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New energy benchmarking model for budget hotels

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ABSTRACT

Hotels in some countries or regions can not currently establish the energy benchmarking model based on statistical analysis due to the lack of building data. In this case, it is a question how to define an energy benchmarking model with fairness and comparability. To alleviate this problem, this paper, taking the budget (limited service) hotel as an example, develops an energy benchmarking model with composite indicator. At first an energy efficiency indicator is defined as EEUI (Equivalent Energy Use Intensity), which is indicated by energy consumption of unit hotel characteristics. The hotel characteristics involve both the business characteristics and energy use characteristics. The proposed energy benchmarking model is expressed by the weighted sum of major factors impacting on energy use, where EEUI is regarded as the dependent variable while the major factors are regarded as the independent variables. The coefficients of the independent variables are determined by the optimization model built in this paper. In the optimization model, the benchmark value of EUI (energy use intensity) provided by the nation or hotel industry is used as the benchmarking target. Finally the proposed energy benchmarking model is tested on the budget hotels. The purpose of this paper is to provide a simple energy benchmarking model with fairness and comparability to support the macro planning and management of energy saving and emission reduction urgently required by the hotel industry.

1. Introduction

Chinese hotel industry is actively working on cutting down emissions and saving energy. It is in urgent need of the building energy benchmarking model in line with national conditions for evaluating hotel energy efficiency, so as to support the macro planning and management of energy saving, along with the establishment of emissions trading system and the implementation of carbon quota system (Zhang and Wei, 2010) and green hotel certification (Luo and Li, 2013; PRC National Standard, 2007). Even though there are some available mature building energy benchmarking tools, such as the Energy Star (United States) (Energy Star, 2011), EEBPP (Energy Efficiency Best Practice Program) (British) (Falkners, 2000) and VDI3807 (Germany) (Verein Deutscher Ingenieure, 2007), for example some references have learned form the Energy Star to discuss the energy benchmarking of the high-star hotels in China (Wei, 2011), the lack of hotel building data makes it impossible to establish the energy benchmarking model based on statistic analysis or directly use these mature tools. The accumulation of building data is a long process rather than a short duration of time, but the hotel energy benchmarking tool is urgently required.

The first problem we face is, in the absence of enough building data, how to develop a simple hotel energy benchmarking model for temporary use in order to achieve the comparison and ranking of energy performance for hotels in peer group and thus provide useful information to support macro energy saving planning and management. The second problem we face is that, in the past, the traditional energy use intensity (EUI), expressed in unit of building energy use per gross floor area per annum (kWh/m^2/annum), is usually used as the energy consumption indicator of hotel buildings. However, hotels in operation period differ from not only the hotels in construction period but also the other non-profit public buildings (such as schools, libraries). It will be insufficient to use the traditional EUI as energy consumption indicator for the hotels in operation period. For example, let's consider two hotels A, B of the same type, star rating and gross floor area. If hotel A has a low occupancy rate and consumes little energy, while hotel B has a high occupancy rate and consumes more energy. If the traditional EUI is used for energy evaluation, it will be concluded that hotel A performs better than hotel B. Apparently, It is unfair for hotel B because though it consumes more energy, it gains more money. So the second problem comes down to the question of how to

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define a composite indicator in line with the hotel characteristics to make the hotel energy evaluation fair and comparable. Otherwise, the micro and macro management of energy saving and emission reduction will lack scientific support.

This paper discusses a composite energy evaluation indicator, called equivalent energy use intensity (EEUI), which is expressed in unit of energy consumption per hotel characteristics per year. The hotel characteristics, termed as D, include both the energy use characteristics, termed as D_e and operating income characteristics, termed as D_h, i.e., $D = \{D_e, D_h\}$.$D_e$and $D_h$are the set of independent variables involving energy use and operation income, respectively. The key to this problem is how to unify the units of De and D_h, and thus to coordinate their weights.

This study only discusses the budget hotels (equivalent to 2∼3 star hotels) because they belong to limited service hotels, whose energy use is influenced by fewer factors while the high-star hotels have more service items and more complex energy use factors.

One difficulty we face is that no enough building data can be used to establish the energy benchmarking model through statistic analysis, what shall we do? Another difficulty is that the proposed composite indicator EEUI can not be determined and verified by statistic analysis and has no benchmark value provided by the nation or hotel industry, how to guarantee the accuracy of energy benchmarking model? The basis idea of this paper is to use the weighted sum approach, like the regression equation of Energy Star, to establish the energy benchmarking model. In the weighted sum equation, the EEUI is regarded as dependent variable while the major factors impacting on energy use are regarded as independent variables. There are two types of independent variables, related to energy use and operation income, respectively. The coefficients of independent variables are determined by optimization method, which makes the computational EEUI approach the benchmark value of EEUI provided by the nation or hotel industry as close as possible, keeping the error in allowed limits. But we have no such benchmark value of EEUI currently, how to achieve the optimization? Firstly, we derive the EUI formula from the EEUI formula, namely establish the relationship between them. Then the EUI formula is used to establish the optimization model of the coefficients of independent variables. In the optimization model, the coefficients of independent variables are regarded as optimization variables and the independent variables are regarded as constants. Evolutionary algorithm (such as genetic algorithm) is used to obtain the optimized coefficients. Finally, the optimized coefficients are returned to the EEUI formula to replace the initial coefficients thus to form new EEUI formula. Thus hotel energy can be evaluated by the composite indicator including both D_e and D_h.

The energy use of full life cycle of hotels is the sum of energy consumed in the construction period, decoration period, operation period, and post-operation period. This paper only discusses the energy performance benchmarking of hotels in operation period.

This paper is organized as follows. Section 2 presents the previous work; Section 3 describes the definition of the new evaluation indicators EEUI and the selection of key factors that influence the hotel energy use; Section 4 presents the establishment of the simple energy benchmarking model; Section 5 presents the simulation of budget hotel energy evaluation; finally, the conclusions and further work are presented in Section 6.

2. Literature review

In the early 1970s, Europe and America had devoted much effort to gathering the energy use and energy-related data from public buildings. Currently they have established some perfect databases of building energy use, such as the CBECS (Commercial Building Energy Consumption Survey) (Energy Information Adiministration, 2003) established by the United States Department of Energy (DOE). The energy use data is the basis of the development of building energy benchmarking model. The completeness, systematization and accuracy of the databases determine the accuracy of the building energy benchmarking model.

Since the 20th century, some official or unofficial associations and organizations from Europe and America have developed various building energy benchmarking techniques and tools, such as the Energy Star Portfolio Manager (United States) (Energy Star, 2011), EEBPP(Government Energy Efficiency Best Practice Program) (British) (Falkners, 2000) and VDI3807 (Germany) (Verein Deutscher Ingenieure, 2007). The scope of application of these techniques and tools covers the hotel buildings. These benchmarking methods were classified into four types by Sartor et al. (2000): (a) statistical analysis, (b) point-based rating systems, (c) model-based benchmarking, (d) hierarchical and end-use performance metrics.

The general way of establishing the building energy benchmarking model is statistical analysis. A typical energy benchmarking tool based on statistical analysis is the Energy Star (Energy Star, 2011). It was established based on various database with respect to building energy use, such as the CBECS database, including the data of building type, regional location, building characteristic (floor area, occupancy rate, running time) and energy use. Its basis idea is to establish a regression equation on the basis of the practical building data. For simplicity's sake, it uses the multiple linear regression equation to express the relation between the EUI and the key factors that affect the energy use. In the equation, EUI is the dependent variable and the key factors are the independent variables. These key factors are selected by extensive multiple regression formulations, which is constructed to find the statistically characteristics explaining the greatest amount of variance in the EUI. The regression coefficients are identified by statistic analysis. Because there are a wide variety of building types, the buildings are classified into eleven types (including hotel building) in detail and specific energy benchmarking model is offered to a specific building type. It also gives a scoring system based on the probability statistics and quartile to judge a benchmarked building's energy performance level. The Energy Star score is an index from 1 to 100. If the benchmarked building gets a score greater than or equal to the benchmark value, it will receive the Energy Star certification.

The constructed regression models are usually validated through the statistical methods based on actual building data. The Energy Star is particularly suitable in the macro planning and management of building energy in countries having extensive areas and many different climatic zones.

The British building energy benchmarking tool EEBPP (Falkners, 2000) defined two energy efficiency indicators: £/100m^3/annum and GJ/100m^3/annum. The latter is equivalent to the EUI. A building can be benchmarked by comparing its actual values of the two indicators with their benchmark values. The EEBPP also divides the buildings into several types and offers each building type its own energy benchmarking model. The building energy evaluation system is established from top to down. The EUI is regarded as the total evaluation indicator, which can be obtained by integrating the energy use each subsystem. The energy use of equipment in each subsystem can be calculated by simple simulation calculation. The EEBPP emphasizes the connection of computation and building data to obtain the actual and expected classified energy use of equipment running under ideal conditions. For some buildings significantly different from each other in the business hours and heating and cooling degree days, their energy use can be calculated by amending the energy use formula.

The German building energy benchmarking tool VDI3807 (Verein Deutscher Ingenieure, 2007) uses the EUI as energy efficiency indicators, like the EEBPP. Both of them adopt the simple simulation calculation on the basis of the building data with respect to energy use, different from the regression model used by the