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Performance risks of lighting retrofit in Energy Performance Contracting projects

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ABSTRACT

In Energy Performance Contracting (EPC) projects, Energy Service Companies (ESCOs) often provide guarantees on the energy savings of proposed retrofit measures based on a simplified engineering method. In order to assess the risk of saving shortfalls, there is a need to develop an evaluation method based on the probabilistic approach. This study focuses on a proposed probabilistic approach to evaluate the performance risks of common lighting retrofit measures such as replacement of existing lighting, installation of daylight-linked lighting controls and occupancy-based controls. The proposed approach considers the variations in the influential factors affecting energy performance, including daylight availability, occupancy rates, lamp conditions and lighting use patterns. Empirical data is used to develop the probability distribution functions of those influential factors. A hypothetical 40-storey office building with typical design features (such as regularly shaped open plan) in Hong Kong was modeled using *EnergyPlus* to demonstrate the application of this probabilistic approach. The results indicate that the variations in actual energy savings can be substantial in lighting retrofit projects, ranging from 1,267,000 kWh (43% of pre-retrofit consumption) to 1,927,000 kWh (65% ditto) with 90% statistical significance, posing risk on the achievement of guarantee savings in an EPC project setting.

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Introduction

Artificial lighting consumes 20–40% of the total energy use and is one of the major end uses in a typical commercial building (Jenkins & Newborough, 2007; Khan & Abas, 2011). Although numerous studies show that substantial lighting energy use can be saved by retrofitting existing lighting systems with the latest lighting and control technologies (Dubois & Blomsterberg, 2011), some building owners (hosts) are still reluctant to carry out lighting retrofits due to a lack of capital and technological know-how (Fernandes, Lee, Dibartolomeo, & Mcneil, 2014). With this background, the emergence of Energy Performance Contracting (EPC) provides an alternative to those hosts. In EPC agreement, Energy Services Companies (ESCOs) guarantee or share the energy cost savings with hosts and pay all costs associated with design, installation and maintenance. The host only makes a series of pre-agreed payment to the ESCOs when the actual energy savings are realized progressively. In case of a final shortfall in savings, ESCOs will compensate the loss incurred by hosts. EPC has been widely adopted in both developing and developed countries, including Australia, Canada, China, Singapore and the United States (Vine, 2005). Regarding the size and market potential of EPC, Stuart, Larsen, Goldman, and Gilligan (2014) found that in the US, the potential market volume ranges from USD$71 to $133 billion, with lighting installation being one of the major retrofit measures (Larsen, Goldman, & Satchwell, 2012).

Owing to various extrinsic factors affecting lighting energy use, the actual amount of energy savings which may be achieved is uncertain (Lee, Lam, Yik, & Chan, 2013). For example, the level of energy savings resulting from daylighting controls depends on building's architectural features, location and sky conditions; and that of the energy-efficient lamps depends on lighting use patterns, the quality and frequency of maintenance. Since the ESCO bears the performance risks through a guarantee on actual energy savings in EPC projects, it is important to develop a proper risk evaluation method for quantifying the probability of shortfall in energy savings, and thereby assisting the ESCO to price for risk allowance.

Several attempts were made to develop such a risk evaluation method for building retrofit projects. Rickard, Hardy, VON Neida, and Mihlmester (1998) employed the technique of coefficient of variation (CVs) to evaluating investment risk in retrofit projects. However, several over-simplified assumptions need to be made, undermining the practical use of this technique. Mathew, Kromer, Sezgen, and Meyers (2005) adopted the actuarial pricing approach to quantify the risk of energy saving projects. However, the development of such actuarial database requires numerous real project data, including building information, type of energy conservation measures used and actual

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energy savings, and those data are often regarded as confidential in the private sector. In addition, non-standardization of project information and poor data quality are also the factors hindering development of a reliable actuarial database. Mills, Kromer, Weiss, and Mathew (2006) and Jackson (2010) proposed the use of Monte Carlo technique for uncertainty analysis to support decision making in energy efficiency projects. However, their studies mainly focused on the illustration of benefits of using this technique, and the detailed procedures are lacking. Heo, Choudhary, and Augenbroe (2012) proposed a probabilistic methodology based on Bayesian calibration of normative energy models to assess retrofit performance, but the analysis ignores the uncertainties arising from system degradation and weather variations.

As such, there is a need to establish an evaluation method for the contracting parties to ascertain the probability of having energy saving shortfall. The objective of this paper is to develop a probabilistic approach to evaluate the performance risks of common lighting retrofit measures, including replacement of existing T8 lighting with T5 tubes, installation of daylight-linked lighting controls and occupancy-based controls. The detailed procedures of the proposed approach are illustrated for a hypothetical 40-storey office building. The paper is structured as follows. After a brief introduction on the research background, the methodology, which involves the use of *EnergyPlus* and Monte Carlo simulation techniques, is described. The development of probability distribution function (PDF) of the influential factors affecting performance of the above retrofit measures such as daylight availability, occupancy rates, lamp conditions and lighting use patterns are reported. The procedure of adapting an existing typical meteorological year weather file taking into account the annual variations in daylight availability is described. Finally, the results using this probabilistic approach are discussed. With the use of this evaluation method, the performance risks of lighting retrofit projects may be better understood and managed. The detail methods are explained in the following section.

Methods

Fig. 1 shows the procedures and approach to be used for assessing the probability of energy saving shortfall in a hypothetical lighting

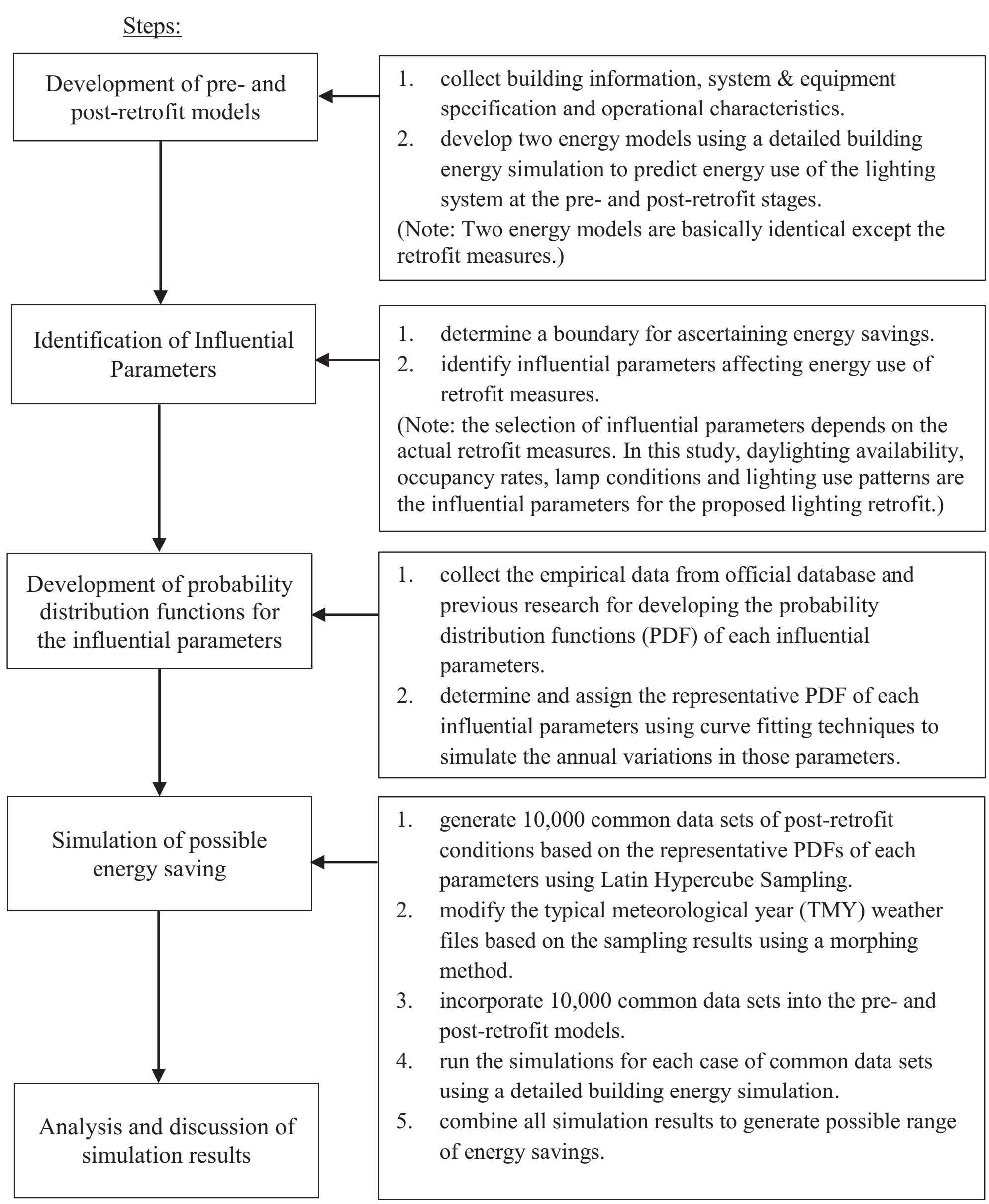

Fig. 1. The procedures for assessing the probability of energy saving shortfall.

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