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Empirical Study on Annual Energy-Saving Performance of Energy Performance Contracting in China

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Received: 20 April 2018; Accepted: 16 May 2018; Published: 21 May 2018

Abstract: A lack of trust in Energy Service Company (ESCo) is the most critical factor affecting the development of Energy Performance Contracting (EPC) in China, compared with other constraints. One cannot easily estimate the energy-saving performance of an EPC project. Under that condition, lack of trust may cause the Energy-Consuming Unit (ECU) to suspect the energy-saving performance promised by the ESCo, thus leaving potentially profitable projects without necessary funding. Currently, specific studies taking an across-projects viewpoint on annual energy-saving performance of EPC projects in multiple subsectors, objectively and quantitatively, are lacking. This paper studies the regression relationships of annual energy-saving quantity in terms of revamping cost and the regression relationships of annual cost saving in terms of revamping cost. The regression results show that there are statistically significant correlations in the above relationships in the nine subsectors investigated. This is significant for ESCos and ECUs, because knowledge on energy-saving performance could contribute to EPC investment decisions and trust relationships between ESCos and ECUs. Then, a multiple linear regression model of revamping cost is set up to analyze its influencing factors. The model indicates that the subsector the sample belongs to, financing, registered capital of the ESCo, and contract period have significant effects on revamping cost. Thus, policy implications regarding innovation of EE promotion technology, clarifying ESCos' exit mechanism, innovation of financing mechanism, and improving the market credit environment for promoting investment in EPC projects, are provided.

Keywords: energy performance contracting; trust; annual energy saving quantity; annual cost saving; investment

1. Introduction

In 2016, energy consumption of China's GDP of 10,000 CNY fell by 5.0% [1], and it was 0.675 tce/10,000 CNY at 2010 constant prices (tce is the abbreviation of ton of standard coal equivalent). However, China's energy intensity still ranked ninth in the world that year [2]. In fact, the Law of the People's Republic of China on Conserving Energy was enacted as early as 1997, requiring improvements in the exploitation, processing, conversion, transmission, and supply of energy, so as to gradually raise the efficiency of energy utilization and promote the development of the national economy in an energy-efficient manner [3]. In addition, from the Eleventh Five-Year Plan for Energy Development in 2007, all previous Five-Year Plans for Energy Development require national goals for energy efficiency (EE) promotion [4–6]. If the latest plan is achieved, by 2020, energy consumption per unit of GDP in 2020 will be 15% lower than in 2015 [6]. The decline in energy intensity needs to be achieved by optimizing the industrial structure and strengthening technological progress. Comparatively, the former is a medium- and long-term process, so greater efforts should be made to improve the efficiency of energy utilization. To achieve universal and potential EE, and also to adapt to the profound social change from a planned economy to a market economy so as to integrate EE projects into the market trading system, learning from the experience of developed countries, China has also gradually popularized the Energy Performance Contracting (EPC) mechanism.

The market for EPC has huge potential in China [7,8]. In 2010, a milestone policy document on opinions of speeding up the implementation of energy performance contracting and promoting the development of the energy-saving service industry was issued [9]. It gives unprecedented policy support to the development of EPC from the aspects of finance, taxation, accounting standards, and financial support. Then, the General Technical Rules for Energy Performance Contracting, the first document on contract specifications for EPC projects, was put out the same year [10]. EPC has achieved rapid development since then: the total output value of the EPC industry increased from 83,629 million CNY in 2010 to 356,742 million CNY in 2016, with an average annual increase of 27.35%; annual energy-saving capacity of EPC projects increased from 10,648,500 tce in 2010 to 35,785,000 tce in 2016, with an annual increase of 22.39%. Despite the rapid development of EPC in China, EPC project investment in the public and private sectors is still facing bottlenecks considering the wide market space for EE promotion and the increasing policy support. The growth rate of EPC project investment has reduced in recent years, as shown in Figure 1. Apart from risk factors [11,12] and financing factors [13,14] that have been widely studied, industry environmental factors, such as the market credit environment, also hinder the rapid development of EPC. On-site fieldwork has found that a lack of trust in Energy Service Companies (ESCos) is the most critical factor affecting the development of EPC in China compared with other constraints, particularly, trust in private ESCos characterized by light assets [15]. In China's current situation, the energy service industry is in its nascent period, the measurement and verification of energy savings are not standardized, and a lack of integrity is a very serious problem [16]. Research has also shown sustainable building energy efficiency retrofits in hotels under the EPC mechanism are largely based on trust, accurate measurement and verification, and team workers' technical skills [17]. At present, ESCos are generally small companies in China, which determines that their company strength and credibility are very common [18]. Under such conditions, Energy-Consuming Units (ECUs) will question whether an ESCo's commitment is true [18]. Other research deems that with the transformation of the market from playing a basic role to playing a decisive role in allocating resources in the new era in China, the long-established government-leading EPC pattern will inhibit development of the EPC market, and there is a relationship between EPC, carbon trading, and energy conservation transactions [19]. The institutional measures and mode integration measures adopted for the above two aspects are the necessary guarantees to face the market integrity [19].

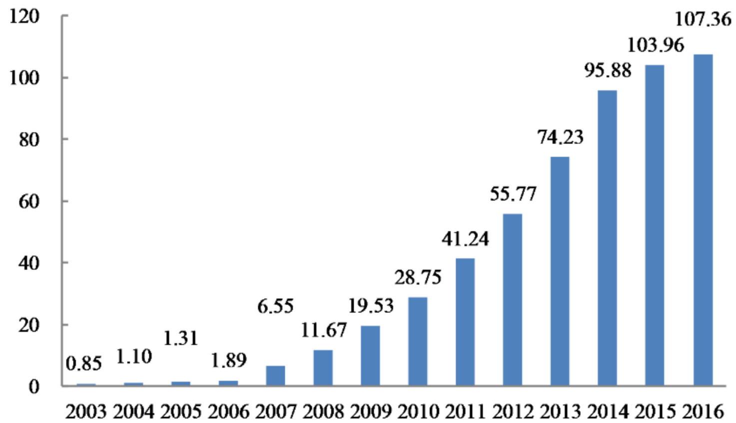

Figure 1. Change of Energy Performance Contracting (EPC) investments in China.

Profit expectation is the power source of EPC. In the EPC mechanism, what an ESCo sells is no longer a specific product or technology, but a specific energy-saving performance service. Its purpose is to sell energy-saving quantity to ECUs [20]. One cannot easily estimate the energy-saving performance of an EPC project, because that does not occur in the project development phase. Under that condition, lack of trust may cause the ECU to suspect the energy-saving performance promised by the ESCo, thus leaving potentially profitable projects without necessary funding. It might be interpreted that one of the main obstacles to developing EE projects is ECUs' lack of information on energy-saving quantity [21,22]. Energy performance estimation plays an essential role in the success of an EPC project for the owner and the ESCo, and several factors are involved that affect the real energy performance, including the EE investment, the energy-saving amount, and the energy market prices [23].

There are existing studies focusing on energy saving quantity of EPC projects. For example, Lee et al. [24] present a probabilistic approach to estimating a range of possible energy savings with the associated confidence levels for chiller replacement in existing buildings, taking into account the annual variations in the influential parameters affecting energy savings. Lu et al. [25] incorporate renters' rebound effect, and investigate the impact that major variables have on the rebound effect to predict more accurate energy saving amounts and design proper retrofitting contracts of EPC. Walter et al. [21] develop a multivariate linear regression model with numerical predictors (e.g., operating hours) and categorical indicator variables (e.g., climate zone) to predict energy use intensity. The model quantifies the contribution of building characteristics and systems to energy use, and the study uses it to infer the expected savings when modifying particular equipment [21]. Meanwhile, there are many studies on energy cost saving of EPC projects or energy efficiency programs [23,26,27]. However, specific studies taking an across-projects viewpoint on estimation of annual energy-saving quantity and annual cost saving in multiple subsectors (e.g., machinery manufacture subsector, chemical subsector, light subsector, coal subsector, building materials subsector, power subsector, metallurgical subsector, building subsector, public facilities subsector) objectively and quantitatively are lacking, and a cost-effective method is needed. This is significant for ESCos and ECUs because knowledge on energy-saving performance could contribute to EPC investment decisions and trust relationships between them, which contribute to promotion of EPC project investment in the public and private sectors. At present, the estimation of annual energy-saving quantity and annual cost saving of EPC projects stays at the operating level of each project, lacking a systematic summary. This paper tries to fill this void.

Before signing an EPC contract, an ESCo first performs EE diagnosis, and then, the EE promotion scheme is determined based on the same kind of facilities at the advanced level of energy consumption. Only by these preparations can the ESCo estimate the investment amount corresponding to the scheme and the energy-saving performance (mainly annual energy-saving quantity and annual cost saving in this paper) generated by the project. Since different EPC projects take different risks and adopt different technologies, there are great differences in energy-saving performance. Projects with higher reference standards (usually with higher investment) generally have better energy-saving performance. This paper uses the ESCo Committee of China Energy Conservation Association's (EMCA's) statistical data on 205 EPC projects, running from 2011 to 2016, to study the relationships of annual energy-saving quantity in terms of revamping cost, and the relationships of annual cost saving in terms of revamping cost by the linear regression method. The regression results show that revamping cost of EPC projects in most subsectors has the diseconomy of scale, and there are statistically significant correlations of the above relationships. As a result, ESCos and ECUs can calculate annual energy-saving performance in terms of revamping cost according to the subsector which the project belongs to.

Further, the multiple linear regression method is used to analyze the influencing factors of EPC revamping cost. It finds that the sector the sample belongs to, financing, the registered capital of the ESCo, and the contract period have a significant impact on revamping cost, while the impacts of registered capital of the ECU, fiscal incentive, and tax preference on revamping cost are not obvious. Therefore, in order to promote EPC investment, it is suggested that ESCos should innovate EE promotion technology and push forward transformation contents from single equipment, single project to energy system optimization and regional EE promotion, and should integrate upstream and downstream resources to enhance the competitive ability. Moreover, the government should innovate effective financing mechanisms and create an environment for both sides of EPC projects to sign long-term contracts. Policy implications are provided accordingly. These policy implications are of great referential significance, particularly, it is of reference and actual meaning to countries whose market for EPC needs further development. Taking China as an example, although the potential of the EPC market is huge, and the momentum of policy promotion is great, most newly established ESCos have weak financial strength and poor financing ability, which has led to a bottleneck in recent years' investment in EPC. Thus, it is important to provide low cost of capital for ESCos, so that greater potential of energy efficiency can be reached through EPC projects. Therefore, policy making in China should be changed from providing financial incentive or tax preference to providing a good financing environment.

2. Data of Annual Energy-Saving Performance

2.1. Data Sources

Supported by the Chinese government, the World Bank, and the Global Environment Facility, EMCA is an organization of energy-saving service industry associations committed to promoting the EPC mechanism and to fostering and leading the development of an energy-saving service industry in China. It guides the development of EPC industry based on the following six major platforms: communication and cooperation platform, research and consultant platform, capability building platform, international exchange platform, investing and financing consultation platform, information dissemination platform. Since its establishment in 2003, EMCA, which cooperates with responsible government departments, has participated in various studies, and composed the EPC industry development report (e.g., EPC Industry Development Report (2011–2015) [28]) and energy performance contracting cases (e.g., Energy Performance Contracting Cases (2011–2015) [29]).

This paper uses contract information from 205 EPC projects from Energy Performance Contracting Cases (2011–2015) [29] and research on typical projects in 2016 by EMCA. Nearly all contracts selected in this study contain the following information:

- project name;
- project owner;
- project undertakers; and
- contents of case (technical principle and application fields, concrete contents of EE promotion, project implementation situation); and
- annual energy saving quantity and annual cost saving of the project (computational method of energy saving quantity); and
- business model; and
- revamping cost and financing channels; and
- project highlights.

These projects were selected because (1) EMCA clearly points out that these typical projects are strongly representative and reproducible, with obvious energy-saving effect and reasonable return on investment, suitable for promotion in the related subsectors [29], and (2) other than EMCA, there are few national data sources about EPC projects. This contract information provides opportunities for the development of models that use empirical data to estimate annual energy saving quantity and annual cost saving of EPC projects according to revamping cost. Meanwhile, this study could conduct a multiple linear regression analysis to find out the influencing factors of EPC revamping cost.

2.2. Descriptive Statistics

Except for one sample in the electronic information and communication subsector (this study rejects it), EMCA classified the samples into industry, building, and public facilities sectors, and subdivided them into nine subsectors: machinery manufacture, chemical, light, coal, building materials, power, metallurgical, building, and public facilities (Table 1).

Table 1. Classification of the samples.

Main Categories	Subsector	Description of Transformation Contents
Industry	Metallurgical	Includes only the processes.
	Chemical	Includes only the processes.
	Coal	Includes only the processes.
	Building materials	Includes only the processes.
	Power	Includes only the processes.
	Machinery manufacture	Includes only the processes (e.g., industrial lighting system transformation, waste heat utilization of compressors).
	Light	Includes only the processes.
Building	Building subsector	Includes only the infrastructure (e.g., upgrading elevators, reconstruction of building envelopes).
Public Facilities	Public facilities subsector	Includes the processes (e.g., industrial waste heat recovery) or the infrastructure (e.g., lighting system transformation, optimization of central heating pipe networks) as well.

Among them, the largest number of samples are in the industry sector, with 136 samples, including 42 samples in the metallurgical subsector, 14 samples in the chemical subsector, 14 samples in the coal subsector, 14 samples in the building materials subsector, 25 samples in the power subsector, 15 samples in the machinery manufacture subsector, and 12 samples in the light subsector. There were 47 samples in the building industry. There were the fewest samples in the public facilities industry, with only 21. The subsector distribution of samples is shown in Figure 2.

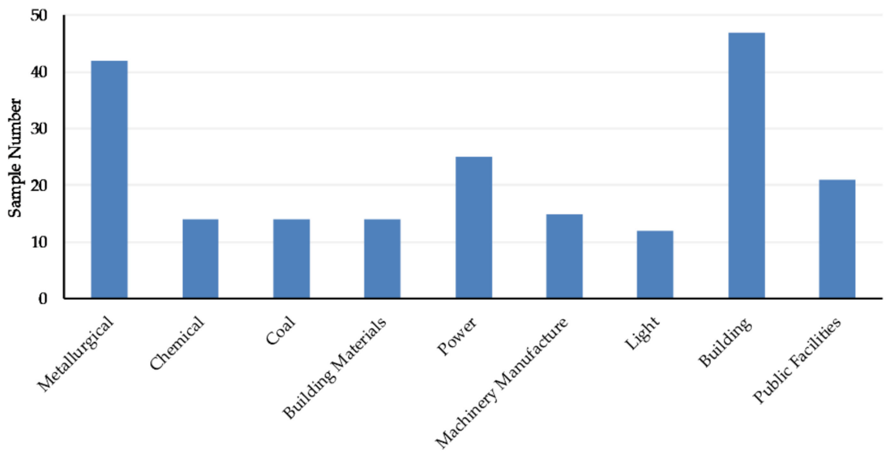

Figure 2. Industrial distribution of the samples.

EE promotion of the samples in the nine subsectors covers 83 technologies, shown in Table 2, including motor modification; heating, ventilation, and air-conditioning (HVAC) reconstruction; lighting system transformation; and launching new energy monitoring and management systems. To get the energy-saving law of each kind of technology, ideally, studied samples should be classified based on the EE enhancement technology used. However, this paper studies the estimation of annual energy-saving performance based on the nine subsectors described above. This is because (1) the number of samples in the classified subsector is too small, based on EE promotion technology (an average of 2.5 samples/technology in this paper), and (2) most of the samples use more than one EE promotion technology, so their energy-saving performance is from several technologies simultaneously. It is difficult to distinguish the contribution of each technology.

Table 2. Energy efficiency (EE) promotion technologies of the samples.

Subsector	EE Promotion Technologies
Metallurgical	Dehumidification transformation of blast furnaces, motor modification, direct reduction of solid waste by rotary hearth furnaces, steam back-pressure power generation byproducts, reform of water pump systems, waste heat generation of electric stove low-temperature flue gas, substitution fuel oil for cold coal gas, retrofit of circulating water systems, recovery of waste heat from slag water, recovery of residual heat from slag steam, heating furnace reformation, power generation with sintering residual heat, sintering waste heat recovery, retrofit of dust removal systems, coal gas recovery, top gas recovery turbine power generation in blast furnaces, waste heat generation of flue gas from submerged arc furnaces, dry quenching waste heat power generation, cooling tower hydraulic fans, flue gas waste heat generation of electric furnaces, retrofit of compressed air systems, recovery of waste heat from dead steam in self-made power plants, lighting system transformation, cooling.
Chemical	Recovery of residual heat of reboiler solvent, heating furnace reformation, recovery of waste heat from high-temperature slag, boiler retrofit, cooling tower hydraulic fans, retrofit of compressed air systems, recovery of waste heat from hydrochloric acid furnaces, motor modification, hydrogen recovery and heat recovery in pure terephthalic acid projects, reformation of water pump systems, retrofit of circulating water systems, retrofit of airtight electric furnaces.
Coal	Transformation of static var generator in substations, cooling tower hydraulic fans, recovery of waste heat from flue gas of coke ovens, dry quenching and waste heat generation, motor modification, waste heat utilization of compressors, retrofit of gas blower systems, low-pressure steam pumps, reform of water pump systems, waste heat generation of calciners, energy monitoring and management systems.
Building Materials	Waste heat generation of cement production lines, motor modification, waste heat generation of glass production lines, retrofit of ball mills.
Power	Lighting system transformation, waste heat utilization of circulating water, motor modification, retrofit of compressed air systems, waste heat generation of coke oven flue gas, optimization of urban heating networks, boiler retrofit, recovery of waste heat from boiler flue gas, compound phase changing heat exchangers, reform of water pump systems, transformation of warm air heaters, transformation of heat exchangers, retrofit of combustion systems, transformation of steam turbines, vacuum-pumping systems of steam ejectors, waste heat utilization of flue gas in photovoltaic glass kilns, retrofit of air preheaters, automatic regulating system for air inlet of cooling towers, photovoltaic tracking systems, energy monitoring and management systems.
Machinery Manufacture	Lighting system transformation, heating furnace reformation, retrofit of compressed air systems, waste heat utilization of compressors, motor modification, waste heat utilization of circulating water, harmonic control and reactive power compensation, electric feed servo energy saving systems, circulating fluidized beds, biodiesel, steam recovery, steam accumulation, regenerative combustion, ladle baking by gas jet, closed counterflow cooling tower, energy monitoring and management systems.
Light	Retrofit of circulating water systems, boiler retrofit, reform of water pump systems, motor modification, transformation of injection molding machines, waste heat recovery from wastewater, waste heat recovery of desiccant, solar photothermal utilization, biogas power generation, mechanical vapor recompression evaporators.
Building	Reform of heating or cooling, chilled water storage systems transformation, ventilation transformation, hot water transformation, lighting system transformation, cookers transformation, upgrading elevators, reconstruction of building envelopes, power distribution transformation, optimization of water supply, use of water, cold chain transformation, swimming pool heating transformation, solar thermal utilization, combined cooling heating and power utilization, establishing energy management systems, establishing battery management systems.
Public Facilities	Motor modification, boiler retrofit, lighting system transformation, heat exchange station transformation, reform of cooling and ventilation in stations, optimization of central heating pipe networks, industrial waste heat recovery, energy monitoring and management systems.

The EE promotion content of the EPC project corresponds to a certain investment and energy-saving performance, so there is a certain relationship between investment and energy-saving performance. In general, the larger the annual energy-saving quantity of the unit investment, the higher the energy-saving performance of the EPC project. Figures 3–11 show bubble charts of samples in the nine subsectors. The horizontal axis represents revamping cost, the vertical axis represents annual energy-saving quantity, and the size of the bubble represents the annual energy-saving quantity of unit investment in a figure. It can be seen that most of the larger bubbles concentrate in areas with lower revamping cost, indicating a diseconomy of scale in EPC projects.

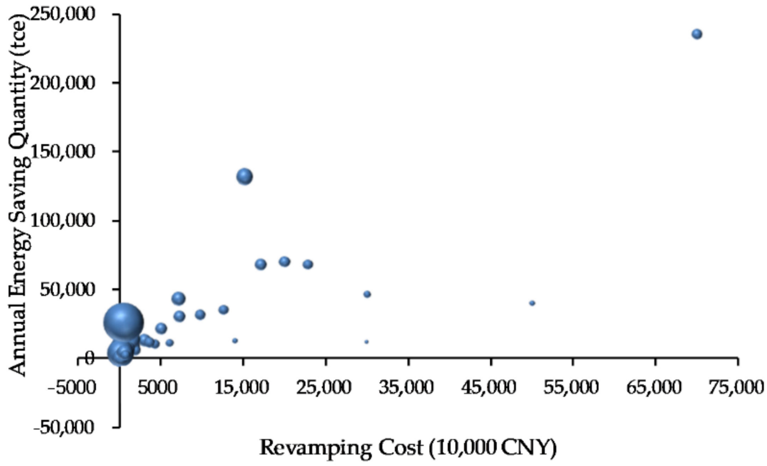

Figure 3. Bubble chart of metallurgical subsector samples.

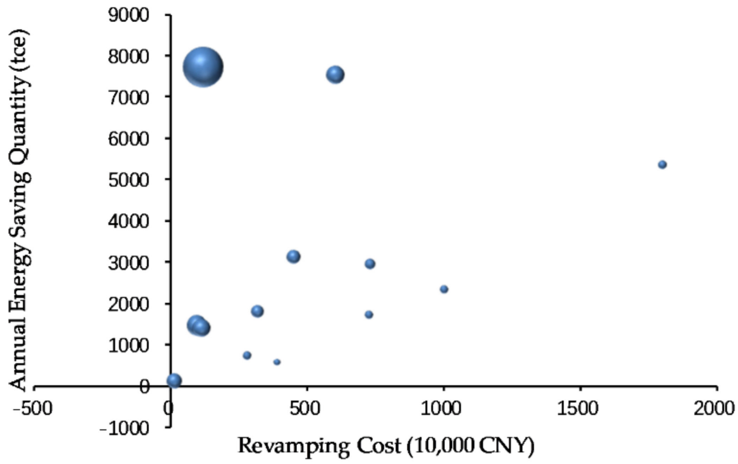

Figure 4. Bubble chart of chemical subsector samples.

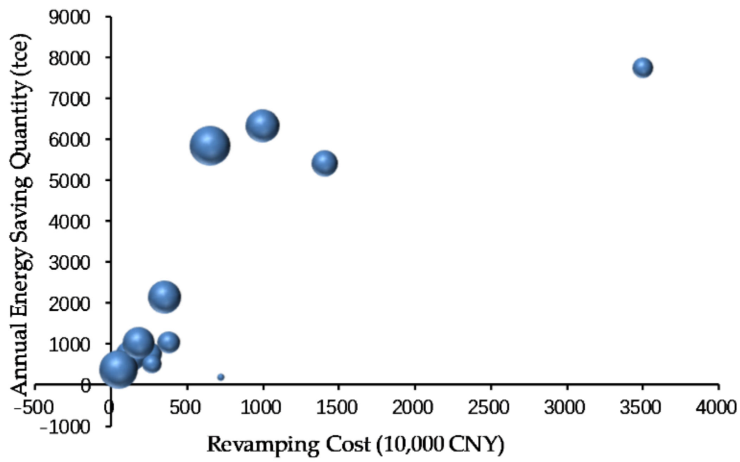

Figure 5. Bubble chart of coal subsector samples.

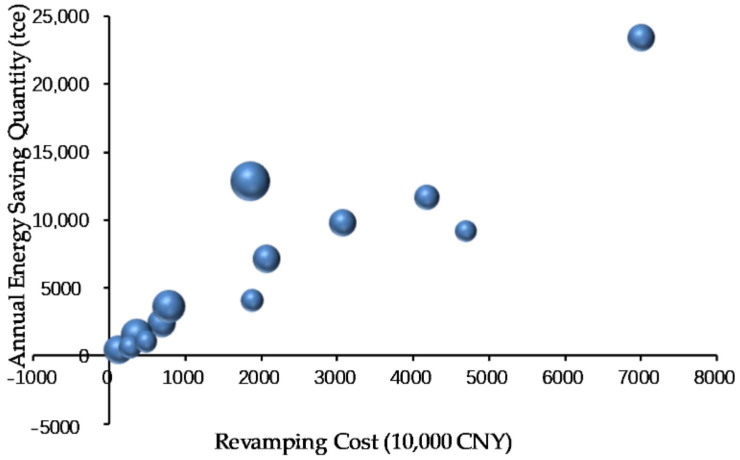

Figure 6. Bubble chart of building materials subsector samples.

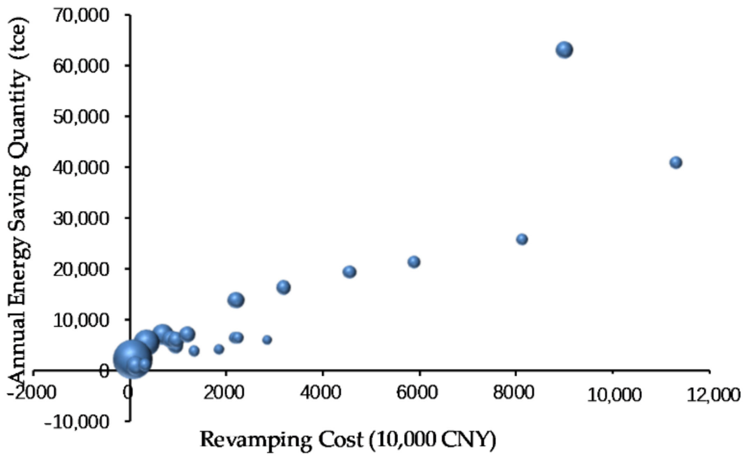

Figure 7. Bubble chart of power subsector samples.

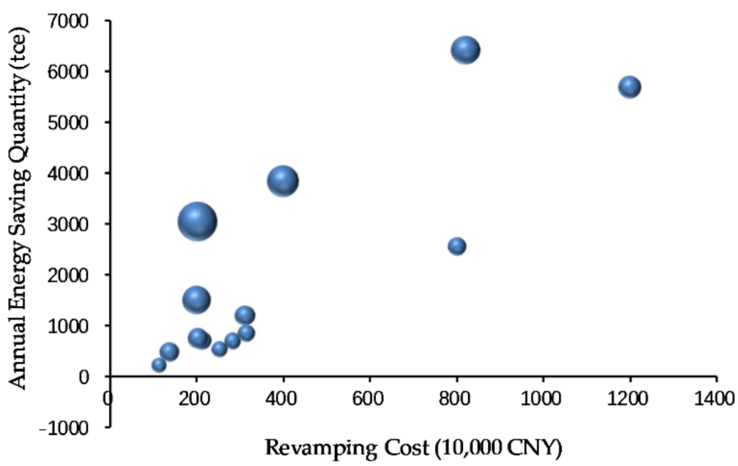

Figure 8. Bubble chart of machinery manufacture subsector samples.

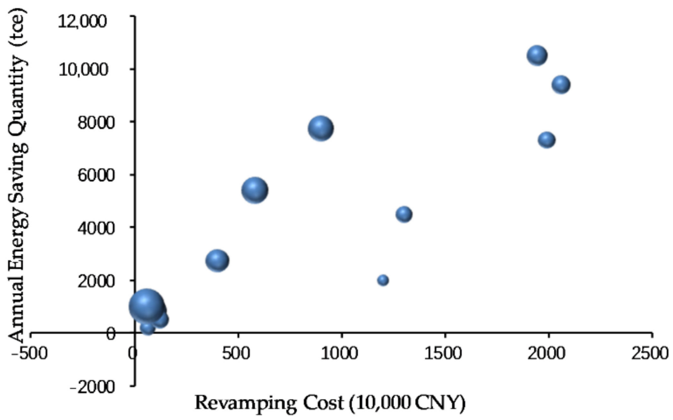

Figure 9. Bubble chart of light subsector samples.

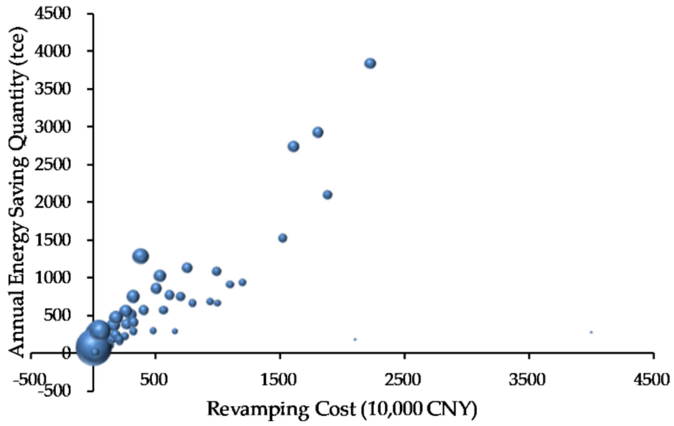

Figure 10. Bubble chart of building subsector samples.

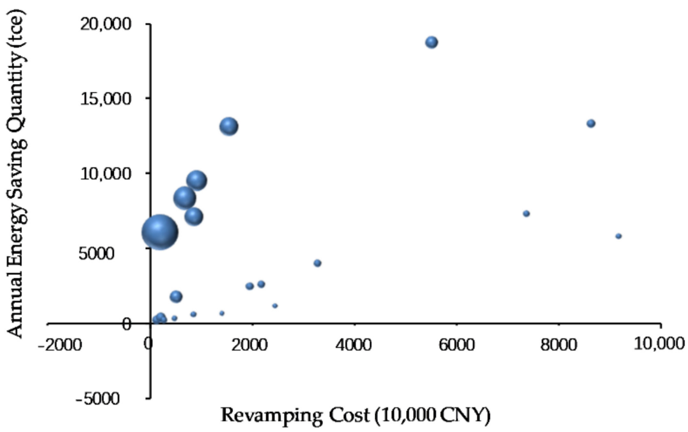

Figure 11. Bubble chart of public facilities subsector samples.

Ten samples were removed from Figures 3–11 for two reasons.

Reason 1: The revamping cost of four samples was too different from the others in the same subsector, far from the average level of the subsector. Considering regression analysis (below), eliminating these extreme values can make the regression results more stable and reliable. These four samples are as follows: (1) EE promotion technology of one sample in the chemical subsector is the retrofit of airtight electric furnaces, with an especially high revamping cost. (2) The same situation occurs in one sample in the coal subsector; its EE promotion technology depends on transformation of the coke-quenching process. (3) Another sample in the coal subsector adopts variable frequency modification of pump motors, and the modification scale is so huge that the revamping cost is very high. (4) One sample in the building subsector uses heat pump technology and chilled water storage technology. Since the building floor area is up to 4 million m^2, the revamping cost is also very high.

Reason 2: There are six samples with only revamping cost data, without annual energy-saving quantity information.

Sample numbers in the subsectors, after elimination, are shown in Table 3. In Section 3, the analysis of energy-saving quantity in terms of revamping cost and annual cost saving in terms of revamping cost is based on the numbers in Table 3.

Table 3. Number of samples in the nine subsectors after elimination.

Subsector	Number of Samples
Machinery Manufacture	14
Chemical	13
Light	12
Coal	12
Building Materials	13
Power	25
Metallurgy	42
Building	43
Public Facilities	20
Total	194

3. Regression Analysis of Annual Energy-Saving Performance

As pointed out in Section 1, the annual energy-saving performance of an EPC project in this paper refers to the annual energy-saving quantity and annual cost saving. Thus, the relationships of annual energy-saving quantity in terms of revamping cost, and the relationships of annual cost saving in terms of revamping cost, are investigated in turn.3.1. Relationship of Annual Energy-Saving Quantity in Terms of Revamping Cost.

3.1. Relationship of Annual Energy-Saving Quantity in Terms of Revamping Cost

We set up a linear regression model of annual energy-saving quantity in terms of revamping cost of each subsector by SPSS22.0 software (Tongji University, Shanghai, China). The results of curve estimation are shown in Tables 4 and 5. In addition, this paper explores ANOVA of the regression (see Appendix A).

According to Table 5, there are significant correlations between annual energy-saving quantity and revamping cost in the nine subsectors, but there are big differences between the subsectors. This is mainly due to differences in the energy saving-potential of the subsectors; for example, the standard coal consumption rate of power supply in China is 40 gce/kWh more than the international advanced level (gce is the abbreviation of gram of standard coal equivalent); the comparable energy consumption per ton of steel in China is 20 kgce/t more than the international advanced level [30]; the intensity of energy consumption for public buildings should be lowered to less than 24.6 kgce/m^2, and for buildings in heating areas in the north, to less than 7.02 kgce/m^2, in order to achieve the goal of controlling China's total energy consumption within 1100 million tce in 2020 [31]. Results of the curve estimation of EPC samples in all nine subsectors for energy-saving quantity in terms of revamping cost can be divided into the following four categories.

Table 4. Coefficients of annual energy-saving quantity in terms of revamping cost in curve estimation.

Subsector	Variables	Unstandardized Coefficients		Standardized Coefficients	T	Sig.
		B	Std. Error	Beta		
Machinery Manufacture	Revamping cost	5.159	1.037	0.821	4.977	0.000
	(Constant)	26.455	514.475		0.051	0.960
Chemical	1/Revamping cost	−39.415	11.539	−0.717	−3.416	0.006
	(Constant)	7.872	0.252		31.191	0.000
Light	ln(Revamping cost)	0.829	0.130	0.895	6.358	0.000
	(Constant)	15.227	12.499		1.218	0.251
Coal	Revamping cost	5.911	1.888	2.021	3.131	0.012
	Revamping cost **2 [a]	−0.001	0.001	−1.286	−1.993	0.077
	(Constant)	−265.899	863.878		−0.308	0.765
Building Materials	ln(Revamping cost)	0.965	0.088	0.958	11.015	0.000
	(Constant)	4.113	2.586		1.591	0.140
Power	Revamping cost	4.292	0.418	0.906	10.278	0.000
	(Constant)	367.430	1612.215		0.228	0.822
Metallurgy	ln(Revamping cost)	0.746	0.059	0.893	12.547	0.000
	(Constant)	28.861	13.121		2.200	0.034
Building	ln(Revamping cost)	0.562	0.082	0.730	6.838	0.000
	(Constant)	16.765	8.338		2.011	0.051
Public Facilities	ln(Revamping cost)	0.696	0.209	0.618	3.333	0.004
	(Constant)	17.868	26.849		0.665	0.514

Note: [a] **2 represents square of variables.

Table 5. Model summary of annual energy-saving quantity in terms of revamping cost in curve estimation *.

Subsector	R	R^2	R_a^2	Std. Error of the Estimate
Machinery Manufacture	0.821	0.674	0.646	1196.193
Chemical	0.717	0.515	0.471	0.822
Light	0.895	0.802	0.782	0.604
Coal	0.855	0.730	0.670	1604.199
Building Materials	0.958	0.917	0.909	0.376
Power	0.906	0.821	0.813	6267.402
Metallurgy	0.893	0.797	0.792	0.760
Building	0.730	0.533	0.521	0.748
Public Facilities	0.618	0.382	0.347	1.174

* Independents: revamping cost of the samples (10,000 CNY).

3.1.1. Light, Building Materials, Metallurgical, Building, and Public Facilities Subsectors

There are power function relationships between revamping cost and annual energy-saving quantity in the light, building materials, metallurgical, building, and public facilities subsectors, i.e., the fitting functions are in accordance with the nature of concave functions. The estimated curves show that the annual energy-saving quantity in these five subsectors increases with increased revamping cost, but the amount of increase decreases. That is to say, the scale between revamping cost and annual energy-saving quantity is diseconomy.

Equation (1) shows the relationship between revamping cost and annual energy-saving quantity of the samples in the light subsector. Average annual energy-saving quantity per unit investment of the 12 samples can be expressed as $(Q/I)_{ave} = \overline{q} = 6.4$ ($\overline{q}$ is average annual energy-saving quantity of unit investment; Q is annual energy-saving quantity (tce); I is revamping cost (10,000 CNY)).

$$Q_{li} = 15.227(I_{li})^{0.829},\ I_{li} \in (0\text{–}2500], \tag{1}$$

where Q_{li} is annual energy-saving quantity of the samples in the light subsector (tce) and I_{li} is revamping cost of the samples in the light subsector (10,000 CNY).

Equation (2) shows the relationship between revamping cost and annual energy-saving quantity of the samples in the building materials subsector. The average annual energy-saving quantity of unit investment of the 13 samples in the subsector is $\overline{q} = 3.4$.

$$Q_{bm} = 4.113(I_{bm})^{0.965},\ I_{bm} \in (0\text{–}8000], \tag{2}$$

where Q_{bm} is annual energy-saving quantity of the samples in the building materials subsector (tce) and I_{bm} is revamping cost of the samples in the building materials subsector (10,000 CNY).

The relationship in the metallurgical subsector can be expressed as Equation (3). Its $\overline{q}$ is 6.8, while three samples have $Q/I = q < 1.0$ (q is annual energy-saving quantity of unit investment), and other samples have relatively smaller q values, resulting in diminishing marginal annual energy-saving quantity. Direct reduction of solid waste by rotary hearth furnace technology, lithium bromide and screw mechanism cooling technology, and dry quenching waste heat power generation technology, respectively, are used in these three samples, so revamping costs are all high.

$$Q_{me} = 28.861(I_{me})^{0.746},\ I_{me} \in (0\text{–}75,000], \tag{3}$$

where Q_{me} is annual energy-saving quantity of the samples in the metallurgical subsector (tce) and I_{me} is revamping cost of the samples in the metallurgical subsector (10,000 CNY).

Equation (4) shows the relationship between revamping cost and annual energy-saving quantity of the samples in the building industry. Its $\overline{q}$ is 2.1, while two samples have $q < 1.0$, including one sample with a renovated heating and cooling system, and other samples with renovated building envelopes, cooling systems, lighting systems, and power distribution systems. As the revamping costs are both high, these two samples adopt the energy expenses entrusted contract model and guaranteed savings contract model, respectively, to ensure investment recovery for ESCos. On the contrary, there is one sample with $q = 18.5$. Intelligent stable pressure and energy-saving water supply equipment are added to it, with revamping cost of only 42,000 CNY. Its energy performance is remarkably higher relative to revamping cost, so the ESCo's share of the contract is smaller.

$$Q_{bu} = 16.765(I_{bu})^{0.562},\ I_{bu} \in (0\text{–}4500], \tag{4}$$

where Q_{bu} is annual energy-saving quantity of the samples in the building subsector (tce), and I_{bu} is the revamping cost of the samples in the building subsector (10,000 CNY).

The relationship in the public facilities subsector can be expressed as Equation (5), with $\overline{q} = 4.6$. Among them, there are 11 lighting system transformation samples (apart from advertising lamp box transformation of one sample, the rest are reconstruction of road lighting systems). Average annual energy-saving quantity of unit investment of these samples is $\overline{q} = 1.2$, demonstrating that the revamping cost of the lighting system was still high in 2011–2016 relative to annual energy-saving quantity. The other 8 samples among the 20 samples use heating system reconstruction or optimization of heating network, including one sample with $q = 31.3$ (its transformation technology is heating according to area, time, and temperature; secondary piping network balance optimization; optimization of heat exchange station and primary piping network). Transformation technology of the remaining one sample are cooling and ventilation transformation, and building new energy monitoring and management systems, with $q = 0.6$. The number of samples in the public facilities subsector is not large, but the subsector covers many subclass samples, such as lighting system transformation, heating network optimization, and ventilation and air-conditioning system transformation, thus becoming a "super subsector." So R^2 of this subsector in Table 5 is only 0.382, which is the lowest among the nine subsectors.

$$Q_{pf} = 17.868\left(I_{pf}\right)^{0.696},\ I_{pf} \in (0\text{–}10,000], \tag{5}$$

where Q_{pf} is annual energy-saving quantity of the samples in the public facilities subsector (tce) and I_{pf} is revamping cost of the samples in the public facilities subsector (10,000 CNY).

3.1.2. Chemical Subsector

The relationship in the chemical subsector can be expressed as Equation (6). Its $\overline{q}$ is 11.0, while there is one sample with $q = 64.3$. It adopts waste heat recovery technology of high-temperature slag, so its revamping cost is small, and annual energy-saving quantity is large.

$$Q_{ch} = \exp\{7.872 - 39.415/I_{ch}\},\ I_{ch} \in (0\text{–}2000], \quad (6)$$

where Q_{ch} is annual energy saving quantity of the samples in the chemical subsector (tce) and I_{ch} is revamping cost of the samples in the chemical subsector (10,000 CNY).

3.1.3. Coal Subsector

The relationship in the coal subsector can be expressed as Equation (7), with $\overline{q} = 4.6$. When revamping cost $I \in (0, 2955.5]$ in Equation (7), annual energy-saving quantity increases with increased revamping cost; when $I \in (2955.5, 4000]$, annual energy-saving quantity decreases with increased revamping cost; one sample is a calciner waste heat generation transformation project with a 35 million CNY revamping cost. Therefore, annual energy-saving quantity increases with increased revamping cost in the coal subsector.

$$Q_{co} = -265.899 + 5.911 I_{co} - 0.001 (I_{co})^2,\ I_{co} \in (0\text{–}4000], \quad (7)$$

where Q_{co} is annual energy-saving quantity of the samples in the coal subsector (tce) and I_{co} is revamping cost of the samples in the coal subsector (10,000 CNY).

3.1.4. Machinery Manufacture and Power Subsectors

Annual energy-saving quantity increases linearly with increased revamping cost in the machinery manufacture and power subsectors.

Equation (8) shows the relationship between revamping cost and annual energy-saving quantity of the samples in the machinery manufacture subsector. It may be that the revamping costs of these samples obtained from EMCA statistics are relatively low, so samples in the subsector do not show diseconomy of scale. Its $\overline{q}$ is 5.1, while there is one sample with $q = 15.0$. Steam heat storage technology used in the sample reduces the influence of steam load fluctuation, saving energy consumption while protecting steam-consuming equipment and steam pipes. The EE promotion effectiveness of the sample is significantly better than that of the other samples.

$$Q_{ma} = 26.455 + 5.159 I_{ma}\ ,\ I_{ma} \in (0\text{–}1400], \quad (8)$$

where Q_{ma} is annual energy-saving quantity of the samples (tce) and I_{ma} is revamping cost of the samples in the machinery manufacture subsector (10,000 CNY).

The relationship in the power subsector can be expressed as Equation (9); its $\overline{q}$ is 6.4. The domain of the revamping cost of the samples is 10 times that of the machinery manufacture subsector, and R^2, as shown in Table 5, is larger than that of the machinery manufacture subsector. Therefore, the linear relationship between revamping cost and annual energy-saving quantity is more significant in the power subsector than the machinery manufacture subsector.

$$Q_{el} = 367.430 + 4.292 I_{el}\ ,\ I_{el} \in (0\text{–}12{,}000], \quad (9)$$

where Q_{el} is annual energy-saving quantity of the samples (tce), and I_{el} is revamping cost of the samples in the power subsector (10,000 CNY).

3.2. Relationship of Annual Cost Saving in Terms of Revamping Cost

As described in Section 2.1, data of the samples also include annual cost saving. Thus, it is also possible to estimate annual cost saving by revamping cost. Results of annual cost saving in terms of revamping cost in curve estimation are shown in Tables 6 and 7. There is also a significant correlation between revamping cost and annual cost saving in each subsector. In addition, this paper explores ANOVA of the regression (see Appendix A). It can be seen that annual cost saving of the samples increases linearly with increased revamping cost in the machinery manufacture, coal, and metallurgical subsectors. The relationships in the other subsectors are consistent with the power function, namely, revamping cost in these subsectors has a diseconomy of scale.

Table 6. Coefficients of annual cost saving in terms of revamping cost in curve estimation.

Subsector	Variables	Unstandardized Coefficients		Standardized Coefficients	T	Sig.
		B	Std. Error	Beta		
Machinery Manufacture	Revamping cost	0.658	0.080	0.916	8.259	0.000
	(Constant)	18.748	38.346		0.489	0.633
Chemical	ln(Revamping cost)	0.688	0.133	0.842	5.181	0.000
	(Constant)	6.105	4.731		1.291	0.223
Light	ln(Revamping cost)	0.831	0.091	0.945	9.100	0.000
	(Constant)	2.285	1.313		1.741	0.112
Coal	Revamping cost	0.355	0.069	0.851	5.132	0.000
	(Constant)	101.811	81.428		1.250	0.240
Building Materials	ln(Revamping cost)	0.867	0.115	0.909	7.534	0.000
	(Constant)	1.346	1.088		1.238	0.240
Power	ln(Revamping cost)	0.865	0.055	0.957	15.809	0.000
	(Constant)	1.229	0.475		2.588	0.016
Metallurgy	Revamping cost	0.262	0.024	0.866	10.964	0.000
	(Constant)	590.687	392.447		1.505	0.140
Building	ln(Revamping cost)	0.641	0.068	0.817	9.501	0.000
	(Constant)	3.078	1.236		2.491	0.017
Public Facilities	ln(Revamping cost)	0.604	0.143	0.705	4.214	0.001
	(Constant)	6.367	6.589		0.966	0.347

Table 7. Model summary of annual cost saving in terms of revamping cost in curve estimation *.

Subsector	R	R^2	R_a^2	Std. Error of the Estimate
Machinery Manufacture	0.916	0.840	0.828	93.618
Chemical	0.842	0.709	0.683	0.594
Light	0.945	0.892	0.881	0.423
Coal	0.851	0.725	0.697	219.339
Building Materials	0.909	0.825	0.811	0.565
Power	0.957	0.916	0.912	0.420
Metallurgy	0.866	0.750	0.744	2211.686
Building	0.817	0.667	0.660	0.603
Public Facilities	0.705	0.497	0.469	0.778

* Independents: revamping cost of the samples (10,000 CNY).

Equations (10)–(18) show the relationship between revamping cost and annual cost saving.

$$S_{ma} = 18.784 + 0.658 I_{ma} \tag{10}$$

$$S_{ch} = 6.105 (I_{ch})^{0.668} \tag{11}$$

$$S_{li} = 2.285 (I_{li})^{0.831} \tag{12}$$

$$S_{co} = 101.811 + 0.355 I_{co} \tag{13}$$

$$S_{bm} = 1.346 (I_{bm})^{0.867} \tag{14}$$

$$S_{el} = 1.229 (I_{el})^{0.865} \tag{15}$$

$$S_{me} = 590.687 + 0.262 I_{me} \quad (16)$$

$$S_{bu} = 3.078 (I_{bu})^{0.641} \quad (17)$$

$$S_{pf} = 6.367 \left(I_{pf} \right)^{0.604} \quad (18)$$

where S_{ma} is annual cost saving of the samples in the machinery manufacture subsector (tce); and S_{ch}, S_{li}, S_{co}, S_{bm}, S_{el}, S_{me}, and S_{pf} are annual cost savings of the samples in the chemical, light, coal, building materials, power, metallurgical, building, and public facilities subsectors.

Except for a slight decrease of R^2 of the samples in the building materials subsector and basically no change of R^2 of the samples in the coal and metallurgical subsectors, R^2 in Table 7 is larger than that in Table 5. The annual energy cost-saving is energy market price multiplied by amount of energy saved [23,26]. R^2 increases, which indicates that the correlation between revamping cost and annual energy cost saving of the samples is greater than that between revamping cost and annual energy-saving quantity in the same subsector through region adjustment, subsector adjustment, and electricity classification adjustment of energy price. This is because what ESCos and ECUs ultimately seek is annual cost saving of projects, not annual energy-saving quantity. Market forces drive both parties to seek high cost-saving projects, for example, some projects with low annual energy-saving quantity but high energy price. Eventually, it makes the correlation between revamping cost and annual cost saving of the samples in the same subsector more significant.

The adjustment role of energy price is reflected among the different subsectors as mentioned above. Samples in the industry sector account for 67.5% of the 194 effective samples in this paper, roughly in accordance with the proportion of 62% from EMCA's statistics in the Twelfth Five-Year Plan [28]. It can be inferred that EPC projects in China are dominated by the industry sector, contrary to most developed countries. In the United States, roughly 70% of ESCo market revenue comes from municipal, local, and state government facilities; universities/colleges; K–12 schools; and healthcare facilities customers; 15% of ESCo market revenue comes from federal government customers. The remaining 15% is split between commercial/industrial private customers and public housing [32]. Reasons for ESCos' limited penetration in the American industrial market are the high cost of developing projects, the highly customized nature of process improvements and the need for industry-specific expertise limiting access to decision-makers within industrial firms, and difficulty evaluating project success [33]. Also, mainly for the reasons cited, there are great differences between the regression results of annual cost saving in terms of revamping cost, and annual energy-saving quantity in terms of revamping cost among the subsectors in this paper. Coefficient of variation (i.e., $c_v = \sigma / \mu$; c_v is coefficient of variation, σ is standard deviation, μ is average value) is a normalized measure of degree of probability distribution dispersion. Coefficient of variation of average annual energy-saving quantity of unit investment (i.e., $\overline{q}$) among the nine subsectors is $c_v = 2.53/5.60 = 0.45$, and of annual cost saving of unit investment (i.e., $\overline{s}$) is $c_v = 0.26/0.75 = 0.35$, as shown in Table 8. This shows that there is a relatively large difference in $\overline{q}$ among the different subsectors, but the difference in $\overline{s}$ among them has become smaller since the adjustment of energy prices.

Table 8. $\overline{q}$, $\overline{s}$, and c_v in the subsectors.

Subsector	$\overline{q} = (Q/I)_{ave}$		$\overline{s} = (S/I)_{ave}$	
Machinery Manufacture	5.1	$\hat{c}_v = 0.45$	0.76	$\hat{c}_v = 0.35$
Chemical	11.0		1.31	
Light	6.4		0.89	
Coal	4.6		0.66	
Building Materials	3.4		0.56	
Power	6.4		0.53	
Metallurgy	6.8		0.95	
Building	2.1		0.52	
Public Facilities	4.6		0.56	

3.3. Results

In Sections 3.1 and 3.2, it can be seen that ESCos and ECUs can calculate annual energy-saving quantity by the function of annual energy-saving quantity in terms of revamping cost obtained from regression according to the subsector where the project belongs, and calculate annual cost saving by the function of annual cost saving in terms of revamping cost. For example, applying Equations (9) and (15), annual energy-saving quantity and annual cost saving are about 21,800 tce and 19 million CNY, respectively, if an investment in an EPC project in the power subsector is estimated to be 50 million CNY. The advantage of this approach is that even if the ECU does not understand the expertise of the EPC project, through revamping cost, it can estimate the average level of annual energy-saving performance, which contributes to EPC investment decisions and trust relationships between ESCos and ECUs.

4. Research on the Influencing Factors of Revamping Cost

Research in Section 3 shows that annual energy-saving performance can be estimated through revamping cost. Nevertheless, what are the main factors that affect revamping cost? This question is studied in this Section.

4.1. Multiple Linear Regression Method of Revamping Cost

In order to further analyze the 194 samples of Table 3, EViews 7.0 software (Tongji University, Shanghai, China) was used to establish a multiple linear regression method as shown in Equation (19). For details, see Table A3 in Appendix A. Some samples do not have registered capital of ECU (such as government departments, hospitals, and other institutions), while others have no information on contract period. By deleting the missing data samples, the sample size of Equation (19) is 144; 50 fewer than the samples in Table 3.

$$\begin{aligned} \log(I) \quad &= \underset{(0.001)}{3.021} - \underset{(0.012)}{1.031}ma - \underset{(0.468)}{0.342}ch - \underset{(0.112)}{0.782}li + \underset{(0.746)}{0.171}co + \underset{(0.635)}{0.209}bm - \underset{(0.550)}{0.231}el - \underset{(0.004)}{1.155}bu + \underset{(0.801)}{0.113}pf \\ &+ \underset{(0.000)}{1.423}F - \underset{(0.860)}{0.0632}J + \underset{(0.000)}{0.372\log(REG_E)} + \underset{(0.797)}{0.0127\log(REG_Y)} + \underset{(0.001)}{0.086}T \\ &n = 144,\ R^2 = 0.638,\ Prob(F - statistic) = 0.000 \end{aligned} \tag{19}$$

where ma is the machinery manufacture subsector; ch is the chemical subsector; li is the light subsector; co is the coal subsector; bm is the building materials subsector; el is the power subsector; bu is the building sector; pf is the public facilities sector; F indicates whether or not the project is financed; J indicates whether the project enjoys financial incentive or tax preference; REG_E is registered capital of the ESCo; REG_Y is registered capital of the ECU; and T is the contract period.

The regression model of Equation (19) includes

- one constant term: 3.021;
- one dependent variable: $\log(I)$;
- three numerical variables: $\log(REG_E)$, $\log(REG_Y)$ and T; and
- ten categorical variables: eight subsectors; whether or not the sample is financed; whether or not the sample enjoys financial incentive or tax preference.

Metallurgical subsector is not included in Equation (19). This is because we have chosen metallurgical subsector to be the base group or benchmark group. There is a general principle for including dummy variables to indicate different groups: if the regression model is to have different intercepts for, say, g groups or categories, we need to include $g - 1$ dummy variables in the model, along with an intercept [34]. The intercept for the base group is the overall intercept in the model, and the dummy variable coefficient for a particular group represents the estimated difference in intercepts between that group and the base group; including g dummy variables along with an intercept will result in the dummy variable trap [34].

All other subsectors are compared to metallurgical subsector in Equation (19). Surely the other subsectors can be chosen to be the base group. This study explains it through an example. Consider the following simple model of revamping cost determination:

$$\log(I) = \beta_0 + \delta_0 ma + \beta_1 T + u. \quad (20)$$

In Equation (20), only two observed factors affect revamping cost: machinery manufacture subsector and contract period. Since $ma = 1$ when the sample belongs to machinery manufacture subsector, and $ma = 0$ when the sample does not belong to machinery manufacture subsector, the parameter δ_0 has the following interpretation: δ_0 is the difference in revamping cost between the sample belongs to machinery manufacture subsector and does not belong to machinery manufacture subsector, given the same amount of contract period (and the same error term u). In Equation (20), we have chosen the sample does not belong to machinery manufacture subsector to be the base group, that is, the group against which comparisons are made. We could choose the sample belongs to machinery manufacture subsector as the base group by writing the model as

$$\log(I) = \alpha_0 + \gamma_0 D + \beta_1 T + u, \quad (21)$$

where D indicates the project does not belong to machinery manufacture subsector; the intercept for the sample that belongs to machinery manufacture subsector is α_0, and the intercept for the sample that does not belong to machinery manufacture subsector is $\alpha_0 + \gamma_0$; this implies that $\alpha_0 = \beta_0 + \delta_0$ and $\alpha_0 + \gamma_0 = \beta_0$.

In any application, it does not matter how we choose the base group, but it is important to keep track of which group is the base group [34]. The results of regression model of Equation (19) are same if the other subsectors are chosen to be in the base group. This study chose metallurgical subsector to be the base group, only because it ranks first in Figure 2, Tables 2 and 3, etc.

4.2. Analysis of Factors Influencing Revamping Cost

4.2.1. The Subsectors

The coefficient of the machinery manufacture subsector in Equation (19) is −1.03 if other influencing factors are fixed, which means $(e^{-1.031} - 1) \times 100\% = -64.3\%$. This shows that the average revamping cost of the machinery manufacture subsector is 64.3% lower than that of the metallurgical subsector, statistically. Similarly, revamping cost of the chemical subsector is 29% lower than that of the metallurgical subsector. Revamping cost in the light, building materials, power subsectors, and building sector is 54.3%, 18.9%, 20.6%, and 68.5% lower, respectively, while revamping cost in the coal subsector and public facilities sector is 18.6% and 12.0% higher, respectively, than that of the metallurgical subsector. Therefore, the average revamping cost of the 144 samples in the statistical sense are as follows, in decreasing order: coal subsector, followed by public facilities, metallurgical, building materials, power, chemical, light, machinery manufacture, and building subsectors. This is partly because samples in the light, machinery manufacture, and building subsectors are mainly small projects.

4.2.2. Financing

Financing has a significant impact on revamping cost, statistically, if other influencing factors are fixed. Compared to samples that do not adopt financing methods, revamping cost of financed samples is $(e^{1.423} - 1) \times 100\% = 315\%$ higher on average. This is because most ESCos presently in China were established in recent years by policy stimulus, and have little experience and light assets. They are basically at the initial stage of development. Many of them cannot rely solely on their own funds to undertake projects, and need to be financed by financial institutions. Obviously, it will be more conducive to expanding the scale of investment if ESCos are able to get financing. However, we also found that only 34 of the 144 samples have financing (revamping cost comes partly from financing for 28 samples, and entirely from financing for 6 samples), and the other 110 samples are almost exclusively invested by ESCos. The difficulty in financing is another bottleneck for the development of EPC in China [13,14]. The characteristics of EPC project financing used to guarantee repayment of the loan are the future cash flow of the project and the asset value of the project itself, rather than the credit of the investors. The future income of projects has great uncertainty, which brings great risks to banks and other financial institutions. This characteristic also indirectly validates that this research has important practical value.

4.2.3. Financial Incentive or Tax Preference

Financial incentive or tax preference has no significant impact on revamping cost statistically if other influencing factors are fixed. China has incorporated EPC projects into the policy support system, which provides either financial incentive or tax preference. However, in terms of quantity, only 15 samples get financial incentive, 10 samples enjoy tax preference, and only four samples receive both financial incentive and tax preference, among the 144 samples. Financial incentive or tax preference should have an energizing effect on EPC projects. However, Equation (19) shows that the coefficient of financial incentive or tax preference is negative, and the corresponding probability value of the coefficient is 0.860. There are some reasons for this. (1) There may be multiple collinearity between financial incentive or tax preference and other factors. Upon testing, what is found is that the correlation coefficient between financial incentive or tax preference and the light subsector is relatively large. In addition, five samples get financial incentive or tax preference in the 10 effective samples of the light subsector, which is the highest proportion in all the subsectors. (2) Financial incentive or tax preference often happens in the phase of project implementation, that is, it is not clear whether the project will get such incentives in the future while determining revamping cost. (3) The amount of financial incentive or tax preference is not large. Specifically, EPC projects received 760 million CNY from the central financial award in total in Twelfth Five-Year, while the total investment in EPC projects was 371,100 million CNY in the same period. (4) In addition to asset incentives, there are a number of complex relationships between ESCos and the Chinese government, for example, some incentives are gratuitous, but there are additional conditions. The above four reasons make the impact of financial incentive or tax preference on revamping cost more complex, vague, and difficult to show.

4.2.4. Registered Capital

Registered capital of ESCos has a significant impact on revamping cost, statistically, if other influencing factors are fixed. If the registered capital of an ESCo increases 1%, the revamping cost will increase 0.37%, on average. In the 144 samples, seven samples use a guaranteed savings contract model, five samples (all in the building subsector) use an expense entrusted contract model, one sample uses a hybrid guaranteed savings and shared savings contract model, and the remaining 131 samples use a shared savings contract model. The distribution of contract models also explains why ESCos invested in most of the samples. In the shared savings contract model, the EPC project is financed and serviced by an ESCo, the energy cost saving is shared by the ESCo, and the ECU within the contract period according to negotiated rate, and ownership of the transformed facilities will be transferred to the ECU after the contract expires. Therefore, ESCos usually negotiate with ECUs on the shared rate of cost savings by improving the revamping cost ratio in this contract model. The funds that the ESCo can use are positively related to the ESCo's registered capital, hence registered capital of the ESCo influences revamping cost.

The ECU's registered capital has no significant impact on revamping cost statistically if other influencing factors are fixed. This is because investments of most samples come from the ESCo or the ESCo is responsible for part of the financing, even though the ECU invests in the EPC project, because coming from various subsectors, their registered capital is quite different.

4.2.5. Contract Period

Contract period has a significant impact on revamping cost, statistically, if other influencing factors are fixed. If the contract period increases 1%, the revamping cost will increase $(e^{0.086} - 1) \times 100\% = 9\%$, on average. In shared savings contracts, in order to obtain the maximum benefit, ESCos tend to negotiate longer contract periods, while ECUs love shorter contract periods. The result of the game is that a longer contract period often requires that the economic lifespan of the project is relatively longer, thus the revamping cost is pushed up.

5. Results and Discussion

5.1. Key Findings

5.1.1. Annual Energy-Saving Performance Based on Revamping Cost

Firstly, there are significant correlations between revamping cost and annual energy-saving quantity in the nine subsectors. Results of the curve estimation of EPC samples for annual energy-saving quantity in terms of revamping cost can be divided into four categories: power function (i.e., light, building materials, metallurgical, building, and public facilities subsectors), S curve (i.e., chemical subsector), quadratic curve (i.e., coal subsector), and linear function (i.e., machinery manufacture and power subsectors). ESCos and ECUs can calculate annual energy-saving quantity by the function of annual energy-saving quantity in terms of revamping cost.

Secondly, there are also significant correlations between revamping cost and annual cost saving in the nine subsectors. Moreover, the correlation between revamping cost and annual energy cost saving of the samples is greater than that between revamping cost and annual energy-saving quantity in most of the subsectors. Results of the curve estimation of EPC samples for annual cost saving in terms of revamping cost can be divided into two categories: power function (i.e., chemical, light, building materials, power, building, and public facilities subsectors) and linear function (i.e., machinery manufacture, coal, and metallurgical subsectors). Li et al. [14] assume $p(I, \alpha) = \alpha\sqrt{I}$ (where p is annual cost saving, I is revamping cost) for the annual energy bill saving in EPC projects. Though it is similar to most of the conclusions of Equations (10)–(18), the results of this study are based on subsectors and have more data support. ESCos and ECUs can calculate annual cost saving by the function of annual cost saving in terms of revamping cost.

5.1.2. Influencing Factors of Revamping Cost

As demonstrated in the multiple regression model shown in Equation (19), the sector the sample belongs to, financing, the registered capital of the ESCo, and the contract period have a significant impact on revamping cost, while the impacts of registered capital of the ECU, fiscal incentive, and tax preference on revamping cost are not obvious.

Specifically, firstly, the average revamping cost in this study are as follows, in decreasing order: coal subsector, followed by public facilities, metallurgical, building materials, power, chemical, light, machinery manufacture, and building subsectors. Secondly, compared to samples that do not adopt financing methods, revamping cost of financed samples is 315% higher on average. Thirdly, if the registered capital of an ESCo increases 1%, the revamping cost will increase 0.37% on average. And fourthly, if the contract period increases 1%, the revamping cost will increase 9% on average.

5.2. Policy Implications

Diseconomy of scale in EPC projects of most subsectors is shown in Sections 2 and 3. Moreover, high-investment projects of a similar nature, compared to their small counterparts, usually require longer average investment returns and bring more risks [13]. Therefore, small ESCos can compete for projects with small investment intensity to make limited funds turn around faster and improve their viability. Nevertheless, it is quite plausible that the most cost-effective projects have already been completed, leaving less "low-hanging fruit" for ESCos to target [35]. This has contributed to the intensifying competition in low-revamping-cost EPC projects. Moreover, it is necessary to expand EPC investment from the perspective of further improving energy utilization efficiency by the whole society. As can be seen in Figure 1, investment in China's EPC projects in 2016 totaled 107,355 million CNY, 126 times the 851 million CNY in 2003, but the growth rate of investment in 2015 and 2016 slowed obviously. The Thirteenth Five-Year Plan for the energy conservation and environmental protection industry [36] clearly puts forward expanding and strengthening the energy-saving service industry, and sets a target of total output value of the industry at 600 billion CNY in 2020 (the total output value in 2017 was about 414,800 million CNY). It can be seen that there is a large gap in the investment of EPC projects at the national level. This paper proposes four policy implications for promoting investment in EPC projects.

5.2.1. The Government Can Guide ESCos to Innovate EE Promotion Technology

The subsector of the project has a significant impact on revamping cost. On the one hand, this is due to the difference of energy-saving potential in the different subsectors, as discussed in Section 3.1, and on the other hand, it may also be related to the lower level of EE promotion technology in some subsectors. For example, the intensity of energy consumption for public buildings (not including buildings in heating areas in the north) was 22.5 kgce/m^2 [31] in 2015, lower than most developed countries. Meanwhile, ESCos generally obtain energy saving by using a single technology. Hence, the EE promotion space is relatively limited, which leads to the low average investment in EPC projects in the building subsector. Therefore, only by ESCOs' innovating of EE promotion technologies and promoting EE service content from single equipment, and a single project, to expanding to energy system optimization and regional EE promotion, can the EPC investment gap be alleviated at a deeper level. In China, EPC mechanism is introduced by the government from developed countries, so the government may develop measures to promote ESCos to innovate EE promotion technology.

5.2.2. The Government Need Clarify ESCos' Exit Mechanism

Registered capital of ESCos has a significant impact on revamping cost. EPC is really a market-oriented mechanism, but in China, the government has taken a top-down approach to promoting it after its introduction. This led to the total number of enterprises engaged in energy-saving service reaching 6137 in 2017. Therefore, after China entered the new development stage of letting the market decide the allocation of resources, it is necessary for ESCos to integrate upstream and downstream resources, and ESCos with less competitive strength will have to be eliminated. Therefore, the government should make clearer rules to facilitate the withdrawal of ESCos.

5.2.3. The Government Should Innovate Financing Mechanism and Improve the Market Credit Environment

Financing and contract period have significant impacts on revamping cost. In 2015, China officially abolished five management measures on financial incentives, including interim measures for the management of financial incentive funds for energy performance contract projects. The way to stimulate EPC industrial development with subsidies is no longer the main means, and the government, in its support for the industry, has begun to focus on providing a good institutional environment and policy guidance. Financing is the key to ensuring adequate investment in EPC projects, therefore, an effective financing mechanism for EPC projects should be developed. For the term of the contract period, a good institutional environment improved by the government helps to build a market credit environment, which will help ESCos and ECUs carry out designs for longer contract periods.

5.3. Discussion

Because the samples of this study from EMCA's statistics may not be fully representative, people will find that the annual energy-saving quantity and annual cost saving of some EPC projects are quite different, in practice, from the results calculated by Equations (1)–(18). The reasons the samples in this paper may not be fully representative are as follows: (1) Ninety percent of the 204 samples adopted shared savings contract models, quite different from the 63% in Twelfth Five-Year from EMCA's statistics [28], due to small projects usually having low investment and a short payback period, and tending to adopt a guaranteed savings contract model. (2) The typical projects from EMCA's statistics do not contain projects with poor energy-saving performance. (3) Other reasons, such as reporting biases, etc. In a word, it can be judged that the above samples, as a whole, may not wholly represent the EPC industry in China.

Therefore, the results of the curve estimation as shown in Tables 4–6 are conditional, and the details are as follows: (1) The EE promotion technology used by the assessed EPC project should be within the scope of the technology used in the 204 samples, i.e., the technology should be found in Table 2. If the EE promotion technology adopted by the project is relatively new, it is necessary to carry out a professional assessment to determine investment and benefit, rather than mechanically apply the results in this paper. (2) The revamping cost of the assessed EPC project should also be within the scope of the sample investment. If the investment is beyond the scope, the calculated annual energy-saving performance may deviate. (3) The time of project evaluation should be close to 2016. If it is a project takes place many years later, it will lead to a deviation, due to the progress of technology, the increase of marginal cost of EE investment year by year, and the change of energy price.

In addition, it is important to note that the difference of outlier elimination will lead to a difference of research conclusions. For example, if the sample with 35 million CNY revamping cost in the coal subsector in Section 3.1.3 is removed as an exception, the relationship of annual energy-saving performance in terms of revamping cost will change correspondingly. A variety of factors affect whether a sample is an exception or not, such as the classification method of samples. This paper is based on the classification of the nine subsectors according to EMCA. If the sample number is large enough, research on the relationships of annual energy-saving performance in terms of revamping cost will be more meaningful based on the classification of EE promotion technology, because the same EE technology may be used in different subsectors, but energy-saving performance has more commonalities.

6. Conclusions

Despite the rapid development of EPC in China, EPC project investment is still facing bottlenecks, considering the wide market space for EE promotion and the increasing policy support. A lack of trust in ESCo is the most critical factor affecting the development of EPC in China compared with other constraints. This study focuses the regression relationships of annual energy-saving performance in terms of revamping cost. The results show that there are statistically significant correlations in the above relationships in the nine subsectors investigated. It is significant for ESCos and ECUs, because knowledge on energy-saving performance could contribute to EPC investment decisions and trust relationships between them. To find out what are the main factors affecting revamping cost, a multiple linear regression model is set up. It indicates that the subsector the sample belongs to, financing, registered capital of the ESCo, and contract period, have significant effects on revamping cost. These findings will be helpful to formulate the related support policies.

This paper also has some limitations. First, the samples of this study from EMCA's statistics may not be fully representative, therefore, the results of the curve estimation, as shown in Tables 4–6, are conditional. Second, the difference of outlier elimination will lead to a difference of research conclusions (e.g., the relationships of annual energy-saving performance in terms of revamping cost); the relationships can be studied more meaningfully based on the classification of EE promotion technology, when more samples are collected in the future.

Author Contributions: H.R., X.G., and C.M. analyzed the data; H.R. and C.M. wrote the paper.

Acknowledgments: We thank Zhonghan Liu from University of Houston for providing language help.

Conflicts of Interest: The authors declare no conflict of interest.

Appendix A

Table A1. ANOVA of revamping cost in terms of annual energy-saving quantity in curve estimation *.

Subsector	Sum of Squares		df	Mean Square	F	Sig.
Machinery Manufacture	Regression	35,436,882.655	1	35,436,882.655	24.766	0.000
	Residual	17,170,546.550	12	1,430,878.879		
	Total	52,607,429.206	13			
Chemical	Regression	7.878	1	7.878	11.668	0.006
	Residual	7.427	11	0.675		
	Total	15.304	12			
Light	Regression	14.754	1	14.754	40.424	0.000
	Residual	3.650	10	0.365		
	Total	18.403	11			
Coal	Regression	62,747,324.159	2	31,373,662.079	12.191	0.003
	Residual	23,161,090.616	9	2,573,454.513		
	Total	85,908,414.774	11			
Building Materials	Regression	17.148	1	17.148	121.341	0.000
	Residual	1.555	11	0.141		
	Total	18.703	12			
Power	Regression	4,149,422,721.139	1	4,149,422,721.139	105.636	0.000
	Residual	903,447,660.773	23	39,280,333.077		
	Total	5,052,870,381.912	24			
Metallurgy	Regression	90.841	1	90.841	157.424	0.000
	Residual	23.082	40	0.577		
	Total	113.923	41			
Building	Regression	26.185	1	26.185	46.761	0.000
	Residual	22.959	41	0.560		
	Total	49.144	42			
Public Facilities	Regression	15.296	1	15.296	11.107	0.004
	Residual	24.790	18	1.377		
	Total	40.086	19			

* Independents: revamping cost of the samples (10,000 CNY); dependents: annual energy-saving quantity (tce).

Table A2. ANOVA of revamping cost in terms of annual cost saving in curve estimation *.

Subsector	Sum of Squares		df	Mean Square	F	Sig.
Machinery Manufacture	Regression	597,789.255	1	597,789.255	68.207	0.000
	Residual	113,937.200	13	8764.400		
	Total	711,726.454	14			
Chemical	Regression	9.458	1	9.458	26.843	0.000
	Residual	3.876	11	0.352		
	Total	13.334	12			
Light	Regression	14.801	1	14.801	82.811	0.000
	Residual	1.787	10	0.179		
	Total	16.589	11			
Coal	Regression	1,266,923.556	1	1,266,923.556	26.334	0.000
	Residual	481,096.179	10	48,109.618		
	Total	1,748,019.735	11			
Building Materials	Regression	18.098	1	18.098	56.760	0.000
	Residual	3.826	12	0.319		
	Total	21.924	13			
Power	Regression	44.090	1	44.090	249.928	0.000
	Residual	4.057	23	0.176		
	Total	48.148	24			
Metallurgy	Regression	66.636	1	66.636	111.143	0.000
	Residual	23.982	40	0.600		
	Total	90.619	41			

Table A2. *Cont.*

Building	Regression	32.833	1	32.833	90.270	0.000
	Residual	16.368	45	0.364		
	Total	49.201	46			
Public Facilities	Regression	10.739	1	10.739	17.756	0.001
	Residual	10.886	18	0.605		
	Total	21.625	19			

* Independents: revamping cost of the samples (10,000 CNY); dependents: annual cost saving (10,000 CNY).

Table A3. Multiple regression results *.

Variable	Coefficient	Std. Error	*t*-Statistic	Prob.
Constant	3.020673	0.892696	3.383764	0.0009
Machinery manufacture subsector	−1.030871	0.404814	−2.546531	0.0120
Chemical subsector	−0.341498	0.469324	−0.727639	0.4681
Light subsector	−0.781959	0.488855	−1.599572	0.1121
Coal subsector	0.170786	0.525832	0.324792	0.7459
Building materials subsector	−0.209356	0.440275	−0.475511	0.6352
Power subsector	−0.230760	0.385362	−0.598814	0.5503
Building subsector	−1.155329	0.391073	−2.954256	0.0037
Public Facilities subsector	0.112704	0.446362	0.252495	0.8011
Financing	1.423285	0.283553	5.019462	0.0000
Financial incentive or tax preference	−0.063197	0.357215	−0.176916	0.8598
Log(REG_E)	0.372210	0.076802	4.846377	0.0000
Log(REG_Y)	0.012741	0.049293	0.258464	0.7965
T	0.086389	0.023537	3.670422	0.0004
R-squared	0.473740	Mean dependent var		6.656395
Adjusted R-squared	0.421114	SD dependent var		1.678460
S.E. of regression	1.277049	Akaike info criterion		3.419146
Sum squared resid	212.0109	Schwarz criterion		3.707878
Log likelihood	−232.1785	Hannan–Quinn criter		3.536470
F-statistic	9.002013	Durbin–Watson stat		2.214652
Prob(F-statistic)	0.000000			

* Dependent variable: log(*I*).

Table A4. Abbreviations.

Acronym	ESCo	EPC	ECU	CNY	tce	EE
Full Name	Energy Service Company	Energy Performance Contracting	Energy-Consuming Unit	Chinese Yuan	Ton of standard coal equivalent	Energyefficiency
Acronym	HVAC	gce	Q	I	$\bar{q}$	q
Full Name	Heating, ventilation, and air-conditioning	Gram of standard coal equivalent	Annual energy-saving quantity	Revamping cost	Average annual energy-saving quantity of unit investment	Annual energy-saving quantity of unit investment
Acronym	*li*	*bm*	*me*	*bu*	*pf*	*ch*
Full Name	Light subsector	Building materials subsector	Metallurgicalsubsector	Building subsector	Public facilities subsector	Chemical subsector
Acronym	*co*	*ma*	*el*	S	$\bar{s}$	c_v
Full Name	Coal subsector	Machinery manufacture subsector	Power subsector	Annual cost saving	Average annual cost saving of unit investment	Coefficient of variation
Acronym	σ	μ	REG_E	REG_Y	T	D
Full Name	Standard deviation	Average value	Registered capital of the ESCo	Registered capital of the ECU	Contract period	The project doesn't belong to machinery manufacture subsector

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