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Overview of Energy Performance Contracting

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Abstract

Under the support of China's "dual-carbon" goal, the energy-saving service industry stands on the wind in the general environment, and under the strong support of China's policies, the management problems in the energy-saving service industry have also become the focus of academic research. At present, there are a lot of theoretical researches on energy performance contracting, mainly from three perspectives, one is to discuss the risk analysis of energy-saving service projects for energy-using units, the choice of energy performance contracting model and the selection of energy-saving service companies (ESCOs); the second is the distribution of energy performance contracting process of the various stakeholders, which includes the optimal contract decision-making of energy-saving services for energy-saving projects; the third is the study of financing in energy efficiency services, the impact on the supply chain, and the impact on other aspects such as social welfare. With the continuous development of the field, scholars are studying more in-depth and detailed issues.

Keywords

Energy Performance Contracting; Energy Saving Services; Carbon Trading.

1. Introduction

Energy performance contracting refers to a business operation mode in which a specialized energy-saving service company signs an energy-saving service contract with an energy-using unit to provide agreed services for its energy-saving project, and the energy-using unit pays the energy-saving company a service fee for the energy-saving benefits generated by the energy-saving project. Energy performance contracting has been introduced into China since December 1997, when the loan agreement and project agreement of the China Energy Conservation Promotion Project came into force. on April 2, 2010, the General Office of the State Council forwarded the notice of the National Development and Reform Commission and other departments on accelerating the implementation of energy performance contracting and promoting the development of energy-saving service industry, which cleared the obstacles of capital, taxation, accounting and finance in the promotion of energy performance contracting. In 2010, the industry began to develop rapidly. During the "Twelfth Five-Year Plan" period, the state further implemented financial, tax and financial support policies to guide specialized energy-saving service companies to adopt energy performance contracting to implement energy-saving reforms for energy-using units, and energy-saving services flourished, playing a greater role in China's energy conservation and emission reduction cause.

2. Contractual Energy Management Model

The basic operation mode of energy performance contracting is mainly divided into the following four types: (1) Energy-saving benefit-sharing type: under this mode, part or all of the investment in the energy-saving project is borne by the energy-saving service company. During the contract period, the ownership of the project belongs to the energy-saving service company,

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and both parties share the energy-saving benefits proportionally; at the end of the contract, the ownership of the energy-saving project is transferred to the energy-using unit without compensation, and the energy-saving benefits generated thereafter are fully attributed to the energy-using unit. (2) Energy-saving guarantee: under this model, the energy-saving service company commits to guaranteeing the energy-saving benefits on the premise of the energy-saving service company's commitment to the energy-saving benefits, and the energy-using unit pays for a certain number of years of energy-saving benefits as the energy-saving project's. The energy-using unit pays a certain number of years of energy-saving benefits in advance as the full investment in the energy-saving project and the service fee of the energy-saving service company, and commissions the energy-saving service company to implement the energy-saving project. If the promised energy savings are not achieved, the energy-saving service company will compensate or restore the original status. Both the ownership of the project and the benefits generated belong to the energy-using unit. (3) Energy cost hosting: Under this model, the energy-using unit entrusts the agreed energy costs, equipment or system, to the energy-saving service company for management, which is responsible for the equipment or system renovation and management, and pays for the actual energy costs consumed. The saved energy costs go to the energy-saving service company. The ownership formed by the energy-saving service company's capital contribution belongs to the energy-saving service company during the contract period, and is transferred to the energy-using unit at no cost after the end of the contract. (4) Energy-saving equipment leasing: under this model, the energy-saving service company leases the energy-saving equipment to the energy-using unit, which pays for the rent with the energy-saving benefits generated by the equipment, and at the expiration of the contract period, the energy-saving service company can either transfer the equipment to the energy-using unit, or take it back.

3. Contractual Energy Management Parties and Research Results at Home and Abroad

The relevant parties involved in energy performance contracting mainly include energy users related to energy performance contracting projects, energy-saving equipment manufacturing companies, third-party organizations (e.g., banks, government, etc.), and energy-saving service companies (referred to as ESCOs).

Since the country set the "dual-carbon" goal, the state has paid more attention to this part of energy saving and emission reduction. Research at home and abroad has taken different directions, and energy conservation service programs (EPCs) have been shown to improve building energy efficiency and greatly boost the building retrofit market. (Zhou et al., 2020) However, under changing economic and market conditions, climate change, and unplanned and inappropriate use of buildings, the energy efficiency benefits of EPC may be affected (Lee et al., 2018; Zhang et al., 2018), and therefore, EPC projects are also considered to be high-risk investments (GaebuzovaSchlifter and Madlener, 2016). Therefore, Ma Shaochao and Zhan Wei (2016) conducted a risk evaluation and risk sharing study on contract energy projects based on ESCO perspective, combined with the characteristics of energy performance contracting projects and literature search, established the index system of risk sharing factors, and calculated the influence weights of risk sharing factors by using the network hierarchy analysis method (ANP). Wang Zhenshuang et al. (2020) address the uncertainty of the whole life cycle of low-carbon building energy performance contracting projects, establish the risk evaluation index system of low-carbon building energy performance contracting projects based on the theory of the whole life cycle evaluation of low-carbon buildings, and utilize the Brusselator model to evaluate the uncertainty of the systematic risk of low-carbon building energy performance contracting projects. In the allocation of EPC project risk, mainstream scholars

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focus on allocating energy-saving benefits through the initial contract design and allocating EPC risk at one time. (Shang et al., 2020; Martinello et al., 2020) While Wan et al. (2022) took Chinese commercial buildings as an example, chose the method of qualitative research to describe the whole picture of EPC project risk allocation, established a dynamic risk allocation model of EPC for commercial buildings in China, and adopted the so-called bow-tie model through the modification of the theory of incomplete contracts to establish the EPC risk allocation theoretical model, and established operational and EPC three-stage risk allocation models. Some foreign scholars also study from the aspect of energy performance, Liu et al. (2023) established a game theoretic model describing the strategic interaction between manufacturers' ex ante capacity decisions and energy service companies' energy-saving investment decisions in terms of digitalization and intelligence, through which the effects of stochastic market demand on all stakeholders, supply chain efficiency and total energy consumption were revealed; Dmitriy N. Karamov et al. (2022) investigated the application of energy performance contracting in the electrification of remote rural areas; Margot Pellegrino et al. (2022) assessed the behavior of occupants in a project with ambitious goals based on the energy performance contracting approach.

For energy-using companies, if they want to use energy-saving services, the first thing to consider is the choice of energy-saving methods, Ouyang Jianjun et al. (2018) analyzed the optimal dynamic mass production strategy of manufacturing enterprises under the given energy-saving methods by constructing the dynamic mass production decision-making model of manufacturing enterprises under the three energy-saving methods of self-energy saving, energy-saving benefit sharing, and energy-saving energy guarantee, and then discussed the optimal manufacturing enterprise The results show that: when facing the first two energy-saving methods, when the ratio of energy-saving investment cost coefficient between energy-saving service company and manufacturing enterprise and the expected energy-saving rate of adopting contractual energy management are small, manufacturing enterprises should choose the latter, and vice versa, and when facing the latter two energy-saving methods, when the expected energy-saving rate of adopting contractual energy management is small, there is no difference in the choice of the two by the manufacturing enterprises, and vice versa. the former. Meanwhile, Ouyang Jianjun et al. (2018) also studied the problem of how to choose the optimal energy-saving method when two competing enterprise manufacturing industries face the two methods of self-energy saving and energy-saving benefit sharing by establishing a game model. Yang Tianjian et al. (2018) established a profit maximization model for self-invested energy saving and a Steinberg model for outsourced energy saving under a given subsidy scenario, used Stackelberg dynamic game to determine the optimal energy-saving and benefit-sharing ratios, and compared and analyzed the influencing factors of the choice of energy-saving methods of energy-using companies under different subsidy scenarios. In addition, Lv Xuejiao et al. (2018) also studied the contractual energy management model for green buildings based on contract flexibility.

After choosing the energy saving method, if the enterprise needs to cooperate with the energy saving service company, it will involve the problem of choosing the energy saving service company, i.e., ESCO, and on the question of what indexes are used to choose ESCOs, Okay and Akma (2010) compared and analyzed ESCO indexes in 38 different countries; Okay et al. (2008) and Stuart et al. (2014) found that "guaranteed savings", "credit", and "shared savings" are the most important indicators for energy-using firms to measure ESCOs. are three important indicators for energy-using enterprises to measure the strengths and weaknesses of ESCOs; Yang Feng et al. (2015), in their study on the selection of energy-saving service companies (ESCOs) based on a multi-attribute reverse auction model, point out that energy users can choose ESCOs based on the "amount of energy savings" and the "project lead time", and the "amount of energy savings" and the "project lead time"."Bertoldi et al. (2006), Fang et al. (2012),

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and Suhonen and Okkonen (2013) point out that economy, cost and benefit, and energy-saving equipment installation services are important indicators for energy users to evaluate ESCOs. Vine (2005) also argued that energy-saving equipment and technology, energy-saving program design, EPC contract, and reliability of energy-saving equipment are also the concerns of energy users in selecting ESCOs. And then Zhang et al. (2019) used the multi-objective weighted gray-target decision-making model in gray system theory to study the ESCO selection problem in the presence of multiple objectives.

Martiniello et al. (2020) stated that after the selection of the energy efficiency service company, the energy efficiency service contract relates to the respective interests of both the energy user and the energy efficiency service company, and the unique partnership between the ESCO and the EPC building owner requires both parties to reach a bilateral goal in terms of energy efficiency. Yan Qu et al. (2012) applied principal-agent theory towards the process of outsourcing energy-saving services in existing buildings to conduct a study on energy-saving guaranteed contracts. An interest game model between owners of existing buildings and energy efficiency service companies is established and contract parameters that maximize the owner's expected profit are determined. Peng Hongguang et al. (2014) used a linear function of energy cost savings as a payment from an energy-using unit to an energy-saving service company and established a Steinberg game model to study the design of energy-saving service outsourcing contracts, and the study found that the optimal contract is a combination of both benefit-guaranteed and benefit-sharing forms. While Xu Xiaoyan et al. (2015), under the premise of selecting the energy contract management model as the energy saving guarantee type, take the decision-making problems of initial project investment, contract duration and excess energy saving benefit reward in the energy saving guarantee type EPC contract as the object of research, and set up a decision-making game model between the customer and the energy saving service company to analyze the optimal contract decision of the two.

Energy performance contracting project is not a project that can be completed in a short period of time, it has a main feature that the payback period is long, some contract period is five or six years, some is more than ten years, and the investment is huge, when the contracted project is gradually more and more projects, the return of funds will be very difficult, and it is completely infeasible to rely on the energy saving service enterprises only to bear the funds of the energy saving service project, so it involves the financing aspects, Huang Zhiye et al. (2016) from the small and medium-sized energy-saving service enterprises and the bank's long-term repeated lending and borrowing cooperative relationship, for the energy-saving service enterprises in the loan process of the bilateral moral hazard problem, the introduction of the potential revenue sharing coefficient brought about by the bank's loan insufficiency in order to design the incentive mechanism, the establishment of the small and medium-sized energy-saving service enterprises and the bank's bilateral moral hazard under the long-term relationship contract planning model The impact of the discount factor under the relationship contract between banks and enterprises is analyzed. Financing has a certain risk, Duan Xiaoping (2013) also used hierarchical analysis and fuzzy comprehensive evaluation method to evaluate the financing risk of China's energy performance contracting projects. And Duan Xiaoping and Chen Fenggong (2018) analyze the causes of risk under the premise of using the theory of negotiation position, identify the risk factors of energy performance contracting project financing in stages according to the theory of the whole life cycle; on this basis, they comprehensively use the hierarchical analysis method and fuzzy comprehensive evaluation method to evaluate the risk status of the financing of the whole energy performance contracting project and the degree of risk in each stage. In addition, the choice of financing mode is also important, Wen Yao and Cao Peng (2015) studied the project financing mode based on energy performance contracting. Guo Jingjuan et al. (2020) studied the financing mode of energy performance contracting based on network cosurance, introduced the network cosurance credit mode by combining the

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characteristics of energy performance contracting, argued the advantages of the application of this mode in the field of energy performance contracting in China at the present stage, and analyzed the revenue distribution of energy-saving service companies under the network cosurance credit mode by combining with the modified Shapley value method, and demonstrated that this mode helps to increase the revenue distribution of energy-saving service companies. It is argued that this model can help to improve the income of energy-saving service companies, and also can transform the contribution and risk borne by enterprises in cooperation into income, and is a financing model that can promote energy-saving service enterprises to choose on their own initiative. Yu Fengguang and He Haiyan (2015) also researched the many problems existing in the application of financial leasing in China's energy performance contracting.

The process of energy-saving service projects inevitably involves a certain distribution of benefits, which is important for each party involved in energy-saving projects. Zhang et al. (2019) used the "principal-agent" model to analyze the distribution of excess energy-saving benefits under the energy-saving benefit-sharing in-depth, and made a three-pronged explanation of the distribution of excess energy-saving benefits. three explanations. Liu, Huimin et al. (2020) take the energy cost trusteeship in the energy performance contracting model as an example, and based on the profit-seeking nature of stakeholders, adopt the fuzzy interval Shapley value method to construct the energy saving benefit distribution model of the core stakeholders (building owners, energy saving service companies, and financial institutions), and propose that the government should not encourage energy saving renovation projects only for the sake of accomplishing energy saving targets, and it should optimize the external environment of building energy saving renovation. external environment of building energy efficiency retrofit. Zhang Wenjie and Yuan Hongping (2020) paid more attention to the distribution of energy saving subsidies in energy performance contracting projects, and studied the distribution of energy saving subsidies in the projects by constructing a "principal-agent" model around the energy performance contracting projects for the purpose of optimizing the allocation of resources.

In addition, different scholars have conducted relevant studies on other impact aspects of energy efficiency services. Some scholars have analyzed the impacts on the supply chain from different perspectives. Zhao Daozhi and Shi Gongming (2015) analyzed the relevant decisions of ESCOs and the overall emission reduction effect of the supply chain based on a supply chain consisting of a single supplier and a single manufacturer. Zhou Yanju et al. (2017) considered the study of consumer low-carbon preference, the behavior of a single manufacturer with emission reduction investment behavior and a single retailer under the information asymmetry of the initial carbon emissions of products under the carbon allowance trading mechanism. The optimal misreporting coefficients of manufacturers under different supply chain rights holders are comparatively analyzed, and the impacts of manufacturers' misreporting on the supply chain under different carbon market states and government quota decisionsare further discussed, and finally a penalty mechanism is added to constrain the manufacturers. The optimal misreporting coefficients of manufacturers under different supply chain rights subjects are analyzed comparatively, and the impacts of manufacturers' misreporting on the supply chain under different carbon market states and government quota decisions are further discussed, and finally the penalty mechanism is added to constrain the manufacturers. After that, Fan Wenping et al. (2021) constructed a three-level low-carbon supply chain model with vertical shareholding among enterprises under the emission reduction benefit-sharing contract and emission reduction guarantee contract respectively, and compared and analyzed the impacts of shareholding strategies on the decision-making and profits of supply chain enterprises under different energy-saving and emission reduction contracts. Liao et al. (2021) analyzed the use of the Stackelberg game model to explore the participation of energy-saving

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service companies in supply chain cooperation and emission reduction strategies under the background of carbon trading policy. And Liao et al. (2022) also studied the supply chain cooperative emission reduction decision-making problem of energy saving service companies (ESCOs) providing embedded low-carbon services under the energy cost hosting contract, and the results show that: the supply chain will choose to cooperate with ESCOs in emission reduction under certain conditions, and when the embeddedness reaches a certain value, the common degree of carbon emission reduction value of the two companies will start to converge, and a high embeddedness can realize a better emission reduction effect, and a high embeddedness can achieve better emission reduction effect. can realize a better emission reduction effect, and the embeddedness has a U-shaped change relationship with the expected profit of the supply chain and a positive correlation with the expected profit of the ESCO. Wang Yong and Long Chao (2019) studied the cooperative emission reduction of a three-level supply chain system under decentralized decision-making, coordinated decision-making and cooperative decision-making.

In addition to analytical modeling by considering the problem from the above seven aspects in the energy saving service program, some other scholars even carry out research with actual energy saving service programs. Hui Ning et al. (2017) conducted a study on the application of contractual energy management in oil and gas field development enterprises. Zhang Yudong and Liu Dongxiao (2020) studied the practice review and path optimization of contractual energy management from the perspective of energy management cases in Shandong Province; Zhang Xiaomao (2021) considered contractual energy management as a solution to carbon peaking and carbon neutrality in public institutions in Shanghai in a study based on the example of contractual energy management in public institutions in Shanghai.

Some other scholars have studied some other aspects of contractual energy management, Shang Tiancheng et al. (2008) proposed the use of the Black-Silkos model (B-S model) to evaluate energy management projects. Chen, Weida et al. (2019) explored the impact of energy saving and emission reduction retrofitting and social welfare of remanufacturing companies utilizing contractual energy management (EPC) by comparing it with the original production model under the carbon tax policy. Deng et al. (2015), on the other hand, analyzed the government's regulatory efficacy for building energy efficiency service providers under the game theory perspective. Shen Chaohong et al. (2010) also analyzed the differences between energy efficiency companies in expanding their markets under three different contracts, i.e., spot sales, financial leasing, and contractual energy management. Wu Jiepeng et al. (2018) analyzed the optimal incentive contract under the unobservable situation of investment level and low-carbon energy-saving capacity of low-carbon service providers, while Zhang Hui and Guo Jingjuan (2021), in response to the problem that the current formal contract can not effectively incentivize the joint efforts of the EPC cooperative subjects, analyzed the cooperative relationship between the two parties under two different contractual relationships with the help of the principal-agent theory, and explored the incentive role of the relational contract. The relationship contract is a good incentive for EPC partners to work together. In addition Wang appearing (2016) researches the quality assurance contract in energy performance contracting by defining a series of concepts such as quality, service object satisfaction and effective complaints in energy performance contracting, establishing quality assurance rules and incentive and penalty mechanisms, and expanding energy performance contracting from the pure energy saving quantity dimension to the energy saving quantity and quality dimension. Chen Xiaochun and Tang Jia (2016) studied and discussed the incentive policy of energy performance contracting.

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4. Conclusion

Building energy-saving service industry is an emerging industry, from the above literature review, although there have been a lot of literature research on energy-saving services at home and abroad, but the whole energy-saving service process involves a lot of aspects, such as extended warranty strategy in energy contract management, financing factoring, etc., domestic scholars involved in this aspect of the content of the research is very little, which requires us to constantly explore the process will be This requires us to constantly explore the various problems that will arise in this process. Energy-saving service industry is an immature industry, so many things are constantly moving forward and groping, can be said to be a long way to go.

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