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To cite this article: Jeong-A Kang *et al* 2019 *IOP Conf. Ser.: Earth Environ. Sci.* **238** 012043

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Study on the Definition of Reference Building Based on Analysis of Design of Retail Buildings

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Abstract. By 2030, South Korea plans to reduce greenhouse gas (GHG) emissions by 37% compared to current business-as-usual emissions. In response, the aim of the study proposed here is to analyze current building design trends in South Korea and provide baseline data to develop a reference model for the effective reduction of GHG emissions in South Korea's building sector. First, the energy conservation plans of a recently 3 year designed retail building will be examined. The subject of the survey was divided into the areas of construction, machinery equipment, electric equipment, and lighting. Second, statistical analysis will be performed for the medium, median, and mode values for each item investigated, which will be used to determine representative values to apply to the reference building. Third, the building will be compared with another building of similar size and finalize the settings of the reference building. Last, using simulation tools, energy consumption will be estimated and characteristics analyzed for the reference building. By expanding the energy consumption characteristics of the reference building model obtained from this study and comparing them with the building energy consumption characteristics in South Korea's National Integrated Building Energy Management System (NIBEMS), a detailed target for the national-level building energy performance enhancement and greenhouse gas reduction management can be defined. In addition, the energy consumption potential for each technological element can be analyzed by using the reference building and policy improvement measures and incentive criteria can be established.

1. Introduction

Many countries are establishing institutional measures for greenhouse gas reduction. South Korea has also set a target of 37% reduction against business-as-usual by 2030. Notably, buildings account for 26.7% of the total greenhouse gas emission in South Korea (Yu et al., 2009). Hence, the Korean government has suggested diverse policies for better energy efficiency of buildings. However, objective and quantified criteria to support these policies are still lacking.

Jeong et al. (2014) proposed the definition of a reference model of standard non-residential building in South Korea, based on the result of a survey on building energy conservation plans. They analyzed

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energy consumption volume by using ECO2, a domestically developed simulation program. However, the ECO2 program has a disadvantage in that detailed adjustment of setting is impossible. Kim (2017) determined the energy value according to the actual operating schedule of buildings by conducting an on-site survey, but analysis of the trend of latest buildings was limited owing to the characteristics of the survey method. Kim et al. (2017) unified the legend for buildings based on national statistics data and thereafter conducted a detailed analysis by using EnergyPlus simulation program on 11 models, but errors were observed owing to limitation of the statistical data. The abovementioned studies have the following limitations: first, the use of a more detailed simulation program is necessary; second, better understanding of trends of latest buildings is required; finally, a fundamental correction is required for national statistics data.

The National Renewable Energy Laboratory (NREL) defined a reference non-residential building model in 2011. The definition process included five stages: classification of the use of buildings, selection of eight cities per temperate region, classification of the year of completion of buildings, establishment of characteristic data of buildings, and weighting factor correction. Models appropriate for each region and year were defined, analyzed, and thereafter corrected (Deru et al., 2011).

Similarly, the EU defined a reference residential building based on TABULA/EPISCOPE project. Europe's definition of the reference residential building resulted in structuralization of diverse energy characteristics of the member countries by updating the characteristics of the countries and unifying and standardizing the system for information exchange between countries (TABULA Project Team, 2010).

These studies demonstrated that a reference building model that reflects the unique characteristics of each country or region can help the establishment of policies appropriate for each of them and that setting a proper standard system enables information exchange between nations and reflection of latest issues in policies.

This study aims to contribute to efficient policy establishment and operation by enabling the definition of a reference building model that functions as the benchmark for policy and system establishment through more detailed analysis appropriate for the circumstances in South Korea.

2. Method

In South Korea, a building energy conservation plan system has been implemented, as a policy for efficient management of energy used by buildings. The building energy conservation plan policy is implemented based on the Green Building Creation Support Act and the Building Energy Saving Design Standards (Ministry of Land, Infrastructure and Transport, No. 2017-71), which are applied to buildings whose total floor area is 500 m² or larger. The review method of building energy conservation plans specifies a verification of whether the obligations for the construction, mechanical equipment, and electric equipment areas are fulfilled and whether the energy performance index (EPI) grade in the field of construction, mechanical equipment, electric equipment, and new and renewable energy equipment is 65 points or higher. As an exception, the benchmark is 74 or higher EPI points for a newly constructed public building or an annex to a main building (Anon. A).

A survey was conducted based on the abovementioned building energy conservation plans. The areas subject to the survey included construction, mechanical electricity, and new and renewable energy, according to the content of the building energy saving plan. The details of the surveyed items are shown in Table 1.

Table 1. Items of survey

Construction	(1) Scale of Building Total floor area, aspect ratio, window to wall ratio (WWR), number of stories, etc.
	(2) Insulation Heat transmission coefficient of exterior wall/roof/and the floor, type of insulation material, etc.
Mechanical Equipment	Type of cooling/heating equipment used and its efficiency
Electric Equipment	Design illuminance, lighting power, lighting source

The survey for this study was conducted on the retail buildings of commercial buildings accounting for 40% of greenhouse gas emissions (Cho and Kim, 2013) according to building use. Buildings completed in the past three years were surveyed, in order to identify the latest trends. EnergyPlus and OpenStudio programs capable of detailed modeling were used for the analysis.

The surveyed items were subjected to statistical analysis to obtain the average value, median value, mode, etc. and based on the statistic values, the representative value to be applied to the reference building was selected. Subsequently, the validity of the variables was verified by comparing them with those of an actual building designed to have a similar size and thereafter, they were corrected. The energy consumption of the defined reference building was calculated and the characteristics were analyzed by using a simulation tool.

3. Data analysis

3.1. Building

The collected data were analyzed and the average floor area of 25 buildings was 13,060 m². Most of them had floor area of 2,000 m² or less. For the number of stories, the value calculated with the average as the representative value and thereafter rounded off was 5: 4 above ground and 1 below with a ceiling height of 4.6 m. The average value of the number of above-ground stories except for underground stories was 3.6, but the mode value of actual buildings was 4.

The shape of the buildings was square with an aspect ratio of 1.96. Most of them were facing southwest. The WWR of exterior wall was estimated to be 17.72%. The WWR of retail buildings with floor area less than 10,000 m² was 15% on average, whereas the ratio of facilities with floor area 10,000 m² or larger was 34%. This indicates that the window ratio increases as the floor area increases, which is believed to be because large-scale retail buildings use larger windows such as curtain wall, rather than ordinary partial windows.

When the average value was applied, the heat transmission coefficient of the building envelope was 0.259 W/m²K for the exterior wall, 0.147 W/m²K for the roof, 0.204 W/m²K for the floor, and 1.752 W/m²K for the window. Regarding the standard heat transmission coefficient of the Building Energy Saving Design Standards (Ministry of Land, Infrastructure and Transport, No. 2017-71) shown in Table 2 (KICT, 2018) reference buildings' building envelopment heat transmission coefficients are all fulfilled the standards in the southern region.

Table 2. Heat transmission coefficients and standards for reference building (KICT, 2018)

		Reference building (W/m ² K)	Building energy saving design standards	
			Central region (W/m ² K)	Southern region (W/m ² K)
Building envelope heat transmission coefficient	Exterior wall	0.259	0.260 or below	0.320 or below
	Roof	0.147	0.150 or below	0.180 or below
	Floor	0.204	0.300 or below	0.350 or below
	Window	1.752	1.500 or below	1.800 or below

A functional 24-mm-thick double window consisting of 6-mm-thick ordinary glass, 12-mm-thick argon gas layer, and 6-mm-thick low-e glass was most widely used for retail buildings. Notably, low-e glass accounted for approximately 73%, which shows that the proportion of functional windows applied is very high.

3.2. Heating, ventilation, and air conditioning (HVAC)

Diverse types of heating equipment were used according to the scale of retail buildings. The most widely used type was electric heat pump (EHP). EHP was also most widely used for air conditioners. The wide use of EHP for HVAC is believed to be because of its characteristics, which enable easier control of the air in each room or zone in retail buildings. The capacity of both the heater and air conditioner calculated automatically from EnergyPlus was applied to the reference building.

3.3. Internal Loads

In this study, internal loads were applied the reference building, referring to Deru et al. (2011) and surveyed data. According to Deru et al. (2011), occupancy and electric equipment density were 6.19 people/m², 3.23 W/m², respectively. However, lighting density was applied 8.95 W/m² from the surveyed data.

4. Result and discussion

4.1. Retail Reference Building

Figure 1 (KICT, 2018) displays the retail reference building obtained from the result of this study's survey and analysis. It is a square-shaped building with three stories above ground and one below, and a total floor area of 13,060 m².

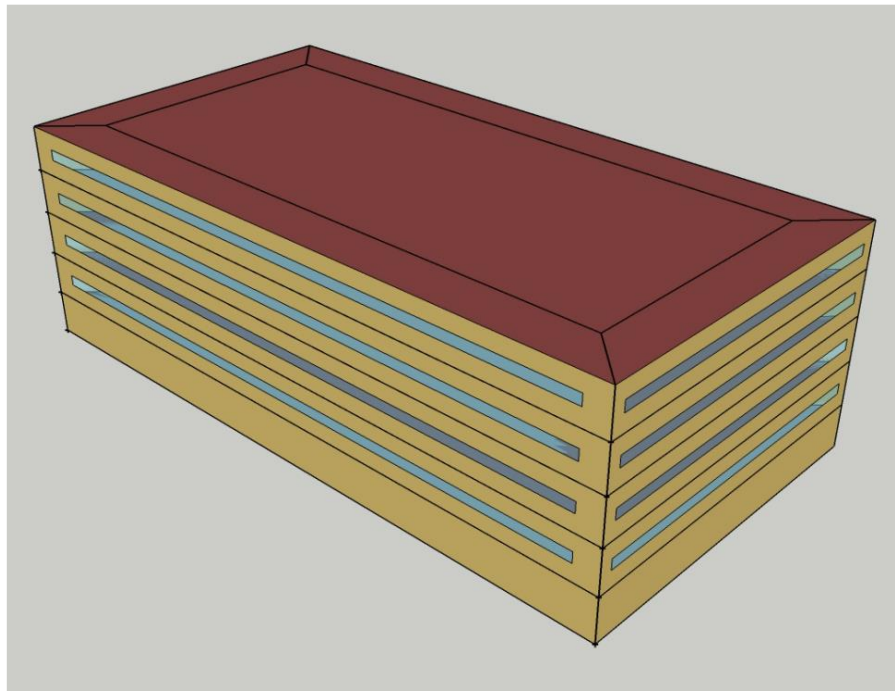


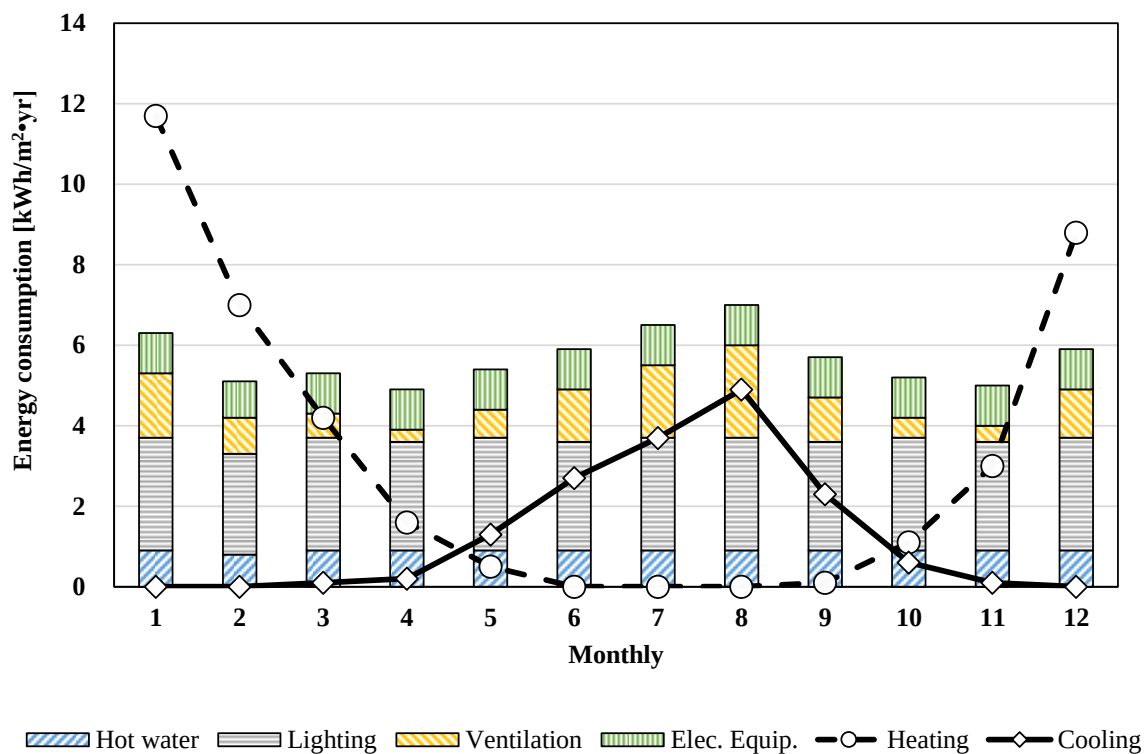
Figure 1. Modeling of retail reference building (KICT, 2018)

4.2. Result of Energy Requirements Analysis

Figure 2 (KICT, 2018) demonstrates the monthly energy consumption for lighting, electricity equipment, fan, hot water, cooling, and heating, which was obtained from the result of analysis by using EnergyPlus and OpenStudio programs. For retail buildings, the cooling and heating operation schedule was set at dual setpoint, as shown in Table 3. In addition, the set temperature was 26°C and 20°C, the cooling and heating standard in South Korea.

Table 3. Cooling and heating operating period and setpoint temperature

	Operating period	Setpoint temperature
Cooling	1/1–12/31	26°C
Heating	1/1–12/31	20°C

**Figure 2.** Monthly energy consumption of reference building (KICT, 2018)

The cooling operates around the year regardless of the season according to the dual setpoint setting. As a result, the total energy consumption was 122.1 kWh/m², as shown in Figure 2 (KICT, 2018). In addition, Figure 3 compares the average energy consumption in 2015-2017 of the retail buildings across the country with the energy consumption of the reference model (Anon. B; C).

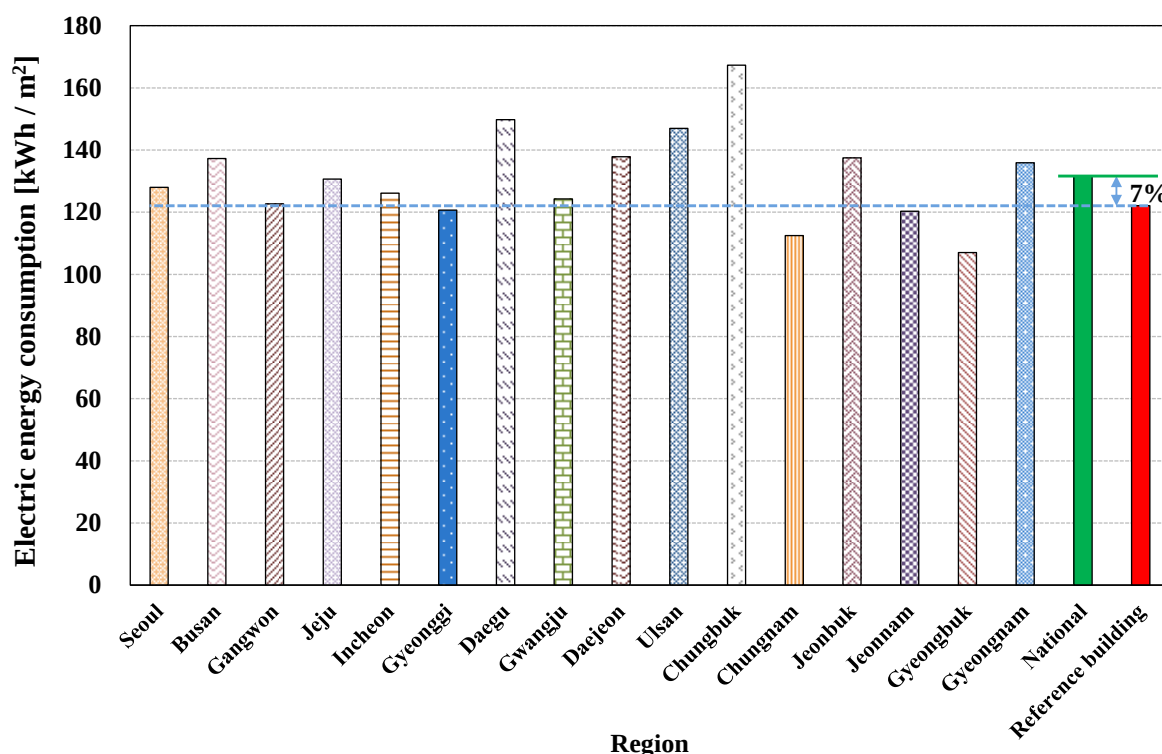


Figure 3. Comparison of energy consumption of regional retail buildings

5. Conclusion

This study aimed to propose a reference building that can function as the basis for the national energy policy by collecting data of latest buildings, based on South Korea's system of obliging buildings to submit energy conservation plans. The following is the summary of this study.

(1) The data of 25 buildings of retail buildings designed in the past three years were collected, including the building energy conservation plans that should be submitted in order to obtain a permit for new construction according to state laws and regulations, EPI review reports, and design documents and drawings, for the analysis of the design status of the buildings.

(2) The reference building obtained from the analysis has a total floor area of 13,060 m²; a square shape with four stories above ground and one below; the heat transmission coefficient of the building envelope of 0.259 W/m²K for the exterior wall, 0.147 W/m²K for the roof, 0.204 W/m²K for the floor, and 1.752 W/m²K for the window. The most widely used window is a 24-mm-thick functional window to which low-e coating is applied. The ratio of EHP application is high for HVAC equipment. The total lighting density is 8.95 W/m².

(3) The annual total energy consumption of the reference building is 122.1 kWh/m², which is about 7% less than the national average for the past three years. The result will have to be corrected for better accuracy by applying the load density value of electric equipment.

By expanding the energy consumption characteristics of the reference building model obtained from this study and comparing them with the building energy consumption characteristics in South Korea's NIBEMS, a detailed target for the national-level building energy performance enhancement and greenhouse gas reduction management can be defined. In addition, the energy consumption potential for each technological element can be analyzed by using the reference building and policy improvement measures and incentive criteria can be established.

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Acknowledgements

This research was supported by a grant from the National Research Foundation of Korea (NRF) grant funded by the Korea government (MSIT) (No. NRF-2017R1C1B5018390); and the Urban Architecture Research Program, funded by the Ministry of Land, Infrastructure and Transport (No. 17AUDP-C127876-01).