



# Comparative study on the indoor environment quality of green office buildings in China with a long-term field measurement and investigation



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## ABSTRACT

On account of the actual performance of green building in China is not systematically researched, this paper follows the results of recent POE surveys within green and conventional office buildings in two climate zones of China. Occupants completed a questionnaire related to environmental satisfaction, meanwhile, a long-term objective measurement was proceeding to characterize the immediate environment experienced by the occupants. This study analyzes the subjective and objective measurements of indoor environment quality (IEQ) from four parts: thermal environment, indoor air quality, visual and acoustic environment. The result indicates that green buildings possess significantly higher satisfaction level than conventional buildings, and the actual performance of green buildings basically achieve the design goal of IEQ. The indoor operative temperature of buildings in both climate zones is compared to find the difference of indoor temperature in the interim period and influence of occupants' behavioral habit. At last, two typical thermal comfort model are used to assess the occupants feeling in different climate zones in China.

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## 1. Introduction

In recent years, the world is facing problems like global warming, financial crisis, and the requirement of sustainable development, which all demand every country to push green building policy. With a lot of motives for buildings to be “green”, including environmental, economic, and social benefits, green buildings are being built all over the world [1]. Both technical and non-technical actions were taken to improve the building environment and make the building more energy efficiency [2,3]. Accompanied with the great development of green buildings, many researches about design and evaluation of green buildings have been taken across the building types and climate zones [4,5]. For example, greater indoor environmental variability is called, such as operable windows, shade devices, automated controls of HVAC systems [6,7], and the foreign researches related to the evaluation of different ventilation mode buildings [8–10] and lighting environment [11,12], and factors affecting IEQ satisfaction [13,14] are abundant.

Up to the June of 2014, about 1500 buildings have been certified by China's Green Building Labelling, with a total building floor area more than 170 million square meters. However, less than 100 buildings are certified by the Operation Label of China's Green Building Labelling. One objective of the design is to provide a higher level of indoor environment quality (IEQ) than buildings that use conventional practices. On paper, these buildings are regarded as high-performance buildings. And many studies suggest that in office buildings better indoor environments can bring in occupants' higher satisfaction with well-being and productivity [15–17]. However, their actual performance is seldom validated from the perspective of occupants. Abbaszadeh et al. conducted a research on green buildings certified by LEED to compare user's satisfaction of Indoor Environment Quality (IEQ) in all kinds of aspect [18]. They found that green building is superior to non-green building in the overall average satisfaction for thermal sensation, Indoor Air Quality (IAQ), decoration, cleaning, maintenance, office space feeling. But in some of the items such as light environment, sound environment and office layout, green building is not superior to conventional building in average user satisfaction. A pre-/post-study conducted by Grady and Korkmaz shows improvements in asthma and depression symptoms, and perceived productivity in LEED buildings [19]. Siu-Kei Wong et al. (2009) surveyed the

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prevalence of sick building syndrome (SBS) among apartment residents and their evaluation of IEQ, and the results showed that residents with SBS symptoms, in particular nose and head symptom that could be attributed to air quality and density, were less satisfied with their IEQ than those without [20]. Young S. Lee and Suk-Kyung Kim (2008) founded that LEED-certified buildings were superior to non-LEED-certified buildings in terms of office furnishings quality, IAQ, and cleanliness and maintenance quality [21]. However, a study of two LEED offices and a sample of conventional offices in the same city suggested no difference in overall satisfaction with IEQ [22]. By surveying a green university building and two conventional university buildings, Warren L. Paul and Peter A. Taylor found no significantly difference in lighting, ventilation, acoustics, humidity, serenity and aesthetics between the two building types [23].

With <The green building evaluation standard> [24] guiding design and construction, it's important to carry on researches about actual performance of green buildings in China. This paper mainly focuses on green office buildings built in about recent 5 years to assess the IEQ of green office buildings in China.

### 1.1. Post-occupancy evaluation (POE)

POE has its origins in the United States and has been used in one form or another since 1960s. Preiser and colleagues define POE as “the process of evaluating buildings in a systematic and rigorous manner after they have been built and occupied for some time” [25]. The British Council for Offices (BCO) summary that a POE provides feedback of how successful the workplace is in supporting the occupying organization and individual end-user requirements [26]. POE usually involves feedback from the building occupants, through questionnaires, interviews and workshops, but may also involve more objective measures such as environmental monitoring, space measurement and cost analysis [8,27–29]. Fergus Nicol and Susan Roaf (2005) explored the differences and similarities of POE and field studies of thermal comfort in buildings and pointed out that POE should be understood as reflecting the changing nature of the relationship between people, the climate and buildings [29].

The POE has become an important tool for the improvement of building design and operations. In the POE research, some researchers find that the occupants tend to be more forgiving and still have a high satisfaction level although green buildings may be hotter or colder sometimes [18,30]. Except for the forgiving factor, the comparison between physical parameter and satisfaction may lead to some findings [31].

**Table 1**  
Building information of the 10 green office buildings in the study.

Building	Construction area	Floors	Building	Construction area	Floors
NO.1	29,290 m <sup>2</sup>	9	NO.6	9760 m <sup>2</sup>	8
NO.2	5700 m <sup>2</sup>	6	NO.7	19,231 m <sup>2</sup>	9
NO.3	12,096 m <sup>2</sup>	2	NO.8	7706 m <sup>2</sup>	7
NO.4	5175 m <sup>2</sup>	4	NO.9	6231 m <sup>2</sup>	6
NO.5	7386 m <sup>2</sup>	6	NO.10	5117 m <sup>2</sup>	3

With the questionnaire survey and physical measurement, the study uses the POE methods to examine the occupied building in four important aspects, thermal comfort, indoor air quality, lighting and acoustic environment, in order to assess the actual building environmental performance. This study tries to find the gaps between the design goal and the actual performance by comparing the measurement result with the green building evaluation standard, to find the difference between conventional building and green building with POE methodology, and to explore the factors that influence the actual performance and occupant satisfaction.

### 1.2. Objective of this study

In accordance with the background and previous research, we took a longitudinal field study to discuss the following four issues. (1) How the green office buildings perform compared with the conventional buildings on the aspect of IEQ? (2) Are there any differences of IEQ among buildings in different climate zones? (3) How to assess the thermal environment of green buildings in different climate zones?

## 2. Methods

### 2.1. Case study buildings

After extensive searches, 10 green office buildings built after 2008 are selected for this long-term research and some of the building information is presented in Table 1. 42 conventional office buildings built in recent 10 years are also used in the study for the questionnaire survey related to environmental satisfaction. Among them, 2 buildings with similar size were chosen for the long-term research at the first study stage, considering the operability of the measurement and the limit of the instruments and data loggers. Some of the buildings are shown in Fig. 1. They are located in Beijing, Tianjin and Shanghai, which belong to typical climate zones of China. Beijing and Tianjin, the two neighboring cities, belonging to



**Fig. 1.** Some of the buildings selected for this study.

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