Energy and Buildings 75 (2014) 402–409

Contents lists available at ScienceDirect

Energy and Buildings

journal homepage: www.elsevier.com/locate/enbuild

Development of methodology for estimating electricity use in residential sectors using national statistics survey data from South Korea

Jung-Hyun Yoo [a], Kee Han Kim [b,*]

[a] Land & Housing Research Institute, 462-2, Jeonmin-Dong, Yuseong-Gu, Daejeon, Republic of Korea
[b] Department of Architecture, Texas A&M University, 3137 TAMU, College Station, TX 77843-3137, USA

ARTICLE INFO

Article history:
Received 22 August 2013
Accepted 17 February 2014

Keywords:
Electricity use in residential sector
Statistic survey
Occupant behavior

ABSTRACT

This study proposed a methodology for estimating the current and future electricity use in residential sectors in South Korea. Such amounts are reflected by changes in occupants' lifestyles, and can be detected using national statistics survey data. At first, the representative family types, including the number of family members and the attribution of family members were defined, and each family member's daily activities was scheduled by the statistics survey data. Then, estimations were performed by connecting the each occupant activities to the corresponding residential appliances. The estimated annual electricity use obtained from the statistics data was 3677 kWh/year for a household comprised of a four-member family, 3061 kWh/year for a household comprised of a three-member family, and 2913 kWh/year for a household comprised of a two-member family, respectively. The estimated annual electricity use showed 8% difference, on average, as compared to the residential annual electricity use of energy-efficiency design criteria in South Korea, and 16% difference, on average, compared to approximately 1500 actual examples of residential annual electricity use in Seoul, South Korea. The reason for these differences could be that the proposed methodology only estimated the electricity use for weekdays, without including weekends, holidays, and vacations. Further development of this methodology will be required to account for these differences.

1. Introduction

Future electricity use in South Korea generally has been estimated by analyses of large amounts of past statistical data of obtained from utility companies. The Key World Energy Statistics 2012 [1] and the Worldwide Trends in Energy Use and Efficiency [2] from the International Energy Agency (IEA) also have helped with future electricity use estimations by providing electricity demand changes in the residential sectors of several countries, including South Korea. However, these conventional approaches cannot provide accurate estimations because they do not consider factors that may cause future electricity use changes attributable to occupants' lifestyles. Therefore, a number of researchers have become increasingly focused on occupant behaviors in houses that generate electricity use as a way to solve these estimation problems. Occupants' economic and psychological factors are especially important with regards to affecting a selection of residential appliances, as well as usage patterns. Research has shown that electricity use in houses also depends upon occupant behaviors attributable to occupant characteristics [3]. Wood [4] emphasized the importance of time-series electricity use analysis of each residential appliance in a particular house, in order to reflect the occupant's characteristics and how those characteristics impact electricity use. Yuasa [5] and Murakami [6] emphasized representative links between occupant characteristics (i.e., size of house, residential appliances in the house, etc. attributable to the number of family members and the family type) and the corresponding residential appliances in order to reflect the impact of occupant behavior on electricity use. In addition, social science information such as statistical data that shows family members' daily activities, represented by the American Time Use Survey (ATUS) [7], recently have been applied to an analysis of building electricity use. Chiou [8] and Tanimoto [9] suggested methodologies that could be used to estimate electricity use by applying the statistical data regarding family members' daily activities. They estimated electricity use by linking each family member's activities to the corresponding residential

* Corresponding author. Tel.: +1 979 220 8199.
E-mail address: keehankim@outlook.com (K.H. Kim).

http://dx.doi.org/10.1016/j.enbuild.2014.02.033
0378-7788/

appliances. These methodologies have strength in that family members' activities were considered in the estimations of electricity use. However, these studies still do not reflect changes in family lifestyles in the electricity estimation models because the models do not use representative family types. They linked the family types to their residential appliances, but only randomly. Therefore, a methodology estimating electricity use in houses in South Korea that analyzes the details of electricity use according to residential appliances and based upon the number of family members, family types, and family activities, was suggested for this study. Such a methodology can also be used for estimating future changes in electricity use according to changes in the occupants' lifestyles.

2. Methodology

The following factors which can affect electricity use in the residential sector were selected for analysis in this study: (1) number of family members, (2) size of the house, (3) family type, (4) occupant behavior, and (5) residential appliances. Fig. 1 shows the overall flow of the proposed modeling procedure for estimating the electricity use of residential houses. Multi-family houses were chosen to be the target of this study because house type does not vary significantly in terms of electricity use, depending upon the areas examined in South Korea. In addition, electricity used for heating and cooling was ignored. Most multi-family houses in South Korea use natural gas from district heating systems for heating, and rarely use electricity for cooling; the amount of electricity used for cooling in residential sectors in South Korea is very small (i.e., approximately 2% of the total annual electricity used in the residential sector). As described in the previous literature review, representative family types can be a significant factor in accomplishing an accurate future estimation of electricity use. Thus, households comprised of a two-member family, three-member family, and four-member family were all set in this study as representative family types based on an analysis of the relevant sources, including the distribution of the number of family members, the average ages of householders, and so on, as obtained from the 2010 report of population and housing census [10]. In addition, representatives of each family member's activity and their daily schedule were set as well, according to an analysis of the relevant information, including activities schedules and the distribution of activities of the people in each position (i.e., worker, housewife, student, etc.), obtained from the 2009 report of the Korean Time Use Survey (KTUS) [11]. After that, the electricity use of each family type could be estimated by linking each family member's activity to the corresponding residential appliances using a VBA-based program called Schedule Ver. 2.0 [12]. The estimated electricity use was validated through the residential annual electricity use according to the energy-efficiency design criteria of South Korea, and the approximately 1500 actual residential annual electricity use examples obtained from Seoul, South Korea. Lastly, there was a limitation to this study: generally, occupant behaviors can be estimated along two categories, weekdays and weekends (including holidays), but only weekdays were considered here because weekend behaviors could increase the level of uncertainty with regards to electricity use estimation.

2.1. Family types

Representative family types, including the number of family members and the attribution of family members, were set by the 2010 report of population and housing census [10]. Fig. 2 shows the distribution of each number of family members; 90% of the total number of family types in 16 million households were considered to be one-member family through four-member family households. Of the total of 11 million households, 3.5 million two-member family, 3.2 million three-member family, and 4.3 million four-member

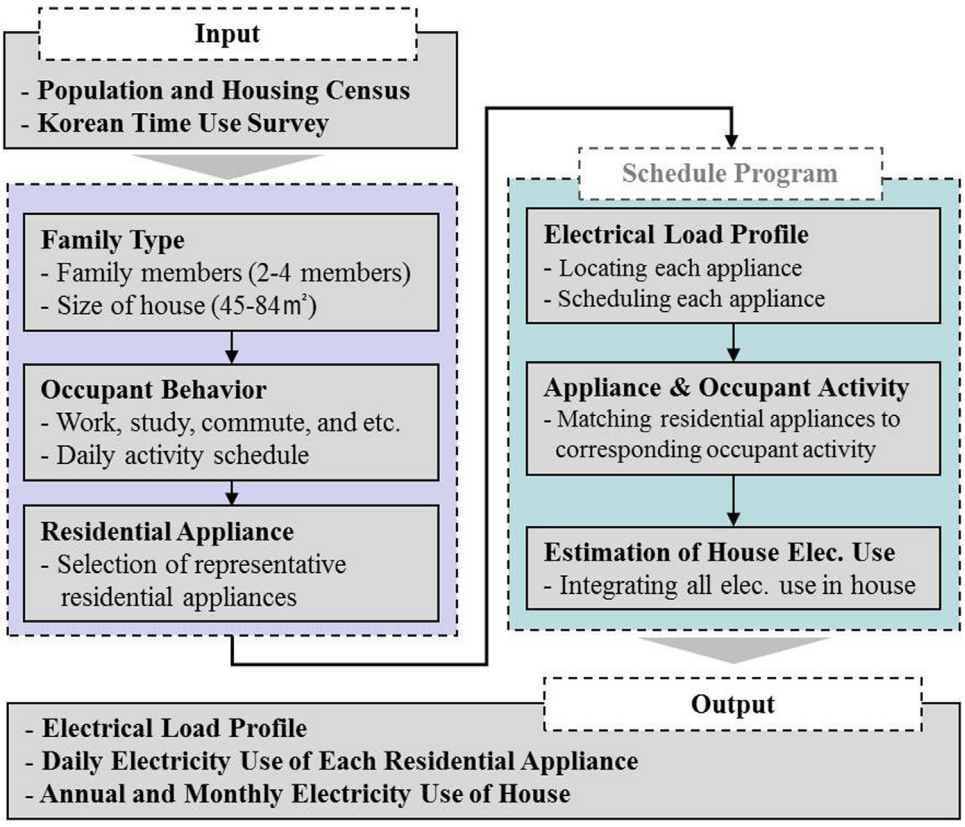

Fig. 1. The overall flow of the electricity use estimating procedure.