and comfort overall in individual buildings.
- All-round improvements in ratings for design, needs, image and health.

As noted the majority of 'green' buildings in the current dataset are first generation. It is anticipated that there will be an improvement in the next generation of green buildings.

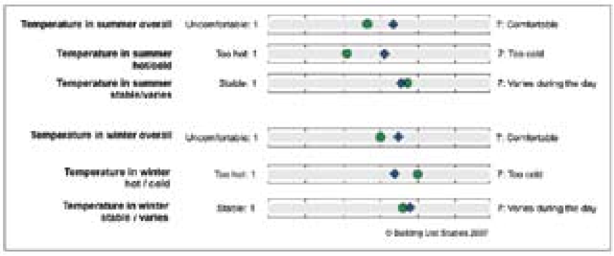

Figure 2 – temperature
Circles = green intent (n=22); Diamonds = conventional (n=23); Building Use Studies Australian dataset 2007.

Figure 2 presents comparisons for the temperature variables showing both the summary variable and the more detailed ratings averages. For temperature:

- Green buildings were generally rated as much hotter in summer overall on average, however, the best green buildings tend to outperform the best conventional.
- Green buildings are colder in winter, both relatively (compared with conventional) and absolutely in terms of the rating scale.
- Temperatures in green buildings tend to have a higher variability in both summer and winter (not shown on Figure 2).

Our experience of the green buildings that are rated poorly for thermal comfort is that, despite the best design intentions, they have inherent problems such as poorly configured controls, partial understanding of how users interact with the controls, inability to rectify problems quickly, and, in some situations, design concepts that do not work in reality.

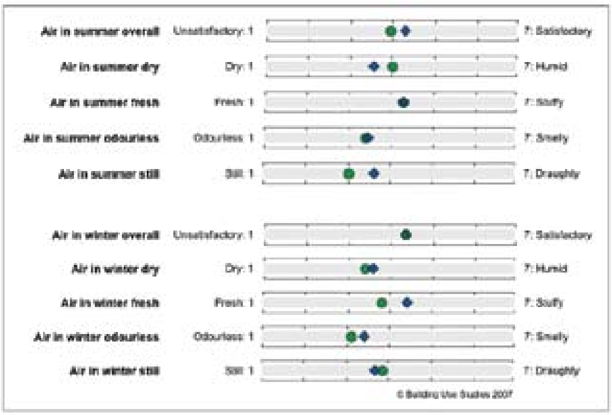

Figure 3 – air/ventilation
Circles = green intent (n=22); Diamonds = conventional (n=23); Building Use Studies Australian dataset 2007.

Figure 3 has the air/ventilation comparisons.

- Conditions in both green and conventional buildings in winter are generally good and often similar, although they can be characteristically dry and still.
- On average, the air conditions in green buildings in summer are perceived as less satisfactory, stuffy and still. On the other hand, a number of successful green buildings rated highly for overall air quality, freshness, no odour, and air movement.

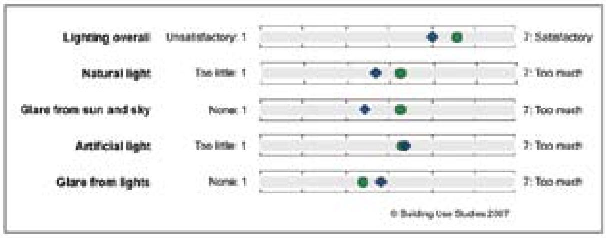

Figure 4 – lighting
Circles = green intent (n=22); Diamonds = conventional (n=23); Building Use Studies Australian dataset 2007.

Figure 4 illustrates the lighting ratings.

- The overall rating for lighting for green buildings is very good. Australia has excellent lighting scores using international comparisons despite very bright sunlight and glare potential[12]
- Ratings for natural light are better in green buildings, which could indicate that more care has been taken with design for good daylight and thus reduction of artificial light. This has resulted in improved ratings for glare from lights (ie. there is less glare in green buildings). Newer buildings benefit from improvements in lighting technology and the introduction of 'flat' computer screens, which are less susceptible to glare.
- Ratings for glare from sun and sky are worse overall in green buildings, which suggests that there is some way to go in the effective control of daylight.
- Ratings for artificial light are about the same in green buildings as for conventional.

In both cases, occupants still think that there is too much artificial light. Users dislike high levels of artificial lighting when there is adequate daylight, and where they have no practical opportunities to turn them off.

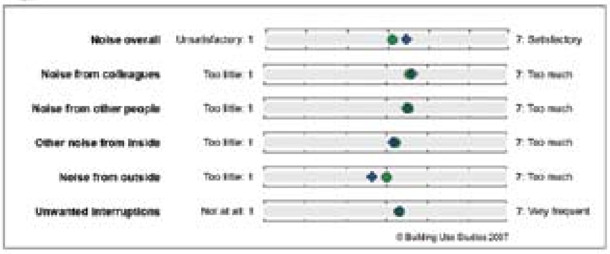

Figure 5 – noise
Circles = Green intent (n=22); Diamonds=Conventional (n=23); Building Use Studies Australian dataset 2007.

Figure 5 has noise ratings.

- Green buildings are noisier on average for the noise overall summary variable.

This is to be expected given that many green buildings studied have hard reflective concrete surfaces internally (included for their thermal capacity to moderate internal temperature) which can exacerbate internal noise.

- The rating for noise from external sources is better in green buildings.

Conventional buildings are generally rated as too quiet inside, with reduced outside awareness. People prefer not to be disconnected from the outside, especially if they are sitting in the middle of deep-plan offices.

- With an increasing trend (concurrent with green office developments) away from individual offices towards open plan, users often perceive an increased noise level in their work environments.

Overall, the pattern that emerges from the comparisons between the conventional and green buildings is that:

- A small number of green buildings outperform the dataset overall: that is, they rate better on most variables. To achieve this, such buildings require relatively higher levels of on-site management and aftercare fine-tuning and are usually occupied by organisations who have a vested interested in making them work properly.
- Thermal discomfort - too hot in summer, and too cold in winter - has been noted as a common problem with many of the green buildings in the dataset. However, this does not apply just to Australia. A similar analysis of buildings in the United Kingdom [13] indicated summertime comfort was an issue, although conditions in winter tended to be better than conventional buildings.
- Green buildings return a greater level of variation in their user responses on nearly all variables as may be seen in Figure 6, which shows medians and interquartile ranges for the summary variables. The green building scores usually have greater ranges between the best and the worst.
- Occupants' ratings of image, design, health and whether their needs are met are better or much better than ratings for the 'physical' indoor environment variables such as temperature, ventilation and noise in the green buildings studied. This may be because the green buildings are newer and, to some extent, reflect the wishes of staff that they should have less environmental impact. It can also be attributed to greater attention paid to satisfying user needs early in the design process (ie. more careful briefing and targeting), the involvement of users in decision making, and increased monitoring and feedback, all of which are hallmarks of mar[illegible]set.

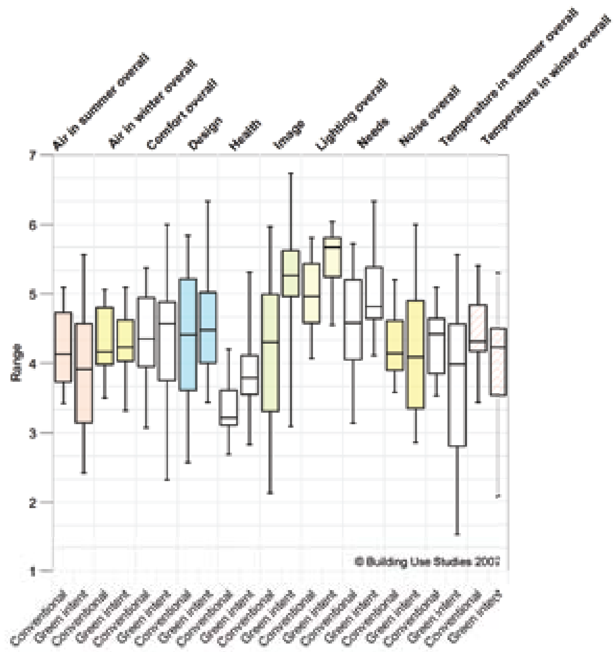

Figure 6 – summary variable comparisons showing medians, percentiles and ranges.

Box and whiskers plots show (from the bottom) the lower range, lower quartile (i.e. 25th percentile), the median (50th percentile), upper quartile (75th percentile), and the upper range.

The scale range is 1 = Unsatisfactory; 7 = Satisfactory, so better scores tend to be towards the top of the plot.

For further plots for all ten summary variables please go to: www.usablebuildings.co.uk/Pages/Protected/GreenBuildingComparisons/index.html

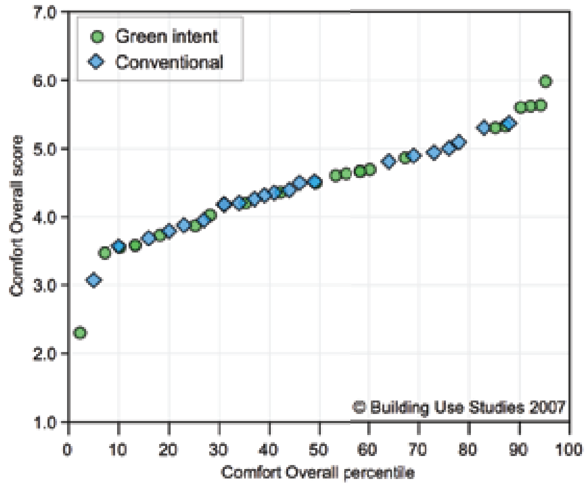

Figure 7 – percentile plot for variable 'comfort overall'

For further plots for all ten summary variables please go to: www.usablebuildings.co.uk/Pages/Protected/GreenBuildingComparisons/index.html

This requires the use of a password. Follow Password menu item on www.usablebuildings.co.uk

For similar plots for the UK go to: www.usablebuildings.co.uk/Pages/Protected/GreenBuildingComparisonsUK/index.html

- Perceived productivity scores for the green buildings in the Australian dataset are on average marginally lower than conventional buildings. However, a wider variation in performance is also apparent. Perceived productivity is mainly driven by poor thermal comfort scores, an example of which is shown in Figure 8, where the association between the variables is strong. As seen in the scatterplot, green buildings tend to cluster bottom left (poor summertime thermal comfort) and top right (good summertime thermal comfort).

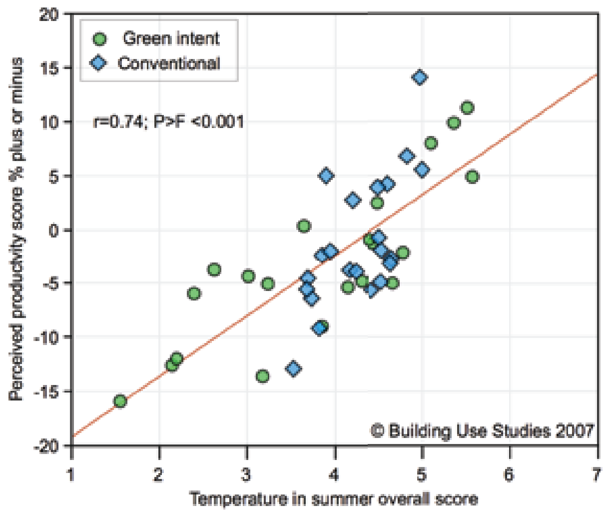

Figure 8 – summertime thermal comfort and perceived productivity

For further plots please go to: www.usablebuildings.co.uk/Pages/Protected/GreenBuildingComparisons/index.html

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Why do occupants appear more tolerant of green buildings?

Indoor environment research on thermal comfort [14] show that users are more often tolerant of conditions where they have more control, sometimes irrespective of whether conditions are actually physically better. Users appear to be happier if they understand how the building is supposed to work either because the design intent is made clear and/or because the controls are easy to understand and work well.

Increased user satisfaction and tolerance occurs with:

1. Clear communication of design intent and ESD features, so that users and building managers know how systems should operate.

   This applies to all types of users ranging from casual visitors through part-time and full-time staff to the facility management team. When people understand how things work, they are more likely to be tolerant of environmental conditions even if systems don't always operate as they intended.

2. Usable controls which indicate to the user what they are for, what they are supposed to do, and give feedback on whether they have worked properly. [15]

3. Organisations committed to ESD principles that make an effort to ensure that systems are working properly and be more prepared to use the controls.

   This has been seen to work best where owners or designers are tenants in their own green buildings. Their greater understan ding of design intent, results in a higher level of tolerance. This also applies in instances where occupants are consulted and have a collaborative role in the brief-making and design processes.

4. Better management feedback and intervention, especially in situations where the users themselves may have little control, as with larger open-plan offices for example.

   As may be expected, people will be happier if their complaints taken seriously and acted on quickly by the facilities management team. Even if nothing can be done, users will generally be less dissatisfied.

5. In-situ facilities management which matches the requirement.

   Often, buildings demand a greater level of care and attention than is actually given or affordable. Green buildings often require relatively higher levels of management understanding and maintenance, and more diligence with commissioning to get things to work properly.

6. Monitoring in-use performance of green buildings.

   This helps increase the chances that problems will be picked up and rectified.

Forgiveness

Building Use Studies has developed a measure of tolerance or 'forgiveness'. If the forgiveness [16] score is greater than 1, then the occupants may be said to be more tolerant: that is, although they may have detailed criticisms about some of the conditions, they are prepared to overlook them.

Figure 9 shows forgiveness scores plotted on the bottom axis against perceived productivity ratings for green and conventional buildings in the current Australian dataset. While derived measures like this should always be treated with care, they can give clues to some of the finer points. In this instance, it can be seen that:

1. For all the data points, two thirds have forgiveness scores greater than 1 (more forgiving), and one-third less than 1.

2. Green buildings are tending to the highest scores (most forgiving), although interestingly, the lowest is also a green building.

3. The more forgiving occupants are, the more likely they are to have higher perceived productivity scores. However we consider this to be an association NOT the cause.

In addition the data suggest that occupants are more tolerant of green buildings. Not only do occupants like the idea of green buildings, green buildings share many of the features that occupants like. The concern becomes that green buildings are more likely to perform poorly in the very area which occupants tolerate least and which has the greatest knock-on effect, namely thermal discomfort.

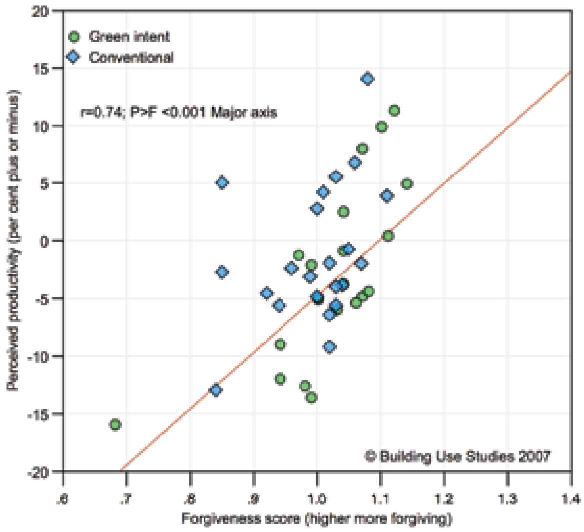

Figure 9 – 'forgiveness' and perceived productivity
Forgiveness is a derived score obtained by dividing the score for the summary variable "comfort overall" by the average of the summary variables for temperature in summer and winter, ventilation/air in summer and winter, noise and lighting. Scores above 1.0 indicate a higher level of tolerance

Conclusions

Our present analysis has lessons that can be learnt from occupants' experiences and feedback in 22 Australian buildings specifically built with ESD objectives, compared with 23 conventional buildings surveyed using the Building Use Studies methodology.

Our review shows that in the green buildings studied:

- A wider spectrum of performance is evident, with the best green buildings outperforming conventional buildings, especially for thermal comfort and forgiveness.

  But the situation is not uniform and the green buildings studied are not better in all categories.

- Thermal comfort conditions in summer are generally poor, although there are some notable exceptions.
- Winter conditions can often be too cold.
- Ratings for design, image, health and needs are usually better.
- Perceived productivity scores are marginally lower on average, but a number of successful green buildings surpass conventional ones.
- Occupants seem to be more tolerant.
- Ratings for lighting are good.
- Internal noise is often worse.

We need also to emphasise that:

- Figures 1 to 5 show comparisons based on averages. It is just as important to examine the variation within the dataset, as in Figure 6. Green buildings have greater variation, and this needs to be examined more closely.
- There are buildings which successfully fulfil their “green” design intent and others that do not. While our dataset contains both, we have not done any sub-analyses to separate these out at this stage. Nevertheless, it is important to note that when designed and operated properly and in a user-responsive manner, green buildings achieve positive environmental outcomes and simultaneously deliver positive feedback for comfort and productivity [17]. On the other hand, poor realisation of design intent coupled with little attention to user needs inevitably leads to poor environmental outcomes, with feedback from users that is worse than in many conventional buildings.
- Good green buildings build on the experience of the earlier successes and mistakes. It is to the credit of the innovators that they have allowed their buildings to be studied and scrutinised so useful lessons can be learnt.

The outcomes for the first-generation green buildings appear to indicate that good intentions outstrip performance. However, it should be noted that many of these were developed without the guidance of currently available frameworks such as GreenStar and the National Australian Building Environmental Rating Scheme, and without the benefit of lessons from preceding buildings.

Given the attention on green building design towards meeting climate change challenges, coupled with a growing knowledge and skill base arising from the experience in earlier buildings, we expect rapid improvement in performance in the near future.

Our experience is that successful green buildings consistently include client commitment for environmental design, clear goals for environmental performance, and an integrated multi-disciplinary team approach to design that is both mindful of user needs and willing to go back into the building to diagnose and correct problems.

Further, as discussed elsewhere [18], post-occupancy evaluations (POEs) are increasingly an integral part of realising ESD objectives.

The use of POE (hindsight) to close the loop on building performance to develop forward views (foresight) [19] is crucial for further development of successful green buildings. It is heartening to see the growing willingness of designers, developers and clients to share experiences and put findings into the public domain so that lessons can be learned more quickly and applied more broadly.

This paper has provided an overview rather than specific building cases. The next step is to look in more detail at lessons learned across green buildings with design, technical, organisational, business and user perspectives treated equally; providing the crucial information of what works well, what does not, and how we can feed this forward into the design and implementation of the next generation of buildings. ■

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[1] Building Use Studies, London, UK.

[2] University of Technology, Sydney, Australia.

[3] Encompass Sustainability, Melbourne, Australia.

[4] These include offices, schools, libraries, teaching accommodation and laboratories.

[5] Studies are carried out a minimum of one heating and cooling season after the buildings are occupied so this article applies to buildings completed by 2005.

[6] Details of the Building Use Studies Occupant Survey method can be found at www.usablebuildings.co.uk/WebGuideOSM/index.html . The Building Use Studies (BUS) method was originally developed for the Office Environment Survey (Wilson and Hedge,1987), and then adapted for the Probe (Post-occupancy Review Of Buildings and their Engineering) project (1997-2002) in the United Kingdom. Probe was first published as a series in Building Services Journal. Today, the BUS database comprises over 300 buildings worldwide, including over 50 buildings from Australia.

[7] Two of Australia's most prominent green buildings, 60L and 40 Albert Road, fall into this category.

[8] Complexity encouraged the growth of facilities management.

[9] See Bannister P., Why Good Buildings Go Bad And Why Some Are Just Born That Way, AIRAH 'pre-loved' buildings conference, 2006. www.airah.org.au

[10] For further plots please go to: www.usablebuildings.co.uk/Pages/Protected/GreenBuildingComparisons/index.html (Requires password. To apply follow the Password menu item on www.usablebuildings.co.uk)

[11] The implications are that over-simple occupant questionnaires with only a few variables may not capture the full context, thereby distorting the results and making them too optimistic.

[12] Using Building Use Studies international benchmark comparisons.

[13] Leaman A and Bordass W (2007), Are Users More Tolerant Of Green Buildings? Building Research and Information, November 2007.

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[17] For example, 40 Albert Road, Melbourne. Thomas, L. and Vandenberg, M. (2007), 40 Albert Road, South Melbourne: Designing for Sustainable Outcomes – A Review of Design Strategies, Building Performance and Users' Perspectives in BEDP Environment Design Guide, (CAS45, May 2007). Melbourne: Royal Australian Institute of Architects.

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