



Energy use of households in apartment complexes with different service life



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ABSTRACT

Government policies aimed at reducing energy use have focused on technical aspects of building structures, not residents' behaviors in households. However, many studies have argued that residents' behaviors might play a prominent role in the reduction of energy consumption in households. Compared to the impact of buildings' features on energy use, little research exists that considers household characteristics in addition to building features in analyzing the effect of residents' behaviors on energy use. Thus, this study aims to obtain an insight into the effect of residents' behaviors on energy use. Our research starts from the assumption that there are some differences in energy consumptions between households with different service life. To investigate the energy consumption in 20 households, we visited maintenance offices to obtain the metering data, and conducted in-depth interviews to investigate the residents' energy use behaviors in terms of heating, cooling, bathing, cooking, lighting, appliance and ventilation. Contrary to our expectation, it was identified that the households in the 33-year-old apartments did not use more energy than those in the 11-year-old apartments. Rather, energy conservation behaviors have more effect on energy consumption, regardless of the service life of buildings.

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1. Introduction

The built environment accounts for one third of the energy consumed in Korea, where residential and commercial buildings consume 92.5% of that energy. Overall, 60% of housing in Korea is apartment complexes; thus, households in apartment complexes play a major role in energy consumption in Korea. Government policies in many countries have focused on technical aspects of building structures for reducing energy consumption. The British Performance and Innovation Unit's report on energy policy demonstrates the neglect of behavioral strategies for energy conservation in the household sector [1]. The Korean government has made similar efforts to improve the energy performance of buildings by developing energy efficiency rating and certification systems. However, these energy policies have had little effect on energy saving.

To reduce problems caused by high energy consumption, governments have developed various regulations aimed at improving the energy efficiency of buildings. For example, the EPBD (Energy Performance of Building Directive) in 2003 is one initiative; this required all European member states to adopt performance-based

energy regulations to decrease heating, cooling, ventilation, lighting and hot water energy consumption in buildings. Nevertheless, energy savings are suspected to be difficult in reality [2–5]. Recently, many studies started to argue that residents' behavior might play a prominent role in the reduction of energy consumption in households [1,2,6,7]. It would be essential for households to adopt alternative behavioral strategies in order to reduce energy consumption effectively.

Compared to the impact of buildings' features on energy use, such influence of residents' behaviors has not been well studied. Further, there is little work considering household characteristics in addition to building features in analyzing the effect of residents' behaviors on energy consumption [8,9]. The average life of apartments in Korea is about 22 years due to early demolition of apartments for reconstruction; this is very short compared to that of other countries [10]. Although the physical service life has not run out, many apartments that have deteriorated have been destroyed, due to the negative perception of old apartments in terms of energy efficiency. Building waste from the early destruction has caused the consumption of construction resources as well as environmental pollution.

Our research starts by questioning what factors affect the patterns of energy use in households. It was assumed that there might be some differences in the energy use of households as a result of different service life. Thus, we selected two apartment complexes, each with a different service life, to conduct a comparative

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study on energy use. Contrary to the previous research, we first investigated the energy consumption of the households, residents' energy-related behavior, and residents' energy conservation behavior in the two complexes. Next, we compared the effects of building features, energy-related behavior and energy conservation behavior on energy use respectively in the two sets of apartments with different service life. This study aims to obtain an insight into the effect of residents' behaviors on energy use.

2. Related works

There is a wide range of factors affecting energy use, and these factors have various correlations among them. Many researchers have tried to identify the factors that influence the reduction of energy use. The previous research was reviewed, centering on the following three factors: building features, household characteristics and resident behaviors.

2.1. Building features

The physical features and functionality of buildings have been focused on as factors affecting energy use and efficiency. Several building parameters influence energy use, such as urbanization rate, age, building type, design of dwelling, insulation, ventilation, heating systems, energy type and window size [2,7,11–13]. Sherman et al. [14] argued that different kinds of ventilation systems have different energy requirements. Ventilation in housing provides fresh air to dilute internally generated pollutants, thus assuring adequate indoor air quality. For this ventilation service, energy is required, either directly to move the air or indirectly to condition the outdoor air. Francis et al. [15] investigated ways to save energy by assessing the natural ventilation performance of residential building designs. Concerning cost and energy saving issues, Bakos (2000) investigated various insulation protection approaches for the same building by comparing the performance of the insulations. It was found that the correct combination of insulation material and the promotion of new thermal insulation techniques lead to considerable energy saving [16–19].

Until now, most recent research has emphasized energy efficiency in high-rise buildings, remodeling buildings, and energy saving and environment-friendly buildings. Wan et al. [20] investigated several elements in high-rise residential buildings such as the floor areas of residential apartments, the ratios of the areas of bedrooms and living and dining rooms to the total apartment area, the window-to-wall area ratios, the types of fenestration, and the external shading devices in facades of residential buildings. They then tried to identify how those elements influence energy efficiency. Seo et al. [10] investigated by how much energy savings were improved after remodeling deteriorated apartments with insulation, ventilation and solar radiation. Branco [6] analyzed the total consumption of a low-energy multifamily complex that was designed to use a minimum amount of thermal energy by combining several renewable energy systems.

2.2. Household characteristics

Compared to the public sector, more energy is consumed in the residential sector. Thus, the characteristics of households are critical in influencing energy use. However, little work has been done on the impact of household characteristics on energy use. Several researches argue that age, family size, income and ownership are important characteristics determining the energy use in households [2,10]. Vringer [21] investigated the influence of household

income, expenditure, residents' ages and family size, based on the expenditure and energy use of 2800 households. He concluded that household income is an important factor in determining energy use because energy use is increased along with the growth in income. Dillman et al. [22] investigated energy saving measures targeting households in the USA. They found that there was a differential effect associated with income on energy saving. It seemed that lifestyle cutbacks were somewhat related to making temporary home adjustments to save energy, but were not related to taking permanent home-related energy conservation actions. Additionally, the poor accept lifestyle cutbacks while the wealthy invest in conservation.

Leth-Petersen and Tøgeby [23] identified the general owner-occupied trend in energy use. According to them, more energy is used in rented dwellings compared to those that are owner-occupied. Focusing on the importance of income growth in a cross-country analysis, Lenzen et al. [24] assessed the importance of various socioeconomic-demographic characteristics of households in energy requirements. It was found that there was no single uniform cross-country relationship between energy requirements and household expenditure. This result confirms previous findings that characteristics of energy consumption are unique to each country, and determined by various features such as resource endowment, historical events, socio-cultural norms, behavior and present market conditions, as well as energy and environmental policy measures.

2.3. Resident behaviors

To understand the patterns of residents' energy use, recent studies have moved closer to actual energy conservation behaviors [1,25–27]. Occupants' operations and activities in a building can be viewed as being caused by physiological needs, or social and cultural norms, or by a combination of these factors that constitute human behavior. Santin [2] tried to identify how much the characteristics of household and behaviors, as well as the physical features of the buildings, affect energy use for heating. The result shows that the physical features of the buildings have 42% weight, whereas the characteristics of household and behaviors have 4.2% weight for the effect on energy use. However, he expected that the weight of the residents' effect on energy use will be on the rise in the future. Yu [7] argued that social and economic factors partly determine residents' attitudes toward energy consumption, and the residents embody such impact in their daily activities and behaviors, thereby influencing building energy consumption.

Social-psychological studies have dealt with various complicated relationships, and influences between the structure of energy saving behavior and energy use [26,28–30]. Barr et al. [1] developed a framework of the energy behaviors for understanding the patterns of the residents' energy use, where the energy conservation behaviors are divided into two fundamental categories. This study is to analyze the pattern of the energy use based on Barr et al.'s framework. The first type of energy conservation behavior is 'habitual' activities that are related to the habitual elements of an individual's lifestyle in their daily activities, directing energy saving choices. Such behaviors include thermostat setting, closing off unused rooms, altering room use, window closure when heating is on, using a clothes line rather than a tumble drier, not completely filling the kettle before boiling, and putting a full load of washing on rather than a half load. The second type of energy conservation behavior is 'purchasing' activities. For example, insulation, double glazing, energy saving products, using low-energy light bulbs and adjusting curtain heights. This group has a diversity of actions on an effort-related scale to identify behaviors as definitively 'energy saving' actions.

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