Application and risk assessment of the energy performance contracting model in energy conservation of public buildings

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Abstract

With the development of China’s economy, the total area of public buildings is continuously increasing, and higher energy consumption in this field is gradually becoming prominent. In order to improve this situation, China has been working on energy savings in public buildings since 2007. Energy-saving models and energy policies have become the lifeline of sustainable energy development. Furthermore, the energy-saving renovation of public buildings, as a key project, has attracted the attention of governments and scholars. In the report of the 18th National Congress of the Communist Party of China, energy conservation and emission reduction were given a prominent place. The 13th Five-Year Plan (2016-2020) aims to further promote China’s energy conservation work. On the one hand, administrative and legal measures should be taken to strengthen energy conservation. On the other hand, it is necessary to speed up the establishment of a long-term market-based energy-saving mechanism and to rely on market forces to remove various obstacles to energy conservation. Energy performance contracting (EPC) is a practical and effective method applied in energy conservation. Therefore, this research aims to put forward a relatively perfect energy-saving risk management system for EPC public building projects based on analysis of the factors influencing investment risks of energy-saving projects and the use of quantifiable risk management models, thus providing some theoretical support for the risk decision-making of energy service companies.

Keywords: energy performance contracting (EPC), public buildings, risk assessment, energy conservation

1 Introduction

Currently, energy-saving services are emerging in many countries around the world. However, from a global perspective, the development is uneven. According to the results of a country-wise survey, the developmental speed of energy-saving services in different countries is highly variable; energy-saving services in some countries, such as the United States, Sweden, the United Kingdom and so on, have a history of >30 years, while this process in some countries started only in the late 1990s or in recent years; moreover, the emergence of energy-saving services-related enterprises, i.e., energy-saving companies or ESCOs, in countries, such as Lithuania, Nepal, South Africa and so on, started after 2000. Secondly, in terms of market scale, some countries that

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have been involved in this field earlier have developed a relatively stable energy-saving service industry, especially the United States, which has >2100 professional energy-saving enterprises, some of which have formed transnational groups and occupy an absolute market share in this industry.

Since 1992, the energy-saving service industry has gradually developed in Asia. In recent years, the total area of public buildings in China is continuously increasing. The steep increase in energy consumption in public buildings is prominent, which also leads to serious environmental pollution. Energy conservation and emission reduction are crucial to the sustainable development of energy management. Energy consumption in China is pretty huge, and buildings account for nearly 30% of the total energy consumption, of which public buildings take up the highest proportion. Therefore, this field has become the focus of energy managers. The 13th Five-Year Plan for Energy Development proposed to further boost energy revolution, energy conservation and emission reduction, in addition to accelerating the supply-side structural reform on energy. The standards for energy efficiency for buildings were raised to lower the energy consumption in public buildings, and with this aim, energy performance contracting (EPC) has been carried out in public buildings, such as administrative office buildings, hospitals and schools. ESCOs can take advantage of national policy support to make a big splash, relying on national energy conservation and emission reduction policies to create new markets for EPC service industries.

2 Raised questions

2.1 Relevant theories

EPC, also known as contract energy management, is a concept that originated in the 1970s as a new type of market-based energy efficiency mechanism, and its related terminology is very diverse.

EPC has been applied for >40 years. It refers to a contract between an ESCO and the energy-using unit, which aims to save energy for the energy-using unit. The energy-using unit shall pay the service fee to the ESCO. EPC has achieved the goal of energy conservation for energy-using units.

In general, it is represented by the following definition of the British Energy Industry Exchange: "The contractual management of certain aspects of a customer’s energy use, transferring some risk from the customer to the contractor (usually based on the provision of a recognized level of service), with the key feature being the transfer of technical risk associated with equipment performance from the customer to the contractor".

A more precise definition is that of the World Energy Efficiency Organization: "energy savings to the customer at a cost that depends on the amount of energy saved". The term "energy savings" refers to improvements in energy efficiency. At the core of this concept is the Energy Efficiency Compact, which includes the following: (1) a full range of services including feasibility analysis, design, engineering, structural management, installation, operation, maintenance and financing; (2) compensation based on measured results; and (3) transfer of major technical, financial and operational risks to the contractor. China defines World Energy Efficiency Association as "an energy efficiency investment approach that uses reduced energy costs to cover the full cost of an energy efficiency project".

2.1.1 Risk assessment

It can also be called safety assessment. Based on risk identification and risk estimation, the probability and magnitude of risks in the energy system can be obtained. Under the EPC model, the research team comprehensively analyses and further judges the probability of risks and the extent of losses. The risk factors affecting EPC projects are systematically generalised and summarised from many aspects such as raising problems, analysing problems and risk characterisation. There is a relatively wide range of risk factors in the implementation of the whole project, including the risks arising from the implementation of conventional engineering projects, as well as comprehensive risks such as the measurement risks of savings and the assessment of energy-saving potential. So far, most research works on the investment risks of energy-saving projects have just focussed on assessment
and evaluation, while the theory and practice of risk management for energy-saving services in EPC projects are under-researched. Therefore, based on analysis of the factors influencing the investment risk of energy-saving projects, this research tries to form a set of risk management systems with widespread application by using a quantifiable risk management model, which provides a theoretical basis for ESCOs to make energy-saving investment decisions in public building projects.

2.2 Current research status

The EPC engineering model is an internationally highly recognised and adopted model. As early as the 80s of the past century, i.e., the 1980s, China selected some pilot projects to try the EPC engineering contracting model. After >30 years of development, this model has been gradually recognised and applied to projects of a certain scale, long duration and considerable technical complexity. In housing construction, municipalities and large infrastructure projects, it should take no more than 6 years to promote the application of the EPC engineering contracting model. This is a new way of contracting and project organisation in the construction industry.

Scholars have carried out rich exploration on the application of EPC in the risk assessment of public buildings. The United States, Germany and France have corresponding policies in the energy conservation of buildings. In 1970, the U.S. Department of Energy began to implement a series of energy-saving incentives for buildings and equipment. Germany has also been focussing on the energy conservation of buildings for 40 years. France has achieved significant results in the energy-saving renovation of buildings. In the above-mentioned Western countries, the main measures taken by ESCOs are as follows: promoting information diffusion [16], providing financial institutions with rich channels to develop capital source services; guiding the formulation of model contract for regulatory measurement, inspection standards and the International Performance Measurement and Verification Protocol (IPMVP); taking the lead in building government office buildings; and establishing a third-party financing network to promote mutual exchange, information diffusion, investment promotion and market penetration. To establish an equipment-leasing structure, most research references have pointed out that energy-saving services in buildings should be developed through the EPC model, and mechanism innovation should be adopted to promote energy-saving renovation and achieve energy conservation and emission reduction.

The traditional model keeps design and construction separate. Therefore, in the current market, general contracting cannot be fully integrated either. The EPC on behalf of design companies is beneficial to the construction project as a whole, which is especially true for design. Wang [10] summarised the contribution of the EPC model to the government’s energy conservation, especially emphasising that the government can strengthen analysis in fiscal and financial affairs, taxation and other aspects, in addition to providing policy support in these aspects. Huang [4] put forward the dilemma that China’s energy-saving services in buildings face when implementing the EPC model.

Wang [13] analysed the organisation and functioning of ESCOs that provide technical support for energy-saving services in buildings and government-entrusted supervision.

The overall literature also shows the achievements made in the research on energy-saving services in buildings under the EPC model. However, research on the development of public buildings under the EPC model is still at the initial stage, and there is still lack of sufficient theoretical research on the main issues, such as policy application, financing models, contract management and quality management. Relevant government departments, representatives of energy-saving enterprises and scholars have introduced the advanced experience and development of energy-saving services in the United States, Europe, Japan and other countries to China through international conferences and papers. Especially, research on the design of the EPC mechanism and the methods of development of energy-saving services for buildings are still underdeveloped.

The author attempts to expand the existing research results and analyse the hidden risks in the implementation of China’s EPC projects in public buildings. Combining the characteristics of public building projects and the EPC model, the author conducts an objective analysis and system integration of the risk factors affecting
EPC projects and thereafter builds a risk control system for EPC public building projects. The main difficulty in cost control is in the construction phase, and the main means of control is contractual measures.

The main reason why the "construction"-oriented EPC management model is still in an advantageous position today is that the construction company has a strong advantage in two of the three phases of the EPC project, except for the design capability, which accounts for an absolute proportion of the total cost of the construction project (Table 1). The EPC model is a mature cost-control model for the leading construction companies. This can be achieved by using mainly contractual measures in the accounting phase.

| Serial number | Contract content     | Advantages                                      |
|---------------|---------------------|------------------------------------------------|
| 1             | Construction costs  | Lower investment                               |
| 2             | Construction cycle  | Significantly reduced construction time         |
| 3             | Project quality     | Design authenticity can be achieved            |
| 4             | Resource allocation | Optimised for increased space savings          |
| 5             | Integrity risk      | Helps to promote integrity                     |

3 Proposition and description of risk management hypotheses for the application of EPC in public building projects

3.1 Definition of issues

Risk analysis is one of the important tasks in the implementation of EPC projects and also the key part to achieve the benefit sharing for ESCOs. The EPC mechanism provides an objective overview of the uncertainty of the whole project and it can capture the risks of the project during the negotiation, implementation and operational phases, including the risks during the project implementation and the risks posed by EPC [14].

3.2 Factors of risk allocation for EPC projects

According to the characteristics and operations of the projects, the main factors affecting the risk allocation of EPC projects are as follows:

3.2.1 Characteristics of the projects

When the public building projects start, ESCOs will participate in the energy-saving design and analysis of the projects. Many participants are involved in the whole process, including energy-using units, energy-saving equipment manufacturers, ESCOs, third-party organisations, and so on. All these characteristics make it more difficult to control the risks of energy-saving projects in practice.

3.2.2 The main risk-bearing factors for both parties of the energy-saving service contract

The general attitude towards risks refers to the attitude taken by people towards risks, which can be positive, negative or neutral. Therefore, risk attitudes are generally divided into risk preference, risk aversion and risk neutrality, respectively. Risk attitudes exert a great influence on all factors of risk management.

3.2.3 The main risk-bearing factors for both parties of the energy-saving service contract

Every energy-saving project has risks, and it is impossible to completely avoid or eliminate risks. Only through rational analysis and judgement, finding out the causes for risk occurrence, taking scientific countermeasures and successfully avoiding the occurrence of unfavourable factors can we reduce the probability of risk occurrence. The ability to manage risks depends on the relevant experience, technology, talents and resources
of all parties involved in managing risks.

3.2.4 Risk control completed through multiparty cooperation

There are many participants in EPC projects, and any risks do not exist independently in a certain operation process. All risks affect each part of the project in a mutual way [17].

3.3 Hypotheses

$H_1$: Control the risk of reliability and reduce EPC risks.

$H_2$: Control the risk of contract operation and reduce EPC risks.

$H_3$: Control the financial risks and reduce EPC risks.

$H_4$: Control the risk of the market and other external environment and reduce EPC risks.

$H_5$: Control the risk of energy-saving technology and reduce EPC risks.

$H_6$: Control the risk of income acquisition and reduce EPC risks.

The ultimate goal of EPC’s application of risk management in public building projects is to achieve the best quality and most reasonable risk allocation scheme. Therefore, the author puts forward the above hypotheses based on the risk allocation of EPC projects: the risks undertaken by public building projects need to be capped. The comprehensive risks borne by the project are matched with the rewards ultimately obtained.

4 Empirical study on the relationship between EPC project risk and EPC risk

Research projects need to be investigated. This research mainly adopted the method of random sampling to conduct questionnaire analysis. The total number of questionnaires issued was 2200. The closed items in the design questionnaire were 50, and 1980 valid questionnaires were collected. The overall return rate of the questionnaire was 90%. According to the researcher’s experience, the ratio between the number of people surveyed and number of items on the scale was moderate, and the samples can meet the needs of subsequent research. In order to meet the requirements of representativeness of survey data, the samples in this survey were all buildings with area of $>10,000\ m^2$ used for office, tourism, commerce, science, education, culture, health and transportation. The samples were typical for analysis, which objectively included various types of public buildings as much as possible so as to make the research comprehensive. This paper analyses the self-compiled scale of the relationship between public building project risk and EPC risk. The EPC risk scale includes the six dimensions of credit, contract operation, finance, market external environment, energy-saving technology and income-earning risk. Each dimension has four corresponding items. The public building project risk scale includes the following four items: project cost risk, management risk, social environment risk and progress development risk.

4.1 Reliability test of the two scales

This study adapted the internal reliability test method, and Cronbach’s alpha coefficient was used to test the scale items. A low alpha coefficient indicates low reliability of the tested factors, and vice versa. SPSS18.0 software was applied to analyse the data, and the final results showed that the Cronbach’s coefficients of controlling the risks of reliability, contract operation, finance, market and other external environmental, energy-saving technology and income acquisition were all $>0.76$, with the overall Cronbach’s coefficient of the scale being $>0.957$. As for the risk scale of the public building projects, the overall $\alpha$ value of the items tested by Cronbach’s $\alpha$ coefficient was 0.892, which was $>0.7$. The analysis showed that the two scales had high reliability and stability.

Risks exist for both energy-saving customers and energy-saving services. From the perspective of contract energy management companies, this paper classified the risks of the EPC project into the following aspects.
4.1.1 Risk of reliability

Energy-saving customers and ESCOs establish reliable cooperation by signing energy management contracts. The risk of reliability for both parties to the contract energy management project affects the credit rating of the company itself. Besides, the willingness and ability of both parties to perform their obligations directly cause the success or failure of the contract energy management project, and even the long-term development of the company; the contract - when ignored by either of the parties - may directly cause the breakdown of the cooperation relationship between the two parties.

4.1.2 Risk of contract operation

The contract risks of EPC projects mainly include the constraints of the contract on the stability of EPC projects, the standardisation of the contract text, the rights and obligations required in the contract and the rationalisation of risk sharing [18]. As part of the operation of public buildings, EPC projects have operational risks that are interrelated with the construction and development risks of public buildings. Various unfavourable factors, such as the development and site selection, design and construction of public buildings, definitely bring operational risks to EPC projects [1]. For example, changes in the energy-saving design and delays in the construction period resulting from changes in the public building design can lead to delays in contract energy management projects and changes in various contract relationships in public buildings, thus bringing about communication barriers between the ESCOs and relevant agencies. If the ESCO lacks the operation and management capability, it will have a negative impact on the overall operation of the EPC project.

4.1.3 Financial risks

Financial risks mainly refer to the risks related to finance, such as inflation, increases in interest rate and risks of financial institutions.

4.1.4 Risk of the market and other external environment

The market risk of contract energy management project mainly refers to the uncertainty of future market price, market potential and sustainability, all of which influence the ESCO's agreed-upon goals. The external environment includes macro-politics, economy and natural environment, changes in which can bring risks. For example, national political stability, the domestic and foreign economic environment, the orientation of national policies, natural disasters and so on can impose certain risks on EPC projects.

4.1.5 Risk of energy-saving technology

Currently, the world's construction industry has been focussing on buildings’ energy efficiency, which researchers and the government have attached great importance to. Therefore, they can deal with the matter together. This important technological field is also an effective way to solve the global energy crisis. At present, the application of energy-saving technology in EPC projects can further promote the success of projects.

Technologists can analyse the sources of the risks that mainly evolve from the feasibility and advancement of energy-saving technology. The specific analysis is conducted as follows.

4.1.6 Risks in technological feasibility

Any error in energy-savings diagnosis or energy consumption evaluation of EPC public building projects during the preliminary evaluation can directly affect the feasibility of the scheme [5]. Objective and accurate analysis and judgement of the technological feasibility can reduce the probability of failure, i.e., the risks in technological feasibility.

4.1.7 Risks in technological advancement

Energy-saving technologies for public building projects have a life cycle. When an energy-saving technology gets into a recession, new and more advanced energy-saving technologies will emerge. The original energy-saving technologies have to face the risk of being replaced by other new and more advanced energy-saving technologies.
4.1.8 Risk of income acquisition

The ESCO plans and distributes the profits that the company can obtain by calculating the amount of energy savings and other energy-saving effects of public building projects, although the company’s energy-saving calculation cannot accurately predict the change in conditions and degrees of various factors. If the factors affecting energy savings develop in a direction unfavourable to the ESCO, it will affect the company’s income, thus further affecting its profit distribution plan and generating risks in obtaining interests. This kind of risk has a profound impact on the subsequent operation of the ESCO. Calculation specifically refers to the adverse impact that income distribution may bring to the subsequent operation and management. According to the analysis, the income of the contract energy management company depends on the predicted amount of energy savings calculated in the early stages and the energy-saving performance assessed in the later stages.

4.2 Analysis of the influencing factors of contract energy management risk measures based on reducing project risk

There is a highly positive correlation between the project risk and the contract energy management risk, and the above influencing factors are analysed according to the ESCO’s requirements on the contract energy management risk to be achieved [7]. By using the analytic hierarchy process (AHP) to obtain the distribution proportion of specific indicators, it is proposed to establish the target satisfaction model of impact factors so as to find the impact degree of contract energy management risks [12].

It was assumed that there were $n$ influencing factors including $m$ problems. The relative importance of the influencing factor was $w_i (i = 1, L, n), \sum_{i=1}^{n} w_i = 1$, $w_i$ was used to evaluate these influencing factors by establishing a hierarchy model and using AHP. Due to the interaction between various factors, it was assumed that the degree of correlation between various problems was $c_j (j = 1, L, m)$. Therefore, the SPSS software could calculate $w_i$ and $c_j$. Furthermore, the satisfaction degree of the solutions to each problem can be obtained by the Delphi method (Huang and Du, 2011), which was recorded as $b_j (j = 1, L, m)$. Finally, the improvement degree of influencing factors was as follows:

$$\alpha_i = w_i \sum_{j=1}^{m} a_{ij} b_j / c_j \tag{1}$$

Table 2 was formed by using the data for houses of good quality by applying SPSS software. The improvement degree $\alpha_i$ of each influencing factor was calculated by using the influencing factor model and the results are shown in Table 3.

The proportion of each kind of risk is different in the process of contract energy management project. On analysis of the data model [8], significant positive effects were observed on public building project risks by controlling the risks of reliability contract operation, finance, market and other external environmental, energy-saving technology and income acquisition, which in turn verifies the assumptions $a_1$, $a_2$, $a_3$, $a_4$, $a_5$ and $a_6$. The author believes that in the operation of EPC in public building projects, the greatest risk that the ESCOs have faced is the risk of income acquisition. In the early development stage of EPC in the public building projects, the risk of the energy-saving system is relatively small. Accurate energy-saving calculation and scientific selection of energy-saving performance evaluation methods play an important role in reducing the risk of earning profits for the ESCOs.

5 Measures of risk control in the contract energy management project

Energy-saving technology is the key to the prevention and control of energy-saving risks in public building projects; the risks directly affect the evaluation of energy-saving performance, thus affecting the success of energy savings in public building projects. The contract risk is the key factor in the organisation and operation of energy savings in public building projects. The contract risk refers to the possibility that contract interests
Table 2 EPC relationship between project risk and contract energy management risk

| Project risk                                      | Risk in social environment | Risk in schedule development | Risk in project cost | Risk in management |
|--------------------------------------------------|-----------------------------|-------------------------------|----------------------|--------------------|
| Risk of the market and other external environment| 2                           | 0                             | 3                    | 3                  | 0.0648             |
| Financial Risk                                   | 4                           | 0                             | 2                    | 3                  | 0.1789             |
| Risk of energy-saving technology                  | 5                           | 5                             | 3                    | 4                  | 0.2397             |
| Risk of income acquisition                        | 5                           | 5                             | 5                    | 5                  | 0.3133             |
| Risk of contract operation                        | 4                           | 5                             | 5                    | 5                  | 0.1413             |
| Risk of reliability risk                          | 5                           | 4                             | 2                    | 3                  | 0.0663             |
|                                                  | 0.1018                      | 0.2235                        | 0.4148               | 0.2655             |

Table 3 Improvement degree of the influencing factors

| Influencing factors                                      | $\alpha_j$ |
|---------------------------------------------------------|------------|
| Risk of the market and other external environment       | 12.88      |
| Financial risk                                          | 43.57      |
| Risk of energy-saving technology                         | 95.09      |
| Risk of income acquisition                               | 140.08     |
| Risk of contract operation                               | 58.87      |
| Risk of reliability risk                                 | 25.34      |

may suffer losses due to the breakdown of contract relations [12].

5.1 Establishment of an appropriate evaluation method for energy-saving potential

Energy saving is the application of appropriate steps to save and try to not waste energy as much as possible; so, how is one to evaluate the energy-saving potential? Energy-saving potential refers to the part that uses less energy or saves energy. As for the companies, they should not only design public building projects with the same quantity and quality as before but, at the same time, reduce energy consumption as much as possible. This paper analysed the information index system of economy, energy management and environment and then applied the scientific assessment methods of the energy efficiency potential to carry out a detailed pre-analysis of energy-saving projects, so as to determine the energy-saving performance index of the ESCOs and form an energy-saving transformation scheme.

5.2 Selection of energy-saving schemes

The development of contract energy management in our country is still in the primary stages. It is very important to evaluate the energy-saving plan in the early stages of the construction and development of public building projects. Therefore, our first choice of an appropriate energy-saving plan should be technically reliable and economically reasonable. As for reducing the cost barriers of public buildings contract energy management,
it is necessary to carry out optimal design [2]. Through investigation, it is found that the level of formulating energy-saving schemes for public building projects in China is relatively low in both theory and practice.

5.3 Establishment of an evaluation index system for EPC project risks

At present, most ESCOs in China have neither been established for a long time nor participated in many projects. The overall management level of the set companies is backward, and the data collection process of the risk evaluation index system is complicated [15]. The existing risk assessment system for EPC in Chinese public building projects is still at the primary stage. It is necessary to establish a risk evaluation index system for EPC projects, which can effectively identify and control the risks of EPC projects and contribute to the success of EPC projects and green buildings.

5.4 Strengthening the service management capability of the ESCOs

The process of risk analysis and evaluation is the crucial link in the risk management process of public building projects. In the operation process of the projects, high investment, long construction period and susceptibility to external factors can bring risks to the projects, which requires ESCOs with outstanding comprehensive strength and strong management capability [6]. In this case, the ESCOs need to gain the trust of customers in the project and enhance their own management capability by establishing enterprise reputation.

Elements of a contract energy management programme include energy use diagnosis, energy consumption benchmarking, energy efficiency measures, quantified energy savings targets, ways to share energy savings benefits, and measurement and verification programmes. Such elements also need to be defined in writing by contract with the owner. The energy consumption benchmark is determined based on the energy consumption status of the energy-using unit or energy-using equipment or link within a certain time period of the implementation of the energy management contract. Energy consumption benchmark determination, measurement and verification can be entrusted to a third-party organisation approved by both parties to the contract for supervision and audit.

5.5 Controlling the risks of EPC projects through restraining both parties

The energy-saving operation of public building projects should establish mutually beneficial and mutually trusted cooperation through signing management contracts between EPCs and energy-using agencies. Besides, the contracts should specify the rights, obligations and risk sharing of both parties, including with suppliers of energy-saving equipment, guarantee companies, commercial banks and so on. Furthermore, the ESCOs should understand and analyse the operating conditions of public building projects and carry out effective management. All these measures can be regarded as the main restraint methods for both parties to control and avoid risks. According to the current situation of contract energy management, it is necessary to continuously improve the formulation of various specific risk articles in the contract.

The interest of the client is to get excellent energy-saving equipment and long-term energy savings and environmental benefits with no or less investment, while the ESCO wants to earn profit from the success of the project. Many cases have proven that sincere cooperation between both parties is most important, and that the ESCO’s quality service and the client’s close cooperation during the whole project are the guarantee of project success.

5.6 With the aid of third-party evaluation, institutions to avoid energy-saving measurement errors

The elements of the contract energy management project include energy use condition diagnosis, energy consumption benchmarking and verification programme, and so on, which can be entrusted to a third-party organisation approved by both parties to the contract for supervision and audit.

The success of the EPC project depends on the final completion of the energy-saving target, which requires measurement and evaluation of the energy-saving effect of the contract energy management project during the operation of the EPC project. However, this work should be carried out by a third-party evaluation organisation
in order to achieve a fair, objective and impartial result, whose evaluation of the energy-saving effect will be more professional. Compared with the ESCOs and the energy-saving customers, the third-party evaluation organisation has more obvious advantages in carrying out measurement and evaluation, thus effectively avoiding risks caused by measurement errors of the energy-saving effect.

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