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Making optimal investment decisions for energy service companies under uncertainty: A case study

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ABSTRACT

Varied initial energy efficiency investments would result in different annual energy savings achievements. In order to balance the savings revenue and the potential capital loss through EPC (Energy Performance Contracting), a cost-effective investment decision is needed when selecting energy efficiency technologies. In this research, an approach is developed for the ESCO (Energy Service Company) to evaluate the potential energy savings profit, and thus make the optimal investment decisions. The energy savings revenue under uncertainties, which are derived from energy efficiency performance variation and energy price fluctuation, are first modeled as stochastic processes. Then, the derived energy savings profit is shared by the owner and the ESCO according to the contract specification. A simulation-based model is thus built to maximize the owner's profit, and at the same time, satisfy the ESCO's expected rate of return. In order to demonstrate the applicability of the proposed approach, the University of Maryland campus case is also presented. The proposed method could not only help the ESCO determine the optimal energy efficiency investments, but also assist the owner's decision in the bidding selection.

1. Introduction

Large energy savings potential sets the stage for a considerable increase in energy efficiency investment over the coming decades. With the appearance of energy price increases, resource scarcity, and sustainability development, energy efficiency has become one of the most efficient ways to increase the amount of energy available for use [1]. The contribution from buildings towards energy consumption, both residential and commercial, has steadily increased, reaching figures between 20% and 40% in developed countries, and has exceeded the other major sectors, industrial and transportation [2]. Taking the United States in 2012 for example, the energy consumption of the building sector comprises about 39.69% of total energy use, as compared with 32.14% for industry and 28.17% for transportation [3]. However, existing building stocks do not perform energy efficiency sufficiently. According to the U.S. DOE [4], nearly 75% of the commercial buildings are over 20 years old and 30% were built more than 50 years ago. Estimation of the unrealized energy efficiency potential ranges from 15% to 25% [5]. From a broader perspective, global energy efficiency investments are only around half the size of upstream oil and gas investments, and are distributed unevenly across countries and energy-consuming sectors [6].

To start facilities upgrades and energy renovations, EPC (Energy Performance Contracting) becomes one of the most commonly adopted contracting methods, especially for existing building stocks. EPC allows facility owners to upgrade aging and inefficient assets without capital investment [7]. In a typical EPC, the ESCO provides a turnkey service in investigating, designing, financing, and renovating those aging and inefficient assets with multiple energy conservation measures. Then, the capital investments are paid for through the guaranteed energy savings specified in a multiyear contract. After the contract ends, all additional cost savings accrue to the owner. According to Stuart et al. [8], EPC has currently grown at more than 20% per year, driven by increasing and fluctuating energy prices, federal and state energy savings mandates, the continued lack of capital and maintenance budgets for federal facilities, and growing awareness of the need for large-scale action to limit greenhouse gas emissions. Making an appropriate investment decision could not only help the ESCO explore maximum energy efficiency potentials, but also assist in binding the win–win partnership between the owner and the ESCO.

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Conservation options are often available for the improvement of the buildings' energy efficiency. In most cases, state legislation is open-ended on the types of energy conservation measures that may be included, but legislation may restrict the budget categories that can be used to pay for such measures. As a result, the decision-making process plays a critical role with respect to the energy efficiency investments. System-design engineers are often sent out before the EPC start by the ESCO to evaluate energy efficiency conditions for the selected buildings and to draft the energy conservation measures plan. In the plan, each potential energy conservation measure is identified and the bundle of measures is determined with compensated environmental, energy, financial, and social factors [9]. For instance, lighting with a short payback period can offset the longer payback periods of boiler and chiller replacements or renewable energy systems, if they're bundled under one contract. Then, the itemized cost saving is estimated, and the origin investment scheme is established.

In general, a balance of concerns exists within the energy efficiency investment decision-making. Varied initial energy efficiency investment results in different annual energy savings achievement. Neither too high nor too low energy efficiency investment would generate satisfied energy savings revenue for EPC. On the one hand, the ESCO would not like to make an overly high investment. Overestimated energy conservation performance or unpredicted energy price drops may fail to reach the expectation of energy savings revenue. Since the total costs are paid from energy savings, the ESCO tends to be fairly conservative when selecting energy conservation technologies. On the other hand, the ESCO would not like to make an overly low investment. The revenues generated over the project's economic lifetime need to be sufficient to pay for the full investment. Besides, the higher annual savings revenue is more competitive for winning the bidding. Therefore, to balance the generated revenue and potential loss, a cost-effective investment decision is needed in the stage of selecting energy efficiency technologies because of their irreversible nature.

Since the retrofit uncertainties of EPC that might significantly affect the final profitability for ESCO, difficulties of making the investment decision are increased. In order to evaluate the potential energy savings profit through EPC, and thus making the cost-effective energy efficiency investment decision, a simulation-based approach is presented for the ESCO in this research. The remaining paper is structured as follows: Section 2 reviews the related EPC studies on the energy efficiency investment and savings revenue. The results show that specific guidance is still needed when the ESCO makes investment decisions. Section 3 then presents the proposed method of optimal decision-making on energy efficiency investment. In Section 4, the University of Maryland campus case is selected to demonstrate the applicability of the proposed approach. Finally, Section 5 concludes and discusses the directions for future research.

2. Related studies

Energy efficiency investment tends to increase dramatically each year, especially after EPC emerges, which helps to solve the initial capital financing dilemma [10,11]. In past decades, the investment on EPC grew despite the onset of a severe economic recession, which matched with the incremental energy demand and the explored efficiency potentials [12]. However, as one of the most pervasive anomalies in energy economics, industrial firms do not always implement the most cost-effective conservation investments [13]. This lag of energy efficiency improvement is called the “energy efficiency gap” [14] or the “energy paradox” [15]. Several causations and explanations for the improvement lag have been raised in the past literature [16–19]. According to Sardianou [18], financial constraints, economic parameters, market imperfections, and organizational and human-related factors were listed as the five major factors hindering industrial energy efficiency investments in Greece. For other European countries, the greatest perceived barriers of energy efficiency in foundries are the lack of devoting resources and the lack of business continuity guarantee [17]. In developing countries, barriers are more pronounced as weak energy policy frameworks, financial constraints, and weak information systems [16]. Similar research has also been conducted by Mills et al. [19]. Risks associated with the energy efficiency projects were classified into five aspects, namely economic, contextual, technology, operation, and measurement and verification.

From the economic perspective, the more investment has been made in renewable energy technologies, the more energy savings revenue would be expected to generate as return. However, due to the interactions among the uncertainties, large potential risks have been imposed on the project's profit [20]. Energy efficiency investments are often capital-intensive with long payback times during which the energy market conditions are changing [21,22]. Multiple uncertainties have thus been added in, such as performance of energy conservation measures, fluctuation of energy market price [23], weather conditions, varied human operations, and random occupancies [24,25]. Even though the ESCO could better manage the performance risks by ensuring system efficiency, optimization control, and regular maintenance, the actual energy savings revenue was still uncertain [26,27]. In real practice, the energy efficiency savings were frequently found to be less than the estimation in private buildings, and the shortfall was discussed under the heading of “rebound effect” [28,29]. Difficulties of making the investment decision based on estimation were increased [22].

Many researchers confirmed a quite robust link between project investment and the environmental uncertainties. Early scholars indicated that an increase in uncertainty will raise the marginal valuation of investment, giving a positive link between capital-accumulation and risk [30,31]. According to Bond et al. [32], modern panel data techniques stimulated a variety of empirical studies, most of which are supportive of negative investment impacts on uncertainty. Fuss and Vermeulen [33] also applied business sentiment surveys to address price and demand uncertainty, as perceived by company managers in Belgium. The valuation techniques for risk assets provide powerful tools for estimation in uncertain environments [34,35]. An alternative method is to incorporate uncertainty measures embedded in the term structure of relevant prices, like interest rates or option prices. Though a range of options is available for uncertainty indicators, no consensus is yet obtained for the appropriate way to proxy uncertainty in empirical models. The risk valuation techniques were introduced and commonly used in economic analysis under uncertainty, aiming to model and price those opportunities [36]. Kjærland [37] showed the consistency between the real options theory and the aggregate investment behavior in Norwegian hydropower. The value of investment opportunities was estimated and the relationship between the price of electricity and the optimal timing for decision-makers to implement investment strategies was determined.

Specifically, efforts have also been made to promote energy efficiency investment worldwide, such as for the United States [21,38], China [39,40], Australia [41], Iran [42], Greece [43], and South Africa [44]. According to Ansar and Sparks [15], households and firms were inclined to delay making energy efficiency investments until internal rates of return exceeded values of 50% and higher. Taking this situation into consideration, Lin and Huang [45] presented an entry and exit model on the energy saving investment