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Original citation:
Ahmed, A, Montazami, A & Dawud Al-Eisawi, A 2013, The Relationship Between Peoples' Satisfaction and LEED Building Rating in Jordanian Office Buildings. in R Soetanto (ed.), *Sustainable Building and Construction Conference (SB13).* Coventry University, Coventry, pp. 353-363, Sustainable Building and Construction Conference 2013, Coventry, United Kingdom, 3-5 July.

Publisher: Coventry University

THE RELATIONSHIP BETWEEN PEOPLES' SATISFACTION AND LEED BUILDING RATING IN JORDANIAN OFFICE BUILDINGS

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Abstract: *The study investigates differences in occupants' satisfaction in three office buildings meeting different levels of LEED certification in Jordan during the summer of 2012. This study is carried out based on post occupancy evaluation to measure occupants' perceptions of the internal environment, control over internal environment and also its impact on their performance. The result is evaluated using further analysis of the building micro-climate, active and passive design features. The study shows significant difference in occupants' satisfaction relating to air, quality, visual and acoustic comfort, however this difference does not always match the overall rating of the building especially in the area of acoustic comfort and lighting quality. This may be partly due to the fact that LEED focuses on reducing energy consumption rather than provide a high-level of occupants' satisfaction.*

1 INTRODUCTION

Buildings designed in different locations around the world have different characteristics related to their energy and environmental performance. Most people spend fifty percent of their lives within indoor environments and there is evidence that the quality of internal environment greatly influence occupants health, mental state, and performance (Sundstrom, 1994). Better physical environment of offices will boost the employees and ultimately improve their productivity (Carnevale 1992, Clements-Croome 1997). Physical environment can be explained around thermal, lighting, acoustic and air quality. Green building has now become a flagship of sustainable development in this century that takes the responsibility for balancing long-term economic, environmental and social health. Various concepts of assessing Green buildings have been proposed around the world. Leadership in Energy and Environmental Design (LEED) is an Environmental Assessment Methodology developed by the US Green Building Council launched since 1998.

LEED is a voluntary scheme that helps buildings owners to demonstrate leadership, innovation and social responsibility. LEED certification provides independent verification of building projects' sustainability credentials. There are four levels of LEED certification: Certified, Silver, Gold and Platinum. LEED certification can start from individual buildings and homes, to entire neighborhoods and communities addressing the entire lifecycle of a project. LEED projects have been successfully established in 135 countries. International

projects outside the United States, make up more than 50% of the total LEED registered square footage. (USGBC, 2013). Figure 1 shows the six key LEED criteria. The focus of this paper is on the Indoor Environmental Quality criteria, which includes thermal comfort, air quality, natural light and occupant control over indoor environment.

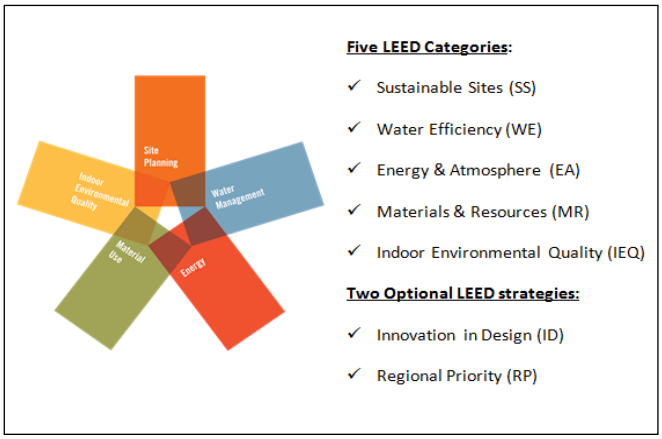

Figure 1: LEED Criteria

The aim of this study is to evaluate the peoples' perception regarding the internal environment, their performance/health and level of control in three office buildings in Amman Jordan meeting different levels of LEED certification. The results of occupant perception regarding internal environment in different buildings are compared against the LEED rating of the buildings. The results are used to evaluate the robustness of the LEED criteria in meeting people's satisfaction in these buildings.

2 METHODOLOGY

This study is conducted using case study approach and post occupancy evaluation POE using quantitative research methodology. Information about the case study building have been collated and used as the basis for interpretation of user responses from the questionnaires. The type of questionnaire used in the research project is a closed questionnaire, since the choice of response was already set by the questionnaire; furthermore, it included questions concerned about specific facts of the issue being reached (Naoum, 2010). The questionnaires focussed on collecting data on peoples' perception regarding internal environment, their heath and performance and also their level of control over the internal environment. The six main aspects are: Demographics, Thermal and air quality comfort, Acoustic comfort, Lighting comfort, Productivity, Health and Personal control. The questionnaires were distributed to the occupant of the 3 buildings each meeting different LEED criteria and a total of 63 responses were returned and analysed.

2.1 Location and climate: Aman - Jordan climate

Jordan is a small country, but it has four different bio-climatic regions, which includes;
The mountain areas cover about 10% of the total land area of the country and classified under the Mediterranean bio-climatic region. The country is also surrounded by steppe area known as Irano-Turanian bio-climatic region. The majority of Jordan from the eastern sides, is considered as dessert, which is about 80% of the total land area of Jordan and belongs to the Saharo-Arabian bio-climatic region. The Rift Valley bio-climatic region starts from the

northern parts of the Dead Sea and extends to the south of the Gulf of Aqaba at the Red Sea: furthermore, the inland sand dune areas and sandy mountains of Wadi Rum belong to the 'Tropical Penetration' also known as Sudanian or Subtropical bio-climatic region (Al-Eisawi, 1996). The case study buildings in this paper are located in Amman. Since approximately 80% of Jordan is considered as desert areas, it explains why 95% of the total population occupies only 5% of the country (Al-Eisawi, 1994) leading to highly densely populated cities such as Amman.

2.2 LEED buildings

The three LEED buildings that are discussed in this study are rated as 'Gold', 'Silver' and 'Certified'. The design technologies that are applied in these buildings and also the location of these building are discussed as follows:

Gold certified: WHO Headquarter Building

The WHO Headquarter Building is rated as Gold. This building is located in Al Abdali Dakhiliyeh Circle, Amman, Jordan (on a land of 2,500 m2 area). This building is a 4 story office building which includes a basement floor for parking and services. The GF is for the common facilities between WRO and CEHA, such as a reception hall, meeting rooms, library and video conference room. Figure 2 shows the external view and location of the WHO building. This office is located within one block from the main road with a high level of background noise.

Figure 2: WHO building Gold Certified - External view and location (Source: Engicon report)

The WHO building has sustainable systems incorporated to improve the operation as well as minimise the impact of the building on its environment. The building has Sustainable Drainage Systems that collect about 90% of rainfall which is treated stored and used for non-portable uses. The building also uses water efficient appliances such as automatic sensor fixtures and flow restricting devices to improve water efficiency. Solar thermal systems have been installed to provide hot water supply for the building. The building has full air-conditioning with high COP and air heat recovery system. The building spaces have individual lighting control in addition to using remote switching for general lighting areas (parking, corridors), individual control is very important in ensuring effective management of electrical lighting systems especially when there is adequate day lighting available to maintain interior lighting levels.

Silver certified: The Embassy of the Kingdom of the Netherlands

The Embassy building consists of offices, meeting and storage facilities with total floor areas 1253 m². The building consists of solar PV and Solar thermal renewable systems. The building has also been designed and constructed to reduce solar heat gain and reduce building heat island using sun shading devices integrated into the building's south facade. Figure 3 shows the design philosophy of the building. The HVAC strategy includes heat pump and thermal storage load and dry cooler and air handling unit. This building is located in a quiet location within three blocks away from the main road with a low background noise level. The assessment of background noise was done based on prior experience of the location and the relative closeness of the building to sources of noise such as roads etc.

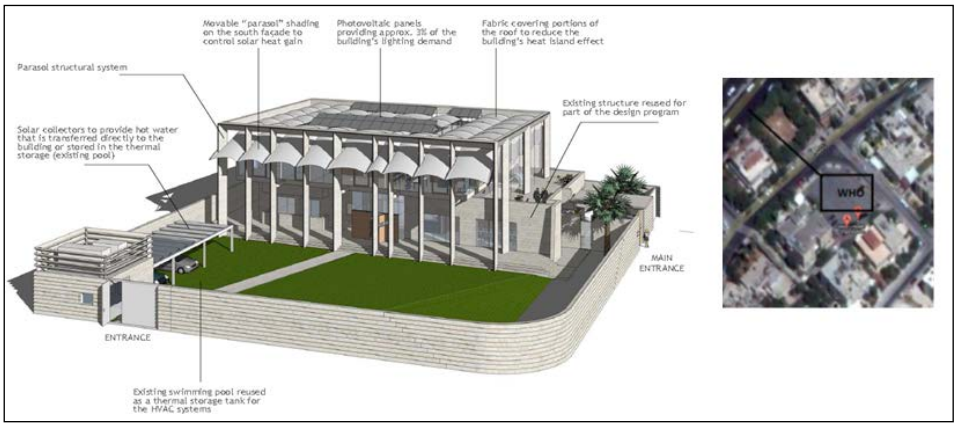

Figure 3: Silver Certified Netherlands Embassy (Source: Al Nasa'a 2009) and location map

Certified: Engicon office building

The Engicon is an office building that works on unique projects of different scales and complexities. This building is located in Amman- Jordan. This office building has a central heating system with individual control, double glazing with individual control and mechanical system. Figure 4 show the external view and location of this office building. This office is located a block away from the main road with the moderate background noise level.

Figure 4: Certified building – Engicon office building and location map (Source: Engicon website)

2.3 Peoples' perception

The people's perceptions are gathered about the internal environment, andtheir health and performance by distributing 25 questionnaires to each of the three case study buildings. In the silver building all the responders filled the questionnaires while in Gold and Certified the number of responders were 21 and 18 respectively.

The focus of the questionnaire is on the occupants' perception regarding their internal environment, its impact on their health and performance and their control over the internal environment. The internal environmental issues are focused around four categories of thermal comfort (summer/winter), air quality (summer/winter), lighting comfort (quality and quantity) and acoustic comfort. There are also questions on people's productivity and their health based internal environment and the peoples' control over the internal environment.

3 DISCUSSION AND ANALYSIS

The people's perception regarding internal environment, their health and performance and also their level of control are questioned.

3.1 Internal environment

Internal environment are questioned around four factors of thermal comfort, air quality, acoustic comfort and a lighting comfort.

Thermal comfort: Peoples' perception regarding thermal comfort in winter and summer are explored. The occupants were asked to rate thermal comfort conditions in their offices based on likert scale (1= Uncomfortable and 7=Comfortable). ANOVA T test has been carried out to analyses the data and compare the thermal comfort responses in the three buildings for both summer and winter conditions. The results show that there is no significant differences between thermal comfort responses in summer ($n=64$, $P>0.05$) while there is a significant differences between thermal comfort in winter ($n=64$, $P<0.05$).

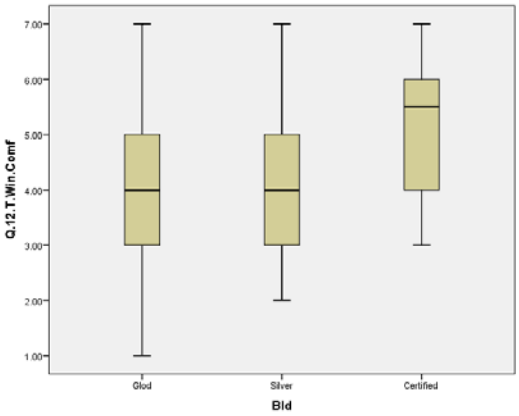

Figure 5: Average of occupants perception regarding thermal comfort in winter in three LEED Building (1= Uncomfortable…….7= Comfortable)

Figure 5 shows the average occupants vote in the certified building is around 6 (which is close to comfortable) while the occupants votes in the Silver and Gold building is around 4. According this piece of analysis, it can be concluded that thermal comfort in the Certified rated building is better than the Gold and Silver buildings, despite it receiving the lower LEED accreditation in comparison to the other two buildings.

Air quality: Occupants' perception regarding air quality in winter and summer was established. The survey question was asked; 'How would you describe air quality in your office in summer and winter' based on likert scale (1= Fresh / Odourless and 7= Humid / Smelly). ANOVA T test is carried out between the air quality in these three buildings in both summer and winter. The results shows that there is not any significant differences between air

quality during winter (n=36, P>0.05) but there is a significant differences between air quality during summer (n=36, P<0.05). The BOX plot in Figure 6 shows the level of air quality (Freshness and ardour level) in the Gold, Silver and Certified rated buildings. This analysis shows that air quality in the silver building is better than the Gold and Certified buildings.

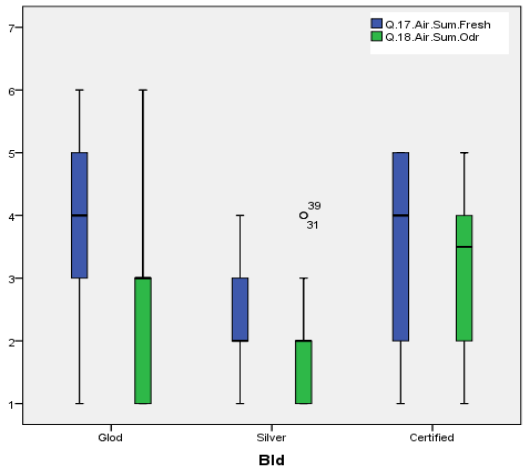

Figure 6: Average of occupants perception regarding air quality in summer in three LEED Building (1= Fresh / Odourless ……5= Stuffy/Smelly)

Acoustic comfort: The acoustic factors which affect speech intelligibility are background noise level and reverberation time (Shield et al, 2003a). Background noise commonly refers to any undesired sounds that impedes what a person wants or needs to hear (Knecht et al 2002). The source of background noise level in offices can be divided into the following three sources.

1. Noise from inside the office. Noise sources inside an office are workers and the office's equipments.
2. Noise from outside the office (within the buildings). This noise source usually refers to the noises that are transferred from different parts of the building such as corridors, meeting areas and other offices.
3. Noise from outside the organisation (building). These noise sources usually refer to the environmental noises such as those from transportation systems, industrial, plant and also rain fall on lightweight roofs which are transmitted through the building envelop.

In order to have an idea of the main internal sources that may impair the speech intelligibility and may not allow colleagues to hear each other properly, the relationship between overall noise and the sources of noise are investigated with a regression analysis. The results show that there is a significant relationship between the 'Overall noise inside the office' and 'Noise from outside office (but within the department) (n=36, P<0.05)' and 'Noise from workers' (n=36, P<0.05). Table 1 shows the result of this regression analysis.

As the main requirement of acoustic comfort is a sufficiently 'quiet' environment which enables communication tasks to be carried out comfortably and without distraction, i.e. with no unwanted sounds or vibration. Poor acoustic factors affect speech intelligibility inside offices meaning that colleagues would be unable to hear each other and hence transfer of information between them would be impaired. As it is discussed the overall noise inside the office is related to the noise from colleagues as well as the noise from other departments. Therefore, there is a risk of lack of speech intangibility in these offices. For these reasons

occupant' perceptions of how well hear their colleagues and how well their colleagues hear them are questioned based on the scale shown in Table 2.

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	.143	.443		.324	.747
	Q.26.N.Inside.Workers	.395	.104	.442	3.780	.000
	Q.27.N.Inside.Others	.226	.145	.182	1.556	.125
	Q.28.Noise.Outside.Office	.312	.133	.327	2.346	.022
	Q.29.Noise.Outside. building	.020	.125	.022	.161	.872

a. Dependent Variable: Q.25.N.overall

Table 1: Results of regression analysis between noise and different noise sources

Very well	**Quite well**	**Okay**	**Not very well**	**Not at all**

Table 2: Questionnaires administered to occupants of three LEED buildings regarding speech intelligibility

The ANOVA T test was carried out between the responses from occupants from different offices. The result shows that there is a significant difference between responses in different buildings ($n=63$, $P<0.05$). Figure 9 shows the average of speech intelligibility in the three offices.

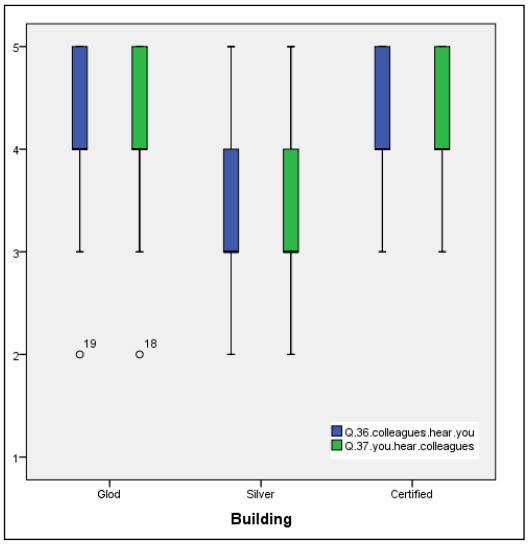

Figure 7: Average of occupant's perception regarding speech intelligibility in three LEED Building (1= Very well ……5= Not at all)

Figure 7 shows that on average in the 'Gold' and 'Certified' rated buildings the level of colleagues hearing each other was 4 which means 'not very well', however in the 'Silver' building the level of colleagues hearing each other was 3 which is 'ok'. This means the Silver rated building has better speech intelligibility compared to the 'Gold' and 'Certified' rated buildings. This difference warrants further investigation but may relate to the following;

- Office layouts: The Silver and Gold buildings are cellular while the 'Certified' office is open plan. This may be the reason why speech intelligibility in the Silver rated building is better than Certified.

- Office envelops: The envelop of Silver rated building is concrete which is a better sound insulator which can have a significant impact in preventing noise travel from other parts of organisation inside the offices.
- Office location: The noise from outside the building does not have an impact on speech intelligibility; this may be related to the use of an air-conditioning system that results in a reduction in the need to open windows. This means that the buildings envelop is completely sealed. According to the regression analysis the dominant noise level which people hear is noise from the cars. The noise level which is heard from cars in the Gold and Certified rated buildings is higher than the Silver rated building and may related to the location of the Silver building as it is located in a quieter region compared to the other two case study buildings. According this piece of analysis, it can be concluded that the level of acoustic comfort in the Silver rated building is better than the Gold and Certified buildings. The reasons for these differences should be investigated in detail in further study.

Lighting comfort: Lighting comfort can be discussed relative to quantity and quality of light with the source of natural and artificial light. The quantity of light is related to the amount of required light level on working surfaces and the quality of light is related to glare and uniformity etc. According to the ANOVA T test there was not any significant difference between quantity of light from both natural and artificial light in three LEED buildings. The only differences between the three LEED buildings are about the quality of light (Glare) with the source of Artificial light (n=63, P>0.05). As shown in Figure 10 the level of glare in the Gold and Certified buildings is close to unsatisfactory while in the Silver building it is close to satisfactory.

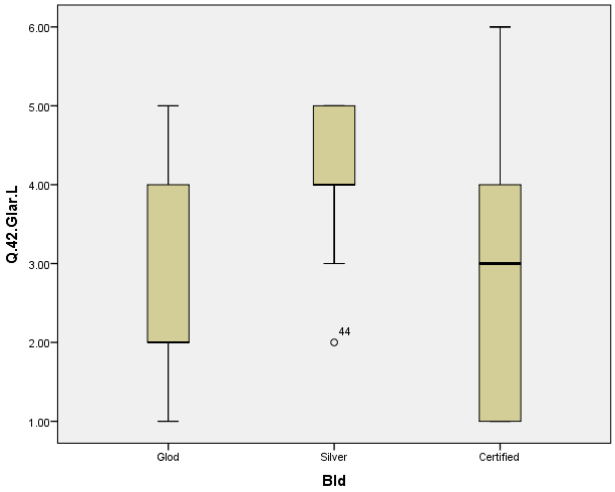

Figure 10: Average of occupants' perception regarding Glare from artificial light LEED Building (1= Unsatisfactory ……7= Satisfactory)

Results of assessing internal environment

Table 3 summarises the internal environment in the Gold, Silver and Certified buildings, which shows that the buildings have different 'Thermal comfort in winter', 'Air quality in summer', 'Acoustic comfort – speech intelligibility' and 'Lighting comfort'. Table 3 rates each internal environmental factor ('1'= best internal environment and '2' = poor internal environment). As can be seen the sum of the Silver building in three out of four conditions has better internal environment while in the Certified building one out of four conditions stated better internal environment and in the Gold building none of the conditions resulted in

best condition marks. It can be concluded that the occupants in the Silver building are more comfortable compared to the Gold and Certified buildings, in addition occupants in the Certified building are more comfortable than the Gold. Overall it can be concluded that there is not any significant relation between LEED accreditation and peoples' satisfaction about internal environment. This may be related to the fact that LEED guidelines do not consider the Acoustic comfort, and artificial light in its criteria.

Name of Building	*WHO*	*Embassy*	*Other*
LEED Credit	**GOLD (G)**	**Silevr (S)**	**Certified (Ce)**
Thermal comfort in winter	2	2	1= Certified is the best
Air quality in summer	2	1= Silever is the best	2
Acoustic comfort *Speech intelligibility*	2	1= Silever is the best	2
Lighting comfort *Glare from artificial light*	2	1= Silever is the best	2
Total Grade	**None / Four**	**Three / Four**	**One / Four**

Table 3: Summary of internal environment

3.2 Occupants' Health and performance

According to the extensive research there is a significant relationship between 'peoples' performance and health' and internal environment (CIBSE, 1999).

Health: Peoples' perceptions regarding their health when they are inside these buildings are questioned. The survey question asks; 'How would you describe your health when you are inside this building?' through the lickert scale (1=Less healthy, 7= More healthy). The results are compared between the three buildings. The results show that the people's perception regarding the occupants' health are not significantly different according to the ANOVA T test, ($n=63$, $p> 0.05$).

Performance: Peoples' perception regarding their performance when they are inside these buildings is questioned. The survey question asks; 'How would you describe your productivity when you are inside this building?'

Productivity decreased by				**Neutral**	**Productivity increased by**			
-40% or less	-30%	-20%	-10%	0	10%	20%	30%	+40% or more

Table 4: Questionnaires administered to occupants of three LEED buildings regarding performance

The levels of performance are compared between the three buildings according to the ANOVA T test. The results show that the people's performance in these three buildings are significantly different ($n=63$, $P<0.05$). The results show that the occupants productivity in the 'Gold' and Certified building increases by 20% while the productivity of people in the 'Silver' building only increased by 10%. As it is discussed in the previous sections the internal environment in the 'Silver building is better than the other two buildings and it was expected that the peoples' productivity would be higher in this building as well, but the responses suggest that it is not. The reason for this difference may be related to the level of occupants control over the internal environment which is assessed in the next part.

3.3 Control over internal environment

Bauman (1999) argues that giving people individual control over the environmental conditions in their workplaces, designers and facility managers can help increase worker satisfaction and productivity. The occupants' perception about the control levels over the various internal environments which are Heating, Cooling, Ventilation, Lighting and Noise are questioned through the likert scale (1= No control and 7= Full control). The ANOVA T test is carried out between the participants perceptions on the levels of control. There is a significant difference between the peoples' perception over the control of internal environment ($n=63$, $p<0.05$). Table 6 shows the average of control over the various internal environments.

Internal environmnet control	*WHO*	*Embassy*	*Other*
	GOLD (G)	Silevr (S)	Certified (Ce)
Heating control	5.66	2.16	4.44
Cooling control	6.61	2	4.4
Ventilation control	4.19	1.6	4
Lighting control	2.61	1.88	3.27
Noise	6.09	5.28	2.72
Average control	**5**	**3**	**4**

Table 6: The average of control over the various internal environments

As it can be seen the control over the various internal environments in the Silver building is less than the Gold and Certified. This can be one of the main reasons for the lack of consistency between performance and the level of internal environment. In addition, one of the other reasons may due to the acclimatisation as the occupants of the Silver building are from Netherlands, which it can be assumed are more used to a colder climate in comparison to Jordan.

5 Conclusion

This study uses post occupancy evaluation to investigate the occupant's satisfaction with the internal environmental condition of three LEED certified office buildings in Amman Jordon. The study shows the importance of the level of control over the comfort factors and its relation with occupant performance. In addition, according to this study, it can be concluded that there is inconsistency between the level of comfort inside the building and LEED accreditation. This may be related to the fact that the LEED criteria are heavily weighted towards energy reduction and less weighted towards occupants' satisfaction within the internal environment. It can be argued that that internal environment has a significant impact on people's performance and by developing the LEED criteria not only is it possible to save fuel energy; but also possible to improve occupants performance and reduce the cost of running businesses through increased productivity. It appears that if LEED criteria consider improvements in these two key areas of acoustic comfort and lighting quality, in particular source of artificial light under the 'Indoor Environmental Quality Criteria' as well as control over these factors, the higher LEED criteria buildings not only can perform better in terms of energy use but also occupants can have a higher performance.

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