Evaluation of measures to improve residential energy policies considering occupant characteristics

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A B S T R A C T

This study is aimed to identify the energy-saving policies in the residential sector that reflect the diversity of occupants using a statistical method such as IPA and ANOVA. To collect the sample data, one-to-one interview was carried out in 1500 households in Seoul city to investigate energy consumption status and occupant characteristics. Result from the field survey showed that about 50.1% of respondents expect the increase of energy consumption in the future due to needs for convenience, while 28% responded that energy consumption would decrease. It was also surveyed that each household spends about 76 USD and 62 USD (393kWh/month) per month in gas and electric utility fees, respectively. Due to the preference for larger appliances, the capacity of the home appliances was similar regardless of family members. The survey result on energy attitudes and practices revealed that the older the respondents, the more seriously concerned they are about environmental problem, however, the lower the age, the higher the number of respondents check their energy consumption for energy save. Finally, recommend the increases in the unit prices of current energy costs and thereby fostering energy conservation are deemed as the priority to improve energy saving plan derived from the evaluation of the government's eight major policies from the perspective of their effectiveness and importance.

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1. Introduction

Energy consumption in residential sector takes into a significant portion of total energy usage in both industrialized and developing country. Especially, the statistic documents [1,2] showed that the residential sector was accounted for around 30% of total energy consumption in the year 2012. From this reason, many countries positioned the energy consumption for residential sector as a principal energy savings area.

In general, energy saving measures for the residential sector has been carried out through so-called 'hardware-based enhancements' that are intended to improve the performance of buildings such as reinforcement of heat insulation, air tightness performance, etc. Such efforts have fostered efficient energy consumption in the residential sector and likely helped expand the supply of high-performance houses in developing country including Korea where 200,000 new houses are supplied every year [3—5]. However, hardware-based measures are helpful in providing quantitative and effective technologies; it is difficult to use those measures to provide specific alternative plans upon detailed analyses of energy consumption [6].

Meanwhile, energy consumption in the residential sector can be largely divided into three stages: construction, operation, and dismantlement. Ramesh et al. [7] analyzed that 80% or more of total energy consumption is take place at the operating stage or, in other words, during residential occupancy. Such an analysis result suggests the need for a software-based approach to the subjects that actually consume energy attributable to occupant behaviour. Moreover, the analysis of Hans [8], Zhun et al. [9] and Gill et al. [10] indicates that securing consistent enhancements in energy efficiency in the residential sector requires a strong focus on the behaviour and attitudes of residents.

For this reason, many researchers have studied consumer behaviours and attitudes specifically responsible for energy consumption. Wood et al. [11] analyzed consumer preferences in the selection and use of home appliances through detailed evaluation of economic and psychological characteristics of consumers. They also found that identifying the relationship between the effectiveness of information provided to residents and energy saving can

not only offer diverse interpretations on consumption trends but also expand the possibilities for energy-saving measures that reflect the characteristics of the users. Guera et al. [12–14] analyzed the gas and electric power consumption of 1500 households in terms of residential type to examine the relationships between consumption behaviours and resident behaviours. They found that residents responded more sensitively to electrical power consumption than gas consumption. .

Thomas et al. [15] and Kavgic et al. [16] described the behaviours of residents using the statistical method of bottom-up modeling for 100 households and experimentally analyzed the correlation between residents' behaviours and attitudes to energy consumption by examining their effect on the households' heating energy consumption. In addition, Kelly [17] quantitatively measured the organic relationship between the behaviours and attitudes of residents and their energy consumption by statistically modeling resident behaviours regarding home appliance use and energy consumption types using a structural equation. The abovementioned studies have confirmed not only that resident behaviours and attitudes have direct effects on energy consumption but also that improving their behaviours and attitudes can help lead to more reasonable energy consumption.

Meanwhile, these research results show the need for detailed measures for improving consumption habits and inducing rational consumption. Abrahamse and Steg [18] and Wood et al. [19] have measured the impact of public information on energy consumption to promote efficient energy use, concluding that providing such information can indeed induce changes in consumption behaviours. This implies that a one-sided provision of information has limitations. For example, residents' sensitivity to information differs considerably depending on their income and education levels.

This analysis was reinforced through subsequent studies. Yuasa et al. [20] provided one-person and four-person households with a manual on energy saving and observed their energy-saving efforts over a month. They found that the one-person households showed higher level of energy saving efforts in hot water supply and home appliance usages than the four-person households and that the four-person households showed more active participation levels in reducing lighting and standby power usages. This result indicates that energy-saving measures with considerations for the diversity of consumers can help maintain energy-saving behaviours over the long term.

Moreover, Yoo [21] have pointed out that diverse policies and information related to energy consumption can have more significant impacts than mechanical improvements to building performance can. He classified levels of energy-saving behaviours by income level and age group, finding that the lower the income level and the higher the age of the group was, the higher the interest in energy saving and the level of energy saving efforts was. This result implies that the diversity of residents must be reflected in the information they are given with in order to improve their attitudes and make the information relevant to their lifestyle.

The abovementioned studies suggest that it is desirable to consider the diversity of energy consumers in order to maintain efficient energy consumption over the long term. However, Galvin [22], Druckman et al. [23] have pointed out that energy-saving information has only a short-term effect on energy consumption and that it is advantageous to take into account the so-called 'rebound effect' to verify the actual effect. Information and policies are provided one-sidedly without considering users' consumption or residential form which accelerates the rebound effect and limits the fostering of consistent and reasonable energy usage over the long term [24,25].

These earlier studies indicate that resident attitudes to energy consumption can foster efficient energy use more effectively than

hardware-based improvements such as improvements in the performance of buildings. Presenting energy-saving measures that reflect the diversity of consumers is especially seen to effective long-term and consistent saving behaviour. However, quantitative evaluations such as those on heating or power consumption have been carried out in a limited sample group and only few studies have examined macroscopic issues such as the establishment of policies.

Based on literature review, this study targeted to provide the efficient national policies that take the diversity of residents into account for rational consumption in residential sector Specifically, the study researches 1500 households and diagnoses their attitudes to energy and the environmental issues by age, income level, and household member through an ANOVA. In addition, the study intends to suggest directions by conduction an IPA of these policies in terms of their importance and effectiveness.

2. Method

2.1. Field interview

Table 1 shows an outline of the survey. 1500 households in Seoul consisting of individually heated apartments were divided into four regional groups and were set as the sample population to reflect the number of households and household members by region based on the population census [26]. The survey was carried out through one-to-one interviews during visits to the households from July 26 to October 19, 2013.

2.2. Survey items

There are three survey items: (1) basic information about the respondents, such as age, occupation, living floor area, and monthly mean income, (2) energy-use items such as home appliances usage pattern and monthly mean consumption of gas and electrical power and, (3) items related to interests in energy and the environment, and policy improvement. Details on the items are provided below.

(1) Basic information

This information identifies the characteristics of residents who consume energy by dividing the respondents by number of household members, age, income level, and education level.

(2) Energy use item

This information identifies the differences in consumption by household members by investigating the possession status and actual use status of home appliances that consume energy and the monthly mean expenditure on gas and electrical power.

(3) Environment/policy improvement item

This information reflects the differences between resident characteristics via an ANOVA of their level of interest in energy and the environment (energy consumption attitudes) and their level of energy-saving behaviour (saving attitude). To study long-term energy measures, an IPA was carried out on the effectiveness and importance of eight policy aspects, including financial support, energy management, and provision of information.

2.3. Survey result

Table 2 shows the distribution of survey respondents.