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Strategic design of cost savings guarantee in energy performance contracting under uncertainty

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HIGHLIGHTS

- A methodology is proposed to assist Energy Service Companies to maintain competitiveness in winning bids.
- Uncertainties within the energy cost savings are modeled stochastically using the Monte-Carlo simulation.
- A strategic energy savings guarantee design curve is derived, where all points return as appropriate guarantees.
- A campus case is presented to demonstrate the applicability for finding appropriate guaranteed savings value.

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ABSTRACT

Among the key barriers to profit in Energy Performance Contracting (EPC) are uncertainties about attaining the realized energy cost savings and potential disputes over the guaranteed cost savings. In this paper, a methodology has been proposed to assist the Energy Service Company (ESCO): (1) to evaluate the risk threshold if the guarantee has already been made, and (2) to determine the guarantee design, if the guarantee has not been made yet, that not only promises the ESCO's profitability from EPC but also maintains its competitiveness to win the bid. Uncertainties within the energy cost savings are modeled stochastically using Monte-Carlo simulation, taking both the energy price fluctuation and the facility performance variability into account. Based on that, a strategic energy savings guarantee design curve is derived, that all the points on it would return as appropriate guarantees. Finally, a campus case is presented to demonstrate the applicability for finding the appropriate guaranteed savings value. This method is also worth popularizing in similar performance-based projects.

1. Introduction

Due to fast-growing energy-efficient technologies, a great potential of savings has been explored within the existing facilities that fuel the growth of the current economy. In Europe, the energy efficiency potential is assessed to be 7.5% of the total energy use [1]. Buildings, responsible for 40% of the energy consumption and 36% of the carbon emissions worldwide, are targeted as the sector with the largest energy efficiency margin [2]. According to the U.S. Energy Information Administration [3], nearly 75% of commercial buildings in the United States are over 20 years old and are constrained by aging infrastructure and inadequate operating resources. Thus, the energy efficiency of buildings plays an important role in achieving environmental goals. However, a wide gap exists between the technologies available and those actually implemented [4]. In order to address these situations, Energy Performance Contracting (EPC) has been adopted as one of the most common contracting models for existing buildings [5]. In the past two decades, the EPC market has shown a remarkable growth trend matched with the incremental energy demand and potential for energy and other efficiencies. On average, 20% of revenue growth has been achieved annually by the Energy Service Companies (ESCOs) [6–8].

EPC is a contracting method between the owner and the ESCO that emerged in North America after the oil crisis in the 1970s. Basically, EPC uses the operational savings of utility bills to fund repayment of capital for building improvements and avoids the initial capital expenditures [9]. Two common models for payment used in EPC are the Guaranteed Savings Model (GSM) and the Shared Savings Model (SSM) [10]. Compared with SSM, GSM specifies a certain amount of energy savings guarantees in the contracts

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Nomenclature

G_0	initial energy cost savings guarantee
$f(t)$	adjustment factor at year t
G	annual energy cost savings guarantee
β	the owner's excess savings shared percentage
N	the maximum year of contracting period
T	contracting period
$S(t)$	energy cost savings at year t
$P_E(t)$	energy price at year t
P_{E0}	initial energy price before project starts
α_{Et}	energy price drift coefficient at year t
σ_{Et}	energy price volatility coefficient at year t
ε_P	a random variable for energy price uncertainty $\varepsilon_P \sim N(0,1)$
$Q(t)$	realized amount of energy savings at year t
$\hat{Q}(t)$	engineer's estimation of amount of energy savings at year t
α_{Qt}	drift coefficients of amount of energy savings
σ_{Qt}	volatility coefficients of amount of energy savings
ε_Q	a random variable for amount of energy savings uncertainty $\varepsilon_Q \sim N(0,1)$
$D(t)$	differences between the realized energy cost savings and the guaranteed cost savings
$D_O(t)$	profit difference held by the owner
$D_E(t)$	profit difference held by the ESCO
D_{E_total}	total discounted profit difference from the ESCO's perspective
r	expected rate of return
δ	convergence criteria

in order to meet the payback obligation [11]. According to Goldman et al., [7], the ESCOs market shifted away from SSM to GSM over the last decade, and 86% of EPCs currently use GSM. The main reasons for this shift are the greater certainty of savings, the lower financing costs, and the lower transaction costs for GSM contracts from the owners' perspective [11]. Therefore, the underperformance risk is reallocated in the form of a guarantee, which is offered by the ESCO to the owner regarding the periodical energy savings. In other words, risks of failing to meet the annual guaranteed energy saving are covered by the ESCOs [12].

Since the ESCO is encouraged to develop more desirable energy efficient solutions, the well-designed savings guarantees go a step further to unite the ESCO and the owner for a shared goal [13]. In practice, the forms of the energy savings guarantee might be tailored to fit the particular requirements of legislation, regulations and owner due to the uniqueness of each project [5]. But, in general, the ESCO reimburses the owner if there is a shortfall in the realized energy savings compared with the guarantee, and shares the excess profit at a predefined percentage if over-performed. Thus, the guarantee is the key of a contract funding a capital works upgrade out of existing cash flow. However, tradeoffs exist in the energy savings guarantee design due to the risk reallocation. On the one hand, conservative guarantees are preferred since most of the ESCOs are risk averse. Either the unforeseeable energy prices drop or the defective energy conservation performances may result in an undesirable energy savings realization. On the other hand, the ESCO needs high-energy savings guarantees to get favorable financing rates, which ensure the benefits that persist over the project's economic lifetime and are sufficient for paying the investment [14]. Also, the owner prefers to secure the energy savings before contracting starts in order to avoid the risks induced by uncertainties. Therefore, to balance the potential losses, financing benefits and bidding competitiveness, the energy savings guarantee would go neither too high nor too low, based on the estimation.

Current energy cost savings guarantees are mostly determined based on empirical estimations, due to the long-term contracting and the environment complexity. According to Goldman et al. [15], no discernible pattern or formula (e.g., guaranteed savings are set at 80% of the predicted savings) has been found for the guaranteed savings decision. Among the key barriers to profit in EPC are the uncertainties about attaining the realized energy cost savings and the potential disputes over the guaranteed cost savings. Deviations between the guarantee and the realized energy cost savings frequently occur during the implementation of EPC [13]. Shonder and Hughes [16] analyzed the measurement and verification reports from all ongoing projects of the Oak Ridge National Laboratory database. Statistical results show that the realized cost savings was 110% of the total guaranteed cost savings. Cost savings shortfalls were only realized in 7 of 88 projects, and the average amount of the additional cost saving was 12% of the guaranteed cost savings. Hopper et al. [11] found that 72% experienced greater savings than were guaranteed by the ESCO based on the NAESCO/LBNL database. Nineteen percent encountered savings shortfalls, of which 63% realized shortfalls greater than 10%. In the meantime, Goldman et al. [15] also examined the difference between the predicted and realized energy savings. The results showed that the realized savings exceeded the predicted savings in 63% of the cases. Hopper et al. [11] also found that 54% of projects had realized energy savings that exceeded predictions, and 34% experienced shortfalls relative to the predicted savings. According to Ghosh, et al. [17], the ambiguity regarding realization of estimated savings was ranked as one of the highest market barriers for the adoption of EPC in the private building sector.

Owing to the absence of standard procedures for the energy cost savings guarantee designs, a methodology has been proposed in this paper for the ESCO to determine how much the annual cost savings should be guaranteed, and what percentage of the excess profit should be shared, before contracting starts. If the guarantee has already been made, the proposed method could help to evaluate the profit risk threshold. The remaining paper is structured as follows: in Section 2, previous studies on the risk valuation and allocation techniques in other performance-based contracting systems are reviewed. Comparably, special characteristics of EPC are also pointed out. Then, Section 3 presents the method and the general process for determining the appropriate guarantee design. In Section 4, the proposed method is applied to a campus case. The existing guarantee design of the contract is evaluated, and other potential guarantee designs are also explored. Conclusions are presented in Section 5.

2. Valuation and allocation of contracting risks

Many industrial sectors involve performance-based contracting in fields, such as commercial shipping, public transport, health services and energy generation, besides EPC [18]. The performance-based contracting method buys performance through an integrated acquisition and logistics process, delivering improved capability to a range of products and services. Generally, long contracting periods and a large number of uncertainties are the major concerns of retrofit risks in these projects [19–22]. To deal with the varied uncertainties underlying the preset contracting period, contractual guarantees are commonly adopted in the performance-based pro-