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# User's perception of indoor environment associated with energy performance in apartment complexes with different service life

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ABSTRACT

Residents' illnesses related to new houses have recently become a popular topic for Sick Building Syndrome research. Compared to the research dealing with symptoms experienced by residents in newly built houses, little attention has been paid to the healthy life of residents in old houses. Thus, we investigate residents' experience of healthy life in two apartment complexes that have been in service for different amounts of time and ascertain whether any difference exists between them. It is generally believed that the energy efficiency of old apartments has decreased, and thus residents' comfort and health in such apartments would deteriorate according to the apartments' service life. This study aims to obtain an insight into residents' perceived experience in older apartments. We use three survey methods for the investigation and analyze the data from the residents' perspective. The results show that the physical properties of the apartments do not have much influence on the residents' perceived comfort and health; further, energy efficiency does not affect their perceived comfort and health either. The critical influencing factor for residents' discomfort is the indoor temperature, not any of the other physical conditions of the apartments.



## 1. Introduction

There have been numerous reports on 'Sick Building Syndrome (SBS)' that focus on newly built houses [1–4]. Residents' illnesses related to new houses have recently become a popular subject for SBS research. In 2005, the Korean Ministry of Environment legislated that optimal indoor air quality must be maintained in newly built apartment complexes, and the city of Seoul adopted a certified indoor air quality system in 2008 that requires the measurement of air quality in newly built houses to ensure the standards are being met [5,6]. Compared to the research dealing with a variety of symptoms experienced by residents in newly built houses, little attention has been paid to the healthy life of residents over longer periods in older houses [5,7,8]. Our research questions start from this point. How residents perceive the indoor environment in older apartment complexes; what relationships exist between energy efficiency of the buildings and residents' perception of the indoor environment.

Residents can create a healthier indoor environment by maintaining comfortable physical conditions such as temperature, humidity and light. However, there may be a potential conflict between strategies to reduce energy use and to create healthy buildings [9]. For example, the ventilation rate may be reduced to save energy but the level of pollutant concentrations may increase. In order to provide healthy and energy-efficient buildings, the HOPE (Health Optimization Protocol for Energy-efficient Building) project was performed in Europe. To provide sustainable healthy houses, several sustainable building criteria such as the Building Research Environmental Assessment Method (BREEAM) in the UK, Leadership in Energy and Environmental Design (LEED) in the USA have been introduced [10,11]. These criteria usually include three important related requirements: good energy performance, good indoor environment quality (IEQ) and good health of the occupants. A building cannot be considered to be healthy if it does not meet any of these criteria [12,13].

However, it is generally believed that the energy efficiency of old apartments is decreased, thus residents' comfort and health in such apartments would deteriorate according to the apartments' service life [14–16]. Our research originates from a question based on this anecdotal view. Our assumption is that the energy efficiency of the apartments might affect residents' perception of the indoor environment. We investigate residents' perceived comfort and health in two apartment complexes with different service life and identify whether any difference exists between them that is dependent on the service life. The research questions of the study are:

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**Table 1**
Criteria for sustainable and healthy buildings.

| Reference | | Criteria |
|---|---|---|
| System | BREEAM [18] | Management, Health & Wellbeing, Energy, Transport, Water, Materials, Pollution |
| | LEED [19] | Sustainable sites, Water efficiency, Energy & atmosphere, Materials & resources, Indoor environmental quality |
| Project | HOPE [9] | Thermal comfort, Air quality, Lighting, Noise, Energy & Wellbeing |
| | PeBBu [20] | Air quality, Ventilation, Thermal comfort, Noise & Light |
| Bluyssen et al. [17] | | Thermal comfort, Daylight and visual comfort, Ventilation, Noise |
| Roulet et al. [13] | | Energy performance, Indoor environment quality, Healthy |

(1) Is there any difference in the pattern of the energy use between residents who live in two apartment complexes with different service life?
(2) Is there any difference in residents' perceived comfort of indoor environments in two apartment complexes with different service life?
(3) Is there any difference in residents' perceived health in two apartment complexes with different service life?

This study aims to obtain an insight into residents' experience of healthy life in old apartments, rather than newly built ones. Compared to previous research focusing on quantitative evaluation of physical comfort and harmful substances in indoor environments, this research is significant in that it analyzes residents' perceived comfort and health qualitatively. We believe that residents' perceived experience would affect their healthy life in residential environments, where perceived health is not measured by any physical examination, but by questioning them on their perceived symptoms related to health status.

## 2. Methodology

In order to develop the instrument for the investigation, we reviewed representative criteria for healthy buildings as shown in Table 1. These are green building assessment systems including BREEAM and LEED, research projects related to performance criteria for healthy buildings including the HOPE and PeBBu research projects, and other criteria proposed by re such as Bluyssen [17] and Roulet et al. [13]. Special emphasis is placed on performance criteria for healthy buildings and on methods, guidelines, protocols and tools to evaluate/measure the health status of buildings or designs for buildings. They argued that these criteria should be considered in order to comply with sustainable policy by assuring the minimum level of a healthy, comfortable, and energy-efficient environment for buildings. Emphasizing the three above criteria, this research investigated the households' energy use, and residents' perceived comfort and health in two apartment complexes with different service life, and then identified the relationships among the criteria.

For this investigation, we selected two apartment complexes that had a 22-year gap in service life. In the history of apartment construction in Korea, there have been several development phases, and the two complexes are representative of development phases in the 1970s and 2000s. The energy performance of each apartment complex reflects the typical energy performance of the general group of apartments from a similar period with similar service life. It is generally assumed that the energy performance of apartment complexes may decline significantly over a cycle of 20 years in Korea. Thus, in selecting our cases, we chose two complexes of a similar scale and similar environmental features, but with a 22-year age difference. In addition, to reduce the impact of the characteristics of the households, 20 households with similar features of age, family size, income and apartment size were first selected in each apartment complex; in total, 40 households from the two apartment complexes. Each household has four family members exhibiting similar lifestyles, and the subjects of the survey were housewives in their forties who had lived in their apartments for a similar length of time. Three survey methods were used in this study: a field survey inspection of each apartment, providing information on the building and its surrounding environment; in-depth interviews investigating the pattern of energy use of each individual household; and a questionnaire survey of residents, identifying how residents perceive the indoor environment and their health.

### 2.1. Assessment of energy use and its pattern

To investigate energy use, we visited maintenance offices in each complex and obtained selected households' yearly meter data for electricity and gas, measured by the Korea Electric Power Corp., Korea District Heating Corp. and the Korea Gas Safety Corp. This study analyzed the actual usage of each household for electricity, heating, cooking and hot water among the maintenance fee items. To identify the pattern of energy use of the households, using an in-depth interview, the household's control behaviors in terms of thermal, indoor air quality and lighting environment were investigated in detail.

### 2.2. Assessment of comfort and health as perceived by residents

We investigated residents' perceived comfort and health through a customized questionnaire. Comfort was evaluated by several criteria concerning thermal comfort, air quality, lighting and noise. These criteria were separately judged for summer and winter Residents' perceived health was investigated by enquiring whether they had recently experienced any symptoms, and further, whether they thought that these were caused by the apartment's indoor environment. In unhealthy buildings, a high prevalence of a number of symptoms is generally expected under the umbrella of SBS: headaches, dry throat, itchy eyes, stuffy nose, irritated skin, etc. This study developed indicators for the questionnaire and investigated the residents' perceived health symptoms.

## 3. Case study: results

### 3.1. Characteristics of apartments and the surrounding environments

As shown in Table 2, there were basic differences in building characteristics because the two apartment complexes have a different service life and are located in different regions. The old apartment complex in Banpo has 15 south-facing apartment-style buildings constructed in 1978, each one 12 stories, with 1164 households who live in different sized apartments with corridor access. They adopted a district heating system using liquefied natural gas (LNG) supplied from a cogeneration plant, in addition to electricity and city gas for cooking. An express bus terminal and a transfer station for three subway lines are located in the complex surroundings; thus, the floating population can be large at times around the department stores and underground shopping malls near the transportation hub. Further, the Han River is near the apartment complex, and residents have easy access to the river