Cooperation Between a Scenic Spot and an Energy Service Company Based on Contract Energy Management

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Abstract. Energy conservation and emission reduction are important for all countries, and the problem of high energy consumption in scenic spots is increasingly prominent. Contract energy management (EPC) can effectively make up for the lack of energy-saving technology and experience for scenic spots. Based on the benefit sharing contract mode of energy conservation, this paper establishes two-stage Stackelberg game models between the scenic spot as energy user (EU) and the energy service company (ESCO), and analyses the allocation of energy conservation subsidies in EPC projects. The study found some conclusions. First, when the energy saving of an EPC project reaches the subsidy standard and the EU gains all energy saving subsidies, the ESCO will not sign an energy saving revenue sharing EPC project contract with the EU. Second, compared with other subsidy allocation scenarios, the optimal energy saving income sharing ratio of the EU is the highest when the energy saving of EPC projects reaches the subsidy standard and all the energy saving subsidies are allocated to the ESCO. Third, when the unit energy saving subsidy is high, in the cases that the energy saving subsidy standard is met and the energy saving subsidy is shared by the ESCO and the EU or the energy saving subsidy is fully allocated to the ESCO, the optimal energy saving is higher than the optimal energy saving when the EPC project does not meet the energy saving subsidy standard. Finally, whether the energy saving subsidy policy can encourage the ESCO depends on the energy saving standard and subsidy amount set by the government. When the subsidy for energy conservation is relatively high, the subsidy policy can effectively encourage the ESCO to save energy.

Key words: contract energy management; subsidies for energy conservation; scenic spot energy saving; revenue sharing

1. Introduction

Nowadays, the contradiction between energy use and environmental protection is becoming more and more serious in the world, and the pressure of resource and environmental problems is increasing. Energy saving is a practical choice and effective measure for a country to ease resource constraints. In recent years, with the improvement of living standards, people's willingness to travel has been enhanced, and tourism has been vigorously developed. As many regions have begun to build special scenic spots, the number of large scenic spots increases rapidly. While tourism is promoting economic growth, the problem of high energy consumption in scenic spots is becoming increasingly prominent. There are many exquisite buildings, service

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facilities, artificial fountains and a variety of lights in scenic spots. These facilities consume a lot of energy such as electricity when they are in operation. Due to the pursuit of time and efficiency, most scenic spots seldom consider the use of energy-saving and environmental protection technology and equipment in the initial construction. Even if some scenic spots consider energy saving, it may not be reasonable in energy saving program formulation and equipment selection because the managers do not have professional knowledge and experience in energy saving transformation technology.

It makes the dilemma of high energy consumption of scenic spots persist. It is not only bad for the profit of scenic spots, but also has a great negative impact on resource conservation and environmental protection. Thus, energy saving is an urgent problem to be solved in the development of scenic spots.

Contract energy management (EPC for short) is a new energy-saving mechanism based on market operation that can help solve the shortcomings of traditional energy-saving management methods, and is widely regarded as important and valuable [1]. Under the EPC mechanism, the energy conservation service company (ESCO) and the energy user (EU) agree on energy conservation goals of energy conservation projects with a contract. In order to achieve the energy conservation goals, the ESCO provides necessary services to energy users, while the EU pays the ESCO energy saving service fee or energy management fee to make up for the investment of the ESCO. Thus, energy saving service companies gain profits[2].

Governments around the world have promulgated many policies, regulations and plans related to energy conservation and environmental protection, among which EPC is an important and widely adopted mechanism. For example, the US government has formulated the "Federal Government Performance Contract" (ESPC) Act. The US Department of Energy also provides specific guidance and assistance to government agencies in developing documents related to contracted energy management. The "Federal Government Building Energy Efficiency Promotion Program" (FBI) implemented by the Canadian government has elaborated the method guide and implementation procedure for government agencies to execute contract energy management projects. According to the 14th Five-Year Comprehensive Work Plan on Energy Conservation and Emission Reduction of China, the government of China will take measures to speed up the energy-saving renovation of existing buildings in public institutions and encourage the use of contract energy management mode.

Enterprise energy saving actions may face multiple risks, including financial risk, energy saving effect risk, technology risk and operation risk. EPC can reduce the energy saving risk of enterprises and make the energy saving projects beneficial to all parties involved[3]. Therefore, EPC is an effective way to help scenic spots out of the predicament of high energy consumption. On the one hand, as an energy user, scenic spots can obtain professional services from energy saving service providers in EPC projects, which can improve the scenic spots’ energy efficiency, energy saving cost. On the other hand, the ESPC provides energy saving services and gain benefits from energy saving projects. In addition, EPC projects also create social benefits of energy conservation and emission reduction.

The promotion of EPC mechanism has attracted wide attention and many scholars have carried out research on it. In the early stage, relevant literature mainly focused on the feasibility analysis and specific implementation of EPC mechanism[4], as well as the empirical research on the hindrance to EPC[5] and the development of ESCO[6][7]. Qu et al.[8] analyzed the factors affecting contract energy management and their impact degrees, and provided suggestions for EPC contract design. Yuan et al.[9] studied the evolution of China's EPC policy system. They found that the guidance and protection of policies and regulations as well as fiscal incentives play a significant role in promoting the development of EPC.

In recent years, some scholars have begun to study the parameter optimization in EPC contracts, and analyzed EPC project mechanism, energy-saving benefit sharing and decision-making of energy-saving project participants with mathematical models. Zhou et al.[10] studied the impact of EPC on two competitive manufacturers with different energy efficiency. The results showed that in an EPC project, the total output of the two manufacturers increased, the output of the ESCO decreased and the output of the company served by the ESCO increased. Shang et al.[11] established a bargaining model for energy efficiency distribution based on Rubinstein negotiation model, and analyzed the equilibrium strategies of both parties. Their solved the problem of profit distribution between the ESCO and energy users. Qin et al. [1] noted that choosing an appropriate EPC business model is an important factor affecting the effective implementation of a project. They proposed a new behavior decision method (TODIM) to solve the problem of EPC business model selection. Liao et al.[12] built Stackelberg game models to explore the supply chain cooperation emission reduction strategy of energy saving service companies under the carbon trading regulation. By comparing the profits and emission reduction effects under different cooperation modes, they obtained the conditions and profit-sharing ratio of energy-saving service companies to participate in emission reduction. Xu and Wu[13] studied the decision of three parameters in energy-saving guaranteed EPC contracts including initial project investment, contract term and excess energy-saving benefit reward. They analyzed the contract decision process and optimal contract decision by establishing the decision game model between the customer and the energy saving service company. Although existing studies have discussed EPC contract formulation and energy saving benefit distribution from multiple perspectives, there is no literature to analyze the proportion of energy saving income sharing and energy saving of energy-saving benefit sharing EPC projects in which scenic spots participate.

To implement the contract energy management mechanism and support the energy conservation service industry, governments around the world have introduced a series of preferential policies. Most countries implement energy-saving subsidy policies for some EPC projects. At present, only energy-saving benefit-sharing energy management contract projects in our country can apply for national financial subsidies, while EPC projects with other modes (such as energy-saving cost credit, energy-saving income guarantee, financial leasing, etc.) are not within the support scope of energy-saving subsidy policy[7].

In addition, energy conservation and benefit sharing contract energy management is the most common one among the four business modes of contract energy management. Therefore, the EPC project studied in this paper is limited to the energy conservation benefit sharing contract energy management project. It is worth noting that after applying for subsidies to relevant departments, whether EPC projects can get energy saving subsidies ultimately depends on whether they have reached the energy saving subsidy standards set by the policy. If the energy saving of an EPC project is lower than the energy saving subsidy standard, the project will not be eligible for energy saving subsidy. When an EPC project meets the energy-saving subsidy standard, the energy-saving subsidy can be allocated between the EU and the ESCO in a variety of ways. If all energy conservation subsidies are allocated to ESCO (EU), it may cause EU

(ESCO) to feel negative and not cooperate actively. Thus, it will negatively affect the completion effect of EPC projects and the income of each participant. When energy saving subsidies are distributed proportionally between the EU and the ESCO, there is also the question of how the sharing scale should be set. If a scenic spot and an energy saving service provider participate in EPC projects, how can they obtain greater energy saving and obtain greater energy saving benefits?

The energy conservation subsidy policy of contract energy management has a far-reaching impact on the completion effect of EPC projects. When formulating relevant policies, we should fully consider the reality of subsidy objects, the rationality of subsidy distribution mechanism and subsidy method, so as to achieve the ideal policy incentive effect. Some scholars have studied the influence, form and mechanism of government energy saving subsidy policy. Zhou and Huang[14] discussed the selection and design of contract subsidies for energy-saving products under two different objectives: minimizing total energy consumption and minimizing average energy consumption. They mainly analyzed the two forms of subsidy, fixed amount subsidy and discount subsidy.

Zhang et al.[15] built a signal game model between enterprises and the government considering government subsidy policies for energy conservation and emission reduction. They analyzed the selection mechanism and influencing factors of government and enterprise strategies, and provided scientific suggestions for effectively restraining government-enterprise collusion behaviors. Some scholars have studied the impact of the government's energy-saving subsidy policy on the implementation effect of EPC projects. Lu and Shao[2] constructed a two-stage optimal decision model to study the EPC pricing and energy-saving level decision of the ESCO under the government subsidy policy. The allocation of energy conservation subsidies between the ESCO and the EU will affect the participation enthusiasm and benefits of both sides, but few literatures have focused on the impact of different allocation methods of subsidies on EPC projects. Zhang and Yuan[16] studied the allocation of energy conservation subsidies in EPC projects by constructing a "principal-agent" model. They analyzed the factors that affected energy savings under four subsidy configuration scenarios.

The most closely related to our study is literature [16]. It adopts the principal-agent model and only considers the energy saving of the ESCO decision projects. However, EU has a greater dominance in the game with the ESCO, and the EU's decision in EPC contracts will also affect the operation of the entire project. Based on the above discussion, in order to explore how scenic spots should solve the problem of high energy consumption with the help of EPC mechanism under the government's energy-saving subsidy policy, we established Stackelberg game models between scenic spot as the EU and the ESCO. We analyze the sharing ratio of energy-saving income and energy saving decisions of the game participants and the maximum benefits and energy savings of both parties under different subsidy configurations.

The rest of this article is organized as follows. The second section introduces the problem description and model introduction. The third section gives the equilibrium solutions under four kinds of subsidy allocation scenarios. The fourth section compares the decision making and energy saving benefits of the EU and the ESCO under different subsidy allocation scenarios, and gives sensitivity analysis. Finally, the research conclusions and policy implications are summarized.

2. Problem description and assumptions

Based on the energy conservation revenue sharing contract, we discuss the allocation of government energy conservation subsidies in EPC projects under the background of scenic spot energy use. We build a two-stage Stackelberg game model consisting of a scenic spot (EU) and an energy service company (ESCO). The EU first decides the ratio of energy-saving revenue sharing δ, and then the ESCO decides the energy saving e (which directly reflects the level of ESCO's energy saving efforts). Finally, both sides reach an energy-saving revenue sharing agreement.

In energy management (SSM-EPC) projects, the ESCO funds the installation of the energy saving equipment initially and maintains the equipment throughout the contract period. Upon the completion of the project, the EU and the ESCO will share the energy saving income in accordance with the proportion agreed in the contract after both parties confirm the energy saving $e(e > 0)$. Note that the ESCO only participates in the sharing of energy conservation benefits during the sharing period, which has been specified by both parties in the EPC project contract[11]. The sharing ratio of energy-saving benefits obtained by the EU is δ, and the sharing ratio of energy-saving benefits obtained by the ESCO is $1-\delta$, where $0 < \delta \leq 1$. $\delta = 1$ means that EU receives all energy saving benefits during the energy saving benefit sharing period. After the end of the project contract, the ownership of energy-saving equipment will be transferred to EU for free, and all the energy saving income generated in the future will belong to the EU[12].

In China, only energy conservation revenue-sharing projects can apply for contract energy management financial subsidies, while whether EPC projects can get energy conservation subsidies mainly depends on the energy saving of the project. According to the Interim Measures for the Management of Financial Incentive Funds of Contract Energy Management Projects, the annual energy saving of a single project applying for financial subsidy (incentive) shall be more than 100 tons of standard coal (including 100 tons), among which the annual energy saving of industrial projects shall be more than 500 tons of standard coal (including 500 tons)[17]. Therefore, only when the EPC project energy saving to achieve energy saving subsidy standard $\underline{e}$ to get subsidies, otherwise you won't get subsidies. These two conditions are indicated in terms of S (Subsidy) and N (No subsidy), respectively. For EPC projects that meet the subsidy standards, the energy saving subsidy will be issued according to the amount of energy saving subsidy per unit as s.

The proportion of the EU in each unit subsidy is $\varphi(0 \leq \varphi \leq 1)$, then the proportion of the ESCO is $1-\varphi$. The sharing ratio of the EU and the ESCO's energy saving subsidies reflects their bargaining power over the allocation of subsidies, which is determined by the company's qualification and strength, social reputation, energy saving rate guarantee and other factors. When the bargaining power of the two parties is far apart, the extreme situation of allocating energy efficiency subsidies to one side or the other will occur. Therefore, subsidy allocation for EPC projects that meet subsidy standards can be subdivided into the following three scenarios: (1) When $\varphi = 1$, all energy conservation subsidies are allocated to the EU, namely scenario (S, N); (2) When $\varphi = 0$, all energy saving subsidies are allocated to the ESCO, namely scenario (N, S); (3) When $0 < \varphi < 1$, the energy saving subsidy is shared by EU and ESCO in a certain proportion, namely scenario (S, S). scenario (N, N) indicates that EPC projects do not meet the energy saving subsidy standard. Therefore, there are four scenarios in the allocation of energy saving subsidies for EPC projects {(N, N), (S, N), (N, S), (S, S)}.

This article makes the following assumptions：

(1) It is assumed that all decision-makers are completely rational and risk neutral, and they all make decisions to maximize their own profits. The influence of cognitive bias and risk preference of both parties on energy saving income is not considered.

(2) It is assumed that the ESCO undertakes all the investment in energy-saving renovation in the EPC project[16]. We used $\frac{1}{2}he^2$ to describe the cost of energy-saving renovation in ESCO[10]. It includes all kinds of costs that ESCO needs to invest in energy-saving renovation, such as equipment maintenance cost, human resource cost, etc. $h(h > 0)$ is the cost coefficient of energy-saving renovation in ESCO. The larger h is, the smaller the efficiency of energy-saving renovation in ESCO is. e is energy saving of the project (i.e. energy saving level).

(3) According to literature [17], the detailed rules and subsidy amount are delegated to provincial energy conservation authorities. Different regions have different subsidy levels, such as 360 yuan/ton of standard coal in Tianjin and 300 yuan/ton of standard coal in Hubei. It is assumed that EPC projects that meet subsidy standards can receive subsidy s(s>0) per unit of energy saving.

3. Model construction and solution

The energy saving benefits π of the EPC project is determined by the energy saving e and a random variable ε representing exogenous uncertainties. ε follows a normal distribution with a mean of 0 and a variance of σ^2. Energy saving benefits of EPC projects are as follows:

$$\pi = e + \varepsilon \quad (1)$$

Based on the above assumptions, the energy saving benefit of EU is $\pi_{EU} = \delta\pi$, and the energy saving benefit function of ESCO is $\pi_{ESCO} = (1-\delta)\pi - \frac{1}{2}he^2$. Substituting formula (1) into the expressions of π_{EU} and π_{ESCO}, we get:

$$\pi_{EU} = \delta(e + \varepsilon) \quad (2)$$

$$\pi_{ESCO} = (1-\delta)(e + \varepsilon) - \frac{1}{2}he^2 \quad (3)$$

Since both EU and ESCO are perfectly rational and risk-neutral, the expected energy-saving benefits of EU and ESCO can be expressed in formula (4) and (5), respectively.

$$E(\pi_{EU}) = \delta e \quad (4)$$

$$E(\pi_{ESCO}) = (1-\delta)e - \frac{1}{2}he^2 \quad (5)$$

3.1. Scenario NN

When $0 < e < \underline{e}$, the EPC project does not achieve energy saving subsidy standards and is unable to get energy saving subsidy. ESCO first decisions under constraint conditions section energy e, its objective function is $maxE(\pi_{ESCO}) = max\ [(1-\delta)e\ -\frac{1}{2}he^2]$. Then the EU makes decisions to maximize its profit $maxE(\pi_{EU}) = ma\,x(\delta e)$. Thus, Proposition 1 is obtained with backward induction.

Proposition 1: when $0 < e < \underline{e}$, the optimum section of the EPC project for energy is $e_{NN}^{*} = \frac{1}{2h}$, the optimal energy-saving benefit sharing ratio is $\delta_{NN}^{*} = \frac{1}{2}$. The optimal profit of ESCO is $E(\pi_{ESCO}^{NN}) = \frac{1}{8h}$, and the optimal profit of EU is $E(\pi_{EU}^{NN}) = \frac{1}{4h}$.

Proof of Proposition 1: the ESCO's decision problem can be written as

$$\begin{cases} maxE(\pi_{ESCO}) = max\ [(1-\delta)e\ -\frac{1}{2}he^2] \\ 0 < e < \underline{e} \end{cases} \tag{6}$$

Formula (6) can be written as Equations (7).

$$\begin{cases} maxE(\pi_{ESCO}) = max\ [(1-\delta)e\ -\frac{1}{2}he^2] \\ g_1(e) = e > 0 \\ g_2(e) = \underline{e} - e > 0 \end{cases} \tag{7}$$

Introduce the generalized Lagrange multiplier λ_1^* and λ_2^*, the K-T condition of formula (7) can be written as Equations (8).

$$\begin{cases} 1-\delta-he-\lambda_1^*+\lambda_2^* = 0 \\ \lambda_1^* e = 0 \\ \lambda_2^*(\underline{e}-e) = 0 \\ \lambda_1^*, \lambda_2^* \geq 0 \end{cases} \tag{8}$$

The following four cases can be obtained by solving the Equations (8): (1) when $\lambda_1^* = 0$ and $\lambda_2^* = 0$, $e = \frac{(1-\delta)}{h} < \underline{e}$; (2) when $\lambda_1^* = 0$ and $\lambda_2^* \neq 0$, there is no solution; (2) when $\lambda_1^* \neq 0$ and $\lambda_2^* = 0$, there is no solution; (4) When $\lambda_1^* \neq 0$ and $\lambda_2^* \neq 0$, there is no solution. By substitute $e = \frac{(1-\delta)}{h}$ into $E(\pi_{EU}) = \delta e$, we have $E(\pi_{EU}) = \delta\frac{(1-\delta)}{h}$. We obtain $\delta_{NN}^{*} = \frac{1}{2}$ with the first order conditions. Then $e_{NN}^{*} = \frac{1}{2h}$, $E(\pi_{ESCO}^{NN}) = \frac{1}{8h}$ and $E(\pi_{EU}^{NN}) = \frac{1}{4h}$.

3.2. Scenario SN

When $e \geq \underline{e}$ (that is, the EPC project energy saving the subsidization standard) and all energy-saving subsidies are allocated to the EU. Then, the ESCO's expected revenue is $E(\pi_{ESCO}) = (1-\delta)e\ -\frac{1}{2}he^2$, and the EU's expected revenue is $E(\pi_{EU}) = (\delta + s)e$. Both parties intend to maximize their expected revenue. Thus, we have Proposition 2 with backward induction.

Proposition 2: when $e \geq \underline{e}$ and the EU gets all energy subsidies, the ESCO does not cooperate with the EU for energy conservation based on a revenue-sharing energy management contract.

$E(\pi_{ESCO})$ is a quadratic function of one variable with an opening downward about e and the axis of symmetry is $e = \frac{(1-\delta)}{h} < \underline{e}$. Since $e \geq \underline{e}, e$ values on the right side of the axis of symmetry, $E(\pi_{ESCO})$ decreases with the increase of e, therefore, when $e_{SN}^{*} = \underline{e}$, $E(\pi_{ESCO})$ reaches its maximum value. With backward induction, we have the optimal $e_{SN}^{*} = \underline{e}$ and

$\delta_{SN}^{*}=1$. Then, the optimal profit of the EU and ESCO is $E(\pi_{EU}^{SN})=(1+s)\underline{e}$ and $E(\pi_{ESCO}^{SN})=-\frac{1}{2}h\underline{e}^2$, respectively. $E(\pi_{ESCO}^{SN})=-\frac{1}{2}h\underline{e}^2<0$ implies that the ESCO will not cooperate with the EU in energy saving. This conclusion is different from literature [16]. This is because literature [16] did not consider the contract decision of EU and took the energy saving revenue sharing ratio as an exogenous parameter.

3.3. Scenario NS

When $e\geq\underline{e}$ (that is, the EPC project subsidization standard section energy) and all energy saving subsidies are allocated to the ESCO, the ESCO's expected profit is $E(\pi_{ESCO})=(1-\delta+s)e-\frac{1}{2}he^2$, and the EU's expected profit is $E(\pi_{EU})=\delta e$. Then, we have Proposition 3 with backward induction.

Proposition 3: When $e\geq\underline{e}$ and the ESCO gets all energy subsidies, the game equilibrium is as follows. (1) $e_{NS}^{*}=\frac{1+s}{2h}$ and $\delta_{NS}^{*}=\frac{1+s}{2}$ if $\underline{e}<\frac{1-\delta+s}{h}$. The optimal profit of the ESCO and the EU is $E(\pi_{ESCO}^{NS})=\frac{(1+s)^2}{8h}$ and $E(\pi_{EU}^{NS})=\frac{(1+s)^2}{4h}$, respectively; (2) $e_{NS}^{*}=\underline{e}$ and $\delta_{NS}^{*}=1$ if $\underline{e}\geq\frac{1-\delta+s}{h}$. The profit of the ESCO and the EU is $E(\pi_{ESCO}^{NS})=s\underline{e}-\frac{1}{2}h\underline{e}^2$ and $E(\pi_{EU}^{NS})=\underline{e}$, respectively.

3.4. Scenario SS

When $e\geq\underline{e}$ (that is, the EPC project subsidization standard section energy) and the energy saving subsidies are shared proportionally between ESCO and the EU, the ESCO's expected profit is $E(\pi_{ESCO})=[1-\delta+(1-\varphi)s]e-\frac{1}{2}he^2$, and the EU's expected profit is $E(\pi_{EU})=(\delta+\varphi s)e$. Then, we have Proposition 4 with backward induction.

Proposition 4: When $e\geq\underline{e}$ and the energy saving subsidies are shared proportionally between ESCO and the EU, the game equilibrium is as follows. (1) $e_{SS}^{*}=\frac{1+s}{2h}$ and $\delta_{NS}^{*}=\frac{1+s-2\varphi s}{2}$ if $\underline{e}<\frac{1-\delta+(1-\varphi)s}{h}$. The optimal profit of the ESCO and the EU is $E(\pi_{ESCO}^{SS})=\frac{(1+s)^2}{8h}$ and $E(\pi_{EU}^{SS})=\frac{(1+s)^2}{4h}$, respectively; (2) $e_{SS}^{*}=\underline{e}$ and $\delta_{NS}^{*}=1$ if $\underline{e}\geq\frac{1-\delta+(1-\varphi)s}{h}$. The optimal profit of the ESCO and the EU is $E(\pi_{ESCO}^{SS})=[(1-\varphi)s]\underline{e}-\frac{1}{2}h\underline{e}^2$ and $E(\pi_{EU}^{SS})=(1+\varphi s)\underline{e}$, respectively.

4. Analysis and discussion

Next, we compare and analyze the optimal decision, energy saving and profit of EPC project participants in different situations, as well as the influence of some parameters on the optimal decision, energy saving and profit of project participants.

Proposition 5: (1) $\delta_{NS}^{*}>\delta_{NN}^{*},\delta_{NS}^{*}\geq\delta_{SS}^{*}$; $\delta_{NS}^{*}=\delta_{SS}^{*}$ if $\underline{e}\geq\frac{1-\delta+s}{h}$; (2) $\delta_{SS}^{*}>\delta_{NN}^{*}$ if $0<\varphi<\frac{1}{2}$; $\delta_{SS}^{*}\leq\delta_{NN}^{*}$ if $\frac{1}{2}\leq\varphi<1$and $\underline{e}<\frac{1-\delta+(1-\varphi)s}{h}$, $\delta_{SS}^{*}=\delta_{NN}^{*}=1/2$ if $\varphi=\frac{1}{2}$; $\delta_{SS}^{*}>\delta_{NN}^{*}$ if $\frac{1}{2}\leq\varphi<1$ and $\underline{e}\geq\frac{1-\delta+(1-\varphi)s}{h}$.

Proposition 5 (1) shows that, compared with other subsidy allocation scenarios, the optimal energy saving income sharing ratio of the EU is the highest when the energy saving of EPC projects reaches the subsidy standard and all the energy saving subsidies are allocated to the ESCO (i.e. NS scenario). The EU's energy saving income consists of energy saving income from project operation and energy saving subsidies issued by the government. Compared with the scenario SS in which the EU receives some subsidies, when all energy saving subsidies are allocated to the ESCO, the EU will try its best to increase the sharing ratio of energy saving income to maximize its energy saving income. Compared with scenario NN in which the energy saving does not reach the energy saving subsidy standard, under (N, S) subsidy configuration, the EU will try to increase its income by increasing its share of energy saving income due to the increase of project energy saving or the impact of energy saving subsidy policy. When energy saving subsidy standard $\underline{e}$ is high and the energy-saving subsidies is proportional shared between the ESCO and the EU, the optimal energy saving income sharing ratio is the same as that in scenario NS.

Proposition 5 (2) shows that, when the EU has less bargaining power for the allocation of energy conservation subsidies than the ESCO, the EU will require a higher proportion of energy conservation income sharing under SS scenario than that under scenario NN. It implies that when that EU finds that it is in a disadvantageous position in subsidy allocation and the project energy saving is high, it will take measures to gain more income in EPC projects. When the allocation ratio of energy saving subsidies of the EU is greater than or equal to that of the ESCO, whether the optimal ratio of energy saving income sharing of the EU under scenario SS is greater or lower than that under scenario NN is mainly affected by the energy saving subsidy standard. $\underline{e} < \frac{1-\delta+(1-\varphi)s}{h}$ implies that the EPC project can obtain energy subsidies with low energy saving. Since the EU can also obtain certain energy saving subsidies in scenario SS, its sharing ratio of energy saving income will be lower than that in NN scenario.

Corollary 1： (1) $\frac{\partial \delta_{NS}^*}{\partial s} > 0$ if $\underline{e} < \frac{1-\delta+s}{h}$,otherwise, δ_{NS}^*=1；(2)when $\underline{e} < \frac{1-\delta+(1-\varphi)s}{h}$, $\frac{\partial \delta_{SS}^*}{\partial \varphi} < 0$, $\frac{\partial \delta_{SS}^*}{\partial s} \geq 0$ if $0 < \varphi \leq \frac{1}{2}$, otherwise, $\frac{\partial \delta_{SS}^*}{\partial s} < 0$； $\delta_{SS}^* = 1$ when $\underline{e} \geq \frac{1-\delta+(1-\varphi)s}{h}$.

According to Corollary 1 (1), under scenario NS, when the energy saving subsidy standard is low ($\underline{e} < \frac{1-\delta+s}{h}$), the EU's optimal energy-saving benefit sharing ratio increases with s. At this time, since all subsidies are taken by the ESCO, subsidy increasing will stimulate the EU to ensure that it is not at a disadvantage in the allocation of energy saving benefits by increasing its share of energy saving benefits. $\delta_{NS}^* = 1$ when the energy-saving subsidies standard is high enough ($\underline{e} \geq \frac{1-\delta+s}{h}$). it implies that the EU gains all energy saving benefits. If the energy saving subsidy standard is high, the EPC projects need to achieve high energy saving. It will cause more serious loss of energy-saving equipment. When the energy saving income sharing period ends, there may also be problems such as difficult to guarantee energy saving, high replacement cost and maintenance cost of later energy-saving equipment. These issues would damage the EU's interests. At this time, the EU can not get energy saving subsidies, so the EU will try to get all the energy saving income to protect its own income.

Corollary 1 (2) shows that under scenario SS, when the energy saving subsidy standard is low ($\underline{e} < \frac{1-\delta+(1-\varphi)s}{h}$), if the bargaining power of the EU for energy conservation subsidy allocation is less than or equal to that of ESCO, δ_{SS}^{*} increases as the subsidy of per unit of energy saved increases. Otherwise, δ_{SS}^{*} decreases as the subsidy of per unit of energy saved increases. This is because the EU is at a disadvantage in the sharing of energy saving subsidies when the proportion of EU's energy saving subsidies does not exceed that of the ESCO. The increase of subsidies will encourage the EU to increase its share of energy saving revenue to get the desired benefit from the EPC projects. Meanwhile, δ_{SS}^{*} is also affected by the bargaining power in subsidy allocation φ. δ_{SS}^{*} decreases with the increase of φ. That is because when the EU's share of energy-saving subsidies increases, it eases the competition between the EU and the ESCO.

Proposition 6: (1) $e_{NS}^{*} > e_{NN}^{*}$ if $s > \frac{1}{2}$; when $0 < s \le \frac{1}{2}$, $e_{NS}^{*} \le e_{NN}^{*}$ if $\frac{1}{2h} \ge \underline{e} \ge \frac{1-\delta+s}{h}$, $e_{NS}^{*} > e_{NN}^{*}$ if $\frac{1-\delta+s}{h} \le \frac{1}{2h} < \underline{e}$;

(2) $e_{SS}^{*} > e_{NN}^{*}$ if $s > \frac{1}{2(1-\varphi)}$; when $0 < s \le \frac{1}{2(1-\varphi)}$, $e_{SS}^{*} \le e_{NN}^{*}$ if $\frac{1}{2h} \ge \underline{e} \ge \frac{1-\delta+(1-\varphi)s}{h}$, $e_{SS}^{*} > e_{NN}^{*}$ if $\frac{1-\delta+(1-\varphi)s}{h} \le \frac{1}{2h} < \underline{e}$;

(3) $e_{SS}^{*} = e_{NS}^{*}$ if $\underline{e} < \frac{1-\delta+(1-\varphi)s}{h}$, $e_{SS}^{*} = e_{NS}^{*} = \underline{e}$ if $\underline{e} \ge \frac{1-\delta+s}{h}$; when $\frac{1-\delta+(1-\varphi)s}{h} \le \underline{e} < \frac{1-\delta+s}{h}$, $e_{SS}^{*} < e_{NS}^{*}$ if $0 < h \le 1$, $e_{SS}^{*} < e_{NS}^{*}$ if $h > 1$ and $\underline{e} > \frac{1+s}{2h}$, otherwise, $e_{SS}^{*} \ge e_{NS}^{*}$.

According to Propositions 6(1) and 6(2), if the subsidy of per unit energy saving is high, the optimal energy saving in scenarios NS and SS is higher than that in scenarios NN. It indicates that when the financial subsidy is high, the subsidy policy can effectively encourage the ESCO to make more energy conservation efforts. However, when the subsidy standard for energy saving is high enough, if the subsidy per unit energy saving is low and the energy saving subsidy standard is lower than or equal to the optimal energy saving in scenario NN, then the optimal energy saving in scenarios NS and SS is lower than or equal to the optimal energy saving in scenario NN. On the contrary, when the energy saving subsidy standard is lower than the optimal energy saving standard under scenario NN, even if the ESCO is negative about energy saving, the energy saving subsidy policy will promote it to achieve higher energy saving than the case it does not meet the energy saving subsidy standard.

Proposition 6 (3) indicates that when an EPC project meets the energy saving subsidy standard, if the energy saving subsidy standard is too high or too low, the optimal energy saving when the energy saving subsidy is fully allocated to ESCO is equal to that when the energy saving subsidy is shared by the EU and the ESCO. When the energy saving subsidy standard is not too high or too low, if ESCO's energy saving renovation efficiency is high enough, the optimal energy saving rate is higher when all the subsidies are allocated to ESCO than that when the energy saving subsidy is shared by the EU and the ESCO.

Corollary 2: (1) $\frac{\partial e_{NN}^{*}}{\partial h} < 0$; (2) if $\underline{e} < \frac{1-\delta+s}{h}$, $\frac{\partial e_{NS}^{*}}{\partial h} < 0$ and $\frac{\partial e_{NS}^{*}}{\partial s} > 0$, $e_{NS}^{*} = \underline{e}$ if $\underline{e} \ge \frac{1-\delta+s}{h}$; (3) if $\underline{e} < \frac{1-\delta+(1-\varphi)s}{h}$, $\frac{\partial e_{SS}^{*}}{\partial h} < 0$ and $\frac{\partial e_{SS}^{*}}{\partial s} > 0$; $e_{SS}^{*} = \underline{e}$ if $\underline{e} \ge \frac{1-\delta+(1-\varphi)s}{h}$.

Corollary 2 (1) shows that when the EPC project cannot obtain energy-saving subsidies, the optimal energy saving is only related to the ESCO's energy-saving renovation cost coefficient. Because a larger h means a higher cost for the ESCO to complete a unit of energy saving, thus the ECSO will set a low energy saving target to control its cost. Corollary 2 (2) shows that when the energy saving subsidy is all allocated to the ESCO, if the energy saving subsidy standard is low, the optimal energy saving decreases as the efficiency of the ESCO's energy saving renovation decreases, but increases as the subsidy of per unit of energy saving increases.

Proposition 7: (1) if $0 < \underline{e} \leq \frac{1}{2h}$ and $\frac{\underline{e}h}{2} < s \leq \underline{e}h$, or $\underline{e} > \frac{1}{2h}$ and $\frac{\underline{e}h}{2} < s \leq \frac{1+4\underline{e}^2h^2}{8\underline{e}h}$, $E(\pi_{ESCO}^{NS}) \leq E(\pi_{ESCO}^{NN})$, otherwise, $E(\pi_{ESCO}^{NS}) > E(\pi_{ESCO}^{NN})$;

(2) if $0 < \underline{e} \leq \frac{1}{2h}$ and $\frac{\underline{e}h}{2(1-\varphi)} < s \leq \frac{\underline{e}h}{(1-\varphi)}$, or $\underline{e} > \frac{1}{2h}$ and $\frac{\underline{e}h}{2(1-\varphi)} < s \leq \frac{1+4\underline{e}^2h^2}{8\underline{e}h(1-\varphi)}$, $E(\pi_{ESCO}^{SS}) \leq E(\pi_{ESCO}^{NN})$, otherwise, $E(\pi_{ESCO}^{SS}) > E(\pi_{ESCO}^{NN})$;

(3) $E(\pi_{ESCO}^{NS}) = E(\pi_{ESCO}^{SS})$ if $\underline{e} < \frac{1-\delta+(1-\varphi)s}{h}$; $E(\pi_{ESCO}^{NS}) > E(\pi_{ESCO}^{SS})$ if $\underline{e} \geq \frac{1-\delta+s}{h}$; $E(\pi_{ESCO}^{SS}) < E(\pi_{ESCO}^{NS})$ if $\frac{1-\delta+(1-\varphi)s}{h} \leq \underline{e} < \frac{1-\delta+s}{h}$.

Proposition 7 (1) states that when both the energy saving subsidy standard and the energy saving subsidy per unit of energy saving are low or high, the optimal expected profit of the ESCO in scenario NS is less than or equal to that in scenario NN. Otherwise, the conclusion is reversed. Therefore, whether the energy saving subsidy policy can be positively responded by the ESCO depends on the energy saving standard and subsidy. Government should fully investigate the qualification, strength and energy saving rate of these companies, and reasonably formulate energy saving subsidy (incentive) policies. Proposition 7 (2) is similar to Proposition 7 (1). Proposition 7 (3) indicates that when the energy saving subsidy standard is low, the optimal expected profit of the ESCO in scenario NS is equal to that in scenario SS. When the energy saving subsidy standard is relatively high, the optimal expected profit of the ESCO when all the energy saving subsidy is allocated to the ESCO is greater than that when the energy conservation subsidy is shared by the ESCO and the EU.

Corollary 3: (1) $\frac{\partial E(\pi_{ESCO}^{NN})}{\partial h} < 0$; (2) $\frac{\partial(\pi_{ESCO}^{NS})}{\partial h} < 0$, $\frac{(\pi_{ESCO}^{NS})}{\partial s} > 0$; $\frac{\partial(\pi_{ESCO}^{NS})}{\partial \underline{e}} \leq 0$ if $\underline{e} \geq \frac{1-\delta+s}{h}$; (3) $\frac{\partial(\pi_{ESCO}^{SS})}{\partial h} < 0$, $\frac{(\pi_{ESCO}^{SS})}{\partial s} > 0$, $\frac{\partial(\pi_{ESCO}^{SS})}{\partial \underline{e}} \leq 0$ if $\underline{e} \geq \frac{1-\delta+(1-\varphi)s}{h}$.

Corollary 3 (1) shows that when EPC projects cannot receive energy-saving subsidies, the ESCO's optimal expected profit decreases as its own energy-saving efficiency decreases. Corollary 3 (2) shows that when the EPC projects meet the energy saving subsidy standard and all energy saving subsidies are allocated to the ESCO, the optimal expected profit of the ESCO decreases with the reduction of its energy saving efficiency and increases with the increase of subsidies of per unit of energy saving. However, when the energy-saving subsidy standard is high, the optimal expected profit of the ESCO is negatively correlated with the energy-saving subsidy standard. Corollary 3 (3) shows that when the EPC projects meet the energy-saving subsidy standard and the energy-saving subsidy is shared between the ESCO and the EU, the conclusions are similar to Corollary 3 (2). This is because the scenario NS is essentially the extreme case of the scenario SS.

Proposition 8: (1) $E(\pi_{EU}^{NS}) > E(\pi_{EU}^{NN})$ if $\underline{e} < \frac{1-\delta+s}{h}$; when $\underline{e} \geq \frac{1-\delta+s}{h}$, $E(\pi_{EU}^{NS}) > E(\pi_{EU}^{NN})$ if $s > \frac{1}{4}$, $E(\pi_{EU}^{NS}) \leq E(\pi_{EU}^{NN})$ if $s \leq \frac{1}{4}$ and $\underline{e} \leq \frac{1}{4h}$, $E(\pi_{EU}^{NS}) > E(\pi_{EU}^{NN})$ if $s \leq \frac{1}{4}$ and $\underline{e} > \frac{1}{4h}$;

(2) $E(\pi_{EU}^{NS}) = E(\pi_{EU}^{SS}) > E(\pi_{EU}^{NN})$ if $\underline{e} < \frac{1-\delta+(1-\varphi)s}{h}$; $E(\pi_{EU}^{NS}) < E(\pi_{EU}^{SS})$ if $\underline{e} \geq \frac{1-\delta+s}{h}$; when $\frac{1-\delta+(1-\varphi)s}{h} \leq \underline{e} < \frac{1-\delta+s}{h}$, $E(\pi_{EU}^{SS}) \geq E(\pi_{EU}^{NS})$ if $\underline{e} \geq \frac{1+s+s^2}{4h(1+\varphi s)}$, otherwise, $E(\pi_{EU}^{SS}) < E(\pi_{EU}^{NS})$.

Proposition 8 (1) shows that when the energy-saving subsidy standard is relatively low, if the EPC project meets the energy-saving subsidy standard and all the energy-saving subsidy is allocated to the ESCO, then the optimal expected profit of the EU is greater than that when the EPC project does not meet the energy-saving subsidy standard. When the energy saving subsidy standard is high enough, the optimal expected profit of the EU when the energy saving subsidy standard is reached and all the energy saving subsidy is allocated to the ESCO is greater than that the EPC project does not meet the energy-saving subsidy standard if the subsidy per unit of energy saving is high enough. It is worth noting that when the unit energy saving subsidy is small and the energy saving subsidy standard is lower than the threshold value of $\frac{1}{4h}$, the EU can obtain more profit in the case that the EPC project does not meet the energy saving subsidy standard.

Proposition 8 (2) shows that when the energy saving subsidy standard is small, the optimal expected profit of the EU in the two situations of the EPC project meets the energy saving subsidy standard is equal, and both are higher than the optimal expected profit in the case of the EPC project does not meeting the energy saving subsidy standard. When the subsidy standard for energy conservation is high enough, if the subsidy standard is met and the subsidy is shared between the ESCO and the EU, the optimal expected profit of the EU is higher than that when the subsidy is fully allocated to the ESCO.

Corollary 4: (1) $\frac{\partial E(\pi_{EU}^{NN})}{\partial h} < 0$; (2) $\frac{\partial E\left(\pi_{EU}^{NS}\right)}{\partial h} < 0$ and $\frac{\partial E\left(\pi_{EU}^{NS}\right)}{\partial s} > 0$ if $\underline{e} < \frac{1-\delta+s}{h}$; otherwise, $E(\pi_{EU}^{NS}) = \underline{e}$; (3) $\frac{\partial E\left(\pi_{EU}^{SS}\right)}{\partial h} < 0$ and $\frac{\partial E\left(\pi_{EU}^{SS}\right)}{\partial s} > 0$ if $\underline{e} < \frac{1-\delta+(1-\varphi)s}{h}$; otherwise, $\frac{\partial E\left(\pi_{EU}^{SS}\right)}{\partial s} > 0, \frac{\partial E\left(\pi_{EU}^{SS}\right)}{\partial \varphi} > 0, \frac{\partial E\left(\pi_{EU}^{SS}\right)}{\partial \underline{e}} > 0$ and $\frac{\partial E\left(\pi_{EU}^{SS}\right)}{\partial h} = 0$.

Corollary 4 (1) shows that when the EPC project fails to meet the energy saving subsidy standard and cannot obtain energy saving subsidy, the optimal expected profit of the EU decreases with the energy saving efficiency of the ESCO, and the impact of energy saving efficiency on the EU's optimal expected profit is greater than that on the ESCO's optimal expected profit. Corollary 4 (2) shows that when the EPC project meets the energy saving subsidy standard and all the energy saving subsidies are allocated to the ESCO, if the energy saving subsidy standard is low, the optimal expected profit of the EU decreases with the ESCO's energy saving efficiency and increases with energy saving subsidy per unit of energy saved. If the energy saving subsidy standard is high enough, the EU's optimal expected profits constant for $\underline{e}$. Corollary 4 (3) is similar to Corollary 4 (2) when the energy-saving subsidy standard is low. However, when the energy saving subsidy standard is high, when the energy saving subsidy standard is met and the subsidy is shared by the ESCO and the EU, the optimal expected profit of the EU is positively correlated with the subsidy of per unit of energy saved, the sharing proportion of the EU in the unit subsidy and the energy saving subsidy standard.

5. Conclusions

In order to respond to the national call for energy conservation and emission reduction, and reduce energy costs, EU with high energy consumption can effectively make up for their shortcomings in energy conservation technology and experience by participating in contract energy management projects. Both the EU and the ESCO seek to maximize their own energy saving benefits when making EPC contracts, and the way of energy saving subsidies distribution will affect the decision making and energy saving benefits of both parties. This paper constructs Stackelberg game models to compare the optimal energy saving and energy saving income sharing ratio of EPC projects under different energy saving subsidy allocation scenarios, as well as the optimal expected energy saving income of both parties of EPC projects. This paper also analyzes the influence of key parameters such as energy per unit saving subsidy, subsidy sharing ratio, the ESCO's efficiency of energy saving and energy saving subsidy standard on the decisions and profits of the EU and the ESCO. The main conclusions of this paper are as follows：

(1) The ESCO will not cooperate with the EU for an EPC project when the energy saving of the EPC project reaches the subsidy standard and the EU receives all the energy saving subsidies.

(2) Compared with other scenarios, the optimal energy saving income sharing ratio of the EU is the highest when the energy saving of the EPC projects reaches the subsidy standard and all the energy saving subsidies are allocated to the ESCO. Taking the failure to meet the energy saving subsidy standard as the benchmark, when the bargaining power of the allocation of energy saving subsidy of the EU is smaller than that of the ESCO, the EU will require a higher proportion of energy saving income sharing when it meets the energy saving subsidy standard and the subsidy is shared between the ESCO and the EU.

(3) When the subsidy per unit energy saving is high, the subsidy is shared between the ESCO and the EU or the subsidy is all allocated to the ESCO, the optimal energy saving is higher than that when the EPC project does not meet the subsidy standard. Therefore, higher energy conservation subsidies can effectively encourage the ESCO to save energy. The energy saving of the EPC project under different energy-saving subsidy allocation methods also depends on the energy-saving efficiency of the ESCO and energy-saving subsidy standard.

Whether the energy-saving subsidy policy can be positively responded by ESCO depends on the energy-saving subsidy standard and subsidy amount. When the ESCO's optimal expected profit is related to its energy efficiency or subsidy amount, it is negatively related to the former and positively related to the latter. In which subsidy method the EU can obtain higher optimal expected profit, it is related to the size of key parameters such as unit energy saving subsidy, share proportion of the EU in unit subsidy, the ESCO’s energy saving efficiency and energy saving subsidy standard.

To realize energy saving renovation and maximize its profit, the EU needs to take the external policy conditions, internal bargaining power and energy saving service company's energy saving renovation efficiency into account. This paper also has some limitations. Subsequent studies can take the government as the decision-making subject and the subsidy amount of government decision-making, and further discuss it in a more complex game model. In addition, risk preference or equity perception factors can also be considered to analyze their impact on the allocation of energy saving subsidies for EPC projects, the actions of both parties to the contract and energy saving income.

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