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Evaluating the Performance of Bioclimatic Design Building in Nigeria

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Abstract
Bioclimatic design is an important strategy toward achieving sustainable building. Through the implementation of bioclimatic concept in buildings, energy demand can be reduced leading to increased users satisfaction. Using a set of questionnaire, a bioclimatic design evaluation was conducted to assess the satisfaction and perception of occupants in a residential building with the best practice of bioclimatic design strategies, particularly natural ventilation and daylighting. The questionnaire was based on a five-point Likert scale, covering various performance criteria of building, specifically on the architectural elements of thermal comfort, indoor air quality, visual comfort, acoustic comfort and landscape elements. Findings showed a positive relationship between perceptions and building performance criteria.
Keywords: Bioclimatic design; Performance evaluation; Satisfaction and perception; Nigeria

1. Introduction
Buildings and activities in buildings contribute to a major share of global environmental concerns (Urge-Vorsatz et al. 2015). Energy use in building is one of the most important environmental issues and managing its use is inevitable in any functional society. Being the most populous country in Africa with a growing population of over 160 million people, Nigeria energy demand and consumption has been on the increase due to recent economic growth and development. Nigeria domestic sector is responsible for more than half of Nigeria's energy use, estimated at over 65% (Irimiya et al. 2013) which is clearly above the world average of about 31% (Saidur et al. 2007). The demand for energy in buildings is exacerbated by extreme high temperature and intense solar radiation which drives the quest to use more energy within buildings. The major and the single most significant end use of energy in Nigerian residential sector has been attributed to space cooling, lighting including the combination of other substantial uses such as cooking and appliances (ECN-UNDP, 2007).

These observations provide strong reasons to economise the use of energy wherever possible. The residential sector have been shown to be the largest overall end users, and numerous studies and practical experience show that there is a large potential for energy savings here, probably larger than in any other sector. There is need therefore to promote the improvement of the energy performance of buildings in Nigeria, which can be achieved by adopting bioclimatic design strategy in the design of buildings (Manzano-Agugliaro et. al. 2015).

2. Bioclimatic Design
Architects today incorporate principles of sustainable design as a matter of necessity. But the challenge of unifying climate control and building functionality, of securing a managed environment within a natural setting—and combating the harsh forces of wind, water, and sun—presented a new set of obstacles to architects and engineer. Bioclimatic design is a term coined in the early 60s by the Olgyay brothers (Olgyay, 1963). It refers to an alternative way of constructing buildings so that local climatic conditions are taken into account and a number of passive solar technologies are utilized in order to improve energy efficiency; the term passive solar technologies refers to heating or cooling techniques that passively absorb (or protect from, e.g. natural shading) the energy of the sun and have no moving components (Tzikopoulos et al. 2005).

Bioclimatic structures are built in such a way that, during winter months, exposure to cold temperatures is minimized and solar gains are maximized; during the summer, bioclimatic structures are shaded from the sun and various cooling techniques are employed, often with the aid of renewable energy sources (Manzano-Agugliaro et al. 2015). The principle behind bioclimatic design is the understanding of the climatic factors of a site by analysing the influence of microclimate; including solar radiation, sunshine, temperature, humidity, rainfall, wind velocity and direction (Hyde, 2000).

This type of design allows substantial savings in air conditioning and lighting. By correctly orienting the house, using insulation to its best advantage and correctly placing openings (windows and doors), energy bills can be saved. Bioclimatic design can be a feasible solution to the problem of increased energy consumption of the building sector and for the improvement of IEQ. Some of the main issues which bioclimatic architecture focuses on are: heat gains for the environment (solar), natural lighting, wind use for comfort and structural cooling etc. An essential part of the bioclimatic architecture is that it combines various building aspects such local climate, local topography, building's orientation, site location, fenestration etc. Successful implementation of bioclimatic design strategies not only reduces energy use and CO2 emissions of buildings, but more importantly increases the resident's satisfaction (Tzikopoulos et al. 2005).

Therefore the objective of this study is to promote sustainable building in Nigeria through the application of bioclimatic design strategy. Residents' perception and satisfaction with the implemented bioclimatic design strategy in a residential hostel building will be evaluated against performance criteria of building: the architectural elements, thermal comfort, indoor air quality, visual comfort, acoustic comfort and landscape elements.

3. Methodology

This study investigates the level of satisfaction and perception of residents of a bioclimatic design building in Nigeria. The research is underpinned by a review of extant literature to extract taxonomy of variables in the relevant domains; and empirical survey using quantitative and qualitative techniques. The study adopts the use of a questionnaire survey which was conducted through a self-administered questionnaire to 519 respondents, in which 322 were fully completed. Satisfaction and perception level of respondents was based on a five-point Likert scale ranging from -2 to +2, where -2 represents 'very dissatisfied/very poor', and +2 represents 'very satisfied/very good'.

3.1. Building description

The surveyed building is a low rise multi-residential hostel building located in the University of Nigeria, Nsukka campus. The building can accommodate up to 1083 residents at one time, with 19,414.60m^2 of total floor area and 20.35 m^2 of a typical room's floor area. . Background information of the building is seen in Table 1. The building is naturally ventilated, which is also acknowledged as free-running building. It is one of the residential hostels in the University of Nigeria, Nsukka campus regarding implementation of bioclimatic designs due to the building allowing for the best utilisation of natural ventilation and daylighting. The building layout that is based on a courtyard arrangement (Figure 1) lets the transoms on top of the entrance door and wall to fully function in providing air circulation and daylight in the rooms. With the utilisation of daylight, it could improve the occupants' psychological health and productivity. Then, the presence of wall openings creates a wind pressure inside the rooms. The building's orientation to the sun's path is north– south which directly reduces the thermal effect in the room. Only the service areas such as the toilet, bathroom, store, staircase and balcony are located at a west–east orientation. Regarding the enclosure and facade design, the building was designed with special features such as glare protection and adjustable natural ventilation options. The windows are made of louvres type, which are tinted, offer the resident the possibility to control daylight penetration and channel the outside air/wind.

Table 1. Background information of the Case study building

Characteristics	Residential hostel Building
Year established	1997
Form of building	Low-rise
Building layout and arrangement	Courtyard arrangement
Orientation to sun path	N–S
Shape of the building's floor plate	Rectangle
Wind direction of the locality	SW
Floor level (excluding GF)	3
Bed spaces	1083
Bed occupants	924
No. of rooms	163
Total floor area (m^2)	19,414.50
Density (no. of residents/m^2)	0.059
Energy efficiency index (kWh/m^2/year)	32.96
Typical room's floor area (m^2)	20.35
Typical room volume (m^3)	47.72
Window area (m^2)	4.21
Window to wall ratio	0.66
Operable window area (m^2)	4.21
Operable window to wall ratio	0.43
Window design	Louvre
Window location	N–S
Green area (%)	54.60

N: north; E: east; S: south; SW: southwest.

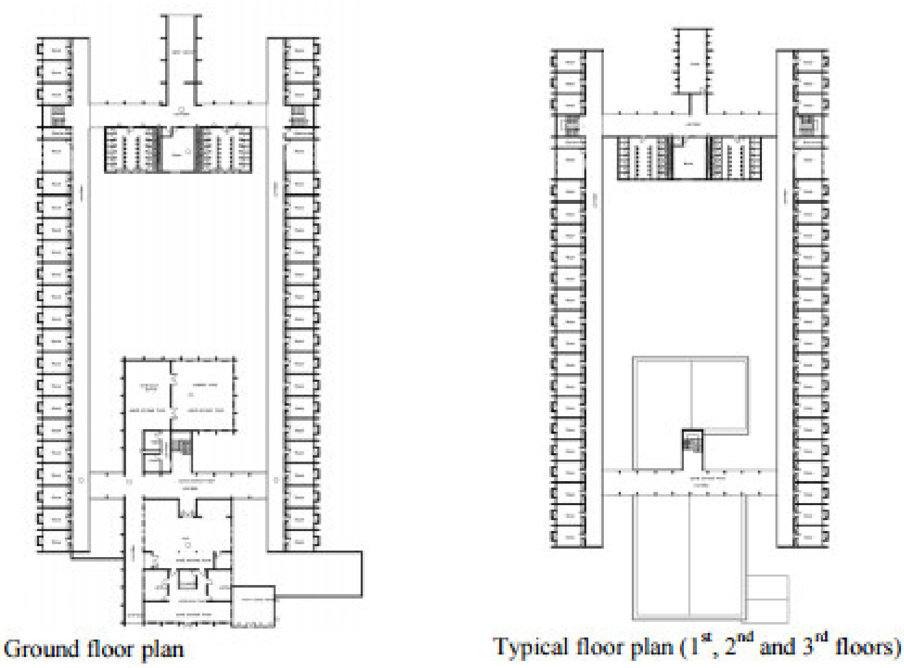

Figure 1. Lady Ibiam Hostel (Uzuegbunam, 2012)

Figure 2. Lady Ibiam Hostel (Uzuegbunam, 2012)

3.2. Perception and satisfaction survey

As described in Uebersax (2006), a series of Likert items were employed in a structured questionnaire to measure occupants perceptions on the bioclimatic design strategy in a university hostel building. Five performance criteria (architectural element, visual comfort, acoustic comfort, landscape elements and combination of thermal comfort and indoor air quality) with thirteen questions were enquired after a thorough review of literature. In order to acquire for the residents' perception, the questionnaire was constructed on a five-point Likert scale, where each number responds to a specific scale:

- -2: very poor/very uncomfortable/much decreased/very hot/still air/too dark/very dissatisfied/very noisy
- -1: poor/uncomfortable/decreased/hot/inconspicuous still air/dark/dissatisfied/noisy
- 0: fair/neither/neutral/no changes
- +1: good/comfortable/increased/cool/breezy/bright/satisfied/quiet
- +2: very good/very comfortable/much increased/very cool/very breezy/too bright/very satisfied/very quiet

A Likert scale – which comprises several Likert items to measure a construct – is an acceptable way of eliciting the strength of opinions using numbers to represent implicit meanings as applied by Akadiri (2015). The questionnaires were distributed to all occupants with the minimum number of feedbacks relying on 95% confidence level and ±5% margin of error from the overall population. All the collected questionnaires were analysed by using a statistical software package to find out the frequency of responses and the inter-correlation between each performance criteria.

4. Findings

The results derived from the analysis of empirical questionnaire survey were cross-referenced to the published literature wherever appropriate and to complement each other for validation. A total of 322 out of 519 questionnaires were retrieved fully filled by the respondents. Findings of perception and satisfaction survey at multi-residential building with the best practice of bioclimatic design strategies are presented in Table 2.

Table 2. Findings of perception and satisfaction survey in the surveyed building

Performance criteria	Likert scale /Residents perception (%)				
	-2	-1	0	+1	+2
Architectural elements					
1. Residential building layout (Internal courtyard with open corridor)	0.4	8.7	28.7	50.2 Good	12.1
2.Overall quality of the residential building	1.1	6.0	28.7	52.1 Good	12.1
3.Overall comfort level of the room	0.8	4.5	29.1	53.6 Comfortable	12.1
4. Influence of room conditions on the degree of work productivity	0.8	4.5	26.8	49.4 Increased	18.5
Thermal comfort and indoor air quality					
5. Thermal comfort/indoor air temperature in the room	3.4	11.7	29.7	43.6 Cool	11.7
6. Ventilation and air quality of the room	1.9	13.4	29.8	46.2 Good	8.8
7. Air movement in the room (without the aid of mechanical fan)	13.7	22.1	26.7	30.9 Breezy	6.5
Visual comfort					
8. Adequacy of natural daylight in the room	4.2	12.0	34.4	40.9 Bright	8.5
9. Adequacy of artificial light in the room	1.1	8.8	35.1	46.2 Bright	8.8
10. Quality of the lights in the room	1.5	7.7	28.8	48.5 Satisfied	13.5
Acoustic comfort					
11.Noise/vibration level in the room	2.7	15.6	41.6 Neither	33.6	6.5
Landscape elements					
12. Landscape quality at the surrounding residential building	1.5	8.0	33.7	48.7 Good	8.0
13. Landscape setting quality in the internal courtyard	1.5	6.1	35.9	48.9 Good	7.6

Majority of the residents is in comfort level in all aspects, where more than 40% of them are ‘satisfied’ with the condition of the room and building. About 50.2% and 52.1% of the residents claimed that the residential building layout which is the internal courtyard, and overall quality of the residential building is ‘good’, respectively. 53.6% of the residents were ‘comfortable’ with the condition of the room while 49.4% claimed that the condition of the rooms aided work productivity. In terms of thermal comfort and indoor air quality, 43.6% of the residents felt ‘cool’ with indoor air temperature. About 46.2% claimed that the ventilation and air quality of the room are ‘good’ and 30.9% of them felt ‘breezy’ air movement in the room though without the aid of mechanical fan. In terms of the visual comfort, majority of the residents (48.5%) are ‘satisfied’ with the quality of light in the room. They claimed that the adequacy of both natural daylight (40.9%) and artificial light (46.2%) in the room are ‘bright’. The acoustic comfort was the only performance criteria where majority of the residents felt no difference. About 41.6% voted for ‘neither’ on the noise/vibration level in the room. Finally, majority of the residents claimed that the landscape quality in both surrounding residential building (48.7%) and in the internal courtyard (48.9%) is ‘good’. Further statistical analysis to correlate each performance criteria with the overall comfort and the degree of work productivity with regard to the residents’ perception and satisfaction by using Pearson correlation is presented in Table 3.

Table 3. Correlation between the performance criteria with the overall comfort and work productivity at surveyed building

		Building layout	Overall quality of building	Thermal comfort	Ventilation and air quality	Air movement	Natural daylight	Artificial light	Light quality	Noise/vibration level	Landscape	Internal courtyard quality
Overall comfort	Pearson correlation	.284**	.354**	.409**	.432**	.250**	.328**	.242**	.308**	.276**	.337**	.288**
	Sig. (2-tailed)	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
Work productivity	Pearson correlation	.192**	.246**	.336**	.311**	.239**	.135*	.268**	.268**	.230**	.236**	.125
	Sig. (2-tailed)	.003	.000	.003	.000	.000	.039	.000	.000	.003	.000	.052

**. Correlation is significant at the 0.01 level (2-tailed), *. Correlation is significant at the 0.05 level (2-tailed).

Relevant finding highlighted significant positive relationship of perception and satisfaction levels with the overall comfort and degree of work productivity in relation to the performance criteria. There is 'moderate' or 'weak/fair' relationship showed by all performance criteria in both relationships; overall comfort level and degree of work productivity, when the r values were in the range of 0.5 to 0.3 (moderate) and 0.3 to 0.1 (weak/fair).

5. Analysis and discussion

A large number of the residents at the building are satisfied and feel comfortable with the room and building condition. This is due to the building's orientation with a square internal courtyard. Courtyard as a space can provide climatic as well as visual or acoustic protection. The courtyard geometry as well as its material makeup should be considered in the design stage in order to provide the highest level of indoor thermal comfort possible (Meir, 2000). In addition, the courtyard was developed to be climate responsive. Furthermore, courtyard can be utilized as an appropriate place for promoting natural, healing environment. The combination of two types of windows and fixed large, arch-top transom on top of the entrance door allow extra light into the entryway and promote cross ventilation. According to Haase and Amato (2006), the installation of louvred window significantly improves the indoor air quality by increasing the efficiency of natural ventilation. Moreover, a shallow building with optimal orientation and a maximum of five floors is more applicable for exploiting wind for natural ventilation, which well demonstrated in the studied building. Majority of the residents are 'satisfied' with the quality of light in the room. The application of daylighting involves designing buildings for optimum use of natural light and provides numerous benefits over artificial lighting. Generally it is understood to be beneficial both to health and well-being while gives a significant saving on energy (Akadiri et al. 2012).

Lechner (2009) pointed out that large window area than walls, high ceilings with high windows, and O-shaped floor plans (fully enclosed) are the basic design in providing daylighting in the building (Almhafdy et al., 2013). Additionally, the type of glazing and window gives major significance on the performance of natural light and thermal performance of adjacent space (Husin and Harith, 2012). The acoustic comfort was the only performance criteria where majority of the residents felt no difference. This finding is supported by Lee (2010) study of office layout affecting privacy, interaction, and acoustic quality in LEED-certified buildings, where respondents reported lower satisfaction with noise level. The presents of 'good' landscape quality in both surrounding residential building and internal courtyard influence the microclimate atmosphere and improve thermal comfort especially in a warm and humid climate (Yahia, and Johansson, 2014). Plants cool the surface of the planet in two ways. They cool the air by evaporating water through their leaves. They also moderate the temperature of the ground surface by shading it from direct sunlight. Shading is an essential strategy to reduce thermal stress and by using vegetation and shading devices, it is possible to achieve thermal comfort during the warmest hours in the dry season which is the most problematic season in Nigeria.

Shading also reduces the direct gain of energy through windows and the resultant 'internal' greenhouse effect. Lowering air-conditioning demand leads to energy and cost savings and reduces the emission of waste heat energy. Finally, shading shelters people from direct exposure to the sun, which is important as thermal discomfort has been suggested to relate more to higher radiation exposure than higher air temperatures (Emmanuel, 2005). Even more dramatically, the temperature difference between shaded and non-shaded ground can be as much as 36°F. Based on a study in Valencia, Spain, researchers found that a temperature monitor exposed to direct sunlight warmed to about 104°F in midday sun, while a shaded monitor at the same site registered below 80°F (Gomez et al. 2004). In a similar study in Phoenix, Arizona, the surface temperature of asphalt measured 140°F on a hot summer day, while a nearby patch of shaded grass measured 104°F (Mueller and Day, 2005). In both cases, the biggest differences occurred on the hottest afternoons. Additionally, the green infrastructure is a crucial part of the urban fabric that is highly perceived by residents contributing to their physical, cognitive and social well-being (Mansor et al., 2010). Majority of the residents claimed that the degree of work productivity has 'increased' considerably and it indicates acceptance of occupants towards existing implementation of bioclimatic design strategies, as the building performance highly correlated with the occupant's satisfaction (Hashim et al., 2012). The occupants expectations and needs in existing buildings is needed to achieve sustainability objectives in buildings (Amasyali and El-Gohary, 2016). However, further improvements need to be done in all criteria due to the 'moderate' or 'weak/fair' relationship by all performance criteria in both relationships; overall comfort level and degree of work productivity as a result of statistical analysis by using Pearson correlation.

6. Conclusions and recommendations

The application of bioclimatic design strategies based on an internal courtyard arrangement at a residential university hostel building in a region with tropical hot climate is able to provide a comfortable room with less electricity usage, particularly for the lighting purposes. This in turn has significant impact on the perception and satisfaction level of the residents in a positive manner. Majority of the residents perceived that comfortable levels were achieved according to the performance criteria: architectural elements, thermal comfort and indoor air quality, visual comfort, acoustic comfort and landscape elements. Therefore, the north-south building orientation and internal courtyard, the fixed transom on top of the entrance door and internal walls, centrally located louvre windows, the wall opening in the room, large horizontal overhangs along the windows and good landscape setting should be highly considered in building design especially for residential buildings towards promoting sustainable building.

The approach has a great potential in analyzing building performance as it uses a strategic approach to achieve the best quality in building services, whereby the assessment integrates the building occupants' behaviour, perception and opinion as the building users. As recommendations, bioclimatic design building should integrate, firstly, more than one of the data collection methods. The combination of several methods (questionnaire survey, focus group, documentary analysis and monitored data), which form a methodological triangulation, will be able to enhance the credibility and persuasiveness of a study. This is by giving a more detailed picture of the situation that facilitates the validation of data through cross verification from more than two sources in the study. For comparison, other residential buildings should be included especially with the different application of bioclimatic design strategies. In order to substantiate the findings further, more similar investigation should be done in the future, in particular comparing a bioclimatic design buildings with conventional buildings to determine differences in building performance. At the moment, the author is processing similar investigation on another four buildings that have similar characteristics in order to provide more evidence to substantiate the findings.

References

Urge-Vorsatz, D., Cabeza, L.F., Serrano, S., Barreneche, C., Petrichenko, K. (2015), "Heating and cooling energy trends and drivers in buildings", Renewable and Sustainable Energy Reviews, Vol.41, pp: 85–98

Irimiya, Y., Humphery, I. A., Aondover I. I. (2013) "Assessment of Energy use Pattern in Residential Buildings of Kano and Kaduna Northern Nigeria", American Journal of Engineering Research, 2 (10):271-275

Saidur, R.., Masjuki, H. H., Jamaluddin, M. Y. (2007) "An application of energy and exergy analysis in residential sector of Malaysia, Energy Policy, 35(2):1053 – 1063

ECN-UNDP (Energy Commission of Nigeria and United Nations Development Programme). Renewable energy master plan: final draft report. 2005 http://www.iceednigeria.org/REMP%20Final%20Report.pdf. Accessed 17 June 2015.

Olgyay, Victor. (1963) "Design with Climate", Princeton: Princeton University Press.

Tzikopoulos, A. F., Karatza, M. C., Paravantis, J. A. (2005) "Modeling energy efficiency of bioclimatic buildings. Energy and Buildings", 37(5): 529–544.

Manzano-Agugliaro, F., Montoya, F.G., Sabio-Ortega, A., Garcia-Cruz, A. (2015) "Review of bioclimatic architecture strategies for achieving thermal comfort", Renew. Sustain. Energy Rev., 49: 736–755.

Hyde R. (2000) "Climate responsive design: a study of buildings in moderate and hot humid Climates", New York: E and FN Spon.

Uzuegbunam, F. O. (2012) "Sustainable architecture for student hostels in hot-humid tropical environment: Using University of Nigeria Enugu Campus as a Case-Study", Journal of Environmental Management and Safety, 3 (1): 121-138.

Uebersax, J.S. (2006), "Likert scales: dispelling the confusion", Statistical Methods for Rater Agreement, available at:www.john-uebersax.com/stat/likert.htm (accessed 4 February 2016).

Akadiri, P. O. (2015) "Understanding barriers affecting the selection of sustainable materials in building projects", Journal of Building Engineering, 4: 86-93.

Meir I. A. (2000) "Courtyard microclimate: A hot arid region case study" in Steemers K. and S. Yannas (eds.) (2000) Architecture-City-Environment. Proc. 17th PLEA Int. Conf. - refereed papers, pp. 218-222.

Haase, M. and Amato, A. (2006) "Performance Evaluation of Three Different Façade Models for Sustainable Office Buildings", Journal of Green Building, 1 (4): 89-103.

Akadiri, P. O., Chinyio, E. A., Olomolaiye, P. O. (2012) "Design of a sustainable building: A conceptual framework for implementing sustainability in the building sector", Buildings, 2:126-152.

Lechner, N. (2009) "Heating, cooling, lighting: Sustainable design methods for architects", 3rd ed. New Jersey: John Wiley and Sons.

Almhafdy, A., Ibrahim, N., Ahmad, S. S., Yahya, J. (2013) "Courtyard Design Variants and Microclimate Performance", Procedia-Social and Behavioral Sciences, 101:170-180.

Husin, S. N. F. S. and Harith, Z. Y. H. (2012) "The performance of daylight through various type of fenestration in residential building", Procedia – Social and Behavioral Sciences, 36:196-203.

Lee, Y.S. (2010) "Office Layout Affecting Privacy, Interaction, and Acoustic Quality in LEED-certified Buildings", Building and Environment, 45(7): 1594–1600.

Yahia, M. W. and Johansson E. (2014) "Landscape interventions in improving thermal comfort in the hot dry city of Damascus, Syria—The example of residential spaces with detached buildings", Landscape and Urban Planning, 125: 1–16.

Emmanuel, M.R. (2005) "An urban approach to climatesensitive design: Strategies for the tropics", Spon Press, Oxfordshire.

Gomez, F., Jabaloyes, J., Vano,E. (2004) "Green zones in the future or urban planning", Journal of Urban Planning and Development, 130: 94-100.

Mueller, E.C. and Day, T.A. (2005) "The effect of urban ground cover on microclimate, growth and leaf gas exchange of oleander in Phoenix, Arizona", International Journal of Biometeorology. 49: 244-255.

Mansor, M., Said, I., Mohamed, I. (2010) "Experiential Contacts with Green Infrastructure Diversity and Well-being of Urban Communities", Asian Journal of Environment Behaviour Studies, 2:33–48.

Hashim, A. E., Samikon, S. A., Nasir, N. M., Ismail, N. (2012) "Assessing Factors Influencing Performance of Malaysian Low-Cost Public Housing in Sustainable Environment", Procedia - Social and Behavioral Sciences, 50: 920–927.

Amasyali, K., M. El-Gohary, N. (2016) "Energy-related values and satisfaction levels of residential and office building occupants", Building and Environment, 95: 251-263.