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# Improvements of the operational rating system for existing residential buildings

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## HIGHLIGHTS

- Building Energy Consumption Certification (BECC) for existing building is launched.
- Data of 504 multi-family housing complexes are used for empirical analysis.
- Potential problems of BECC are found in terms of classification and grading system.
- Improved BECC is developed by the energy benchmarking and modified grading process.
- Comparison between the current and improved BECC is conducted for validation.

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## ABSTRACT

The Building Energy Consumption Certification (BECC) evaluating the energy performance of existing buildings has been launched since 2016 to reduce the operational energy consumption in existing buildings in South Korea. However, the current BECC has some potential problems, and these problems should be solved to evaluate the energy performance of existing building more accurately. Thus, this study aims to identify the potential problems in the current BEEC using the hypothesis testing. And then this study proposes the improved BECC using the energy benchmarking process and the modified grading process to solve the potential problems. As a result of the hypothesis testing based on the data of 504 multi-family housing complexes (MFHCs), the potential problems were identified as follows: (i) the current classification criteria caused the irrational judgements, and (ii) the current grading system was lacking in its assessment function (over 94% of MFHCs ranked in the average level as grades “C” and “D”). To solve these problems, this study proposed the improved BECC. The energy benchmarking process provides the reasonable classification criteria, and the modified grading process finds the reasonable number of grades and its range. The result of comparative analysis based on 504 MFHCs indicated that the improved BECC could solve the problems in the current BECC. That is, over 94% of MFHCs were ranked in grades “C” and “D” in the current BECC while they were shown in all five grades (i.e., grades “A”, “B”, “C”, “D”, and “E”) in the improved BECC. The policy-makers can more accurately assess the energy performance of existing MFHCs by using the improved BECC.



## 1. Introduction

Various political actions (e.g., regulations and supportive policies) have been implemented in the developed countries to reduce the greenhouse gas emissions and energy consumption in the building sector, which accounts for about 40% of the global primary energy consumption [1–3]. The primary energy consumption in existing multi-family housing complexes (MFHCs) accounts for about 35% of the total amounts of building sector in South Korea [4]. Thus, political actions (e.g., the penalty to the buildings which have relatively poor energy efficiency or the incentive to facilitate the voluntary energy savings by the residents) are required to manage the energy consumption of the existing MFHCs.

The representative green building policies in South Korea can be summarized as follows: (i) *Green Standard for Energy and Environmental Design* (G-SEED) as green building certification; (ii) *Building Energy Efficiency Rating* (BEER) as energy performance certificates (EPCs) based on the simulated energy demand; and (iii) *Building Energy Consumption Certification* (BECC) as EPCs based on the actual

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**Nomenclature**

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|---|---|---|---|
| BECC | Building Energy Consumption Certification | G-SEED | Green Standard for Energy and Environmental Design |
| BEER | Building Energy Efficiency Rating | MAPE | mean-absolute-percentage error |
| CEI | $CO_2$ emission intensity | MFHC | multi-family housing complexes |
| EPBD | Energy Performance Of Buildings Directive | RMSE | root-mean-square error |
| EPCs | energy performance certificates | SSE | sum of squared error |
| EU | European Union | WCSS | within-cluster sum of squares |
| EUI | energy use intensity | | |

energy consumption data [5–15]. While the G-SEED and BEER evaluate the energy performance of new buildings based on the estimated operational energy demand, the BECC evaluates the energy performance of existing buildings based on the actual operational energy consumption. In this regard, the BECC can be an effective policy to evaluate the energy performance of the existing MFHCs.

Some previous studies have explored the potential problems in the current BECC [16–18]. For instance, the current BECC may lead to the irrational judgements for the energy performance of the existing MFHCs since it does not reflect the difference of climate conditions due to subdividing MFHCs based on the local government jurisdictions and most of the MFHCs could be included in the same grade. Despite these potential problems, there is a lack of studies for identifying the potential problems in the current BECC and improving the current BECC for the successful implementation of the BECC in South Korea.

Therefore, this study, as a follow-up research by Jeong et al. [16], aims to identify the potential problems in the current BECC using the hypothesis testing, and to propose the improved BECC solving the potential problems of the current BECC. The improved BECC is proposed using the energy benchmarking process and the modified grading process. This study uses the energy benchmarking process developed by Jeong et al., which helps to determine accurate energy benchmarks and classify the benchmarking groups through the statistically proven data-mining techniques [16] (for the model of the energy benchmarking process, refer to Fig. S1 in the supplementary material). And the modified grading process is newly developed in this study. In addition, to verify the validity of the improved BECC, this study compares the results between the current BECC and the improved BECC based on 504 MFHCs. The improved BECC proposed in this study can more accurately evaluate the energy performance of MFHCs by solving the potential problems of the current BECC. Ultimately, it is expected to lead to a reduction in the operational energy consumption of MFHCs.

Section 2 describes energy performance certificates using the operational rating and the potential problems of the current BECC via literature review. Section 3 describes the method to demonstrate the potential problems of the current BECC through statistical analysis and the improved BECC, which uses the energy benchmarking process and the modified grading process, in order to solve the potential problems of the current BECC. In Section 4, the validity of the improved BECC is demonstrated by applying 504 MFHCs to the improved BECC and the current BECC. Finally, Section 5 includes the brief description of the results and limitations of this study, and future study.

## 2. Review of the Building Energy Consumption Certification (BECC) SYSTEM

### *2.1. Energy performance certificates using the operational rating*

The operational rating evaluates the energy performance of existing buildings based on the actual energy consumption. Also, various building information on physical attributes (e.g., area, axis, floors, etc.) and socioeconomic attributes (i.e., residents, housing price, etc.,) should be considered to establish the operational rating [16,17,19–21]. That is, since the operational rating considers various building attributes that can affect the building energy consumption, it is proper to evaluate the energy performance of existing buildings.

The European Union (EU) initiated the Energy Performance of Buildings Directive (EPBD) in 2002 to reduce the $CO_2$ emissions from building sector. The EPBD defined a regulation that made it compulsory to evaluate the energy performance of new and existing buildings, and it included a clause that made it mandatory to attach the EPCs on the contract documents of buildings. Based on the EBPD guideline, the U.K., Germany, France and some EU countries established the regulation for the EPCs using the operational rating [22–26].

Similarly to the EPBD (e.g., Display Energy Certificates in U.K), the operational rating provided by the BECC in South Korea should be attached to the contract documents. The BECC has been implemented from 2013 through 2015 on a pilot basis, and it has been officially applied to over 500 households of MFHCs in 2016 [27]. While the site energy use intensity (EUI) of target building is used as an evaluation index to determine the grade of the EPCs, the source EUI and $CO_2$ emission intensity (CEI) are presented for reference regardless of evaluation [28,29]. Though some studies has pointed the expected problems in the current BECC, they didn't provide the alternative ways for addressing the potential problems with the scientific validations [16,18].

As shown in Table 1, the previous studies have analyzed the historical energy consumption data with the statistical value to evaluate the building energy performance as the operational rating. These studies have used various methodologies such as regression analysis, artificial neural network, data envelope analysis, multiple decision-making approach methods, and data-mining techniques. They commonly had the process to find the reliable energy benchmark with the homogeneous condition considering the attributes of buildings. In this regard, the expected problems in the current BECC can be identified through the validation of the energy benchmark in the current BECC.

### *2.2. Potential problems in the current BECC*

The clauses, which correspond to the operational rating system in the current BECC, can be summarized as follows: (i) the operational rating is evaluated by the districts based on the local government jurisdictions; (ii) the benchmarking clusters are classified by average enclosed area (AEA) based on the criteria of the Korean Census (refer to Table 2) [30]. The AEA stands for the area divided the total enclosed area by the number of households, and has been used as a unit size of households in MFHCs in South Korea [16]; (iii) the results of the operational rating in the current BECC are provided by five grades (refer to Table 3); (iv) the energy performance of the MFHCs are evaluated by site EUI including heat and electricity energy; (v) the mean value of site EUI is used as the benchmark;