# Development of an Energy Performance Assessment System for Existing Buildings

Youn-Kwae Jeong, Jong-Won Kim, Tae-Hyung Kim, Jong-Woo Choi, Hong-Soon Nam and Il-Woo Lee
ETRI (Electronics and Telecommunications Research Institute)
Daejeon, South Korea
ykjeong, jongwkim, taehyung, jwchoi89, hsnam, iwlee@etri.re.kr

***Abstract*—In this paper, we describe the development of an energy performance assessment system to evaluate the energy performance of existing buildings to deliver energy efficiency improvements by building remodeling. In consideration of the performance effect of building structure and operation, this system uses two kinds of building energy models, such as ISO 13790 and EN15232, to calculate the energy consumption of a building. In order to run an accurate building energy model, we use bill based energy consumption data and the Bayesian calibration method to find the current value of uncertainty parameters such as performance coefficient and deterioration coefficient of various building components. So, this system can accurately evaluate the energy performance of an existing building. Also, it can provide Energy Conservation Measures (ECM) for remodeling of existing buildings. The proposed system can be used as an effective and accurate energy performance assessment tool for improving energy efficiency of existing buildings through building remodeling.**

***Keywords- building energy paerformance; assessment; buildung energy model; Bayesian calibration; ECM.***

## I. INTRODUCTION

Recently, the Korean government has announced it will reduce greenhouse gas emissions by 37% from the previous projected emission levels for 2030. It takes about 22% of national energy consumption in the building sector. Therefore, building remodeling strategies to improve the energy efficiency of buildings to cope with these requirements have been actively promoted. In Korea, there are official building energy simulation programs, such as ECO2, ECO2-OD (Office Design)[1], Building Energy Simulation for Seoul (BESS) that evaluate the energy performance and validate building energy efficiency rating of a new building. But now there is no tool to evaluate the energy performance of existing buildings. Therefore, a new way is needed to effectively determine the deterioration and performance degradation of building structures and equipment according to the aging of the building. Also, a way to determine the energy efficiency of the building in accordance with the operating method is needed. In this paper, we describe the functional element of the system and the energy performance evaluation model based on ISO13790[2] and EN15232[3] and the way to improve the accuracy of the model by using bill based energy consumption data of existing building and stochastic energy model calibration method. Finally, we show the comparison results between actual energy consumption and predicted energy consumption.

## II. SYSTEM ARCHITECTURE

To evaluate the energy performance of existing buildings, it is very important to know how to effectively find the current value of unknown variable related to the performance of building components according to their age. We proposed three methods to effectively derive the coefficient of performance and deterioration, and to apply them to building energy model in calculating building energy consumption. First, we use the Bayesian calibration method, which is a stochastic energy calibration model that uses actual energy consumption data based on the bill. Second, we use the deterioration equation method that can predict the deterioration degree of building components according to their age. Third, we use the monitoring method to directly measure the actual value with respect to building components influencing the energy performance of buildings. Fig.1 shows the conceptual architecture of an energy performance assessment system for existing buildings.

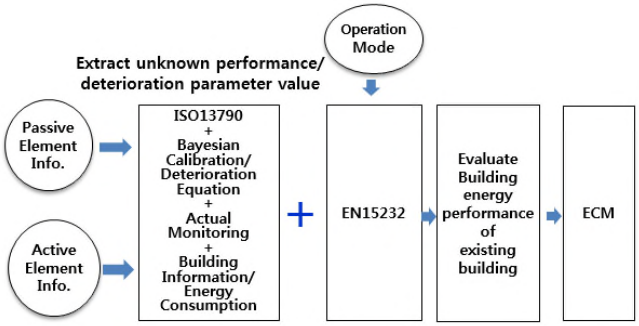


Figure 1. Conceptual architecture of an existing building energy performance assessment system

Fig.2 shows the functional architecture of the existing building energy performance assessment system. The system consists of 5 functions, namely, input file generation function, building model generation function, sensitivity analysis function, building energy model calibration function, and ECM generation and analysis function.

### *A. Input File Genergation*

This function asks the user to input the attribute values of each building component such as envelope, heating, cooling, renewable energy, measured data, and operation mode etc. Also, it makes Excel-based building information and a list of input parameters with uncertainty and it selects probability distribution for these input variables. Excel-based building

 ISBN: 978-1-61208-509-8 

information consists of building attribute data (total floor area, floor number, location, etc.), envelope and thermal attribute data (azimuth area, u-value, etc.), buildings structure, building operation, building energy systems, renewable energy (solar, photovoltaic and wind power), Building Automation and Control System (BACS) information, weather data (monthly mean air temperature, wind speed, solar radiation data), monthly energy consumption data based on bill and energy source, the schedule data to calculate the monthly average indoor heat value, and etc.

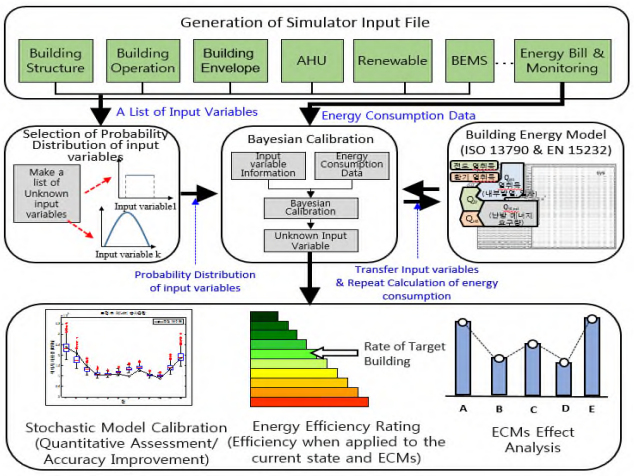


Figure 2. Functional architecture of an existing building energy performance assessment system

## B. Building Energy Model Generation

This function creates a building energy model to calculate energy performance for existing buildings based on ISO13790 and EN15232 energy model. ISO13790 calculates the energy used by heating, cooling, hot water, lighting, ventilation. EN15232 rates the operation mode of BACS and applies efficiency coefficient according to the operation mode to ISO 13790 energy calculation.

## C. Sensitivity Analysis

The sensitivity analysis is to identify the input variables that greatly influence energy consumption in the energy model. It is performed by Morris method to exclude input variables with low influence from Bayesian calibration.

## D. Building Energy Model Calibration

This function performs calibration of input variables of the energy model by using the actual energy usage data of the analytic target building. It is performed in the building energy model calibration considering the inherent uncertainty of the unknown input parameters automatically generated building energy model. The unknown variables of building energy model are corrected by a stochastic model calibration scheme based on Bayesian theory. Bayesian calibration is a process that estimates the probability distribution of the calibrated input variables to make the predictive value of a building energy model similar to the actual building energy consumption. It uses the Metropolis-Hastings Markov Chain Monte Carlo (MCMC) sampling method.

## E. ECM Generation and Economical Effect Analysis

This function is to predict the current value of an unknown variable with respect to each passive/active component of the building by using the calibrated building energy model as a base model. After that, it provides users with various ECMs for improving building energy performance. Users can select ECMs and it analyzes the energy and cost saving effects according to the user's selection of ECMs. It automatically provides the user with an optimal alternative in terms of the energy and cost saving effect. Finally, it reports energy consumption, energy reduction rate, $CO_2$ reduction, payback, etc.

# III. EXPERIMENTAL RESULTS

The developed prototype system was applied to three actual buildings in Seoul. The performance evaluation results are shown in Table I. This confirms excellent results in terms of energy calculation and error rate when compared to the ECO2-OD, which is used in conventional institutions.

TABLE I. EXPERMENTAL RESULTS APPLIED TO TESTBED BUILDINGS

| | *Building Name* | *Actual Energy Consump. (KWh/m$^2$) 2013* | *ECO2-OD (KWh/m$^2$)* | *Developed Tool (KWh/m$^2$)* | *ECO2-OD Error rate (%)* | *System Error rate (%)* |
|---|---|---|---|---|---|---|
| *1* | *Credit Center* | 233.3 | 214.8 | 229.8 | 8.0 | 1.5 |
| *2* | *Hwain Building* | 169 | 194.2 | 185.2 | 14.9 | 9.6 |
| *3* | *Kaite Tower* | 295 | 237.1 | 290.5 | 19.6 | 1.5 |

# IV. CONCLUSION

In this paper, we described a new building energy performance assessment system to accurately evaluate the energy performance of existing buildings in Korea. This system can provide the user with ECMs and analyze the economic effect to retrofit existing building components. Experimental results verified that it is more accurate than the official building energy simulation program ECO2-OD. In addition, it has 1.5% error rate between the calculated energy consumption and actual energy consumption. So, it is expected that this system is a very useful building energy performance assessment system for building remodeling and building energy efficiency certification for existing buildings.

## ACKNOWLEDGMENT

This work was supported by the Korea Institute of Energy Technology Evaluation and Planning (KETEP) and the Ministry of Trade, Industry & Energy (MOTIE) of the Republic of Korea (No. 20142010102370).

 ISBN: 978-1-61208-509-8 

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 ISBN: 978-1-61208-509-8 