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A Literature Review on Energy Performance Contracting Project Financing

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Abstract

Under the global "dual carbon" goals, Energy Performance Contracting (EPC) has become the core market-oriented model for energy conservation and emission reduction, playing a significant role in the transformation of high-energy-consumption industries and building energy efficiency retrofits. However, financing difficulties have severely restricted its large-scale promotion. This paper focuses on the core issues of overcoming financing difficulties, model innovation, and scenario adaptation for EPC projects, systematically reviewing relevant literature from four dimensions: EPC theory and practice, project financing, and EPC project financing theory and practice. The study finds that the difficulties in financing EPC projects stem from five major pain points: high project risks, insufficient ESCO qualifications, and lack of collateral. Theoretical research focuses on innovative paths such as building a risk management and control system and integrating carbon trading. At the practical level, research directions such as optimizing contract terms and adapting to diverse scenarios have been formed. Adaptation solutions for characteristic scenarios such as rural energy transformation in China and renovation of old apartment buildings in Slovakia have been explored. Existing research covers various aspects of theory and practice, but there is still room for expansion in areas such as policy adaptation in different regions and cross-industry financing scheme migration. By integrating research threads, this paper clarifies the strengths and weaknesses of existing research, providing theoretical support for the construction of targeted financing solutions and the improvement of policy systems in the future, thereby assisting the EPC model in fully exerting its energy conservation and carbon reduction efficiency.

Keywords

Energy Performance Contracting; project financing; energy conservation and emission reduction; model innovation

1. Introduction

Guided by the global "dual carbon" goals, energy conservation and emission reduction have become the core issue in the transformation and development of various industries. Energy Performance Contracting (EPC), as a key market-oriented

energy conservation model, plays an irreplaceable role in the transformation of high-energy-consumption industries and building energy conservation and renovation. Through the win-win cooperation mechanism between Energy Service Companies (ESCOs) and Energy Users (EUs), it effectively breaks the financial and technological bottlenecks of energy conservation and renovation, injecting sustained momentum into low-carbon development. However, EPC projects generally face the core dilemma of difficult and expensive financing, which has become a key bottleneck restricting their large-scale promotion. Issues such as high project risks, insufficient ESCO qualifications, lack of collateral, and imperfect guarantee mechanisms, coupled with adaptability challenges in different scenarios, make it difficult for financial resources to effectively meet project needs. Meanwhile, although the diversified models in the field of supply chain financing provide ideas for solving financial constraints, the specificity of EPC projects makes it difficult to directly apply existing solutions. Against this backdrop, systematically reviewing research results related to EPC project financing, clarifying core disputes in theoretical research and key obstacles in practical applications, holds significant theoretical and practical importance. This paper focuses on the core issues of breaking the dilemma, innovating models, and adapting scenarios for EPC project financing. It conducts a literature review from four dimensions: EPC theory and practice, project financing, and the theory and practice of EPC project financing. The aim is to integrate existing research threads, identify the strengths and weaknesses of current research, provide theoretical support for the construction of targeted solutions and the improvement of policy systems, and assist the EPC model in fully exerting its energy conservation and carbon reduction efficiency.

2. Literature review on energy performance contracting

2.1. Overview of theoretical research on energy performance contracting

In the theoretical research field of energy performance contracting (EPC), relevant studies based on the game theory paradigm have become the mainstream research orientation. Under the global "dual carbon" goals, EPC is the key to energy-saving transformation in high-energy-consumption industries. However, the EPC cooperation decision-making of competing manufacturers in the manufacturing industry still needs to be further explored. Unlike the urban-rural income gap, which stems from differences in production methods, the core contradiction of EPC cooperation lies in the co-opetition relationship between enterprises and product characteristic differences: competing manufacturers are both suppliers and demanders of EPC energy-saving services, and they also produce substitutable products in the market, forming a unique co-opetition dynamic. This relationship directly affects the effectiveness of EPC decision-making: the stronger the product substitutability, the lower the EPC revenue-sharing ratio set by customers, and the

higher the energy-saving service level of ESCOs is usually. However, under a high service cost coefficient and a specific sharing ratio range, the service level will first decrease and then increase. Although EPC can increase total market output, reduce prices, increase consumer surplus, and benefit both parties, its impact on energy consumption is not unidirectional—when the market size is small and product substitutability is weak, it may exacerbate energy consumption, and effective energy saving can only be achieved when both are at a high level. Rising service costs will drive energy consumption down, and the matching degree between product substitutability and market size is the core that affects the environmental benefits of EPC. Blind implementation may trigger a rebound in energy consumption [1].Under the traditional model, energy consumption units (EU) occupy a dominant position and enjoy most of the benefits, while energy service companies (ESCO) as the main implementers only receive a small amount of contract-period revenue, leading to an imbalance in the interests of both parties and dampening the enthusiasm for ESCO cooperation. Although EU often demonstrates altruistic behavior to achieve a win-win situation, the actual results often deviate from expectations. Existing research has addressed the game relationship in EPC, but it lacks an in-depth exploration of the key factor of altruistic preference, and it is not clear how the altruistic preferences of EU and ESCO affect their decision-making and revenue distribution. At the same time, the altruistic preferences of different entities vary across cultures and scenarios, and their mechanism of action in core decisions such as revenue sharing ratio and investment amount in the EPC scenario is not yet clear. Therefore, research needs to address how to quantify the impact of altruistic preference on EPC projects, construct decision-making models that are adaptable to different altruistic preference scenarios, balance the interests of both parties, and provide theoretical support for the stable development of the industry [2].The current situation of high energy consumption and low efficiency in the manufacturing industry makes technological cooperation a key path to enhance energy efficiency. However, disadvantaged manufacturers often find it difficult to collaborate with dominant manufacturers possessing efficient energy-saving technologies due to their inability to bear the cooperation costs. Existing research has mostly focused on the application of pure enterprise co-opetition or EPC models in both supply and demand sides, but has neglected the cooperative decision-making issues among manufacturers based on EPC in a competitive environment. In a duopoly market, homogeneous product competition coexists with significant technological gaps, leading to a "co-opetition" relationship among manufacturers. However, existing research has not clarified the feasibility of EPC cooperation in this scenario. At the same time, there is a lack of systematic exploration on how factors such as market size, revenue sharing ratio, and technological gap affect the cooperative decision-making of both parties, as well as the optimal level of cooperation when dominant manufacturers retain some

technologies. Therefore, the research needs to address three core issues: first, the feasibility of EPC cooperation between superior and inferior manufacturers in a competitive market; second, the optimal decision-making of EPC cooperation between both parties and the mechanism of its impact on profits; third, the optimal level of cooperation under the technology retention strategy of dominant manufacturers. Ultimately, this research aims to provide theoretical support for manufacturers' cooperative decision-making and the improvement of industry energy efficiency [3].

2.2. Overview of Practical Research on Energy Performance Contracting Projects

In the field of practical research on energy performance contracting (EPC), EPC-related research on actual cases from different countries is a key focus for researchers. Distributed Energy Resources (DERs) investment is the core support for the expansion of distribution networks, but traditional investment models have significant shortcomings: firstly, there is a lack of comprehensive management of the entire project lifecycle, making it difficult to ensure the coherence and effectiveness of the investment process; secondly, distribution network operators (DNOs) and energy consumers (ECs) fail to achieve precise matching at the investment level, leading to difficulties in balancing the interests of both parties. At the same time, the EC group has obvious limitations in capabilities and resources. Most ECs (such as large shopping malls, public institutions, communities, etc.) lack energy renovation technology, and some also face funding shortages, making it impossible for them to independently carry out energy renovation projects related to DERs investment. Furthermore, different ECs have varying profit demands and project scales, and existing investment mechanisms lack targeted adaptation solutions, making it difficult to meet investment needs in diverse scenarios. Based on this, the research needs to address the key issues of how to construct a scientific EPC investment model, achieve full-process project control and precise matching between DNOs and ECs through reasonable mechanism design, and adapt to different scenario needs, ensuring that both parties obtain satisfactory expected returns, thereby promoting the optimization and expansion of distribution networks [4].The application of EPC in the energy service market of Türkiye is still in its developmental stage and has not fully played its role. Existing research lacks a systematic analysis of the current status of EPC application in the Turkish market, as well as the perceptions and practical barriers faced by participants. The alignment between relevant legislation and market practices also needs to be clarified. The core research issues focus on three aspects: First, the level of awareness and practical experience of Turkish market participants (EVD representatives, facility staff, independent energy managers) regarding EPC, including differences in implementation processes and outcomes between energy efficiency projects with and without EPC participation; second, the main obstacles in advancing EPC projects,

especially prominent issues in financing, contract design, and technical awareness; third, the future preferences of market participants towards EPC and the influencing factors, providing a basis for market expansion. Furthermore, it is necessary to verify the correlation between EPC application and key project indicators (such as payback period, budget, energy saving rate, etc.), clarify whether current EPC practices meet standard requirements, and ultimately provide policy and practical references for the standardized and scaled development of the Turkish EPC market [5].As a globally promoted energy-saving marketization tool, Energy Performance Contracting (EPC) faces numerous insurmountable obstacles in rural energy management in China. Rural houses account for one-third of the country's total building stock, and their low-carbon transformation is crucial to achieving the national carbon neutrality goal. Existing research indicates that the traditional EPC model is difficult to adapt to rural scenarios, and the core issues urgently need to be clarified and resolved. Research should focus on four core issues: First, the key reasons for the failure of the traditional EPC model in rural areas, clarifying the impact mechanisms of obstacles such as limited economic capacity of farmers, weak awareness of energy conservation, small project scale, high operation and maintenance costs, and lack of mutual trust; second, the core design elements of an EPC model suitable for rural areas, exploring how to break through existing bottlenecks through optimization of risk and benefit allocation, financing mechanisms, and payment collection methods; third, the differences in practical effects of different adaptive models, verifying the feasibility and applicability of innovative models such as local government participation and direct settlement with the power grid; fourth, the policy support system for the large-scale promotion of rural EPC, identifying the policy and technical safeguards required for the promotion of adaptive models, ultimately providing an effective path for the low-carbon transformation of rural energy [6].Educational buildings in Malaysia consume high amounts of energy, accounting for a significant proportion of energy consumption in commercial buildings. EPC (Engineering, Procurement, and Construction) is an effective mechanism to address the issues of high investment and high operation and maintenance costs in their energy-saving renovation. However, existing research mostly focuses on energy-saving measures themselves, lacking a dedicated EPC model specifically for educational buildings. The core research issues revolve around three aspects: first, how to select energy-saving measures suitable for tropical climate educational buildings based on preliminary energy audit data (such as optimization and replacement of chillers, lighting renovation, and establishment of energy management systems); second, how to construct a scientific EPC model through regression analysis to clarify the prediction methods for key indicators such as energy savings, cost savings, carbon emission reductions, and return on investment; third, how to determine a reasonable distribution ratio of energy-saving benefits between ESCO (Energy Service Company)

and the school, and analyze the impact of different distribution schemes on the benefits of both parties. In addition, the research needs to verify the feasibility and effectiveness of the constructed EPC model, ensuring that it meets national energy efficiency standards, and provide a replicable practical solution for educational buildings to achieve energy conservation, carbon reduction, and cost control through the EPC model [7].

3. Literature review on project financing

3.1. Overview of supply chain financing decision-making and coordination under different financing modes

Currently, researchers primarily focus on the study of supply chain decision-making, coordination, and influencing factors under different financing models. The difficulty in financing for small and medium-sized enterprises (SMEs) is a key issue that restricts the development of supply chains. As an important mode of supply chain finance, accounts receivable financing involves only banks and SMEs in traditional models, which have defects such as insufficient credit and high loan risks. Although the participation of core enterprises provides a new approach to solving this problem, the strategic interaction and equilibrium mechanism among the three parties are not yet clear. The core research issues focus on three aspects: first, how to construct a tripartite evolutionary game model involving banks, SMEs, and core enterprises, and analyze the payoff matrix and replication dynamic equations under the strategies of "weak regulation/strong regulation" and "default/no default"; second, clarifying the relationship between the reputation loss of core enterprise default and the total amount of accounts receivable, as well as the impact mechanism of key factors such as bank loan interest rates on the game evolutionary equilibrium; third, exploring a stable strategy combination that can achieve a win-win situation for all three parties, and verifying the actual effect of core enterprise participation in reducing bank loan risks and enhancing the credibility of accounts receivable. In addition, the research needs to verify the validity of the model through numerical simulation, providing theoretical support for optimizing the accounts receivable financing model, formulating reasonable loan interest rates, and improving credit constraint mechanisms, thereby facilitating the sustainable development of supply chain finance [8].The financial constraints faced by small and medium-sized enterprises (SMEs) are a key bottleneck in the development of supply chains. As important internal financing models in supply chain finance, supplier financing (SF) and supplier investment (SI) urgently require clarification of their decision-making mechanisms and coordination issues. Existing research has mostly focused on risk aversion among SMEs, neglecting the impact of core enterprises' (suppliers') risk attitudes on financing strategies, and lacks a systematic comparison and coordination mechanism design for these two types

of internal financing models. The core research questions revolve around four aspects: first, how supplier risk aversion (measured by CVaR) affects equilibrium decisions such as wholesale prices and order quantities, as well as the profits of both parties, under SF and SI models; second, the applicable scenarios and Pareto improvement areas of SF and SI models, comparing their advantage boundaries relative to bank credit financing (BCF); third, the mechanism by which key parameters such as profit-sharing coefficients and investment ratios affect the decisions and profits of the two models; fourth, how to design a financing cost-sharing mechanism to achieve centralized decision coordination in supply chains when both suppliers and demanders are risk-averse. The research aims to reveal the selection logic of supply chain financing strategies under risk aversion, providing theoretical support for core enterprises to develop adaptive financing schemes and enhance the overall efficiency of the supply chain [9].Under the backdrop of carbon emission reduction policies, capital-constrained manufacturers face financing challenges in their green investments. Green credit financing (GCF) and traditional trade credit financing (TCF) are two key solutions, yet their applicable scenarios, emission reduction effects, and impacts on supply chain profits remain unclear. The core research questions focus on three aspects: First, the differences in financing mechanisms between GCF (hard constraints on carbon emission reduction) and TCF (soft constraints on penalties for excess carbon emissions), clarifying the formation logic of equilibrium decisions such as manufacturer production volumes and supplier wholesale prices under the two modes; second, the impact mechanisms of key parameters such as green investments, carbon emission limits, and bank interest rates on the performance of the two financing modes, as well as the strategic preference differences between the two parties in the supply chain; third, a comparison of social welfare between the two financing modes, exploring the path to achieving a win-win situation for manufacturer profits and social welfare. Furthermore, the research needs to clarify how the government can guide manufacturers to choose suitable financing modes by setting carbon emission limits, providing theoretical support for the green transformation of the supply chain and optimization of financing decisions, while verifying the emission reduction effectiveness and economic feasibility of the two financing modes under different constraints [10].In the green supply chain, green innovation cooperation led by manufacturers is prone to raise fairness concerns among green retailers, which in turn affects product greenness and channel profits. However, existing research lacks coordination mechanisms and profit allocation scheme designs tailored to this scenario. The core research issues focus on four aspects: First, the impact mechanism of green retailers' fairness concerns on product greenness, channel profits, and pricing strategies, clarifying their differentiated effects in cooperative and non-cooperative scenarios; second, how to construct a profit allocation

coordination mechanism (Shapley Value Mechanism (SVM), Nucleolus Solution Mechanism (NSM), Tau Value Mechanism (TVM)) tailored to this scenario based on cooperative game theory; third, the differences in profit allocation logic, beneficiary entities, and alliance stability among the three coordination mechanisms; fourth, the moderating effect of the degree of green retailers' fairness concerns on profit allocation results under the three coordination mechanisms, exploring the feasibility of narrowing the profit gap between manufacturers and retailers. The research aims to address channel conflicts caused by green retailers' fairness concerns, provide a theoretical basis for selecting appropriate coordination mechanisms in supply chains under different power structures, and verify the moderating value of fairness concerns in profit allocation [11].

3.2. Overview of supply chain financing adaptability and decision-making research in multi-channel or multi-agent scenarios

In the theoretical research field of energy performance contracting (EPC) project financing, core issues such as overcoming financing difficulties, risk management and control, and constructing innovative models are the focus of researchers' attention. When multi-channel retailers (offline + third-party platforms) sell green products, the demand growth brought by platform channels exacerbates financial constraints. Bank credit financing (BF) and third-party platform credit financing (TF) are two core solutions, but their compatibility and impact on supply chain decisions have not been clearly defined. The core research issues focus on three aspects: First, the impact of the two financing models on retailers' dual-channel operations, clarifying the formation mechanism of differences in retail prices, interest rates, and manufacturer wholesale prices under TF and BF models; second, the key conditions for retailers to choose TF or BF, comparing the advantages and disadvantages of the two models in terms of profit, demand, and pricing boundaries; third, the moderating effect of revenue sharing rate on supply chain decisions under the two financing models, clarifying its differential impact on wholesale prices and retail prices. In addition, the research needs to verify the applicable scenarios of TF model as a "win-win strategy", revealing its inherent logic in reducing interest rates, stimulating demand, and simultaneously increasing manufacturer wholesale prices, providing theoretical support for the financing decisions and supply chain pricing optimization of multi-channel green product retailers under capital constraints [12].The core challenge faced by financially distressed manufacturers is capital turnover difficulties, and the reasonable selection of supply chain financing schemes directly affects the overall efficiency of the supply chain. However, existing research has not yet clarified the adaptation logic of different financing modes under price-sensitive demand. The core research issues focus on three aspects: First, in dual-channel and multi-stage supply chains, the differentiated impact mechanisms of three financing schemes,

namely, reverse factoring, non-reverse factoring (including external financing and trade credit), and hybrid reverse factoring, on the profits of manufacturers and retailers; second, under price-sensitive demand scenarios, the applicable boundaries of various financing schemes, and clarifying the moderating effects of key factors such as market size on scheme selection; third, the preference differences and causes of various supply chain entities (manufacturers and retailers) towards different financing schemes, explaining the contradiction between total supply chain profits and individual preferences. The research aims to solve the financing decision-making challenges faced by financially distressed manufacturers, reveal the core differences in profit creation among different financing schemes, and provide theoretical basis and practical reference for enterprises to select the optimal supply chain financing scheme based on market size and demand characteristics [13].In a multi-manufacturer-led multi-channel supply chain (including online direct sales and retailer channels), channel expansion exacerbates manufacturers' financial constraints. However, existing research has primarily focused on single-manufacturer or single-channel financing, lacking targeted discussions on the multi-manufacturer scenario. The core research questions revolve around three aspects: First, under decentralized decision-making, the impact mechanisms of two financing modes, namely bank loan financing and retailer prepayment financing with price discounts, on the optimal pricing (wholesale price, direct sales price, retail price) and channel demand of supply chain members (multiple manufacturers, retailers); second, the moderating effects of key parameters such as manufacturers' initial capital levels, price discounts, and bank interest rates on financing mode selection, clarifying the adaptive financing schemes under different capital constraints; third, a performance comparison between the two financing modes, elucidating the advantage logic of the prepayment mode in profit retention, channel demand enhancement, and its impact on decision-making interactions among multiple manufacturers. The research aims to address the challenging issue of differentiated financing decisions under the financial constraints of multiple manufacturers, reveal the differences in the impact of the two financing modes on the overall and individual benefits of the supply chain, and provide theoretical support for enterprises to select optimal financing strategies based on their capital conditions and market parameters [14].

4. Literature review on financing of energy performance contracting projects

4.1. Overview of theoretical research on financing risk management and control and innovative models for energy performance contracting projects

Energy Performance Contracting (EPC) is a key model for promoting energy conservation and emission reduction. However, financing challenges have become a

core bottleneck restricting the implementation and development of related projects in China, which urgently requires systematic clarification and resolution. The core research issues focus on five aspects: First, the project carries high risks, with a time mismatch between investment and returns, and strict credit approval due to banks' insufficient understanding of the industry, making financing difficult; second, energy-saving service companies are mainly small and medium-sized enterprises with low registered capital and creditworthiness, making it difficult to meet the loan requirements of financial institutions; third, the industry has low recognition, and the market has limited understanding of the EPC operation model, increasing the difficulty of evaluation by financial institutions; fourth, projects lack effective collateral, with unclear ownership of core assets during the contract period, making it difficult to meet traditional financing collateral requirements; fifth, the financing guarantee mechanism is imperfect, with energy-saving service companies lacking guarantee resources and insufficient external guarantee support. The research aims to comprehensively analyze the root causes of the financing difficulties of China's EPC projects, providing a theoretical basis for subsequently constructing targeted financing solutions, improving the policy support system, and enhancing the accessibility of industry financing, thereby facilitating the large-scale promotion of the EP model to achieve energy conservation and emission reduction goals [15].Energy Performance Contracting (EPC) is a key model for promoting energy conservation and emission reduction. However, high financing risks and difficulties in financing have become the core bottleneck restricting the development of related projects in China. Existing research lacks a systematic risk management framework. The core research issues focus on five aspects: First, clarifying the formation mechanism of financing risks and identifying how factors such as principal-agent problems and information asymmetry lead to multidimensional risks in policies, markets, financial institutions, energy-using units, and energy-saving service companies; second, constructing a scientific risk identification system and comprehensively identifying risk factors throughout the entire life cycle of the project using a hierarchical holographic modeling method; third, empirically analyzing key influencing factors of risk and exploring the correlation between variables such as technological progressiveness and loan-to-value ratio and financing risks; fourth, establishing an adaptive risk evaluation model and combining the Analytic Hierarchy Process (AHP) and Fuzzy Comprehensive Evaluation (FCE) to achieve quantitative risk assessment; fifth, designing effective risk prevention mechanisms and verifying the feasibility of introducing financial leasing and multi-party collaboration models to reduce risks and alleviate financing difficulties. The research aims to fill the research gap in financing risk management for EPC projects in China, provide theoretical basis and practical solutions for risk control for energy-saving service companies, financial institutions, and policymakers, and facilitate the large-scale promotion of the EPC model [16].The development of the

carbon trading market provides a possibility for relying on the carbon emission reduction potential of projects to overcome financing difficulties. However, existing research has not fully integrated the correlation mechanism between carbon trading and EPC financing. The core research issues focus on three aspects: First, constructing an EPC financing model that is compatible with the total carbon control and quota trading system, and clarifying differentiated financing path designs based on carbon demand (self-use/non-self-use) and trading periods (before trading/after trading). Second, establishing a scientific carbon emission rating model, describing carbon trading price fluctuations through parabolic fuzzy numbers, and quantifying and defuzzifying the carbon option price range by combining the fuzzy binary tree model. Third, verifying the feasibility of this financing model and rating model, and analyzing their practical effects on improving the availability, profitability, and flexibility of project selection for EPC projects. The research aims to fill the research gap in the integration of carbon trading and EPC financing, provide new financing solutions for energy-saving service companies (ESCOs) and energy-using units, and provide theoretical and practical support for the coordinated development of the carbon trading market and EPC projects [17].

4.2. Identify the Headings

In the field of practical research on the financing of energy performance contracting (EPC) projects, practical application issues such as contract term optimization, adaptation to different scenarios, and analysis of factors affecting implementation are the focus of researchers' attention. Energy performance contracting (EPC) is an important mechanism for energy conservation and emission reduction in China, but the formation mechanism of contract terms (investment scale, investment share, contract duration) and the impact of financing on them have not been clearly defined, and existing research lacks quantitative analysis. The core research issues focus on three aspects: first, constructing a bargaining theory model between ESCOs and energy-using units to clarify the structural impact of factors such as capital costs and risk preferences of both parties on the core terms of the contract; second, based on nearly 140 EPC contract data from 2010 to 2011, empirically testing the quantitative impact of ESCOs' and energy-using units' registered capital, financing methods (equity, loan, lease, etc.), industry type, and government subsidies on investment scale, energy-saving effect, and contract duration; third, verifying the key role of effective financing (especially low-cost debt financing) in enhancing the investment level of EPC projects, extending contract duration, and enhancing energy-saving effect, and clarifying the financing optimization path in scenarios where ESCOs bear the majority of investment share. The research aims to reveal the formation logic of EPC contract terms, highlight the core supporting role of low-cost financing for the effectiveness of EPC projects, and provide theoretical and empirical evidence for improving financing mechanisms, optimizing contract design, and promoting

industry development [18].There is potential for energy conservation in a large number of old apartment buildings built during the pre-socialist era in Slovakia, but there is a lack of systematic research on the applicability of the EPC (Engineering, Procurement, and Construction) model in the renovation of such buildings. Existing research results are difficult to support financing decisions under different economic scenarios. The core research issues focus on three aspects: First, select five representative old apartment buildings and design renovation schemes covering building envelope (exterior walls, roof insulation, etc.) and technical systems (heating, lighting, etc.), clarifying the energy-saving and investment characteristics of different sub-schemes. Second, construct five economic scenarios: optimistic, baseline, negative, pessimistic, and extreme, and quantify the feasibility of EPC financing under different scenarios through indicators such as payback period and net present value. Third, compare the EPC adaptability of building envelope and technical system renovation measures, and analyze the impact mechanism of economic fluctuations (changes in investment costs and energy prices) on the attractiveness of EPC. The research aims to fill the gap in EPC financing research for old apartment buildings, clarify the applicable scenarios and limitations of the EPC model, provide decision-making basis for single owners (such as municipal authorities) to promote building renovation through EPC, and offer references for subsidy design or combination of multiple financing methods for building envelope renovation [19].In the context of promoting energy conservation and emission reduction globally, the promotion of the EPC (Engineering, Procurement, and Construction) model for urban residential buildings is crucial for reducing energy consumption. However, the multiple factors involved in the implementation of this field and their interaction mechanisms have not been clearly defined, which restricts the effective implementation of the model. The core research issues focus on three aspects: First, systematically identifying the key influencing factors of EPC implementation in global urban residential buildings, sorting out 47 core factors covering both supply and demand sides, and clarifying the attributes and scope of each factor; second, using the Interpretative Structural Modeling (ISM) to construct a hierarchical system of factors, clarifying the hierarchical relationships between core thematic factors, intermediate supporting factors, cross-influencing factors, and grassroots driving factors; third, analyzing the influence scope and action paths of each factor, focusing on clarifying the extensive influence of risk factors and the cross-dimensional action mechanisms of some factors on higher-level factors. The research aims to reveal the complex network of factors in the implementation of the EPC model for urban residential buildings, providing a basis for identifying participating entities, key links, tools, and environmental elements in the implementation process. At the same time, it provides theoretical support for emphasizing residents' needs and leveraging the driving role of grassroots factors, facilitating the large-scale application of the EPC model in the field of urban

residential buildings [20].

5. Summary

This article systematically reviews the relevant literature on energy performance contracting (EPC) project financing, focusing on the core issue of overcoming financing difficulties, model innovation, and scenario adaptation. From four dimensions: EPC theory and practice, project financing, and EPC project financing theory and practice, the article clarifies the core viewpoints and analytical framework of existing research. At the core research level of EPC project financing, existing results reveal the complexity and scenario differences of the issue: in terms of financing theory, the root causes of financing difficulties are concentrated in five major pain points: high project risks, insufficient qualifications of energy service companies (ESCOs), low industry recognition, lack of collateral, and imperfect guarantee mechanisms. Building a systematic risk control system and integrating carbon trading market design to innovate financing paths can explore directions for resolution; in addition, government policy support and financial mechanism optimization can effectively alleviate the negative impact of financing constraints. In terms of EPC project financing practice, research has extended from contract clause design and single scenario adaptation to multiple scenario applications and analysis of influencing factors, confirming that the adaptability of financing schemes directly determines project effectiveness. This effect is particularly significant in characteristic scenarios: China's rural energy transformation needs to overcome bottlenecks such as limited farmer capabilities and small project scales, Slovakia's renovation of old apartment buildings needs to adapt to different economic fluctuation scenarios, and urban residential building energy conservation needs to clarify the mechanism of action of 47 core influencing factors. The supporting role of low-cost debt financing in improving project investment levels and extending contract terms has been verified through empirical data. Although current research covers theoretical dilemmas, risk control, model innovation, and multi-scenario practice, there is still room for expansion in terms of policy adaptation in different regions and cross-industry financing scheme migration. In the future, it is necessary to further strengthen the integration of theory and practice to provide more comprehensive financing support for the large-scale promotion of EPC projects.

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