

Energy Performance Contracts in Imperfect Markets: A Study on Energy Efficiency Retrofits of Commercial Buildings in China

by Shiyu Wan

Thesis submitted in fulfilment of the requirements for
the degree of

Doctor of Philosophy

A collaborative dual doctoral research degree program with
Beijing Jiaotong University, China

Principal supervisor: Dr Grace K C Ding

Co-supervisors: Dr Goran Runeson and Dr Michael Er

University of Technology Sydney
Faculty of Design, Architecture and Building

January 2022, Sydney, Australia

Certificate of Authorship/Originality

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Acknowledgements

In my doctoral study at the University of Technology, Sydney (UTS), many people have helped me. I am very appreciative and express my thanks to the following people.

Firstly, I would like to thank my supervisors for their great patience and support in guiding me in my research. I would not have finished my research without the supervision team of Dr Grace Ding, Dr Goran Runeson and Dr Michael Er who provided critical comments and supportive advice from the beginning to the end. Due to the COVID pandemic in 2020, my supervisors took adjunct positions, but they still spent great energy and much of their time on me.

In particular, I would like to express my appreciation to Dr Grace Ding for her great support and tireless efforts reading my thesis, giving me feedback and encouragement and guiding me to finish my research in time. She showed me how to be a good academic. I would like to articulate my thanks to Dr Goran Runeson who spent much time and assisted me in my research with economic theories and direction. His wealth of knowledge and valuable comments influenced me in both research and my life. I would like to acknowledge Dr Michael Er for his overall support, encouragement and advice. Dr Er and Dr Ding offered me great opportunities to be a research assistant for their research projects, which allowed me to gain valuable experience and overcome financial difficulty during the COVID pandemic.

I give many thanks to my friends and staff in the School of Built Environment in the Faculty of Design, Architecture and Building for their support and encouragement. I also give many thanks to all those who participated in the surveys and interviews. In particular, my initial points of contact helped me gain further interviews.

I also acknowledge that the Chinese Scholarship Council and UTS offered a scholarship for my study. With the cooperation of UTS and Beijing Jiaotong University, I am very

appreciative that I could join this dual doctoral program to pursue my dream of being an academic.

I would also like to acknowledge Dr Rhonda Daniels for her assistance in thesis editing.

I would like to thank my family for their great understanding and support during my whole PhD journey. I particularly want to thank my parents for their unconditional love and careful education and all their efforts and sacrifices to help me be a better person. I also give my special thanks to my loving and caring husband Hao Tian for his great support and understanding. During my PhD journey of three and a half years, we had a long-distance relationship. I am very appreciative that he was always there for me when I faced ups and downs.

Thanks to everyone for giving me such a wonderful experience in this PhD journey which explored my limitations and absorbed energy. I gained much and matured. I am very appreciative.

Publications

The followings list peer reviewed publications which are related to the research during the candidature.

Journal Papers:

Wan, S., Ding, G., Runeson, G. & Liu, Y. 2022, ‘Sustainable Buildings’ Energy-Efficient Retrofitting: A Study of Large Office Buildings in Beijing’, *Sustainability*, vol 14, no. 2, pp. 1021.

Wan, S., Liu, Y. Ding, G., Runeson, G. & Er M. 2022, ‘Risk Allocation for Energy Performance Contract from the Perspective of Incomplete Contract: A Study of Commercial Buildings in China’. *International Journal of Climate Change Strategies and Management*. Vol. ahead-of-print No. ahead-of-print.

Presentations in International Conferences:

Wan, S., Ding, G., Runeson, G. Er M. & Liu, Y. 2020, ‘Develop a system dynamic model of the risk allocation of commercial building energy efficiency retrofit under energy performance contract in China’. *Pacific Rim Real Estate Society (PRRES) Conference 2020*.

Wan, S., Ding, G., Runeson, G. Er M. & Liu, Y. 2019, ‘A Dynamic Model of Risk Allocation of Energy Efficiency Retrofits under Energy Performance Contract for Office Buildings in China’, *Abstract Proceedings of 2019 International Conference on Resource Sustainability - Cities (icRS Cities)*.

Abstract

Energy consumption in buildings has become an important issue in China. As major energy consumers, commercial buildings have become the target for energy efficiency retrofit. An energy performance contract (EPC) is a new mechanism which offers a series of retrofit strategies by energy service companies. EPCs are a tested and effective mechanism to improve energy efficiency, however they have not been widely used in the current building energy efficiency market. To establish why the market has not reacted as expected, this research examines the nature and characteristics of the EPC market, and then proposes an incentive mechanism to encourage the uptake of EPCs in the market of commercial building energy efficiency retrofit in China.

The research had three research questions: i) What are the market barriers to the uptake of EPCs in the commercial building energy efficiency retrofit market, ii) What are the reasons contributing to these market barriers and iii) How can the uptake of EPCs in the commercial building energy efficiency retrofit market be incentivised. The research followed a quantitative paradigm to test the existence of market imperfections as defined in microeconomic theory. Multiple research methods including qualitative and quantitative practices were applied to collect data. A questionnaire survey and interviews were used to test the existence of market imperfections in the EPC market. The argument that the EPC market suffers from different kinds of imperfections is supported by empirical findings and the policy implications are discussed. Lastly, based on potential strategies identified through interviews, a detailed incentive mechanism for the EPC market is developed from the conceptual framework of transaction costs defined in institutional economic theory. Two case studies selected from demonstration cities of pilot EPC projects in China demonstrate the successful application of such incentives and identify shortcomings. The analysis of case studies provides support for implementing the incentive mechanism proposed in this research to boost EPC uptake and help the market become more competitive.

The barriers to the EPC market have been fully investigated using formal models in economic theory. The research formalises the economic characteristics of the imperfect EPC market from three perspectives: incomplete information, market power and externalities. These three perspectives reveal the nature of the EPC market in a theoretical and holistic way. Adapting the theory of transaction costs as a tool to deal with the imperfections, these market imperfections are addressed by policy design. In the long term, policies of energy price and carbon tax are theoretically suitable. Strategies of information disclosure, particularly energy performance benchmarking, and reforming the existing financing system are identified as necessary for the market. Subsidies and energy consumption limits are identified as useful in the short term. The research outcome shows the nature of energy efficiency market under EPCs and provides policymakers with a framework for generating market incentives in the EPC market and offers information to stakeholders on the current market situation. The findings have the potential to boost the uptake of EPCs and improve the energy efficiency of commercial buildings in China.

Key words

Energy performance contract (EPC), energy efficiency market, building energy efficiency retrofit, commercial buildings, market barriers, market imperfections, transaction cost, policy design

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List of Abbreviations

ANOVA	Analysis of variance
BEER	Building energy efficiency retrofit
BEPBD	Building energy performance benchmarking and disclosure
BO	Building owner
CABEE	China Association of Building Energy Efficiency
CBEER	Commercial building energy efficiency retrofit
CHURDCQ	Commission of Housing and Urban-Rural Development of Chongqing, China
CNY	Chinese Yuan
CSTID	Centre of Science & Technology and Industrialisation Development, China
ECMP	Energy consumption monitoring platform
EITC	Economic and Information Technology Commission, Shanghai
EMC	Energy management contract
EMCA	ESCO Committee of China Energy Conservation Association
EPC	Energy performance contract
ESCO	Energy service company

FYP	Five-Year Plan
Gov	Government
HREC	Human Research Ethics Committee
HVAC	Heating, ventilation, and air conditioning
IE	Independent expert
LEED	Leadership in Energy and Environmental Design
LSD	Least significant difference
MOF	Ministry of Finance, China
MOHURD	Ministry of Housing and Urban-Rural Development of the People's Republic of China
MSB	Mean square between
MSE	Mean square error
M&V	Measurement and verification
PCA	Principal component analysis
R&D	Research and development
SCD-URLCMC	Shanghai Changning District Urban Renewal and Low Carbon Project Management Centre
TCs	Transaction costs
tce	tonne coal equivalency
USD	USA dollar

Chapter 1 Introduction

1.1. Overview

This research develops an understanding of the nature of the market for energy efficiency upgrades under a market mechanism called an “energy performance contract” (EPC). It defines the research scope in the field of commercial buildings to examine whether the characteristics of the market conform to the characteristics of market imperfections defined by microeconomics. It then discusses policies to reduce the imperfections and so increase the use of EPCs. Policies are designed by using the conceptual framework of transaction costs in institutional economics. This chapter provides an overview of the environment and the research. It starts with a description of the research background and how the research problem is identified. It then presents the research gaps and significance. The research questions, aims and objectives are outlined. The research focus and scope are defined. The chapter concludes with the structure of the thesis.

1.2. Background and Research Problem

The contribution of mankind to climate change is currently one of the biggest political issues in the world. Energy consumption has been increasing rapidly with the development of society (UNFCCC 2021). Energy consumption of buildings accounts for about 30% of the total energy consumption, in which building operations account for around 28% of global CO₂ emissions (Abergel & Delmastro 2020). Building energy consumption in China accounted for approximately 37% of total national energy consumption in 2018 (THUBECRC 2020). Building energy consumption per area in public buildings, such as offices, hotels, hospitals and schools, is 5–15 times that of residential buildings (THUBECRC 2016). This means that commercial buildings account for an estimated 44% of total national building energy consumption (Ma et al. 2017). The increase in the floor area and a growing demand for energy has led to higher energy consumption in commercial buildings (THUBECRC 2016). Meanwhile, the energy intensity of commercial buildings is very high compared to other types of buildings,

depending on the type of building envelope and equipment and operational schedules for using HVAC (Heating, ventilation, and air conditioning) and lighting systems (Burton 2013). In general, commercial buildings with their high energy consumption have large potential for energy efficiency improvements.

Energy efficiency has been recognised as a key strategy for mitigating the growth in energy consumption and related emissions of greenhouse gases (Bukarica & Tomšić 2017; Zhou et al. 2020). The most effective way to improve energy efficiency for existing buildings is building energy efficiency retrofit (BEER) (Ma et al. 2012; Wu, Wang & Xia 2016). BEER provides great opportunities to reduce energy consumption in buildings by improving the building envelope and mechanical systems while preserving building indoor environment and comfort (Han, Liu & Sun 2006; Xu, Chan & Qian 2011). Much attention has been paid to the issue of sustainable BEER (He 2018; Juan, Gao & Wang 2010; Xu & Chan 2013). Sustainable BEER should consider economic vitality, environmental quality, and social equity at the project level (Xu et al. 2015).

Many global organisations have made great efforts to promote sustainability in the built environment, with instruments such as Leadership in Energy and Environmental Design (LEED) in the US, the Building Research Establishment Environmental Assessment Method (BREEAM) in the UK, the National Australian Built Environment Rating System (NABERS) in Australia, and the Assessment Standard for Green Buildings in China (Ling, Wei & Lian 2018). These systems have provided good technical solutions to achieve sustainability. However, with no integration of true market sustainability strategies and retrofit management, these systems find it very hard to attract the attention of stakeholders involved in BEER (Häkkinen & Belloni 2011). Meanwhile, the methods are based on a voluntary agreement and need to be supported by some form of regulation to make the assessments more effective (Fan, Chan & Qian 2018). More importantly, implementing a sustainable BEER not only requires a comprehensive technical scheme including professional design and innovative energy efficiency technologies, but also substantial capital investment (Xu et al. 2015). Therefore, BEER faces both technical and financial challenges. An energy performance contract (EPC) is a market mechanism designed to address these issues by providing financial and technical solutions (ICF 2007; Zhou et al. 2020).

An EPC is a turnkey service, where energy service companies (ESCOs) provide customers with a set of energy efficiency measures aimed at guaranteed energy savings, such as energy audit, design and installation of energy efficient equipment (ICF 2007; Xu, Chan & Qian 2011). It has been demonstrated that EPCs can greatly improve building energy efficiency and promote building retrofits (Zhang et al. 2015). In the 13th Five-Year Plan (2016–2020) the Chinese government proposed the Building Energy Efficiency Development Plan to promote energy efficiency retrofits, in which EPCs are a highly promoted market mechanism (MOHURD & MOF 2017; NDRC 2016). EPCs are an opportunity for the Chinese government to convert BEER from government-driven to market-driven.

Although EPCs have theoretical success, both governments and academics point out that investment in EPCs in the building sector is relatively low (Ruan, Gao & Mao 2018). The major potential of EPCs in the building sector has not yet been as well recognised as in other industrial sectors (Ruan, Gao & Mao 2018; Zhang et al. 2018). This phenomenon could be known as market barriers to energy efficiency, and its persistence is the main driver of this research. The term “market barrier” is used in economic theory to describe factors that prevent a market from being efficient, which was introduced to energy efficiency research to present the limitations of adopting a certain energy efficiency activity (Qian, Chan & Choy 2013; Sorrell et al. 2004). Sustainable BEER under the EPC mechanism is a complex system that involves the characteristics of the energy efficiency market (a general market that includes various industries related to energy efficiency activities), and many kinds of risks inherent in the EPC process (Zhang et al. 2018). Therefore, the problem is how to make EPCs sustainable in the building sector in China. Sustainable development of an EPC market means the price of the activity of energy efficiency can be achieved by a competitive market of EPCs. The purpose is to improve the efficiency of the EPC market in China. As a result, the regular use of EPCs can be improved accordingly. In order to promote EPCs in BEER sustainably, there is a need to examine the nature of EPC markets and to identify the key influential factors and risks of EPC projects, and evaluate methods to overcome those market barriers.

1.3. Research Gaps and Significance

An EPC is a theoretical energy saving and cost-effective method for BEER. It has been demonstrated to have the ability to improve building energy efficiency and greatly promote the building retrofit market (Zhang et al. 2015; Zhou et al. 2020). However, compared to other industries, EPCs in the building sector are still developing slowly (Zhang et al. 2018). Under changing economic and market conditions, and unscheduled and inappropriate use of buildings, the final energy savings and benefits procured through EPCs are uncertain. Therefore, EPC projects are considered to be a high-risk investment (Garbuzova-Schlifter & Madlener 2016). At this stage, most existing research focuses on the risks of EPCs (Lee, Lam & Lee 2015; Wang, Peng & Wang 2018; Wang et al. 2019), but cannot give specific answers on the reasons for the current EPC situation and targeted solutions. Some researchers have identified the factors that are important to the success of EPC projects (Lee, Lam & Lee 2015; Xu, Chan & Qian 2011), but they focus only on the project development and do not address how these factors contribute to the development of the market. The nature of the EPC market and the solutions that lead to sustainable development of an EPC market are not addressed in detail.

Meanwhile, as EPCs are a new and evolving alternative in the energy efficiency market, there continue to be several gaps in our knowledge. The relationship between ESCOs and building owners is more complicated than in the traditional energy efficiency market. The characteristics of ESCOs under EPCs are very different from traditional energy efficiency suppliers (e.g. energy efficiency technology companies) and this increases uncertainties in conducting energy efficiency projects. Therefore, although some research has discussed the barriers of energy efficiency markets, what is not yet clear is the unique character of EPCs and the market barriers to the uptake of EPCs. With the new concept of EPCs involved in the existing energy efficiency market, there is a need to bridge the gap of knowledge of the barriers to the uptake of EPCs in an imperfect market.

Despite extensive research conducted into energy efficiency markets where the concept of market barriers has been discussed (Marquez, McGregor & Syme 2012), little effort has focused on analysing these barriers using economic theories. From a theoretical perspective, the imperfections of the energy efficiency market have not been fully investigated. Most of the studies only addressed some factors of the imperfections and

only focused on the factors themselves (Gan 2009; Liu et al. 2020; Recalde 2021), but have not treated them in-depth to reveal the nature of the market in a theoretical and holistic way.

Moreover, some researchers have focused on the role of transaction costs on energy efficiency in the building sector (Fan, Chan & Qian 2018; Kiss & Mundaca 2013; Qian 2012; Qian, Chan & Khalid 2015). They stated that high transaction costs hinder the development of energy efficiency. Sorrell et al. (2004) stated both the approach of transaction cost theory in institutional economics and the approach of neoclassical economics can explain the market barriers of energy efficiency. However, they did not show a clear explanation of the relationships between transaction costs and market imperfections. In the discussions, the boundaries between market failures and transaction cost theory are blurred. Meanwhile, although the existing research shows the high transaction costs in energy efficiency projects, few studies have empirically designed market incentives for the energy efficiency market from the perspective of transaction costs. Especially under the EPC mechanism, with the extra administration and uncertainties involved, it is necessary to have further theoretical discussion on what types of government intervention could be involved to reduce the costs of EPCs with practical implications.

Moreover, considering solutions to market barriers, policy support can provide a sound environment for market development (Goldman, Hopper & Osborn 2005; Zhang et al. 2018). Zhang et al. (2018) analysed the policy drivers for EPC projects, but did not relate the policies to a particular barrier. Zhou et al. (2020) assessed detailed impacts of incentive policy, China's Five-Year Plan policy and business innovation for the EPC market. They showed a holistic view on how supportive policies motivate the initial EPC market. However, their research only presented a general direction of policy without targeted policy design. With no targeted policy design for particular market imperfections, the government was not able to leverage its relatively small policy investment into much larger improvements in the energy efficiency market through EPCs. Therefore, in the current EPC market, the appropriate role of government is still unclear. There is still a research gap in the theoretical basis for government action in particular circumstances.

The research significance includes theoretical significance and practical significance.

The theoretical significance of this research is to:

- establish the theoretical characteristics of the EPC market.
- test if market imperfections defined in microeconomics present barriers to EPCs.
- determine if transaction cost theory in institutional economics can be adapted to be used as a tool to design incentives for the uptake of EPCs.

The practical significance of this research is to:

- provide a framework for policymakers on how to generate market incentives in the EPC market.
- reveal the nature of the market and offer more knowledge to EPC stakeholders on the current market situation, which may help them reduce risks and make suitable decisions on using EPCs and conducting CBEER in the future.

1.4. Research Questions

Based on the research problem of how to transform EPCs in the building sector in China, the overall research question aims to understand how to improve the uptake of EPCs in the Chinese commercial energy efficiency retrofit (CBEER) market. The three main sub-questions are:

- What are the market barriers to the uptake of EPCs in the CBEER market?
- What are the reasons limiting the uptake of EPCs in the CBEER market?
- How can the uptake of EPCs in the CBEER market be incentivised?

1.5. Research Hypotheses

This research focuses on investigating the nature of market barriers to the uptake of EPCs to develop an incentive mechanism for the market. According to the theoretical analysis

of theories of market imperfections, the research proposition forms. The overall working hypothesis (H_w) in this research is expressed as:

H_w : The EPC market exhibits characteristics of market imperfections as defined in economic theory.

According to the theories of market imperfections, the overall working hypothesis is refined and expanded into four hypotheses (H_1 , H_2 , H_3 , H_4) to provide a clear guideline to explore the nature of the EPC market and serve as a testing tool of the characteristics of barriers to the uptake of EPCs.

H_1 : That barriers to the uptake of EPCs correspond to incomplete information as defined in economic theory.

H_2 : That barriers to the uptake of EPCs correspond to market power as defined in economic theory.

H_3 : That barriers to the uptake of EPCs correspond to externalities as defined in economic theory.

H_4 : That barriers to the uptake of EPCs correspond to public goods as defined in economic theory.

1.6. Research Aim and Objectives

Based on the research questions, this research aims to explore the way to incentivise the EPC market to achieve more regular use of EPCs in the commercial building sector in China. It takes the EPCs of CBEER in China as an example to discuss the market characteristics of China's CBEER. It analyses the influential factors of EPC development in an imperfect market environment and explores a framework to incentivise the EPC market for sustainable development. To better answer the research questions and achieve the research aim, there are six main research objectives:

Objective One: Develop a theoretical framework for understanding the current situation of the EPC market in commercial buildings.

There are four steps to achieve objective one:

- i) identify the characteristics of the energy efficiency market through literature review.
- ii) identify the current development and limitations of the EPC market in commercial buildings in China through literature review.
- iii) review the theories of market imperfections under microeconomics and the theory of transaction costs under institutional economics through literature review as a theoretical foundation for this research.
- iv) develop a theoretical framework for theory test and application to analyse and improve the EPC market.

Objective Two: Study empirical data from surveys to identify the overall barriers to the EPC market.

There are two steps to achieve objective two:

- i) identify the real market concerns in practice through a questionnaire survey.
- ii) identify critical factors for the uptake of EPCs in the CBEER market, which leads to the interviews to meet objective three.

Objective Three: Study the empirical data from the questionnaire survey and interviews to test the existence of market imperfections.

There are two steps to achieve objective three:

- i) identify the main reasons contributing to market barriers through interviews.
- ii) test the existence of market imperfections.

Objective Four: Analyse policy implications for EPC markets to deal with market imperfections.

Objective Five: Triangulate the empirical data from interviews to discuss incentive mechanisms in practice from the perspective of transaction costs in the Chinese context.

There are four steps to achieve objective five:

- i) explore the potential policies and strategies to deal with market barriers from interviews to understand the market expectations.
- ii) explain the extent to which transaction costs can be used to explain the problem of market imperfections in the EPC market.
- iii) explain how transaction costs within Williamson's theoretical framework can be used to design appropriate policy to deal with market imperfections.
- iv) develop the incentive mechanism for the CBEER market for more regular use of EPCs.

Objective Six: Triangulate the case study's empirical findings to verify the proposed incentive mechanism.

There are two steps to achieve objective six:

- i) analyse the experiences of existing EPC policies and implementation through two case studies.
- ii) demonstrate how the incentive mechanism can be used to improve the uptake of EPCs by addressing market imperfections through the case studies.

1.7. Research Focus and Scope

This research focuses on examining the existence of market imperfections in the EPC market and revealing the nature of the energy efficiency market in the sector of commercial buildings in China. It seeks to formalise the theories of market imperfections to incentivise the market to become more competitive with reduced transaction costs. Although some technical barriers are addressed, this research does not give an account of detailed BEER technologies. This research is only concerned with developing an understanding of the existing energy efficiency market. This research is based on the EPC market. The sector of commercial buildings is selected as the investigating area to collect empirical data. Therefore, the research scope is limited to the energy efficiency market

under the EPC mechanism in the sector of commercial buildings in China. A detailed introduction to the energy efficiency market and explanation for selecting the commercial building sector are provided in Chapter 3.

1.8. Thesis Structure

This thesis has eleven chapters. Figure 1-1 presents the structure of the thesis and provides a clear indication of the stages of research.

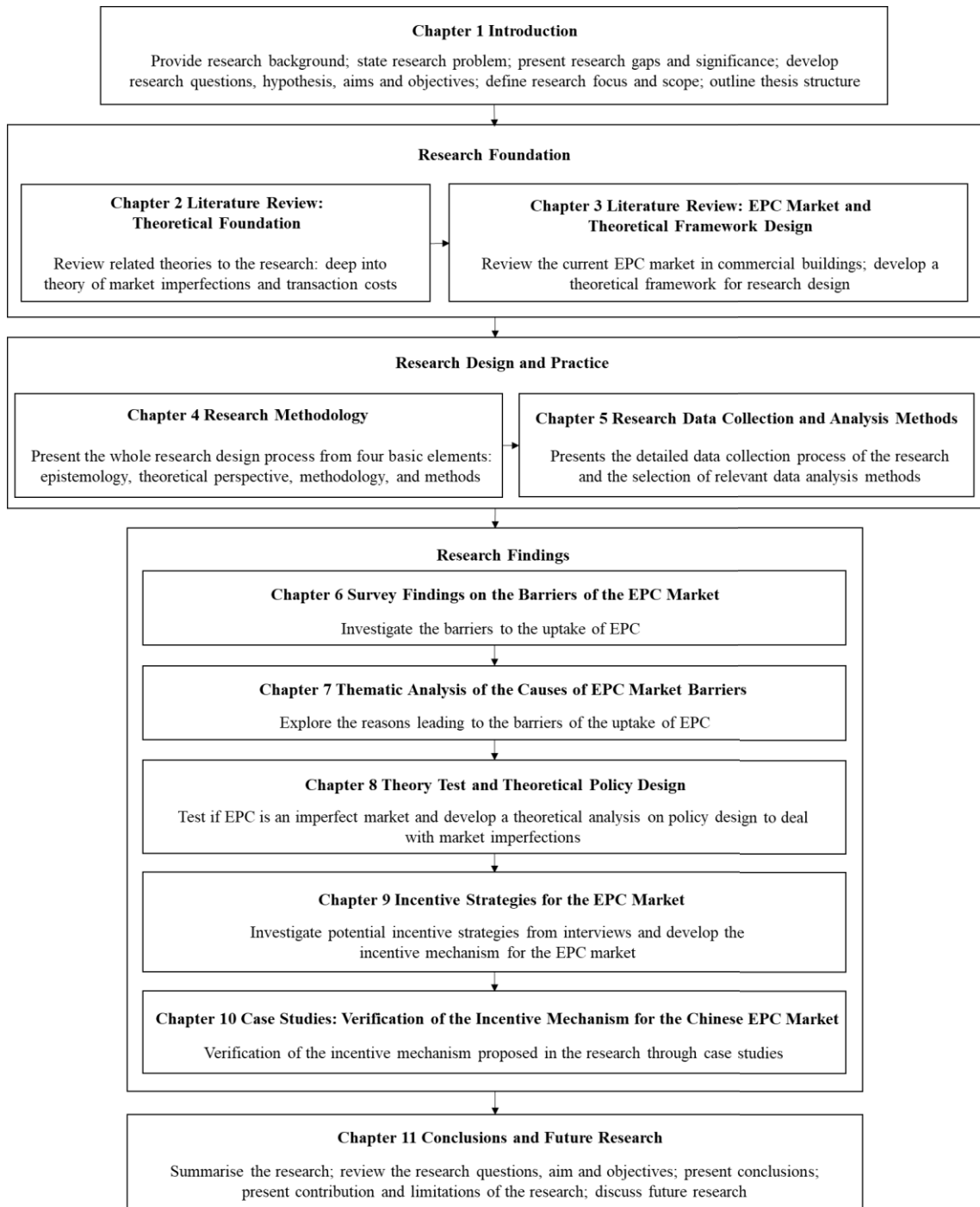


Figure 1-1 Thesis structure

Chapter 1 Introduction

This chapter introduces the research background and states the research problem. It discusses the research gap and explains how this research is significant to theory and practice. It puts forward the research questions, hypothesis and related aims and objectives. It defines the research focus and scope. It also outlines the thesis structure.

Chapter 2 Literature Review: Theoretical Foundation

This chapter presents the relevant theories of this research. According to the research question, this research is designed based on the microeconomic theory of price formation for the theory test. Through a short outline of a microeconomic theory of price under markets, this chapter first introduces the theories of market imperfection. Then the theory of transaction cost within Williamson's theory of organisations in institutional economics is introduced for policy design in this research.

Chapter 3 Literature Review: EPC Market and Theoretical Framework Design

This chapter conducts a systematic literature review to provide a foundation for this research. It starts by introducing the main concepts of the energy efficiency market and CBEER. Then the concept of EPCs and the current Chinese EPC market are reviewed. The particular risks of CBEER under EPCs are explored. Later, the current policy system of China's building energy conservation is reviewed. Based on this information, a theoretical framework to investigate market imperfections and incentivise the market based on the conceptual framework of transaction costs is developed to guide the research design.

Chapter 4 Research Methodology

This chapter presents the research design process from four basic elements: epistemology, theoretical perspective, methodology, and methods. The objectivist epistemology and positivist theoretical perspective are chosen as philosophical assumptions for this research. A quantitative paradigm is outlined as the research approach as this research tests the market imperfections and follows the deductive research inquiry process. Multi-

methods are designed to collect research data to answer the research questions and achieve the research objectives.

Chapter 5 Research Data Collection and Analysis Methods

This chapter presents the detailed data collection process of the research and the selection of relevant data analysis methods. Data collection starts with the use of a questionnaire survey to identify factors impacting the uptake of EPCs. It continues with semi-structured interviews to explore the reasons for the barriers to the uptake of EPCs and identify potential ways to improve the market. This is followed by two case studies that are used to conduct an abductive verification of the proposed incentive mechanism in the research and demonstrate how the incentive mechanism can be used to improve the uptake of EPCs in the market.

Chapter 6 Survey Findings on the Barriers of the EPC Market

This chapter investigates the barriers to the uptake of EPCs mainly based on the questionnaire survey data. The empirical data from interviews are used to explain some findings from the questionnaire survey, which may increase the reliability of the findings. It starts by exploring the critical factors influencing the uptake of EPCs through the overall descriptive analysis and principal component analysis. Then a comparative analysis is conducted of both the overall variables and the critical influencing factors identified in the previous section through ANOVA tests. The results prepare for the analysis of the causes of market barriers in the next chapter.

Chapter 7 Thematic Analysis of the Causes of EPC Market Barriers

This chapter explores the reasons leading to the barriers to the uptake of EPCs in commercial buildings. Causes of the barriers are identified and analysed through the thematic analysis based on interview data.

Chapter 8 Theory Test and Theoretical Policy Design

This chapter discusses the existence of market imperfections. It shows how the factors impacting the barriers of the EPC market identified in the last chapter connect with the theories of market imperfection. The purpose is to test if the EPC market conforms to the

characteristics of market imperfections defined in economic theory. Then a theoretical analysis of government intervention that deals with those market imperfections is conducted to reduce the costs of EPC projects.

Chapter 9 Incentive Strategies for the EPC Market

This chapter discusses the potential incentive strategies for the EPC market to propose a policy package to deal with identified market imperfections. It starts with exploring the potential strategies to deal with market imperfections through interviews. Those potential strategies are analysed based on the conceptual framework of transaction costs. An overall framework and a detailed incentive mechanism for the EPC market are developed.

Chapter 10 Case Studies: Verification of the Incentive Mechanism for the Chinese EPC Market

In this chapter, cases of policies are analysed to test the validity of the incentive mechanism proposed in Chapter 9 and demonstrate how the proposed incentive mechanism can better facilitate the EPC market by eliminating, reducing or compensating for market imperfections.

Chapter 11 Conclusions and Future Research

This chapter summarises the research. It presents the findings of the research and the implications for both theory and practice. It starts by reviewing the research questions, aim and objectives. A conclusion with major findings follows, then it discusses the contribution and limitations of the research. Lastly, potential future research directions are suggested.

Chapter 2 Literature Review: Theoretical Foundation

2.1. Introduction

This chapter demonstrates the theories that are used for this research. According to the research question, this research is designed based on the microeconomic theory of price formation for the theory test. Firstly, through a short analysis of a microeconomic theory of price under markets, this chapter extends the analysis into theories of market imperfection. Then the theory of transaction cost within Williamson's theory of organisations in institutional economics is introduced for policy design in this research. The purpose of this research is to provide a foundation to test the theory of market imperfections and use transaction cost theory to develop a theoretical framework of incentive mechanisms in the uptake of energy performance contracts (EPCs) in the energy efficiency market for the sector of commercial buildings.

2.2. The Microeconomic Theory of Price

2.2.1. Price in Perfectly Competitive Markets

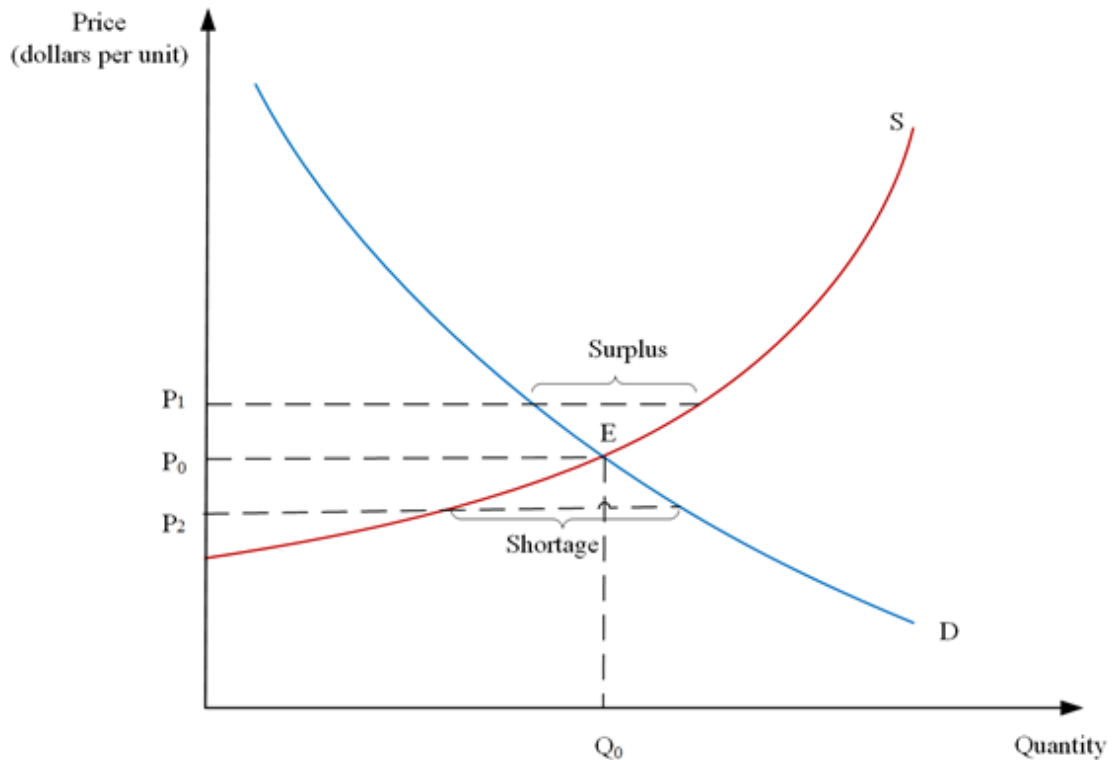
Microeconomics focuses on the behaviour of individual economic units (consumers, firms, workers and investors) and their interactions in markets. It explains how and why individual economic units make decisions and reveals how markets operate and evolve (Mankiw 2020; Pindyck & Rubinfeld 2009). To determine how to allocate scarce resources, microeconomics offers theorems and models to examine the activities that happen in the market. This research focuses on the uptake of EPCs for commercial building energy efficiency retrofit (CBEER) in the energy efficiency market. To establish an effective way to understand the nature of the EPC market and promote the market, microeconomics is adopted as the base for this research.

All the behaviours from the perspective of economics can be described as trade-offs, and all the trade-offs are based on prices (Besanko & Braeutigam 2013; Pindyck & Rubinfeld 2009). In a market economy, prices are determined by the interaction of economic units.

In a centrally planned economy, prices are determined by the government (Pindyck & Rubinfeld 2009). Howarth & Andersson (1993) take prices as a tool to investigate the market response to reveal market conditions. In China, the pricing of energy commodities is very complex (Chen 2007). The price of coal, which is the main energy source for power generation in China, varies according to market demand (Wang, Zhang & Zhang 2012) and the price combines costs from several types of systems including power generation, power transmission, power distribution, power supply and electricity consumption (Chen 2007). Meanwhile, China is implementing market-oriented reform which further brings into play the role of the market in allocating resources (Zhang 2020). This means the state is not only maintaining some control of the electricity price, but is also making use of market mechanisms (Chen 2007; Zhang 2020). The purpose is to let the market lead the price.

For the energy efficiency market, it is suggested that the market will show a socially efficient outcome if energy prices can reflect the whole social costs and benefits of energy utilisation and production. This happens in a perfectly competitive market, in which market prices reflect the true transactions between buyers and sellers (Pindyck & Rubinfeld 2009). In a perfectly competitive market, there are many buyers and sellers, and a single buyer or seller cannot influence market price (Mankiw 2020; Pindyck & Rubinfeld 2009).

The key determinants of price are supply and demand (Perloff 2017; Pindyck & Rubinfeld 2009). They reflect how prices change in the market. Figure 2-1 shows the tools (Pindyck & Rubinfeld 2009, p. 25). This is best illustrated in the familiar microeconomic diagram below that combines the two essential concepts: supply and demand. The supply curve shows the quantity of a good that producers are willing to sell at a given price, and the demand curve shows how much consumers are willing to buy as the price per unit changes. Supply curve S intersects with demand curve D at the equilibrium point E , which presents the equilibrium (or market-clearing) price (P_0) and quantity (Q_0). At the equilibrium point E , the price equates the quantity supplied to the quantity demanded. P_1 and P_2 show the situations when the market price deviates from the equilibrium price. The market mechanism is the tendency in a free market for prices to change until they reach their equilibrium points. All these concepts are also implicit in Williamson's framework. Williamson's framework is introduced in Section 2.5.



Source: Pindyck & Rubinfeld (2009, p. 25)

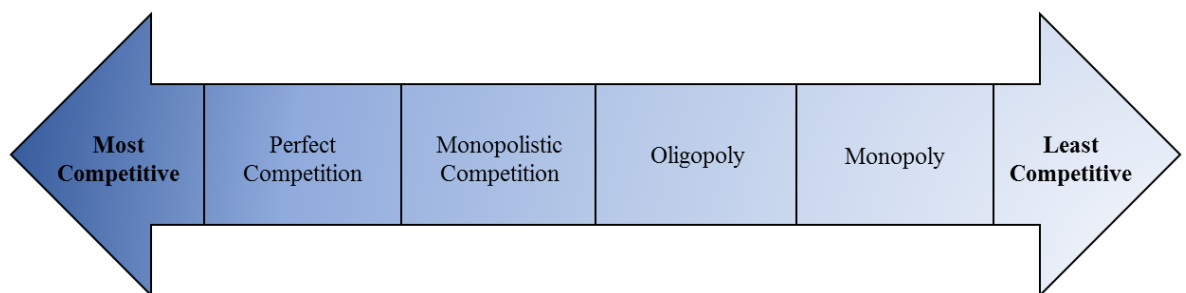
Figure 2-1 Price determination of in the market

According to the saying from Adam Smith, a competitive market can be relied on for efficient resource allocation (Debreu 1959). Under a competitive market, an equilibrium set of prices and quantity is the most efficient way to allocate resources without any government activities (Fisher & Rothkopf 1989). Meanwhile, to evaluate a market allocation outcome, economic efficiency which is defined as a maximisation output where no one can be made better off without someone else being worse off is a measurement (Pindyck & Rubinfeld 2009). This achieves the objective of economic efficiency that can help ensure a competitive market. However, there are some cases when the market is economically not efficient because the price in the market cannot reflect the proper relationship between consumers and producers (Pindyck & Rubinfeld 2009). If efficient resource allocation does not exist, the market fails (Wolf 1993). Market failure is defined as the market not operating at optimum efficiency (Ledyard 1989). The key questions about what kinds of market failures, how those distort the resource allocation, and what can be remedied when the market fails are addressed in Section 2.4. For those non-competitive markets, the pricing, investment and output decisions of companies are addressed, based on different market structures, in the next section.

2.2.2. Market Power and Market Structures

In a perfectly competitive market, the large number of sellers and buyers of a good ensures that no single seller or buyer can affect its price. The market forces of supply and demand determine price. Individual firms take the market price as a given in deciding how much to produce and sell, and consumers take it as a given in deciding how much to buy. In an imperfectly competitive market, the firms may be able to affect price and may find it profitable to charge a price higher than the price of producing one additional unit of a good in a perfectly competitive market (Mankiw 2020; Pindyck & Rubinfeld 2009). In this situation, these firms have market power. The degree of market power can be shown by the gap between price and the cost of producing the last unit (Massey 2000). Under different degrees of market power, the market structures are different.

There are four principal types of market structures: perfect competition, monopolistic competition, oligopoly and monopoly. The classification of market structures is based on the statements of economic theory by Marshall that “shade into one another by imperceptible degrees” (Reisman 2011, p. 124). Figure 2-2 shows the four types of market structures and their degree of competitiveness, where the closer the type of market structure to the left, the more competitive the market is.



Source: adapted from Kwach (2018)

Figure 2-2 Market structures

(1) Perfect Competition

As discussed in the previous section, a perfect competition market is defined as “a perfect market is a district, small or large, in which there are many buyers and many sellers all so keenly on the alert and so well acquainted with one another’s affairs that the price of a commodity is always practically the same for the whole of the district” (Reisman 2011,

p. 125). There are four conditions implicit in the definition of the perfect market (Cowell 2018; Mankiw 2020; Reisman 2011). The first condition is product homogeneity. The commodities referred to have the same quality. The second condition is full information. Marshall's economic theory stated the perfect competition market structure as "every dealer who has a perfect knowledge of the circumstances of the market expects that price to be established" (Reisman 2011, p. 125). The third condition is mobility and transportability. It means the geographical delimitations of a market may cause the different costs of a commodity. Therefore, the market price assumes that the different costs are tolerably nearly complied with. The fourth condition is absence of collusion. It assumes that "there is no close combination among dealers on either side" (Reisman 2011, p. 125). Each individual buyer and seller makes their own decision only based on the quantity supplied and they only consider the effect of their actions on the price (Mankiw 2020). As described in the previous section, the equilibrium occurs when the price equates the quantity supplied with the quantity demanded (see Figure 2-1). In a perfect competition market, individual companies take the market price as a given in deciding how much to produce and sell, and consumers take it as a given in deciding how much to buy (Cowell 2018). Neither has any power over prices.

(2) Monopolistic Competition

Monopolistic competition is similar to perfect competition. The difference is the heterogeneity of products (Mankiw 2020; Pindyck & Rubinfeld 2009; Reisman 2011). A monopolistically competitive market has two principal characteristics. Firstly, companies compete by selling differentiated products that are highly replaceable but not complete substitutes for each other. Secondly, it is fairly easy for new firms to enter the market with their own brands and for existing firms to leave if their products become unprofitable (Cowell 2018; Mankiw 2020; Pindyck & Rubinfeld 2009). In most monopolistic markets, the power of each firm is small. Usually enough firms compete, with brands that are sufficiently substitutable, so that no single firm can increase price without losing sales. Because firms lack power, average costs and prices will be close to minimum.

(3) Oligopoly

An oligopoly is a market in which only a few sellers compete with each other and account for most or all of total production (Cowell 2018; Mankiw 2020). New sellers find it difficult to enter the oligopolistic market because of the barriers of market entry. Because only a few sellers are competing, the principal consideration is how their actions will affect the competitors, and how the competitors are likely to react. Therefore, in an oligopolistic market, a company sets price based on these strategic considerations regarding the expected behaviour of its competitors. For this type of market, “each firm is doing the best it can given what its competitors are doing” (Pindyck & Rubinfeld 2009, p. 450).

(4) Monopoly

A monopoly is a market that has only one seller but many buyers (Cowell 2018; Mankiw 2020; Pindyck & Rubinfeld 2009). As the sole producer of a product, the monopolist in the market completely controls the amount of output offered for sale. To maximise profit, the knowledge of demand and cost is critical for the monopolist. Considering the market demand curve, the price or quantity sold can be determined by the monopolist.

2.2.3. Market Barriers to Energy Efficiency

In the present context of energy efficiency, a barrier is “a mechanism that inhibits a decision or behaviour that appears to be both energy efficiency and economically efficient” (Sorrell et al. 2004, p. 27). The term “market barrier” was introduced in research of technical and economic potential for energy efficiency by using engineering–economic models (Qian, Chan & Choy 2013; Sorrell et al. 2004). Energy efficiency is a general concept here including all kinds of activities related to improving the energy performance such as buildings and manufacturing. According to Figure 2-1 the supply and demand model in the competitive market introduced in Section 2.2.1, if the value of the energy savings generated by an activity of energy efficiency exceeds the cost of this improvement, competitive producers could increase their profits by exploiting consumers’ willingness to pay for the change. It means the efficient price of this activity of energy efficiency can be achieved by competitive markets. However, this is an idealised model. In reality, there is a differential between the level of energy efficiency

achieved and the level judged to be efficient (Howarth & Andersson 1993). This has been explained in microeconomics mainly in terms of “market barriers” related to buyers’ and sellers’ decision making and as the factors behind the so-called “energy efficiency gap” (Carlsmith et al. 1990; Howarth & Andersson 1993). However, the economic underpinnings of the presumed energy efficiency gap have not been firmly established (Howarth & Andersson 1993). Many research projects have been conducted by energy efficiency practitioners rather than academics and were rather selective in their use of theory. While there is a reasonable assumption that market barriers impede the adoption of a certain energy efficiency activity, little effort has focused on the analysis of these barriers using formal models rooted in economic theory (Ge et al. 2017; Howarth & Andersson 1993; Zhang et al. 2018). Such research will be helpful in clarifying the view of barriers and linking them to the traditional idea of market failures (Sorrell et al. 2004).

2.2.4. Barriers to Efficiency in Risk Markets

The issues about risk are whether risk constitutes a market failure and whether risk discourages investment. Sutherland (1991) presented a view that perfectly competitive markets assume perfect knowledge and perfect foresight. However, in actual markets, all investments are characterised by a future return that is subject to some risk. This normal business risk certainly characterises highly competitive markets and does not constitute a market failure. Rather the risks are an essential element in facilitating changes in output caused by changes in demand. However, some risks due to uncertainties under asymmetric information may be classified as market barriers to investments (Tandon 2015). Therefore, whether risk constitutes a market failure or whether risk discourages investment depends on the trigger of risk events.

2.3. The Theories of Market Imperfections

Market imperfection is defined as “anything that interferes with trade” (DeGennaro 2005, p. 4). As mentioned above, competitive markets tend to allocate resources efficiently. Under certain conditions prevalent in the real world, markets fail to perform efficiently (Randall 1983). Market imperfections generate costs that interfere with trades that rational individuals make, which make markets fail to function efficiently (DeGennaro 2005). Market failure is defined as a “situation in which an unregulated competitive

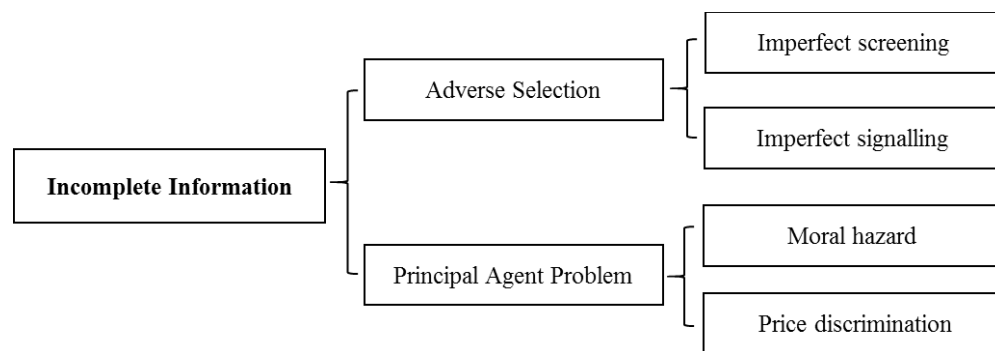
market is inefficient because prices fail to provide proper signals to consumers and producers” (Pindyck & Rubinfeld 2009, p. 315). Those failures are caused by structural characteristics of the energy efficiency market (Howarth & Andersson 1993). Competitive markets fail for four basic reasons: incomplete information, externalities, public goods and market power (Bukarica & Tomšić 2017; Pindyck & Rubinfeld 2009; Wolf 1993).

2.3.1. Incomplete Information

Imperfections identified in the market always come from the lack of knowledge of transaction parties, for example, the seller of a product probably has a much better idea about its quality than the customer (Tandon 2015). Incomplete information is also defined as asymmetric information facing contracting parties (Giraudet 2020; Pindyck & Rubinfeld 2009). When two economic agents undertake a transaction under uncertainty, it is quite possible, indeed likely, that they will possess different information about it (Tandon 2015). One is likely to be better informed than the other about things that bear directly upon the transaction. This asymmetry makes it more difficult, and perhaps even impossible, to complete the transaction. Asymmetric information will impede the occurrence of mutually beneficial trades (Mankiw 2020; Pindyck & Rubinfeld 2009). There are three typical reasons for incomplete information. First, there is a positive cost of improving consumer information (Howarth & Andersson 1993). As the performance of suppliers is hard to observe and the consumers lack knowledge of the production, the suppliers may receive more benefits than they expected. Second, the uncertainty about the products or services may cause customers to reject or hesitate to take an action (Fisher & Rothkopf 1989). In the building energy efficiency market, if the tenants could not ascertain the benefits of building energy efficiency directly and transaction costs exceed the benefits through their investments, even the most rational cost-effective energy saving plan will be rejected by the tenants (Fisher & Rothkopf 1989). Third, a high discount rate is always used when consumers make decisions with a high degree of uncertainty (Sutherland 1991).

Incomplete information may lead to two broad categories of problems: adverse selection and the principal–agent problem (Giraudet 2020; Mas-Colell, Whinston & Green 1995) (Figure 2-3). Adverse selection occurs when part of the relevant information is hidden

from one party. There are two subcategories: imperfect screening and imperfect signalling. Imperfect screening occurs when the seller cannot observe buyers' types and imperfect signalling happens when the seller is unable to convey the quality of its products to prospective buyers (Giraudet 2020). As a result, too many low quality products and too few high quality products are sold (Pindyck & Rubinfeld 2009). Principal-agent problems arise when the principal hires an agent to carry out a task. There are two subcategories: moral hazard and price discrimination (Giraudet 2020). Moral hazard occurs when the principal cannot observe the agent's *ex post* actions. Price discrimination occurs when a multiproduct monopolist cannot observe the agents' types *ex ante*.



Source: adapted from Giraudet (2020) and Mas-Colell, Whinston & Green (1995)

Figure 2-3 Problems in situations of asymmetric information

2.3.2. Externalities

Externalities are defined as “action taken by either a producer or a consumer which affects others but is not accounted for by the market price” (Pindyck & Rubinfeld 2009, p. 315). Economic activities often create those spillovers, and the effects can be positive or negative (Wolf 1993). The positive externalities occur when the economic activity does have some benefits to other parties, and negative externalities occur when the economic activity imposes costs on others (Pindyck & Rubinfeld 2009). Coase (1960) emphasised that the problem of externalities could be attributed to the lack of a market, which in turn could be explained by one or both of two things: lack of clearly defined property rights and transaction costs. Coase's observations on externalities have come to be called the Coase Theorem (Tandon 2015). In short, it argues that if property rights are clearly defined and there are no transaction costs the problem of externalities disappears.

In energy markets, the most common way to eliminate externalities is to impose various environmental and energy charges or taxes, and promote technologies for positive externalities to society (Bukarica & Tomšić 2017). Meanwhile, legal standards of energy efficiency act as an efficient method to force the industry to find innovative solutions to remedy a market failure (Owen 2004). As a supplement, promotion of the concept of energy efficiency and sustainability to the public has a direct impact on consumers' purchase decisions which may influence the whole market (Bukarica & Tomšić 2017).

2.3.3. Public Goods

Based on the characteristic that whether the good or service is excludable or not and rival or not, goods or services can be grouped into four categories (Mankiw 2020) (see Figure 2-4).

		Rival in consumption?	
		Yes	No
Excludable?	Yes	Private Goods • Ice-cream cones • Clothing • Congested toll roads	Club Goods • Fire protection • Cable TV • Uncongested toll roads
	No	Common Resources • Fish in the ocean • The environment • Congested nontoll roads	Public Goods • Tornado siren • National defense • Uncongested nontoll roads

Source: Mankiw (2020, p. 213)

Figure 2-4 Classification of goods or services

Public goods are goods or services that have two key characteristics: non-rival and non-excludable (Tandon 2015). Non-rival means that one person's consumption of the good does not reduce the amount available for someone else to consume and all people can consume them equally at the same time. Non-excludable means that no one can be prevented from consuming the good once it has been produced and made available to anyone. Whether goods are excludable or rival in consumption is often a matter of degree.

This research needs to examine goods that are not excludable, public goods and common resources, because these two concepts are related to the study of externalities and they are discussed later in this research. Different from public goods, common resources are rival in consumption but not excludable (Mankiw 2020). The environment is taken as common resources in this research. No one could be excluded from joining the environment, while if someone pollutes the environment, others will have problems accessing a good quality environment. For both public goods and common resources, externalities arise because something of value has no price attached to it.

Public goods are offered to consumers with an extremely cheap price (Mankiw 2020; Pindyck & Rubinfeld 2009). In a competitive market, the quantity of a public good is generally expected to be less than the efficient level. It arises when the market fails to supply goods that many consumers value. Hence, public goods are a source of market failure. One reason that the quantity of public goods is less than the efficient level is an externality effect – each member of society ignores the benefit other members of society receive when they supply a public good (Borland 2020). With public goods, since they are non-excludable, people are going to hope that others will pay for and provide the good, and they can “free ride” on this behaviour from others (Tandon 2015). Energy efficiency innovations are an example that brings benefits to society and can be considered as a public good (Dennis 2006). Sometimes companies are reluctant to invest in innovations, waiting for others to develop knowledge or adopt new patterns, and then gain experience – the so-called free rider effect (Bukarica & Tomšić 2017; Wolf 1993). Possible policies to increase the provision of public goods to the efficient level are to have the government finance provision of extra amounts of the good, or to seek to create excludability and hence increase incentives for supply by assigning ownership of the good to some individual or group in society (Borland 2020). It is advantageous for the government to produce public goods because the government can tax or charge to pay for it (Pindyck & Rubinfeld 2009). In addition to this, policy instruments should ensure that enough investments are made in innovations of energy efficiency. The most widespread remedy for this market failure is a voluntary agreement with industries (Bukarica & Tomšić 2017).

2.3.4. Market Power

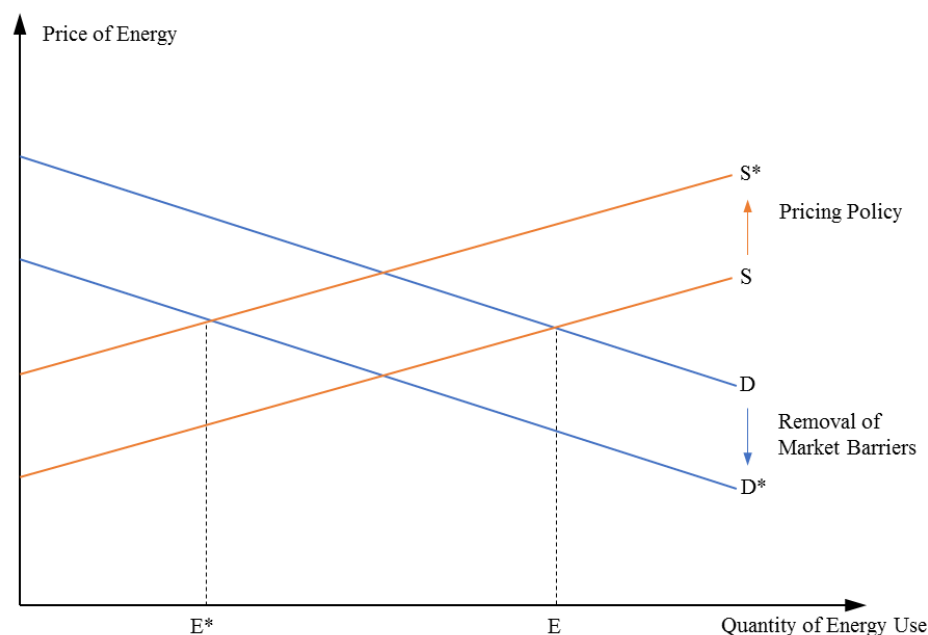
Market power refers to markets where sellers or buyers have the power to set either the price or quantity (Pindyck & Rubinfeld 2009). In competitive markets sellers and buyers can only accept the market price. No single seller or buyer can affect the price. There are two types of market power: monopoly power and monopsony power. Monopoly power refers to the ability of a seller of a product to charge a price greater than the competitive marginal price. Monopsony power means that the purchasing decision of a buyer can affect the price of a good. The reasons for this power vary, but normally include situations where there is a single or a small number of sellers or buyers in a market. Consequently, these markets are inefficient, because the sellers may charge a higher price with a resultant lower quantity to be consumed and also be reluctant to innovate. In a monopsony, the buyers may purchase a good for less than the price that would prevail in a market without this market power (Pindyck & Rubinfeld 2009; Wolf 1993). Bukarica & Tomšić (2017) argue that utility markets are far away from competitive markets because there are not enough players and it may influence the market price. They state that the energy sector was historically uncompetitive in general. Apart from lack of competition in the market, imperfect market structures also include a way in which electricity prices are structured by electricity producers and regulators.

2.4. Government Intervention in Market Failure

Both Dahlman (1979) and Rugman (1980) assumed that all the market failures can be treated as externalities because they cause a divergence between private and social cost. Meanwhile, Dahlman (1979) argued that externalities may present themselves as transaction costs and that those costs can be internalised in some way. In order to make up for the deficiency caused by market failures, it is necessary to concentrate on ways of dealing with market failures. Government intervention has been justified as a method where market imperfections can be reduced through government activities (Pasour Jr 1981). The government can intervene for better resource allocation (Fisher & Rothkopf 1989; Wolf 1993). Dahlman (1979) concluded that without interference in the price mechanism, some transactions would not be carried out. Wolf (1993) suggested that the theory of market failure is flexible enough to support specific regulatory interventions designed to support a specific outcome. For an energy efficiency perspective in the

building sector, Hasegawa (2004) stated that government intervention may be preferred, not because there is an external effect, but because there is a risk of irreversible and serious damage or lack of information.

Based on the analysis by Grubb (1991), achieving an ideal level of energy efficiency involves a two-step process (see Figure 2-5) (Howarth & Andersson 1993). The first step is pricing policy. Energy prices can be set to reflect the full social costs of energy production and utilisation, including external costs (for example, cost of environmental damage). Proper pricing shifts the costs of the energy supply curve inward from S to S^* . The second step is the removal of market barriers. Policies can be implemented to improve market performance given prevailing prices, shifting the demand curve from laissez faire D to the cost-effective D^* without reductions in energy services. Only when these measures are implemented simultaneously will energy use be reduced from the status quo E to the socially efficient level E^* without offsetting social costs.



Source: Howarth & Andersson (1993, p. 263)

Figure 2-5 Two-stage process of energy efficiency

There are three typical instruments for government to conduct interventions: direct regulation, taxes and subsidies (Cherry, Kallbekken & Kroll 2012; Jaffe & Stavins 1995). The traditional methods of taxation, regulation and subsidies are effective in controlling environmental issues (O'Hagan 1984b). The government can remedy an externality by

either requiring or forbidding certain behaviours (Mankiw 2020). If the certainty of the effects of instruments can be confirmed, regulatory instruments are expected to play a central role (Hasegawa 2004). Instead of regulating behaviour in response to an externality, the government can use market-based policies (taxes or subsidies) to align private incentives with social efficiency. The government can internalise the externality by taxing activities with negative externalities and subsidising activities with positive externalities (Mankiw 2020). Economists have argued that the total abatement cost could be reduced by flexibly transferring the responsibility for the reduction from those with higher marginal abatement cost to those with lower marginal abatement cost (Hasegawa 2004). This can be achieved by means of shifting from unitary regulation to economic instruments such as taxes and tradable permit schemes (Baumol et al. 1988). However, how to choose those instruments to control environmental issues and how to use those instruments to design policy is still an issue for the existing market (Hasegawa 2004).

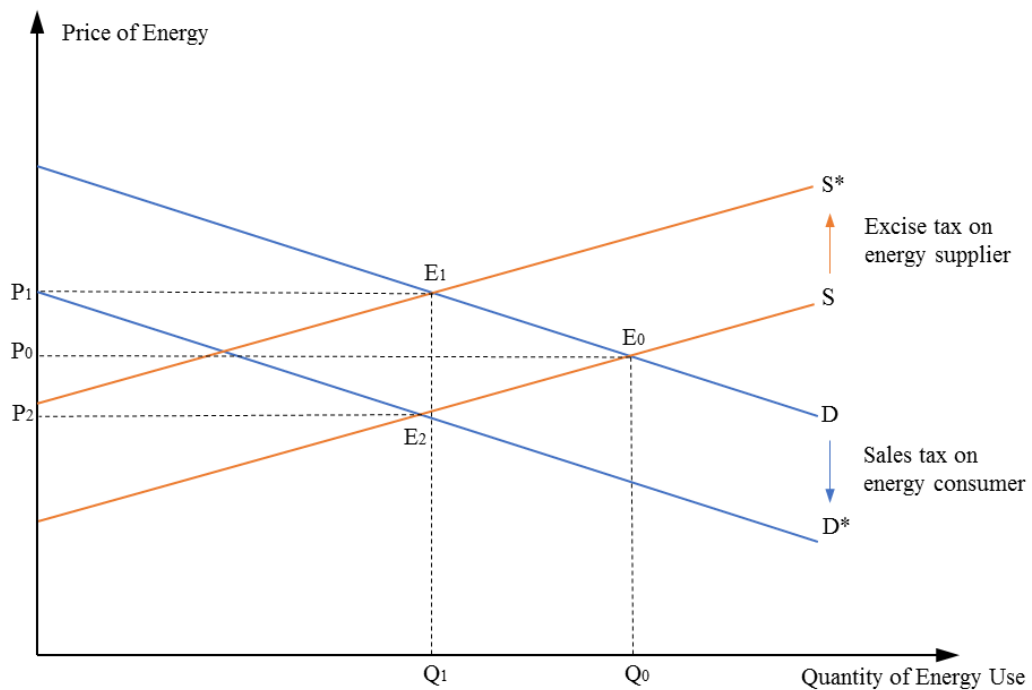
2.4.1. Direct Regulation

Direct regulation comprises standards or commands and prohibitions in relation to inputs, processes and outputs (Testa, Styles & Iraldo 2012). Regulations may be classified and their effectiveness evaluated on the basis of the market failure they attempt to remedy (Spulber 1989). Regulation of prices, entry and quality of service in the utilities, such as electricity, attempts to address imperfections in competition associated with barriers to entry. Environmental regulations directed at air and water pollution or natural resource depletion are aimed at externalities, where transactions create costs for third parties. Finally, regulation of product quality or contract terms is directed at costs or benefits of market transactions that are not reflected in the terms of exchange.

Regulation seems like a straightforward solution, since it simply involves mandating a maximum amount of emissions that would be allowed, but implementing it has the same problems that the quantity intervention in the output market had in that it asks for detailed information. Specifically, there is the issue of how the mandated maximum amount of emissions are to be distributed among the producing firms. In order to achieve efficiency, the policymaker would need to have detailed information on firms' costs of abatement in order to mandate the different levels of emission or abatement on each firm. However, this information is often difficult for government regulators to obtain (Mankiw 2020).

2.4.2. Taxes

A commodity tax is “a government fee or charge on certain transactions involving the production or sale of certain commodities” (Tandon 2015, p. 183). A Pigovian tax is a price restriction method proposed by the economist A. C. Pigou (Tandon 2015). It imposes a commodity tax equal to the size of the price differences caused by externalities. O'Hagan (1984a, p. 589) demonstrated that a “Pigovian tax will generally be optimal in the competitive market irrespective of whether or not the total tax payment covers total damages at the optimum; and in some circumstances both subsidies and regulation may be practical as well as efficient”. It had traditionally been acknowledged that a Pigovian tax would maximise welfare in relation to an environmental externality (O'Hagan 1984b). Based on who the tax is levied on, it can be called an excise tax or a sales tax (Tandon 2015). An excise tax is levied on sellers and a sales tax is levied on buyers of goods. Figure 2-6 shows these two types of taxes influence the supply and demand.



Source: adapted from Tandon (2015)

Figure 2-6 Effect of excise taxes and sales taxes

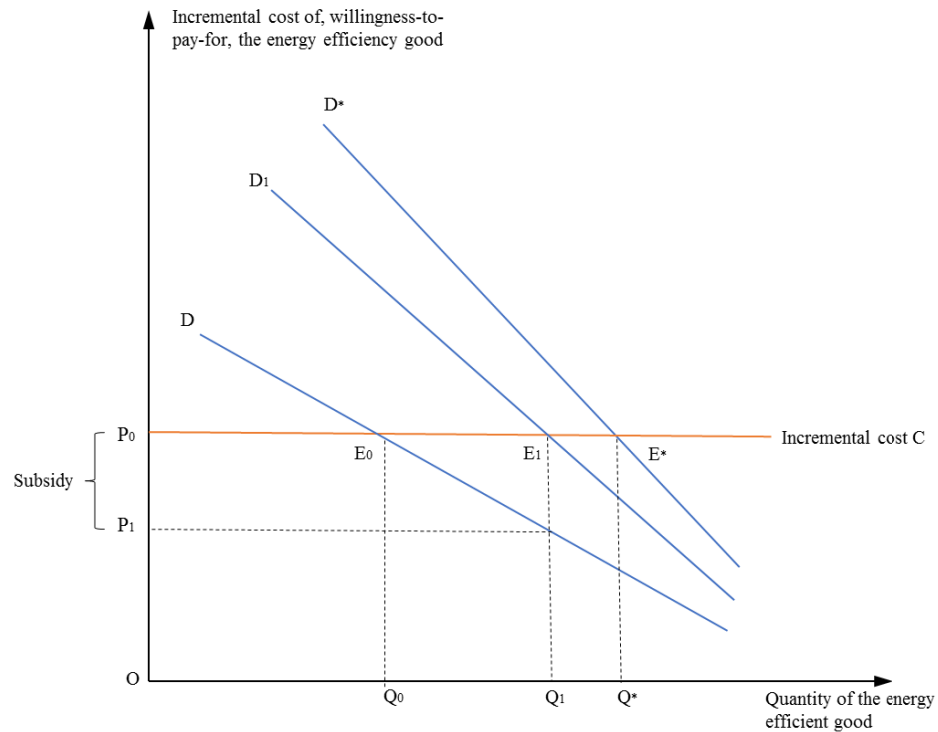
In the figure, S is the supply curve of energy without tax, and S^* represents the tax-inclusive supply curve. The supply curve goes up because the cost of energy per unit is increased by adding the excise tax. The vertical distance between S and S^* is the amount of the excise tax. The excise tax changes the equilibrium quantity from Q_0 to Q_1 . D in this figure is the demand curve of energy without tax, D^* represents the tax-inclusive demand curve. The demand curve goes down because D^* represents the demand curve as a function of the price (the “sticker” price), because consumers know that there will be a sales tax levied on top of the price. The demand curve D is still the demand as a function of the total price; the total price is the sticker price plus the sales tax per unit. The vertical distance between D and D^* is the amount of the sales tax. The sales tax changes the equilibrium quantity from Q_0 to Q_1 .

The Pigovian tax is levied on the final output and is intended to address the problems caused by the emission of pollution from the production process. A more direct solution to the problem of negative externalities caused by a production process is effluent fees which try to reduce the amount of pollutant itself (Tandon 2015). Faced with having to pay a fee for any pollutants they emit, firms will look for ways to avoid paying it. The only way to do this is to reduce the pollution before discharge.

2.4.3. Subsidies

In the most general definition of subsidy, it is defined as “any government assistance that i) allows consumers to purchase goods and services at prices lower than those offered by a perfectly competitive private sector, or ii) raises producers’ incomes beyond those that would be earned without this intervention” (Schwartz & Clements 1999, p. 120). A subsidy is a negative tax (Tandon 2015). Instead of charging fees in transactions (buying or selling) from economic agents as taxes do, the government pays fees for agents to undertake transactions. The government offers subsidies to either buyers or sellers, depending on the type of subsidy.

Here we investigate further how government subsidies on energy efficiency influence the market (see Figure 2-7).



Source: adopted from Allcott & Greenstone (2012)

Figure 2-7 Effect of subsidies on energy efficient goods

In Figure 2-7, the horizontal axis represents the quantity of the energy efficient good that is purchased, while the vertical axis shows the incremental costs of purchasing that good. The supply price set by the market is shown in the figure as incremental cost C . Demand curve D^* represents the ideal situation that energy price is equal to the social cost, which means there are no externalities in this market situation. Demand D represents the current market demand situation where there are unpriced energy externalities. Now put subsidy in the market. The incremental cost of the energy efficiency good, the willingness-to-pay-for, is reduced from P_0 to P_1 . Then the quantity of the energy efficient good can move from Q_0 to Q_1 . As a result, the demand curve D moves to D_1 to reach a new equilibrium. It could be found that the new demand curve D_1 is closer to the ideal situation that the demand curve is D^* . The demand curves D , D_1 and D^* are constructed based on a model of investment in energy efficiency in the research (Allcott & Greenstone 2012).

Subsidies can be specific or ad valorem (Pindyck & Rubinfeld 2009; Tandon 2015). Subsidies can be classified into seven categories (Schwartz & Clements 1999): i) direct government payments to producers or consumers (cash subsidies or cash grants); ii) government guarantees, interest subsidies to enterprises, or soft loans (i.e., low-interest government loans) (credit subsidies); iii) reductions of specific tax liabilities (tax subsidies); iv) government equity participations (equity subsidies); v) government provision of goods and services at below-market prices (in-kind subsidies); vi) government purchases of goods and services at above-market prices (procurement subsidies); and vii) implicit payments through government regulatory actions that alter market prices or access (regulatory subsidies).

2.5. Institutional Economics: Williamson's Theoretical Framework and Transaction Cost Theory

2.5.1. Introduction of Institutional Economics

Institutional economics reveal the nature and role of social institutions (Hodgson 2001). It explains the origin of the institutions and ways to improve economic efficiency. The recent approach of institutional economics dates from Williamson (1975) who used the term “new institutional economics” to refer to his analysis of transaction costs about the nature and structure of the firm. Based on the statement from (North 1986), institutional economics are used to discuss alternatives defined by institutions through shaping the structure of political decision and property rights and norms of behaviour of people. Institutional economics not only characterise goods and services but also the performance of agents rather than the two determinants in price theory of price and quantity. Institutions affect economic performance by determining the cost of transaction and production (Furubotn & Richter 2010).

2.5.2. The Theory of Transaction Costs

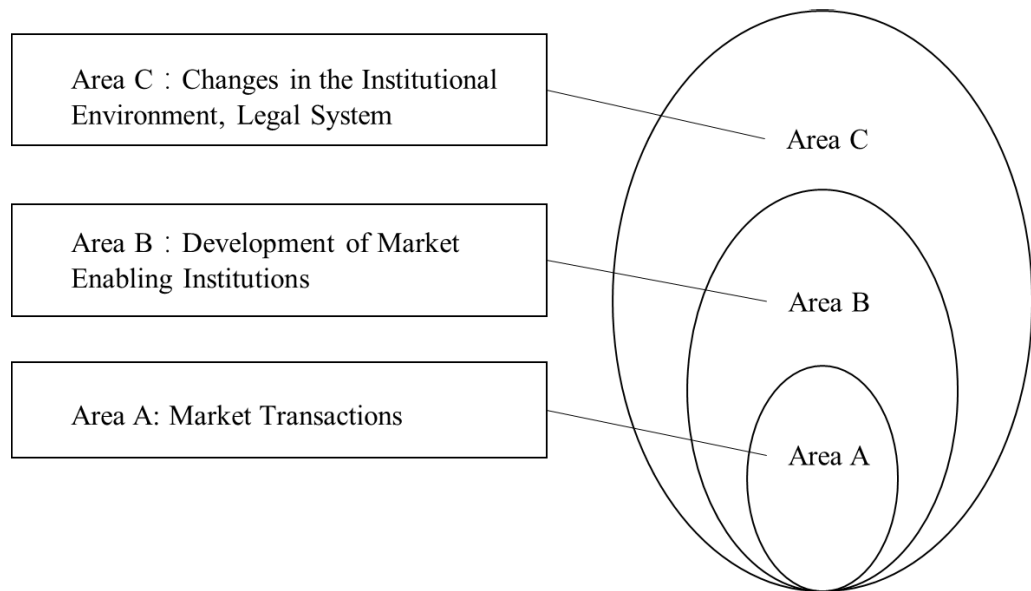
Initially, the concepts of transaction costs and internalisation were put forward in the article on “the nature of the firm” by Coase (1937), who stated that what kind of organisation is adopted by a firm depends on transaction cost, and the boundary is decided by the external market transaction cost and internal firm management cost. In Coase's

original formulation, transaction costs refer to “the cost of using the price mechanism” (Coase 1937, p. 390) or “the cost of carrying out a transaction by means of an exchange on the open market” (Coase 1937, p. 395). Although his statement does not directly link market operation with inefficiency, and transaction costs with market failures, it implies market failure – barriers – since allocation does not occur at zero transaction costs but provides for monopoly with sizable transaction costs. Later, Arrow (1969, p. 48) defined transaction costs as the “costs of running the economic system”. Those costs are different from production costs and are economically equal to friction in physical systems (Williamson 1985).

Williamson (1985) based his theory of economic organisation on the proposition that transaction costs determined the organisation of markets and its participants. He used and extended Arrow’s definition of transaction costs and divided them into two groups: *ex ante* and *ex post*. *Ex ante* transaction costs include “drafting, negotiating, and safeguarding an agreement” (Williamson 1985, p. 20), which is similar to the concepts of transaction costs in conventional microeconomic, while *ex post* transaction costs include maladaptation cost, haggling cost, setup and running cost associated with the governance structures, and bonding costs of achieving secure commitments (Williamson 1985, p. 21). Later, researchers further extended this definition under different circumstances. For example, in the sector of environmental policy, transaction costs are understood as the costs of producing and implementing policies (Coggan et al. 2013); in the field of construction, transaction costs are defined as the costs of technology implementation in the *ex ante* period, and monitoring and enforcement in the *ex post* period (Kiss & Mundaca 2013). For a specific energy efficiency project, transaction costs include information searching cost, negotiation cost, approval and certification cost, monitoring and verification cost, trading cost and contracting cost, etc. (Fan, Chan & Qian 2018; Mundaca T et al. 2013). In summary, transaction costs provide the primary explanation for the particular form taken by both large-scale economic institutions and specific contractual relationships (Williamson 1985). The flexibility and comprehensiveness, demonstrated in the next section, make this a useful framework for this research. The next section identifies the organisational characteristics, and transaction cost theory allows a general analysis where microeconomic theory deals with specifics without integrating them into a whole.

2.5.3. Boundaries of Using Transaction Costs

Based on the different definitions of transaction costs, transaction costs can be applied at different transaction levels. McCann et al. (2005) studied the boundaries of transaction costs and made a model of the distinctions of transaction levels shown in Figure 2-8.



Source: adapted from McCann et al. (2005)

Figure 2-8 Boundary issues relating to Transaction Costs

This model shows clearly the involvement of policy and non-policy cost (policy cost associated with the policy implementation, and non-policy cost generated in the parties of voluntary transactions). In the figure, Area A is the simple market transaction costs, Area B is the activities involving other institutions for resource allocation, and Area C is the government's intervention for market failures, and sometimes a broader institutional involvement like the legal system (McCann et al. 2005).

This research focuses on the market transactions for the EPC market. Although it involves government intervention and part of policy design, the purpose is to reduce the transaction costs within the EPC project. Therefore, the boundary for this research is using the transaction cost under the market transaction level.

2.5.4. Behavioural Assumptions

“Transaction cost economics characterizes human nature as bounded rationality and opportunism” (Williamson 1985, p. 44). First, bounded rationality is the cognitive assumption which means a human cannot make a decision totally rationally without complete knowledge. Based on bounded rationality, there are two processes to economise: the decision processes and governance structures (Williamson 1985). Second, “opportunism refers to the incomplete or distorted disclosure of information”, which is “responsible for real or contrived conditions of information asymmetry” (Williamson 1985, p. 47). Bounded rationality and opportunism are the original problems leading to uncertainties in economic activities (Slater & Spencer 2000; Williamson 1985).

Meanwhile, transaction cost theory makes assumptions that two cooperative companies are risk-neutral, treat each other as equal, have rich business experience and have employees specialised in all areas of management, law, technology and finance (Miles 2012). With these assumptions, the theory focuses on differences in contracting issues between the cooperative companies and on the costs involved in contracts (Williamson 1985). Therefore, government interventions should be designed carefully in order to help companies reduce transaction costs for better cooperation in the EPC market.

2.5.5. Theory Application and Conceptual Framework

The application of transaction cost theory to the BEER market is fairly new, and few studies have empirically analysed transaction costs on BEER market incentives (Fan, Chan & Qian 2018). Fan, Chan & Qian (2018) claim that transaction costs have substantial influences on the effectiveness of implementation of policy, and discourage companies from entering the energy efficiency market. Based on several papers which analyse how transaction costs affect some energy efficiency industries, all of these research findings follow “transaction cost determinants” to develop, considering different stakeholders, the implementation process and uncertainties (Coggan et al. 2013; Fan, Chan & Qian 2018; Kiss 2016; Qian, Chan & Choy 2013). Transaction cost determinants are the rational economic reasons and can act as a conceptual framework for organising transactions (Fan, Chan & Qian 2018; Williamson 1985).

Williamson (1985) proposed transaction cost determinants as three dimensions: asset specificity, frequency and uncertainty. All of these affect the amount of transaction costs, which are widely used in the decision making analysis for stakeholders (Fill & Visser 2000). The three dimensions are presented in detail.

(1) Asset Specificity

Asset specificity stands for the extent to which assets can be used for different purposes and utilised by different users without sacrificing their productive value. As Williamson (1985, p. 55) said, “asset specificity refers to durable investments that are undertaken in support of particular transactions, the opportunity cost of which investment is much lower in best alternative uses or by alternative users should the original transaction be prematurely terminated”. It emphasises the specificity of the use of assets and investment purpose. “Transactions that are supported by investments in durable, transaction-specific assets experience ‘lock in’ effects, on which account autonomous trading will commonly be supplanted by unified ownership (vertical integration)” (Williamson 1985, p. 53). Asset specificity can be divided into at least into four types: site specificity, physical asset specificity, human asset specificity, and dedicated assets (Fan, Chan & Qian 2018; Williamson 1985). Definitions of each asset specificity are shown in Table 2-1. Different types can be analysed by specific organisational issues, such as nonstandard contracting, corporate governance, regulation, and so forth.

Table 2-1 Definitions of asset specificity

Types of Asset Specificity	Definitions
Site specificity	Specialised investments have to be located on a particular site.
Human asset specificity	Specialised skills, knowledge, and learning-by-doing cannot be transferred to alternative transactions.
Physical asset specificity	Specialised instruments and equipment used in a particular transaction.
Dedicated asset	Discrete investments in generalised production for the capacity to sell a number of products to particular buyers, such as expanding the existing plant for a specific customer.

Source: Williamson (1985) and Fan, Chan & Qian (2018)

In the context of energy efficiency transactions, asset specificity relies on the value of the specific investments due to the application and specific set-ups. There are usually three types of asset specificity: site specificity, human (knowledge) asset specificity, and physical asset specificity (Fan, Chan & Qian 2018). For BEER under EPCs, site specificity refers to the energy efficiency design, equipment instalment and facility update to the specific site; human (knowledge) asset specificity is understood as the specific knowledge and technologies required by ESCOs; and physical asset specificity refers to the non-standard contract due to the implementation of the EPC that the stakeholders need to negotiate and develop during the EPC process (Fan, Chan & Qian 2018; Kiss 2016; Qian, Chan & Khalid 2015).

(2) Uncertainty

Williamson (1985) divides uncertainty into primary uncertainty, secondary uncertainty, and behavioural uncertainty. Primary uncertainty always happens naturally in the physical environment, which is always in a contingent state. Secondary uncertainty comes from lack of communication between contracting partners, which is always caused by poorly designed contracts. Behavioural uncertainty is attributed to the opportunism attribution. In the context of energy efficiency transactions, uncertainty includes technological uncertainty, institutional uncertainty and behavioural uncertainty (Fan, Chan & Qian 2018; Qian, Chan & Khalid 2015). The uncertainty of EPCs is analysed in Chapter 3 Section 3.5.

(3) Frequency

Frequency refers to the frequency of transactions, and the higher the frequency the lower the transaction costs. Specialised governance structures can affect transaction costs (Williamson 1985). Because transaction costs can require less effort to learn and gather information by the transaction parties, transactions can be repeated (Coggan, Whitten & Bennett 2010). The precondition is that past experience can be transferable to new cooperation, such as transferable knowledge, information and technologies (Coggan et al. 2015). Therefore, any incentive mechanism design is required to contain more transferable knowledge or skills to reduce transaction costs (Fan, Chan & Qian 2018).

2.5.6. Linkage between Transaction Costs and Market Failure

As the previous section elaborated, transaction costs are the costs of using the market mechanism as defined by Coase (1937). It costs to organise market exchange or overcome the obstacles to an efficient market process. Arrow (1969) was the first to link market failure to transaction costs. He assumed that transaction costs can be considered a general cause of market nonexistence or failure. Most market exchanges face different degrees of costs, where different types of market failures show different forms or magnitudes of different transaction costs. Tamara (2015) stated that the different forms of market failure present themselves as the different perspectives of characters of transaction costs. Tamara (2015, p. 2) elaborated it as “all types of market failure where the costs of market exchange are exhibited may be traced to transaction costs and all types of market defects may reflect transaction costs or have transaction cost roots of a specific kind”. The boundaries between market failures and transaction cost theory are blurred. However, there are precedents for the approach used here, to discuss the market failures individually as barriers to efficiency in microeconomics and to discuss them collectively as transaction costs under Williamson’s framework (Furubotn & Richter 2010). There are specific examples in the research of energy efficiency: Sorrell et al. (2004), Schleich (2007) and Qian (2012) studied barriers to energy efficiency from an economic perspective. Those barriers were explained both by the market failure approach and the transaction cost approach (see Table 2-2).

Since all forms of market failures can be explained by transaction costs, it is logical to establish linkages between market failures and the concept of transaction costs (Tamara 2015). However, analysing market failure through the overall coverage of transaction costs is missing. From the perspective of new institutional economics, of which Williamson is the best example, when transaction costs are too large, they inhibit exchange, production and economic growth (Williamson 1985). From the perspective of transaction cost economics, transaction costs in energy efficiency create frictions during projects. Therefore, it emphasises policy interventions to remove the frictions for a smoother transaction. This situation calls for an in-depth study of how to enable market stakeholders to trade smoothly in energy efficient development, with the aim of reducing the transaction costs involved in transactions of energy efficiency projects. From the perspective of microeconomics, barriers to energy efficiency distort the marginal costs,

revenue and utility from the general equilibrium values. There is a relationship between the barriers to energy efficiency and the frictions in the transactions of energy efficiency projects (Qian 2012).

Table 2-2 Barriers to energy efficiency from economics perspectives

Barriers	Common Claims	Remarks: Energy efficiency transaction cost considerations
Risk	Energy efficiency investment represents a higher technical or financial risk than investing in conventional buildings. The business and market uncertainty encourages short term capital return.	High asset specificity and higher risks than other forms of investment. Perceptions of risk may depart from that of a rational decision maker in the neoclassical economic model and may bias against energy efficient investment.
Imperfect information	Lack of information on energy efficiency leads to high risks thus extra costs. It also leads to a distorted market caused by inefficient products driving efficient products out of the market.	Transaction costs associated with acquiring, understanding and applying information. Bounded rationality may apply. Transaction costs of information acquisition may be high due to quality and credibility.
Hidden costs	Energy efficiency potential may be overestimated by failing to account for the reduction in utility associated with energy efficiency technologies and other additional costs.	The transaction costs associated with hidden items may outweigh the potential savings in energy costs.
Access to capital	Energy efficiency investments may be avoided if market stakeholders have insufficient capital through internal funds and have difficulty raising additional funds. Energy efficiency investment could also be inhibited by internal capital budgeting procedures, investment appraisal rules and the short-term/instable incentives.	Transaction costs associated with obtaining additional funding may be more significant for small cost-saving projects. The transaction costs of assessing investment opportunities may inhibit optimal decision making. Severe costs may force managers to focus on strategic investments and overlook small cost saving opportunities.
Split incentives	The cost and benefit of energy efficiency investment is borne by different parties and it is difficult to appropriate the benefits of the investment.	Transaction costs may inhibit shared saving contracts to overcome split incentive problems.
Bounded rationality	Owing to constraints on time, attention and the ability to process information, individuals do not make decisions in the manner assumed in perfect economic models. To avoid loss in time, money and risk, they tend to neglect energy efficiency, even when given good information and appropriate incentives.	Cost constraints may lead to the use of imprecise rules of thumb, which may neglect the small cost savings from energy efficiency improvement. Loss aversion and status quo bias may undervalue the benefits of energy cost saving. Risk aversion with respect to gains reinforces this inertia.

Source: Sorrell et al. (2004), Schleich (2007), and Qian (2012)

As there is a tight linkage between Williamson's concept of transaction costs and market failure, it is adopted in this research to help develop the theoretical framework of dealing with market imperfections. Meanwhile, although it is very difficult to measure the absolute value of transaction costs due to their characteristics, they can be easily observed based on the determinants of transaction costs that were introduced in Section 2.5.4 (Sorrell et al. 2004). Therefore, addressing transaction costs can be more powerful if they work together with the market failure approach to explore evidence from real society to test the theory of market imperfections.

2.6. Summary

This chapter introduced the basic concepts of this research from the theory of price under microeconomics to Williamson's theory of transaction costs under institutional economics. The linkage between market failures and transaction costs was analysed through a literature review. With the goal of achieving an efficient market, this chapter examined four situations where markets fail to function on prices well and what government can do to deal with these failures by adapting transaction cost theory. These two theories are set as the theoretical foundation for this research. The theory of market imperfections is tested in the market of commercial building energy efficiency retrofit by using EPCs (Chapter 8). The theory of transaction costs is used directly as a tool and together with the theory of market imperfections to design the incentive mechanism for the EPC market by dealing with market barriers (Chapter 9). The next chapter provides an overall view in the literature of the current situation of commercial building energy efficiency retrofit under EPCs in China.

Chapter 3 Literature Review: EPC Market and Theoretical Framework Design

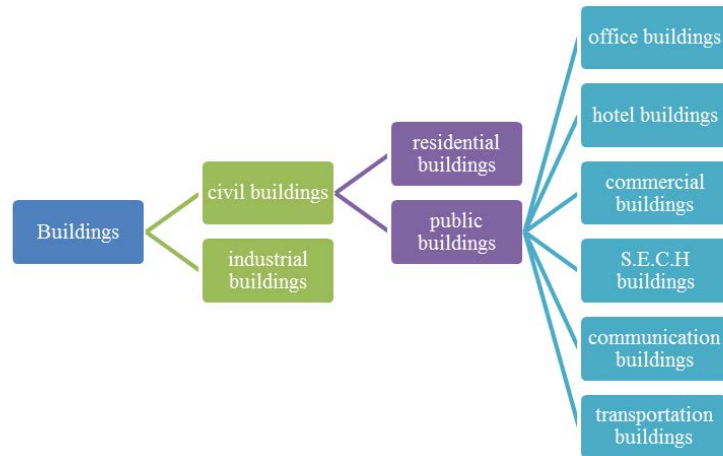
3.1. Introduction

This chapter provides a systematic literature review to provide the background for the research by introducing energy performance contracts (EPCs), commercial building energy efficiency retrofit (CBEER), the Chinese EPC market, risks of CBEER under EPCs in China and the Chinese policy system of energy conservation. As this research focuses on examining EPCs in the CBEER market, it is important to evaluate the current EPC market and how EPCs operate in commercial building retrofits. This information puts the research into perspective and shows that there are various market barriers to CBEER and risks of using EPCs.

3.2. Energy Efficiency Retrofits for Commercial Buildings

3.2.1. Building Classifications

China National Standard GB50189-2015 makes a systematic classification of buildings (MOHURD 2015), shown in Figure 3-1. Buildings are broadly divided into civil and industrial. Civil buildings include residential buildings and public buildings, noting that public buildings in China are not limited to government owned properties. Public buildings can be divided by functions into office buildings (e.g. business office buildings and government institutes), hotel buildings (e.g. hotels, restaurants, entertainment venues), commercial buildings (e.g. shopping centres, retail, and financial buildings), SECH (science, education, culture and health) buildings (e.g. schools, hospitals, museum, gymnasium), communication buildings (e.g. post, telecommunication buildings, broadcast buildings) and transportation buildings (e.g. airports, stations).



Source: adapted from MOHURD (2015)

Figure 3-1 Building classifications in China

However, building functions can vary within one building. For example, office buildings may include not only offices but also shopping centres. Thus in a broad sense, commercial buildings are used in the service sector (Hou et al. 2016) and can be defined as a building that can offer people not only business activity functions but also services, entertainment, culture and leisure or relaxation characteristics (Wan 2009). This research investigates commercial buildings where demand is sensitive to price changes in China. Therefore, in this research, commercial buildings refer to buildings used for business activities, including business office buildings (not government office buildings), retail, shopping centres, hotels, commercial complexes, and other related building types (see Figure 3-2).

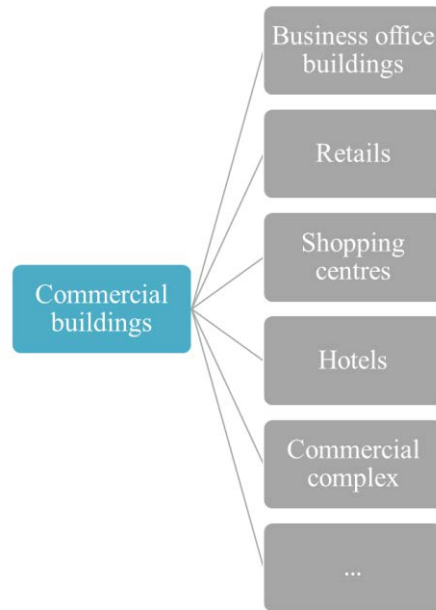


Figure 3-2 Classification of commercial buildings

This research examines the characteristics of the EPC market, thus the focus of this research is on the overall market situation but not a particular technology of energy efficiency. As the buildings all operate in the same market, there is no need to further distinguish between the different subcategories of commercial buildings. Rather, energy saving potential is the most important consideration. Therefore, the research scope is the energy efficiency market in commercial buildings. In the following, the term “CBEER market” is used to refer to the energy efficiency market in commercial building energy efficiency retrofits. More details about the energy saving potential of commercial buildings and the energy efficiency market are discussed below.

3.2.2. Energy Saving Potential of Commercial Building Retrofit

Commercial buildings consume a great amount of fossil fuel and release a corresponding amount of carbon dioxide in the sector of public buildings (Hong et al. 2015). As demonstrated by the Database of Building Energy Consumption and Carbon Emissions in China, carbon emissions from China’s commercial buildings (referring to the broad definition in Section 3.2.1) constitute approximately 40% of carbon emissions generated through China’s civil building sector over the past decade (Ma & Cai 2018; Ma & Cai 2019).

Most commercial buildings were built before the first national design standard for energy efficiency of a public building in 2005 (GB50189-2005) in China (MOHURD 2005). Those buildings consume a great amount of energy and are now in need of retrofitting (Hou et al. 2016). Energy statistics, energy audit and energy diagnosis show that all kinds of commercial buildings consume a significant amount of energy (Hou et al. 2016; Ma & Cai 2019). Hong (2009) suggested that in the annual energy use of public buildings (especially large shopping centres, high-class hotels, high-class offices, etc.), about 50–60% is for HVAC (Heating, ventilation, and air conditioning), and 20–30% is for lighting. The potential for energy savings in public buildings is estimated to be around 50% by energy efficiency design of the building envelope, lighting and HVAC systems (Hong 2009). Commercial buildings generally have greater internal heat load intensity from lighting, equipment and occupants than residential buildings, so heating retrofits may not be as effective as residential buildings (McNeil et al. 2016).

3.2.3. Energy Efficiency Market

The energy efficiency market is not one single market but a mixture of various industries including appliance manufacture, construction, and more (Bukarica & Tomšić 2017). The supply side of the energy efficiency market includes various institutions involved in financing and implementation of energy efficiency projects (banks, investment funds, energy service companies, service providers, design engineers, constructors, etc.) (Bukarica, Morvaj & Tomšić 2007). The demand side of the energy efficiency market includes project sponsors with ideas for renters, building managers, public sector institutions and local authorities (Bukarica & Tomšić 2017).

The performance of the energy efficiency market can be evaluated according to the actual energy efficiency improvements delivered, according to the number of successfully implemented energy efficiency projects (Bukarica & Tomšić 2017). This research sets the research scope as the sector of commercial buildings and focuses on a particular market mechanism of EPCs, therefore the willingness to conduct CBEER and use EPCs can represent the situation of the energy efficiency market.

3.3. Energy Performance Contracts (EPCs)

3.3.1. General Explanation of EPCs

An EPC is a market mechanism to implement energy efficiency retrofits by guaranteeing saved energy consumption costs (Carbonara & Pellegrino 2018). This is known as a financing package from ESCOs and includes energy savings guarantees, associated design, and installation services for energy efficiency projects (Xu 2012; Xu, Chan & Qian 2011). The UK's Energy Efficiency (Encouragement, Assessment and Information) Regulations 2014 define an EPC as “a contract under which energy efficiency measures are provided; verified and monitored during the whole term of the contract; and paid for by reference to a contractually agreed level of energy efficiency improvement or other agreed criterion such as financial savings” (DECCUK 2014, p. 2). The unique feature of an EPC is that it is an innovative form of contracting, developed to overcome the major barriers to delivering cost-effective energy efficiency. EPCs differ from traditional contracts, which are invariably price-driven, and are a results-driven way of ensuring the quality of performance (AEPKA 2000).

3.3.2. Relationship of Stakeholders in CBEER under EPCs

For commercial buildings, there is a landlord–tenant relationship if the building owner leases part or all of the building out (Halvitigala, Murphy & Levy 2011) and the property right is separated from the usage right (Brown 2001). Under EPC, ESCOs undertake the entire energy efficiency retrofit including energy audit. However, in order to demonstrate transparency energy audits are sometimes offered by other institutions with relationships to either building owners or both owners and ESCOs (Dong & Lin 2016). The relationship between each stakeholder of a commercial building retrofit under an EPC is shown in Figure 3-3.

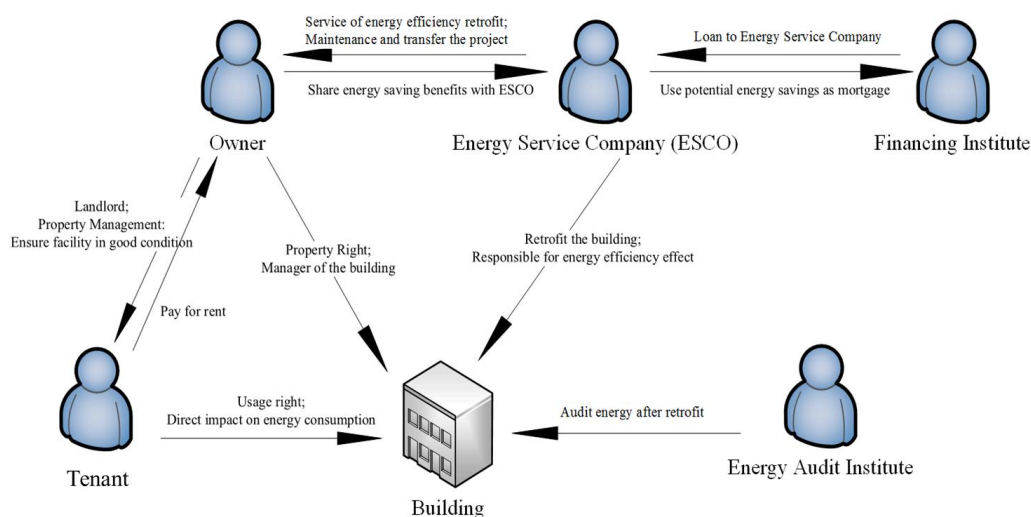
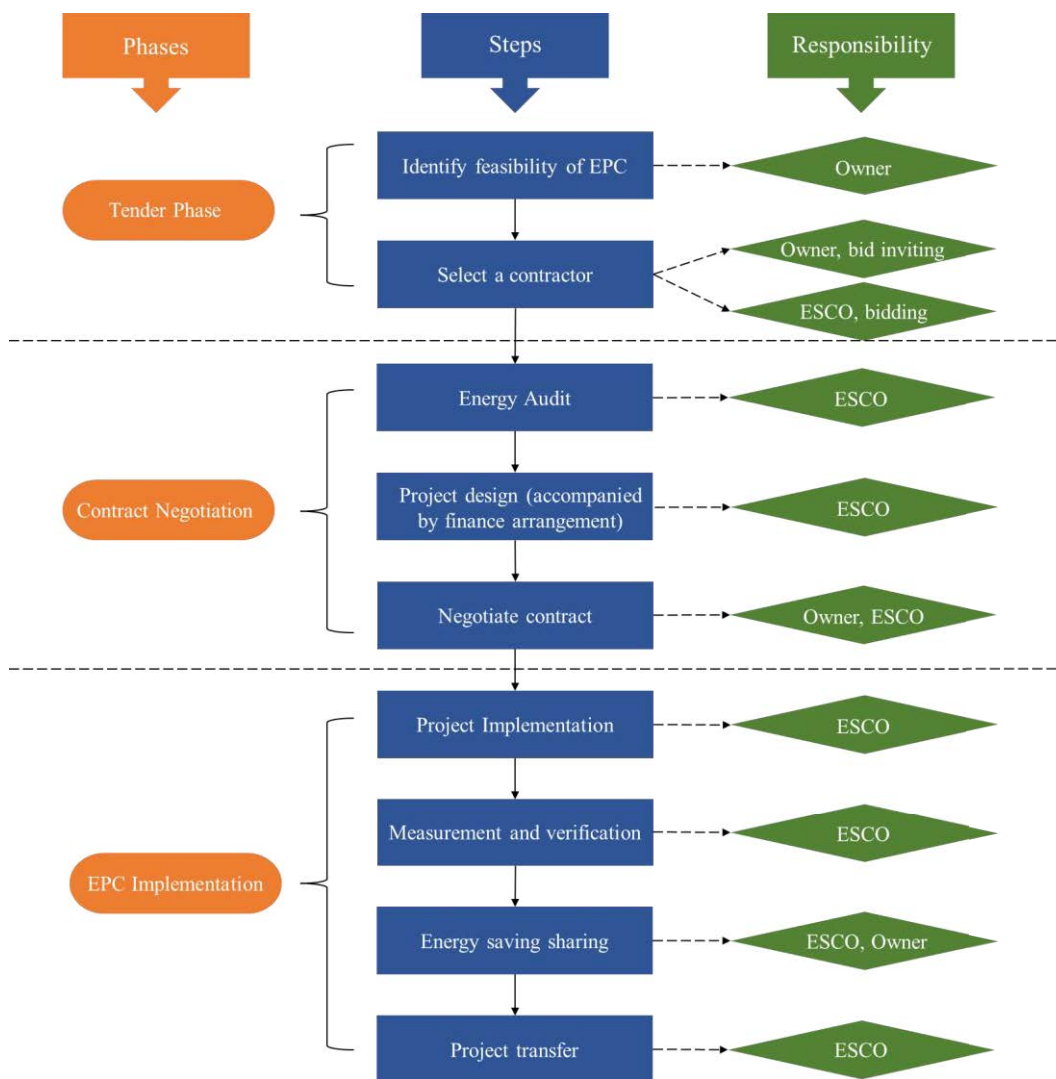


Figure 3-3 Relationship between stakeholders of CBEER under EPCs

3.3.3. General Process of an EPC Project

There are various stages to implement an EPC mechanism for different projects. To summarise a typical EPC process, this part compares the general EPC process in four countries: Australia, China, UK and US. The UK's Guide to Energy Performance Contracting Best Practices (DECCUK 2015) summarised a typical EPC process in the UK as five stages: identify requirements, resources and funding approach; tender phase; full investment grade proposals; install energy conservation measures; and monitor service delivery performance. Similarly, in Australia Australasian Energy Performance Contracting Association (2000) outlined four major steps towards implementing an EPC involving deciding whether or not to use an EPC; selecting a preferred supplier; developing and agreeing on the final scope of the project; and negotiating and awarding a contract. In China, the general process of an EPC adds more details: project organisation; project suggestion; finance; contract negotiation; construction; operation and maintenance; energy audit; and project transfer (Guo 2016; Huang 2016). In the US, Maryland Energy Administration of United States (2014) defined the EPC process begins with the identification of potential energy efficiency projects, proceeds through the definition of an EPC project and concludes with the selection of a contractor and award of the performance contract. Based on the comparison of four countries' practice, it can be seen that the general process is the same, and can be generalised as three main phases: tender phase; construct negotiation; and EPC implementation. These stages can also be divided into several steps, including identify the feasibility of an EPC, select a contractor,

energy audit, project design, negotiate the contract, project implementation, measurement and verification, energy saving sharing, and award contract and transfer project (shown in Figure 3-4).



Source: Adapted from DECCUK (2015); AEPCA (2000); Guo (2016); Huang (2016) and MEAUS (2014)

Figure 3-4 General EPC process

The detailed information is as follows.

Phase 1: Tender Phase

Step 1: Identify the feasibility of an EPC

An EPC project begins with a preliminary analysis of building conditions by engineers (or facility managers) engaged by the building owner, which starts with the collection of utility, cost and usage information. Then a more in-depth facility profile is conducted to identify the boundaries and scope of the potential projects, including facility operation information and basic background data on the major energy systems, including HVAC, controls, lighting, water fixtures, building envelope, O&M, new technologies, and renewable resources (Xu 2012).

Step 2: Select a contractor (ESCO)

Once the owner feels that the project has potential to use the EPC mechanism, a request for proposal (RFP) will be drafted and issued for relevant ESCOs who are interested in this project, which is the mechanism for selecting the “Preferred Proponent” with whom the owner then negotiates an EPC. The RFP defines the general scope of work, along with specific requirements that must be addressed by a performance contract (AEPCA 2000). After a pre-proposal meeting and a site visit, two or more proposals will be received from ESCOs for competitive bidding. Based on the best overall program (through proposal scoring, references, and interviews), an ESCO will be selected (MEAUS 2014). Cost is not the main driver for the selection (AEPCA 2000).

Phase 2: Contract Negotiation

Step 3: Conduct energy audit

The selected ESCO will carry out a technical audit and establish all the details of the project, which is needed to negotiate with the owner.

Step 4: Design the project

The ESCO will develop a detailed planning and project design which will include the identification of possible energy savings and efficiency improvement actions.

Meanwhile, an “investment grade” audit should also be conducted in this step, including financing suggestions, cost and payment analysis (Xu 2012). The ESCO arranges for long-term project financing that is provided by a third-party financing institution.

Step 5: Negotiate contract

After the facility owner accepts the investment proposal, and financing sources are identified and secured, it is time to draft and sign the contract. The contract negotiations include the guaranteed savings, contract period and exact costs associated with the entire project. In addition, the method for monitoring energy savings and the financing arrangements can also be finalised at this stage.

Phase 3: EPC Implementation

Step 6: Implement the project

Project construction follows the process of other capital construction projects. EPCs are used to purchase a wide variety of building equipment and services. Common improvements in existing buildings include energy-efficient HVAC systems; energy management control systems; motor replacements; variable-speed drives for pumps and fans; building envelope improvements; and water-efficient fixtures. Renewable energy and cogeneration systems may also be purchased. In addition to equipment installation, the ESCO may propose various repair and maintenance services (Zhang et al. 2018).

Step 7: Measure and verify energy savings

The measurement and verification (M&V) of energy savings involves calculating cost savings. The most used protocol for the M&V of performance contracts is the International Performance and Measurement Verification Protocol (IPMVP) (MEAUS 2014; Xu 2012). The schedule for conducting M&V and for issuing regular reports to the building owner should be clearly established in the EPC contract. In some cases, clients hire a third party to review and confirm the ESCO’s M&V reports (AEPKA 2000).

Step 8: Share energy savings

The sharing of the savings from reduced use of energy is based on the benefit allocation in negotiated contracts.

Step 9: Transfer project

Once the contract period has been completed, the project should move into the service delivery phase. The ESCO should transfer the project to the owner. In some cases in China, ESCO and the owner should also apply for government EPC finance subsidies (Hou et al. 2016).

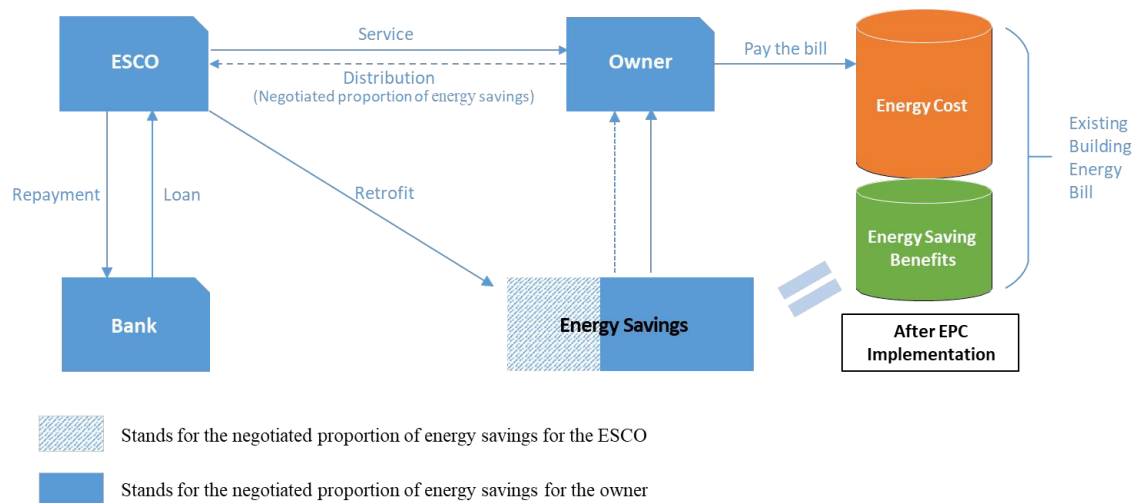
3.3.4. Business Model of EPCs

The business model of an EPC is the base for the successful implementation of EPC projects. It is related to the EPC project operations and refers to the project agreement between owners and ESCOs (Hopper et al. 2005; Shang et al. 2017). It also identifies the roles of energy customer and ESCOs in the implementation of EPC projects and defines the participants' responsibility and risk sharing in an EPC project (Pätäri & Sinkkonen 2014).

There are different business models of EPCs in existing research studies. The most common ones are shared savings model, guaranteed savings model and energy-cost trust model (Guo 2016; Qin et al. 2017; Shang et al. 2017). The three main business models of EPCs are defined in the existing literature as follows.

(1) Shared Savings Model

In the shared savings model (see Figure 3-5), the ESCO signs a financing and performance contract with the owner confirming the benchmark and energy savings. The ESCO has responsibility for designing, financing and implementing an EPC project (Shang et al. 2017). During the project, the owner and the ESCO share the project benefits according to specified negotiated proportions. When the project term is over, the energy saving equipment is transferred to the owner. Thereafter, all the benefits from the achieved energy savings accrue to the owner. The ESCO undertakes both the performance and the credit risk in this model (Qin et al. 2017). That means a fixed portion of the energy savings is paid to the ESCO over a fixed period, leaving almost “zero risks” to the owner (Li, Qiu & Wang 2014).



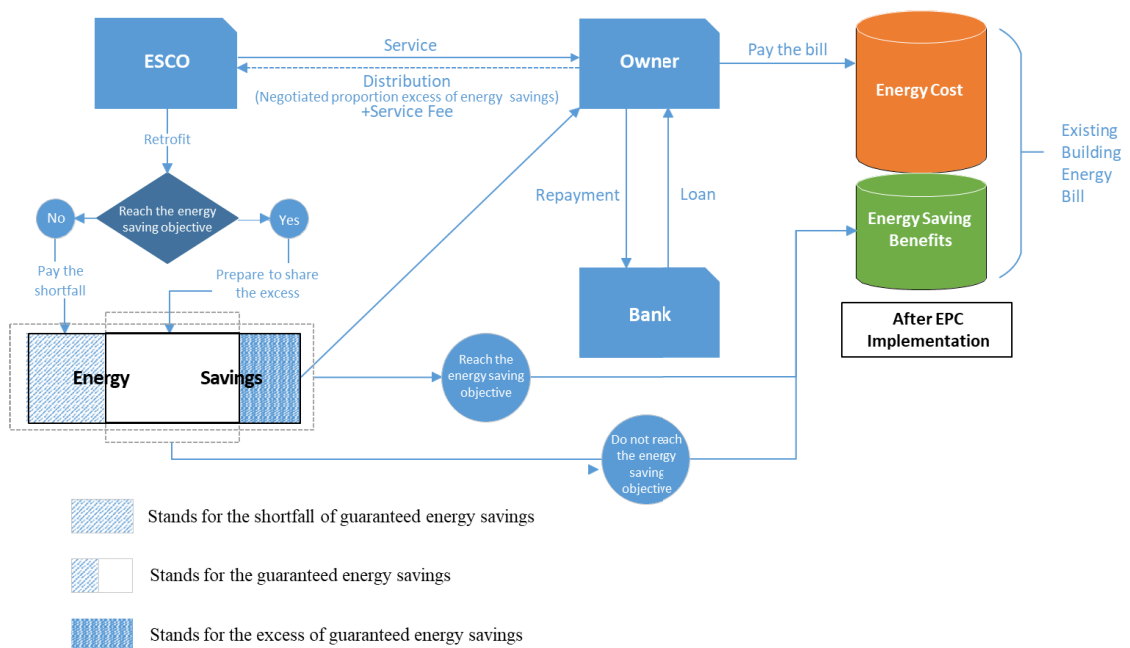
- When the EPC project transfers to the owner, the owner can receive all the energy savings as the benefits.

Source: adapted from Shang et al. (2017); Qin et al. (2017); and Li, Qiu & Wang (2014)

Figure 3-5 Process of shared savings model

(2) Guaranteed Savings Model

In the guaranteed savings model (see Figure 3-6), the owner finances the EPC project internally (through banks and other financing agencies) (Qin et al. 2017). In return, the ESCO guarantees a certain level of energy savings. When the savings on an energy bill fall short of the guaranteed level, the ESCO will pay the owner the difference. Any savings above the guaranteed amount will be shared by the ESCO and the owner according to the proportions specified in the contract (Akman, Okay & Okay 2013; Guo 2016; Xu 2012).



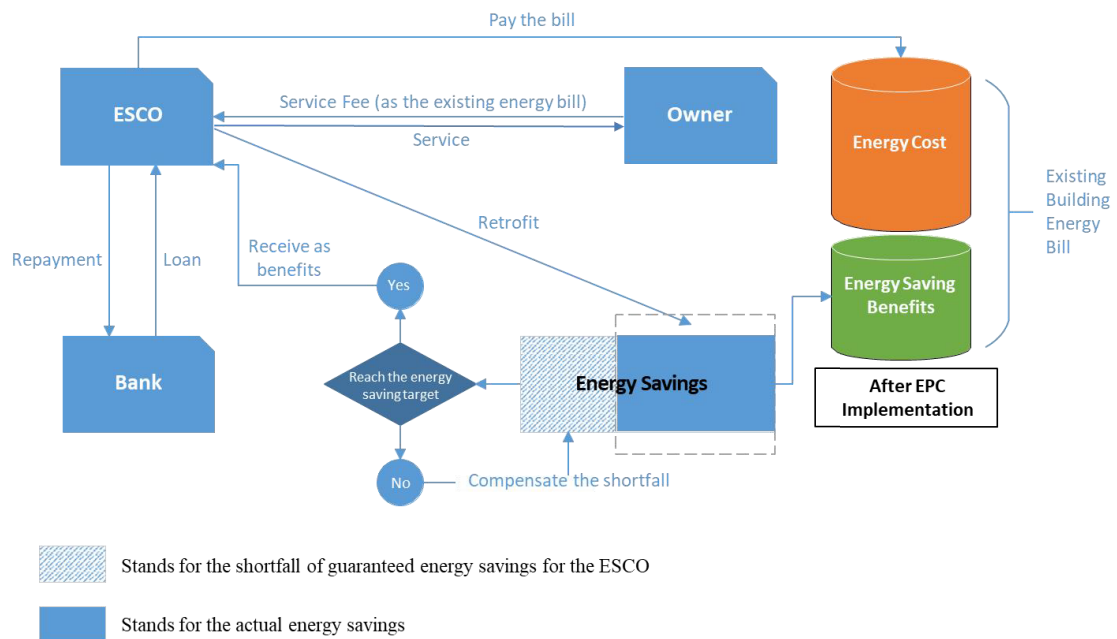
- When the EPC project transfers to the owner, the owner can receive the actual energy savings as the benefits.

Source: adapted from Qin et al. (2017); Akman, Okay & Okay (2013); Guo (2016); and (Xu 2012)

Figure 3-6 Process of guaranteed savings model

(3) Energy-cost Trust Model

In the energy-cost trust model (see Figure 3-7), the ESCO takes over and transforms the energy system of the facility. The ESCO is responsible for the operation and maintenance of the entire energy system and pays the energy costs according to the energy saving target in the contract. Meanwhile, the ESCO can earn all of the additional profits from energy savings once it achieves the targets. If the bill exceeds the given cost, ESCO must compensate the owner for the excess (Goldman, Hopper & Osborn 2005; Hopper et al. 2005; Qin et al. 2017; Shang et al. 2017).



- When the EPC project transfers to the owner, the owner can receive the actual energy savings as the benefits.

Source: adapted from Goldman, Hopper & Osborn (2005); Hopper et al. (2005); Qin et al. (2017); and Shang et al. (2017)

Figure 3-7 Process of energy-cost trust model

3.4. Development and Limitations of EPCs in China

3.4.1. EPC Development in China

China's EPCs were established in 1997 by the cooperation program of the "World Bank/Global Environment Facility – China Energy Improvement". This program launched three pilot ESCOs (Beijing Yuanshen Energy Saving Technology Co. Ltd., Liaoning Energy Saving Technology Development Co. Ltd., and Shandong Energy Project Co., Ltd.) (Jiang et al. 2013; Liu & Lei 2009; Lu & Sun 2012). In 2003, the ESCO Committee of China Energy Conservation Association (officially abbreviated to EMCA) was established to deal with energy efficiency issues (EMCA 2013). After that, ESCOs experienced rapid growth. In 2004, there were 60 ESCOs, and in 2007 that had increased ten-fold to 692. EPC projects were implemented in sectors of energy-intensive industries, buildings and transport (Zhang, Li & Chen 2011). China's later experiments were motivated by the efficiency of ESCOs. The purpose was to use the advantage of energy efficiency services and access to private finance and not be hindered by government bureaucracy (Larsen, Goldman & Satchwell 2012). Through the implementation of EPC projects by ESCOs, the energy efficiency investment increased steadily from 19.53 billion CNY in 2009 to 111.34 billion CNY in 2017 (Zhou et al. 2020). After introducing government incentives in 2010, employees of ESCOs doubled within a year (Zhou et al. 2020). In 2011, EMCA recorded 3,900 ESCOs. In 2016, there were over 6,000 ESCOs (EMCA 2016). Based on the census data collected by EMCA, at the end of 2020, there were over 7,000 ESCOs (EMCA 2021).

In 2010, a milestone policy document was issued on "Suggestions of Speeding up the Implementation of Energy Performance Contracting and Promoting the Development of the Energy-saving Service Industry" to start implementing EPCs in the building sector (CPGPRC 2010). It gave unprecedented policy support to the development of EPCs from the aspects of taxation, accounting standards and financial support. The same year, the General Technical Rules for EPCs were published, which was the first document on contract specifications for EPC projects (GAQSIQPRC & SA 2010).

In 2011, China's 12th Five-Year Plan (2011–2015) started promoting the building energy efficiency market by national compulsory policies on public building energy efficiency improvements and CO₂ emission targets (EMCA 2016). The overall target on energy efficiency retrofits was to reduce energy intensity in the ordinary commercial buildings (gross floor area less than 20,000 m²) by 10% and in large-scale commercial buildings (gross floor area equal to or more than 20,000 m²) by 15% (MOF & MOHURD 2012). The Chinese government selected four cities which represent a range of different climate zones and other local conditions – Tianjin, Shenzhen, Chongqing, and Shanghai – to carry out pilot energy-efficiency building retrofits using the EPC mechanism. This program was called “key pilot cities for energy conservation renovation of public buildings program”, which was supported by a central government financial subsidy of 20 CYN/m² of energy conservation area (equivalent to approximately AUD\$4.15/m²) for the purpose of improving energy performance by 20% (Hou et al. 2016). In this program, the task for each city was to complete retrofitting of 4 million m² gross floor area of buildings within two years (MOF & MOHURD 2011).

China has repeatedly committed itself to ensure that its CO₂ emissions peak by 2030 and that it attains carbon neutrality before 2060 (Wei et al. 2022). In 2016, the Chinese government proposed the 13th Five-Year Plan (2016–2020) on Building Energy Efficiency Development to promote building energy efficiency retrofit, in which the EPC is a highly recommended market mechanism in a series of government policies on building energy efficiency retrofit (NDRC 2016). In 2017, the first four pilot cities had completed the target and the Chinese government started the second phase of energy efficiency improvements. In this phase, the government stopped financial support for EPC projects. Instead, they gave more financial support to finance institutions to help ESCOs access loans for retrofits (known as “Green Finance Policy”) (MOHURD & MOF 2017). Meanwhile, a compulsory policy regulated that the scale of the uptake of EPCs on BEER projects should be no more than 40% of total BEER projects for each capital and key appointed cities in every province in China (MOHURD & MOF 2017).

It can be seen that, at present, the EPC mechanism is being encouraged by the Chinese government, and the Chinese government also wants to encourage the role of the market by supporting financial institutions. However, as Zhang et al. (2018) argued, although the building energy service industry is developing rapidly as a result of the policies and financial support, it is still lagging far behind economic development in the entire building

sector. Thus how to improve the uptake of EPCs to promote the CBEER market is still a problem.

3.4.2. Current EPC Market Status

(1) Overall Situation

Currently, the energy service industry in China is in its nascent period (Sun, Liu & Qayyum 2021; Zhou et al. 2020). EPCs cover three major fields: building, manufacturing and transportation (mainly municipal street lights). The number of EPC projects implemented in the building sector is the largest, followed by manufacturing, then transportation. In the building sector, the projects are mainly distributed among government buildings, commercial buildings, schools and hospitals, mostly aiming at energy efficiency retrofits of central air conditioning, heating, lighting and power systems. The EPC projects in the industrial sector are mainly distributed in the iron and steel, building materials, petrochemical, light manufacturing, metallurgy, coal, and electric power industries. The projects in the industrial sector mainly focus on the recovery and utilisation of residual heat/gas/pressure, energy saving transformation of the motor systems, energy system optimisation, and furnace/boiler transformation. EPC projects in the field of transportation mainly include municipal street lamps and energy saving renovation projects of petrol stations (Dai, Sun & Wang 2017; Sun 2012, 2014). Given the large amount of building construction and great potential energy savings in the building sector, both governments and academic research point out that investment in EPCs in the building sector is relatively low and the major potential of EPCs in the building sector is not yet well developed compared with other industrial sectors (Ruan, Gao & Mao 2018; Zhang & Wenjing 2018).

(2) Market Share

In order to identify why EPCs have not developed in the building sector as well as they have in other industries, it is important to understand the current market share of EPC projects in China. There is currently available only data on electro-mechanical system energy efficiency retrofit by EPCs in 2011. Although the coverage of the database is inadequate and not up-to-date, it can be used to describe and explain the market to some extent.

EMCA conducted a nationwide survey of 782 ESCOs in 2011 on implementation of EPC projects. The projects were mostly electro-mechanical system retrofits (Sun 2011). In the survey, there were 288 ESCOs conducting 1,800 electro-mechanical system energy efficiency retrofit projects. In a sample of 379 projects, 192 were in the building sector, 187 in manufacturing and none in transportation. The number of projects and investment are shown in Table 3-1. The number of EPC projects in the building sector was similar to the number of manufacturing projects, while the investment in manufacturing was 3.6 times that of building. This is because manufacturing projects involve many high-tension apparatuses which need greater investment. Although the investment in manufacturing is greater than in building, due to the largest number of projects in building, it is difficult to draw conclusions about the relative use of EPCs. It needs more analysis.

Table 3-1 EPC projects and investment scale in electro-mechanical system energy efficiency retrofit

Implementation Area	Project Number	Total Investment (in 10,000 CNY)	Average Investment (in 10,000 CNY)
Building	192	31797	166
Industry	187	112029	599
Transportation	0	0	0
Total	379	143826	379

Source: Sun (2011)

Focusing in more detail on EPC projects in the building sector, Table 3-2 shows the market subdivision of electro-mechanical system retrofits by EPC in the building sector.

Table 3-2 Market subdivision of electro-mechanical system retrofit by EPC in building sector

Category	Number	Percentage (%)	Investment (in 10,000 CNY)	Percentage (%)	Average Investment (in 10,000 CNY)
Office building	44	22.92	8573	26.96	195
Hotel	56	29.17	7961	25.04	142
Shopping mall	37	19.27	5263	16.55	142
Supermarket	28	14.58	3473	10.92	124
Hospital	10	5.21	2385	7.50	239
School	6	3.12	621	1.95	104
Gymnasium	1	0.52	400	1.26	400
Boiler room	10	5.21	3121	9.82	312
Total	192	100	31797	100	166

Source: Sun (2011)

Table 3-2 shows that office buildings, hotels, shopping malls and supermarkets represent the most retrofitting projects. In these four types of buildings, office buildings have the highest average investments.

Compared with the building sector, most EPC projects in manufacturing are state-owned businesses, which means the state has ownership or control rights over those industries, and the policies and interests of the government determine their behaviour. Although China is experiencing system reforms, those industries still constitute a high percentage of all businesses. In contrast, in the building sector, only government buildings, and parts of schools and hospitals can be controlled directly by the government. Therefore, in the promotion of EPCs by the Chinese government, those state-owned businesses are the main supporters of the policies, and that may partly explain why EPCs in manufacturing have developed faster than in the building sector.

(3) Effects of Policy Implementation

Considering the different characteristics of the target markets of building and manufacturing, EPC policies may have different efficiencies when they are implemented in practice. The idiom of “stick” versus “carrot” is used for a category of policy instrument as a deterrent reward formulation to induce certain behaviours (Vedung & Van der Doelen 1998). For the green policy instruments in the built environment, the sticks include energy saving obligations, mandatory green building codes, renewable portfolio standards, fuel, carbon and green taxes, while the carrots include feed-in tariffs, net metering, tradable certificates, capital cost subsidies, grants, tax credits, loan guarantees, competitive contract, bidding and tendering (Al-Saleh & Mahroum 2015). Chinese EPC policies are at both national and local levels and have been clarified as three types: regulation and compulsory standard for energy efficiency of buildings, energy saving subsidies provided by both national and local government and tax reduction for ESCOs (Hou et al. 2016; Wang 2015; Zhang et al. 2018). The first two belong to the stick instrument and the energy saving subsidies belong to the carrot instrument. Contemporary discussion of environmental policy has moved on from justifying whether government intervention is needed to support energy conservation innovation to how this ought to be designed for optimal effect (Al-Saleh & Mahroum 2015; Mulki & Hinge 2010; Veugelers 2012).

Focusing on the specific EPC policies, there are three main policies for EPC projects in every field (industry, building and transportation), listed in Table 3-3.

Table 3-3 General laws and policies for EPC projects

No.	Policies	Content	Properties
1	Law of People's Republic of China on Energy Conservation (MEEPRC 2018)	The state applies fiscal and pricing policies to support the promotion of energy conservation measures such as power demand management, energy performance contract and voluntary agreements for energy conservation.	Mandatory law (compulsory regulation)
2	Opinions of speeding up the implementation of energy performance contracting and promoting the development of the energy saving service industry (CPGPRC 2010)	Principles: Supporting the market and strengthening the policy guidance, in order to establish a sound energy conservation service system. Policy Measures: (1) Increasing financial support: the EPC projects shall be incorporated into the scope of investment within the central budget and special fund support, in terms of allowances or rewards; (2) Implement tax support: exemptions of some business taxes; Enterprise income tax by ESCOs undertaking EPC projects shall be exempted from the first to the third year; (3) Deduct the taxable income: the expenditures for ESCOs in EPC project may be deductible for current tax liabilities; (4) Deduct the taxable income: the assets transferred by ESCOs to energy users shall be subject to tax treatment according to the assets with the expiration of the period of depreciation or amortisation.	National regulation (compulsory regulation and tax reduction)
3	Interim measures for financial incentive funds for EPC projects (MOF & NDRC 2010)	For EPC project using shared saving business model, if a non-manufacturing project can save from 100 tce to 1000 tce annually or a manufacturing project can save energy from 500 tce to 1000 tce annually, the central finance will reward the project 240 CNY/tce and the local finance will reward the project no less than 60 CNY/tce.	National regulation (subsidies reward)

Source: MEEPRC (2018); CPGPRC (2010) and MOF & NDRC (2010)

Except for the financial incentive funds, the general EPC policies offer the same support for energy efficiency retrofit in every field. In these subsidy policies, the subsidy is different for manufacturing project and other projects, and it seems that the government gives stronger finance support to the building sector than the manufacturing industry. However, this is just a superficial number, and does not mean that if the subsidy threshold in the building sector is lower than in manufacturing that subsidies in building are higher than other industries. Whatever the case, those policies play an important role in improving EPC projects in all areas (EMCA 2016; Zhang et al. 2018; Zhang, Wei & Zhou 2018), although they have different effects on different areas. Whether the subsidy threshold is set at the right level to incentivise the building market is still a question to be discussed.

3.4.3. Driving Forces for EPC Development

Policy factors are regarded as the main driving force for the development of EPCs in China in many research findings (Bo et al. 2015; Hou et al. 2016; Zhang et al. 2018; Zhang, Li & Chen 2011). As mentioned before, Chinese EPC policies are both national and local, and have been classified into three types: regulations and compulsory standards for energy efficiency of buildings; energy saving subsidies; and tax reduction for ESCOs (Hou et al. 2016; Zhang et al. 2018). Based on this policy background, Zhang et al. (2018) defined four types of drivers and their survey outcome is shown in Table 3-4, and suggests that EPCs in China's building sector are mainly driven by building energy efficiency policies (Zhang et al. 2018).

Table 3-4 Drivers of Chinese experiments with EPCs in the building sector

Drivers	Definition	Responses	Percentage (%)
A: Full policy driven	Driven by strictly compulsory policies	168	67.7
B: More policy and less profit-driven	Driven mainly by policy and limited economic profits	58	23.4
C: More profit and less policy driven	Driven mainly by economic profits and partly policies	16	6.5
D: Full profit driven	Driven fully by economic profits	6	2.4
Total		248	100

Source: Zhang et al. (2018)

In order to evaluate the impact of policies to stimulate EPC development, Zhang et al. (2018) investigated 248 EPC projects on the power of the policy to stimulate EPCs. The participants were asked to score each of the three types of policies from 0 (not powerful) to 10 (most powerful). They found that the regulation and compulsory standard are the most powerful policy factors to stimulate and scale up EPC adoption in the building sector with an average score of 9.2. Meanwhile, their investigation stated that subsidies and tax reductions were not being implemented as expected, due to the bureaucracy in the provision of services by authorities, a complex and time-consuming process of verification of savings, and the threshold of annual energy saving of 100 tce (ton coal equivalency), which is relatively high for most EPC projects in the building sector.

Hou et al. (2016) considered that policy design for encouraging EPC leads to differences not only in incentive mechanisms but also in government fiscal expenditure, and they suggested connecting the subsidy level or subsidy allocation with EPC application can vigorously improve the function of the market mechanism. In addition, many researchers supported the notion that a favourable policy framework (such as building certifications and CO₂ taxes) can shorten the payback time of energy efficiency investments, reducing EPC investment risks (Wu et al. 2018). Identification and establishment of quality standards and certification schemes for ESCOs are essential in order to boost the EPC market and maintain confidence in ESCOs (Marino et al. 2011).

Furthermore, some researchers suggest that a CO₂ emission trading system (ETS) would be a great opportunity for improving the energy efficiency of buildings and thus a great market demand for upscaling EPCs in the building sector in China (Dong 2016; Zhang et al. 2018). Zhang et al. (2018) estimated that a lower carbon price may stimulate more EPC projects in the building sector; however, a low carbon price may not be powerful enough to stimulate ESCOs' potential for investment in energy retrofit of buildings. Meanwhile, benefits are the main point of concern for both owners and ESCOs (Zhang et al. 2015). Pätäri & Sinkkonen (2014) conducted a two-round Delphi study to analyse the core concepts of EPC development and stressed that one of the key development needs is to determine both the visible and invisible benefits of EPC projects.

Up to now, the most comprehensive research reflecting the current EPC market in China and its development is from Zhou et al. (2020) and Zhang et al. (2018). More details are provided below.

Zhou et al. (2020) used two types of sources to analyse the overall EPC market in China and the key factors driving the market. The two types of resources are the EPC market data collected by EMCA and information from 21 US–China pilot projects selected from 2015 to 2017. Their research findings identified the role of government incentives, the role of China’s Five-Year Plan, and the role of business innovations. They mentioned the importance of overcoming market barriers for long-term development of the EPC market in China. However, the study did not show what the market barriers were. Meanwhile, any market mechanism cannot exist on the incentive policies forever. Although this research addressed that business innovation is a way for stakeholders to overcome the market barriers, it did not show a detailed and clear path to achieve sustainable growth of the market without incentive policies in the future.

Zhang et al. (2018) conducted a national field survey of managing energy efficiency of buildings under EPCs in China’s building sector. In their survey, they identified 272 ongoing EPC projects and 12 completed EPC projects from China Association of Building Energy Efficiency’s project database. Through a pre-coded questionnaire survey, telephone interviews and on-site visits to the post EPC projects, they collected abundant data from both building owners and ESCOs on driving forces, barriers, existing performance of contracts, main measures installed, types of technologies and their views on trends in project costs, payback times, savings and policy framing. However, their research only confirmed that government policy is the main driving force, and there was no thorough analysis of market barriers and related issues.

The previous research showed the driving forces for the early stage EPC market in China (Table 3-4). While there is a long-term goal to achieve a sustainable growth of the EPC market, it is important to address the role of the EPC market itself. Therefore, it is necessary to identify the current barriers to implementing EPCs in the building sector.

3.4.4. Limitations of EPCs in China's Building Sector

At present, the Chinese EPC market is relying on policy intervention. What happens if or when the subsidies go away? How sustainable are the gains made through using these policy instruments?

The fragmentation of the building sector is an important obstacle to innovation (Hufen & de Bruijn 2016). Decisions to conduct or not to conduct building energy efficiency retrofit are taken by different actors including building owners, facility managers, tenants and ESCOs (Al-Saleh & Mahroum 2015; Hufen & de Bruijn 2016). Considering the moral hazard that may arise in the landlord–tenant relationship, the landlord is not usually incentivised to invest in energy-efficient equipment as the tenant is the party that will usually pay the energy bills and benefit from any savings. The landlord may not be able to recover the cost of energy efficiency investment through the purchase price or rent charged for the property, and the tenant is being encouraged to under-invest in energy efficiency relative to the social optimum, thereby creating a so-called ‘market failure’, which is an economic concept presenting that competitive markets fail to reflect the real market price (Gillingham, Newell & Palmer 2009; Pindyck & Rubinfeld 2009).

Neoclassical economists present that market failures can be a result of several factors including misplaced incentives; negative externalities (i.e. unpriced costs such as air pollution); imperfect competition; path dependency; free riding; distortionary fiscal, economic and regulatory policies; and asymmetric information (Cornes & Sandler 1996). Misplaced incentives are of particular relevance to the built environment sector. These are the result of the so-called ‘principal–agent problem’ in the economics literature, where an agent has the authority to act on behalf of a customer, yet does not fully reflect their best interests (Brown 2001). The landlord–tenant case is one of the misplaced incentives. Meanwhile, in the building sector, it is common that the user right is separated from the property right (Guo 2016). Energy users are related to the real energy consumption and their behaviour can greatly influence the results of building energy efficiency retrofit (Yu et al. 2011).

There are several other obstacles to EPCs in the existing incentive structure:

- Weak incentives. For some organisations, the costs of energy usage in some infrastructure such as public swimming pools or cinemas constitutes only a small proportion of their total costs of business operation. For this reason, there is little ‘sense of urgency’ for energy conservation (Hufen & de Bruijn 2016).
- Split incentives in time. The time needed to recoup investments is often lengthy. It is unclear whether the business case for energy conservation is still valid given this long payback period, particularly given the fluctuations in energy prices and technological developments (Hufen & de Bruijn 2016).
- Long periods for negotiations. There is substantial divergence of opinions between owners and ESCOs about capital efficiency, income share proportion, contract period and energy savings verification (Hou et al. 2016).
- Long payback period and big loan problem. For some small scale ESCOs, it is hard to obtain loans from financial institutes and the loan threshold is often too high for them. Thus the willingness for ESCOs to use EPCs is relatively low (Hou et al. 2016).
- Prospective innovations make it attractive to wait and see. The technological development of some energy saving products, such as lighting or solar panels, makes it attractive to delay investments in anticipation of solutions that are less expensive (Hufen & de Bruijn 2016).
- Limited energy savings in buildings compared with other industrial sectors. The amount of energy saving of buildings is not as high as in industry, and the process of energy efficiency retrofit for buildings is more complicated than for industry. Compared with industry EPC projects, building EPC projects are less attractive to ESCOs, therefore the ESCOs are more willing to invest in industries with high energy saving benefits (Wang 2015).

Apart from risk factors and financing factors that have been widely studied (Hu & Zhou 2011; Wang, Peng & Wang 2018), industry environmental factors, such as the market credit environment, also hinder the rapid development of EPCs (Ruan, Gao & Mao 2018). Kostka & Shin (2013) found that a lack of trust in ESCOs from the client is the most critical factor affecting the development of EPCs in China compared with other constraints, particularly lacking trust in private ESCOs with small assets. 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 (Xu et al. 2015). The measurement and verification of energy savings are not standardised, and a lack of integrity is a very serious problem (Qian & Guo 2014). Other research deems that EPC, carbon trading and energy conservation transactions have relationships and each of the mechanism is in the initial stage, which will inhibit the development of each other (Dong 2016). The institutional measures and mode integration measures adopted for the above two aspects are the necessary guarantees to ensure market integrity for EPC market development (Dong 2016).

In conclusion, EPC projects in the building sector have not developed as well as for other industries basically because EPCs in the manufacturing industry are driven more strongly by policy than in the building sector. Most industries belong to state-owned businesses and they can also save a great amount of energy consumption by energy efficiency retrofit. Meanwhile, complicated property structures in the building area are another obstacle limiting EPC development in buildings. Also, limited energy savings and technology innovations deepen this problem. However, the factors limiting the EPC market were identified case by case, and it needs a comprehensive analysis to show a holistic overview on the market barriers of the EPC market. Furthermore, whether current policies function as an effective incentive in the building sector is not clearly evident and should be studied further. Thus, it is necessary to investigate how to make use of the EPC mechanism to inspire all stakeholders in the building sector to conduct CBEER.

3.5. Risks of CBEER under EPCs in China

When conducting CBEER by an EPC, there is a different risk picture to the contracting parties which may influence the sustainability of CBEER to some extent. Zhang et al. (2018) found that insufficient risk specifications were a major cause of contract failures and disputes. Identifying the key risks inherent in EPC projects will help investigate different parties' concerns on the use of EPCs and propose practical measures to enhance the sustainability of BEER under EPCs (Garbuzova-Schlifter & Madlener 2017; Wang et al. 2018).

There is much research focusing on EPC risks. Initially, Mills et al. (2006) identified the risks of energy efficiency projects and classified them into five categories: economic, contextual, technological, operational, and measurement and verification. They then divided these factors into intrinsic and extrinsic factors based on the controllable condition. Their research is the foundation of risk identification in EPCs because an EPC is a particular type of energy efficiency project (Lee, Lam & Lee 2015). Focusing on the Chinese EPC market, Hu & Zhou (2011) expanded the classification and identified the main risks of EPC projects as political and legal risks, market risks, technology risks, management risks, financial risks, project quality risks, and client risks. Later, Lee, Lam & Lee (2015) identified the risks of EPC as seven categories: economic risk, financial risk, project design risk, installation risk, technology risk, operational risk, and measurement and verification risk. Based on the research, the risks of EPC projects are summarised into two groups: external risks and internal risks (see Figure 3-8). The following sections explain each risk.

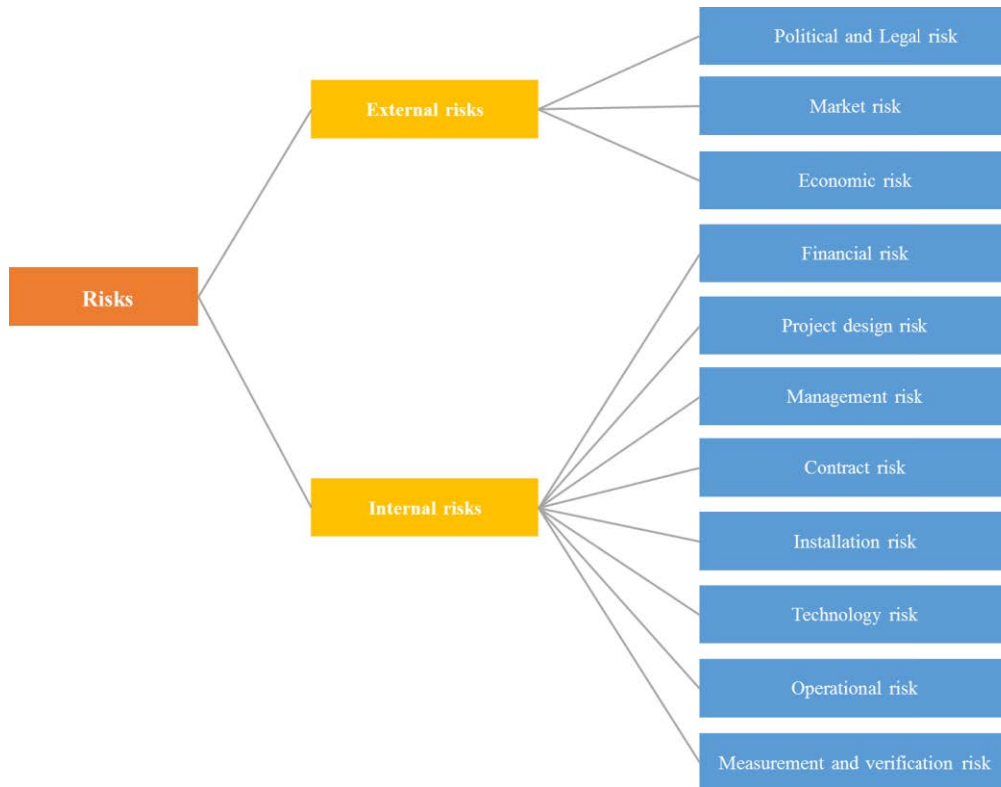


Figure 3-8 Risks of CBEER under EPC in China

3.5.1. External Risks

(1) Political and Legal Risk

Overall, a nation's overall economic development planning, regional development and industrial development will have a significant impact on EPC projects (Hou et al. 2016; Shi, Niu & Wang 2012). In addition, incentives like tax exemptions for EPC projects or ESCOs from the government will also change the behaviour of ESCOs and owners, which lead to changes in their final energy saving benefit allocation (Garbuzova-Schlifter & Madlener 2016; Wang & Sun 2012). Once the policies are adjusted, the risks may appear (Hu & Zhou 2011). In this regard, the government should play a role as a market creator as well as a rule-setter for energy efficiency investment and further improvement of ESCOs' activities (Lee et al. 2003; Marino et al. 2011) and stakeholders should include this issue in the EPC project design.

(2) Market Risk

Market risk is brought by uncertainties in the market, and mainly has three aspects: market demand, industry competition and new market modes (Gan 2009; Garbuzova-Schlifter & Madlener 2016; Shi, Niu & Wang 2012; Wang & Sun 2012). Firstly, there are market demand risks. Advanced energy saving technologies, as well as the EPC mechanism, have not been well established in China. Hence some enterprises are not willing to put themselves in an environment full of technological risks and energy saving guarantee risks.

Secondly, there are market competition risks. Although the development of EPCs in China is in the early stage, the energy saving market and potential are great. Thus, many foreign ESCOs, relying on abundant funds and advanced technology, are looking for opportunities to enter the Chinese energy saving market (Hu & Zhou 2011).

Thirdly, there are risks related to the energy commodity market. A carbon trading system is a new mode for the energy market which has a great influence on the motivation for energy efficiency retrofits. Volatile prices are a key risk premium in both equity and commodity-energy markets, leading to an upward bias of energy futures contracts prices relative to expected spot prices (Doran & Ronn 2008), which will lead to the shortfalls based on the original energy saving sharing of EPC projects.

(3) Economic Risk

Economic risk is the possible losses which result from variations in construction cost, interest rate, exchange rate, demand charges and fuel costs (Garbuzova-Schlifter & Madlener 2016; Lee, Lam & Lee 2015; Miles 2012; Wang & Chen 2008; Wang & Sun 2012; Zhang et al. 2018). Those economic risks will significantly impact the stability of the profit from EPC projects (Bannai et al. 2007). In most standard forms of the EPC contract, a relevant clause is stipulated that both contracting parties bear the risk of variations in energy costs and demand charges, and the baseline of those costs will be adjusted accordingly when such variations occur (Lam & Lee 2014). Sometimes, economic risk can be changed into market risks due to the influence of price on the market demand. It is very important to consider those risks in advance and incorporate them into the EPC project design process.

3.5.2. Internal Risks

(1) Financial Risk

In general, the financial risk includes financial cost, additional costs on deciding whether getting a bank loan, changes of inflation or interest rate during the contract period, or delays in payments, and all these macroeconomic factors cause economic risk to EPC projects (Garbuzova-Schlifter & Madlener 2016; Hu & Zhou 2011; Shi, Niu & Wang 2012; Zhang et al. 2018).

(2) Project Design Risk

An accurate estimate of energy saving is critical to the success of EPC projects (Lee, Lam & Lee 2015), which is influenced by two factors: information on the facility and inappropriate design. Apart from proper engineering design, the availability of building operating data, which is used to predict energy performance for the new upgrade, is important for the ESCOs to evaluate the risk of expected energy savings (Borgstein, Lamberts & Hensen 2018; Garbuzova-Schlifter & Madlener 2016; Mills et al. 2006). Meanwhile, energy models are widely used to estimate or predict the average energy consumption of a building. However, they only provide approximate figures with significant uncertainties (Faggianelli, Mora & Merheb 2017). Uncertainties in estimating energy savings will become larger when the quality of system operation data is poor and the modelling phase is different or not correct enough, thus building energy assessment has been a great risk in project design (Faggianelli, Mora & Merheb 2017; Lee et al. 2013; Rivalin et al. 2018; Tian et al. 2018). In practice, before both parties commit themselves to an EPC contract, the ESCO will carry out a detailed energy audit to evaluate the scope for saving energy and the feasibility of proposed plans for achieving the saving (Lee, Lam & Lee 2015). Selecting technologies and feasible solutions are the two critical management methods related to the success of the projects (Wang & Sun 2012; Zhang et al. 2018).

(3) Management Risk

Management risk refers to inappropriate management methods in the application of EPCs (Hu & Zhou 2011; Wang & Sun 2012). Usually, the management risk is equal to the decision risk. If the decision makers lack long-term vision and perspective of the overall situation, wrong strategic decisions may be made and bring unnecessary losses to EPC projects (Hu & Zhou 2011). In addition, in some cases, the change of owner or management of the building will also create some risks in continuing the energy saving management process (Zhang et al. 2018). Thus it is important to include sustainable strategies in the project management process.

(4) Contract Risk

Contract risk refers to two types of risks in incomplete or inappropriate contracts (Hu & Zhou 2011). An incomplete contract means that the EPC stakeholders have not addressed all matters, including various possible risks and loss undertaking in the EPC beforehand. Improper contracts are contracts that cannot be implemented or executed (Wang & Sun 2012; Wang & Po 2007). Garbuzova-Schlifter & Madlener (2016) stated the two reasons for contract risks are no explicit risk pricing in the EPC and poor prior risk division between an ESCO and an owner. Hence how to identify and allocate risks between stakeholders should be agreed during the contract negotiation process.

(5) Installation Risk

EPC projects often involve the removal of existing equipment and installation of new equipment in existing buildings. The removal and installation work may only be allowed at specific hours to minimise the disruption to occupants (Waltz 2003). Project delays may occur, resulting in delays in materialising the actual energy savings.

(6) Technology Risk

Technology risk means that the equipment performance or lifetime variations are caused by inaccurate sizing, improper system selection, improper operation of equipment, or unexpected deterioration (Garbuzova-Schlifter & Madlener 2016; Mills et al. 2006; Waltz 2003). In general, the ESCO is fully responsible for any technology risks during the contract period. These risks can be limited if proper system design, equipment selection, and regular maintenance are performed.

(7) Operational Risk

Operational risk means variations in energy savings attributed to changes in the prescribed operation schedule and control strategies (Hu & Zhou 2011; Shi, Niu & Wang 2012). For example, tenants' complaints on noise and air quality may cause a change in the prescribed schedule of system operation, leading to the extension or reduction of operating time, hence affecting the actual energy savings (Mills et al. 2006; Zhang et al. 2018). In practice, the contracting parties often negotiate on the allocation of operational risks. In most contracts of EPC projects, the ESCO would not be liable for a shortfall in savings when the host does not operate the system in accordance with the agreed control strategy and procedures (Lam & Lee 2014; Lee, Lam & Lee 2015; Wang & Sun 2012).

(8) Measurement and Verification Risk

Measurement and verification (M&V) risks include modelling errors, poor data quality for M&V works, and measuring imprecision (Daly, Cooper & Ma 2014; Mills et al. 2006; Waltz 2003). Upon completion of energy saving projects, ESCOs and owners may have different opinions of the measurement methods, leading to a halt to the project (Wang & Chen 2008). These risks are all intrinsic and can be managed by model validation, proper metering, and implementation of recommended M&V plans (Lee, Lam & Lee 2015).

3.6. China's Current Building Energy Conservation Policy System

China's current building energy conservation policy has two systems: the government regulatory policy system and the economic policy system (Wan, Liu & Lai 2017). Figure 3-9 summarises the whole of China's energy conservation policy system. The details are explained in the following sections.

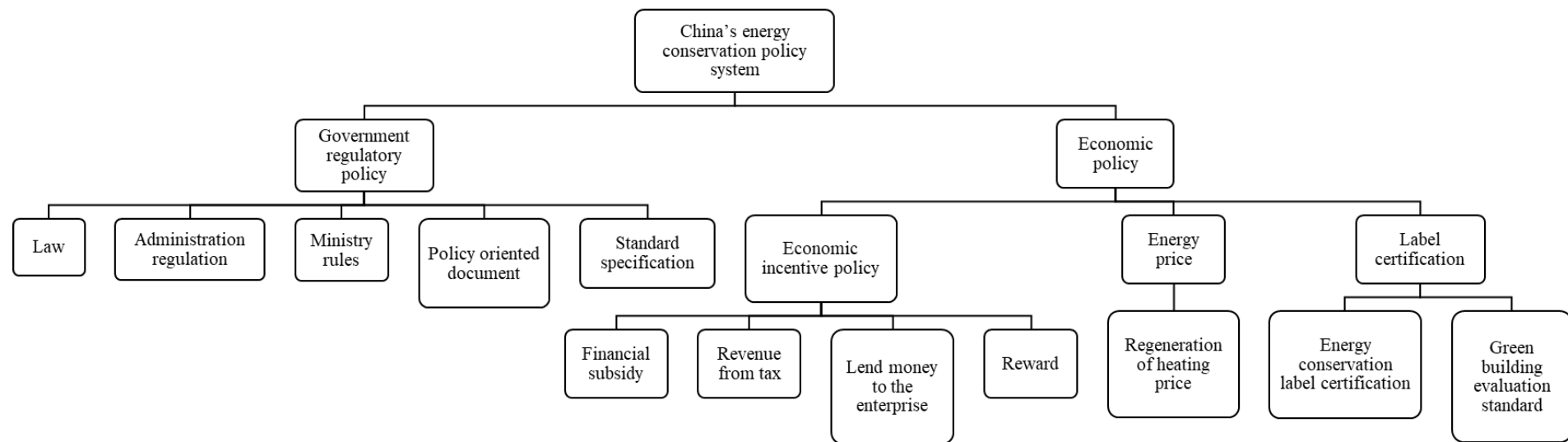


Figure 3-9 China's energy conservation policy system

3.6.1. The government regulatory system

The government regulatory method intervenes directly in the allocation of market resources or changes indirectly the supply–demand relationship between producer and consumer through legislation and administrative regulation. At the national level, there are five grades of legal systems, including laws, administrative regulations, ministry rules, policy-oriented document, standard specification and technical directives, which develop a legal base for related policies and strategies. At present, the technical content included in regulations has been applied widely and contains many kinds of techniques for energy conservation and renewable resource generation. However, the related economic bodies have no choice but to engage a specific service to achieve the government’s stated goals, otherwise, they will be subject to legal or administrative sanctions.

In order to make the implementation effective, regulations must follow these three principles: the provision of energy conservation content should be clear, which will allow the influenced economic bodies to understand the concrete demands; for energy conservation on green building, it is important to break the macro goal into definite technical specifications for industry and implementation; and the efficiency supervisory control method should be developed, for example, by promoting related laws and strategies on energy consumption standards of green building.

3.6.2. The economic policy system

The economic policy method, no matter whether it belongs to punishment or incentive, is based on the theory of classical economics and welfare economics in order to change the marginal costs or benefits (Dai, He & Di 2007). In China, the economic policy system includes three main instruments: economic incentive policy, energy price, and energy conservation and green building label certification.

The first instrument of economic incentive contains four main methods: financial subsidy, revenue from tax, lending money to the enterprise and reward. All of those contribute to the five agents: consumers, which includes the final consumer both of individuals and companies who are all concentrated on the downstream of green building construction; capital construction organisations, such as the land developer who is responsible for preparing land; development organisations, such as the building developer, owner or estate investor; equipment producers; and government.

In the use of financial subsidies and tax revenue, most of the policy is offered to the development organisation. Consumers obtain less but would receive more compensation in the second type of economic incentive, energy price policy, especially in the area of renovation of heat metering in north China. However, the conflict between the different economic subjects and the unclear setting of energy prices make it urgent to establish a more marketable and efficiency resource allocation.

To meet the demand of energy conservation for buildings in the new economic environment, the government in China has developed an energy label certification institution to measure the energy usage efficiency of buildings and offer energy efficiency information for the market, which now not only contains the energy conservation label certifications but also green building evaluation standards.

3.7. Theoretical Framework for Research Design

Chapter 2 analysed the relevant economic theories. Previous sections (Section 3.4.1, 3.4.2, 3.4.3, 3.4.4) in this chapter have introduced the current situation of the Chinese EPC market. An EPC as a market mechanism is designed to improve the current CBEER market. However, due to the limitations of EPC development in the building sector in China and the risks associated with EPC projects, the effect of EPCs has not been fully utilised and EPCs are not widely used in the commercial building sector. Those potential market barriers might justify a public policy intervention to overcome them. Therefore, this section discusses the potential to improve the EPC market by disentangling market failures. The main task is to develop a theoretical framework for this research based on the economic theories and presumed market barriers. The purpose of the theoretical framework is to guide the research to achieve the potential of the EPC market. The theoretical framework combines the process of theory testing to examine the characteristics of market imperfections in the Chinese EPC market and the abductive process of policy design to remedy the market barriers to improve the transactions of EPC projects.

3.7.1. Potential to Improve the EPC Market

The EPC is designed as a market mechanism to improve the market for CBEER, while the effect of EPCs is not fully played out. The market barriers in terms of the energy efficiency gap imply the existence of several energy saving potential categories (Bukarica & Tomšić 2017). This section discusses the potential to improve EPCs in CBEER. It takes the structures that Jaffe & Stavins (1994) and Bukarica & Tomšić (2017) have established as references and modifies them according to the theoretical analysis in Chapter 2. Overall, there is a hypothetical potential for the EPC market that can only be reached only when actual government programs are designed to overcome all market barriers. The hypothetical potential of improving the EPC market can be divided into three categories: technical, economical and social. Technical potential is the scenario where market failures related to technical issues are eliminated, such as where inadequate provision of information on the buildings causes the failure to achieve promised energy savings. Economic potential represents cost-effectiveness and proper dealing with market power. “Market forces will achieve some of the economic potential” (Bukarica & Tomšić 2017, p. 972). Social potential represents the true social optimum, which incorporates the additional energy conservation by internalising the environmental externalities of energy consumption (Jaffe & Stavins 1994). It aims to improve the understanding and appreciation of the social context in which energy related behaviours and decisions occur (Bukarica & Tomšić 2017).

3.7.2. Theoretical Framework of Promoting the EPC Market

Based on the previous analysis on the potential to improve the EPC market, the theoretical foundations analysed in Chapter 2, and analysis on the current situation of the Chinese EPC market in this chapter, a theoretical incentive framework is developed. It addresses the four perspectives of market imperfections and the way to remedy the market imperfections based on the conceptual framework of transaction costs (see Figure 3-10). The detailed explanation of the theoretical framework follows.

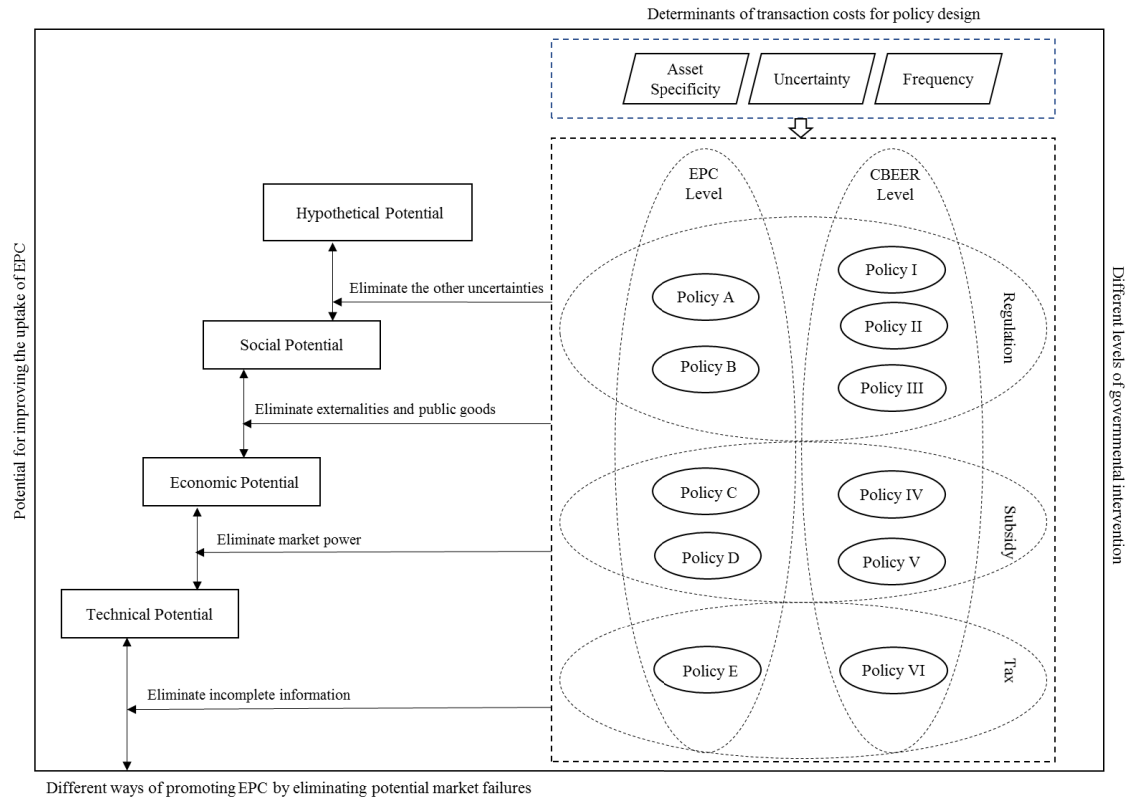


Figure 3-10 Theoretical framework of research

It assumes that the potential of EPCs could be fully utilised if all the market barriers can be eliminated. Then a hypothetical potential could be reached. In Figure 3-10, the left dimension shows the potential for improving the uptake of EPCs. Each plateau represents the sub-category of the total potential of improving the uptake of EPCs. They are technical, economic and social potential. Those potentials could be achieved by dealing with the corresponding market imperfections (see the bottom dimension of Figure 3-10). This leads to one of the main tasks to identify what kind of market imperfections exist in the EPC market. To deal with these market failures, there are different levels of government intervention (see the right dimension of Figure 3-10). By applying the framework of government intervention in market failure (Section 2.4), policies could be designed to be more targeted to each type of market imperfection. Meanwhile, these policy designs can be set up as two levels (CBEER and EPC): focusing on the nature of the CBEER market and characteristics of the EPC mechanism separately. The conceptual framework of transaction costs (see the upper dimension of Figure 3-10) should be applied during the whole process of policy design, as they are easier to observe and can be a reference to know if the policy is designed effectively to deal with the market imperfections.

This theoretical framework is designed to improve the performance of the EPC market. By eliminating each type of market imperfection, the market can achieve different levels of potentials for the uptake of EPCs in the CBEER market.

3.8. Summary

This chapter introduced the main concepts of this research. It showed the current status of the EPC market in the sector of commercial buildings and the constraints on its development. Although EPC have been demonstrated to have the ability to improve building energy efficiency and promote the building retrofit market, EPC projects are considered to be high-risk investments. Government regulatory and economic policy systems were reviewed for a better understanding of the Chinese governance system for policy design in the Chinese context. The development of EPCs in commercial building energy efficiency retrofits has been stunted. This chapter presented a theoretical framework for this research. It set the presumed market barriers and the potential solutions based on the economic underpinnings introduced in Chapter 2. Based on this conceptual framework, the research process is presented in the next chapter.

Chapter 4 Research Methodology

4.1. Introduction

This chapter presents the research design process from four basic elements: epistemology, theoretical perspective, methodology and methods. It first presents the philosophical perspective of the research. The objectivist epistemology and positivist theoretical perspective are chosen as the philosophical assumptions. Then a quantitative paradigm is chosen as the research approach considering this research is going to test the theories of market imperfections and the deductive research inquiry process. Lastly, multi-methods are selected to collect research data to reach the research objectives and answer the research questions including both quantitative and qualitative research methods. The following sections explain why and how the research is designed.

4.2. Research Design Process

This research is developed based on the Crotty (1998) framework. The framework shows the whole research design process includes four basic elements: epistemology, theoretical perspective, methodology and methods. Crotty (1998) has explained the meanings of these four terms as follows. Firstly, epistemology is the theory of knowledge embedded in the theoretical perspective and thereby in the methodology, which is a way of understanding and explaining how we know what we know. Secondly, theoretical perspective is the philosophical stance informing the methodology and thus providing a context for the process and grounding its logic and criteria. Thirdly, methodology is the strategy, plan of action, process or design lying behind the choice and use of particular methods and linking the choice and use of methods to the desired outcomes. Lastly, methods are techniques or procedures used to gather and analyse data related to some research question or hypothesis. This structure determines the design of this research project.

4.3. Philosophical Assumptions

4.3.1. Epistemology

“Epistemology deals with ‘the nature of knowledge, its possibility, scope and general basis’ (Crotty 1998, p. 8). It refers to the theory of knowledge which guides the study of ‘how to’ in the broadest sense (Curtis & Curtis 2011). As Maynard (1994, p. 10) explained, ‘epistemology is concerned with providing a philosophical grounding for deciding what kinds of knowledge are possible and how we can ensure that they are both adequate and legitimate’. Crotty (1998) describes three types of epistemologies in social science as objectivism, constructionism and subjectivism. The three epistemological stances show us how we conduct our research and how we present our research outcome. Objectivism is selected as the epistemological stance of this research, for the following reasons.

Objectivism maintains that meaning (including the meaningful reality) is objective and intrinsic, existing outside the operation of any consciousness. In the view of objectivism, the way we know, understand and value is considered to be objectified. If people apply it in the right way, they can find the objective truth (Crotty 1998; Curtis & Curtis 2011).

Constructionism holds the view that there is no objective truth for people to discover. Meaning is not discovered but constructed. In the view of constructionism, different people may construct different meanings. That means, what people know changes from one area to another. Sometimes, in constructionism, object and subject merge as a part to generate the meaning (Crotty 1998). Some qualitative researchers tend to use this, however it has raised the problem of whether a social constructivist can be considered a social scientist (Curtis & Curtis 2011; Runeson & Skitmore 1999).

Subjectivism holds that meaning is imposed by the subject on the object and it does not ascribe the interaction of subject and object. Thus, the object contributes nothing to the production of meaning. In the view of subjectivism, meaning is created from nothing (Crotty 1998; Hennink, Hutter & Bailey 2010).

4.3.2. Theoretical Perspective

In the research, literature ontology is mentioned frequently as the study of being. It is concerned with “what is” (Crotty 1998). Gray (2013, p. 19) described ontology as “the nature of existence and what constitutes reality”. Together with epistemology, it informs a theoretical perspective. Each theoretical perspective represents a particular way of understanding what is (ontology) and what it means to know (epistemology) (Crotty 1998; Gray 2013). Scientists maintain different ontological positions, or different views on the nature of reality, which causes differences in philosophies of science (Runeson & Skitmore 1999). Some scientists consider reality as governed by rules, and understand the purpose of science as being to discover these rules; other scientists see science as a creative process, and they invent classifications and theories to make order in chaos (Runeson & Skitmore 1999). Those two main theoretical perspectives as a general philosophical orientation about the world and the nature of research are defined as positivism and interpretivism (Gray 2013).

These two theoretical perspectives take different perspectives on different types of problems and search for different types of answers. When applying these in practice, what researchers believe will greatly influence the choice of research methodologies selection (Gray 2013). In this research, the positivism perspective is the starting point to recognise that the energy efficiency market under EPCs is an imperfect market and to address the issue of market imperfections. The selection of research methodology is discussed in the next section. The reasons are as follows.

From a positivism perspective, the reality can be perceived by extending the known facts which are available to the senses (Gray 2013). Therefore inquiry is based on scientific observation and measurement of the objective reality that exists outside the world without individual judgment (although it is hard to realise) (Creswell 2009; Creswell & Creswell 2017). There are laws or sciences governing the world, sharing common logical principles to deal with facts (Gray 2013). Those theories need to be tested or verified and refined so that people can understand the world (Creswell & Creswell 2017; Runeson & Skitmore 1999). Therefore, the scientific approach for a positivist is to start with a theory, collect data to support or refute the theory, or make some modifications if needed (Creswell 2009; Runeson & Skitmore 1999).

There is another critical concept needed to make a complement. In order to avoid the challenges caused by the uncertainties of nature and the results of scientific inquiry, a post-positivism world is developed from positivism (Gray 2013). As Onwuegbuzie, Johnson & Collins (2009) explain, post-positivists can only approximate the truth of reality but can never explain it perfectly or completely. This is how we consider the fallible perspective of objectivity, as post-positivist research emphasises the use of inferential statistics (Gray 2013).

From an interpretivism perspective, “the world is interpreted through the classification schemas of the mind” (Gray 2013, p. 23). Rather than beginning with a theory (as in positivism), interpretivists try to understand the world – through personal knowledge and experience – and develop the inquiry by generating a theory or pattern of meaning (Creswell & Creswell 2017).

4.4. Research Approach: Quantitative Paradigm

4.4.1. Research Approaches

There are three research approaches: quantitative research, qualitative research and mixed methods. This part discusses the characteristics of each research approach to provide the background for selecting the research approach in the next section.

(1) Quantitative Research Approach

A quantitative research approach is a means of testing objective theories by examining the relationship among variables (Creswell 2009). There are three different types of testing known as Schema I, II and III (Runeson & Skitmore 1999), shown in Table 4-1. In Schema I, there are a theory and auxiliary statements, and the research is to test if a prediction is true or false. In Schema II, there are a theory and some facts to be explained, and the research is to find out the true auxiliary statements which can be combined with a theory and used to explain the facts. In Schema III, there are a theory and auxiliary statements, and the research is to develop some testable outcomes of the theory. In contrast to the qualitative approach, the process is testing deducted theories deductively using quantitative information, and the research findings can be generalised and replicated (Creswell & Creswell 2017).

Table 4-1 Schemas of testing a theory in quantitative research approach

Schema I	Schema II	Schema III
Theory	Theory	Theory
Auxiliary Statement	Find out the true auxiliary statement	Auxiliary Statement
Predictions: True or False	Facts to be explained	Develop testable outcomes of the theory

Source: adapted from Runeson & Skitmore (1999)

(2) Qualitative Research

A qualitative research approach is a means of exploring and understanding the meaning of a social or human problem (Creswell 2009). Qualitative research focuses on the study in natural settings, trying to understand or interpret the meanings that people bring to the world (Denzin & Lincoln 2011). Qualitative research starts with the possible application of assumptions, a worldview, and the research problems explore the meaning of individuals or groups to social or human problems (Creswell & Poth 2017). The process of qualitative research constitutes an emerging qualitative research inquiry, the collection of data in participants' setting, and inductive data analysis to establish a pattern or a theme focusing on individual meaning. The final written report's structure is flexible but not generalisable (Creswell & Creswell 2017; Creswell & Poth 2017).

(3) Mixed Methods Research

A mixed methods research approach is a means of combining both qualitative and quantitative forms. It is not simply collecting and analysing both qualitative and quantitative data, but also involves both philosophical assumptions and theoretical lenses or worldviews to data, using them in tandem so that the research problem can be better understood and interpreted (Creswell 2009; Johnson, Onwuegbuzie & Turner 2007). Greene (2008) offers a framework showing that mixed methods research is a methodology or research paradigm. The research presents five key considerations on mixed methods: the purpose of mixing, the scope of mixing, what is being mixed, how mixing takes place, and where in the research process mixing is done. Table 4-2 provides more detail.

Table 4-2 Key considerations of mixed methods

Key Considerations	Contents
Purpose of mixing	Overlaps the breadth or depth themes
Scope of mixing	Framing of procedures within philosophical assumptions of the approach and theoretical lens/worldviews to data
What is being mixed	Qualitative and quantitative data (based on research question)
How mixing takes place	Sequentially (one builds on the other) or concurrently
Where in the research process mixing	Data collection and data analysis

Source: adapted from Greene (2008)

Although it is clear what the mixed methods approach is and how to apply it, there are still two issues to be discussed further. The first one is the difference between “mixed methods” and “multi-methods” because those two terms are often misused; and the second one is, if the philosophical assumptions of quantitative methodology and qualitative methodology can overlap, what the theoretical perspective of mixed methods methodology is. The following part discusses these issues further.

(a) The difference between “mixed methods” and “multi-methods”

According to the previous analysis, mixed methods as a methodology overlaps the philosophical assumptions from both quantitative and qualitative sides (Greene 2008; Johnson, Onwuegbuzie & Turner 2007). However, multi-methods is just a research approach, which combines different research methods (Brewer & Hunter 1989). Multi-methods is used to collect data from different sources in the execution of a study (Takhar-Lail 2014). A multi-methods approach is not limited to combining quantitative data and qualitative data, but different quantitative data (or different qualitative data) can also be combined (Wood et al. 1999). In conclusion, mixed methods is a high-level combination of both quantitative research and qualitative research from philosophical assumptions to data collection and analysis; multi-methods is the use of quantitative methods or qualitative methods or both of them on the level of research method.

(b) The theoretical perspective of mixed methods

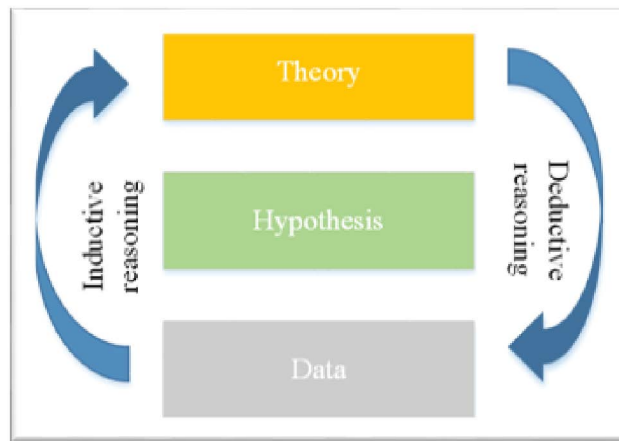
The differences between a quantitative approach and qualitative approach are pinned on their epistemological and ontological assumptions (Creswell & Creswell 2017). However, as the combination of two types of research approaches, mixed methods is supported by those (Creswell & Poth 2017) who maintain pragmatism as their worldview. “Pragmatism is not committed to any one system of philosophy and reality”, it “arises out of actions, situations, and consequences rather than antecedent conditions” (Creswell 2009, p. 10). Hence, mixed methods is viewed by pragmatism as a single research approach combining quantitative and qualitative approaches, which is not only legitimate but also necessary.

4.4.2. Research Approach Selection

Based on the analysis above, the research approach can be selected from three aspects: philosophical assumptions, the strategy of inquiry and the function of research theory. The three are inextricably linked with each other.

Philosophical assumptions are the basic consideration of the selection of research approaches. As previous analyses, if objectivism epistemology and positivism ontology are chosen as philosophical assumptions, a quantitative research methodology may be developed further. If subjectivist epistemology and interpretivist ontology are chosen as philosophical assumptions, a qualitative research methodology may be developed further. If the researcher stands in the middle of epistemology (objectivism and subjectivism) and ontology (positivism and interpretivism), maintaining a constructivist epistemology or pragmatist ontology, they may choose the mixed method as their research methodology (Creswell & Creswell 2017; Crotty 1998; Gray 2013).

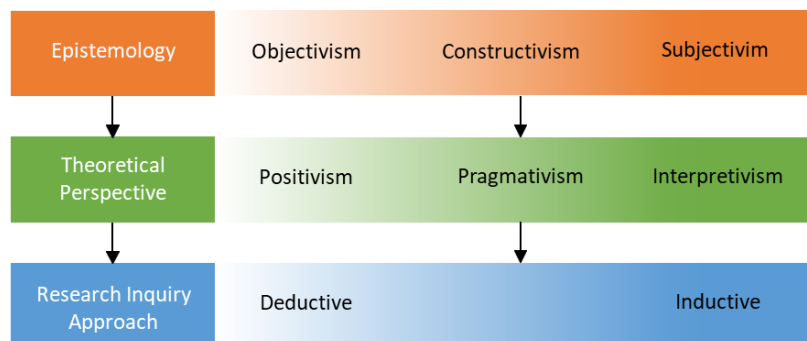
Along with the completed selection of philosophical assumptions, the related research inquiry strategies are incorporated. As shown in Figure 4-1, there are two research inquiry approaches related to each philosophical assumption.



Source: adapted from Brancati (2018)

Figure 4-1 The process of deductive and inductive reasoning approaches

The two approaches to making valid arguments are logically opposed (Brancati 2018). “Deductive reasoning is a top-down approach” (Brancati 2018, p. 78), which can be used to propose specific, testable hypotheses to explain the social world from existing theories. “Through deductive reasoning, researchers can fill gaps in existing theories, identify new conditions under which existing theories apply, or use the basic logic of existing theories to explain other phenomena yet to be explored” (Brancati 2018, p. 79). In contrast, “inductive reasoning is a bottom-up approach” (Brancati 2018, p. 79), which can be used to generalise theories from observing human behaviours and then developing hypotheses to explain those patterns (Brancati 2018). The differences can be shown in Figure 4-2.



Source: adapted from Gray (2013)

Figure 4-2 Research inquiry approaches related to philosophical assumptions

The function of a research theory in combination with the research inquiry is the last important consideration when choosing a methodology. The three research methodologies deal with theories differently. In quantitative research, researchers often test theories to explain their research questions. However, in qualitative research, the entire section of research may generate a theory as the final outcome. Furthermore, in mixed methods research, the inquirer may be both testing theories and generating them (Creswell 2009). This research is based on economic theories. Economic theories are continually tested against observation, and the process of testing and modifying theories is central to the development of economics as a science (Pindyck & Rubinfeld 2009).

Focusing on this research, the main research question is about how to improve the uptake of EPCs in the Chinese CBEER market. The objectivist epistemology and positivist theoretical perspective are chosen as the philosophical assumptions for this research. The basic theory is price theory of microeconomics, under which this research tests the theories of market imperfections. To deal with the market imperfections, another theory of transaction costs under Williamson's theoretical framework in institutional economics is involved. The purpose is to make use of the conceptual framework of the theory of transaction costs to design policies to address market imperfections. About the research inquiry process, the first step is to test the imperfect market theorems, and the purpose is to test that the EPC market exhibits the characteristics of an imperfect market in terms of demand and supply. The second step is using transaction cost theory to construct a theoretical framework for an incentive mechanism that may be used to transform the characteristics of the EPC market to make it conform to a perfect market, i.e. more efficient. Both of these approaches are deductive, so quantitative research is suitable for this research. The process of research design is shown in Figure 4-3.

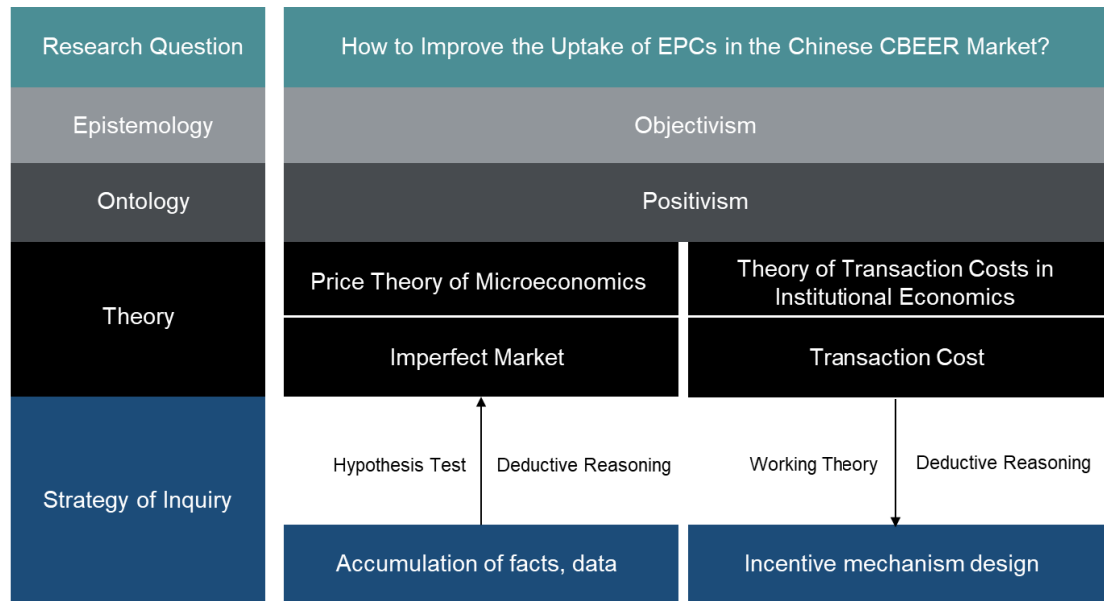


Figure 4-3 The process of research design

4.4.3. Research Inquiry Strategy: Survey

There are two inquiry strategies of quantitative methodology: surveys and experiments. A survey can be used to study a sample of a population. It describes trends, attitudes or opinions by a quantitative or numeric item (Creswell 2009; Singleton & Straits 2017). From sample results, the claims about the population can be generalised if the sample is representative. For the experiment, it can also generalise the claims about a population based on a sample, however it is used to “test the impact of treatments (or intervention) on an outcome, controlling for all other factors that might influence that outcome” (Creswell 2009, pp. 145-146).

Survey is chosen as the quantitative inquiry strategy for this research for three reasons. Firstly, the purpose of this research is to find out the nature of the EPC market and then develop an incentive roadmap for the market, as the features of this market can be known by the attitudes, behaviours and characters of stakeholders in this market. Survey as an inquiry strategy can meet the requirements of the research purpose. Secondly, survey has the advantages of economy of research design (Coughlan, Cronin & Ryan 2009; Creswell 2009). Thirdly, survey can be used with particular data collection methods, collecting both quantitative and qualitative data for better research analysis (Denscombe 2014). For these three reasons, a survey is the preferred type of inquiry strategy for this research design. The next section outlines the data collection methods.

4.5. Research Design: Multi-methods

4.5.1. Quantitative Research Method

(1) Overview

For the quantitative research method, the objective is to quantify data and extrapolate results to a broader population and the process is to measure, count, quantify a problem and analyse the relationships in data. Data is usually presented as numbers or numerical data. The quantitative method is put into use in a large sample size of representative cases and data analysis is statistical. The outcomes of the quantitative research method are to identify prevalence, averages and patterns in data and to generalise to a broader population (Hennink, Hutter & Bailey 2010).

(2) Questionnaire Survey

Considering the characteristics of quantitative research, a questionnaire survey is a typical way to collect data to identify statistical trends, patterns, averages, frequencies or correlations (Hennink, Hutter & Bailey 2010).

There are many types of questionnaires depending on their purpose, their size and their form (Denscombe 2014). A questionnaire is appropriate in the following situations (Denscombe 2014, p. 167):

- “The information required tends to be fairly straightforward – relatively brief and uncontroversial.”
- “There is a need for standardised data from identical questions – without requiring personal, face-to-face interaction.”
- “The respondents can be expected to be able to read and understand the questions – the implications of age, intellect, language, and eyesight need to be considered.”
- “The social climate is open enough to allow full and honest answers.”

Self-completion questionnaires are the most popular way to do questionnaire surveys. They rely on respondents working independently from the researcher, providing answers at their own pace and in their own time (Denscombe 2014).

There are four main advantages and three main disadvantages of questionnaire surveys shown in Table 4-3.

Table 4-3 Advantages and disadvantages of questionnaire surveys

Advantages	Aspects	Reasons
	Economy	They can supply a considerable amount of research data for a relatively low cost in terms of materials, money and time.
	Easy to arrange	Self-completion questionnaires are easier to arrange, than for example, personal interviews. Respondents are free to choose when and where they fill in the questionnaire.
	Standard questions	All respondents are posed exactly the same questions. With self-completion questionnaires, there is little scope for the data to be affected by interpersonal factors or the way the questions are asked.
	Data accuracy	The answers to web-based questionnaires can be fed directly into a data file, thus automating the process of data entry. This effectively eliminates the human error that inevitably arises when people need to read the responses to a paper questionnaire and then enter the data manually via the computer keyboard.
Disadvantages	Pre-coded questions can be frustrating	While the respondents might find it less demanding merely to tick appropriate boxes they might, equally, find this restricting and frustrating – and it could even deter respondents from completing the questionnaire.
	Pre-coded questions impose a structure on the answers	This can bias the findings towards the researcher's, rather than the respondent's, way of seeing things. Questionnaires, by their nature, start to impose a structure on the answers and shape the nature of the responses in a way that reflects the researcher's perception of matters to fit in with a line of thinking established by the researcher.
	Checks on truthfulness	Self-completion questionnaires offer little opportunity for the researcher to check the truthfulness of the answers given by the respondents. The research does not take place face-to-face and because the answers are given at a distance. The researcher cannot rely on a number of clues that an interviewer might have about whether the answers are genuine or not.

Source: Denscombe (2014)

4.5.2. Qualitative Research Method

(1) Overview

For a qualitative research method, the objective is to gain a detailed understanding of underlying reasons, beliefs and motivations and the process is to understand the reasons and the influences or contexts of the research. The data is usually presented as words (textual data). The qualitative method is used with a small number of participants or interviewees who are selected purposively (non-randomly) and data analysis is interpretive. The outcomes of the qualitative research method are to develop an initial understanding and to identify and explain behaviour, beliefs or actions (Hennink, Hutter & Bailey 2010).

Due to the in-depth nature of qualitative research, mining each participant deeply for their experiences can achieve the purpose of in-depth information (rather than breadth in quantitative research) (Hennink, Hutter & Bailey 2010). Data are generated through different methods such as observation, interviews, documents and audio-visual materials (Creswell & Creswell 2017; Denscombe 2014). The options, advantages and disadvantages of qualitative data collection methods are shown in Table 4-4.

Table 4-4 Options, advantages and disadvantages of qualitative data collection methods

Data Collection Types	Options within Types	Advantages of the Type	Disadvantages of the Type
Observations	Complete participant – researcher conceals role. Observer as participant – role of researcher is known. Participant as observer – observation role secondary to participant role. Complete observer – researcher observes without participating.	Researcher has first-hand experience with participant. Researcher can record information as it occurs. Unusual aspects can be noticed during observation. Useful in exploring topics that may be uncomfortable for participants to discuss.	Researcher may be seen as intrusive. Private information may be observed that researcher cannot report. Researcher may not have good attending and observing skills. Certain participants (e.g. children) may present special problems in gaining rapport
Interviews	One-to-one interview (including face-to-face interview, telephone interview and e-mail interview). Group discussions. Focus group.	Useful when participants cannot be directly observed. Participants can provide historical information. Allows researcher control over the line of questioning.	Provides indirect information filtered through the views of interviewees. Provides information in a designated place rather than the natural field setting Researcher's presence may bias responses. Not all people are equally articulate and perceptive.
Documents	Public documents, such as minutes of meetings, or newspapers. Private documents, such as journals, diaries or letters.	Enables a researcher to obtain the language and words of participants. Can be accessed at a time convenient to researcher – an unobtrusive source of information. Represents data which are thoughtful in that participants have given attention to compiling them. As written evidence, it saves a researcher the time and expense of transcribing.	Not all people are equally articulate and perceptive. Maybe protected information unavailable to public or private access. Requires the researcher to search out the information in hard-to-find places. Requires transcribing or optically scanning for computer entry. Materials may be incomplete. The documents may not be authentic or accurate.
Audio-Visual Materials	Photographs. Videotapes. Art objects. Computer software. Film.	Maybe an unobtrusive method of collecting data Provides an opportunity for participants to directly share their reality It is creative in that it captures attention visually	May be difficult to interpret. May not be accessible publicly or privately. The presence of an observer (e.g., photographer may be disruptive and affect responses).

Source: Creswell (2009), Denscombe (2014) and Thomas (2003)

(2) Interviews

Interviews use people's answers to researchers' questions as the source of research data. This method is different from observations which look at what people do and documents which show what has been written and recorded. Interviews are appropriate to use in the following situations:

- Where the aim of the research is to understand opinions, feelings, emotions and experiences in depth rather than report them in a simple word or two.
- Where the research focuses on complicated issues that call for a detailed understanding of how things work, how factors are inter-connected or how systems operate.
- Where the opportunity arises to speak with key players in the field who can give particularly valuable insights and wisdom based on their experience or position.

Considering the characteristics and purpose of the research and each research question, interview is one potential qualitative data collection method for this research. More details are discussed in Chapter 5.

(3) Case Study

Case studies are used to explore in depth a program, event, activity, process, or one or more individuals (Creswell 2009; Singleton & Straits 2017). Case studies can be used on two levels: first, as a qualitative research inquiry strategy in parallel with ethnography, phenomenology, narrative research and grounded theory in a qualitative research methodology; and second, as a qualitative data collection method (Creswell & Creswell 2017; Zainal 2007). This research follows a quantitative paradigm and case study is a potential qualitative data collection method. Case study is used for further data analysis in this research to assist policy design for the EPC market. More details are discussed in the next section and Chapter 5.

There are three main categories of case study: exploratory, descriptive and explanatory case study (Yin 2017). Exploratory case studies set out to explore any phenomenon in the data which serves as a point of interest to the researcher; descriptive case studies set out

to describe the natural phenomena which occur with the data in question; explanatory case studies examine the data closely both at a surface and deep level in order to explain the phenomena in the data. Later, other researchers may add more functions to a case study, making it an interpretive and/or evaluative case study. The literature explains the interpretive case study as a way through which data can be interpreted by developing conceptual categories, supporting or challenging the assumptions; in evaluating case studies, researchers' judgment can be added into the phenomena found in the data (McDonough & McDonough 2014; Zainal 2007).

4.5.3. Research Design

In order to answer the main research question on how to incentivise the uptake of EPCs in the field of commercial building retrofit, there are three sub-questions to be answered and six objectives to be achieved at the same time. Considering these three research questions and six objectives, multiple research methods including both quantitative and qualitative data collection methods are chosen for this research. As this research aims to test market imperfections of EPC market, the focus is on the barriers and difficulties of transactions of EPC projects. Therefore, building owners and ESCOs are the targeted stakeholders. Further, to better explore the market barriers and test market imperfections, government and independent experts in the field of EPCs are involved. Therefore, the population for the survey in this research contains four groups of participants: building owners, ESCOs, government, and independent experts. This section discusses what kinds of data are needed for each research question and what types of data collection methods can be used to collect those data.

The overall data collection method design is shown in Table 4-5.

Table 4-5 Overall data collection method design

Research Questions	Research Objectives	Research Data Collection Methods	Data Type	Population
What are the market barriers to the uptake of EPCs in the CBEER market?	To develop a theoretical framework for understanding the current situation of the EPC market in commercial buildings	Literature review	- Existing research studies - Online materials on government website - Published reports by the government	-
	To study the empirical data from surveys to identify the overall barriers of the EPC market	Questionnaire survey	Questionnaire survey	- Building owners of commercial buildings who have experience of EPCs or know about EPCs - ESCOs - Government related to EPCs or building energy efficiency policies - Independent experts in EPCs.
What are the reasons limiting the uptake of EPCs in the CBEER market?	To study the empirical data from the questionnaire survey and interviews to test the existence of market imperfections	Literature review; Questionnaire survey; Interview	- Existing research studies - Questionnaire survey - Interviews	- Building owners of commercial buildings who have experience of EPCs or know about EPCs - ESCOs - Government related to EPCs or building energy efficiency policies - Independent experts in EPCs
How can the uptake of EPCs in the CBEER market be incentivised?	To analyse policy implications in the EPC market to deal with market imperfections	Literature review	Existing research studies	-
	To triangulate the empirical data from interviews to discuss incentive roadmaps in practice from the perspective of transaction costs in the Chinese context	Interview	Interviews	- Building owners of commercial buildings who have experience of EPC or know about EPC; - ESCOs - Government related to EPCs or building energy efficiency policies - Independent experts in EPCs
	To triangulate the case study's empirical findings with the detailed incentive framework	Case study	- Interviews. - Existing research studies. - Online materials on government website. - Published reports by the government	Published pilot EPC policies

Focused on the three research questions, the research is designed as follows:

- What are the market barriers to the uptake of EPCs in the CBEER market?

In this part, there are two main types of information needed. One is information on the current EPC market, including the EPC market share, the overall industry situation (the numbers of ESCOs and investments in the EPC market), and the current EPC policies especially for commercial buildings. This type of information needs to be systematically collected and analysed from government files (online materials on government websites; published reports by the government) and existing research studies.

Another type of information is related to identifying EPC market barriers. This information can be gathered through literature review from existing research studies and through a questionnaire survey. Through the systematic literature review, the factors which may affect the uptake of EPCs can be preliminarily identified. Based on literature review, the market barriers can be identified precisely by the questionnaire survey.

- What are the reasons limiting the uptake of EPCs in the CBEER market?

To explore the reasons contributing to market barriers, three steps follow. Firstly, the theories of market imperfections can be reviewed as a foundation for explaining the reasons corresponding to EPC market barriers. Secondly, a questionnaire survey can collect data to have a broad understanding of the barriers in the EPC market. Thirdly, the findings from the questionnaire survey can offer a clue to conduct further interviews to deeply understand the characteristics of EPC market imperfections. As a result, the existence of market imperfections of the EPC market can be explored, and the nature of the EPC market can be revealed.

- How can the uptake of EPCs in the CBEER market be incentivised?

As Chapter 2 suggested, the government can intervene to reduce the effects of market imperfections. The aim is to decrease transaction costs in the EPC process. Therefore, the theoretical analysis of policy design can be conducted through literature review to address the identified market imperfections. Then interviews can be designed to explore the potential incentives, including what the stakeholders' market expectations are and what type of intervention is suitable to reduce the transaction cost related to each market

imperfection. The purpose is to know about the willingness of the market participants to respond to the different types of government intervention. After that, a detailed incentive mechanism can be developed for the Chinese EPC market. Finally, case studies can be adopted to explore the current successful experiences and their effect in both implementation and market response, which can be used to validate the proposed incentive mechanism for the Chinese EPC market.

4.6. Ethical Considerations

Research ethics involves the application of ethical principles to scientific research (Singleton & Straits 2017). All ethical issues need to be considered in research studies because they involve people in the data collection (Creswell 2009; Hesse-Biber & Leavy 2011). Ethical issues are unavoidable in this research because the research problem focuses on the EPC market, which involves contacting building owners, ESCOs, government and independent experts in the EPC field in a questionnaire survey, interviews and case studies for data collection. This research fulfils the requirements of the Australian Code for the Responsible Conduct of Research and UTS Research Management Policy and was approved by the Human Research Ethics Committee (HREC) of the University of Technology Sydney (UTS) on 2 September 2019. The approval number is UTS HREC REF NO. ETH19-3793 (see Appendix 1). The application for ethics approval in this research clarified how the research will be conducted ethically. This is related to confidentiality in the collection and management of data, noting and reducing exposure of project participants to risks. As a result, all data collected are subject to a series of processes to ensure the anonymity of participants and protect their identity. All anonymous data collected can be accessed by researchers in this project (the student and supervisors) and UTS.

4.7. Summary

This chapter presented the whole research design process. This research is based on the philosophical assumptions of objectivist epistemology and positivist theoretical perspective. Based on the quantitative paradigm this research tests the imperfect market theorem (microeconomics) and uses the theory of transaction costs (institutional economics) to address market imperfections. During the deductive research inquiry process, multiple research methods including qualitative and quantitative practices are applied to collect the data for the research. The next chapter presents the detailed data collection process and introduces the related data analysis methods.

Chapter 5 Research Data Collection and Analysis Methods

5.1. Introduction

This chapter presents the data collection process and the selection of data analysis methods. Data collection in this research used a questionnaire survey to identify factors impacting the uptake of energy performance contracts (EPCs) and semi-structured interviews to explore the reasons corresponding to the barriers to using EPCs for commercial building energy efficiency retrofit (CBEER). The use of case study is to collect information to verify the proposed incentive mechanism for the EPC market. This chapter provides an overview of the data collection process and analysis methods in this research, followed by details on each data collection and analysis method.

5.2. Overall Process of Data Collection and Analysis

The overall process of data collection and analysis methods is presented in Figure 5-1. Three data collection processes were conducted in this research: questionnaire survey, interview and case study. Questionnaire survey was conducted to identify the overall barriers of the EPC market. The findings guided the following interviews to explore the reasons corresponding to the market barriers. The empirical data from surveys and interviews tested the existence of market imperfections. Then a theoretical analysis of policy implications was conducted to address the identified market imperfections. Following are empirical market responses, collected through interviews, to the potential policies and strategies to deal with existing barriers in the EPC market. This helps develop a detailed incentive mechanism for the uptake of EPCs for the CBEER market in the Chinese context. Lastly, two case studies were used to validate the proposed incentive mechanism and demonstrate how it can be adopted to incentivise the EPC market based on the current market experiences.

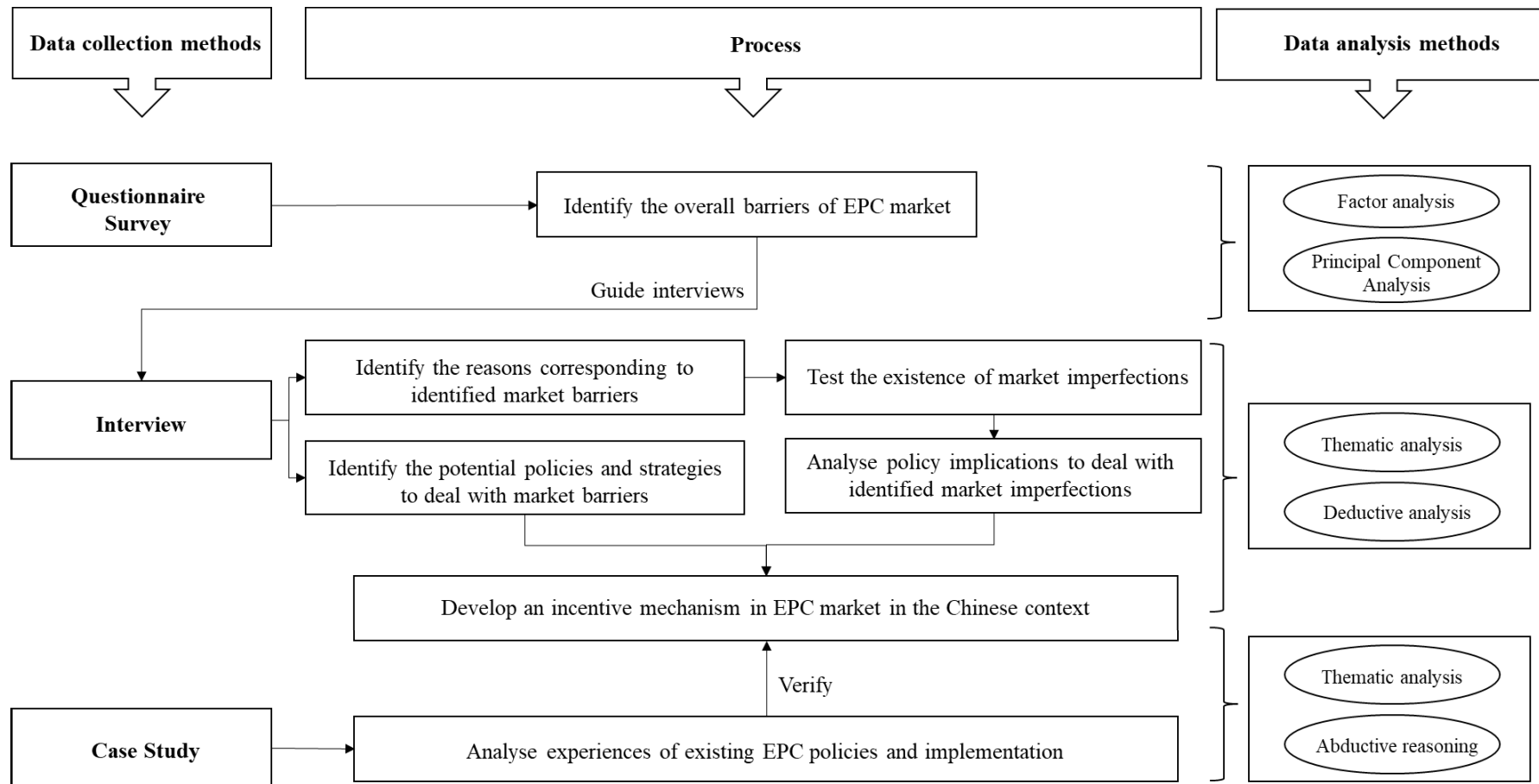


Figure 5-1 Overall process of data collection and analysis

5.3. Questionnaire Survey

5.3.1. Overview

The purpose of the questionnaire survey is to identify factors impacting the uptake of EPCs for CBEER in China. The questionnaire is firstly designed according to the strategies suggested by Bradburn, Sudman & Wansink (2004) and Krosnick & Presser (2010). The validity of the questionnaire is tested by pilot questionnaire surveys. Self-administrative questionnaire surveys were conducted with four groups of participants: building owners, staff in ESCOs, staff in government departments relating to EPCs, and independent experts in the EPC field. Ninety-eight questionnaires were collected, and ninety-five respondents were left after data cleaning. The validity and reliability of the data collected from questionnaire survey are tested. ANOVA and factor analysis are used to analyse the data collected from questionnaire surveys.

5.3.2. Questionnaire Design

The core of a survey is its questionnaire. In this research, the design of questionnaire is developed from two parts: the design of questions based on conventional techniques (Bradburn, Sudman & Wansink 2004) and the design of the structural features of questions based on the methodological research (Krosnick & Presser 2010). In details, there are four steps: design questions, design scales, design the order of questions, and test and evaluate questionnaire.

(1) Step one: design questions

This step includes designing the contents of questions and the structures of questions (Brace 2004). The questions in the questionnaire survey are attitude type questions. Therefore, the questions are structured according to the three components of attitudes: cognitive, evaluative, and behavioural components (Bradburn, Sudman & Wansink 2004). The cognitive component consists of a set of beliefs about the attitude object. The evaluative component consists of evaluation of the object. The behaviour component is related to respondents' attitudes in relation to their actions. According to the research questions, the cognitive component in this questionnaire is designed as the potential factors impacting the uptake of EPCs for CBEER in China. The evaluative component is

designed by the degree of identity and importance of each factor. The behaviour component is the attitudes towards the above potential factors.

Expect for the general information of respondents, other questions in the questionnaire are designed based on the three components of attitude questions design. The questionnaire was designed in English and translated into Chinese so the surveys were conducted in Chinese, then the data collected from the surveys were translated from Chinese into English. In the questionnaire, the wordings of questions uses well defined professional terminologies, therefore there are comparatively less problems in the translation process.

(2) Step two: design scales

This step includes designing the number of points on rating scales and labelling of rating scale points (Brace 2004). The choice of scale of questions will shape the information to be collected (Bradburn, Sudman & Wansink 2004). Although sensory research traditionally uses 9-point scales, psychometric research has shown that most subjects cannot reliably distinguish among more than six or seven levels of response (Thomas 2022). For attitude-related work, four to five scale points may be quite sufficient to simulate a reasonable reliable indication of response direction (Bradburn, Sudman & Wansink 2004). Although even-numbered scales can more effectively discriminate between satisfied or dissatisfied opinions, odd-numbered scales can offer participants opportunities to report neutral, moderate, or extreme attitudes more accurately (Bradburn, Sudman & Wansink 2004). Mid-points in scales could offer participants an opportunity of showing their neutral ideas. Likert scale is a pioneer in the field of attitude measurement. The fundamental idea behind Likert scales is that an attitude can be thought of as a set of propositions about beliefs, evaluations, and actions held by individuals (Krosnick & Presser 2010; Norman 2010). For parts two to four of the questionnaire, a five-point Likert scale is selected to assess the relative agreement or importance of the above issues. Then the rating scale points are labelled as 1 denotes “strongly disagree” or “extremely unimportant”; 2 denotes “disagree” or “unimportant”; 3 denotes “neutral”; 4 denotes “agree” or “important”; and 5 denotes “strongly agree” or “extremely important”.

(3) Step three: design the order of questions

Survey results may be affected not only by the wording of a question, but by the ordering of items in a questionnaire. To minimise errors, the questions should be guided by the same aim when designing a questionnaire from a set of questions (Krosnick & Presser 2010). Question order has two major ways to make decision: serial (location in sequence of items) and semantic (location in sequence of meanings) (Bradburn, Sudman & Wansink 2004; Krosnick & Presser 2010). In this research, the order of questions follows a serial way to design, as in the literature review, the potential barriers are identified and grouped by several items.

Overall, the questionnaire survey is divided into four parts: general information on respondents, key factors impacting the uptake of EPCs, the significance evaluation of risks and improvements in the uptake of EPCs for CBEER in China.

- The first part collects general information on respondents. The aim of this part is to understand the background of respondents, ensure the sample meets the criteria of recruitment, and enable analysis of the differences between the respondents.
- The second part is the main part of this survey. The aim of this part is to identify the barriers to the uptake of EPCs for CBEER in China. This part asks about respondents' understanding of and concerns about the uptake of EPCs in CBEER and has ranking questions of the key factors impacting the uptake of EPCs. This part guides the exploration of barriers to the uptake of EPCs in the interviews.
- The third part is used to compare and explain the barriers to EPCs which are collected in the second part of the survey.
- The fourth part is a preliminary study of potential solutions. The follow-up interviews and case studies explore the full picture of improvement measures of EPCs. This part explores respondents' ideas on how to improve the uptake of EPCs and is a reference for developing the incentive mechanism for the EPC market.

(4) Step four: test and evaluate questionnaire

The questionnaire was tested and evaluated by a pilot questionnaire survey carried out before the formal survey. There are two ways to pre-test a questionnaire: methods without data collection and methods with data collection (Krosnick & Presser 2010). The difference is that the method without data is evaluated based on expert reviews and the method with data collection is evaluated based on a small sample of the relevant population. Previous research shows that questionnaires will benefit from a multimethod approach to testing (Rothgeb, Willis & Forsyth 2007). In this research, expert review is used to examine whether items (questions, sequences, and processes) cause problems and opinions from a small group of the relevant population that examined the evidence of whether items (questions, sequences, and processes) cause problems. The detailed pilot questionnaire survey is elaborated as follows.

After the approval by the University of Technology Sydney Human Research Ethics Committee (Ethics approval No. ETH19-3793) on 2 September 2019, a pilot questionnaire survey was conducted to test the validity of the questionnaire. The questionnaire was sent on 5 September 2019 to six participants by a link to “Survey Star” (a Chinese professional questionnaire survey platform) on “WeChat” (a Chinese communication software). The recruitment of the six participants was based on personal contacts. Five of the participants filled out the survey as one of the participants dropped out due to personal issues. The pilot questionnaire survey was open for 10 days and received 18 comments in total from the five respondents.

(a) The role of participants

The five participants have rich work experience in building energy efficiency retrofit and EPCs:

- two academics specialising in building energy efficiency and EPCs.
- one participant from a government agency who participated in the first pilot EPC projects in China, and was responsible for policy design and the implementation of building energy efficiency retrofits.

- one industry professional who had many years of practical experience in building energy efficiency retrofit and extensive knowledge about EPCs.
- one independent expert who worked for an industry association investigating public building energy efficiency.

(b) Comments from participants

Overall, all the comments showed that the content of the questionnaire covered all the aspects of the questions to be explored and the display form of the questionnaire on Survey Star was convenient and made it easy to answer. It took each participant about 15–20 minutes to complete. The comments were mainly about minor adjustments and supplements on the contents and display format. Comments can be summarised into the following items.

- A question was added to part 1 of the survey on “professional qualification” to better reflect participants’ work experience and professional skills.
- One question was added to involve participants who may not have participated in EPC projects directly but may have indirect experience of EPC projects like policy design, research, and other EPC related activities.
- Terminology to define EPCs was added at the start of the survey as some people in China refer to an “energy performance contract (EPC)” as an “energy management contract (EMC)”.
- The influence of climate zone and building type on commercial building energy saving potential was added to Question 1 of part 2 as suggested.
- Post-EPC project evaluation was added to part 4 as one of the improvements for the uptake of EPCs for commercial building energy efficiency retrofit in China.
- The format of the survey was improved in the online survey platform in Survey Star for better and easier participation.

The revised questionnaire survey is included in Appendix 2.

5.3.3. Data Collection: Formal Questionnaire Survey

The formal questionnaire survey was sent on 19 September 2019 by a link to “Survey Star” via WeChat or emails. Approximately 200 questionnaires sent by the researcher and some of the questionnaires were collected using the snowballing technique. By 31 December 2019, 98 responses had been received. Due to using the snowballing technique, the response rate could not be calculated.

(a) Recruitment of participants

The questionnaire survey is aimed at four groups: building owners, staff in ESCOs, staff in government departments relating to EPCs, and independent experts in the EPC field. The group of building owners includes actual owners who have the property right of the buildings and the facility managers who have the right of management of the buildings. In some contexts, the real building owners and the facility managers are the same, which means the owner is the facility manager of their own building. In some contexts, the facility managers are hired by building owners to manage the buildings. This research includes these two groups together as building owners.

The process of participant recruitment followed the following four steps.

Step 1: Look for the source of participants. For building owners and ESCOs who have undertaken EPC projects, a name list was established based on “Pilot EPC Cases” published online by the ESCO Committee of China Energy Conservation Association. For building owners and ESCOs who have joined EPC projects but are not yet included in the “Pilot EPC Cases”, the related information was obtained by searching online. For governments and independent experts in the EPC field, there were some existing relationships with the researcher, thus they were reached by personal contacts.

Step 2: Contact potential participants. After compiling the whole list (including the names, contact numbers, addresses and email addresses), the information sheet, consent form and weblink to the questionnaire form was sent out by email or WeChat.

Step 3: Apply a snowball strategy. Based on the rules of “snowball sampling”, sample respondents were identified using a referral from the existing respondent group. The use of the existing respondents and their professional network is opportunity to increase the

data collection while ensuring the focus characteristics of the sample group are maintained. Therefore, more surveys are completed by respondents who are suggested by the existing respondents.

Step 4: Send out reminders. The survey continued for 3.5 months. Reminders were sent out monthly to boost survey response rates.

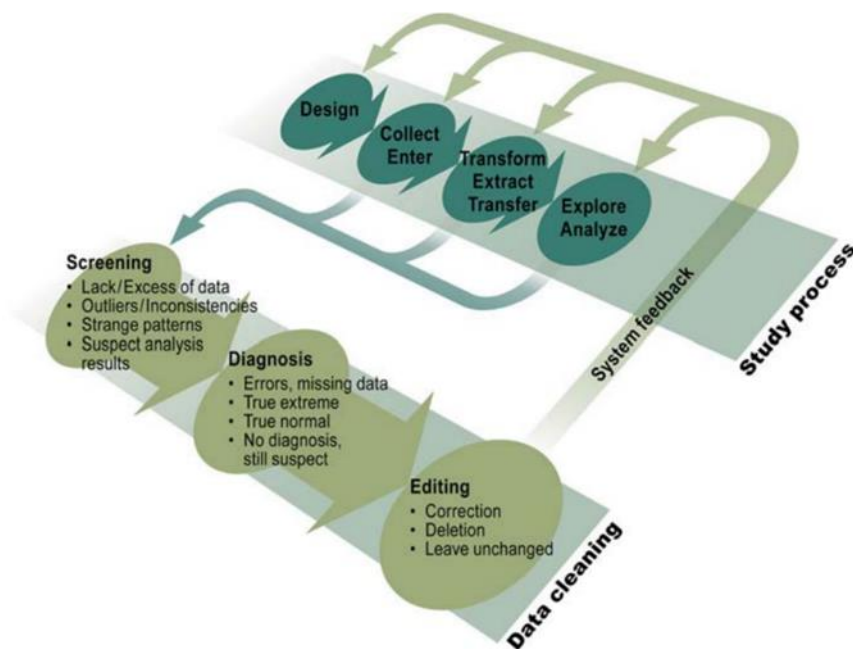
(b) Response rate and sample quality

Because the questionnaire was published on the WeChat platform using the snowballing technique, it is not possible to calculate the response rate. An EPC is a new concept in the CBEER market, and the number of people who have professional knowledge or EPC experience is not known but small. The population is limited; thus, the sample size is small. The later personal interviews confirmed this situation. As the sample size is small, the sample representative is very important to maintain the sample quality (Memon et al. 2020). Comparing the responses from the small sample is a way to test replication of the sample (Sauro 2013; Schoot R van de 2020). For different groups of respondents, the answers are different from the total sample but consistent within the group (the detailed results are explained in Section 5.3.4). Therefore, this sample is likely to be representative (Singh 2007). Meanwhile, as supplementary materials, same findings from the follow-up interviews as a triangulation method can help to cross validate the information through various methods. The questionnaire survey and interview results are close enough to indicate that the sample size is enough while drawn different ways. There is still potential for sampling bias due to the limitations associated with the time, the distribution of questionnaires, and the proportional number of ESCOs that failed to conduct EPC projects compared to the overall number of respondents. This bias and accuracy of findings are examined when the themes are tested in the validation process associated with the follow-up interviews.

5.3.4. Data Pre-processing

(1) Data Cleaning

Data cleaning intends to identify and remove incompleteness, errors and inconsistencies from responses to make sure they all match the target criteria of the survey (Bryman 2016). The goal is to ensure the data quality so it represents the population and has a convincing result. The process of data cleaning can be summarised as a three-stage process, involving repeated cycles of screening, diagnosing and editing of data abnormalities as shown in Figure 5-2 (Van den Broeck et al. 2005).



Source: adopted from Van den Broeck et al. (2005)

Figure 5-2 Data cleaning framework

Based on this data cleaning framework, a detailed checklist was developed for this survey (Table 5-1). After the six-step check, there were 95 respondents left.

Table 5-1 Checklist of data cleaning

No.	Screening Item	Diagnosis	Editing
1	Missing data	All 98 responses are complete.	-
2	Respondents who do not meet the research target criteria	The online questionnaire already set the criteria for participants.	-
3	Respondents who speed through the survey	The average time for answering the whole questionnaire was 12 minutes. The longest time was 35 minutes. The answering time of Respondent No. 3, 19, 31 was too short, under 5 minutes.	Delete the responses of Respondent No. 3, 19, 31.
4	Respondents who continually choose the same answer choice	Respondent No. 3 and 31 selected the same answer choice continually in part 2.	Respondent No. 3 and 31 were already deleted in step 3.
5	Inconsistent responses	There were no inconsistent responses.	-
6	Outliers	The data are dealt with by descriptive analysis setting standardised values as variables. From the result, data over three times the standard deviation are considered as outliers. The outliers are Respondent No. 3, 9, 14, 15, 19, 31.	The outliers are dealt with in two ways. For the outliers (No. 3, 19, 31) with poor data quality according to the previous steps and the relativity of the respondents' basic information, these outliers were already deleted in step 3. For the outliers with good data quality (No. 9, 14, 15), the skewed result happens due to the differences between the groups. Those types of outliers need to be analysed in depth. Those data are kept and analysed by the ANOVA (Analysis of Variance) test later.

(2) Data Quality: Reliability and Validity

For a questionnaire to be regarded as acceptable, it must possess two very important qualities which are reliability and validity. Reliability measures the consistency of the questionnaire while validity measures the degree to which the result from the questionnaire agrees with the real world. There are different statistical ways to measure the reliability and validity of the questionnaire. This section provides details of the reliability and validity of the questionnaire survey.

(a) Reliability

Reliability signifies the issue of consistency of measures, that is, the ability of the measurement instrument to measure the same thing each time the instrument is used (Singh 2007). In this research, reliability is used to test that 1) the questions in part 2 of the questionnaire can consistently measure the barriers of the EPC market in CBEER; 2) the questions in part 3 of the questionnaire can consistently measure the risks of conducting CBEER under EPC; and 3) the questions in part 4 of the questionnaire can consistently measure the potential improvements of using EPCs.

Reliability is an important technical index to measure the quality of the questionnaire. It inherently depends on three key elements: stability, internal reliability and inter-observer consistency. Stability entails asking whether a measure is stable over time so that researchers can be confident that results relating to the measure for a sample of respondents will not fluctuate. Internal reliability consistency seeks to assess whether the indicators that make up the scale or index are consistent. Inter-observer reliability refers to the potential for problems that can arise due to the involvement of more than one observer in activities such as recording of observation or translation of data into categories. Internal reliability is normally used to measure the reliability coefficient in a statistical way (Bolarinwa 2015; Singh 2007).

There are two main methods of measuring the reliability coefficient: Split-half reliability and Cronbach's alpha. Cronbach's alpha is chosen to measure the reliability of this questionnaire survey for the following reasons. In split-half reliability, as the name suggests, half of the test is analysed for the extent to which the questions all measure the same underlying construct. Then the result of this analysis is compared to the overall

analysis, to assess the reliability of the tests. It measures the extent to which the two halves of the tests have the same means and standard deviations. Cronbach's alpha is commonly used to test the internal reliability without strict restrictions and it correlates the performance of each half of responses with an overall score. It calculates the average of all possible split-half reliability coefficients and a computed alpha coefficient varies between 1, denoting perfect internal reliability, and 0, denoting no internal reliability. The figure of 0.70 is often used as a rule of thumb to denote an accepted level of reliability (Bolarinwa 2015; Singh 2007). The Cronbach's alphas for the questions in three parts of the questionnaire are shown in Table 5-2.

Table 5-2 Reliability statistics

Part of the Questionnaire	Cronbach's Alpha	Cronbach's Alpha Based on Standardised Items	No. of Items
2	0.892	0.899	34
3	0.877	0.880	27
4	0.794	0.803	7

All the Cronbach's alphas in Table 5-2 are over 0.70, therefore this questionnaire is likely to have good statistical reliability.

(b) Validity

Validity aims to assess whether the questions in the questionnaire have captured the topic under investigation effectively. In this research, validity is used to test that 1) the questions in part 2 of the questionnaire can effectively explore the barriers of the EPC market in CBEER; 2) the questions in part 3 of the questionnaire can effectively explore the risks of conducting CBEER under EPC; 3) the questions in part 4 of the questionnaire can effectively explore the potential improvements of using EPCs. The higher the validity, the more effectively the results of this questionnaire can represent the items to be tested and the more the purpose of the questionnaire can be achieved.

There are two types of validity: external and internal. External validity signifies the extent to which a research study can be generalised to other situations. Internal validity refers to the true causes, which result in an outcome. It signifies the rigour with which the study

was conducted and the extent to which the designers of a study have considered alternative explanations for any causal relationships they explore (Biasutti & Frate 2017). The external validity of this research is considered by a clear definition of the survey population and a careful set of inclusion and exclusion criteria in the recruitment of participants. For internal validity, there are two sub-categories: content validity and construct validity. Table 5-3 shows the content and accomplishment of the content and construct validity. The content validity is tested by the pilot questionnaire survey. The construct validity is tested by statistical analysis KMO and Bartlett tests.

Table 5-3 Summary of internal validity

Internal Validity	Content Validity	Construct Validity
What it measures	Whether the test covers a representative sample of the domains to be measured	The extent to which the instrument measures a theoretical construct
How it is accomplished	Ask experts to assess the test to establish that the items are representative of the outcome	Correlate performance on the instrument with performance on an established instrument

Source: Biasutti & Frate (2017)

The KMO and Bartlett tests were the first statistical analyses performed to verify the suitability of the data for exploratory factor analysis (Biasutti & Frate 2017). A KMO value over 0.70 is good; a KMO value over 0.60 is acceptable (Russell 2002), and the values of the Bartlett test suggest that the null hypothesis must be rejected when there is a significance level of 0.05 (Snedecor & Cochran 1989). The results of the three parts are shown in Table 5-4. The KMO values indicate that the validity of data of the three parts is good and additional factor analysis on the questions of the three parts can be conducted.

Table 5-4 KMO and Bartlett tests

KMO and Bartlett Test Item		Part 2	Part 3	Part 4
Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		0.772	0.744	0.771
Bartlett Test of Sphericity	Approx. Chi-Square	1768.190	1489.595	232.467
	df	561	351	21
	Sig.	0.000	0.000	0.000

(3) The Profile of Respondents

The profile of the valid 95 respondents is summarised.

(a) Location

The respondents were from 14 cities with the majority from four main cities: Beijing (44.21%), Chongqing (8.42%), Shanghai (15.79%) and Shenzhen (10.53%) (see Table 5-5).

Table 5-5 Location of respondents

No.	Location	Frequency	Percentage (%)
1	Beijing	42	44.21
2	Shanghai	15	15.79
3	Shenzhen	10	10.53
4	Chongqing	8	8.42
5	Tianjin	5	5.26
6	Guangzhou	3	3.16
7	Lanzhou	3	3.16
8	Chengdu	2	2.11
9	Qingdao	2	2.11
10	Changchun	1	1.05
11	Hangzhou	1	1.05
12	Hunan	1	1.05
13	Shenyang	1	1.05
14	Xian	1	1.05
Total		95	100

The data distribution appears to be consistent with the locations where the pilot EPC projects are being implemented (Beijing, Chongqing, Shanghai and Shenzhen), which would be expected that the sample appears to be representative. People in these cities have more exposure to EPCs, compared to the other cities. The number of questionnaires received from Beijing is much larger than the responses from other cities. There are four potential reasons. Firstly, Beijing is the seat of the central government (Ministry of

Housing and Urban-Rural Development of the People’s Republic of China), therefore more questionnaires were sent to participants who are working in government in Beijing than in the other cities. Secondly, the major associations related to EPCs in the building sector, the ESCO Committee of China Energy Conservation Association and the China Association of Building Energy Efficiency, are located in Beijing. Therefore, more questionnaires were sent to participants who work in these associations. Thirdly, since there are a number of universities in Beijing, more questionnaires were sent to independent experts in Beijing than in other cities. Lastly, a large number of ESCOs and commercial buildings are clustered in Beijing.

(b) Highest educational qualification

Respondents’ highest educational qualification gives an overview of the degree of education (see Table 5-6). Over two-thirds of respondents have a postgraduate degree including a master’s degree (47.37%) or PhD (21.05%), and 28.42% have an undergraduate degree.

Table 5-6 Highest educational qualification of respondents

Highest Educational Qualification	Frequency	Percentage (%)
Secondary Education	3	3.16
Undergraduate Degree	27	28.42
Master’s Degree	45	47.37
PhD	20	21.05
Total	95	100

(c) Organisation

The respondents are from 10 types of organisations. They were divided into four groups based on the nature of those 10 organisations: independent experts, government, building owners and ESCOs (see Table 5-7). The independent expert group includes respondents from institutes of education. The government group includes respondents from government and industry associations. The industry associations are guided by the government. The mission of industry associations is to promote the market and help the government to deliver policies and establish technical standards. Therefore, they have

similar characteristics to the government and can be classified in the same group. The third group of building owner combines respondents who are from development and facility management companies, for the reasons outlined in Section 5.3.2. The remaining respondents are the fourth group of ESCOs. The group consists of the companies that can conduct building energy efficiency retrofit in the construction industry. Table 5-7 shows that about a third of respondents are ESCOs and a third are building owners.

Table 5-7 Organisation of respondents

Working Organisation		Frequency		Percentage (%)	
Participant Group	Organisation				
Independent Experts	Education	21		22.11	
Government	Government	8	11	8.42	11.58
	Industry association	3		3.16	
Building Owners	Development company	17	31	17.89	32.63
	Facility management company	14		14.74	
ESCOs	Energy service company	14	32	14.74	33.68
	Engineering consultant	9		9.47	
	Construction company	1		1.05	
	Design consultant	7		7.37	
	Supplier of building materials	1		1.05	

(d) Position

The position of respondents is shown in Table 5-8. Most of the respondents are general employees (33.68%) or directors (31.58%).

Table 5-8 Position of respondents

Position in Organisation	Frequency	Percentage (%)
Intern	2	2.11
General employee	32	33.68
Manager	16	16.84
Director	30	31.58
President	15	15.79

Total	95	100

(e) Professional context and experience

Respondents' professional context and professional experience impact the responses as these play a significant part in the understanding of the EPC market and the technologies of building energy efficiency retrofits. Of the 95 respondents, around 31% were construction and project managers and 23% were professional mechanical and mechatronic engineers (see Table 5-9). The responses of these two professions constituted over half of the total professions. In China, there is a special professional qualification which can show at which level people get their qualifications. There are three levels of professional qualification: Primary, Intermediate and Senior. This classification can help determine respondents' professional skills. Most of the respondents (over 82%) have an intermediate or senior professional qualification, showing that the answers related to respondents' professions are credible.

Table 5-9 Professional Context and Experience of respondents

Professional Context and Experience		Frequency	Percentage (%)
Profession	Public administration	15	10.79
	Architecture	10	7.18
	Mechanical & mechatronic engineering	32	23.02
	Electrical engineering	8	5.76
	Construction and Project management	43	30.94
	Property management	21	15.11
	Measurement & Verification	4	2.88
	Marketing	6	4.32
	Total	139	100
Professional Qualification Level	Primary	17	17.90
	Intermediate	39	41.05
	Senior	39	41.05
	Total	95	100

(f) Working experience

Respondents' working years can show their overall experience. Table 5-10 shows the working experience of the respondents. About 42% of respondents have worked in their organisations for more than 10 years. Respondents who have worked in their organisations for 6–10 and 2–5 years are similar at around 24% of the total. Around 30% of respondents have worked in building energy efficiency for more than 10 years and about 25% for 6–10 years. The respondents who have worked longer in this area offer more credible opinions in the survey. Ten participants had less than one year working in the organisation and 12 participants had less than one year working in building energy efficiency. The follow-up ANOVA tests show there is no significant difference between participants who have less than one year working experience and the participants who have longer working experience. This is true for time in both their organisation and the sector of building energy efficiency.

Table 5-10 Working experience of respondents

Working Experience		Frequency	Percentage
Working Experience in the Organisation	1 year or less	10	10.53
	2–5 years	23	24.21
	6–10 years	22	23.16
	More than 10 years	40	42.10
	Total	95	100
Working Experience in Building Energy Efficiency	1 year or less	12	12.63
	2–5 years	29	30.53
	6–10 years	24	25.26
	More than 10 years	30	31.58
	Total	95	100

(g) EPC experience

EPCs are new concepts in Chinese energy efficiency retrofits and respondents' familiarity with EPCs may influence the result of this survey. EPC experience is shown in Table 5-11. Of the 95 respondents, 10.53% are extremely familiar with EPCs, 37.89% are familiar with EPCs, and 44.21% have some familiarity with EPCs. The remaining 7.37% of

respondents are not familiar with EPCs and some of them are completely unfamiliar with the concept. Around 30% of the total respondents have joined one EPC project and 28.42% have joined 2 to 3 EPC projects. Of the respondents who have not joined EPC projects, 64.29% have been involved in EPC activities like EPC policies, education, research and training. The other 10 respondents that have not joined an EPC project have had no involvement in any EPC activities at all. For the respondents who have joined EPC projects, over one-quarter of the EPC projects involved updating air conditioning systems. Around 20% of EPC projects included lighting and heating and cooling systems updating. Three respondents were involved in energy cost trusteeship in EPC projects. The item “energy cost trusteeship” was not set as an option for responses in the related question, however three respondents filled this item in the “Other” option. Energy cost trusteeship is a term used for the business model of energy-cost trust to conduct EPCs. Although energy cost trusteeship can involve all types of retrofits, in order to reflect the real situation of respondents, this item is listed in the table as well.

Table 5-11 EPC experience of respondents

Item		Frequency	Percentage (%)
Familiarity with EPCs	Extremely unfamiliar	4	4.21
	Unfamiliar	3	3.16
	A little familiar	42	44.21
	Familiar	36	37.89
	Extremely familiar	10	10.53
	Total	95	100
Number of EPC Projects Participated	0	28	29.47
	1	29	30.53
	2–3	27	28.42
	4–5	4	4.21
	Over 5	7	7.37
	Total	95	100
EPC activities (for respondents who participated in at least one EPC project)	Upgrade building envelope	19	8.22
	Upgrade lighting system	47	20.35
	Upgrade air conditioning system	58	25.11

Item		Frequency	Percentage (%)
	Upgrade heating and cooling system	46	19.91
	Upgrade distribution system	28	12.12
	Develop building energy management system	30	12.99
	Energy cost trusteeship	3	1.30
	Total	231	100
EPC activities (for respondents who had not participated in any EPC projects)	No involvement in any EPC activities at all	10	35.71%
	EPC policies education, research, and training	18	64.29%
	Total	28	100

5.3.5. Data Analysis Methods

(1) Comparison between Groups: Analysis of Variance (ANOVA)

There are four groups of participants in the questionnaire survey. To know whether the opinions from four groups of participants can represent the situation of the EPC market of this research, the significance of the difference should be tested within the groups. Meanwhile, the theories of market imperfection are tested in this research. It shows that there are different opinions between the groups which contribute unbalanced information. Therefore, significance tests can be used to ascertain whether characteristics shown in the sample reflect the population trends and how significant differences are to predict that differences are real and truly represent the field situation (Singh 2007).

Based on the characteristics of the data in the three parts, the parametric method is chosen. Parametric methods are based on data measured on an interval or ratio scale. They assume that the variable of interest is normally distributed, thus allowing slightly more statistical power to detect differences across the group. For this research, there are four main groups of participants. Therefore, the Analysis of Variance (ANOVA) test can be chosen because it can compare three or more unmatched groups (Singh 2007). As this research does not explore the multi-influences on the dependent variables, one-way ANOVA test is used because it deals with one independent variable and one dependent variable. It examines

whether groups formed by categories of independent variables are similar, because if the groups seem different then it is concluded that the independent variable influences the dependent variable (Mooi, Sarstedt & Mooi-Reci 2018).

The purpose of performing the ANOVA test is to determine if a certain number of population means are equal (Lane 2020). It is used to test hypotheses that examine the difference between two or more means. The null hypothesis tested by ANOVA is that the population means for all conditions are the same, where H_0 is the null hypothesis and k is the number of conditions. This can be expressed as follows:

$$H_0: \mu_1 = \mu_2 = \dots = \mu_k \quad (1)$$

In this research, there are four groups of independent variables, therefore, k is set as 4 and the null hypothesis is:

$$H_0: \mu_{Gov} = \mu_{IE} = \mu_{ESCO} = \mu_{BO} \quad (2)$$

Where Gov = Government,
 IE = Independent Experts,
 $ESCO$ = Energy Service Companies,
 BO = Building Owners.

This formula means the null hypothesis is set as the four groups of participants (government, independent experts, ESCOs and building owners) have similar opinions. If the null hypothesis is rejected, then it can be concluded that at least one of the population means is different from at least one other population mean. An alternative hypothesis (indicated as H_1) is set as

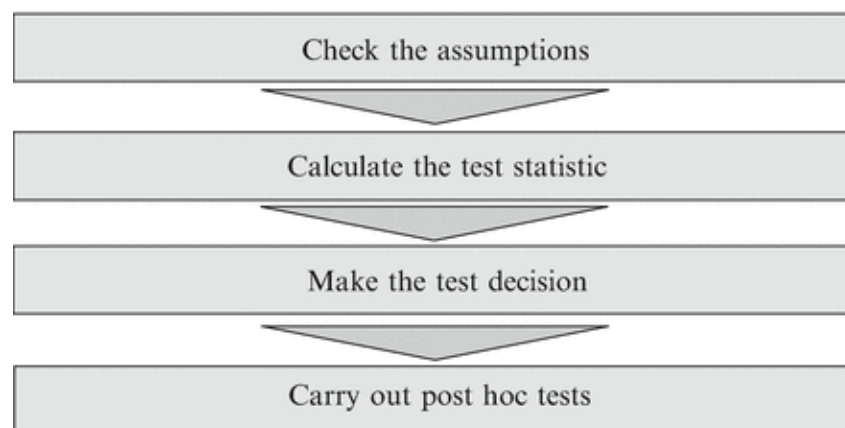
$$H_1: \text{At least two of } \mu_{Gov}, \mu_{IE}, \mu_{ESCO}, \mu_{BO} \text{ are unequal.}$$

In this research, the purpose of using ANOVA is to test that the means of the four groups are equal. Thus, the difference of the sample means should be measured and then compared to the variability within the sample observations. It is based on two estimates of the population variance (σ^2). One estimate is called the mean square error (MSE) and is based on differences among scores within the groups. MSE estimates σ^2 regardless of whether the null hypothesis is true (the population means are equal). The second estimate is called the mean square between (MSB) and is based on differences among the sample

means. MSB only estimates σ^2 if the population means are equal. If the population means are not equal, then MSB estimates a quantity larger than σ^2 . Therefore, if the MSB is much larger than the MSE, then the population means are unlikely to be equal. On the other hand, if the MSB is about the same as MSE, then the data are consistent with the null hypothesis that the population means are equal (Lane 2020; Mooi, Sarstedt & Mooi-Reci 2018).

The critical session in an ANOVA is comparing MSE and MSB (Lane 2020; Mooi, Sarstedt & Mooi-Reci 2018). Since MSB estimates a larger quantity than MSE only when the population means are not equal, a finding of a larger MSB than an MSE is a sign that the population means are not equal. F ratio is the standard method for determining the probability of getting a bigger difference if the population means were all equal. F is based on the ratio of MSB to MSE. The F ratio tests the difference in group means to conclude whether groups formed by the values of the independent variable are different enough not to have occurred by chance, and if groups' means do not differ significantly then it can be concluded that the independent variable did not have an impact on the dependent variable.

This research follows the framework Mooi, Sarstedt & Mooi-Reci (2018) put forward to conduct ANOVA tests (see Figure 5-3).



Source: adopted from Mooi, Sarstedt & Mooi-Reci (2018)

Figure 5-3 Framework for conducting ANOVA test

Step 1: Test for the equality of variances.

ANOVA is a parametric test that relies on distributional assumptions (Mooi, Sarstedt & Mooi-Reci 2018). ANOVA is rather robust, because it can be used when the sample size of each group is greater than 30 and the dependent variables are measured on an ordinal scale and not normally distributed. However, violations of the assumption of the equality of variances can bias the results significantly, especially when the groups are of very unequal sample size. Therefore, a homogeneity of variance test has been conducted accordingly. Levene's test is used to test for the homogeneity of variance. The null hypothesis is that population variances across the sub-samples are the same, whereas the alternative hypothesis is that they differ. If the p-value associated with Levene's statistic is lower than 0.05, the null hypothesis should be rejected. This means the variances are heterogeneous. On the contrary, if a p-value is larger than 0.05 it implies that the variances are homogeneous. As the ANOVA test is a robust method, if the p-value is lower than 0.05, according to Howell (2013, p. 234) the results of variance analysis are more likely to be valid when the ratio of largest variance to smallest variance was four or below among the groups. Meanwhile, a post hoc test can show more details of a violated homogeneity of variances.

Based on these rules the homogeneity of the variances was tested. In the 34 statements of the part 2 of the questionnaire, 16 variances were violated in homogeneity, but the ratio of largest variance to smallest variance in each statement was around one less than four. The other 18 variances were homogeneous. This means that the results of the ANOVA test in part 2 of the questionnaire can be accepted as valid. In the part 3 statements of the questionnaire, 5 variances were violated in homogeneity, but the ratio of largest variance to smallest variance in each statement was around one less than four. The other 22 variances are homogeneous. Therefore, the results of the ANOVA test in part 3 of the questionnaire can be accepted as valid. In the part 4 questions of the questionnaire, 7 variances were homogeneous, therefore the results of ANOVA tests in part 4 of the questionnaire are considered as valid.

Step 2: Calculate the score of MSE and MSB, and the F ratio.

The scores of *MSE*, *MSB* and *F* ratio can be calculated based on the following formulas (Lane 2020; Mooi, Sarstedt & Mooi-Reci 2018):

$$MSE = \frac{\sum_{j=1}^k \sum_{i=1}^{n_j} (x_{ij} - \bar{x}_j)^2}{n-k} \quad (3)$$

$$MSB = \frac{\sum_{j=1}^k n_j (\bar{x}_j - \bar{x})^2}{k-1} \quad (4)$$

$$F = \frac{MSB}{MSE} \quad (5)$$

where *i* represents the sample in each group; *j* represents the group; the overall number of the group is denoted with *k*; $\bar{x}_j$ describes the mean in the *j*-th group; *n_j* stands for the number of observations in that group; *x_{ij}* stands for the score of the *i*-th sample in the *j*-th group. The calculation results are shown in Appendix 5.

Step 3: Make the decision based on the statistic results (considering F ratios and significances).

Making the test decision in ANOVA is to compare F ratios with the critical values. By using SPSS, the p-value is provided rather than the critical value. If the p-value is less than 0.05, the null hypothesis should be rejected.

Step 4: Carry out post hoc tests.

Post hoc tests make multiple comparison on each pair of groups and explore which group differs significantly from each other group (Mooi, Sarstedt & Mooi-Reci 2018). There are many types of post hoc tests, like Least Significant Difference, Bonferroni correction, and Tukey's honestly significant difference test. The original testing method named Least Significant Difference (LSD) test was developed by Fisher to explore all possible pairwise comparisons of means comprising a factor using the equivalent of multiple t-tests (Hilton & Armstrong 2006). The other methods are based on LSD to correct its α error. This research uses the LSD method to conduct post hoc tests although it may increase α error. LSD is more sensitive than the other methods to detect differences between groups (Allen 2017; Hilton & Armstrong 2006). Based on the purposes of using

ANOVA test and the design of the questionnaire survey, LSD is more suitable to show the differences following an ANOVA test. The follow-up interviews provide more detail on the results of the questionnaire survey, which can overcome any α error caused.

The results of the ANOVA tests on four groups are shown in Appendix 5 and the results of multiple comparisons on each pair of groups are shown in Appendix 6. There are some differences between the four groups of participants (ESCOs, building owners, government and independent experts). To make sure their responses are representative, further tests on the differences within the groups based on the respondents' professional qualifications and working years are conducted. The results show there is no significant difference between the different respondents' professional qualifications and working years within each group. Therefore, their responses are representative. The detailed analysis and findings of interpreting the differences with theory test are introduced in Chapter 6 and Chapter 8.

(2) Factor Analysis

The purpose of this questionnaire survey is to identify the main EPC market barriers. As participants listed many items, there is a need to explore the important items which reflect the main barriers that lead to the imperfections of the EPC market. In this multivariate analysis, often data with many variables to be analysed faces the problem of multidimensionality. Multidimensionality is signified by a condition wherein groups of variables often move together because more than one variable may be measuring the same driving principle governing the behaviour of the system. Factor analysis is a suitable method to deal with this distortion because it can be used to simplify the problem by replacing a group of variables with a single new variable or a smaller set of factors. There are two objectives of factor analysis: to reduce the number of variables and to detect structure in the relationships between variables (Singh 2007).

There are two main factor analysis methods. The first one is common factor analysis, which extracts factors based on the variance shared by the factors. The second one is principal component analysis, which extracts factors based on the total variance of the factors.

(a) Common factor analysis

Common factor analysis differs from principal component analysis fundamentally. Factor analysis studies the inter-relationship among the variables to find a new set of variables fewer in number than the original variables and express what is common among the original variables.

(b) Principal component analysis

Principal component analysis (PCA) is a data reduction technique, which uses basic mathematical principles to reduce the number of observed variables to a smaller number of principal components which include the largest portion of the variance of the observed variables (Karytsas & Choropanitis 2017). The method generates a new set of variables, called principal components, and each component is a linear combination of the original variables. All the principal components are orthogonal to each other so there is no redundant information. The principal components as a whole form an orthogonal basis for the space of the data (Singh 2007).

The objectives of a principal component analysis are to extract the most important information from the data, compress the size of the data keeping only the essential information, simplify the description of the data set, and analyse the structure of the observations and the variables (Karytsas & Choropanitis 2017).

The principal components are extracted in a way that the first principal component accounts for the largest amount of total variation in the data. The second principal component is defined as that weighted linear combination of observed variables, which is uncorrelated with the first linear combination and accounts for the maximum amount of remaining total variation not already accounted for by the first principal component. The first principal component is a single axis in space and when each observation is projected on the axis, the resultant value forms a new variable having maximum variance among all possible choices of the second axis.

Therefore, a full set of principal components is as large as the original set of variables. In some social and psychological problems, the sum of the variances of the first few principal components exceeds 70% of the total variance of the original data. The reason for retaining a group of components is the latter components are of truly substantive importance. Thus this approach has sometimes been criticised for its subjectivity (Wold, Esbensen & Geladi 1987).

This research needs the main factors contributing to the imperfections of the market. Considering the characteristics that principal component analysis can extract factors based on the total variance of the factors, principal component analysis is chosen to analyse the main barriers of the EPC market. The detailed analysis and findings are introduced in Chapter 6.

5.4. Interview

5.4.1. Overview

The purpose of the interview is to understand the reasons behind the barriers to the uptake of EPCs for CBEER in China and explore ways to incentivise the market. Semi-structured interviews were conducted with key representatives who have professional knowledge and experience of EPCs in commercial buildings. The data sample was the same four groups in the questionnaire survey. Twenty-six interviews were conducted across seven Chinese cities in total. Considerations of ethical issues were presented and approved by the Human Research Ethics Committee of the University of Technology Sydney. A hybrid qualitative approach to thematic analysis is used to analyse the interview data.

5.4.2. Data Collection

After ethics approval, the interviews were conducted from October to November 2019 across seven Chinese cities (Chongqing, Beijing, Tianjin, Shanghai, Chengdu, Lanzhou, and Xian). These cities were selected based on the market experience of EPCs. The selection details are discussed in the following part. The interviews were conducted in Mandarin and transcribed to Chinese, then the data were analysed in English and the main contents were translated from Chinese into English. To avoid potential meaning loss, or errors during translation, there are some safeguards used during the translation process as follows (Brazill 2016; Lee 2017). Firstly, translator's language skill has great impact on the errors of translation (Stiegelbauer 2016). The researcher's first language is Chinese but with considerable skills in English Secondly, to make sure the translation of contents is correct, the researcher sent back the transcripts to the interviewees to check if the original meanings of their ideas were recorded correctly and that nothing was missing. As the contents of the interviews are mostly research based, there was a common, well

defined professional terminology. Therefore, there is not many ambiguities in the meanings of the contents. and any uncertain expressions were fully explained understood during the process of the interviews. Lastly, the translated main themes are discussed with the supervisors of the researcher as confirmation of the accuracy of the translation.

Each interview lasted between 45 and 60 minutes. All interviews were audio-recorded with the consent of interviewees. During the interviews, the interviewees were asked questions focusing on the existing EPC market, their experiences of EPC projects, the difficulties and challenges they faced, market barriers and risks, causes of the barriers and risks, the way to avoid risks, and possible measures to improve the uptake of EPCs. Each interview process was guided by the “Guide to the Interviews” (shown in Appendix 3). The potential interview questions were designed and sent to each participant in advance to ensure the quality of the interviews. The overall questions are shown in Appendix 4. This section elaborates on the details of recruiting participants, choosing the interview location, and some strategies for conducting interviews.

(1) Recruitment of Participants

The interview targeted four groups: building owners, ESCOs, government and independent experts in the EPC field. The contact details of building owners and ESCOs were obtained from pilot EPC projects published online by the ESCO Committee of China Energy Conservation Association. Industry contacts facilitated the initial interviews with further data collecting using a “snowball sampling” strategy (Francis et al. 2010; Johnston & Sabin 2010).

The process of participant recruitment followed the same first three steps as participant recruitment for the questionnaire survey (see Part (a) in Section 5.3.3). An additional source of participants in the first step was potential participants from the respondents who did the questionnaire survey. As the survey was conducted before the interview, it offered an opportunity to ask consent to participate in the interview. At the end of the questionnaire survey, there was a question asking willingness to have a face-to-face interview. People who agreed were chosen for a later interview.

The researcher contacted 27 potential respondents and 26 respondents agreed to participate. Initially four interviews were scheduled for each group to develop themes

with the addition of interviews until reaching saturation point which happened at 26 interviews (Francis et al. 2010; Johnston & Sabin 2010).

(2) The Profile of Interviewees

Due to the time limitation and schedule conflicts, not all the interviews were conducted face-to-face in China. Twenty-two interviews were conducted by face-to-face interviews and four interviews were conducted by telephone in Australia. There were five interviews with government (two from central government, one from the government association, and two from local government), six interviews with independent experts, six interviews with building owners, and nine interviews with ESCOs representing both big and small companies. There were three interviewees from existing relationships, four interviewees from the questionnaires, and the other 19 interviewees from snowballing. The profile of interviewees is shown in Table 5-12.

Table 5-12 Profiles of interviewees

No.	ID	Sector	Position	Location	Interview Form
1	IE1	Independent expert	Associate professor	Chongqing	Face-to-face
2	IE2	Independent expert	Professor	Chongqing	Face-to-face
3	IE3	Independent expert	Associate professor	Chongqing	Face-to-face
4	IE4	Independent expert	Post-doctor	Beijing	Face-to-face
5	IE5	Independent expert	Senior lecturer	Tianjin	Face-to-face
6	IE6	Independent expert	Senior consultant	Beijing	Telephone
7	IE7	Independent expert	Senior engineer	Chengdu	Face-to-face
8	BO1	Building owner	Senior property manager	Chongqing	Face-to-face
9	BO2	Building owner	Senior property manager	Chongqing	Face-to-face
10	BO3	Building owner	Senior engineer	Beijing	Face-to-face
11	BO4	Building owner	Senior property manager	Beijing	Face-to-face
12	BO5	Building owner	Senior property manager	Shanghai	Face-to-face
13	BO6	Building owner	Senior property manager	Shanghai	Face-to-face
14	BO7	Building owner	Project manager	Beijing	Telephone
15	ESCO1	ESCO	General president	Chongqing	Face-to-face
16	ESCO2	ESCO	Senior engineer	Chongqing	Face-to-face
17	ESCO3	ESCO	Project manager	Chongqing	Face-to-face
18	ESCO4	ESCO	Senior manager	Beijing	Face-to-face
19	ESCO5	ESCO	CEO	Beijing	Face-to-face
20	ESCO6	ESCO	CEO	Shanghai	Face-to-face

21	ESCO7	ESCO	Senior engineer	Lanzhou	Telephone
22	ESCO8	ESCO	Senior engineer	Xian	Telephone
23	Gov1	Local government	Head of the department	Chongqing	Face-to-face
24	Gov2	Industry association	Vice Director; Financing Dept. Chief	Beijing	Face-to-face
25	Gov3	Central government	Director	Beijing	Face-to-face
26	Gov4	Local government	Director	Shanghai	Face-to-face

Note: IE, BO, ESCO and Gov are the abbreviations for independent expert, building owner, energy service company and government.

(3) Location Selection

Seven cities are represented: Chongqing, Beijing, Tianjin, Shanghai, Chengdu, Lanzhou and Xian. The reasons for selecting the seven cities are:

- Both Chongqing, Tianjin and Shanghai have had pilot EPC projects and are also leading the development of EPC projects in the building sector nationwide.
- Beijing is the seat of the central government (Ministry of Housing and Urban-Rural Development of the People's Republic of China), thus the principal EPC policies from the central government are published there. The ESCO Committee of China Energy Conservation Association is also located in Beijing, and the role of this association is to help the government to develop the EPC market. The China Association of Building Energy Efficiency is also located in Beijing, and one of its responsibilities is to help develop the EPC market in the building industry. Three participants are from these three institutions. A large number of ESCOs are clustered in Beijing.
- Chengdu, Lanzhou and Xian are the target cities for EPC projects in the 13th Five-Year Plan. These three cities are exploring the potential to develop EPC projects, and some new ESCOs are opening.

These seven cities represent two building climate zones: cold climate zone and hot summer cold winter climate zone.

The location distribution of interviews is shown in Table 5-13.

Table 5-13 Location of interviewees

City	Independent Experts	Building Owners	ESCOs	Government	Total
Chongqing	3	2	3	1	9
Beijing	2	3	2	2	9
Shanghai	-	2	1	1	4
Tianjin	1	-	-	-	1
Chengdu	1	-	-	-	1
Xian	-	-	1	-	1
Lanzhou	-	-	1	-	1
Total	7	7	8	4	26

(a) Interviews in Pilot Cities

Nine interviews were conducted in Chongqing, including three independent experts, one local government, two building owners and three ESCOs. Nine interviews were conducted in Beijing, including one central government, one government association, two independent experts, three building owners and two ESCOs. One interview was conducted in Tianjin, in which the interviewee is an academic in this area who also owns an ESCO. Four interviews were conducted in Shanghai, including one local government official, two building owners and one ESCO.

In the pilot cities, the initial EPC market was established, with both central and local government financial subsidies. With the financial subsidy ending, many ESCOs are being phased out of the market. The remaining companies are more competitive. There are many risks and uncertainties in the EPC projects and most of the ESCOs accept most of the risks. The guaranteed energy savings and credibility of payment by the building owners are the two main concerns of the ESCOs. The retrofit serviceability and the final energy saving benefits are the focus of the building owners. The ESCOs that have more experience have more ability to avoid risks when they negotiate contracts of EPC projects with the building owners. Government endorsement makes cooperation between ESCOs and building owners easier. All the groups (government, ESCOs and building owners) approach works from different perspectives, balancing risks with each other and make the EPC project transaction happen. In addition, how to enhance the role of banks and the

third party of measurement and verification to support EPC projects is still a problem from both theoretical and practical perspectives.

(b) Interviews in Developing Markets

Three interviews were conducted in developing markets. One interview was conducted in each city (Chengdu, Lanzhou and Xian). In Chengdu, the interviewee was an independent expert. In both Lanzhou and Xian, the interviewees were ESCOs.

For these developing markets, the overall situation is that the concept of EPCs is very new to them. The local governments have the task of encouraging building energy efficiency retrofit to use EPCs, however there are no agreed sets of principles and practical rules offering guides to both ESCOs and the building owners. Some of the rules are too general to provide a clear practical guide. Every stakeholder is facing many difficulties when they try to use EPCs. The EPC markets in these cities are at a very early stage, and these cities are the new targets of experienced ESCOs from the pilot EPC cities. Thus, the small ESCOs in these developing markets are facing fierce market competition. This requires developing clear practical guides from different levels to make EPCs more attractive in China.

(4) Strategies Used during Interviews

There are several techniques used in conducting an interview (Hennink, Hutter & Bailey 2010; May 2002) and these techniques are used during interviews:

- pose questions openly and neutrally and in a friendly colloquial manner.
- establish rapport with the interviewees.
- listen and respond to the interviewee by asking follow-up questions and probing.
- motivate the interviewee to tell their story in detail.

(5) Data Quality: Reliability and Validity

To ensure good quality interview data, some questions were added during the series of interviews because information provided in previous interviews demanded follow up

(Denscombe 2014). For example, a reason corresponding to an EPC market barrier was identified from an interview, then in the following interviews more questions related to this issue can be put forward to the participants. To ensure the validity of interview results, all interviews followed the interview guide with minor adjustments as described above. The interview transcripts were compared with the notes written down during the interviews for confirmation (Creswell & Miller 2000). To ensure reliability, transcripts were checked for obvious mistakes made during the transcription. This can ensure there is not a drift in the definition of codes or a shift of meaning during coding procedures (Creswell 2009).

5.4.3. Data Analysis Methods

For the interview data, a thematic analysis was adopted to analyse the reasons behind the barriers of the EPC market. Thematic analysis is a method for identifying themes and patterns of meaning across a dataset in relation to a research question and is possibly the most widely used qualitative method of data analysis (Braun & Clarke 2006). A hybrid thematic analysis combining the inductive and deductive coding process is used for interview analysis. The reason for choosing thematic analysis and a hybrid approach is analysed further. Meanwhile, the procedure for analysing the data by the method is discussed in this section.

(1) Thematic Analysis

There are many different methods of qualitative data analysis such as thematic analysis, content analysis, hermeneutic phenomenological analysis, grounded theory and discourse analysis (Braun & Clarke 2013). According to Sandelowski & Barroso (2003), research findings can be placed on a continuum indicating the degree of transformation of data during the data analysis process from description to interpretation. The use of qualitative descriptive analysis such as content analysis and thematic analysis is suitable for researchers who wish to employ a relatively low level of interpretation, in contrast to hermeneutic phenomenology and grounded theory. The value of qualitative description lies not only in the knowledge that can originate from it, but also because it is a vehicle for presenting and treating research methods as living entities that resist simple classification, and can result in establishing meaning and solid findings (Vaismoradi, Turunen & Bondas 2013).

Thematic analysis and content analysis are the two main analysis approaches in qualitative descriptive study. However, because the boundaries and the division between the two have not been specified clearly, they are often used interchangeably and there is confusion about their similarities and differences (Sandelowski & Leeman 2012), as well as how researchers should choose between them. Content analysis is a systematic coding and categorising approach used for exploring large amounts of textual information unobtrusively to determine trends and patterns of words used, their frequency, their relationships, and the structures and discourses of communication (Crano, Brewer & Lac 2014; Erlingsson & Brysiewicz 2017; Plumins, Sceulovsb & Gaile–Sarkanec 2016). Thematic analysis as an independent qualitative descriptive approach is mainly described as “a method for identifying, analysing and reporting patterns (themes) within data” (Braun & Clarke 2006, p.79).

Both content analysis and thematic analysis share the same aim of analytically examining narrative materials from life stories by breaking up the text into relatively small units of content and submitting them to descriptive treatment (Fereday & Muir-Cochrane 2006). It has been suggested that thematic analysis, as a flexible and useful research tool, provides a rich and detailed, yet complex, account of the data (Braun & Clarke 2006). It is suitable for exploring the meaning of unstructured data such as qualitative results in open-end questions (Kazantsev et al. 2018). Clearly, thematic analysis involves the search for and identification of common threads that extend across an entire interview or set of interviews (DeSantis & Ugarriza 2000). It should be noted that both approaches allow a qualitative analysis of data. By using content analysis, it is possible to analyse data qualitatively and at the same time quantify the data (Crano, Brewer & Lac 2014; Grbich 2012). Content analysis uses a descriptive approach in both coding of the data and its interpretation of quantitative counts of the codes (Erlingsson & Brysiewicz 2017). Conversely, thematic analysis provides a purely qualitative, detailed and nuanced account of data (Braun & Clarke 2006, 2013). For this research, the purpose of the interview is to explore the reasons for the barriers to the uptake of the EPC market and explore potential improvements. It needs a deeper and detailed description of the EPC market and nuanced analysis of the EPC market within the stakeholders. Therefore, this research chooses thematic analysis to analyse the qualitative interview data.

(2) A Hybrid Approach to Thematic Analysis

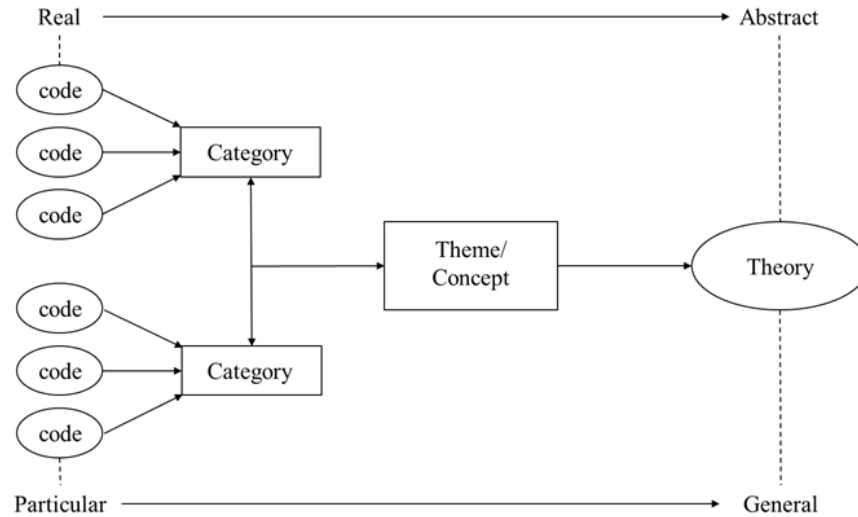
There are two types of thematic analysis: inductive thematic analysis and theoretical thematic analysis (Fereday & Muir-Cochrane 2006). For the inductive thematic analysis, the aims are to generate an analysis from the bottom (the data) up. The analysis is not shaped by existing theory (but the analysis is always shaped to some extent by the researcher's standpoint, disciplinary knowledge and epistemology) (Braun & Clarke 2013). For the theoretical thematic analysis, the analysis is guided by existing theory and theoretical concepts (as well as by the researcher's standpoint, disciplinary knowledge and epistemology) (Braun & Clarke 2013).

As this research explored the operations of an imperfect market and the interview analysis was informed by the questionnaire results, theory-driven thematic analysis was adopted. Boyatzis (1998) suggests that this type of thematic analysis reflects the values of a positivist/quantitative tradition with an emphasis on coding reliability and has strong echoes of "scientific method". There is little regard for subjectivity or the role of the researcher in the process of analysis, which is suitable for this project. In this style of thematic analysis, the analysis is not "in" the data waiting to be found, rather the analysis is developed by the researcher to test the theory in reality. In order not to miss the information the raw data offers, data-driven thematic analysis is also used to look for original ideas from the interviews. Therefore, this research adopts a more theory-driven thematic analysis but also combines the data-driven thematic analysis to investigate the raw data as the initial description. As a result, a hybrid thematic analysis combining inductive and deductive coding approaches is developed.

This research uses the Braun & Clarke (2006) approach as a framework for developing a hybrid approach of thematic analysis. The inductive analysis of interview transcripts is conducted by general text cluster and description. The deductive analysis of interview transcripts is informed by imperfect market theories, (e.g. transaction cost theory, incomplete contract theory, externalities) and the questionnaire results. Further details on what this involved are provided below.

(3) The Procedure of Thematic Analysis

The essence of thematic analysis and the general procedure of abstracting codes to the themes and their relationship between a theory can be summarised in Figure 5-4.



Source: adopted from Boyatzis (1998)

Figure 5-4 Framework of thematic analysis

In a deductive analysis, the theory-driven strategy is based on hypotheses and models drawn from previous research on the topic, which specify the domains of content that are important to cull from the source data and, importantly, the purpose of the research (Crano, Brewer & Lac 2014). For this research, the semi-structured interviews are used to test a hypothesis that the EPC market is an imperfect market. The analysis is informed by transaction cost theory to find potential improvements for the EPC market. Therefore, the coding subjects are already assigned based on the theory. The findings of the previous questionnaire survey designed by the theory can be the initial codes to look for the themes. Meanwhile, in order not to miss additional information the participants offer, data-driven analysis of descriptive coding is also adopted to code the interview transcripts simultaneously. The process of the hybrid approach of thematic analysis for this research is shown in Figure 5-5. The computer-assisted qualitative data analysis software NVivo is adopted to assist with coding and analysis of thematic analysis for this research. It can assist in the production of very complex and nuanced analyses and can aid interpretation and theorising (Silverman 2013). The detailed analysis and findings are introduced in the following three chapters.

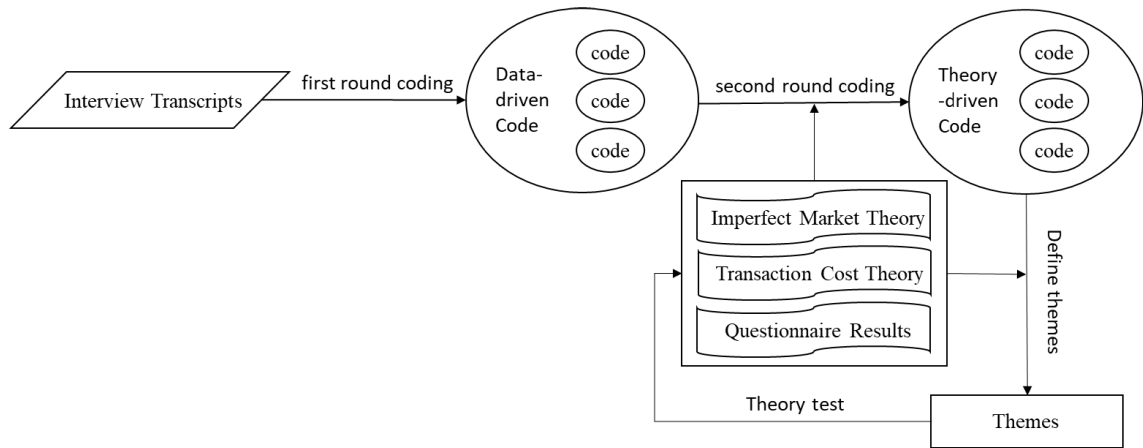


Figure 5-5 Hybrid approach of thematic analysis

Based on the Braun & Clarke (2006) approach, there are six phases of coding and theme development:

i) Familiarising with the data and identifying items of potential interest

In this phase, the tasks are transcribing data, reviewing data, and noting down initial ideas (Braun & Clarke 2006). For this research, all interviews were audio-recorded, and the recordings were transcribed in the original language (Chinese) to preserve a more complete meaning of participants. Verbatim transcripts are adopted because they can avoid missing information (Crano, Brewer & Lac 2014). The interviewer used the strategy of prompts to remind the interviewees of the main and current topics. From the outcome of interviews, the focus is to check that the interviewees did not go off the subject.

ii) Generating initial codes

A code is a summary term that helps a researcher to recover or retrieve some of the data in a highly purposeful way. In this phase, the tasks are coding interesting features of the data systematically across the entire dataset, and collating data relevant to each code (Braun & Clarke 2006). There are usually two cycles of coding.

The first coding cycle is applied during the initial stages of analysis and tends to be both relatively simple and straight forward. It is often descriptive but may also involve preliminary analysis and hypothesis building (Saldana 2009). For this first cycle coding, this research uses both data-driven and theory-driven coding styles to explore the initial

categories of the interview data. The first step is to use descriptive coding (which belongs to data-driven thematic analysis) to summarise the topic of a textual passage in a word or short phrase. The purpose is to explore the explicit content of the interview transcripts. The second step is to use the previous questionnaire results to code simultaneously. The purpose is to explore a more focused content of the interview transcripts.

The second coding cycle tends to be applied during the later stages of analysis and requires more in-depth analytic skills. It is theoretically oriented and typically involves categorising, conceptualising and theorising (Saldana 2009). For this second coding cycle, this research uses hypothesis coding (which belongs to theory-driven thematic analysis) to apply concept-driven codes that are developed before analysis is initiated. The purpose is to explore the implicit and latent content of the interview transcripts.

iii) Identifying themes

A theme has a central organising concept, which shows the content of the data that is meaningful in relation to the research questions (Braun & Clarke 2013). In this phase, the tasks are collating codes into potential themes, gathering all data relevant to each potential theme (Braun & Clarke 2006). There are three main steps in this phase. The first one is searching for patterns and relationships. It should be noted that, in working out which patterns are relevant and important, it is not just a question of which are the most frequent. While frequency is an important factor, it is also about capturing the different elements that are most meaningful for answering the research questions (Braun & Clarke 2013). The second is identifying the core category or story around which the analysis focuses. The third is selecting coding or theoretical coding to identify potential themes. The distinction between themes/concepts and categories is arbitrary, so it does not matter which level of abstraction is called what, as long as the different levels can be differentiated (Saldana 2009).

iv) Reviewing potential themes

In this phase the task is checking if the themes work in relation to the coded extracts and the entire dataset, generating a thematic map.

v) Defining and naming themes

This phase is an ongoing analysis for refining the specifics of each theme and the overall story that the analysis tells, generating clear definitions and names for each theme.

vi) Producing the report

This phase is the final opportunity for analysis. It includes selection of vivid, compelling extract examples, final analysis of selected extracts, relating back of the analysis to the research question and literature, and producing a report of the analysis. In this procedure, discussions and comments are generated based on the integrated analysis of previous statistics and non-numerical data to understand the reasons behind barriers to EPCs and market reaction to related policies.

To keep the quality of the interview findings, verification strategies integral and self-correcting are implemented during the conduct of interviews and data analysis (Morse et al. 2002). Instead of testing reliability and validity that quantitative research does, ensuring rigor from the investigators' actions during the course of the research is the means of achieving validity in qualitative research (Fereday & Muir-Cochrane 2006). The emphasis on strategies that are implemented during the research process is to induce trustworthiness. To attaining rigor in qualitative research, this research strictly follows the above approach outlined by Braun & Clarke (2006).

5.5. Case Study

5.5.1. Overview

The purpose of the case study is to validate or fail the incentive mechanism proposed by the research to improve the uptake of EPCs for CBEER and get more useful information about further improvements to the incentive mechanism for the EPC market. Two case studies are chosen from pilot cities that were conducting EPC projects successfully in China published by the government and industry association. Documents and interviews are the sources of data for case studies. By analysing each type of EPC policy that was implemented in the cases, the proposed incentive mechanism can be verified through abductive reasoning. Through this careful policy design (incentive mechanism), market imperfections can be reduced and the transaction costs of conducting EPCs can decrease

from the three perspectives as asset specificity, uncertainty and frequency, which can improve the uptake of EPCs finally.

5.5.2. Data Collection

(1) Selection of the Cases

Overall, the cases are selected following the proposition of the research (Yin 2003). In this research, cases are selected to explore the current experiences and their effect in both implementation and market response, which can be used to validate the proposed incentive mechanism for the Chinese EPC market. According to the protocol of case studies (Yin 2014), policy designs for the EPC markets are the objects to be explored in the cases, and policy designs in cities/districts are as units of cases.

The detailed process of the selection of cases contains three steps: 1) the selection of a single case or multiple cases; 2) the criteria of selecting potential cases; 3) the selection of final cases (Yin 2014). Firstly, this research is going to select multiple cases (two cases) rather than a single case. The reason is that “analytic conclusions independently arising from two cases, as with two experiments, will be more powerful than those coming from a single case alone” (Yin 2014, p. 64).

Secondly, the criteria of selecting potential cases are as follows. There are three typical measures the government can conduct for making up EPC market failures: regulations, subsidies and taxes. The potential cases should involve the above typical measures. Also, the cases are selected according to factors including investments in EPC projects, the number of EPC projects, and market response. These factors can help show the market change according to the policy changes. There is a demonstration program in China, which contains “the first key pilot cities for energy conservation renovation of public buildings program” (including government office buildings, commercial buildings, hospitals and schools). This program is called the demonstration program for short and was discussed in Section 3.4.1. The projects in this demonstration program mostly meet the specified criteria and qualify as potential cases.

Among the above potential cases, the two cases (Chongqing and Changning) are selected following the strategy of convenience and meeting the above specified criteria. In general,

convenience, access, and geographic proximity are the main considerations for selecting the final cases, which allows for a less structured and more prolonged relationship between researchers and participants (Yin 2014). Meanwhile, techniques suggested by Seawright & Gerring (2008) are assistant for the case selection, in which the methods of diverse and most similar/different cases are adopted. The method of diverse cases aims to achieve the maximum variance along relevant dimensions, which is to be exploratory (hypothesis seeking) and confirmatory (hypothesis testing) (Seawright & Gerring 2008). This method can be used to cover as much as possible all the perspectives of policies to fully validate the incentive mechanism in this research. The method of most similar/different cases choose cases that have similar background conditions that might be relevant to the outcome of interest (Seawright & Gerring 2008). The cases are similar on some of the measured independent variables or differ on some dimensions on the outcome. The selected two cases have similar background but have various policy design strategies, which will show the potential successful experience on the policy design from diverse perspectives.

By collecting various sources of the cases, the selected two cases contain comprehensive information, which could offer a holistic and embedded picture of how policies were implemented and how markets respond. The selected cases and sources of case studies are summarised in the next part.

(2) Sources of Case Studies

Evidence for case studies may come from six sources: documents, archival records, interviews, direct observation, participant-observation and physical artefacts (Yin 2003). Based on the research purpose of the case studies and the availability of the sources, the information of the two case studies in this research is derived from documents and interviews. The sources of the case studies are shown in Table 5-14.

Table 5-14 Profiles of two case studies

No.	Case	Perspective for Policy Design	Source
1	Chongqing's EPC experience	Regulation; Government subsidies from the state to local; Finance platform; Energy audit procedure;	Documents: Handbook for public building energy-efficient conservation and renovation in Chongqing; Unpublished government report;

		Energy assessment; Building energy information platform; Technical standards of EPCs. Contract references	Research articles Interviews and private communication including government, ESCO, and building owner related to this case
2	Shanghai Changning District's EPC experience	Regulation; Local government subsidies; Finance platform; Building energy information platform; Energy performance benchmark	Documents: World Resources Institute (WRI) Building Efficiency Accelerator (BEA) Targets Playbook; Constructing a new, low-carbon future: how Chinese cities are scaling ambitious building energy-efficiency solutions; Unpublished government report; Research articles Interviews and private communication including government, ESCO, and building owner related to this case

5.5.3. Data Analysis Methods

Case study analysis consists of examining, categorising, tabulating or otherwise recombining the evidence to address the initial propositions of a study. The analysis of cases can rely on theoretical propositions or develop a case description (Yin 2003). For this research, the strategy of relying on theoretical propositions is chosen to analyse the cases, because the case studies are used to validate the incentive mechanism proposed by this research and modify it by exploring more useful information.

The validation using case studies can be completed through the method of abduction. In abduction, the major premise is evident, but the minor premise and therefore the conclusion are only probable (Lipscomb 2012; Merriam-Webster 2021). The process of abduction in qualitative data analysis is to examine how the data support existing theories or hypotheses as well as how the data may call for modifications in existing understandings (Kennedy, Thornberg & Flick 2018). In this research, the successful experiences collected from the case studies can be used to support the incentive mechanism proposed by the research.

The configuration is important for case studies, which is the linkage between the text units and the patterns that can be discovered and explained by scientific methods (Olsen 2011). The pattern-matching logic is the dominant mode for analysing the configuration of cases in this research. It is a desirable strategy to compare an empirically based pattern with a predicted one (Yin 2017). If the patterns coincide, the results can help a case study strengthen its internal validity (Yin 2003). As the documents and the interview transcripts are the qualitative data, thematic analysis is adopted to help explore the patterns in the cases. The procedure follows the Braun & Clarke (2006) approach mentioned previously in Section 5.4.3. The detailed analysis and findings are presented in Chapter 10.

5.6. Summary

This chapter introduced the methods used to collect and analyse the data in this research. The detailed processes of data collection were described, and data analysis methods to answer related research questions were stated. The following chapters (Chapters 6, 7, 9 and 10) present the findings from the data collected. The following chapter presents analysis of the data from the questionnaire survey to identify the factors impacting the uptake of EPCs for CBEER.

Chapter 6 Survey Findings on the Barriers to the EPC Market

6.1. Introduction

This chapter aims to investigate the barriers to the uptake of energy performance contracts (EPCs) in the sector of commercial buildings based on the questionnaire survey. The questionnaire survey was used to identify the critical factors impacting the uptake of EPCs by principal component analysis (PCA). Analysis of Variance (ANOVA) method was used to gain a better understanding of the significant differences in the identified nine principal factors on the barriers to adopting and implementing EPCs. Interview results are used to explain more detail and discuss the questionnaire results in depth.

6.2. Critical Factors Influencing the Uptake of EPCs

This section aims to identify the critical factors impacting the uptake of EPCs. It starts by showing an overall picture of people's understanding of the EPC market and all possible factors which may influence the uptake of EPCs based on descriptive analysis. The second part identifies the critical factors influencing the uptake of EPCs based on the method of principal component analysis.

6.2.1. Descriptive Analysis of Factors Influencing the Uptake of EPCs

In reviewing the literature, 34 statements were identified to investigate people's understanding of the EPC market and examine factors influencing the uptake of EPCs in the survey, shown in Table 6-1. A five-point Likert scale was used in the survey to measure the respondents' level of agreement with the proposed statements: 1 – strongly disagree, 2 – disagree, 3 – neutral, 4 – agree, 5 – strongly agree, as discussed in Section 5.3.1. The mean and standard deviation can be calculated accordingly. Table 6-1 shows the overall descriptive analysis of these 34 statements.

Table 6-1 Descriptive analysis of uptake of EPCs of CBEER in China

No.	Statements	Mean	Standard Deviation
1	The government has given great support to the uptake of EPCs in CBEER	3.74	0.970
2	Policies and regulations have given clear provisions on the application of EPCs for CBEER	3.23	0.869
3	Policies are the main motivation for the uptake of EPCs in CBEER	3.69	1.001
4	The subsidies and tax policies provided by the government play an important role in promoting CBEER using EPCs	4.49	0.617
5	Pilot EPC projects play an important role in promoting CBEER using EPCs	3.97	0.676
6	Green Finance Policy has great support on conducting an EPC project	3.79	0.811
7	EPC is well known in CBEER	3.06	0.823
8	ESCOs can offer professional retrofit services including finance, design, construction, energy maintenance	4.27	0.659
9	The ability of the energy service company has a great influence on the effect of energy savings	4.22	0.622
10	The service quality of ESCOs can be effectively guaranteed	3.34	0.694
11	EPCs are useful for promoting commercial buildings conducting energy efficiency retrofit	4.15	0.684
12	EPCs can ensure the energy saving effect of CBEER	3.85	0.699
13	EPCs can effectively solve the financing problem of CBEER	3.91	0.654
14	EPCs can guarantee stakeholders' energy saving benefits	3.76	0.648
15	Contracts of EPC projects clearly specify the rights and obligations for each contracting party	4.08	0.739
16	The allocation of estimated energy savings and energy saving benefits can easily be verified	3.60	0.675
17	The contract period is clearly stipulated and measured	3.59	0.676
18	The contracts clearly define the measures for CBEER	4.15	0.757
19	The contracts clearly ensure the current baseline of building energy consumption	3.59	0.722
20	The contracts clearly define the potential energy savings for CBEER	3.39	0.762
21	Building owners are responsible for investing CBEER	3.57	0.964
22	Building users can get more benefits on CBEER than building owners	3.39	0.879
23	Relationships for making decisions within CBEER are complicated	4.16	0.803
24	The recovery period of investment in CBEER is too long	4.11	0.778

25	The behaviour of the user has a great impact on energy efficiency	4.33	0.535
26	Technologies of CBEER cannot effectively guarantee the effect of energy savings	2.68	0.970
27	Measurement & Verification by a third party provides a very effective help to the energy saving assessment of CBEER	3.93	0.747
28	The building climate zone has a great influence on the energy saving potential of commercial buildings	3.97	0.750
29	The functional types of commercial buildings have a great impact on the owners' decisions for energy efficiency retrofit	4.08	0.753
30	Low energy prices do not encourage demand for energy efficiency	4.06	0.954
31	Building energy savings are limited	3.72	1.048
32	There are a large number of building energy service companies engaged in EPC services	2.86	0.738
33	Building energy savings make it easier to apply for a bank loan	2.53	0.909
34	Information platform for building energy information can help stakeholders explore building energy saving potential	3.57	0.871

In these 34 statements, the mean values of three statements are below 3, which means that in aggregate respondents disagree or strongly disagree with three statements. These three statements are:

- Technologies of CBEER cannot effectively guarantee the effect of energy savings (No. 26).
- There are a large number of building energy service companies engaged in EPC services (No. 32).
- Building energy saving makes it easier to apply for a bank loan (No. 33).

From these three statements, participants do not deny the effect that technologies of CBEER may guarantee energy savings. They do not doubt the effectiveness of energy efficiency technologies. They do not think that there are a large number of building energy service companies engaged in EPC services. They disagree that building energy savings make it easier to apply for a bank loan.

To better validate these opinions, a triangulation method is used to cross validate the information through various methods (Bans-Akutey 2021). As supplementary materials,

the same findings from the follow-up interviews have been elaborated, with the codes referring to the interviewees (see Table 5-12).

Although the number of ESCOs has increased dramatically in the last decade, many ESCOs were reluctant to set their primary business as conducting EPC. (IE6)

We prefer to do the traditional energy efficiency retrofit work rather than EPC because the payback period is very long. ... Commercial bank loans require fixed property as collateral. Although the Changing government tried to use the recording and review system as a government endorsement to support ESCOs to get bank loans, we didn't have any successful cases in our company. (ESCO6)

Of the 34 statements, 11 statements have mean values of over 4, which means the respondents strongly agree with these statements. Among these 11 statements, there are five items related to positive influences of uptake of EPCs. They are:

- The subsidies and tax policies provided by the government play an important role in promoting CBEER using EPCs (No. 4).
- ESCOs can offer professional retrofit services including finance, design, construction, energy maintenance (No. 8).
- EPCs are useful for promoting commercial buildings conducting energy efficiency retrofit (No. 11).
- Contracts of EPC projects clearly specify the rights and obligations for each contracting party (No. 15).
- The contracts clearly define the measures for CBEER (No. 18).

These five items show that overall the participants agreed on the advantages of using EPCs. They understand the theoretical efforts of using EPCs. In the initial EPC market, government policies played an important role in developing the market. These have been discussed further in the follow-up interviews.

Especially in the last two years, I heard that many projects are conducting EPC because of subsidies. Whether it is from the national level or the provincial government level, it seems that there are some subsidies. It is a matter promoted by the state, so people want to try it. Most of the subsidies are given based on the level of energy you have saved. (ESCO7)

The greatest advantages of subsidies for EPC is that they can decrease the financial pressure for the ESCOs. (ESCO4)

In order to reduce EPC risks in the early stage of work for the ESCOs, we think subsidies are important to cultivate the marketability. However, financial subsidies cannot exist forever. They are only a way for the government to support the industry when the market is at an early stage. If the industry continues relying on financial subsidies to survive, it means the industry itself does not have the conditions for marketisation. This will be another problem. (Gov1, IE4)

As EPC developed, from a macro perspective, the benefits it brings have correspondingly raised the awareness of energy efficiency management of building owners. On the other hand, it puts forward higher requirements on the ESCOs. How the ESCOs can further improve their capabilities is also a problem. (Gov3)

We think the final energy efforts greatly depend on the serviceability of the ESCOs. EPC puts forward high requirements to ESCOs, however, we heard that in the market a lot of ESCOs are not very professional. Therefore, we spent a whole year comparing companies and look for the most professional ESCOs. (BO7)

The more experience the more risks ESCOs can avoid. Although the EPC contract can define the rights and obligations of each contracting party and retrofit measures, it is far from a good risk-managed contract. ESCOs bear a lot of risks. (IE6)

Subsidies offered important support to develop the EPC market at the beginning. EPCs promote building owners' consciousness to conduct building energy efficiency retrofit. In the meantime, EPCs put forward high requirements to the ESCOs. The existing contracts of EPC projects can define the rights and obligations of stakeholders but still have a gap for dealing with the risks of EPCs.

Of these 11 statements, there were six items related to the negative influences of uptake of EPCs. They are:

- The ability of the energy service company has a great influence on the effect of energy savings (No. 9).
- Relationships for making decisions within CBEER are complicated (No. 23).
- The recovery period of investment in CBEER is too long (No. 24).
- The behaviour of the user has a great impact on energy efficiency (No. 25).
- The functional types of commercial buildings have a great impact on the owners' decisions for energy efficiency retrofit (No. 29).
- Low energy prices do not encourage demand for energy efficiency (No. 30).

These six items show that participants tend to believe there is a strong relationship between the service quality of ESCOs with the final building energy savings. Making decisions on conducting CBEER is complicated due to complex relationships (such as lease-tenant and owner-facility manager, which are discussed in interview results), investment payback period, changes of building use and energy costs. These were discussed further in the follow-up interviews.

We think there is a big risk in selecting ESCOs because we are not sure their service quality that would have great influences on the energy savings. (BO5, BO6)

If the commercial building is owned, operated and maintained by the developer himself, he will consider the life-cycle costs. While if it is divided into sections, the owned part and the management part, it [deciding to do building energy efficiency retrofit] is very difficult. (BO3)

This building has seventeen owners, so if we want to retrofit this building we need over half of them to support this. Therefore, it is hard to negotiate at the beginning of the project. (BO6)

EPC projects have long terms, maybe five years, eight years, even ten years. Recently we were conducting an EPC project by the energy-cost trust business model and its contract period is 20 years. (ESCO1)

Long-term period of conducting EPC projects brings a lot of financial pressure and the other risks to us. (ESCO4)

The benefits of an EPC account for a small portion of this commercial industry park, therefore the energy savings won't be a priority for the building owner. They prefer to offer a very good indoor environment to attract more tenants. (IE5)

The most influential factor for building owners hesitating to conduct EPC is a low energy price. As commercial buildings pay commercial electricity tariffs. In recent years, commercial electricity price has decreased. This makes a great impact on the final benefits of energy saving. (ESCO4)

When energy prices are high enough, it increases the needs of improving energy efficiency. If energy price stays low, that demand will be curbed. From this point of view, commercial buildings have more advantages of using EPCs than public welfare buildings, for example, schools. The commercial electricity is 1 CNY/m² but the electricity at school is only 0.5 CNY/m². Therefore, ESCOs are more motivated to retrofit commercial buildings than buildings related to public welfare. (Gov1)

Policy change and energy price change will be the biggest risks of using EPCs. (IE4)

Commercial buildings are more sensitive than the other type of building conducting EPC because of the energy price. (IE7)

6.2.2. Principal Component Analysis of Factors Influencing the Uptake of EPCs

In order to know the critical factors influencing the uptake of EPCs, principal component analysis (PCA) followed by Varimax with Kaiser Normalisation (Singh 2007) (rotation converged in 31 iterations) was employed to analyse the 34 statements. The principal components extraction is based on the rules that the information lost in each item should be less than 40% (Hair et al. 1998), therefore a factor loading of over 0.6 was set as the criteria to select each statement. As a result, nine principal components with 23 statements with eigenvalues of greater than 1 were identified and extracted based on the calculation (see Table 6-2). The sum of the variances of the first few principal components is 70.388% exceeding 70% of the total variance of the original data, therefore the results are acceptable (based on the principles of PCA the validity of sum of variance was discussed in Chapter 5, the detailed results are shown in Appendix 7). The other 11 statements are not taken for major discussion as nine principal components with 23 statements cover the major reasons impacting the uptake of EPCs. The following part provides more detail about the nine principal components. As shown in Table 6-2, the nine factors are:

- EPC costs and benefits.
- the complexity of commercial building energy efficiency retrofits.
- uncertainties of using EPCs.
- building energy savings.
- criteria for ESCOs to enter the EPC market.
- policies and regulations.
- financial support.
- service quality of ESCOs.
- EPC market development.

Table 6-2 Rotated component matrix for critical factors influencing uptake of EPCs

No.	Statements	Component Factor Loading									Critical Influencing Factors and Overall Mean	Extraction Sums of Squared Loadings		
		1	2	3	4	5	6	7	8	9		Eigenvalues	% of Variance	Cumulative %
30	Low energy prices do not encourage demand for energy efficiency	0.792									Factor 1: EPC costs and benefits (4.124)	9.158	26.936	26.936
31	Building energy savings are limited	0.725												
4	The subsidies and tax policies provided by the government play an important role in promoting CBEER using EPCs	0.707												
11	EPCs are useful for promoting commercial buildings conducting energy efficiency retrofit	0.678												
8	ESCOs can offer professional retrofit services including finance, design, construction,	0.645												

	energy maintenance													
12	EPCs can ensure the energy saving effect of CBEER	0.634												
24	The recovery period of investment in CBEER is too long	0.613												
18	The contracts clearly define the measures for CBEER													
27	Measurement & Verification by a third party provides a very effective help to the energy saving assessment of CBEER													
23	Relationships for making decisions within CBEER are complicated		0.736								Factor 2: the complexity of commercial building energy efficiency retrofits (4.065)	3.280	9.646	36.583
28	The building climate zone has a great influence on the energy saving potential of		0.651											

	commercial buildings												
29	The functional types of commercial buildings have a great impact on the owners' decisions for energy efficiency retrofit												
21	Building owners are responsible for investing in CBEER												
10	The service quality of ESCOs can be effectively guaranteed												
17	The contract period is clearly stipulated and measured			0.822						Factor 3: uncertainties of using EPCs (3.758)	2.425	7.132	43.715
14	EPCs can guarantee stakeholders' energy saving benefits			0.643									
16	The allocation of estimated energy savings and energy saving			0.614									

	benefits can easily be verified													
15	Contracts of EPC projects clearly specify the rights and obligations for each contracting party			0.609										
20	The contracts clearly define the potential energy savings for CBEER				0.848						Factor 4: building energy savings (3.490)	1.976	5.810	49.525
19	The contracts clearly ensure the current baseline of building energy consumption				0.807									
34	Information platform for building energy information can help stakeholders explore building energy saving potential					0.830					Factor 5: criteria for ESCOs to enter EPC market (3.740)	1.670	4.911	54.435
13	EPCs can effectively solve the financing problem of CBEER					0.755								

2	Policies and regulations have given clear provisions on the application of EPCs for CBEER						0.732				Factor 6: policies and regulations (3.485)	1.616	4.754	59.190
1	The government has given great support to the uptake of EPCs in CBEER						0.655							
3	Policies are the main motivation for the uptake of EPCs in CBEER													
6	Green Finance Policy has great support on conducting an EPC project							0.655			Factor 7: financial support (3.790)	1.546	4.546	63.736
22	Building users can get more benefits on CBEER than building owners													
33	Building energy saving makes it easier to apply for a bank loan													
9	The ability of the energy service company has a great influence on								0.815		Factor 8: service quality	1.185	3.484	67.220

	the effect of energy savings										of ESCOs (4.220)			
25	The behaviour of the user has a great impact on energy efficiency													
5	Pilot EPC projects play an important role in promoting CBEER using EPCs													
32	There are a large number of building energy service companies engaged in EPC services								0.735	Factor 9: EPC market development (2.960)	1.077	3.168	70.388	
7	EPCs are well known in CBEER								0.703					
26	Technologies of CBEER cannot effectively guarantee the effect of energy savings													

The first critical influencing factor is EPC costs and benefits that includes seven items:

- Low energy prices do not encourage demand for energy efficiency (No. 30).
- Building energy savings are limited (No. 31).
- The subsidies and tax policies provided by the government play an important role in promoting CBEER using EPCs (No. 4).
- EPCs are useful for promoting commercial buildings conducting energy efficiency retrofit (No. 11).
- ESCOs can offer professional retrofit services including finance, design, construction, energy maintenance (No. 8).
- EPCs can ensure the energy saving effect of CBEER (No. 12).
- The recovery period of investment in CBEER is too long (No. 24).

The second critical influencing factor is the complexity of commercial building energy efficiency retrofits that includes two items:

- Relationships for making decisions within CBEER are complicated (No. 23).
- The building climate zone has a great influence on the energy saving potential of commercial buildings (No. 28).

The third critical influencing factor is uncertainties of using EPCs that includes four items:

- The contract period is clearly stipulated and measured (No. 17).
- EPCs can guarantee stakeholders' energy saving benefits (No. 14).
- The allocation of estimated energy savings and energy saving benefits can easily be verified (No. 16).
- Contracts of EPC projects clearly specify the rights and obligations for each contracting party (No. 15).

The fourth critical influencing factor is building energy savings that include two items:

- The contracts clearly define the potential energy savings for CBEER (No. 20).
- The contracts clearly ensure the current baseline of building energy consumption (No. 19).

The fifth critical influencing factor is the criteria for ESCOs to enter the EPC market that includes two items:

- Information platform for building energy information can help stakeholders explore building energy saving potential (No. 34).
- EPCs can effectively solve the financing problem of CBEER (No. 13).

The sixth critical influencing factor is policies and regulations that includes two items:

- Policies and regulations have given clear provisions on the application of EPCs for CBEER (No. 2).
- The government has given great support to the uptake of EPCs in CBEER (No. 1).

The seventh critical influencing factor is financial support that includes one item:

- Green finance policy has great support on conducting an EPC project (No. 6).

The eighth critical influencing factor is the service quality of ESCOs that includes one item:

- The ability of the energy service company has a great influence on the effect of energy savings (No. 9).

The ninth critical influencing factor is EPC market development that includes two items:

- There are a large number of building energy service companies engaged in EPC services (No. 32).
- EPCs are well known in CBEER (No. 7).

6.3. Comparative Analysis of Factors Impacting the Uptake of EPCs

This section aims to examine the different opinions between groups (ESCOs, building owners, government and independent experts), which can facilitate understanding the EPC market from the perspective of unbalanced information. It starts by showing overall differences between groups on all the potential factors impacting the uptake of EPCs. The second part identifies the different opinions between groups mainly on the nine critical influencing factors that were identified in Section 6.2.2.

6.3.1. Overall ANOVA Test of Factors Impacting the Uptake of EPCs

Chapter 5 demonstrated how ANOVA tests can be used to analyse the different opinions between the groups. Conducting the ANOVA test (with the confidence level as 0.05) shows that, in the preliminary 34 statements, there are 15 statements whose significances are under 0.05 (highlighted in Table 6-3). That means the four groups have significant differences in those 15 statements. More statistical details are shown in Appendix 5.

Table 6-3 Differences in responses between groups in 34 statements by ANOVA test

No.	Statements	Significance
1	The government has given great support to the uptake of EPCs in CBEER	0.011
2	Policies and regulations have given clear provisions on the application of EPCs for CBEER	0.973
3	Policies are the main motivation for the uptake of EPCs in CBEER	0.804
4	The subsidies and tax policies provided by the government play an important role in promoting CBEER using EPCs	0.017
5	Pilot EPC projects play an important role in promoting CBEER using EPCs	0.342
6	Green Finance Policy has great support on conducting an EPC project	0.422
7	EPCs are well known in CBEER	0.381
8	ESCOs can offer professional retrofit services including finance, design, construction, energy maintenance	0.030
9	The ability of the energy service company has a great influence on the effect of energy savings	0.225
10	The service quality of ESCOs can be effectively guaranteed	0.077
11	EPCs are useful for promoting commercial buildings conducting energy efficiency retrofit	0.528
12	EPCs can ensure the energy saving effect of CBEER	0.001

13	EPCs can effectively solve the financing problem of CBEER	0.002
14	EPCs can guarantee stakeholders' energy saving benefits	0.044
15	Contracts of EPC projects clearly specify the rights and obligations for each contracting party	0.000
16	The allocation of estimated energy savings and energy saving benefits can easily be verified	0.024
17	The contract period is clearly stipulated and measured	0.011
18	The contracts clearly define the measures for CBEER	0.000
19	The contracts clearly ensure the current baseline of building energy consumption	0.012
20	The contracts clearly define the potential energy savings for CBEER	0.375
21	Building owners are responsible for investing in CBEER	0.116
22	Building users can get more benefits on CBEER than building owners	0.428
23	Relationships for making decisions within CBEER are complicated	0.104
24	The recovery period of investment in CBEER is too long	0.031
25	The behaviour of the user has a great impact on energy efficiency	0.724
26	Technologies of CBEER cannot effectively guarantee the effect of energy savings	0.030
27	Measurement & Verification by a third party provides a very effective help to the energy saving assessment of CBEER	0.563
28	The building climate zone has a great influence on the energy saving potential of commercial buildings	0.596
29	The functional types of commercial buildings have a great impact on the owners' decisions for energy efficiency retrofit	0.199
30	Low energy prices do not encourage demand for energy efficiency	0.075
31	Building energy savings are limited	0.909
32	There are a large number of building energy service companies engaged in EPC services	0.687
33	Building energy saving makes it easier to apply for a bank loan	0.003
34	Information platform for building energy information can help stakeholders explore building energy saving potential	0.010

To explore further what contributes to the above differences, multiple comparisons in post hoc tests were conducted through the Least Significant Difference (LSD) method to examine which group has different opinions (the reason for choosing the LSD method was discussed in Chapter 5). The detailed results are in Appendix 6. The conclusions from the statistics are listed in Table 6-4. To make these 15 statements easier to analyse later, they are given a new item number.

Table 6-4 Multiple comparisons of different responses of statements of EPC from four groups

Item No.	Statement No.	The Statements of EPC	Comparisons within Groups		
			Groups	Mean	Summary
1	1	The government has given great support to the uptake of EPCs in CBEER	IE Gov BO ESCO Total	3.43 4.27 4.03 3.47 3.74	Gov>BO>Total>ESCO>IE The Independent Experts and the ESCOs have similar responses, which are significantly different from the responses from the Government and the Building Owners. The Independent Experts and the ESCOs tend to be neutral on this statement, and the Government and the Building Owners tend to agree with this statement.
2	4	The subsidies and tax policies provided by the government play an important role in promoting CBEER using EPCs	IE Gov BO ESCO Total	4.29 4.64 4.74 4.34 4.49	BO>Gov>Total>ESCO>IE The Building Owners have significantly different responses from the Independent Experts and the ESCOs. The responses from the Government are between the responses from the Building Owners and the Independent Experts and the ESCOs. The Building Owners and the Government tend to strongly agree with this statement, and the Independent Experts and the ESCOs tend to agree with this statement.
3	8	ESCOs can offer professional retrofit services including finance, design, construction, energy maintenance	IE Gov BO ESCO Total	3.95 4.64 4.35 4.28 4.27	Gov>BO>ESCO>Total>IE The Independent Experts have significantly different responses from the Government, Building Owners and the ESCOs. The Independent Experts tend to agree with this statement but not as strongly as the other three groups.
4	12	EPCs can ensure the energy saving effect of CBEER	IE Gov BO ESCO Total	3.33 4.09 3.97 4.00 3.85	Gov>ESCO>BO>Total>IE The Independent Experts have significantly different responses from the Government, Building Owners and the ESCOs. The Independent Experts tend to be neutral on this statement and the other three groups agree with this statement.
5	13	EPCs can effectively solve the financing problem of CBEER	IE Gov BO ESCO Total	3.67 4.18 4.19 3.69 3.91	BO>Gov>Total>ESCO>IE The Independent Experts and the ESCOs have significantly different responses from the Government and the Building Owners. The Government and the Building Owners agree with this statement. The responses from the Independent Experts and the ESCOs are between neutral and agree.
6	14	EPCs can guarantee stakeholders'	IE Gov	3.48 4.09	Gov>BO>Total>ESCO>IE

		energy saving benefits	BO ESCO Total	3.87 3.72 3.76	The Independent Experts have significantly different responses from the Government and the Building Owners. The ESCOs' responses are between the Independent Experts and the Government and the Building Owners. The Independent Experts tend to be neutral on this statement, while the other three groups agree with this statement.
7	15	Contracts of EPC projects clearly specify the rights and obligations for each contracting party	IE Gov BO ESCO Total	3.48 4.18 4.29 4.25 4.08	BO>ESCO>Gov>Total>IE The Independent Experts have significantly different responses from the Government, Building Owners and the ESCOs. The Independent Experts tend to be neutral on this statement and the other three groups agree with this statement.
8	16	The allocation of estimated energy savings and energy saving benefits can easily be verified	IE Gov BO ESCO Total	3.29 3.45 3.61 3.84 3.60	ESCO>BO>Total>Gov>IE The Independent Experts have significantly different responses with the ESCOs. The responses from the other two groups are between the Independent Experts and the ESCOs. The Independent Experts tend to be neutral on this statement, and the ESCOs tend to agree with this statement.
9	17	The contract period is clearly stipulated and measured	IE Gov BO ESCO Total	3.24 3.82 3.52 3.81 3.59	Gov>ESCO>Total>BO>IE The Independent Experts have significantly different responses from the Government and the ESCOs. The responses from the Building Owners are between the Independent Experts and the government and the ESCOs. The Independent Experts tend to be neutral on this statement, and the other three groups tend to agree with this statement.
10	18	The contracts clearly define the measures for CBEER	IE Gov BO ESCO Total	3.62 4.73 4.29 4.16 4.15	Gov>BO>ESCO>Total>IE The Independent Experts have significantly different responses from the Government, Building Owners and the ESCOs. The Government also has a significant difference from the ESCOs. The Government strongly agrees with this statement and the other three groups agree with this statement. The responses from Independent Experts are between neutral and agreeing with this statement, but close to agree.
11	19	The contracts clearly ensure the current baseline of building energy consumption	IE Gov BO ESCO	3.29 4.00 3.45 3.78	Gov>ESCO>Total>BO>IE The Independent Experts have significantly different responses from the Government and the ESCOs. The

			Total	3.59	Government also has a significant difference from the Building Owners. The Government and ESCOs agree with this statement and the other two groups tend to be neutral on this statement.
12	24	The recovery period of investment in CBEER is too long	IE Gov BO ESCO Total	3.71 4.45 4.26 4.09 4.11	Gov>BO>Total>ESCO>IE The Independent Experts have significantly different responses from the Government and the Building Owners on this statement. All four groups tend to agree with this statement.
13	26	Technologies of CBEER cannot effectively guarantee the effect of energy savings	IE Gov BO ESCO Total	3.19 2.73 2.39 2.63 2.68	IE>Gov>Total>ESCO>BO The Independent Experts have significantly different responses from the Building Owners and the ESCOs. The responses from the Government are between the Independent Experts and the Building Owners and the ESCOs. The Independent Experts tend to be neutral on this statement, and the Building Owners tend to disagree with this statement.
14	33	Building energy saving makes it easier to apply for a bank loan	IE Gov BO ESCO Total	3.05 2.18 2.19 2.63 2.53	IE>ESCO>Total>BO>Gov The Independent Experts have significantly different responses with the Government, Building Owners. The Government also has a significant difference with the ESCOs. The Government and the Building Owners disagree with this statement and the other two groups tend to be neutral on this statement. The responses from the ESCOs are between being neutral and disagreeing with this statement, but close to being neutral.
15	34	Information platform for building energy information can help stakeholders explore building energy saving potential	IE Gov BO ESCO Total	3.52 4.09 3.77 3.22 3.57	Gov>BO>Total>IE>ESCO The ESCOs have significantly different responses from the Government and the Building Owners. The ESCOs tend to be neutral on this statement and the other three groups tend to agree with this statement.

The analysis shows the groups have a different understanding of the situation of the EPC market and the factors influencing the uptake of EPCs in these 15 items. Although the groups have different responses, those responses are close to each other (distributing to the neighbouring two options). Therefore, they have a similar tendency to evaluate the factors influencing the uptake of EPCs. Figure 6-1 summarises the details of these 15 items from the four groups and shows an overview of the comparisons of these differences.

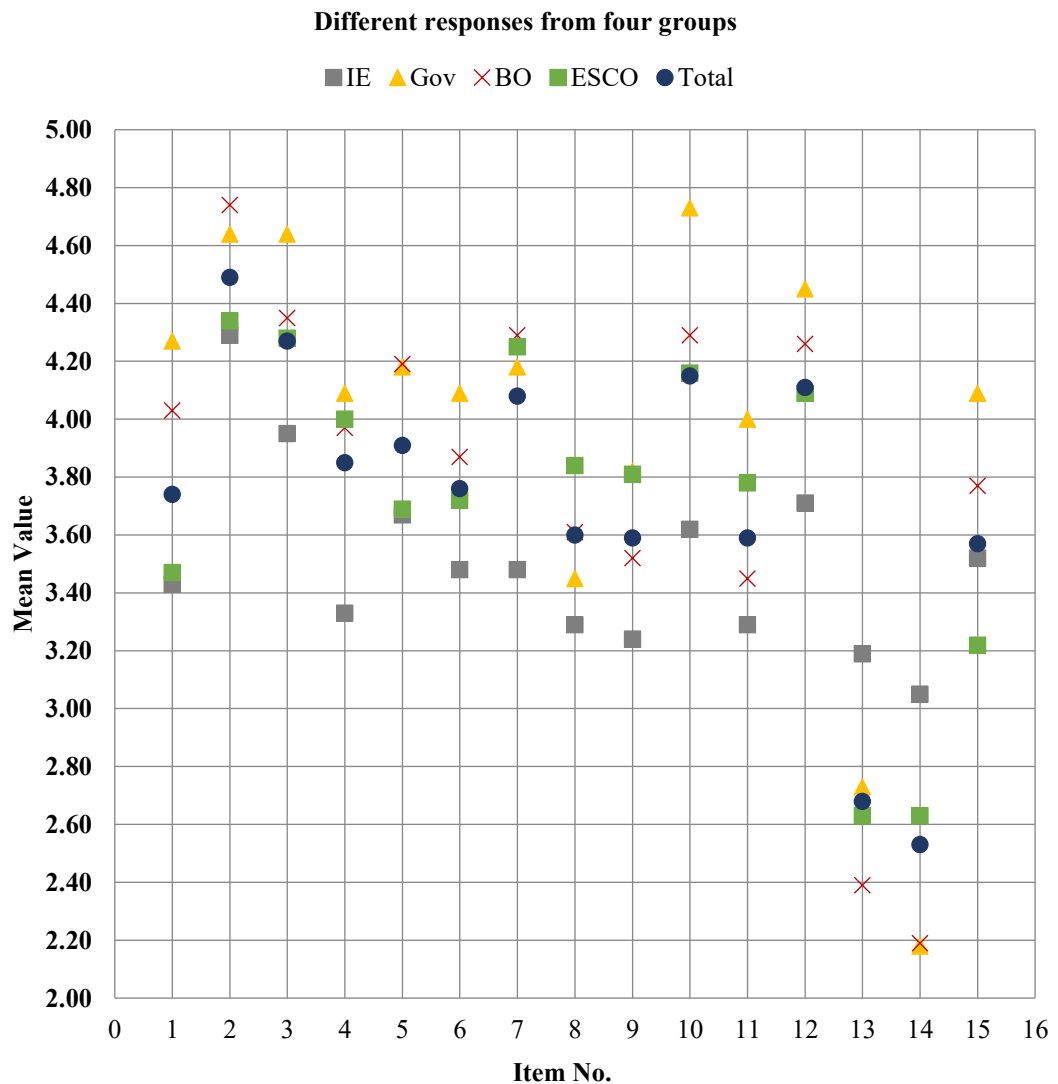


Figure 6-1 Significantly different responses from four groups

Overall, in these 15 items, the government tends to evaluate these statements higher than the other groups and the independent experts tend to evaluate these statements lower than the other groups.

There are nine items where the government has higher scores than the other groups (items 1, 3, 4, 6, 9, 10, 11, 12 and 15) where items 1, 3, 6, 10, 11, 12 and 15 have significantly higher scores and items 4 and 9 have marginally higher scores. The results show that the group of government officials think they have given great support to the uptake of EPCs (item 1). They highly confirmed the effects of EPCs to conduct CBEER (item 3, 4, 6, 9, 10 and 11). They pointed out the payback period of CBEER is too long (item 12). An information platform can help in sharing information about building energy saving potential in the market (item 15). There is one item where the government has significantly lower scores than the other groups (item 14). The government thinks it is currently difficult to use estimated building energy savings as security for a bank loan. For this item, except for the independent experts, both building owners and ESCOs feel it is hard to receive a bank loan only by estimated building energy savings.

Except for the last three items, there are 12 items (items 1–12) where the independent experts evaluate lower than the other groups, especially items 3, 4, 6, 7, 8, 9, 10, 11 and 12 which have significantly lower values. These items are related to the effectiveness of EPC benefits and contracts of EPC projects.

There are three items where the building owners have higher scores than the other groups (items 2, 5 and 7). They think that the policies related to subsidies and taxes will promote CBEER using EPCs (item 2). EPCs are a good way to help them avoid financial problems (item 5). There is no doubt that contracts of EPC projects clearly specify the rights and obligations of contracting parties (item 7). There is one item where the building owners have significantly lower scores than the other groups (item 13). It shows building owners think technologies can effectively guarantee energy savings. As discussed previously, the effectiveness of technology as a source of energy savings would be a major concern for building owners, ESCOs and government. Independent experts maintain a neutral position on the technology issue.

Comparing the responses between building owners and ESCOs shows they two groups have significantly different opinions on five items (items 1, 2, 5, 14 and 15). Comparing the responses between the government and building owners, there is only one item where there is a significant difference: the government has a different opinion from the building owners on item 11. Comparing the responses between the government and building owners, the government and ESCOs, the government and ESCOs have significant differences of opinions on four items (items 1, 5, 10 and 15). Details of the above analysis are in Appendix 6, where significant differences mean there are different opinions between groups. Figure 6-2 shows the mean differences between building owners, ESCOs and government. The red circles highlight the mean differences in the selected different responses within these three groups.



Figure 6-2 Mean differences between building owners, ESCOs and government

The results show building owners are more positive than ESCOs towards government policies on EPC (items 1 and 2). The government thinks that they have given great support to the uptake of EPCs, while ESCOs are neutral on this statement (item 1). Government designs EPCs as a financial tool for conducting CBEER. Building owners rely on EPCs

to solve the financial problems of CBEER, while ESCOs as the investors under EPCs have more financial pressures (item 5). Government is more confident on the issues that contracts of EPC projects can clearly define measures of CBEER and the baseline energy consumption better than ESCOs and building owners respectively (items 10 and 11). Building owners feel it is harder to use building energy savings to get bank loans than ESCOs do (item 14). Both government and building owners are more positive than ESCOs about using building energy information platforms to explore building energy saving potential (item 15).

6.3.2. ANOVA Test of Critical Factors Influencing the Uptake of EPCs

Following the previous principal component analysis in Section 6.2.2, the ANOVA test is used to examine whether the scores for the main nine critical influencing factors identified in Section 6.2.2 differed by the groups of participants. As shown in Table 6-5, significances of three factors are below 0.05 (with the confidence level of 0.05). This means the participant groups have different opinions on these three factors. The three factors are Factor 1 EPC costs and benefits, Factor 3 uncertainties of using EPCs, and Factor 5 criteria for ESCOs to enter the EPC market. Multiple comparisons in post hoc tests are conducted through the LSD method to examine which groups have different responses (see Table 6-6).

Table 6-5 Comparison of means (one-way ANOVA) for critical factors influencing uptake of EPCs

Critical Influencing Factors		Sum of Squares	df	Mean Square	F	Significance
Factor 1 EPC costs and benefits	Between Groups	8.478	3	2.826	3.007	0.034
	Within Groups	85.522	91	0.940		
	Total	94.000	94			
Factor 2 The complexity of commercial building energy efficiency retrofits	Between Groups	1.573	3	0.524	0.516	0.672
	Within Groups	92.427	91	1.016		
	Total	94.000	94			
Factor 3 Uncertainties of using EPCs	Between Groups	11.411	3	3.804	4.191	0.008
	Within Groups	82.589	91	0.908		
	Total	94.000	94			
Factor 4 Building energy savings	Between Groups	5.409	3	1.803	1.852	0.143
	Within Groups	88.591	91	0.974		
	Total	94.000	94			
Factor 5 Criteria for ESCOs to enter the EPC market	Between Groups	16.165	3	5.388	6.300	0.001
	Within Groups	77.835	91	.855		
	Total	94.000	94			
Factor 6 Policies and regulations	Between Groups	.135	3	0.045	.044	0.988
	Within Groups	93.865	91	1.031		
	Total	94.000	94			
Factor 7 Financial support	Between Groups	7.186	3	2.395	2.511	0.064
	Within Groups	86.814	91	0.954		
	Total	94.000	94			
Factor 8 Service quality of ESCOs	Between Groups	5.085	3	1.695	1.735	0.165
	Within Groups	88.915	91	.977		
	Total	94.000	94			
Factor 9 EPC market development	Between Groups	6.334	3	2.111	2.192	0.094
	Within Groups	87.666	91	0.963		
	Total	94.000	94			

Table 6-6 Multiple comparisons between groups for critical factors influencing uptake of EPCs

Critical Influencing Factors	Organisation group		Mean Difference	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
Factor 1 EPC costs and benefits	IE	Gov	-8.17E-01	3.61E-01	0.026	-1.53E+00	-1.00E-01
		BO	-7.55E-01	2.74E-01	0.007	-1.30E+00	-2.10E-01
		ESCO	-4.38E-01	2.72E-01	0.111	-9.78E-01	1.03E-01
	Gov	IE	8.17E-01	3.61E-01	0.026	1.00E-01	1.53E+00
		BO	6.25E-02	3.40E-01	0.855	-6.13E-01	7.38E-01
		ESCO	3.79E-01	3.39E-01	0.266	-2.94E-01	1.05E+00
	BO	IE	7.55E-01	2.74E-01	0.007	2.10E-01	1.30E+00
		Gov	-6.25E-02	3.40E-01	0.855	-7.38E-01	6.13E-01
		ESCO	3.17E-01	2.44E-01	0.198	-1.68E-01	8.02E-01
	ESCO	IE	4.38E-01	2.72E-01	0.111	-1.03E-01	9.78E-01
		Gov	-3.79E-01	3.39E-01	0.266	-1.05E+00	2.94E-01
		BO	-3.17E-01	2.44E-01	0.198	-8.02E-01	1.68E-01
Factor 3 Uncertainties of using EPCs	IE	Gov	-8.20E-01	3.55E-01	0.023	-1.52E+00	-1.16E-01
		BO	-7.34E-01	2.69E-01	0.008	-1.27E+00	-2.00E-01
		ESCO	-9.01E-01	2.68E-01	0.001	-1.43E+00	-3.69E-01
	Gov	IE	8.20E-01	3.55E-01	0.023	1.16E-01	1.52E+00
		BO	8.54E-02	3.34E-01	0.799	-5.79E-01	7.50E-01
		ESCO	-8.09E-02	3.33E-01	0.809	-7.42E-01	5.80E-01
	BO	IE	7.34E-01	2.69E-01	0.008	2.00E-01	1.27E+00
		Govt	-8.54E-02	3.34E-01	0.799	-7.50E-01	5.79E-01
		ESCO	-1.66E-01	2.40E-01	0.49	-6.43E-01	3.11E-01
	ESCO	IE	9.01E-01	2.68E-01	0.001	3.69E-01	1.43E+00
		Gov	8.09E-02	3.33E-01	0.809	-5.80E-01	7.42E-01
		BO	1.66E-01	2.40E-01	0.49	-3.11E-01	6.43E-01
Factor 5 Criteria for ESCOs to enter EPC market	IE	Gov	-8.75E-01	3.44E-01	0.013	-1.56E+00	-1.91E-01
		BO	-4.88E-01	2.61E-01	0.065	-1.01E+00	3.15E-02
		ESCO	2.97E-01	2.60E-01	0.256	-2.19E-01	8.13E-01
	Gov	IE	8.75E-01	3.44E-01	0.013	1.91E-01	1.56E+00
		BO	3.87E-01	3.25E-01	0.236	-2.58E-01	1.03E+00
		ESCO	1.17E+00	3.23E-01	0	5.30E-01	1.81E+00
	BO	IE	4.88E-01	2.61E-01	0.065	-3.15E-02	1.01E+00
		Gov	-3.87E-01	3.25E-01	0.236	-1.03E+00	2.58E-01
		ESCO	7.84E-01	2.33E-01	0.001	3.21E-01	1.25E+00
	ESCO	IE	-2.97E-01	2.60E-01	0.256	-8.13E-01	2.19E-01
		Gov	-1.17E+00	3.23E-01	0	-1.81E+00	-5.30E-01
		BO	-7.84E-01	2.33E-01	0.001	-1.25E+00	-3.21E-01

Note: The mean difference is significant at the 0.05 level.

IE, BO, ESCO and Gov are the abbreviations for independent expert, building owner, energy service company and government.

The results show that in Factor 1 EPC costs and benefits, independent experts have significantly different opinions from the building owners and the government; in Factor 3 Uncertainties of using EPCs, independent experts have significantly different opinions from the other three groups; in Factor 5 Criteria for ESCOs to enter EPC market, ESCOs and independent experts have significantly different opinions from building owners and the government. It can be seen in principal component analysis that Factor 5 is the dominant factor making ESCOs significantly different from building owners and the government. This difference can be interpreted as two aspects: i) building owners and the government are more positive than ESCOs on the issue that building energy information platform can help stakeholders explore building energy saving potential; and ii) building owners and the government thought EPCs can effectively solve the financing problem of CBEER, however this did not reduce ESCOs' financial pressures. From these two perspectives, it can be concluded that a building energy information platform is not effective for ESCOs to explore the building energy saving potential and ESCOs have financial pressures under EPCs.

6.4. Summary

Based on the principal component analysis, there are nine critical influencing factors identified as the main market barriers to the uptake of EPCs. These nine critical influencing factors are: EPC costs and benefits; the complexity of commercial building energy efficiency retrofits; uncertainties of using EPCs; building energy savings; criteria for ESCOs to enter the EPC market; policies and regulations; financial support; service quality of ESCOs; and EPC market development. These nine critical influencing factors lead to the following interviews to explore the reasons behind EPC market barriers. In these nine factors, the four groups of participants have significantly different opinions on three factors: EPC costs and benefits, uncertainties of using EPCs and criteria for ESCOs to enter EPC markets. These three aspects are examined in the interview results to see the unbalanced information between groups of participants. The next chapter is based on these nine critical influencing factors and the differences within groups to explore the reasons behind the market barriers on the uptake of EPCs in the sector of commercial buildings.

Chapter 7 Thematic Analysis of the Causes of EPC Market Barriers

7.1. Introduction

The previous chapter identified nine critical factors influencing the uptake of EPCs from the questionnaire survey. These nine factors were taken as a base in conducting follow-up interviews to explore the reasons behind these factors. This chapter aims to qualitatively investigate the EPC stakeholders' understanding of the reasons leading to barriers to the uptake of EPCs in the sector of commercial buildings based on interview data. Through a thematic analysis, five significant themes or causes of EPC market barriers emerged from the results.

Five themes identified as the contribution to the EPC market barriers are:

- asymmetric information between energy service companies (ESCOs) and building owners
- energy performance gap of building energy efficiency retrofits (BEER) makes EPCs hard to implement
- high barriers for ESCOs to the entry of the EPC Market
- low motivation for commercial building owners
- limitations of initial national policies on the initial market.

The overall connections between the nine critical influencing factors and the five themes are shown in Figure 7-1. The following sections elaborate on each of the themes. The causes of EPC market barriers are the overlay of both the barriers on the traditional commercial building energy efficiency retrofit (CBEER) and the shortcomings caused by the EPC mechanism itself. A comparison of the causes of the market barriers on CBEER and the EPC mechanism is summarised in the last section of this chapter. The purpose of this chapter is to gain a better understanding of the barriers to the EPC market and offer support for theory testing in the next chapter.

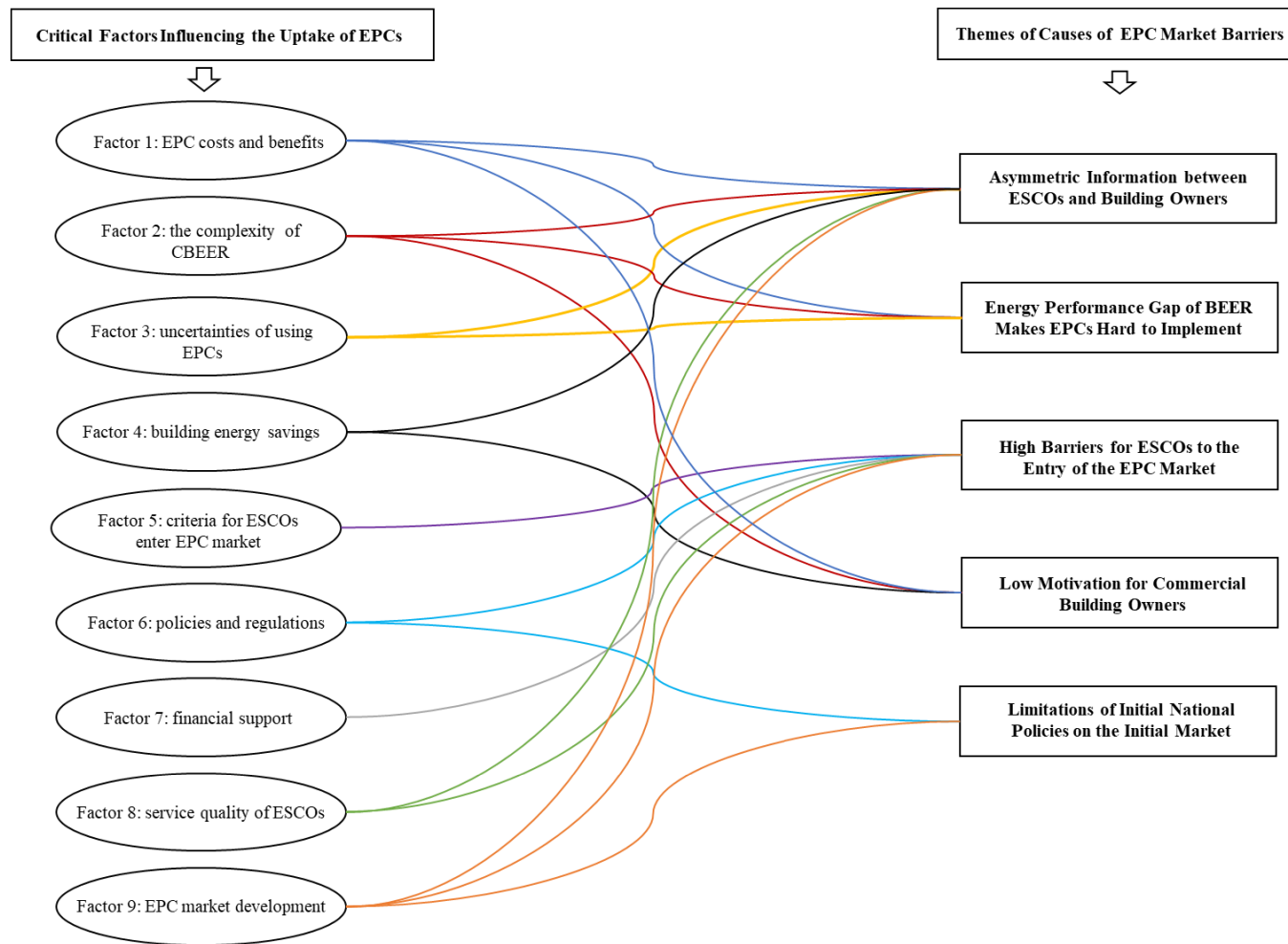


Figure 7-1 Connections between critical factors influencing uptake of EPCs with themes of causes of EPC market barriers

7.2. Asymmetric Information between ESCOs and Building Owners

Asymmetric information between ESCOs and building owners is a theme identified based on the interview data. It includes six aspects (see Figure 7-2): i) inadequate information about existing buildings, with three sub-themes of inadequate initial information about the existing buildings, unconfirmed baseline of BEER, and free rider problems; ii) new concept and incomplete information of using EPCs, with three sub-themes of EPCs are a new concept for building owners, overblown energy saving effects, and unclear energy saving benefits; iii) the lagging facility management system in China; iv) incomplete contracts; v) service quality of ESCOs; and vi) credit risk of building owners.

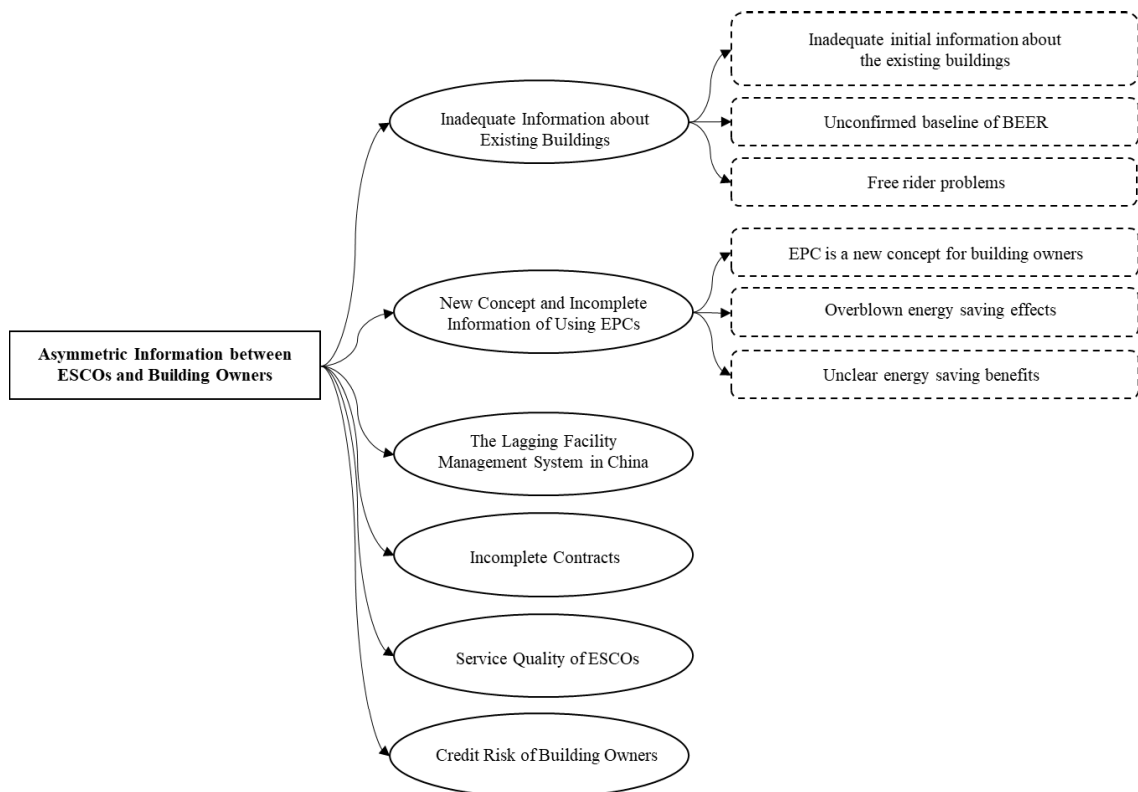


Figure 7-2 Theme 1 asymmetric information between ESCOs and building owners

7.2.1. Inadequate Information about Existing Buildings

Inadequate information on existing buildings reflects the stakeholders lacking knowledge about the existing buildings including physical building information, the operational context of the building, and information about building energy consumption. This directly leads to inaccuracies when assessing the current energy consumption and making a decision of the baseline for the BEER. This issue is considered a significant issue by all the ESCOs and independent experts.

(1) Inadequate initial information about the existing buildings

China's first "Design Standard for Energy Efficiency of Public Building" was published in 2005. Before that, energy conservation design was only for hotel buildings, published in 1993 as "Energy Conservation Design Standard for Thermal Engineering and Air Adjustment in Tourist Hotel Buildings". Therefore, the energy efficiency retrofitting targets are concentrated on those buildings built before 2005. Those buildings were built over 15 years ago, and the initial information of building design has not been preserved in its entirety. Therefore, for some of the retrofits, the ESCOs need to survey the building physical information again, which takes a long time and causes additional costs before retrofits. This creates many difficulties for ESCOs.

Meanwhile, the power of the energy system may have decayed over time, so that the current energy situation is not clear. Although the energy bills can reflect the energy consumption situation, they are influenced by many factors, such as climate condition, business operation and energy management. Without knowing the actual situation of the building, ESCOs are disadvantaged when estimating the building energy savings. All these issues lead to a "long term of investigation for ESCOs before the projects" (ESCO2, ESCO3). Therefore, the investigation cost formed in the preliminary project is very high.

(2) Unconfirmed baseline of BEER

A baseline of BEER is the most important part of conducting an EPC. The baseline of BEER is the current level of energy consumption that shows the start point of retrofits. It decides the amount of energy that could be saved after retrofits. It includes the current energy consumption level and the situation of the building energy system being operated.

It is indisputable that it is hard to decide a precise baseline for BEER (IE2, IE3, IE5, IE6, ESCO4, ESCO7, ESCO8, BO1, BO2, BO5, BO6, Gov1). The reasons are complicated as the climate condition, energy management situation and business operation may interact with the current energy consumption.

[The current energy consumption level] can be affected by a lot of factors, for example, the weather. Last summer was very hot, therefore during the summer, the consumption of air conditioning was much higher than previous years. (ESCO4)

Most of the boundaries of conducting BEER are unclear. Take retrofitting lamps as an example. There are 1,000 lamps in this building, and only 800 lamps are working because there are 200 lamps broken. When you take the energy bills as the baseline of BEER, the energy consumption is related to only 800 lamps. When conducting retrofitting, in fact, there are 1,000 lamps updated. In this case, there will be a gap between your predicted energy consumption and actual energy consumption. The energy saving effect is different from previously agreed energy savings in the contract. (IE6)

The baseline of BEER will influence the [energy saving] benefits of us. If it is not set properly, or it is set to bias and good for ESCOs, we may lose what we should receive. We want a standard or persuasive confirmation for setting the baseline. (BO1)

Although there is a national standard for energy assessment, in practice, there are many details yet to be decided. Unclear retrofit boundaries and energy baseline are major barriers to implementing EPCs. Therefore, an industry level standard for setting a baseline is needed as stressed by independent experts.

To establish the baseline, it may not only be achieved by the precise investigation of building owners and ESCOs but should be established through a basic database in our industry. (IE3)

(3) Free rider problems

The “free rider” problem refers to the burden of sharing resources, which is caused by the use or overuse of them by those who do not pay their fair share or none at all. A free rider, most broadly speaking, is someone who receives a benefit without contributing towards the cost of its production (Hardin & Cullity 2020). The “free rider” problem normally happens in public goods, because once these goods are available to one person, they can be consumed by others at no additional marginal costs, for example, clean air actions. In

this context, the “free rider” problem would cause negative externalities to the ESCOs by the building owners. In this research, it means that under EPCs the building owners make use of ESCOs to retrofit additional elements rather than only energy efficiency components. For example, some equipment may be nearing the end of its life and not functioning very well, so the ESCOs have to replace the equipment.

Some of the building owners made use of EPCs, and let ESCOs resolve issues inherited from the past, which increases the costs of retrofitting for ESCOs. (ESCO2, ESCO3)

The trigger for the “free rider” problem is the incomplete information because the building information is offered by the building owners, and ESCOs fail to get the full information of the buildings. This “free rider” problem brings additional work to ESCOs, which creates large additional costs for ESCOs.

7.2.2. New Concept and Incomplete Information of Using EPCs

(1) EPCs are a new concept for building owners

As a new mechanism, EPCs are hard for building owners to accept directly. Based on conventional thinking, some of the building owners did not believe that there were ESCOs who are going to invest in the BEER and they were not sure about the actual effects of using EPCs.

They [building owners] do not believe in this mechanism. Although they have never tried energy performance contracts at all, they doubt the effect of using EPCs. They call this [EPC] “pie in the sky”. (Gov1)

At the beginning, I felt that I have no confidence in this product [using an EPC] because I had never used it. There is no guarantee for this [energy savings]. It seems to be a selling strategy. How much can they save? (BO1, BO2)

As some of the building owners doubted the effects of EPCs, they preferred to wait for a while to see how the other projects work. This leads to long negotiations between building owners and ESCOs before the decision to use an EPC. The transaction period is longer than the normal BEER.

(2) Overblown energy saving effects

There exists a phenomenon of overblown energy saving effects when ESCOs market their services with misinformation. The purpose of ESCOs is to apply for subsidies. Some of the subsidies are offered in several instalments and the first instalments (in some cases as high as 50% of total subsidies) can be applied at the beginning of the EPC projects. Some ESCOs tried to occupy the market as soon as possible, therefore they exaggerate the energy saving effects.

Some ESCOs' propaganda tactics show the building owners higher assumed energy savings of the buildings than the actual situation. They use this to attract more building owners to cooperate with them. However, after the retrofitting, the actual energy savings cannot reach the targets. Thus, the contracting parties need longer time to receive the energy saving benefits or the ESCOs need to make up the shortfall of the energy savings. (ESCO5, ESCO6)

When they (ESCOs) conducted propaganda to promote EPCs, they used keywords for advertising called 'zero risks', 'win-win cooperation'. In fact, the risks are quite high. In order to get this transaction concluded, there are a lot of things [risks] they neglect. (IE3)

In the EPC market, building owners are in a weak position of not knowing about the real energy saving potential. This affects the willingness of building owners in the market to use EPCs. Meanwhile, overblown energy saving effects mislead the building owners to use EPCs and influence the final energy saving benefits for both contracting parties.

(3) Unclear energy saving benefits

Unclear energy saving effects are mentioned by both ESCOs and building owners. The "unconfirmed baseline of BEER" identified in the last section means that ESCOs cannot estimate the final energy savings precisely. This influences the estimation of final energy saving benefits. Therefore, when the ESCOs introduce EPCs to building owners, they can only make a general estimate of the energy saving by retrofits. However, this leads building owners to doubt the final energy saving benefits of using EPCs.

For the final energy saving benefits, how can I know how much the energy savings come from the retrofits or the way we use energy. I felt vague about how much the ESCO can save. Unless the ESCO has existing successful cases, I am sceptical about the effect of the energy savings. (BO7)

Meanwhile, the changing energy price makes it harder for contracting parties to define clear energy saving benefits (Gov1, IE4, IE7, ESCO4). If the energy price increases, it brings more benefits to the ESCOs, while if the energy price decreases, it brings more benefits to the building owners. Energy price is one of the most critical factors influencing the final energy saving benefits. Changes in energy prices are among the highest risks of using EPCs for the contracting parties.

7.2.3. Lagging Facility Management System in China

The International Organization for Standardisation (ISO) defines facility management as the “organizational function which integrates people, place, and process within the built environment with the purpose of improving the quality of life of people and the productivity of the core business” (ISO 2017). In the current Chinese facility management system, the focus is mainly on security and cleaning (ESCO1). “Most of the facility management companies are lacking professional knowledge of equipment operation and maintenance” (ESCO2). “Their [the facility managers’] abilities to manage the equipment are still at a low level. ... Except some upscale commercial building managers, most of them do not care about energy efficiency. And building energy management mainly relies on labour rather than smart equipment” (ESCO6).

The lagging awareness and service system of facility management companies make the thermal comfort of some commercial buildings far below the standard level. This leads to low energy consumption differences after the retrofits because the existing building functioned poorly before the retrofits. After the retrofits, the building thermal comfort is improved, and more energy is consumed although the energy efficient equipment is replaced. Meanwhile, the poor facility management system means the historical energy data of the building are poorly recorded and saved. This causes “tough work” for the ESCOs (IE5).

7.2.4. Incomplete Contracts

As previously discussed, there are many risks inherent both within particular EPC projects and in the external environment. In an EPC project, it is hard to anticipate each risk when the contract is executed and regulate all the contracting parties’ responsibilities

of each risk in the initial contract. When it is not possible to estimate all the possibilities and cover everything in a contract, it is inevitably incomplete. As a result, when uncertainties happen in the future, the contracting parties may face contract disputes during the contract implementation.

In fact, an EPC is quite complicated from the actual implementation level, so the contract can't be set particularly clear. Especially the usage habits of building owners are difficult to regulate in the contracts. Meanwhile, there will be various changes during the whole EPC implementing process and also all kinds of changes in the building situated in the actual operation. ... For example, if the building owners have more people or customers in this building, energy consumption will naturally increase. This is not easy to calculate nor to predict. It is impossible to explain them all in the contract. This leaves hidden problems for the future. (IE5)

For the time being, I don't think there is a fixed and clear algorithm, or a series of rules to set a clear boundary of responsibility of contracting parties in the contract. There are too many influences on building energy consumption, so it is really difficult to define them completely in the contract. Theoretically, they want to define as many risks as they can in the initial contract, but it will cause high transaction costs. (IE2)

Fully defining the risks of an EPC is very complicated. Even if ESCOs can make the rules clear, it is useless if the building owners do not follow them. Especially in our engineering field, there are a lot of those types of things [unpredictable risks]. These risks all need negotiations in the future. Therefore, communication and transaction cost is relatively high. (IE1)

7.2.5. Service Quality of ESCOs

Building owners are not familiar with EPCs, especially technology issues, and they depend on the ESCOs when the project starts. As the building owners have limited knowledge of evaluating the service quality of ESCOs and selecting a suitable ESCO, the service quality of ESCOs is one of the risks for building owners in using EPCs.

Under EPCs, the building owners commission the whole building retrofits to ESCOs. Therefore, the selection of equipment and construction technologies are all decided by the ESCOs although the building owners will be involved in some parts. In fact, after the ESCOs take over the building, they control the project. (IE4)

From the perspective of ESCOs, as the building owners do not know about them, it is also very hard to build trust with them.

It is very hard to build trust with building owners. There are a lot of ESCOs in the market, how can you prove you have the ability to do better than the other ESCOs. Conducting EPCs is not as same as normal retrofitting projects, the contract is not a lump-sum contract. The building owners need to compare the different technology schemes of different ESCOs. However, building owners are not experts in this area. Even if they can hire the experts to assess the technology schemes, the final energy saving efforts are still very hard to be guaranteed. (ESCO5)

Interviewer: *What makes you get the trust from a building owner in your first case?* It is based on an acquaintance introducing us to the building owner. (ESCO5)

Most of the building owners do not understand professional technologies. So from their perspective, [the higher proportion of energy savings is better]. [As a result], the proportions of energy savings ESCOs estimated are like an advertising. Without professional knowledge, some of the building owners tend to try the higher proportions of energy savings. [However, those high proportions of energy savings are hard to reach]. The results can only be shown after the retrofit. So how can building owners recognise good companies [based on their advertisement]? This is hard to achieve. (ESCO6)

An EPC is not like an energy saving product that can be tested for the energy saving index directly. An EPC needs a comprehensive scheme of energy efficiency services. Without professional knowledge, building owners easily only focus on the estimated energy savings by ESCOs. As “the current service quality of ESCOs are uneven” (IE4), it leads to a phenomenon of “adverse selection”.

The result is that legally overvalued currency will tend to drive legally undervalued currency out of circulation (Selgin 1996). In the case of EPCs, the less experienced ESCOs or the ESCOs without good service quality that put forward high energy saving proportions are taken as overvalued currency, and the experienced ESCOs or the ESCOs with good technical skills that do not exaggerate the energy saving proportions are taken as undervalued currency. Some experienced ESCOs can identify more risks at an early stage and predict the final energy savings conservatively. Therefore, their predicted proportions of energy savings may be smaller than suggested by some less-experienced ESCOs that are in a growth period. As a result, these less experienced ESCOs may be selected by the building owners. After the implementation of the EPC, due to the risks, the less experienced ESCOs may fail to meet the predicted energy savings, leaving an impression on building owners that EPCs do not function well.

7.2.6. Credit Risk of Building Owners

There is a trust problem between ESCOs and building owners: “The problem of untrustworthy owners is widespread” (ESCO2, ESCO3, ESCO4). Some independent experts think this is one of the most important barriers to the uptake of EPCs and the critical aspect for ESCOs selecting a building owner (IE1, IE5, IE6).

The biggest bottleneck of EPC development is mutual trust. Because it [contract] takes too long, and the long period brings [a lot of distrust]. For example, the change of company management personnel, both ESCOs and building owners will face the issue of change of company personnel. If the reason the building owner wants to try EPC is based on the trust of a particular project manager of ESCO. After some time, the project manager leaves the company, this will force the building owner to rebuild the trust with a new project manager. The EPC contract period is too long (some reach over 8 years), and China’s development speed is too fast, unlike those developed countries where the entire construction industry is in a relatively stable development state. In this state, everyone feels that things are hard to predict after 10 years. Therefore, there will be some bottlenecks to uptake of EPCs in this commercial building sector. (IE5)

Most ESCOs stated that building owners’ credits would influence the implementation of the project. The creditworthiness problem of building owners has two perspectives: the credit risks of energy benefit payments and obeying the rules of using energy.

If building owners cannot pay the energy saving benefits on time, it will influence the liquidity of our enterprise. (ESCO5)

I think credit risk is the greatest barrier to using EPCs. Because if we do not intervene in the later operation period of implementing the EPC, [only depends on building owner’s facility management], it is difficult for us to control the overall energy saving effect. You know that the entire energy savings are closely related to how owners use energy, climatic conditions, and other external conditions. If the building owner does not obey the rules we asked about how to use the equipment, it [the energy consumption] is easy to get out of control and reduce the final energy savings which would be far away from our predicted energy savings. (ESCO1)

For the credit risks of obeying the rules of using energy by building owners, “moral hazard” may be one of the triggers. There is always a conflict between “energy saving” and “thermal comforts”.

Some building owners think they are using EPCs, so they do not worry very much about if they are using more energy. [ESCOs pay the retrofit and the energy saving benefits are directly related to ESCOs, not the building owners.] So this will lead to a phenomenon that they use the air conditioner and at the same time open the window because they want the fresh air and a certain degree of indoor temperature. (IE5)

Although the default problem can be solved by legislation on breaching conditions negotiated in the contract, most ESCOs mentioned this would increase business costs. Especially for small ESCOs, this would be a big burden and cause additional financial pressure on them. Some new ESCOs mentioned they would not want to use the courts because they may lose potential customers, and the courts would be their last resort (ESCO6).

7.3. Energy Performance Gap of BEER Makes EPCs Hard to Implement

The energy performance gap is defined as the discrepancy between the predicted and the actual energy savings after retrofits (Fedoruk et al. 2015; Liang, Qiu & Hu 2019). It has been identified as one of the reasons contributing to the limitations of uptake of EPCs for BEER. The energy performance gap includes two aspects: i) the technology issue, with four sub-themes of inaccurate design, inappropriate design, efficiency technologies are not properly operated, and commissioning is now widely used in the market; and ii) changes in building energy use, with four sub-themes of changes of the building operating state, changes of the building vacancy rate, changes in the state of business of the buildings, and energy using habit and rebound effects (see Figure 7-3).

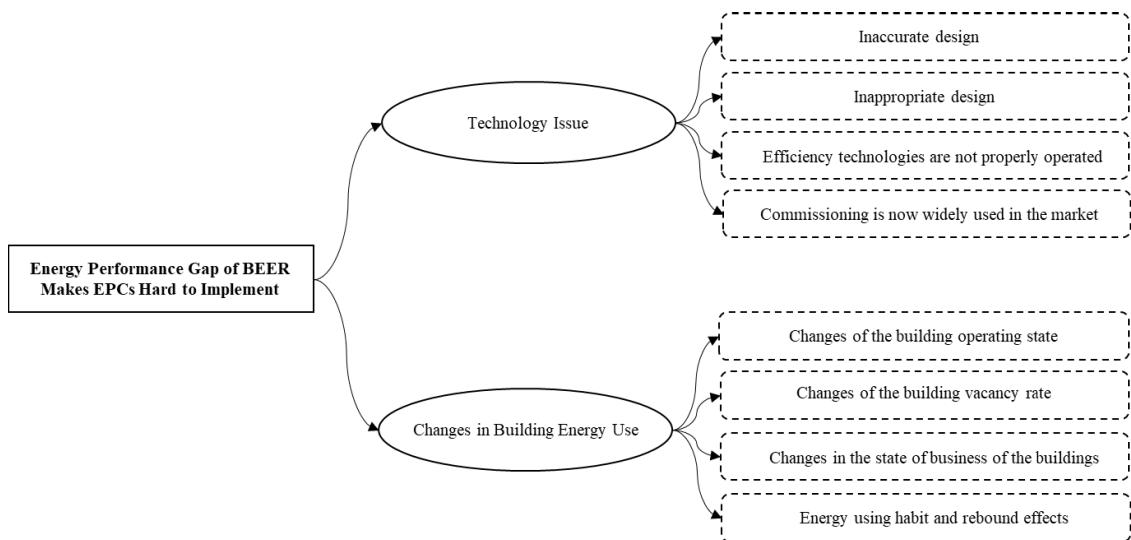


Figure 7-3 Theme 2 energy performance gap of BEER makes EPCs hard to implement

7.3.1. Technology Issues

(1) Inaccurate design

Inaccurate design occurs when the performance of the buildings is only evaluated based on limited energy bills and standardised operating conditions of buildings set for simulation models. It is influenced by many factors, and “inadequate information of existing buildings” identified in the last section is one of the factors contributing to the

inaccurate design. As well as this, inaccurate modelling of building energy operation is the other factor leading to inaccurate design. ESCOs estimate the energy savings based on energy simulation. However, this model-based simulation may be somehow different from the actual energy performance due to the building operation situation and climate conditions.

The problem is that before the retrofit, we simulate the thermal condition by simulation software to predict the energy savings. But in the actual energy management stage, compared to the real energy savings there may be some deviation. But the building owners do not understand this and may doubt the effects of energy efficiency. This will take us some efforts to negotiate with the building owners. Not all the building owners will understand this situation. (ESCO8)

(2) Inappropriate design

Inappropriate design occurs when the ESCOs fail to find one or more problems contributing to building energy inefficiency. The technology schemes they then offer cannot solve the problem appropriately. This is also related to the “service quality of ESCOs” identified in the last section.

I think it [a failure case using EPC] is because they [ESCOs] did not get to the point and solve the key problem of energy consumption. They [ESCOs] changed a facade and an insulation layer, and update an elevator. But they did not take air conditioning into account, which actually is the biggest energy consumer for that building. (BO5)

(3) Efficiency technologies are not properly operated

An EPC is designed as a “turn-key” project, and the ESCOs take over the existing buildings and return the buildings to the building owners after the contract term. However, in most of the survey cases, building owners did not transfer the rights of building energy operation after retrofits completely to the ESCOs (ESCO2, ESCO3). Their facility management groups are still working on the building operation. While the building energy system is totally operated by the ESCOs, they can affect the full impact of an EPC. However, in reality, ESCOs are only there for a regular check within a period and offer help when the facility managers ask for help. Although the facility managers are asked to follow the rules the ESCOs set, there are still many problems especially when the building managers operate wrongly or address problems without informing ESCOs in

time (ESCO6). These will prevent efficient technologies from playing their roles to save energy and make it more difficult for ESCOs to meet the energy saving goal.

(4) Commissioning is now widely used in the market

Commissioning can verify that the energy saving technologies are properly installed and performing normally (Liang, Qiu & Hu 2019), which is identified as a cost-effective quality assurance (Mills et al. 2004). However, the lack of standardised information on the costs and benefits of using commissioning may mean commissioning is not widely used. Commissioning is recommended by all the ESCOs and some of the government officials and independent experts. The survey found that the proportion of commissioning is very limited in existing cases (IE5, ESCO1, ESCO6, Gov4). This may be a reason for the energy performance gap related to technology failures. Lack of commissioning under EPCs will trigger a poor energy performance gap (Gov4).

7.3.2. Changes in Building Energy Use

Compared to the manufacturing industry, building energy is very hard to predict due to the frequent changes in the use of buildings including changes in the building operating state, building vacancy rate, the mix of business in the buildings and energy using habits. There is a dynamic change in the energy consumption of buildings.

Currently, a lot of ESCOs are more willing to do EPCs in the manufacturing industry because of simplicity. In the manufacturing industry, there are not as many variables as in the building sector. All kinds of unstable factors will change energy consumption in buildings. (IE2)

(1) Changes in the building operating state

As commercial buildings are related to business activities, especially for shopping malls and commercial complexes, the running state of the buildings changes all the time.

Take shopping malls as an example, the flow of people is changing all the time. We cannot calculate it very accurately, therefore the predicted energy consumption of air conditioning may make a big difference on the actual energy consumption.... Thus I think it is impossible to calculate it very accurately, the difference [between the prediction with the actual situation] may be very big. Maybe calling it a random difference is not appropriate, but the dynamic change of building energy is great. (IE2)

Meanwhile, the climate condition also influences energy consumption significantly.

For example, this summer in Chongqing is very cool. They [some energy users] did not use air conditioners frequently and some buildings' cooling water temperatures were not set as low as previous. It is obvious they will use less energy than last summer, but can you say they save energy? The actual energy savings are even less. (Gov1)

As energy consumption can be influenced by many uncertainties, it is hard for ESCOs to predict the payback period precisely. As a result, both the building owners and the ESCOs will face a consequence of failing to realise the predicted energy savings caused by these uncertainties.

(2) Changes in the building vacancy rate

In some cases, the building owners are leasing parts of buildings to the tenants. Depending on the market situation, the vacancy rate of the buildings varies. Therefore, the energy savings of the buildings are unstable. This brings risks for both the ESCOs and the building owners (BO5, BO6).

If our vacancy rate is very high, the energy bills every month would decrease and the energy savings would not be the actual energy savings. Under this risk, we would pay more to the ESCOs. We are not sure how much we may lose due to the change in the vacancy rate. (BO5)

At this moment, we have not faced the problem that the building owners would not want to pay the benefits of energy savings due to the increase in vacancy rate. But we are worried about this. Because based on our observation, there are seven projects facing 10% of the surrender of the tenancy. If this rate goes higher, we are not sure if the building owner will put forward the problem of the actual rate of energy efficiency. This would probably lead to the payment problem and further trigger default of the contract. (ESCO6)

(3) Changes in the mix of business type in a building

It is very common that the mix of business of a commercial building changes according to economic and market development, for example, a commercial complex increases the proportion of catering services and decreases the proportion of retail. However, it brings many problems for the uptake of EPCs. It will lead directly to changes in the functions of the building. Under an EPC, if the building owners change the building functions, it will

directly influence how the energy system is set and how the energy is consumed. This will influence the benefits of energy savings for both the building owners and the ESCOs.

Due to the development of e-commerce, the profitability of physical stores has declined. In this context, a shopping mall changed some of its retail stores into catering services. Actually, they were continually changing the building functions. Three ESCOs have negotiated with the building owner of this shopping mall about uptake of an EPC. After a long period of negotiation and assessment, they still did not decide to use an EPC because of the unstable state of business. It is very hard to set an energy saving baseline and the related assessment of final energy savings. (Gov2)

(4) Energy using habits and rebound effects

Energy using habits will influence energy savings significantly, which will influence the final energy saving benefits.

Energy savings are closely related to how energy is used by the building owners. ... If building owners do not use energy properly, it will influence the total energy savings then influence our energy sharing benefits. (ESCO1)

The energy using habit is a cognitive barrier for building owners and their tenants. Some energy usage habits are inattention, and some are caused by rebound effects. Rebound effects are defined as the phenomenon that consumers use more of the energy service after improving energy efficiency (Gillingham, Rapson & Wagner 2016), which is explained in price theory in microeconomics by a fall in supply prices. Because of the rebound effect, more energy may be consumed and the marginal cost of energy services would reduce (Gillingham et al. 2013).

In one case, after retrofits, the building owner believed the building is energy efficient. During the operation period, especially the first month or the first quarter they saw the energy bills decrease a lot. Then the following months or quarters we can see a significant rise in energy consumption. ... but this does not always happen. Some building owners strictly follow our rules and keep energy consumption routine. (ESCO7)

No matter how energy saving appliances are, if they [building owners] use them for a long time, the energy consumption is still high. (Gov1)

As the building owners indirectly receive the energy saving benefits, they have no consciousness that their behaviour of enjoying “further thermal comforts” may contribute to energy consumption rebound (BO7). In most cases, during the operation period of the

EPC, the energy saving benefits are paid from building owners to the ESCOs based on the calculation of the differences between the initial energy bills and the current energy bills. This also leads to the “moral hazard” that the building owners do not want to share the energy benefits, and they tend to consume more (ESCO6). This is not a common phenomenon but still happens in some particular cases due to the “cognitive problem of building owners” (IE6).

Although the ESCOs realise the building owners’ energy use behaviour would impact final energy savings, all of them mentioned it is hard to regulate the behaviour of building owners. First, it is very hard to monitor energy use behaviour. Second, without knowing precisely the energy users’ habits, it is impossible to set targeted rules of energy use.

There is no monitor on building owners’ energy use behaviour, which is a reason for wrangling when the building owners and the ESCOs share the energy saving benefits. (Gov2)

There is a big limitation on only using metering. If you want to use metering to precisely calculate energy consumption in different ends of energy consumption, you need to install electric meters in different energy consumption ends. Although the unit cost of electricity is cheap, the quantity will lead to big investments. We need to consider the costs and benefits of investing in it. (ESCO2)

7.4. High Barriers for ESCOs to the Entry of the EPC Market

The theme of high barriers for ESCOs to the entry of the EPC market is identified as one of the causes of EPC market barriers. There are two perspectives: i) comprehensive service capability of BEER for ESCOs, with two sub-themes of core energy efficiency technologies and R&D ability and resource integration capability; and ii) financial capability (see Figure 7-4).

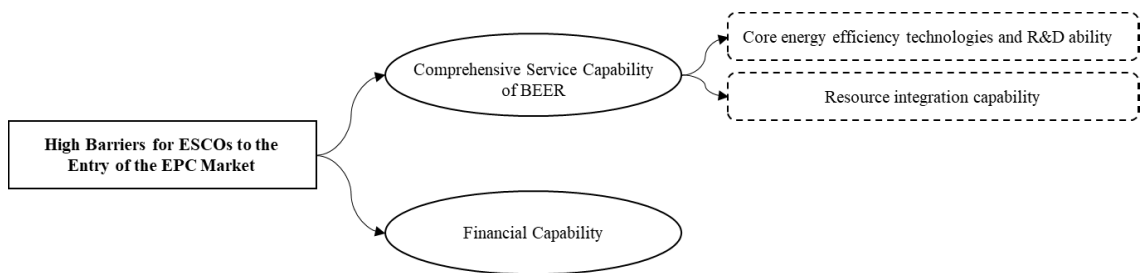


Figure 7-4 Theme 3 high barriers for ESCOs to the entry of EPC market

The literature review (Section 3.4.1) showed the EPC market status. At the end of 2020, there were 7,046 ESCOs (EMCA 2021). However, the interviews show that after the national subsidies were discontinued in 2015, most of the ESCOs no longer undertook EPC projects and some of them even went bankrupt. Due to policy inclination and the surge of market demand, some ESCOs may have had many opportunities to undertake projects in the initial market. However, when those favourable external conditions disappeared and the market entered a steady state of development, those ESCOs that were less competitive were easily eliminated by the market. Although the EPC market did not directly set an entry condition for ESCOs, the requirements for ESCOs to conduct EPCs are very high.

7.4.1. Comprehensive Service Capability of BEER

Unlike traditional energy efficiency projects, EPCs require ESCOs to have capabilities to offer building owners a comprehensive energy efficiency service. Interviews identified two main areas of competitiveness: core energy efficiency technologies and research and development (R&D) ability, and resource integration capability. Conducting EPCs cannot

be easily copied from one ESCO by another ESCO. ESCOs that do not have core competitive advantages are easily eliminated by the market. With the development of the market, the criteria of service capability for ESCOs is higher.

(1) Core energy efficiency technologies and R&D ability

The ESCOs that have competitive advantages always rely on one or several types of core energy efficiency technologies. The “core” energy efficiency technologies mean the particular skills or products an ESCO has to conduct energy efficiency which other ESCOs in the market do not have, for example, electric machines designed by magnetic suspension technique. Some of the technologies are covered by independent intellectual property rights, such as the energy saving control software Techcon series designed by Tongfang Technovator Ltd. The strong technical strength and R&D background of ESCOs allows them to provide better energy saving solutions to the building owners and have better capabilities for risk management (IE2, ESCO1).

We undertake EPC projects because we have the main strength in central air conditioning. As the business unit in our company was developed based on Tsinghua University, our staff are experts in HVAC. ... Meanwhile, we own our independent expertise and technical products and we also undertake a lot of research for building energy efficiency. ... Actually, we accumulated a lot in this industry. It is the core technologies that lead us to undertake the EPC projects, as policies and the capital market are not the main drivers for us. (ESCO4)

Without policy protection and policy support, the companies [ESCOs] all live on their own [service and technology ability]. The ESCOs that have no core technologies find it hard to develop core competitive advantages and continue to do EPC without subsidies. (ESCO2, ESCO3)

Although ESCOs that have competitive advantages mainly depend on their energy efficiency technologies, while they also need a comprehensive of energy efficiency service ability including managing all perspectives of energy efficiency retrofits, finance and maintenance etc. The interviews also revealed that there are many ESCOs whose main role is the manufacture and supply of air conditioning equipment. They expanded their main business by offering energy efficiency services. In the past, BEER was not taken as comprehensive energy efficiency work, and the HVAC system was considered as the main way to improve energy efficiency. Therefore, some building owners follow conventional thinking and rely on their HVAC suppliers. As building owners have

already built trust with their previous HVAC suppliers, there are fewer transaction costs for them to select these types of companies to do EPCs for them (ESCO7). The ability to produce HVAC can also be considered as a core technology of ESCOs in the current BEER market in China.

In the current EPC market, the ESCOs that still tend to undertake EPC projects are the companies that have the core energy efficiency technologies mentioned above. The more projects they undertake, the more experience they gain and the stronger their ability to resist risks. They gain higher market share by conducting EPCs.

(2) Resource integration capability

As mentioned before, conducting EPCs includes a series of energy efficiency services and is a comprehensive energy efficiency scheme. It mainly covers five perspectives: building energy consumption diagnosis (energy audit) services, BEER design consultation, energy efficiency construction, building energy operation management and training services, and investment in the projects. As not all ESCOs can maintain all of these service abilities, the EPC market wants the capability of resource integration to cover all the perspectives of energy efficiency services.

The capability of resource integration is a very good competitive advantage for ESCOs. As the market develops towards a direction of refinement, some ESCOs are more dedicated to particular technologies. They need to build their resource integration skills. (Gov2)

Our company is good at boiler improvement. In some cases, the building owners have requirements on offering entire energy efficiency plans. So we tend to cooperate with other ESCOs who have abilities to design the rest of the parts. We tend to cooperate with the other good ESCOs we are familiar with because it can save a lot of negotiating time. (ESCO5)

7.4.2. Financial Capability

In both research and practice, ESCOs under EPCs are defined as an asset-light type of company. This means these ESCOs have limited fixed assets and the operation of the company mainly depends on its intangible assets. Under EPCs, in the current Chinese market, ESCOs are responsible for the investment in BEER. Meanwhile, without having large fixed assets, the ESCOs find it hard to apply for loans from banks. The bank loan

system in China is detailed in Section 7.6.3. Therefore, ESCOs take on great financial pressure. As the payback period is very long (the payback period of EPCs is detailed in Section 7.5.3), ESCOs will continue facing financial pressure for a long period. This makes ESCOs very sensitive to any uncertainties. In particular, when the building owners fail to pay the ESCOs the energy saving benefits in time, the ESCOs may face the risk of breaking their capital chain (ESCO1, ESCO4, ESCO6).

For our company, we not only undertake EPC projects, but also other types of BEER projects. Currently, we estimate that if we take one to two EPC projects every year, we will not have significant financial pressure. ... In fact, we already apply for commercial loans from the bank based on property mortgage. (ESCO6)

Our company is relatively large, so we are relatively self-sufficient in funds. ... With a big amount of funds, the banks are also willing to cooperate with us. ... But for some small companies, they are under pressure on their cash flow. Once there is a problem with energy saving sharing, or if their payments are not returned, they will immediately be restricted for subsequent development. (ESCO1)

It can be seen that the big companies have stronger financial capability than small companies.

This is why the energy efficiency equipment suppliers or manufacturers tend to be ESCOs. They have less financial pressure. (ESCO7)

As mentioned before, an EPC is a comprehensive energy efficiency service, so those equipment suppliers and manufacturers may not have the comprehensive technology ability. But with big financial support, they can easily gain projects as building owners have limited knowledge of BEER. As a result, there will be some manufacturers and suppliers that play the role of ESCOs, but the benefit of conducting EPCs is not as good as they advertised and then EPCs may not function very well as theoretically described.

Comprehensive service capability and financial capability decide the competitive advantages of ESCOs. The more they have, the stronger they can resist risks in the market. As a result, the EPC market may be controlled only by a few ESCOs that have core competitive advantages.

7.5. Low Motivation for Commercial Building Owners

During the interviews, in general, the building owners were passive regarding BEER or the use of EPCs, and very few of them conducted BEER or used EPCs actively. The low motivation for commercial building owners is shown from two perspectives: one is directly about EPCs, and the other is about BEER itself as the main reason. The causes of the low motivation can be summarised as four perspectives (see Figure 7-5): i) type of building owners, with six sub-themes of companies who have ability to do BEER tend to retrofit their buildings by themselves, energy intensity of the buildings, private enterprises take more consideration of business operation, state-owned enterprises tend to respond to the government's summons but lack initiative, corporate culture and leadership concept, and multiple building owners; ii) split incentives, including two sub-themes of separation of property rights and management rights, and separation of property rights and usage rights; iii) long payback period; and iv) limited energy saving benefits, including with two sub-themes of limited energy savings and low energy price.

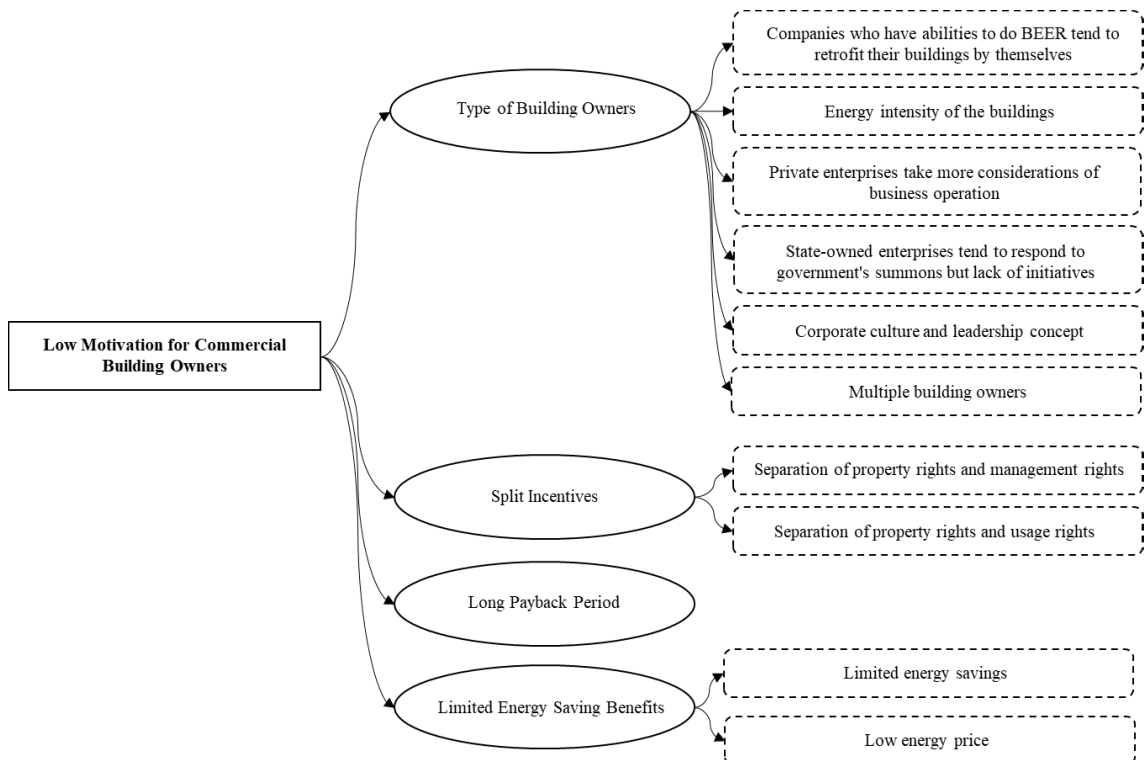


Figure 7-5 Theme 4 low motivation for commercial building owners

7.5.1. Type of Building Owners

Different types of companies have different desires to conduct BEER and use EPCs. The following five situations show how different types of building owners have different responses to BEER or using EPCs. This provides a clearer picture of the low motivations of different types of building owners.

(1) Companies who have ability to do BEER tend to retrofit their buildings by themselves

Some building owners are already developers or have their own department for construction management for building energy systems. When they know about the concept of EPCs, they think they have the ability to also do that. Some of the building owners do not see any difference between their technology skills and those of the ESCOs (BO4). Even if some of the building owners know that they are less professional than the ESCOs, they do not want to have ESCOs take over their projects, because they do not want to share the energy saving benefits with them (BO4). They prefer to keep all the energy saving benefits.

In China, a type of commercial building called a commercial complex has been built widely. A commercial complex means a building or buildings under one or multiple ownerships containing one or more commercial businesses (Insider 2021). The size of this kind of building is very large, and can reach hundreds of thousands of square metres and have more than two commercial uses. The energy saving potential is great, considering the large building area and the multiple commercial uses. However, some of the owners of this type of building are also developers that have the ability to conduct BEER. Taking “Wanda Plazas” in Chongqing in China as an example, the developer holds some of their own properties and also sells some parts. For their owned parts, they can conduct BEER by themselves. For the parts they have sold, they can also offer a service to conduct BEER. Therefore, an EPC is not popular for building owners who have their own ability to conduct BEER (Gov3).

(2) Energy intensity of the buildings

As mentioned above, a commercial complex has great energy saving potential. The energy saving potential is not only decided by the amount of energy used. Energy intensity is an important factor for commercial buildings to show the relationship between energy consumption and the business situation. It is a measure of the energy inefficiency of an activity. For commercial buildings in China, the energy intensity of shopping malls and hotels is higher than the energy intensity of office buildings. The higher the energy intensity, the higher the motivation building owners have (IE7, Gov2, Gov3). Therefore, the building owners of commercial office buildings have less motivation to retrofit their buildings for the purpose of energy efficiency.

(3) Private enterprises take more consideration of business operation

For private enterprise, business operation is always of the greatest interest to the building owners. From the views of building owners, although the construction work of BEER would be managed by ESCOs, the influence of the normal building operation cannot be avoided completely (IE1, IE4). Considering the inconvenience of construction of BEER and the uncertainties of final energy efficiency effects, the building owners feel that they would have a long period of uncertainty which would cause problems for their business operation (IE4).

Meanwhile, energy consumption accounts for a small proportion of their total business operation costs. For shopping malls, the main purpose of building owners is to attract more brands to cooperate with them and offer customers a good thermal environment, and so energy efficiency is the last thing to consider (ESCO7, IE1, IE4). For hotels, the building owners have already included the energy costs in the room prices, and thermal comfort and a good living environment are their priority (IE3, BO7). Taking a commercial office park in Beijing as an example (the name is not disclosed due to confidentiality considerations), this commercial office park is designed at an upscale level for international Fortune 500 companies. The annual rental fees are around 600 million CNY, and the annual energy consumption cost is around 20 million CNY, meaning the energy costs are a small proportion of the high rental income. Even if the energy saving rate could reach 20%, the saved energy costs would still be less than 1% of the total rental

income. But if the park loses 1% of the tenancy income, they would lose 6 million CNY which would be a big loss for the building owner (IE5.)

In these upscale commercial buildings, the priority for the building owners is safety, the second is thermal comfort, the third one is intelligence, for example, smart buildings. If you take energy saving as one consideration, it would be set as the fourth one. In this context, BEER is not taken into account, not to mention EPCs. (IE5)

This issue is caused by the character of commercial buildings, because business operation profits are the most important element for the building owners. EPCs are designed to deal with this problem because commercial building owners are more sensitive to profits. Under EPCs, building owners do not need to invest in the retrofits, which may not influence their commercial business profits. However, the uncertainties make the building owners afraid to do BEER, therefore they also do not like to try EPCs. Building owners from private enterprises are more sensitive to the business profits compared to building owners of public buildings.

(4) State-owned enterprises tend to respond to the government's summons but lack initiatives

A state-owned enterprise (or government-owned enterprise) is a business enterprise where the government or state has significant control through full, majority or minority ownership. State-owned enterprises are less flexible than private enterprises. Therefore, they did not show their interest in EPCs when the ESCOs came to them. However, when the government publishes policies about building energy efficiency and EPCs, they tend to follow the policies, but it also depends how compulsory those policies are (ESCO7, ESCO8, IE5, Gov4). As state-owned enterprises, in addition to the pursuit of interests, they also care about the social responsibilities of their corporation (Gov3, Gov4).

(5) Corporate culture and leadership concept

Corporate culture and the leadership concept decide whether building owners will spend effort on building energy efficiency or not. For commercial building owners, their priority is always their main business. If the benefits from the BEER are not high enough, energy efficiency will not be their consideration. They tend to spend more effort on their main business (IE1). There are few building owners who seek ESCOs to conduct BEER or

EPCs. Some ask for services from ESCOs because of the leaders' advanced concepts of energy efficiency or relevant corporate culture.

The leadership concept is very important. If the leader [of the company] does not think energy efficiency is important, no matter how much energy can be saved, they will not conduct BEER or EPCs. (BO4)

This building owner contacted us to do EPC because he heard about the building energy efficiency and the other successful cases in an industry conference. The leader has the concept of energy efficiency. And the corporate culture in his company is about sustainability. (ESCO7)

For listed companies, although they must report their energy consumption annually, not many of them consider energy efficiency (BO7): "So I think the most important reason is the leadership concept" (BO7).

(6) Multiple building owners

In many cases, a commercial building is owned by multiple owners. Therefore persuading them to uptake EPCs is harder than ESCOs persuading only one building owner.

We have seventeen owners. At the very beginning, we had a lot of worries and we were a little bit hesitant. Thus, we communicate with the ESCO for at least one and a half years. Because of the EPC, we need not pay the retrofit upfront. This helped the seventeen owners come to an agreement more quickly than the traditional BEER. (BO5)

Having multiple building owners means the negotiation time is longer. In such a complicated relationship, it is quite difficult to persuade them to reach an agreement to use EPC. (ESCO8)

Multiple building owners lead to more complicated relationships. It may make the negotiation time very long and it increases ESCOs' transaction costs.

7.5.2. Split Incentives

Split incentives are transactions or exchanges where the economic benefits of energy conservation do not directly flow to the person who is paying for the measure (Klemick et al. 2015; Marquez, McGregor & Syme 2012). There are split incentives that happen between the building owners, the facility managers and the tenants. Facility managers are companies hired by building owners to manage buildings. Under split incentives, the building owners and the facility managers are two different companies, and the building owners are not the users of the buildings.

Under an EPC, building owners sign contracts with ESCOs and the energy saving benefits are allocated to building owners but not to facility managers. During the implementation of an EPC, facility managers need to assist the ESCOs, but without enjoying the energy saving benefits, the facility managers have little motivation to assist the ESCOs. If the building owners have their own facility management department, the split incentives discussed here are not applicable. The split incentives make EPCs hard to implement because “in the process of EPC implementation, you may need to negotiate many things with other companies that are not originally within the scope of the contract” (ESCO4). Similarly, tenants do not enjoy the energy saving benefits but need to follow the rules of energy efficiency. Details are provided below.

(1) Separation of property rights and management rights

Building owners hire facility management companies to operate the buildings. The income of the building owners comes from the profits of rental fees, therefore they “do not consider the costs of operation and also do not reap the benefits of reducing the energy costs” (BO3). For conducting BEER, there is little incentive for the building owners to expend their capital on energy efficiency to decrease energy costs. Although under EPCs building owners do not need to pay the costs of BEER, some of the building owners still maintain the concept of “the less trouble, the better” (BO4). Some building owners consider EPCs to upgrade their equipment because it can increase the value of the fixed properties (BO7). Usually, the time they want to use an EPC is when the existing equipment has reached the end of its life but not from the perspective of energy efficiency. In addition, conducting BEER needs facility managers’ cooperation. Implementing an EPC requires additional work from facility managers therefore facility managers lack incentives to assist ESCOs (ESCO7). Meanwhile, as the building owners are not directly involved in the building operation that is the responsibility of the facility managers, they do not have the overall view of the building operation (ESCO4). When ESCOs negotiate an EPC with building owners, there is an asymmetric information problem as discussed in the first section (ESCO6).

(2) Separation of property rights and usage rights

For commercial buildings, the energy costs are paid by the tenants. Split incentives arise when buildings are occupied by tenants. In traditional BEER, any capital investment made by the building owners to improve energy efficiency will be recouped in part by the tenants (Marquez, McGregor & Syme 2012). Under an EPC, although the building owners do not invest in the BEER directly, they still take the effort they spend on coordinating with ESCOs as their cost of improving energy efficiency (BO7). As a result, the building owners may believe the benefits were taken by the tenants although there are still benefits from energy savings to the base building (ESCO4, IE4). There are no direct incentives for the building owners to start an EPC. Also, the tenants pay for the energy costs, it is hard to ask tenants to share saved energy saving costs with the building owners (ESCO7, Gov1).

In some cases, the tenants are asked to pay fixed “property costs” monthly including the energy costs to the property managers. In this context, if the building energy efficiency is improved, the tenants do not get the benefits and the building owners can have more incentive to uptake an EPC (BO2). At the same time, the tenants have no incentive to save energy based on fixed energy costs, thus it would be very hard to constrain the tenants’ energy use behaviour, which will influence the final building energy performance (IE3).

7.5.3. Long Payback Period

The EPC benefits gradually accrue as savings on energy bills over a period of time. The payback period directly influences the contract period under an EPC. A long-term EPC contract is mentioned by all the ESCOs and most of the building owners, and is considered as one of the barriers to the uptake of EPCs by several independent experts (IE1, IE2, IE5, IE6). The payback period depends on the technical schemes of the retrofits. The survey found that updating a lighting system or adding frequency conversion devices under an EPC has a payback period of around three years. A HVAC system needs five to eight years or even longer (ESCO1, ESCO2, ESCO3, ESCO4). The long payback period is a big challenge to the capital and technical ability of the ESCOs (ESCO1). During the long term of an EPC contract, the uncertainties increase.

With the fast development of the economy and market, the business life cycle is hard to predict, there is a doubt whether the contract of the EPC can be implemented in a long period. The long payback period makes the ECP projects full of uncertainties. ... the contracting parties easily lose trust. Using an EPC is a little bit risky. (IE5)

In this context, building owners lack the motivation to conduct BEER and the ESCOs tend to offer traditional energy efficiency services but do not use EPCs.

7.5.4. Limited Energy Saving Benefits

Two aspects contribute to limited energy benefits: limited energy savings and low energy price.

(1) Limited energy savings

Compared to EPCs in manufacturing, the energy savings of buildings are limited. This is a barrier for BEER because the limited energy savings are directly related to the energy saving benefits (IE2).

The scale of energy savings achieved by BEER is small [smaller than energy efficiency in manufacturing], and the technologies are complex. (Gov2)

We had a preliminary estimation. Normally, the energy costs accounted for 5% of building operation costs. If the energy efficiency rate can reach 10%, the total energy savings are only 0.5% of total building operation costs. This really does not matter to the building owners. (Gov4)

It is very easy for building owners to have “myopia” problems if they do not take life cycle costing and pay-off concepts into account.

(2) Low energy price

“One of the most important market barriers is low energy prices” (IE7). Compared to buildings for the public like schools or museums, the energy price for commercial buildings is higher. For those buildings serving the public, the government offers price subsidies, thus they have lower energy prices than commercial buildings. Therefore, commercial building owners are more sensitive than owners of other types of public buildings. However, given the composition of operation costs of commercial buildings, the energy price of commercial buildings is relatively low (IE7). As a result, the low

energy price on the one hand does not improve the motivation of the building owners to save energy costs, and on the another hand, it does not contribute to a large amount of energy benefits. “An accurate price signal is important to the BEER market and EPC mechanism. Mispricing of energy would be a regulatory barrier in the building energy efficiency market” (IE5).

7.6. Limitations of Initial National Policies on the Initial Market

The limitations of initial national policies on the initial market (that means EPC market is developed in the building sector from 2010 to 2015) is a theme identified in the interview data. It includes four aspects (see Figure 7-6): i) initial national subsidies limit EPC business model innovation, ii) the building energy information platform is not fully developed, iii) the financial system is far behind in using potential energy savings, and iv) discontinued national subsidies impact the initial market.

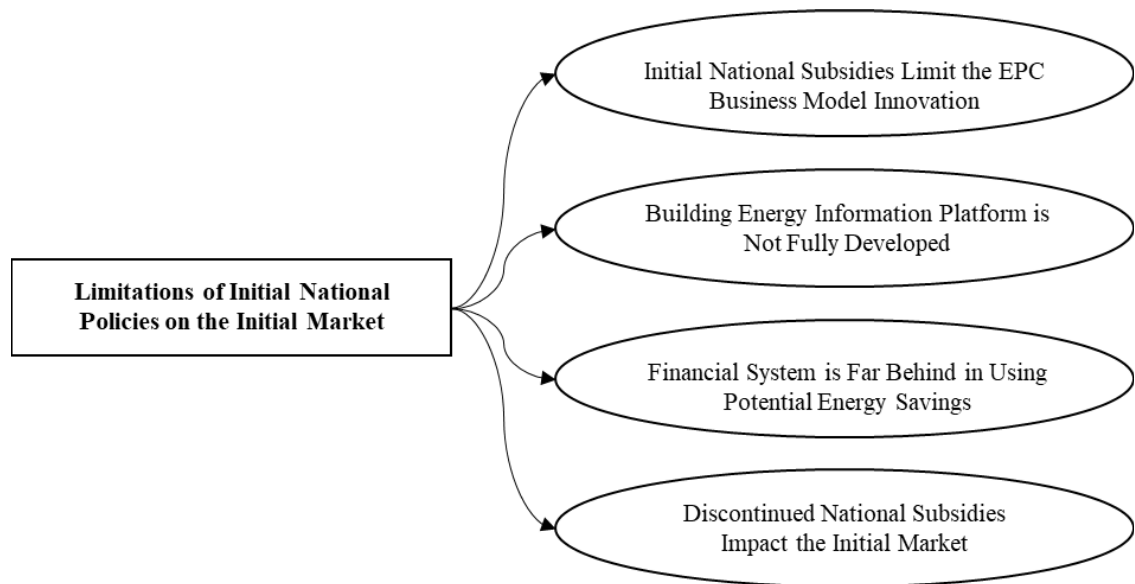


Figure 7-6 Theme 5 limitations of initial national policies on initial market

7.6.1. Initial National Subsidies Limit EPC Business Model Innovation

For national subsidies, only projects using the Shared Savings EPC business model can apply for the financial subsidies. In this context, both building owners and the ESCOs tend to select this business model. The original intention of the government was to promote the motivation of the building owners because in the Shared Savings model the building owners take fewer responsibilities (Gov1). As a result, subsidies virtually restrict model innovation. Because the application of an EPC is complex and changeable, it is necessary for both building owners and ESCOs to follow a suitable or a modified business model according to their own situation (IE5). A suitable EPC business model can help contracting parties allocate their risks properly. “Diversification of the EPC business model can help meet a variety of needs in the market and reduce risks” (IE4).

7.6.2. Building Energy Information Platform is Not Fully Developed

In 2007, the Chinese government, mainly the MOHURD (Ministry of Housing and Urban-Rural Development of the People’s Republic of China), started to build multiple province-level energy consumption monitoring platforms. However, there were some problems with platform development. First, there was a lack of investment for building the platform. “Building the platform needs investment. When there is government support, with central and local finance supports, [the platform can be built widely]. However, there are still a lot of places where the platforms are not well developed” (Gov3).

Second, the operation and maintenance of the platform needs a great amount of financial and professional support. “After a platform is built, it needs operation and maintenance. However, many of the places have maintenance problems” (Gov3). With government financial support, the platforms can be built. However, because the financial support offered by the government was a one-off, the funds were all used for developing platforms and there was nothing for maintenance. During the period of operation and maintenance, if the meters or sensors break, it needs more investment for replacement or adjustments. “However, who should be responsible for this new investment? Without government support, the building owners are reluctant to invest in the maintenance of the platform” (IE5, ESCO2, ESCO3). Meanwhile, broken meters or sensors can lead to missing and

inaccurate data. Without comparability, the data on building energy information cannot be taken as a reference (Gov3). The maintenance issue is the major problem of developing a building energy information platform.

As well as the maintenance issue, the willingness to join a building energy information platform is another barrier (Gov3, IE5). The different types of building owners have different willingness. The buildings serving the public are owned by the government, thus they are more willing to build a building energy information platform because they do not have financial problems. For commercial buildings, it is hard to get them to publish their energy information, because some of them consider their energy information as confidential, for example, hotels. Some big companies that pay attention to their corporate image and listed companies that must report their energy information tend to join the platform. The other types of building owners lack the will. Currently, the platform is only monitored by the local government and is still far away from being able to publish the information for companies (IE7).

7.6.3. Financial System is Far Behind in Using Potential Energy Savings

In the current Chinese financial system, fixed assets are the main loan securities. The potential energy savings are usually not considered as a security (ESCO1, ESCO5, IE3). “The banks prefer the lender to have a collateral, especially a collateral of a relatively certain type, like property or other types of fixed assets” (Gov1). “EPCs originally started in America. Compared to the Chinese market, their financial system allows the ESCOs to use their credibility to apply for the loan. But in China, they only have a purely physical mortgage, which makes EPCs very hard to implement” (IE5). As the ESCOs are light-asset companies, without many fixed assets, they find it hard to get a bank loan (Gov1).

In some cities, governments have published policies to encourage banks to allow future energy saving benefits as loan securities, but it is not very successful in practice. It creates a dilemma. With government encouragement, the banks wanted to try lending financial support to ESCOs that can show future energy saving benefits. However, banks have limited knowledge of EPC projects. As EPCs are full of risks, the banks are very cautious. There are no standards or rules to evaluate the potential and risks of using energy savings

as a mortgage. Banks carefully check the cash flow and credibility of the ESCOs. The big and experienced ESCOs find it easy to receive loans, while the small and/or new ESCOs find it harder to get them (ESCO1). In addition, although the banks allow using future energy saving benefits as loan securities, they only approve a small portion of them (ESCO4). In this context, the ESCOs are still under great financial pressure. Without the support of the financial system, ESCOs, especially the small ESCOs, find it hard to survive (ESCO5, Gov1). From 2019, the government published plans to develop green finance. “At this stage, it [green finance] is only a general framework, it is far away from being put into practice” (Gov2).

7.6.4. Discontinued National Subsidies Impact the Initial Market

EPCs in the building sector started in four pilot cities in China. From 2010 to 2015, the Chinese central government allocated 2 billion CNY annually to support EPC projects including both the building and manufacturing industry. Together with the national subsidies, the provincial governments also offered some incentives for eligible projects. Most of the ESCOs mentioned that the financial subsidies provided a strong signal of the government’s endorsement of EPCs (ESCO1, ESCO2, ESCO3, ESCO5, ESCO7, ESCO8). In 2015, the national financial subsidies were discontinued. This had an impact on the ESCOs, especially the small-size ESCOs (Gov1, Gov3, Gov4, IE1). Without the subsidies, the ESCOs find it hard to undertake more extensive retrofitting projects (to achieve a higher energy saving rate) with a great amount of investment and a long contract period. Therefore, the financial pressure increased for those ESCOs. Meanwhile, without the national subsidies, some of the building owners lacked confidence and motivation to conduct EPCs. Therefore, after the subsidies were halted, some of the ESCOs tended to undertake traditional BEER projects but not EPCs (IE5, ESCO5, ESCO6). At the same time, some ESCOs and independent experts have a positive attitude that “annulled national subsidies may not have a bad impact on the market because it is more a process to filter out the quality ESCOs” (IE1).

We initially established the financial subsidies in order to reduce the risks of the early stage of EPCs and cultivate the market. Financial subsidies cannot exist forever. They are only a guide for the government to support the industry. If an industry has to rely on financial subsidies to survive, the industry itself does not have the conditions for marketisation. (Gov1)

With four to five years' subsidies support, the ESCOs with abilities to conduct EPC have already been developed. Although after the subsidies were annulled, some ESCOs and building owners lack motivation for using EPCs, the initial market is already developed. (IE4)

There are some ESCOs that do not have strong technical skills. ... Without the subsidies, the ESCOs can only get benefits when they can save a great amount of energy. It is a challenge for ESCOs. ... But for the ESCOs that have their core technology, the discontinuation of national subsidies will not influence their business of offering EPC service. (ESCO1)

In some cities, the local governments, such as Beijing, Shanghai and Chongqing, still provide financial support to projects in their jurisdictions (Gov1, Gov3, Gov4). These cities are pilot cities and tried EPCs the earliest. The markets in these cities were developed in the last ten years. However, for the cities that have just started using EPCs, it is still unclear how the market can be developed without national subsidies (IE7).

The five themes contributing to the causes of EPC market barriers have been analysed. The following section discusses the origins of these causes.

7.7. Comparison of Causes of Market Barriers between CBEER and EPCs

The previous discussion highlighted that the causes of market barriers to the uptake of EPCs are not only from EPCs itself. Some of the reasons are from the inherent characteristics of CBEER but affect EPCs to a large extent. By analysing them separately, the causes of analysis and later the proposed policy suggestions are more targeted. Table 7-1 summarises the origins of market barriers and risk bearers in each situation.

Table 7-1 Origins of market barriers and barrier/risk bearers

Causes of Market Barriers			Origins of barriers				Barrier/Risk bearers			
Main themes	Sub-themes		CBEER		EPC		CBEER		EPC	
			BO	ESCO	BO	ESCO	BO	ESCO	BO	ESCO
Asymmetric information between ESCOs and building owners	Inadequate information of existing buildings	Inadequate initial information on the existing buildings	√				√	√		√
		Unconfirmed baseline of BEER	√	√			√	√		√
		Free rider problems			√					√
	New concept and incomplete information of using EPCs	EPC is a new concept for building owners			√					√
		Overblown energy saving effects		√			√		√	√
		Unclear energy saving benefits	√	√			√			√
	Lagging facility management system in China		√				√	√	√	√
	Incomplete contracts				√	√			√	√
	Service quality of ESCOs			√			√		√	√
	Credit risk of building owners				√					√
Energy performance gap of BEER	Technology issue	Inaccurate design		√			√		√	√
		Inappropriate design		√			√		√	√
		Efficiency technologies are not properly operated	√				√		√	√
		Commissioning is now widely used in the market	√				√			√

	Changes in building energy use	Changes of the building operating state	√				√		√	√
		Changes of the building vacancy rate	√				√		√	√
		Changes in the state of business of the buildings	√				√		√	√
		Energy use habit and rebound effects	√				√		√	√
High barriers for ESCOs to the entry of the EPC market	Comprehensive service capability of BEER	Core energy efficiency technologies and R&D ability				√				√
		Resource integration capability				√				√
	Financial capability					√				√
Low motivation for commercial building owners	Type of building owners	Companies who have ability to do BEER tend to retrofit their buildings by themselves				√				√
		Energy intensity of the buildings	√				√		√	
		Private enterprises take more considerations on business operation	√				√		√	
		State-owned enterprises tend to respond to the government's summons but lack initiatives	√				√		√	
		Corporate culture and leadership concept	√				√		√	
		Multiple building owners	√				√		√	
	Split incentives	Separation of property rights and management rights			√	√				√
		Separation of property rights and usage rights	√				√		√	√
	Long payback period		√				√		√	√

	Limited energy saving benefits	Limited energy savings	√			√		√	√
		Low energy price	√			√		√	√
Limitations of initial national policies on the initial market	Initial national subsidies limit the EPC business model innovation			√					√
	Building energy information platform is not fully developed		√			√	√	√	√
	Financial system is far behind in using potential energy savings		√			√			√
	Discontinued National Subsidies Impact the Initial market			√				√	√

In the identified five themes with 36 sub-themes, 11 sub-themes come from the EPC mechanism itself and 25 sub-themes originate in CBEER. The sub-themes in the theme “energy performance gap of BEER” are all from the barriers that occur in CBEER, and the sub-themes in the theme “high barriers for ESCOs to the entry of the EPC Market” are all from the EPC mechanism. The items in the other three themes come from both CBEER and EPCs.

Figure 7-7 shows the origin visually. Although the theme “energy performance gap of BEER” is inherent in the market of CBEER, it makes EPCs harder to use because the profitable and clear energy saving benefits are the dominant problem. The theme “high barriers for ESCOs to the entry of the EPC Market” stresses EPCs have higher requirements for ESCOs. In particular, the financial capability is one of the main criteria for ESCOs to undertake EPCs, which is a major barrier for light-asset ESCOs. As a result, the market entry for ESCOs to conduct CBEER is even more difficult, which may lead to the power of the market being formed gradually.

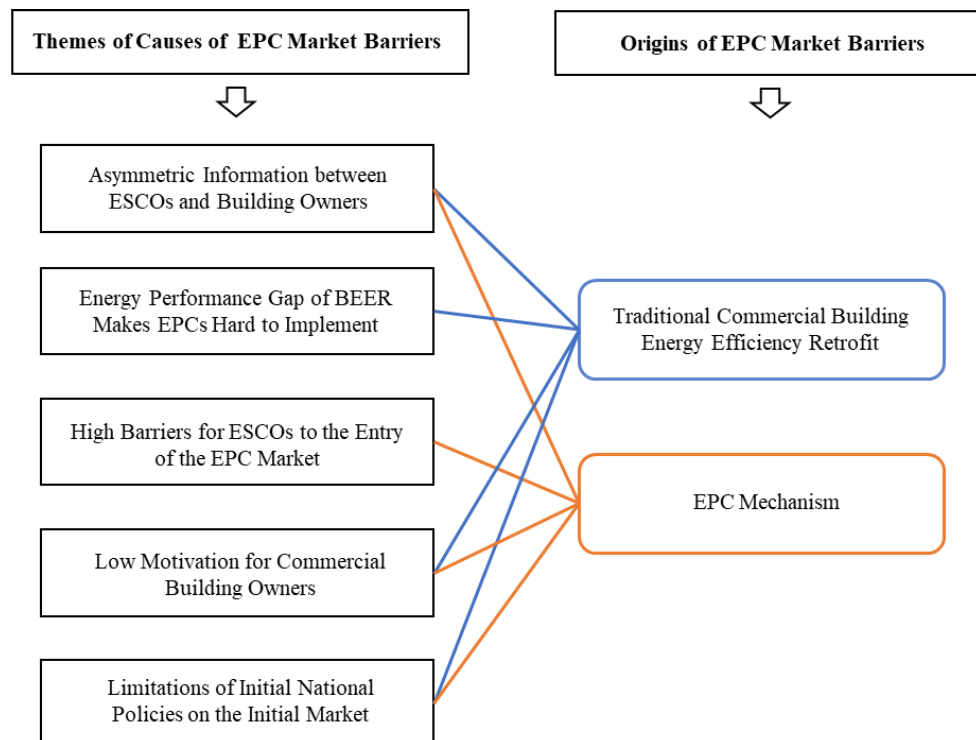


Figure 7-7 Causes and origins of EPC market barriers

In the theme “asymmetric information between ESCOs and building owners”, four sub-themes originate in EPCs. Firstly, the free rider problem happens when building owners want to make use of EPCs and let ESCOs undertake more responsibility for retrofits than the proposed scope of work. As a result, the building owners cause negative externalities to the ESCOs. The cause of the problem is incomplete information. Secondly, the sub-theme “EPC is a new concept for building owners” makes it very hard to use EPCs. The cognition problem makes it difficult for building owners to accept EPCs. Thirdly, the sub-theme “incomplete contracts” shows that without identifying all the uncertainties in the contract, the contracting parties feel unsafe to use EPCs. The last sub-theme “credit risk building owners” is taken as the major worry of ESCOs. In contrast to the traditional CBEER, ESCOs need to invest in the retrofits under EPCs and the energy saving benefits are paid by the building owners to the ESCOs based on the saved energy. The payment behaviour and the decision changes from the building owners will significantly influence the benefits to the ESCOs. Therefore, this is a big barrier for ESCOs.

In the theme “low motivation for commercial building owners”, two sub-themes originate in EPCs. The sub-theme “companies who have ability to do BEER tend to retrofit their buildings by themselves” identified those companies who have ability to do BEER are not the target of EPCs. They want to receive all the energy saving benefits. Those companies are also the main stream of companies that want to improve energy efficiency in traditional CBEER. The other sub-theme “separation of property rights and management rights” states the problem occurring between ESCOs and the building owners (in most situations, particularly the facility managers). Under EPCs, the ESCOs are involved in more activities of maintenance than in traditional CBEER. There are more conflicts between ESCOs and the facility managers. Although the building owners cooperate with the ESCOs, without transferring the rights of property management to the ESCOs completely, the ESCOs feel it difficult to implement a project.

In the theme “limitations of initial national policies on the initial market”, two sub-themes originate in EPCs. One is “initial national subsidies limit EPC Business Model Innovation” and the other is “discontinued national subsidies impact the initial market”. The initial subsidies award the EPC projects using the shared energy saving business model, which incentivised the building owners significantly by shifting risks to the ESCOs. The limited business model of EPCs facilitates the theme “high barriers for

ESCOs to the entry of the EPC Market” because the ESCOs need to take all the responsibility of financing. When the subsidy was stopped, the motivations of both the building owners and the ESCOs to use EPCs decreased.

In the 25 sub-themes originating in CBEER, by undertaking EPCs, there are 18 sub-themes where significant risks are transferred partly or fully from the building owners to the ESCOs. It can be seen that EPCs increased the motivation of the building owners by transferring their risks of undertaking CBEER to the ESCOs. The increase of risks to ESCOs makes EPCs harder to implement and creates higher challenges for ESCOs. In the 11 sub-themes from the EPC mechanism, nine have ESCOs as the risk bearers, and only three of them add risks to building owners. The two remaining sub-themes are an incomplete contract and annulled national subsidies. The contract serves as a binding instrument for both contracting parties. The incomplete contract will influence both building owners and ESCOs due to the uncertainties that could be identified completely in their contract. Similar to the annulled national subsidies, unstable policies would increase the uncertainties of the benefits for both the building owners and the ESCOs.

7.8. Summary

This chapter discussed the themes corresponding to market barriers on the uptake of EPCs by thematic analysis based on interview responses. There are five themes identified: 1) asymmetric information between ESCOs and building owners; 2) energy performance gap of BEER makes EPCs hard to implement; 3) high barriers for ESCOs to the entry of the EPC Market; 4) low motivation for commercial building owners; and 5) limitations of initial national policies on the initial market. These themes offer the evidence for EPC market barriers, which are reviewed in the next chapter with particular attention to whether they qualify as market imperfections or not according to the four perspectives of market imperfections.

Chapter 8 Theory Test and Theoretical Policy Design

8.1. Introduction

The previous chapter analysed and discussed the reasons or themes behind the market barriers of energy performance contracts (EPCs). These reasons imply strong characteristics of market imperfections. This chapter further discusses how these themes connect with the theories of market imperfection. The purpose is to test if the EPC market is an imperfect market in terms of economic theory, which would mean that prices are higher, and the quantity sold lower than in a perfect market. If the argument is valid, a following theoretical analysis of government intervention deals with those market imperfections.

8.2. Testing whether the EPC Market is an Imperfect Market

The theories of market imperfections discussed in Section 2.3 explain how market failures happen in a particular situation from four perspectives: incomplete information, market power, externalities and public goods. Based on the empirical findings in Chapter 6 and Chapter 7 from the questionnaire survey and interviews, this section tests how these findings support the overall hypothesis that the EPC market exhibits characteristics of market imperfections as defined in economic theory.

The testing follows the four perspectives of the theories of market imperfections. The sub-hypothesis that the barriers to the EPC market correspond to the characteristics of public goods is not accepted. The other three sub-hypotheses that barriers to the EPC market correspond to the characteristics of incomplete information, market power and externalities are accepted. The overall argument is the EPC market is an imperfect market with the characteristics of incomplete information, market power and externalities. The overall linkage between the empirical findings of EPC market barriers and the theories of market imperfections is shown in Figure 8-1. Following is the detailed analysis.

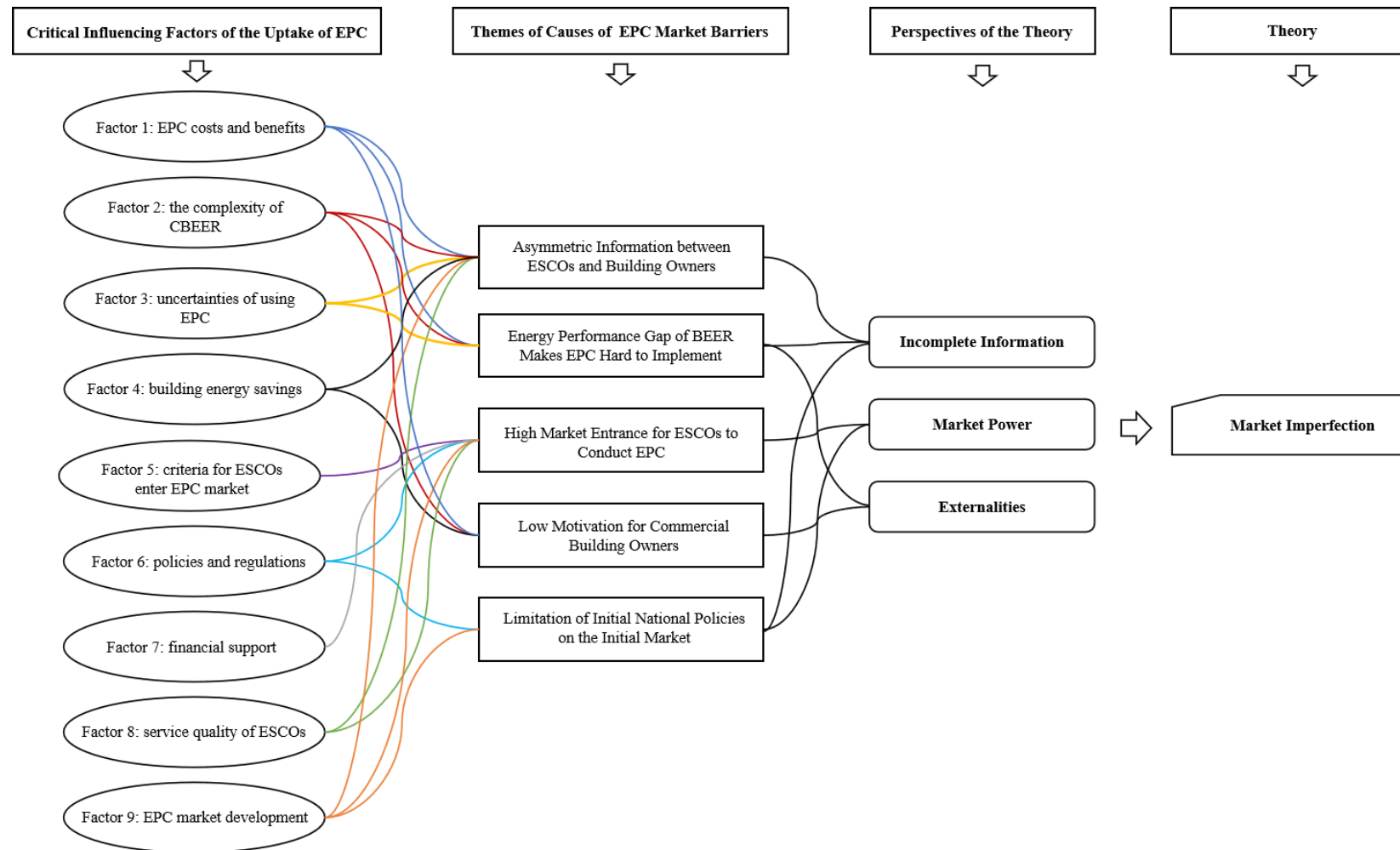


Figure 8-1 Overall linkage between empirical findings of EPC market barriers and theory of market imperfections

8.2.1. Hypothesis 1: Incomplete Information

Hypothesis 1 that the EPC market exhibits the characteristics of incomplete information as defined in economic theory is accepted.

Incomplete information happens when two economic agents undertake a transaction under uncertainty, and it is quite possible that they will have different information about it. One party is likely to be better informed than the other about things that bear directly upon the transaction. The asymmetry makes it more difficult and perhaps even impossible to complete the transaction. This research is based on the concept of incomplete information defined by Giraudet (2020) in his economic research related to energy efficiency as part of the information needed to make a decision is missing and the contracting parties face asymmetric information. In this research, the interview findings show that the EPC market exhibits the characteristic of the theoretical concept of incomplete information.

Incomplete information is part of the reason for the low uptake of EPCs in the commercial building sector. Three themes contribute to this:

- asymmetric information between building owners and ESCOs.
- the energy performance gap of BEER makes EPCs hard to implement.
- limitations of initial national policies on the initial market.

The contracting parties (building owners and ESCOs) hold different professional knowledge and have different priorities and requirements for BEER in the long term. There is a considerable transaction cost in the process of contract negotiation. Chapter 2 reviewed three types of incomplete information. The empirical data show that the three themes show the issue of incomplete information comes from two of the aspects: lack of knowledge from one side of contracting parties and uncertainties.

From the empirical findings, under EPCs both building owners (consumers) and ESCOs (suppliers) suffer from a lack of information or knowledge. The complex relationship of all EPC stakeholders aggravates the asymmetry of information between the contracting parties (building owners and ESCOs) (see Figure 8-2). Meanwhile, as EPCs have a long maintenance period and energy savings as benefits are the responsibility of ESCOs, more

risks caused by asymmetric information are transferred from building owners to ESCOs. As a result, ESCOs are in weak position under EPCs. This is different from normal energy efficiency projects (without using market mechanisms like EPCs) where consumers (building owners) are always in a weak position.

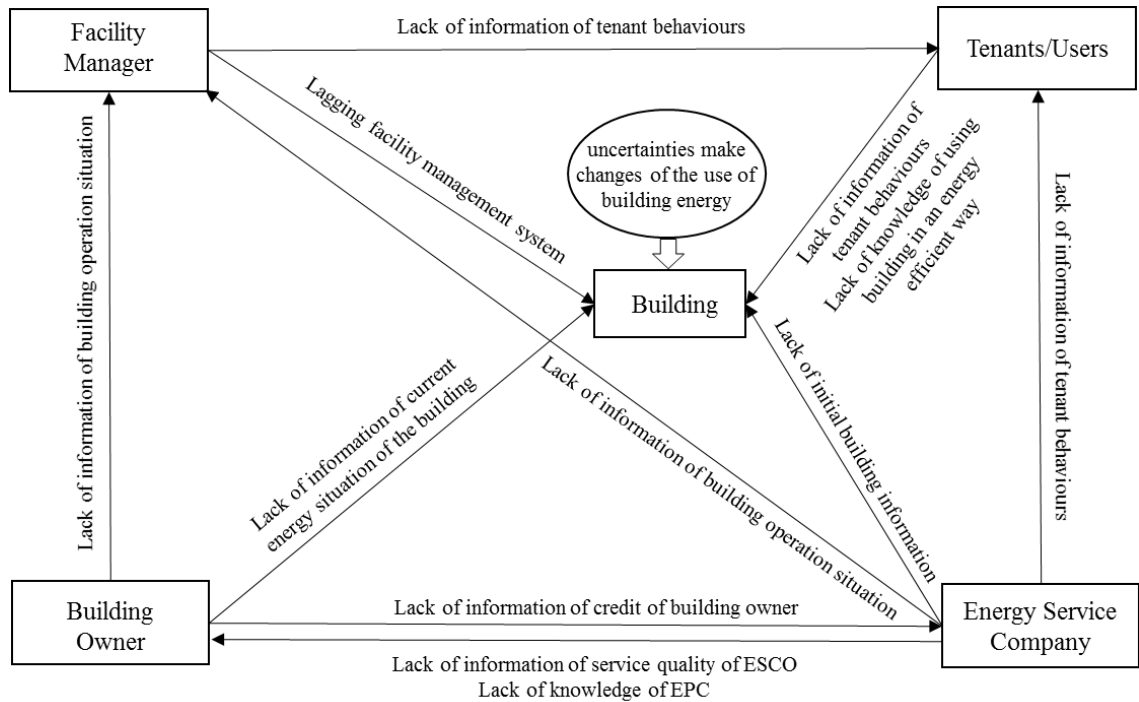


Figure 8-2 Asymmetric information in complex relationship between EPC stakeholders

Figure 8-2 shows building owners and ESCOs are the centre of the EPC transaction. They are the subjects of the EPC contract. The facility managers operate the building and assist the ESCO with the EPC projects. Sometimes, the facility managers are the building owners themselves. In some cases, building owners transfer their rights to the facility managers and let them sign an EPC contract with the ESCOs. The tenants or users pay rent to the building owners and a property management fee to the facility managers. If the building owners use the building themselves, the building owners and users are the same. The utility bill may or may not be included in the property management fee. Each of these relationships can be subject to a variety of asymmetric information. As a result, adverse selection and principal–agent problems happen frequently.

First of all, the lagging facility management system makes all the stakeholders lack information on the existing buildings. Secondly, ESCOs lack knowledge about the initial information of the buildings (including the basic information of architectural and HVAC design, energy consumption information and building operation information) and of the building owners (including business operation, credit information and mechanism of facility management). This makes it hard for ESCOs to set a confirmed baseline for BEER and causes adverse selection problems under imperfect screening when selecting suitable EPC projects. In some situations, the ESCOs take more responsibility for the retrofits that are not included in the retrofitting boundary, which causes “free rider” problems benefitting the building owners. In practice, some stakeholders mistakenly blame this type of problem on the “free rider” issue. This is normally categorised in the issue of “public goods” in economic theory (see Section 2.3.3), but does not fit the situation in this case. However, this type of problem in this situation is caused by asymmetric information, which is strictly classified in economic theory as an issue of incomplete information.

Thirdly, building owners lack information on the service quality of the ESCOs and knowledge of EPCs. The energy saving rate is an important perspective to evaluate ESCOs, but it is also the trigger for the adverse selection problem under imperfect signalling. Besides, this can be used by ESCOs as a tool for price discrimination and lead to the principal–agent problem. Meanwhile, the basic information of the existing buildings and uncertainties during the implementation of the projects make the baseline of BEER harder to confirm and the final benefits even harder to estimate, which has been defined as the problem of the “energy performance gap” (Bukarica & Tomšić 2017; Fedoruk et al. 2015; Liang, Qiu & Hu 2019).

EPCs were designed to encourage building owners to conduct BEER because the costs of using EPCs to conduct energy efficiency retrofits are less than costs of normal retrofitting projects without using EPCs for building owners. An energy efficiency service under an EPC is offered to building owners at an extremely low price. A small number of building owners decide to use EPCs because the price they pay for CBEER under an EPC is very little. However, the inherent cognition of building owners makes most of them still hesitate to take up EPCs. They do not trust this new mechanism because the uncertain benefits that are tightly influenced by energy savings. Meanwhile, another concern is that

the price paid by building owners is uncertain due to the unstable energy savings influenced by multiple factors introduced in Chapter 7. Further, the incomplete information makes the transaction costs even higher than normal energy efficiency projects without using EPCs.

Although EPCs lower the entry level for building owners to save energy, they transfer the responsibility to the ESCOs and even cause negative effects for ESCOs. In normal retrofitting projects without using EPCs, the costs ESCOs pay are the costs of retrofits and a small amount of transaction costs. However, by using EPCs, having such incomplete information, the price is totally dependent on the final energy savings (energy price is given), and the costs that ESCOs pay are the costs of retrofits and higher transaction costs. In some extreme cases, the building owners use EPCs not for the purpose of energy efficiency but for the purpose of upgrading their old equipment to make sure the building functions well. As the old equipment is not fully operational, the current energy consumption is less than the normal level. As a result, the potential energy savings are less than the estimated energy savings by the ESCOs. Thus, the costs that ESCOs pay are higher. In this case, ESCOs are in a very weak position and suffer from the negative externalities caused by the building owners. This kind of problem is caused by asymmetric information.

With these uncertainties, contracts of EPC projects are imperfect. Although the contract can set the rights and obligations of the contracting parties, the side that has more information about the projects would have the advantage. The problem of asymmetric information has already had the government's attention for over ten years. Although the central government sponsors building energy information platforms, the platforms are not maintained very well. Especially for commercial buildings, the energy information platforms are not fully developed. Some platforms can only be used by the government but not the building owners and ESCOs. Based on the above reasons, the willingness to use this mechanism is sub-optimal.

8.2.2. Hypothesis 2: Market Power

Hypothesis 2 that the EPC market exhibits the characteristics of market power as defined in economic theory is accepted.

Market power occurs when the sellers or buyers can affect the price of the products in the market (Pindyck & Rubinfeld 2009). Based on the interviews, two themes contribute to this:

- high barriers for ESCOs to the entry of the EPC Market.
- limitations of initial national policies on the initial market.

The empirical data clearly show that the EPC market conforms to the characteristic of market power.

The EPC mechanism is naturally a monopolistic competition market, thus the ESCOs can offer differentiated services under EPCs to achieve energy efficiency of buildings and it is easy for any ESCO to enter or leave the market. Neither ESCOs nor building owners can influence the price of using EPCs. The price that building owners pay here is equal to the energy saving benefits the ESCOs can receive, which is equal to energy prices multiplied by the energy savings. Energy savings are dependent on the potential energy savings of each commercial building, which are greatly influenced by the service ability of ESCOs. Offering an energy efficiency service requires ESCOs to have a comprehensive energy efficiency service capacity and access to capital. However, limited ESCOs meet all these requirements and have enough market completeness. As a result, some big ESCOs are leading the market and have a large market share, as identified through interviews. Due to resource limitations this research could not find specific data on the overall market to support this.

In Chapter 3 Section 3.4.1, the literature review showed there are over 7,000 ESCOs in China, while the empirical data showed that many ESCOs no longer undertake EPCs as their main business after the national subsidies were discontinued. The ESCOs left are the companies that not only need to have strong technical skills or R&D background but also a great amount of capital support. Although the government provided subsidies at the beginning to form the EPC market, light-asset companies found it difficult to survive

without access to capital. At the very beginning, ESCOs could enter the market freely, while now it is considerably harder for small-size ESCOs to enter the market. Although there are no particular requirements set by the government, the market entry barriers are now higher than at the time when the EPC mechanism was first established. Access to capital actually is the invisible barrier for potential entrants. This situation is caused by the financial system in China. Banks are reluctant to offer financing for ESCOs to conduct EPC projects. Facing the difficulties of finance, small ESCOs have higher financing costs for EPC projects than for normal energy efficiency projects which do not use EPCs. In this situation, substantial market power is emerging as defined in economic theory, favouring a few large firms.

8.2.3. Hypothesis 3: Externalities

Hypothesis 3 that the EPC market exhibits the characteristics of externalities as defined in economic theory is accepted.

An externality as defined in economic theory is when consumption or production has an indirect effect on other consumption or production activities not directly reflected in the market (Pindyck & Rubinfeld 2009).

The findings from interviews show that the EPC market conforms to the characteristic of externalities.

Two themes demonstrate the effects of the externalities of using EPCs:

- the energy performance gap of BEER makes EPCs harder to implement
- low motivation for commercial building owners.

Overall, externalities exist at three levels in the EPC market:

- business operation in the buildings will cause building energy consumption and carbon dioxide emission, which is a negative externality for the environment (as explained in Chapter 2 Section 2.3.3, the environment is classified as a common resource in the market) and human beings

- the activities of CBEER cause externalities to economic subjects that do not receive corresponding benefits but pay for any inconveniences
- by using EPCs, some externalities arise when building owners make use of ESCOs conducting additional works and getting additional benefits when they conduct CBEER under EPCs, in which building owners do not pay for any inconveniences created for ESCOs.

In the first level of externalities, energy consumption in commercial buildings causes negative externalities to the environment. Not all building owners have the perception that they have the responsibility to save energy, which is identified in the theme of low motivation for commercial building owners. Low energy price and limited energy saving benefits from commercial buildings are the two main barriers to conducting CBEER by building owners. Bukarica & Tomšić (2017) stated that energy efficiency services can deliver better living conditions to the public, however markets tend to undersupply the services as they are unpriced.

In this research, the energy price is taken as given. In the scope of this research, the energy suppliers are not included, but it is the background for EPC transactions. The energy sector was taken as an oligopolistic system because energy as a commodity is supplied by a few major suppliers. Governments spend great efforts on the liberalisation of the market. Therefore, “electricity prices are structured by electricity producers and regulators” (Bukarica & Tomšić 2017, p. 970). In this research, the ESCOs and the building owners are the end users of the energy sector and must therefore take the energy price as given. The low energy price compared to other operational costs does not incentivise the building owners properly to save energy based on the empirical findings. That EPC is not used widely can also be explained by low interest in saving energy due to the low price of energy. Although the energy price of commercial buildings has already been regulated by the government to be higher than the energy price of other types of public buildings and residential buildings, it is still far too low to motivate the building owners. Thus, low energy price is the basic reason to explain the low motivation of building owners.

Although building owners paying for CBEER services is a way to partially internalise the negative externalities to the environment, it may cause additional externalities to the other economic agents: tenants. This is the second level of externalities. The separated rights in managing and using commercial buildings are significantly contributing to the second level of externalities, which has been identified in the theme of low motivation for commercial building owners.

The third level of externalities comes from the EPC mechanism, which brings additional externalities to ESCOs. In traditional projects purchasing CBEER services, building owners pay for the services of CBEER. In contrast, under EPCs, the ESCOs undertake CBEER for the building owners not only in the form of professional services but also in the form of investment. The responsibilities the building owners should take in traditional CBEER projects for the adverse environmental and human health effects of energy consumption are transferred to the ESCOs. ESCOs have to bear the consequence of “energy performance gap”, some of which is caused by changes in building use by the building owners. Any activity that leads to changes of energy consumption by building owners would cause a change in the level of externalities. As a result, when ESCOs have equal project opportunities they prefer to choose traditional CBEER or energy trusteeship projects rather than EPC projects.

What is more, the EPC mechanism makes the issue of separated ownership even more significant than it is in traditional CBEER projects because EPC projects have a long period of energy maintenance for investment pay back. To ensure energy savings, an EPC needs a long period of cooperation between facility managers and tenants. As the contract is signed only by the building owner and ESCO, there are no energy saving benefits to be shared with the facility managers and tenants, but the operation of the building energy system by the facility managers and the energy usage behaviours by the building users will influence the final energy saving benefits to some extent. Although there are no compulsory requirements when implementing an EPC, there are many rules to follow. As there is no direct incentive for EPCs, it is hard to achieve their promise. The problem of split incentives is significant. In this situation, both building owners and ESCOs in the interviews reflected that using EPCs requires much negotiation by the parties. As a result, the cost of negotiation makes the contract very hard to settle.

8.2.4. Hypothesis 4: Public Goods

Hypothesis 4 that the EPC market exhibits the characteristic of public goods as defined in economic theory is not accepted.

The interview findings did not show the EPC market conforms to the significant characteristic of public goods. Although during interviews some participants called some issues a “free rider” problem, it is different from the definition of “free rider” in economic theory (which was introduced in Chapter 2). The essence of these superficial “free rider” problems is caused by incomplete information discussed in Section 8.2.1 and shows the consequence as externalities discussed in Section 8.2.3 as “the third level of externalities”.

8.3. Theoretical Solutions to EPC Market Imperfections

The previous section analysed that the barriers to the EPC market identified through surveys and interviews correspond to three typical aspects of market imperfections as defined in economic theory: incomplete information, market power and externalities. This section discusses the methods and the rationale for policies to deal with the market barriers from these three types of market imperfections. This theoretical policy design can be used as a reference to design detailed incentive mechanisms for the EPC market.

The market imperfections (as identified in Chapter 7 and Chapter 8 Section 8.2) can be dealt with by targeted government policies and careful contract design of EPCs between transaction parties. Government policies are the critical methods to deal with market failures, as discussed in Chapter 2. The contract design of EPC aims to deal with the imperfections caused by incomplete information especially the uncertainties within CBEER. Proper risk management and risk allocation can assist the transaction parties to better conduct CBEER under EPCs. Since this research focuses on the macro energy efficiency market and aims to discuss how to improve the uptake of EPCs through government intervention, the issue of risk management within the transaction parties is outside the scope of the research and is not discussed in depth. Figure 8-3 shows the overview of theoretical policy design to deal with EPC market imperfections. The following sections elaborate how each market imperfection can be dealt with by government intervention.

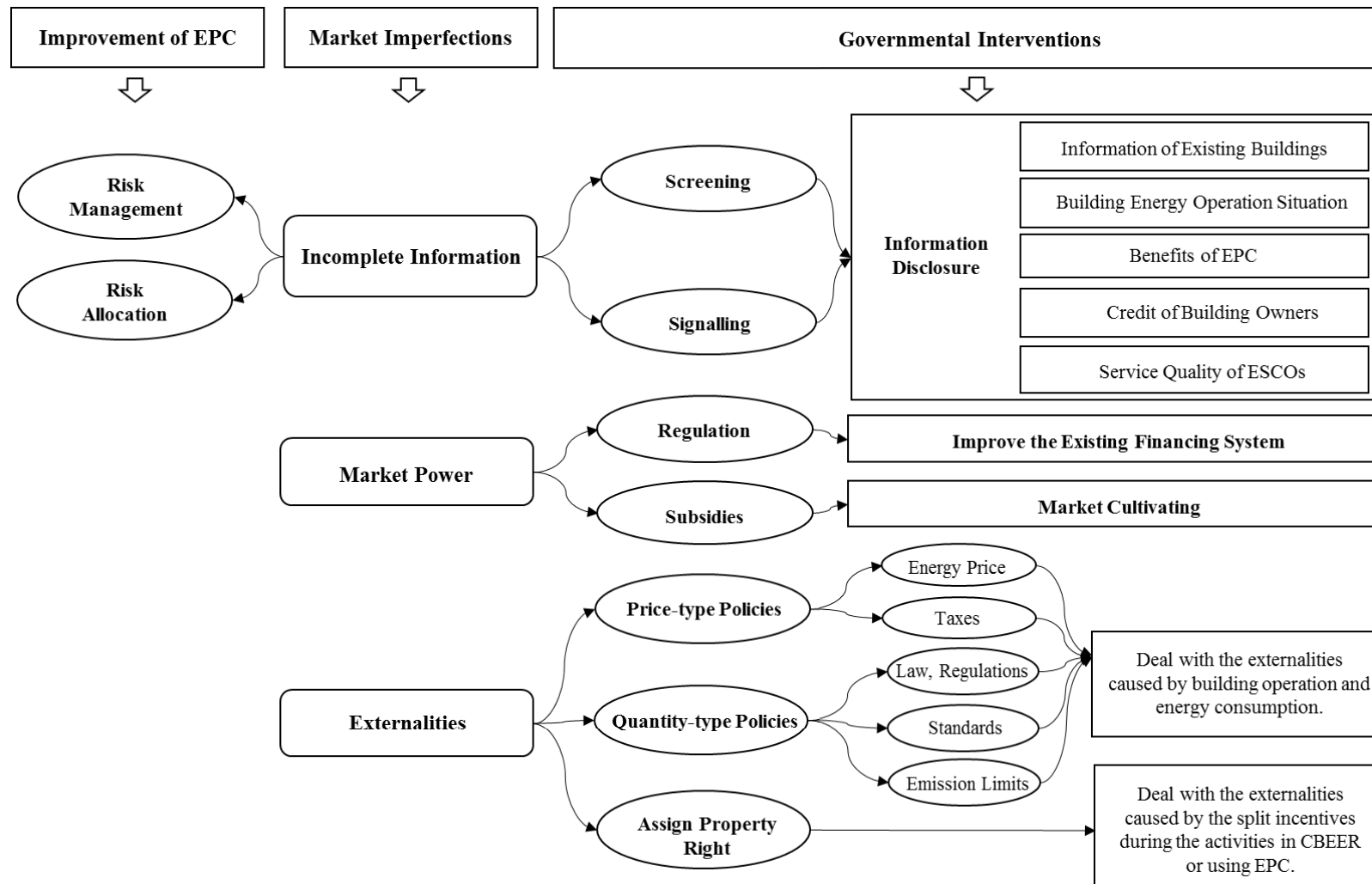


Figure 8-3 Theoretical solutions to EPC market imperfections

8.3.1. Policies for Incomplete Information

Theoretically, there are two types of methods to overcome incomplete information: screening and signalling. In any situation where information is incomplete, economic agents with less information have an incentive to obtain more. Screening is defined as activities in which an agent can obtain more information from the other agent (Tandon 2015). Activities that credibly reveal the agent's type are called signalling (Tandon 2015). A signal is an effective way to solve the problem of asymmetrical information (Li, Liu & Ma 2011).

In this research, fully disclosed information about the existing buildings and building operation is the most important method to remedy the asymmetric information between building owners and ESCOs as a signal method. It would be better to monitor the building operation situation and tenant behaviours for a more precise estimation of energy savings and a better adjustment of the energy efficiency scheme to deal with changes of energy use. These two methods can significantly limit the “energy efficiency gap”. As a result, clearer and more certain benefits of using EPCs could be shown by demonstrating and publishing successful EPCs.

Meanwhile, in order to avoid the credit risks identified in Section 7.2.6, it is necessary to have a credit system that discloses the credit information about building owners, which could act as a signal method offered to ESCOs. In turn, in order to ensure the service quality of ESCOs identified in Section 7.2.5, building owners should be able to access information disclosure about the service quality of ESCOs. At the same time, the quality of facility management system could also be improved.

From an operational perspective, developing information disclosure systems requires significant costs and efforts from the parties searching for and displaying the information. This cannot be fixed by the market itself. Therefore, the government needs to publish related building energy regulations to assist the market to offer screening ways and reasonable signals (Li, Liu & Ma 2011). Li, Liu & Ma (2011) suggested the government could also provide a transaction platform to help the transaction parties to use “screen” and “signal” methods.

8.3.2. Policies for Market Power

Economic regulation (price regulation) and antitrust laws are the common methods a government can use to decrease market power and move a market closer to the competitive ideal (Winston 2007). Direct price regulation is always the method for the control of a monopoly by setting more efficient prices for the monopoly provider (Pindyck & Rubinfeld 2009; Winston 2007). Antitrust laws are another method by which the government can make interventions against a firm that monopolises a market and uses its market power (Winston 2007). It is a set of rules and regulations set to prohibit actions that restrain, or are likely to restrain, competition (Pindyck & Rubinfeld 2009).

In this research, the market power developed because of the market environment (necessity to undertake transaction), for example, a restrictive financing system. One way of overcoming this would be improving the existing financial system by regulating, so that future energy savings are accepted as loan securities. This would remove one of the barriers to market entry for ESCOs. However, as EPCs need ESCOs that have comprehensive skills for CBEER as well as abilities in research and development, there are a limited number of ESCOs qualified to undertake EPC projects. Methods of increasing the size of the market can decrease the existing market power directly. At the same time, subsidising research and development in public research and publishing for ESCOs can decrease the costs of technological development. From an operational perspective, the government or related industry association are able to offer assistance to cultivate the market, so a large number of companies with comprehensive strength emerge.

8.3.3. Policies for Externalities

As discussed in Chapter 2, externalities in economic transactions affect those who are not parties to the transactions themselves, which creates welfare losses to society. The fundamental problem with externalities is that they are typically not mediated by any market. Government interventions are necessary to correct it and can remedy an externality by either requiring or forbidding certain behaviours or by internalising external costs (Mankiw 2020), including price-type policies such as energy price, taxes or fees and quantity-type policies including law, regulations, standards and emission limits/or quotas (Tandon 2015).

Low energy price has been identified as one of the reasons for building owners' low motivation to conduct CBEER in the current situation (see Section 7.6.4). From a long-term perspective, energy price policy should be an efficient way to directly improve building owners' motivations for energy efficiency (Ju et al. 2017). Bukarica & Tomšić (2017, p. 971) stated that the right price signals to consumers in the energy efficiency market can reflect changes in pollution costs, which could lead to more energy efficiency activities. This addresses the externalities in the first level identified in Section 8.2.3: the externalities caused by building operation and energy consumption.

There is an alternative way to deal with this type of externalities. This is a series of methods. First, developing building owners' consciousness of energy savings is necessary to start energy efficiency, for example, by regulating the energy conservation activities by building owners. Second, it is necessary to set a clear limit on energy consumption. Lastly, taxes may be used to reduce overuse of energy.

From the perspective of the Coase Theorem (Coase 1960), an alternative way of dealing with externalities is to assign property rights clearly and reduce or eliminate transaction costs. This method can be used to deal with the externalities in the last two levels identified in Section 8.2.3: the externalities caused by the split incentives during the activities in CBEER or using EPCs.

8.4. Summary

This chapter tested that the empirical EPC market has the characteristics of a theoretical imperfect market with incomplete information, market power and externalities. The issue of externalities of energy consumption is the basic problem of lacking motivation to conduct CBEER in the market. Although the EPC mechanism is designed to internalise the externalities, there are still many barriers that could not be solved due to the major issues of incomplete information and market power. To eliminate these three types of market imperfections, multiple policies are put forward according to the theoretical analysis. The next chapter analyses the detailed policies and strategies to incentivise the EPC market in the actual Chinese context.

Chapter 9 Incentive Strategies for the EPC Market

9.1. Introduction

The previous chapter examined the nature of the energy performance contract (EPC) market in China and put forward theoretical policy design to overcome the market imperfections. This established the theories and laid the groundwork for a better understanding of the overall environment of the EPC market. This chapter discusses the detailed policies and strategies that could be implemented in the actual context of the Chinese market. It focuses on how to smooth transactions among the market stakeholders under EPCs to realise the energy efficiency target. It develops a detailed incentive mechanism for the EPC market considering the concept of transaction costs. It aims to reduce the transaction costs due to the market barriers to EPCs identified above and to propose policy packages accordingly. It starts with discussions about the potential measures for the take up of EPCs from the interview findings, then a detailed incentive mechanism is developed. It closes with three case studies to verify and modify the proposed incentive mechanism through abduction.

9.2. Potential Incentive Strategies Investigated from Interviews

In the last chapter, Section 8.3 discussed theoretical policy design to deal with EPC market imperfections. To show the effect of policies and to evaluate if policies can deal with EPC market imperfections appropriately, the concept of transaction costs is applied to analyse detailed incentives in this section.

As introduced in Section 2.5.2, the scope of this research applying the theory of transaction costs is the transaction of CBEER under EPCs, and the purpose of the policy design is to increase transactions between building owners and ESCOs. The increase of transactions can be achieved by decreasing transaction costs. The policy design should consider three perspectives to decrease the transaction costs from asset specificity, uncertainty and frequency. The essence of decreasing transaction costs is to decrease the

asset specificity and uncertainties and increase the frequency (according to the analysis from Section 2.5.4). This principle is used to investigate the potential incentive strategies from interviews in this section.

On the whole, all the interviewees agreed on government responsibility as “the government needs to undertake social responsibility of energy saving and its role is to serve the public and social sides and develop a good environment (or regulate the market) for economic parties during the transactions” (IE4, Gov4). Social responsibility is often discussed with cooperation as a voluntary practice (Duan et al. 2022). Ji & Miao (2020) found that corporate social responsibility in developing countries may not enhance collaborative innovation, while both direct and indirect government support could enhance the positive effect of environment corporate social responsibility. Both the empirical findings and literature review show that the government play an important role in environmental issues like energy savings. The 21 potential incentive strategies identified from interviews were ranked according to the frequencies with which they were mentioned during the interviews and listed in Table 9-1. These potential incentive strategies are categorised for dealing with the four perspectives of market imperfections and analysed based on the theoretical determinants of transaction cost in the following sections.

9.2.1. Strategies for Incomplete Information

To deal with the issue of incomplete information, nine potential incentive strategies are identified. These incentive strategies aim to deal with four general types of incomplete information (according to the two themes identified in Sections 7.2 and 7.3) and can contribute to the three determinants of transaction costs (which is the conceptual framework of transaction costs in the institutional economics introduced in Section 2.5.5). Figure 9-1 shows the relationship between the incentives related to incomplete information and the determinants of transaction costs.

Table 9-1 Potential incentive strategies

No.	Potential Incentive Strategies	Corresponding to the Issue of Market Imperfections	Determinants of Transaction Costs (TCs)	Frequency
1	Government subsidies	Externalities	Frequency	42
2	Government support and policy guidance	Externalities	Uncertainty; Frequency	39
3	Law, regulation and standard	Externalities	Asset Specificity; Uncertainty; Frequency	32
4	Third-party assessment	Incomplete Information	Uncertainty; Frequency	28
5	Financial support	Market Power	Asset Specificity	27
6	Education and advertising	Incomplete Information; Externalities	Asset Specificity; Frequency	18
7	Information disclosure	Incomplete Information	Asset Specificity; Uncertainty; Frequency	16
8	Building energy information sharing platform	Incomplete Information	Asset Specificity; Uncertainty; Frequency	15
9	Pilot EPC cases	Incomplete Information	Asset Specificity; Frequency	11
10	Play the role of industry association	Market Power	Asset Specificity; Frequency	11
11	Building energy performance benchmarking and disclosure	Incomplete Information; Externalities	Asset Specificity; Frequency	10
12	Standardised EPC contract	Incomplete Information	Asset Specificity; Uncertainty; Frequency	10
13	Successful cases	Incomplete Information	Asset Specificity; Frequency	8
14	Tax policy support	Externalities	Frequency	6
15	Government award	Externalities	Frequency	5
16	Energy insurance	Incomplete Information; Externalities	Uncertainty	4
17	Energy consumption quota push the market	Externalities	Frequency	4
18	Compulsory building energy audit for all existing commercial buildings	Incomplete Information	Asset Specificity; Uncertainty; Frequency	4
19	Enterprise qualification	Incomplete Information	Asset Specificity; Uncertainty	4
20	Credit system improvement	Incomplete Information; Market Power	Asset Specificity; Frequency	3
21	Pledge guarantee	Market Power	Frequency	2

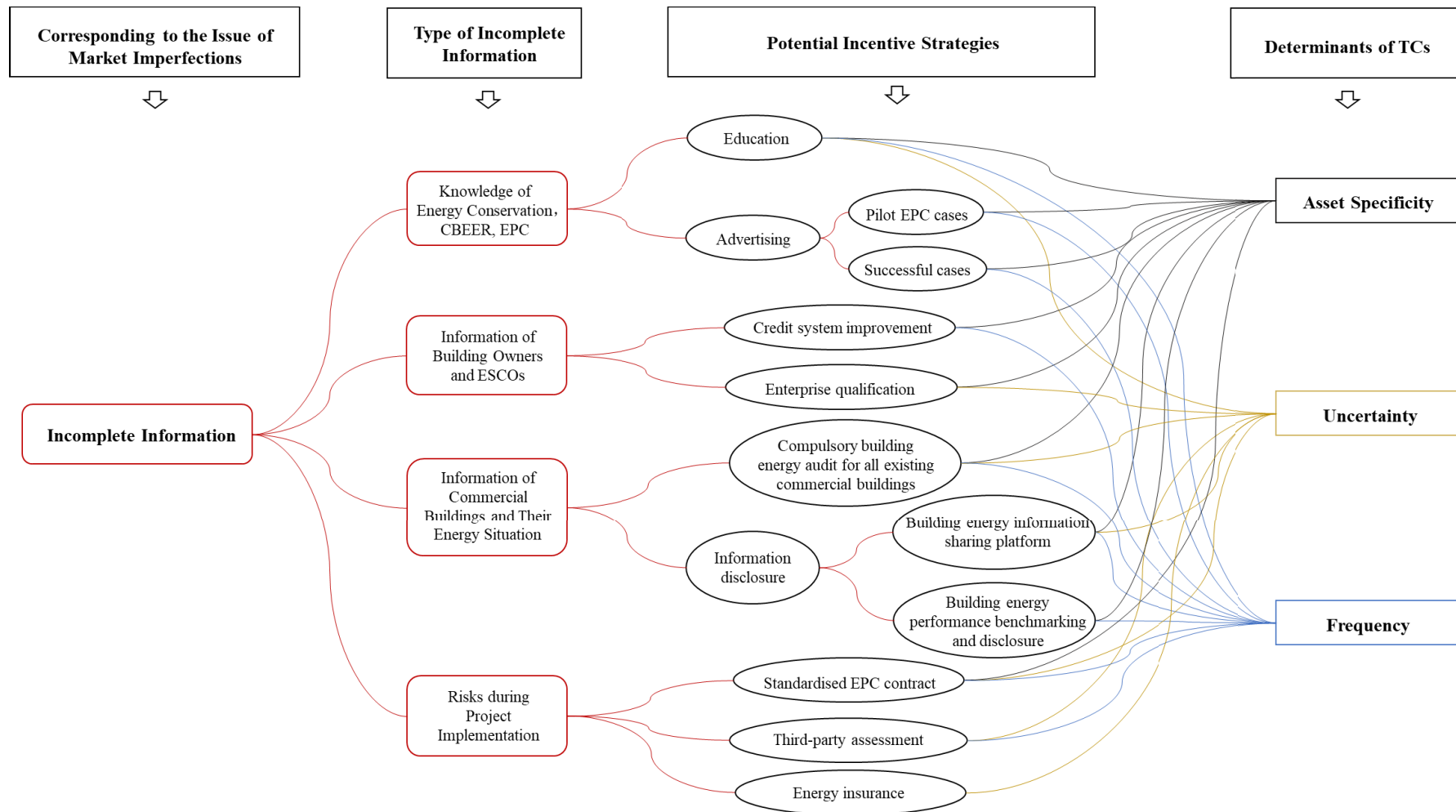


Figure 9-1 Relationship between incentive strategies addressing incomplete information and determinants of transaction costs

(1) Knowledge of Energy Conservation, CBEER and EPCs

There are two strategies identified to limit the gap of knowledge of energy conservation, CBEER and EPCs. They are education in general, and advertising of pilot and successful EPC cases.

(a) Education

Education and advertising are very important for conducting CBEER and using EPCs (IE3). The interviews show that the purpose of education is to popularise the concepts of energy conservation and building energy efficiency and improve building owners' consciousness of energy conservation. This can be used to further deal with the issues of externalities. It is a way to help the building owners build the concept of having the responsibility of saving energy. This can deal with the market imperfections that energy efficiency under EPCs has negative externalities. Education of building owners can be conducted through four ways: government, industry, enterprise and social media.

Although the concepts of 'low carbon', 'energy conservation' and 'carbon emission' have been broadcast a lot from the government to the social media, there is still little content about the benefits of energy conservation for commercial building owners (BO7, ESCO8, IE1, IE3). For example, a campaign called "good building initiative in China" was launched by the China Association of Building Energy Efficiency (CABEE 2020). The campaign ('good building initiative in China') is "a volunteer emission reduction action in the industry. It motivated building owners to commit themselves to reduce energy emissions of their buildings. In this way, more building owners had awareness to conduct BEER" (IE1). Through education, the frequency of CBEER can be increased directly.

(b) Advertising

The purpose of advertising is mainly to popularise the concept of EPCs to building owners. However, "the current advertising strength of EPC is a little bit weak" (ESCO7). The benefits of EPCs and how EPCs contribute to building energy efficiency and building owners are still unclear in the market and it needs the government and industry association to advertise EPCs strongly (BO5, ESCO2, ESCO3, ESCO4, IE1). Meanwhile, the ESCOs also need to strengthen their ability in marketing and develop their own brands in the

market (IE4). Strengthening the advertising of EPCs can decrease the transaction costs of searching information directly and increase the frequency of using EPCs for CBEER gradually. There are two ways for advertising: pilot EPC cases and successful EPC cases.

Pilot EPC cases have played an important role in advertising EPCs to building owners. Pilot cases aim to increase building owners' knowledge of EPCs and show the experience to ESCOs. The purpose is to deal with the incomplete information problem. Most of the building owners knew about EPCs through the pilot EPC cases the government published (BO1, BO2, BO6). "The pilot commercial building energy efficiency retrofit program" implicated in China (introduced in Chapter 3) demonstrated that the commercial building retrofit market has been incentivised and cultivated (IE4), which was also demonstrated by Hou et al. (2016). The interviewees from government stated the main objectives of pilot projects are promoting EPCs to foster deep energy savings, getting real experience from the market, promoting communication and creating business cooperation opportunities in the market (Gov1, Gov2, Gov3). Pilot EPC cases are a good way to develop the knowledge of CBEER under EPCs for the building owners and share experience to ESCOs (BO5, ESCO5). Especially in the initial market, it is a good way to open and promote the market (IE3, IE4). Therefore, pilot EPC cases can increase the frequency of using EPCs for CBEER directly and decrease the asset specificity the ESCOs invest in advertising EPCs and communicating within the market.

Similar to pilot EPC cases, successful EPC cases are a good way to advertise EPCs and CBEER. Most of the building owners and some of the ESCOs stated that the successful cases encouraged them to try EPCs and gave them more confidence (BO4, BO7, ESCO5, ESCO7). Some building owners even introduced other building owners to try EPCs after their own EPC projects were successful (BO5, BO6). "Successful cases show EPC is a beneficial way to conduct CBEER and motivate the stakeholders who are still hesitating to conduct CBEER through EPC" (IE2). By increasing the knowledge of EPCs by building owners, and communicating the experience within ESCOs, the asset specificity related to investments from ESCOs can be decreased and the frequency of EPC transactions increased at the same time. Based on the information collected by independent experts, after conducting several successful EPC cases, some ESCOs expanded their business to other cities (IE7). As a result, some of the big ESCOs are dominant in the market.

(2) Information on Building Owners and ESCOs

There are two strategies identified to offer more information on building owners and ESCOs: credit system improvement and enterprise qualification.

(a) Credit system improvement

Credit system improvement is developed to regulate the payment behaviour of the building owners and service quality of ESCOs (Gov4, IE6). It is identified as a way to offer ESCOs more information related to building owners. Chapter 7 Section 7.2.6 identified credit risks of payment from building owners. A credit system development can limit the credit risks and offer a reference for ESCOs, and vice versa (IE1). As a result, asset specificity related to investment in dealing with default problems can be decreased.

(b) Enterprise qualification

Enterprise qualification is suggested by the independent experts to better know about the service quality of ESCOs before conducting CBEER (IE4, IE6). With better knowledge of the service quality of ESCOs, building owners can save cost and effort in searching for qualified ESCOs. Therefore, the asset specificity from the investment of building owners can be decreased. Meanwhile, the uncertainties related to service quality of ESCOs can be somewhat limited.

There are several ways to achieve enterprise qualification in practice. In the government report “Guidance for Further Promoting Building Energy Efficiency Plan” (MOHURD & MOF 2017), the government put forward actions to “study and establish a ‘whitelist’ and ‘blacklist’ mechanism for ESCOs and third-party institutions of energy measurement and verification”. In the meantime, an industry standard “Requirements for certification of EPC services (RB/T 302-2016)” was published by Certification and Accreditation Administration and implemented from 2017 (CAARC 2017). The standard applies to the certification of EPC services and can be used for evaluation of energy efficiency services of ESCOs, either internally or externally by the organisation (or the customer) (IE6).

(3) Information on Commercial Buildings and Their Energy Situation

There are two potential strategies to offer more information on commercial buildings and their energy situation: a compulsory building energy audit for all commercial buildings, and information disclosure, including a building energy information sharing platform, and building energy performance benchmarking and disclosure.

(a) Compulsory building energy audit for all existing commercial buildings

A compulsory building energy audit is recommended by some building owners, ESCOs and government officials for better knowledge of the current situation of building energy consumption (BO5, BO6, ESCO5, Gov3). It aims to deal with the problem of incomplete information related to uncertain building energy consumption and an inaccurate baseline for CBEER. An energy audit is a method of capturing a description of the energy consumption of buildings and increases the *ex post* likelihood of implementing energy efficiency strategies (Annunziata, Rizzi & Frey 2014).

Access to information about energy consumption can help predict future consumption and plan energy saving strategies aimed at improving energy efficiency and thereby reducing energy consumption (Bennett & Newborough 2001). It can decrease the uncertainty of CBEER and improve the frequency of energy efficiency transactions.

From the perspective of building owners, annual building energy audit reports let both the building owners and government know about their building energy consumption and see the potential energy savings of their buildings (BO5, BO6). From the perspective of ESCOs, audits would be helpful for them to better understand the building energy consumption (ESCO5). It can be seen that asset specificity from both building owners and ESCOs can be decreased under the energy audit method as well.

Interviewees from government mentioned that “it would be better to popularise energy audit, especially the comprehensive building energy audit, which would be helpful to know about where the energy consumption is actually distributed and look for a better strategy of CBEER” (Gov3). An audit provides a scientific basis for the building owners to make a decision on CBEER, and for the government to design suitable energy saving policies and introduce related energy policies and resources for building owners in the first place (Gov3). Therefore, a building energy audit is an effective way to achieve building energy information disclosure.

(b) Information disclosure

Information disclosure means publishing building energy information and sharing the information with stakeholders. It aims to deal with the problem of incomplete information. Information disclosure strategy is supported by most of the ESCOs, government and independent experts. At present, only the government has access to limited building energy information in some cities. The benefits of information disclosure are in the following four perspectives.

From the macro aspect to the micro aspect, first, it can give the government a clear picture of the actual situation of building energy consumption, allowing the government to design precise and targeted policies (ESCO1, Gov1, IE4). Second, it shows the situation of building energy consumption to the building owners, which can encourage building owners to conduct CBEER (BO7, ESCO1, Gov4, IE6). Third, by knowing about the building energy consumption situation, the ESCOs can identify more targeted building energy saving potential and avoid risks due to incomplete information on the buildings (ESCO5, ESCO6).

These three perspectives show that information disclosure can decrease the investment for ESCOs to search for information and the costs of negotiation for both the ESCOs and building owners because it provides a clearer picture of the building energy situation than before. The asset specificity will decrease accordingly, and the frequency of transactions will potentially increase. Lastly, with information disclosure, the building energy maintenance can be monitored and managed during the implementation period of using an EPC, which can process the uncertainties in real time during the implementation period and avoid conflicts related to changeable energy saving benefits (BO5, BO6, ESCO6). As a result, uncertainty of transaction is reduced.

A building energy information sharing platform is a method to achieve information disclosure in practice. Taking the practice of a building energy information sharing platform in Shanghai as an example, the government (both central and local government) invested in the development of the building energy information platform. This platform is not limited to the single function of monitoring building energy consumption but also aims to be a comprehensive information integration platform serving the building energy efficiency market in Shanghai (Gov4). “Building an energy information sharing platform

is a way to decrease the problem of asymmetric information” (IE4). It can improve the service quality of CBEER and EPCs through the dynamic monitoring of building energy information by making use of internet of things and big data (IE1, IE2).

From the technical perspective, a building energy information sharing platform can improve the technical potential of energy efficiency and decrease the risks in CBEER and especially by using EPCs. The difficulties of developing a building energy information sharing platform are collecting the basic information, which requires a large number of meters and, in an ideal situation, requires installing sensors to buildings to auto-detect energy use. From the economic perspective, the costs of installation and maintenance are very high. This can be considered part of the government’s economic policies, or there may be other ways to fund the maintenance of the platform (IE4, IE5, IE7). From the social perspective, how to make use of the data from the building energy information sharing platform, and how to obtain the willingness of the building owners to publish energy information in the market are still unsolved (IE4, IE5).

Overall, a building energy information sharing platform can decrease the asset specificity the ESCOs invest in searching for information on buildings. Although the investment in developing and maintaining a platform is very high, the information it can offer directly increases the frequency of transactions of CBEER. With the platform monitoring the building energy consumption, the uncertainty of CBEER can be decreased and the benefits of using EPCs are more apparent.

Building energy performance benchmarking and disclosure (BEPBD) is a new way to facilitate information disclosure. It compares and ranks the energy consumption of the buildings in operation with the energy consumption of other similar types of buildings, and then releases the results from the government. BEPBD is an important tool to promote the efficient use of energy in commercial buildings and encourage building owners to conduct CBEER. It can provide more accurate understanding of building owners, property managers, building users, ESCOs and financial institutions on building energy consumption, which can solve the information barriers for CBEER and play the role of the market (Gov4, IE4). By solving more problems of incomplete information during project preparation, the asset specificity from both building owners and ESCOs related to information searching can be decreased accordingly. Some governments have used these

tools to formulate policies for the efficient use of energy in buildings (Chung, Hui & Lam 2006; Federspiel, Zhang & Arens 2002).

(4) Risks during Project Implementation

There are three potential strategies to limit risks during project implementation: a standardised EPC contract, third-party assessment and energy insurance.

(a) Standardised EPC contract

A standardised EPC contract can be a reference to instruct contracting parties to negotiate the rules of implementing the projects and regulate the responsibilities to mitigate risks. It aims to deal with the incomplete contract problem identified in Section 7.2.4. A standardised EPC contract can reduce the costs of negotiation and contract design. Therefore, it can reduce asset specificity.

“We adopted a ‘contract sample format’¹ for EPC as a standardised EPC contract design. Although the ‘contract sample format’ should be adjusted according to the various scenarios in practice, its framework offered a roadmap for the contracting parties to negotiate and design the contract” (ESCO4). “It is necessary to regulate the rules of conducting projects for the good development of EPC” (Gov1). The “contract sample format for building energy management contract” was designed by the Centre of Science & Technology and Industrialisation Development (CSTID) and China Association of Building Energy Efficiency (CABEE). The purpose of publishing the contract sample format is to “guide the contracting behaviour of the contracting parties of EPCs in the field of building energy conservation and safeguard the legitimate rights and interests of the contracting parties” (CSTID & CABEE 2014, p. 3).

Meanwhile, “the risks of a contract can be limited by the standard contract sample format in some extent” (IE4). Most of the independent experts believed that the standard EPC contract can maximise the interests of contracting parties to ensure the fairness of the

¹ “Contract sample format” is a shortened form of “contract sample format for building energy management contract”. In order to distinguish concepts of “engineering, procurement and construction (EPC)”, “energy management contract (EMC)” is used instead of “energy performance contract (EPC)” in some situations. This research uses the general terminology “energy performance contract (EPC)”.

contract and the government has the responsibility to design a standard contract as a reference offered for the market (IE4, IE6, IE7). Furthermore, most of the ESCOs and independent experts supported that there is a need to set mechanisms to resolve future conflicts and uncertainties to make up the general rules set in the “contract sample format” (ESCO2, ESCO3, ESCO5, ESCO7, IE1, IE3, IE4). Based on the standardised EPC contract in practice, the frequency of EPC transactions is increased and the uncertainty of using EPCs is somewhat decreased.

(b) Third-party assessment

Third-party assessment is conducting building energy measurement and verification (M&V) by an independent authoritative technical department. It aims to deal with the incomplete information problem of the building energy consumption situation and using EPCs. Some of the building owners stated that it would be better to have a third party to assess the building energy situation before and after retrofitting (BO5, BO6, BO7). Most of the ESCOs believe that third-party assessment is a good way to avoid the conflicts of the confirmation of energy savings with building owners. “Although third-party assessment is a little bit different from the original intention of design EPC, it is a relatively uniform standard for contracting parties to follow to set the baseline for CBEER. ... It is also a useful way to avoid risks for us [ESCOs]” (ESCO1). In order to avoid risks, some ESCOs and building owners used the energy saving verification results from the third party as the reference to share the benefits (ESCO1, ESCO2, ESCO3).

Although the accuracy of the energy saving assessment is still worthy of discussion, both the building owners and the ESCOs thought that “the third parties are fairer and just, after all, they are neutral parties” (ESC 4, BO7) and “third-party assessment can be a reference for the legal basis if the contracting parties have conflicts with the energy saving results” (ESCO2, ESCO3, BO5, BO6). In this perspective, the third-party assessment can make up for the incompleteness of the contract.

Third-party assessment reduces the uncertainties of using EPCs. At the same time, the benefits of CBEER are more certain and clearer to the stakeholders. The frequency of transactions can also be improved. From the interviews, it can be seen that the local government is very supportive of third-party assessment, however government raised a concern about “how to cultivate high quality third-party energy assessment department

and how to monitor their service and make sure the whole process is fair and just” (Gov1, Gov3). “Stakeholders can resort to the third-party energy assessment to limit risks caused by uncertainties of energy saving during the CBEER and sharing benefits under EPC” (IE7). All the independent experts supported third-party assessment as it can be a reference for the government to know about the energy saving situation and decide the target for energy savings (IE2, IE4) and assist the contracting parties to sign the contract (IE7).

(c) Energy insurance

Energy insurance is a risk management approach for EPCs to deal with the uncertain energy savings caused by incomplete information at the design stage. Energy insurance is a risk management mechanism for energy efficiency technologies and renewable energies (Vine, Mills & Chen 2000). Interviewees from government suggested that the insurance mechanism should be developed together with “green finance support” (Gov1, Gov4). It is thought to be put into use for the financial institutions that provide loans to energy efficiency projects especially EPC projects based on predicted energy savings (Gov4). As a result, the uncertainties of using EPCs can be somewhat limited. Although the concept of energy insurance has been put forward for several years, it does not have a clear implementation roadmap in practice.

9.2.2. Strategies for Market Power

To deal with the issue of market power, four potential strategies are identified. These incentive strategies aim to deal with two types of issues of market power (according to the two sub-themes identified in Section 7.4) and can contribute to the two perspectives of transaction costs. Figure 9-2 shows the relationship between the incentive strategies related to market power and the determinants of transaction costs.

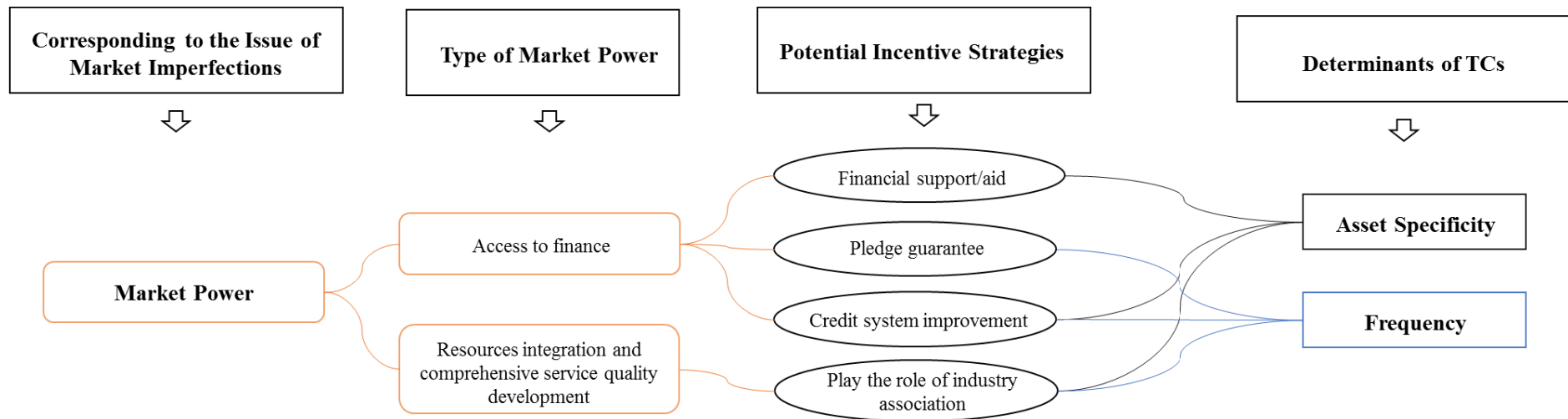


Figure 9-2 Relationship between incentive strategies addressing market power and determinants of transaction costs

(1) Access to Finance

There are three potential strategies to increase the access to finance: financial support/aid, pledge guarantee and credit system improvement.

(a) Financial support/aid

Lack of access to finance is one of most important barriers to the EPC market identified in Sections 7.4.2 and 7.6.3. Financial support here is different from the government subsidies discussed later in Section 9.2.3. Financial support here means the support offered for business financing (mainly for ESCOs) of CBEER by the government. The aim of financial support is to limit the market power and make sure small-size ESCOs can also enter the market fairly easily. With financial support, the costs of financing for companies will decrease. As a result, the asset specificity of investment of EPC is decreased. All the interviewees agreed that financial support is an urgent consideration for policy design. Especially under the EPC mechanism, it is a basis for ESCOs to enter the market (ESCO2, ESCO3, ESCO5, ESCO6).

In addition to using the traditional banking system, various financing models can be adopted, such as independent financing companies and finance leases (ESCO3, ESCO6, Gov4, IE4). This leads to another question on the government's role in the development of a credibility system. Some of the interviewees from government and most of the independent experts stated that government can act as an endorsement or assurance to help ESCOs get mortgage guarantees (Gov4, IE1, IE4).

“Green finance” is mentioned the most by both the ESCOs and the government. “Green finance” offers low interest or other assistance for ESCOs for projects related to energy conservation. At present, “green finance” is only a general concept, and needs a concrete framework and plans to make this concept work (Gov2). Transferring the traditional banking system to a credibility system using predicted energy saving benefits as a mortgage will be a trend to offer financial support for CBEER, especially using EPCs (ESCO1, ESCO2, ESCO3, Gov1, Gov3, Gov4). The credibility mentioned here is the ability of achieving the promised energy savings and paying the financing institution.

(b) Pledge guarantee

A pledge guarantee is part of policies for financial support for energy efficiency (Gov1). Pledging collateral may allow companies to obtain bank loans when they would not normally qualify for unsecured loans (Rezessy & Bertoldi 2010). Matthäus & Mehling (2020) have demonstrated that a multilateral guarantee mechanism can help accelerate energy system decarbonisation and deal with adverse financing conditions for investments in energy efficiency. As a result, the frequency of transactions of EPCs or traditional CBEER can be improved. However, there is no clear pathway or policies showing how to implement the pledge guarantee mechanism for CBEER or EPC projects.

(c) Credit system

Credit system improvement is suggested by the government as fundamental for developing a good environment for conducting CBEER and EPCs (Gov4). It is intended to help develop the financial system (Gov4, IE6). To assist the financial system, Zhang, Li & Ji (2020) demonstrated that better access to credit for financing for manufacturing enterprises is significantly associated with a reduction in their energy intensity. Although there is no similar demonstration for the commercial building sector, it raised a meaningful idea of improving the credit system for CBEER and especially for EPCs. Previous chapters have stated that as light-asset enterprises, ESCOs have significant financing problems. Credit system development can help ESCOs and also building owners to access financing for CBEER. As a result, the asset specificity can be decreased and the frequency of EPC transactions can be much improved.

(2) Resource Integration and Comprehensive Service Quality Development

The role of industry associations is identified as integrating resources and developing comprehensive service quality for the market. From the perspective of ESCOs, the industry association plays a positive role in promoting CBEER and EPCs. “It guides the governmental policies and regulates the industry by implementing industry standards. ... It also sets a direction for the industry” (ESCO4). “The industry association has an ability to organise companies [for service improvement]. ... By conducting credibility evaluation and service quality rating, they help stakeholders find suitable ESCOs. This is a practical way to select good service quality ESCOs” (Gov2).

In practice, the industry association acts more like a resource integration platform, in which companies can find all kinds of resources related to CBEER and EPCs, including but not limited to legal consulting, policy explanation, training, contract design, financing and communication (Gov2, IE4). The purpose is to cultivate the service ability of enterprises and promote market development (Gov2, IE1). In addition, industry associations can also offer relevant training for the ESCOs to build their capacity (Gov2).

Meanwhile, the industry association can assist the guarantee system for financing. “Take a fund offered by Ma’anshan Rural Commercial Bank as an example. This fund is only offered for the EMCA members, because they feel risky to give loans to the other ESCOs [not EMCA members]” (IE4). Independent experts also suggested that it is necessary to have the role of an industry association, for example to conduct customer satisfaction surveys independently for both building owners and ESCOs (IE4, IE6). Therefore, the industry association has a great role in capacity building of ESCOs and offers great resources for ESCOs to make sure the market power can be limited and all the ESCOs have a fair competition environment. As a result, the asset specificity from ESCOs that spend effort looking for resources and building their capacity can be somewhat decreased. Having a more comprehensive service ability, the frequency of CBEER and using EPCs for CBEER can be improved at the same time.

9.2.3. Strategies for Externalities

This section discusses nine potential incentive strategies to deal with the issue of externalities. These incentive strategies can contribute to the three perspectives of transaction costs. Figure 9-3 shows the relationship between the incentive strategies related to externalities and the determinants of transaction costs.

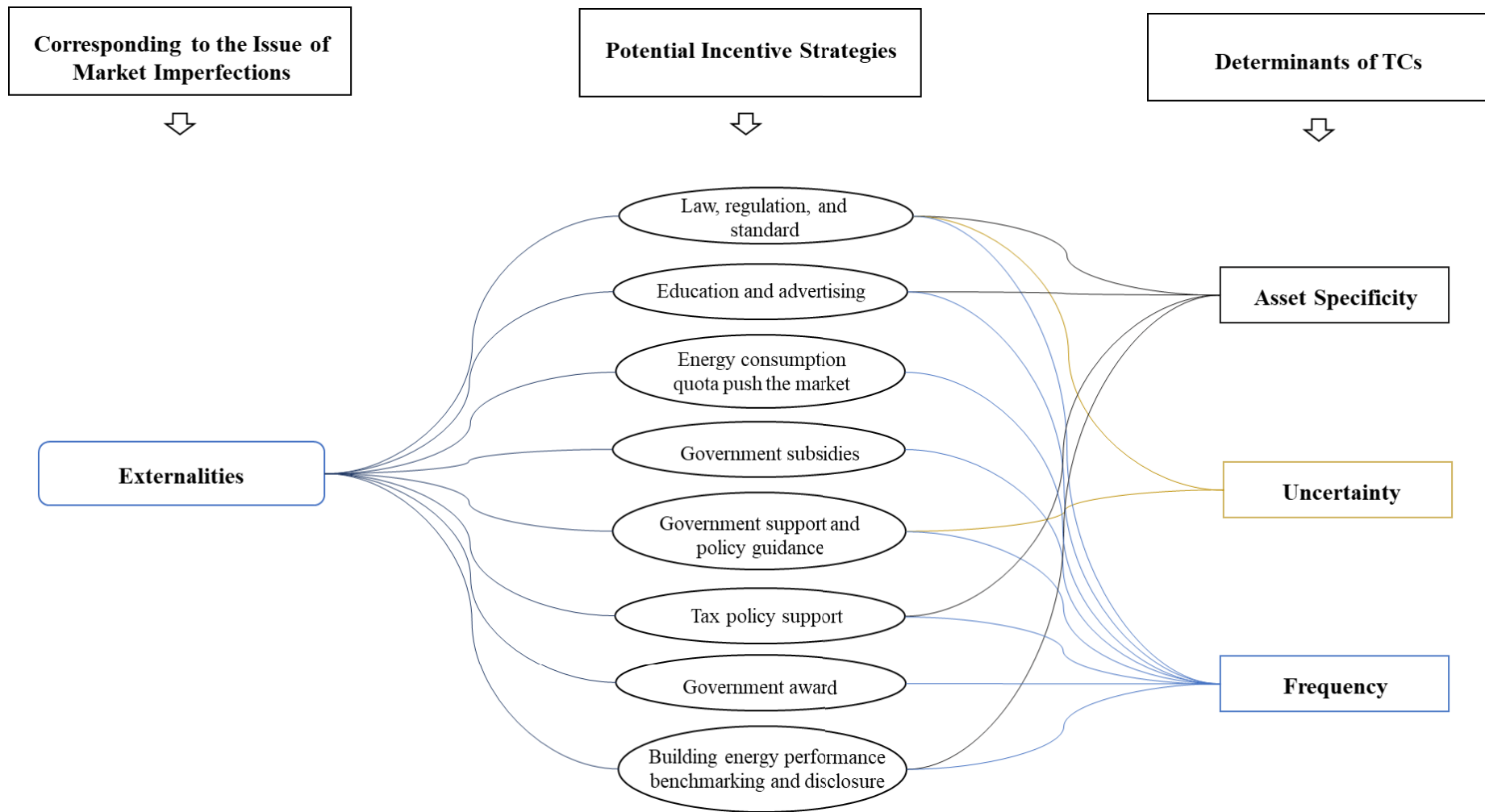


Figure 9-3 Relationship between incentive strategies addressing externalities and determinants of transaction costs

(1) Law, Regulation and Standard

The strategy of “law, regulation and standard” is identified for regulating the behaviours of energy use and implementation of CBEER by stakeholders. There are four aspects: law, regulation framework, government compulsory regulation, and standards on technology, energy operation and energy use. These four aspects actually correspond to the government regulatory system (explained in Section 3.6): law, administration regulation, ministry rules, policy oriented document, and standard specification. From the model of top to down of the Chinese policy system, how the different levels of policies have a role in dealing with the market imperfections is the key point. Most of the interviewees stated that non-compulsory energy efficiency meant commercial building owners did not realise they have a responsibility to save energy.

As discussed in the last chapter, energy efficiency as a public good may cause the problem of externalities. It is very important to regulate responsibilities for reducing energy consumption for economic benefits. The law and administration regulation can only set general rules. For the commercial buildings, it is important to have a more precise regulation on the energy saving target. Therefore, a compulsory local government regulation is needed (Gov1, Gov3). The independent experts stated that it is necessary to develop a regulation framework under a clear scope and clearly regulate the responsibilities of building owners and using EPCs (IE1, IE2, IE4, IE5). By setting regulation to limit energy consumption and responsibilities for energy conservation, the frequency of transactions can be improved directly.

Furthermore, the current standards are aimed at the technology issues of CBEER, which provide references to the energy efficiency services of ESCOs. However, the behaviours of building owners, especially the behaviours of energy usage and maintenance, are not regulated and controlled by the existing standards. “More practical policies should be designed to regulate the behaviours of building owners” (IE2). By following well designed standards covering all the perspectives of implementing EPCs, the stakeholders can avoid spending too much effort (including time and costs searching information and preparing the projects) and limit risks occurring during project implementation. As a result, asset specificity and uncertainty of transactions can be somewhat decreased.

(2) Education and Advertising

The strategy of education and advertising was discussed in Section 9.2.1 Part (1).

(3) Energy Consumption Quota Pushes the Market

An energy consumption quota is defined as “a reasonable level of building energy consumption for special buildings in a certain period by identifying the upper limit of building energy consumption intensity, and is used as an indicator of whether the building energy is efficient” (Xin et al. 2012, p. 250). A building energy consumption quota is a method that government publishes to encourage building owners to conduct CBEER (Gov1, Gov4). It aims to deal with the problem of externalities of energy consumption and the problem that energy efficiency conducted by ESCOs is considered a public good. It changes the concept of building owners taking energy consumption for granted to taking active energy saving actions. “If the actual energy consumption is over the set energy consumption quota, they [building owners] will be charged a higher price” (Gov3). An energy consumption quota is hard to design, because it needs a great quantity of building energy consumption data for various buildings (IE4). Therefore, it is only implemented in several cities. An energy consumption quota can push the market and increase the frequency of transactions of CBEER.

(4) Government Subsidies

Overall, most of the interviewees supported that financial benchmarks play an important role in energy efficiency. One of the most important perspectives of financial benchmarks is offering subsidies to the energy efficiency market. It aims to encourage the initial willingness of building owners to conduct CBEER and deals with the negative externalities of energy consumption.

From the perspective of building owners, “government subsidies give us a signal that government supports conducting CBEER by using EPCs” (BO1, BO2), and “it incentivised us to try EPC, as subsidies were considered as a (benefit) guarantee for us” (BO3, BO4). From the perspective of ESCOs, “it can promote building owners considering CBEER and using EPCs” (ESCO1, ESCO2, ESCO3). “The good advantage is that it can reduce the financial burden on the ESCOs. At the same time, it will bring a disadvantage. There are some companies with poor service quality who also join this

market, and they only want to enjoy the bonus from the policy but do not want to keep a long-term business in this area” (ESCO4). Meanwhile, “the multiple property issue in the building sector makes it hard for the role of government subsidies because of the split incentives” (ESCO8). Government subsidies can motivate the stakeholders in the market, but “only depending on the government subsidies is not enough for the good development of this market” (ESCO5, ESCO6, ESCO7). Therefore, the government subsidies should be more targeted.

Both the government and the independent experts stated that government subsidy is an effective way to develop the market especially aiming at the initial market and forming the scale of the market. However, government subsidy cannot support the market to develop in the long term, as it will lose the function of a market mechanism. Meanwhile, it is important for the government to guide the market to make use of subsidies. This is consistent with the ESCOs previously mentioning that the subsidies need to be targeted.

It can be seen that government subsidies can improve the frequency of transactions directly for the initial EPC market. For long-term market development, although government subsidies can decrease the transaction costs for building owners and ESCOs, it would not be good for the market building its own ability by itself and for good development.

(5) Government Support and Policy Guidance

Both the interviewees from government and ESCOs stated that both CBEER and EPCs developed based on government support and policy guidance on the issue of energy conservation. As an EPC is designed to achieve a market where building owners want to have CBEER actively, government support and policy guidance may aim to develop a comprehensive system for CBEER. They are offered for the initial market for market cultivation. In China, “government subsidies” mentioned in the last part includes government support in funding and through China’s Five-Year Plans. The plans set an overall reduction goal for energy consumption as well as sector and province-specific goals for both energy consumption and energy efficiency. In contrast to incentive funds, this type of government support is related to the overall goal set by both central and local governments.

Both the building owners and the ESCOs take government support as an endorsement and incentive for them for further action. From the perspective of building owners, “at the beginning, we hesitated to do CBEER, but the government guidance promoted us to conduct CBEER” (BO1, BO2). “Without government support and policy guidance, the motivation of building owners is a little bit weak” (BO3, BO4). “The concept of EPC we heard is from the local government [Changning Low Carbon Project Management and Development Centre of Shanghai] and government support gave us confidence because they are more authoritative” (BO5, BO6).

From the perspective of ESCOs, EPCs are a good business mechanism to enhance the role of the market to conduct CBEER as “without government support it is very hard to open the market in such a short term and let building owners have willingness to do CBEER” (ESCO1, ESCO2, ESCO3, ESCO8). “The government should better let enterprises understand the direction of their policies and help enterprises look for more problems the market exists. ... Sometimes enterprises do not know the relevant policies, so I think the government should focus on policy formulation, policy publicity, policy guidance and so on” (ESCO6).

Government support and policy guidance is fundamental for market development. It contributes to increasing frequency of transactions directly. Most of the interviewees appealed for the stability of policies. Having government support and policy guidance, both the building owners and the ESCOs are more confident in the EPC market, which can limit uncertainties related to changes of decisions of stakeholders during CBEER. However, with the gradual development of the market, government support and policy guidance should be more targeted.

(6) Tax Policy Support

Some of the interviewees from the ESCOs, government and independent experts mentioned that a tax or carbon tax would be a way to encourage building owners to conduct CBEER (ESCO1, ESCO2, ESCO3, Gov3, Gov4, IE4, IE6). It can deal with the fundamental problem of externalities related to commercial building energy consumption. By applying tax policy, the frequency of transactions of CBEER can be improved if the benefits of CBEER are higher than paying the tax. The interviewees from the government

mentioned that carbon tax policy can be used together with cap-and-trade policy to curb carbon dioxide emissions (Gov3, Gov4).

At present, the current tax policy is based on “the law of environment protection tax” that stipulates that “enterprises, institutions and other production operators that directly discharge taxable pollutants into the environment are required to pay the Environment Protection Tax (EPT)” (STAPRC 2016). This law regulates the environmental pollution behaviours of companies in manufacturing, while there are no rules to regulate how much energy can be consumed by the building owners. Therefore, there is still no concrete tax policy designed particularly for energy consumption in the building sector. Some ESCOs suggested that if the government can offer tax exemption policies for the enterprises that conduct CBEER, it would be a great encouragement for the ESCOs and will reduce their financial burden especially for using EPCs (ESCO2, ESCO3, ESCO6).

(7) Government Award, Reward or Recognition

Similar to government subsidies, a government award, reward or recognition is also a straightforward way to improve the frequency of transactions of CBEER. The purpose is to deal with the externalities of low motivation by commercial building owners. Some building owners stated that a government award is an encouragement for them to conduct CBEER because it helped them “establish their corporate image” in the industry (BO5, BO6) and they received an “energy conservation bonus” (BO4). ESCO5 thought that “the amount of building energy savings are very limited and the pure building energy saving benefits are not enough to motivate the stakeholders, therefore it is necessary to design various government awards to promote the market”. From the government perspective, they thought that the current subsidies for EPCs are a disguised form of government reward, because parts of the subsidies are given based on the final energy saving results of EPCs (Gov3).

(8) Building Energy Performance Benchmarking and Disclosure

Building energy performance benchmarking and disclosure (BEPBD) was introduced in Section 9.2.1. BEPBD is also an effective method to motivate building owners to conduct CBEER to eliminate the externalities of building energy consumption. The reason is that the lower-ranking building owners may feel bad from consuming too much energy or be

punished by paying further taxes (or the other types of punishment) from this and then take actions (Gov3). The negative externalities of energy consumption can be dealt with accordingly. By dealing with the problems of externalities, the frequency of transactions of CBEER can be increased directly.

9.3. Discussion on Feasible Policy and Strategy Design

Section 8.3 introduced the theoretical policy design to deal with EPC market imperfections. Section 9.3 identified the potential operational policies in the Chinese context based on the empirical findings from interviews. This section further discusses how these two solutions match each other and how the strategies identified in the interviews supplement the theoretical solutions as operational schemes. It addresses the three aspects of market imperfections: incomplete information, market power and externalities.

9.3.1. Incomplete Information

The overall solutions to deal with incomplete information based on theoretical findings and empirical thoughts from interviews are shown in Table 9-2. In the theoretical policy design, the main focus is designing suitable screening and signalling policies for information disclosure on the five perspectives: information on existing buildings, building energy operation situation, credit of building owners, service quality of ESCOs, and the benefits of EPCs. The potential strategies identified in the interviews cover all the aspects of theoretical solutions. They provide a detailed guide on how to implement screening and signalling into practice.

Table 9-2 Overall solutions to incomplete information based on theoretical findings and interviews

Market Imperfection	Theoretical Policy Design		Potential Strategies Identified in the Interviews	
	Theoretical Solutions	Target		
Incomplete Information	Screening and Signalling for information disclosure	Information on existing buildings	Compulsory building energy audit for all existing commercial buildings	
			Information disclosure	Building energy performance benchmarking and disclosure
				Building energy information sharing platform
		Building energy operation situation	Third-party assessment	
		Credit of building owners	Credit system improvement	
		Service quality of ESCOs	Enterprise qualification	
		Benefits of EPC	Education	
			Advertising	Pilot EPC cases
				Successful cases
			Standard EPC contract	
			Energy insurance	

A compulsory building energy audit for all existing commercial buildings is different from the traditional way that only the buildings that already plan to be retrofitted need to do an energy audit. It is much more straightforward for both building owners and the government, and ESCOs can also get benefits. For building owners, it acts as a signalling tool, and for ESCOs and government it acts as a screening tool. A compulsory building energy audit can facilitate setting an appropriate baseline for commercial buildings to conduct retrofits.

Parallel with the compulsory policy of building energy audit is the strategy of information disclosure. There are two technical ways to achieve this. The first one is building energy performance benchmarking and a building energy information sharing platform. Building energy performance benchmarking is a new way in China compared to the traditional concept that benchmarking is defined as the baseline of conducting CBEER. It asks building owners to report their building energy consumption and ranks them. It incentivises the low-ranked building owners to consider building energy efficiency.

However, the willingness to join this type of benchmarking program is still uncertain. There are still some concerns from building owners identified during interviews. Therefore, to maximise the role of this innovative benchmarking, the policy should be designed precisely. A building energy information sharing platform is a tool to assist data collection and information disclosure. However, the cost of investing in and maintaining such a building energy information sharing platform should be considered by the government.

Meanwhile, an authorised third-party assessment institution can offer a more justified energy saving result as a reference for building owners and ESCOs. It acts as a screening tool to avoid controversial issues on the final energy saving results. It also addresses the cost problem of hiring a third party to assess energy saving.

Credit system improvement and enterprise qualification are put forward to show information for building owners and ESCOs. They are practical ways for both building owners and ESCOs to know about their cooperative partners. It should be helpful to deal with the incomplete information but how effective the methods are has not been demonstrated.

The two strategies of education and advertising of pilot EPC cases and successful EPC cases provide more information to both building owners and ESCOs as a signalling tool.

The strategies of a standard EPC contract and energy insurance were identified in interviews. A standard EPC contract can be a reference for contracting parties to think about the potential risks during project implementation. As an EPC is a new mechanism, a standard EPC contract can eliminate some uncertainties for projects. Energy insurance is a compensation mechanism for risk occurrence. It does not deal with the issue of incomplete information directly but can compensate for the outcome of the risks.

9.3.2. Market Power

The overall solutions to deal with market power based on theoretical findings and empirical thoughts from interviews are shown in Table 9-3. In the theoretical policy design, it addressed two government tools of regulation and subsidies to achieve the targets of improving the existing financing system and cultivating the market.

Table 9-3 Overall solutions to market power based on theoretical findings and interviews

Market Imperfection	Theoretical Policy Design		Potential Strategies Identified in the Interviews	
	Theoretical Solution	Target		
Market Power	Regulation	Improve the existing financing system	Access to finance	Financial support/aid
				Pledge guarantee
				Credit system improvement
	Subsidies	Market cultivating	Resources integration and comprehensive service quality development	Play the role of industry association

For the first target, three practical strategies were identified in the interviews showing the way to design regulations for better access to finance. Financial support or financial aid is a way for the government to offer financial support for energy efficiency projects. However, it should be designed carefully to avoid the “free rider” problem (Bukarica & Tomšić 2017). “Green finance” is the main concept put forward for a new financing system development taking potential energy savings as the mortgage in contrast to the traditional property as the mortgage. Credit system development will be supportive for a well-developed green finance system. A pledge guarantee is a small way to support the finance system but depends on how the whole financing system is designed. The issue of collateral is an inevitable problem.

For the second target, the interviewees affirmed the benefits of subsidies offered by the government to cultivate a market, however it is only beneficial for the initial stage of the market. Enterprises should have the ability to live without subsidies from the government. The responsibility for cultivating the service ability of enterprises is suggested in the interviews to be taken by the industry association. Therefore, it needs to set up a short-term and long-term policy design for cultivating the market.

9.3.3. Externalities

The overall solutions to deal with externalities based on theoretical findings and empirical thoughts from interviews are shown in Table 9-4.

Table 9-4 Overall solutions to externalities based on theoretical findings and interviews

Market Imperfection	Theoretical Policy Design		Potential Strategies Identified in the Interviews
	Theoretical Solution	Target	
Externalities	Energy price	Deal with the externalities caused by building operation and energy consumption	
	Taxes		Tax policy support
	Standards		Standard
	Emission Limits		Energy consumption quota push the market
			Building energy performance benchmarking and disclosure
	Law, regulation		Law, regulation
			Government subsidies
			Government award
			Education and advertising
	Assign Property Right	Deal with the externalities caused by split incentives during the activities in CBEER or using EPCs	

In the theoretical policy design, there are seven policies put forward targeting two types of externalities. For the first target on the externalities caused by building operation and energy consumption, there are six types of policies mentioned in theoretical design and four of them were also mentioned by the interviewees. The policies of energy price and emission limits have not been considered in practice. In addition, interviewees put forward additional policies that the theoretical policy design did not cover: government subsidies and award, education and advertising. Meanwhile, the potential strategies identified in the interviews did not mention the policy of assigning property rights. This section further discusses these policies that were only addressed by one approach.

Starting with the energy price, Section 2.4 introduced how energy pricing policy improves energy efficiency. The low price of energy is one of the reasons that building owners have low motivation to conduct CBEER in the current situation. Therefore, energy price policies should be addressed to improve the willingness to join the activities of CBEER. This idea has been verified by Ju et al. (2017) who identified that energy price regulations will benefit China's economy and environment. Their research on the impact of energy

price distortions on energy conservation and consumption structures in China can provide further evidence of the need for energy price reform. However, energy price reform influences various aspects of economics and the market, and requires the government to conduct an in-depth analysis on whether energy price regulations will have positive effects in China. It is a long-term consideration and design. Although it is a long-term goal, it also presents a reference for designing a reasonable and fair energy policy for different sectors, for energy consumption control and energy emission targets (Ju et al. 2017).

Assigning property rights is a type of policy put forward in theoretical policy design. Actually, the previous proposed policies of “law, regulation”, “emission limits” and “taxes” are also manifestations of the government being assigned the responsibility of controlling energy consumption. To deal with the particular split incentive problem under EPCs, proper contract design to assign property rights is necessary because during the process of conducting CBEER under EPCs, all conflicts caused by “rights split” come from the following four issues related to property rights. Firstly, building owners have the property right of the building and the tenants have the usage right of the building. Secondly, the facility management company hired by the building owners has the management right of the building but does not have the right to enjoy the energy saving benefits. Thirdly, when ESCOs conduct CBEER for the building owners, they take the right of managing the property from the facility management company hired by the building owners. Lastly, ESCOs share part of the right of enjoying the energy saving benefits with the building owners. Some interviewees noticed this problem but could not find a better solution in the actual situation. Based on the literature review, it can be found that a well-designed contract can help deal with this problem by assigning property rights clearly.

Government subsidies are mentioned in the interviews. As analysed in Sections 2.4.3 and 9.3.1, it can help get interest from the building owners. The previous section on “market power” explained that subsidies can help to cultivate the initial market involving many sellers joining the market. For the externalities, subsidies are used to encourage more buyers to join the market. However, this method could not solve the problem of externalities at the root, and is more likely to transfer the responsibility of controlling energy consumption to the government. It is not an efficient way to deal with this kind of

problem. However, to build the concept of energy efficiency for the building owners, it is a trial for the initial market in the short term.

Government award is a method put forward in the interviews and it is an efficient way to replace government subsidies because subsidies are given before the action but awards are given after the action. Therefore, the effect of the action (energy efficiency) could be guaranteed. Therefore, in practice, some governments are trying to offer subsidies to EPC projects after the construction work or sometimes when the projects are completed as awards. Although it is an efficient way to guarantee the results of energy efficiency, it did not encourage some of the ESCOs to use EPCs at the very beginning. Because ESCOs face great financial difficulties at the beginning of projects, subsidies would be considered more helpful than awards from this perspective. Which approach is more effective to incentivise the market should be analysed in-depth.

Education and advertising were put forward in the interviews to address the basic problem of people's concept of energy saving. This should be implemented together with assigned responsibility for energy saving (law, regulation, tax, emission limits) by the government.

9.4. Developing an Incentive Mechanism for the EPC Market

Based on the discussion in the previous sections, the incentive mechanism for the EPC market is developed. Overall, the government plays a leading role in the market. It aims to build a legal and sustainable environment for all the stakeholders in the market. From the whole building sector to CBEER and further EPC mechanisms, there are several steps targeted to each sector. Figure 9-4 summarises the overview of incentivising the EPC market.

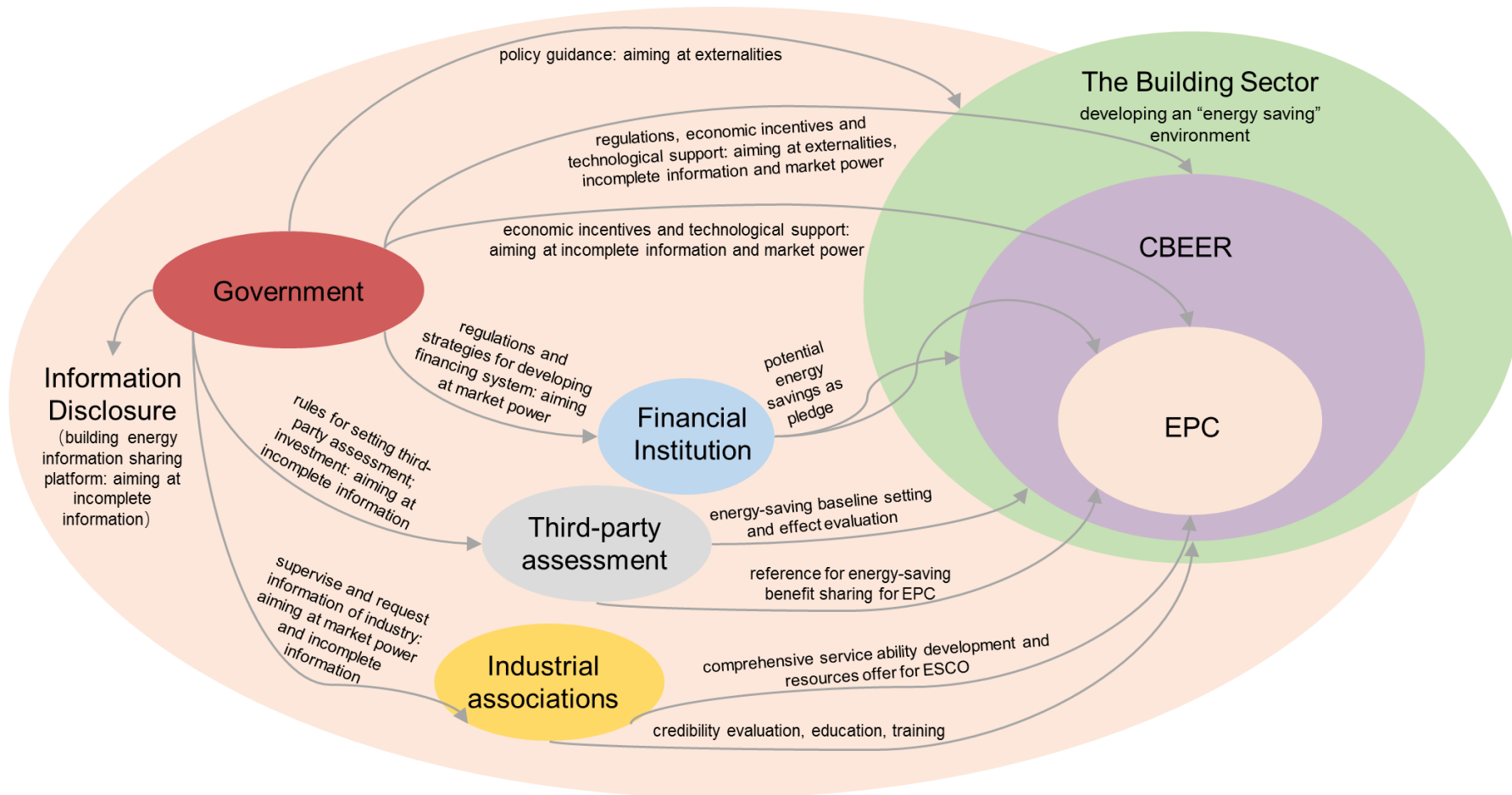


Figure 9-4 Overview of incentivising EPC market

Aiming at the whole building sector, through policy guidance, the first step for the government is to popularise the concept of “energy saving” widely for the public. The purpose is to eliminate the market imperfections of externalities related to energy consumption. By improving the awareness of “energy saving” in the building sector, some building owners may try to look for ways to save energy. At the same time, the government should develop a mechanism of information disclosure for the whole society and particularly focusing on the building sector. It should cover information related to building energy situation, building owners, ESCOs and the other related energy efficiency technologies and innovative strategies.

Targeting the CBEER sector, the first step is to set regulations and economic incentives and offer technological support for the market of CBEER. The purpose is to eliminate the market imperfections of externalities, incomplete information and market power. Meantime, the government should set regulations and strategies to develop a financing system based on taking energy savings as a pledge. It aims to eliminate the market imperfection of market power. In parallel, the government should develop policies to set the mechanism of third-party assessment for building energy measurement and verification. It can help to set the energy saving baseline and affect evaluation of energy efficiency. It aims to eliminate the market imperfection of incomplete information. At the same time, the government should supervise and request information from the industry through industry associations. The industry associations can help the government conduct credibility evaluation, education and training for the stakeholders in the CBEER market. The purpose is to make use of industry associations’ abilities to cultivate the market, then eliminate market imperfections of market power and incomplete information.

After implementing the policies and strategies on the sector of CBEER, both building owners and the ESCOs will have a better environment to conduct CBEER in. Even more building owners will want to conduct CBEER after they know about the benefits from it. Especially when they know about the benefits of EPCs, more building owners may transfer to use EPCs to conduct CBEER. Therefore, for the sector of EPC mechanisms, the purpose of the government is to let stakeholders get access to the benefits of using EPCs and offer both economic incentives and technological support for using EPCs. It aims to eliminate market imperfections of incomplete information and market power. At the same time, similar to the policies on the sector of CBEER, there are three parallel

policies on financing system development for taking the potential energy savings as a pledge, third-party assessment as references for energy saving benefit sharing for EPCs, and industry associations on comprehensive service ability development and resource support for ESCOs. By following the above strategies of policy design, the potential of EPCs can be fully tapped and EPCs would be more attractive for conducting CBEER.

Figure 9-5 provides more details on the concrete policies for dealing with each EPC market imperfection. The policies are divided into three types according to the China's policy system elaborated in the literature review (Chapter 3 Section 3.6) and key components of policies' success proposed by Tanaka (2011): prescriptive measures, economic measures, and supportive measures. Prescriptive measures are regulations, mandates and policies that directly compel the energy saving activities or EPCs. Economic measures are subsidies, taxes or awards that directed financial support to the energy saving activities or EPCs. Supportive measures are tools or methods that assist markets to achieve energy saving targets, but are not mandated or economic. The effectiveness of policies goes from strong to weak for these three types. In these policies, some are targeted on the CBEER as an EPC is a mechanism to conduct CBEER. With the improvement of the market for CBEER, the benefits of EPCs can be improved as well. Some policies are more targeted to EPCs because they focus on the unique character of EPCs and aim to deal with the market imperfections according to EPCs. The overlapping part is for the policies that are targeted for CBEER and EPCs separately.

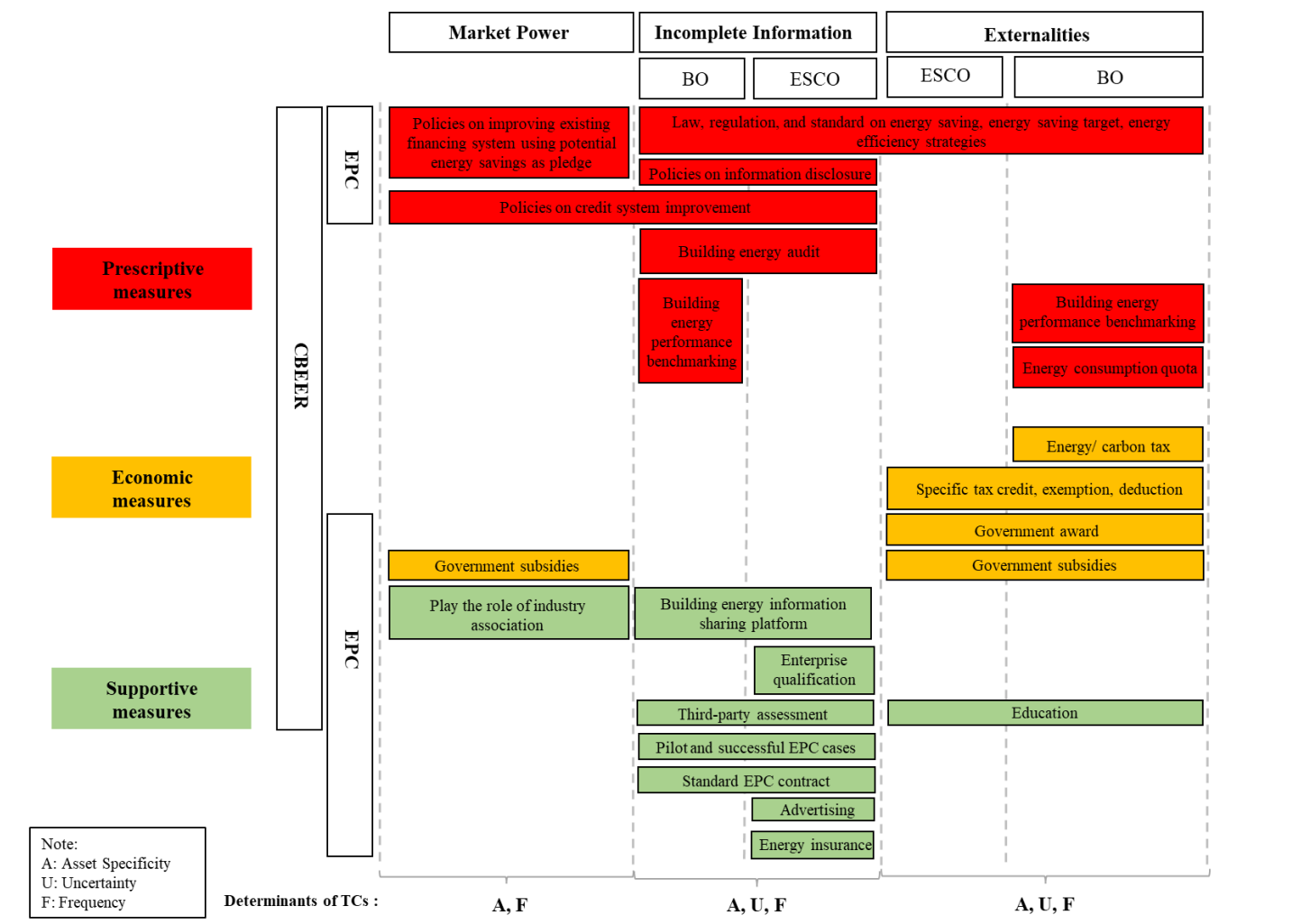


Figure 9-5 Detailed incentive mechanism for EPC market

9.5. Summary

This chapter discussed potential policies and strategies to promote the EPC market in China, gained through stakeholder interviews. Based on the theoretical policy design analysed in Chapter 8 and interview findings elaborated in Section 9.2, a detailed incentive mechanism for the EPC market in China was developed. The next chapter verifies this incentive mechanism through case studies.

Chapter 10 Case Studies: Verification of the Incentive Mechanism

10.1. Introduction

The previous chapter developed and presented an incentive mechanism for improving the uptake of energy performance contracts (EPCs) in the market of commercial building energy efficiency retrofit (CBEER). This chapter tests the validity of the incentive mechanism proposed in Chapter 9 Section 9.4. Using two cases, this chapter can test the validity of the proposition that some of the policies put forward in the incentive mechanism are feasible in actual practice and demonstrate how the proposed incentive mechanism can better facilitate the EPC market in China.

Case studies in this research introduce experience in the development of EPC markets under government intervention. The two cases, in Chongqing and Changning, were selected from a demonstration program in China (see Section 5.5.2). The cases were selected from the projects that had some specified criteria. In the two cases, the markets show positive reaction to published policies. The detailed reasons were introduced in Chapter 5 Section 5.5.2.

The process of analysing the two cases follows the classical case study approach introduced in Section 5.5.3 and a policy evaluation framework proposed by Cheng et al. (2020). The evaluation framework is adapted to an analysis framework to fit this research, shown in Figure 10-1.

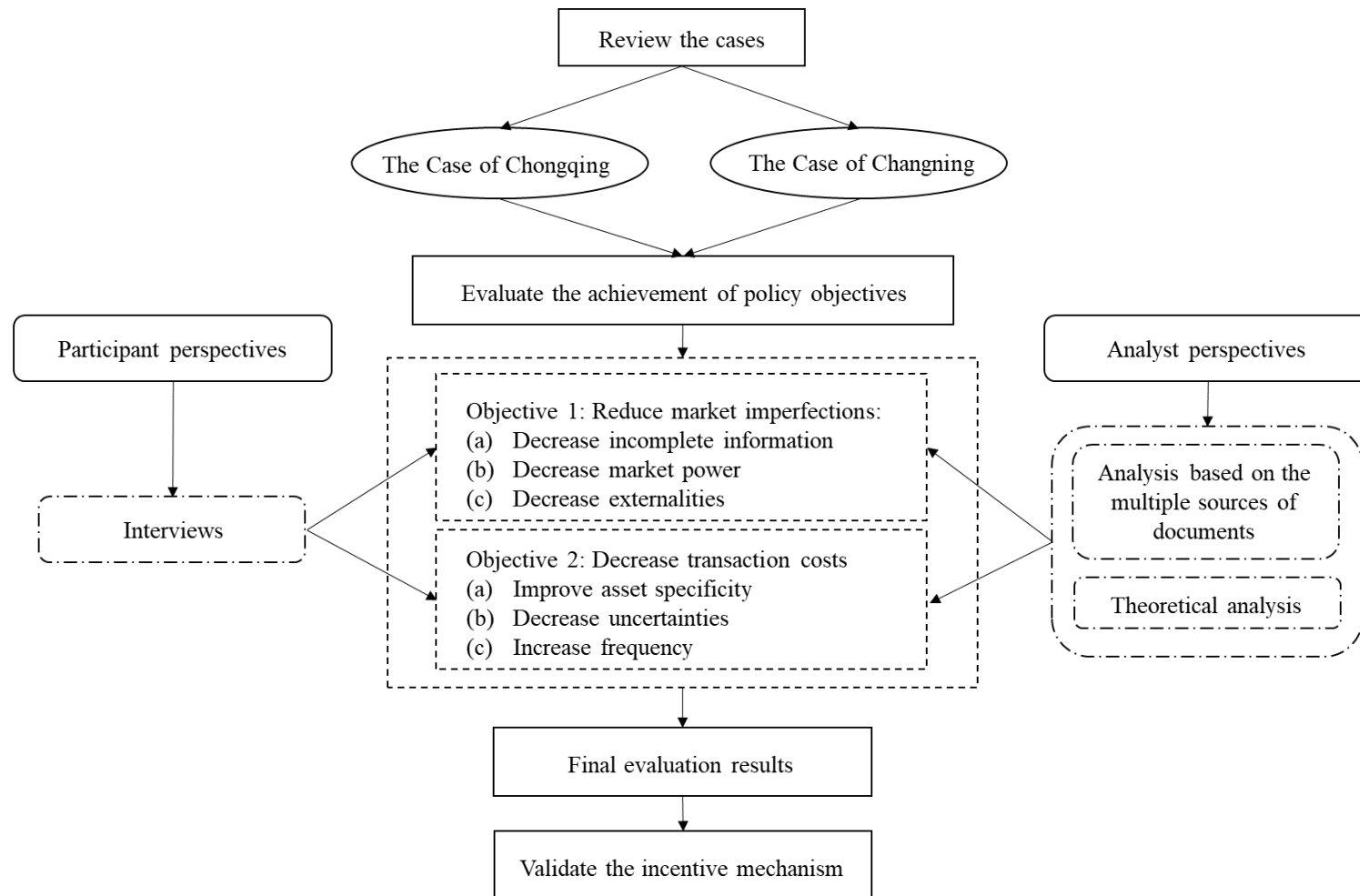


Figure 10-1 Analysis framework of case studies

The first step is reviewing the cases. The background of the case is introduced, then policies implemented in practice are reviewed and summarised. In order to better compare these policies to the proposed incentive mechanism, the policy implementation in each case is reviewed following the policy categories clarified in the proposed incentive mechanism as prescriptive measures, economic measures and supportive measures. Secondly, the two cases are evaluated to identify whether the effects of policy changes can achieve anticipated objectives to reduce market imperfections and decrease transaction costs. Policies are evaluated by incorporating two methods: interview perspective and analyst perspective. The validation of the incentive mechanism flows from the final evaluation results to show (i) the alignment between the practice and the proposed incentive mechanism; (ii) how the proposed incentive mechanism can facilitate the market move closer to perfect competition by eliminating, reducing or compensating for market imperfections; and (iii) how the proposed incentive mechanism can help the market reduce transaction costs to improve the uptake of EPCs and improve CBEER. Further recommendations for future policy designs in China are suggested at the end of it this chapter.

10.2. Case One: EPC Experience of Chongqing

10.2.1. Background of the Case

Chongqing is located in southwest China, and is one of the four direct-administered municipalities in China which report directly to the central government. The city has 560 million square metres of gross floor area of existing buildings (Hou 2019). An energy conservation target for the Chongqing government was set by the central government to reduce 2015 energy consumption per unit of GDP by 16% compared to 2010 (Hou 2019). The central government integrated energy conservation and emission reduction into performance evaluation of local government (Dong & Lin 2016).

In the demonstration program, the Ministry of Housing and Urban-Rural Development (MOHURD) and the Ministry of Finance (MOF) set the task for Chongqing government: the energy consumption per unit area of public buildings should be reduced by more than 20% over 4.44 million square metres of public buildings. Under this program Chongqing could enjoy a special fund of 80 million CNY from the national government for energy conservation and emission reduction.

By the end of 2015, Chongqing government had attracted nearly 300 million CNY of nongovernment funds to put into the market. The EPC mechanism had also been acknowledged by the market during that time. During that period, ESCOs were the dominant retrofit entities and 96% of the projects were conducted through the EPC mechanism. By verification of third-party auditors, after retrofit, the energy saving rate of 9% of projects was between 10% and 20%; the energy saving rate of 84% of projects was between 20% and 25%; and the energy saving rate of 7% of projects was over 25% (Hou et al. 2016).

10.2.2. Policy Implementation

(1) Prescriptive measures

(a) Prescriptive energy saving target

First, a prescriptive energy saving target in the commercial building sector was set by the Chongqing government after the central government set the overall energy saving task for Chongqing. To follow this task, regulation as the major prescriptive measure set implementation measures for the stakeholders in EPC projects. The Commission of Housing and Urban-Rural Development of Chongqing (CHURDCQ) published a regulation “Interim Measures for the Administration of Key City Pilot Projects of Energy Conservation Renovation of Public Buildings in Chongqing” (Dong & Lin 2016). This policy clarified the requirements for the application, implementation, supervision and acceptance of pilot EPC projects.

(b) Technical regulation and standards

Technical regulation and standards make EPC implementation clearer. To provide references for technical methods of CBEER and specify the technical process, CHURDCQ combined local climatic conditions and related environmental characteristics to compile the local technical standard: Technical Standard of the Application of Energy Efficiency of Public Buildings. It served as the main technical basis to guide the energy conservation diagnosis, scheme design, construction management and completion acceptance of the pilot projects for energy efficiency of public buildings in Chongqing. Meanwhile, to better evaluate the performance of energy saving technologies, the

Chongqing government formulated and promulgated regulation: the Regulation on Energy Saving Renovation Technology and Product Performance of Public Buildings in Chongqing (Dong & Lin 2016). This regulation stipulated the main technical measures adopted in the energy efficiency projects of public buildings in Chongqing and the technical performance of the products, to prevent fake and shoddy products from being used in energy efficiency retrofit and ensure the service quality of CBEER.

(2) Economic measures

(a) Subsidies based on the central demonstration program

Subsidies are the economic measures implemented in Chongqing. Based on the central demonstration program, with a 80 million CNY central subsidy from the demonstration program, the local Chongqing government offered local subsidies at a 1:1 ratio to the central subsidy. Chongqing's policy linked the subsidy directly to the energy saving rate and to promoting ESCOs' participation under EPCs. The subsidy amount was 0 CNY/m² when the energy saving rate was below 10%; 17.5 CNY/m² when the energy saving rate was 10% to 20%; 35 CNY/m² when the energy saving rate was 20% to 25%; and 40 CNY/m² when the energy saving rate was equal to or over 25%.

To encourage adoption of the EPC mechanism, Chongqing's government decided to allocate 80% of the subsidy to ESCOs and the remaining 20% of the subsidy to building owners under EPCs. This means that if the building owners chose to use an EPC to conduct CBEER, the building owners could receive 20% of the subsidy from the government with no need to pay for the costs of CBEER. As a result, 96% of the pilot projects were carried out under EPCs and only 4% of the pilot projects did not use EPCs. Meanwhile, the subsidy was designed to be paid in two instalments of 50% each. The first 50% was paid after construction was completed and energy savings were measured and verified by a third-party auditor. The second 50% was paid after the retrofit when the building had been operating for at least three months.

(b) Subsidies offered by a cooperation mode of financing platform

The subsidy policies were completely incorporated with EPCs. At the same time, a financing platform was developed to use EPCs to conduct CBEER. In 2011, Chongqing government, an ESCO named Tsinghua Tongfang and the Bank of Chongqing signed a

strategic cooperation agreement. This agreement agreed that Tsinghua Tongfang would invest 1 billion CNY, and the Bank of Chongqing would credit 2 billion CNY for Tsinghua Tongfang (Hou 2019). The fund in this agreement would be used to conduct CBEER by EPCs in Chongqing. Meanwhile, the CBEER projects using EPCs would have priority to receive the government subsidy. As a result, a financing platform of “government – enterprise – bank” was developed. Policies on improving the existing financing system are categorised in prescriptive measures in the proposed incentive mechanism. Here the financing platform is a new mode developed in Chongqing, which is not prescriptive. More discussion on how this platform works and how it relates to the proposed incentive mechanism is provided in the next section.

(3) Supportive measures

(a) Building energy information sharing platform and energy audit

A building energy information sharing platform as a supportive measure is helpful for delivering the policy of building energy audit and information disclosure that are introduced in the prescriptive measures. Chongqing government used the building energy information collected by the government from the building energy information sharing platform to set a feasible technical route to achieve the energy saving target. The building energy information includes basic physics information and energy consumption of buildings in all the systems including lighting, heating, ventilation and air conditioning (HVAC) systems. The overall idea of conducting CBEER in Chongqing was based on the information on energy consumption statistics, energy audit, and dynamic monitoring of energy consumption of commercial buildings in Chongqing. The choice of technical options for the retrofits was based on three priority principles: “technical application priority”; “the lowest cost priority”; and “the quickest effect priority”. Through investigation and research, a technical system of CBEER with the goal of an energy saving rate of 20% under EPCs had been gradually developed. Currently, only government has access to the platform. Therefore, the main function of the building energy information platform is to know about the current situation of building energy consumption in Chongqing and provide information references for policy design to the government.

(b) Third-party assessment

Third-party assessment offered stakeholders a baseline and reference for setting the energy saving target and applying for subsidies, which reduced disputes during the period of project implementation. A series of policies were published around the policy of third-party assessment. “The Measures for Measurement and Verification of Energy Efficiency of Public Buildings” and “the Guidelines for Measurement and Verification of Energy Efficiency of Public Buildings” served as the main basis for the verification of the energy saving performance of the pilot EPC projects in Chongqing (Dong & Lin 2016). Meanwhile, the government openly selected three qualified organisations on the basis of merit and organised mutual review of the results of the energy saving verification between the organisations.

(c) Quality control

To maintain a good quality energy efficiency service, the Chongqing government conducted dynamic supervision on the service quality of ESCOs through special records. The special records could provide the government comprehensive information of the projects ESCOs conducted and the projects they are going to implement. To better monitor the EPC projects, the Chongqing government formulated and published administration rules: Essential Points for the Examination of the Demonstration Projects of Energy Conservation Renovation of Public Buildings in Chongqing (Dong & Lin 2016), which unified the examination principles, contents and depths of the demonstration projects, and guaranteed the quality of the compilation of technical plans for the pilot CBEER projects.

Meanwhile, the government implemented total quality control for the energy efficiency service. Three rules were set for the whole-process quality control. Firstly, Chongqing government established a preliminary examination system for CBEER projects to check the energy conservation diagnosis and the design of the technical scheme of CBEER and construction documents. Secondly, a joint review system of experts was established. The government organised independent experts to evaluate the applied projects in CBEER technical plans and construction documents. Projects that passed the review could be listed as pilot projects. The purpose was to ensure the feasibility and operability of the technical plan for CBEER. Lastly, the energy saving verification system was established.

After retrofits, the third-party energy saving verification organisation would be entrusted to verify the actual energy saving situation. Half (50%) of subsidies would be allocated according to the verified energy saving results. After the projects passed the acceptance check and operated for at least three months, the third-party energy saving verification organisation would verify the actual energy saving rate and allocate the remaining 50% of subsidies according to the actual verified energy saving rate.

(d) Demonstration projects

The Chongqing government organised a demonstration program called “Application and Demonstration of Suitable Energy Efficiency Technologies of Existing Buildings” (Dong & Lin 2016) to strengthen the integration, innovation, demonstration and promotion of economical and applicable energy efficiency technologies and provide technological support for the CBEER market.

(e) Standard contracts of EPC projects

A policy of a standard EPC contract was published with the aim of reducing disputes during the period of project negotiation and providing a reference for risk management. Chongqing government organised “Standard Contract Forms for Energy Efficiency EPC Projects”. It aimed to standardise the contract design and negotiation between ESCOs and building owners. The goal was to ensure EPCs could be widely used in the building sector and promote the CBEER market to develop sustainably.

(f) Education

Education is the final supportive measure conducted by the government. The Chongqing government frequently organised on-site engineering meetings, energy conservation forums and other activities to summarise and demonstrate the experience of EPCs in the CBEER market. The Chongqing government, together with the central government and local media, also had diverse publicity to consolidate and expand the energy saving concept in the CBEER market.

10.2.3. Analysis and Discussion

The previous section introduced the policies implemented in Chongqing. Comparing the case of Chongqing to the incentive mechanism proposed in Chapter 9 (Figure 9-5), of the 20 policies proposed in the incentive mechanism, 11 policies have been implemented in practice and received a positive response from the market. Table 10-1 summarises which policies proposed in the incentive mechanism have been implemented in practice and classifies them according to the type of market imperfections.

This section evaluates Chongqing's successes and shortcomings in meeting its two primary objectives: dealing with the issue of market imperfections from three perspectives of incomplete information, market power and externalities; and decreasing transaction costs from three perspectives of asset specificity, uncertainty and frequency. The evaluation of the policy achievements in dealing with market imperfections from two perspectives (participant perspectives and analyst perspectives) is summarised in Table 10-1. The validation of the proposed incentive mechanisms can be derived from the analysis and discussion.

Table 10-1 Comparison of case in Chongqing with proposed incentive mechanisms

Policy Objective 1: Reduce Market Imperfection	Proposed Incentive Mechanism		Case in Chongqing	Does the Policy Achieve the Policy Objective	
				Participant Perspective	Analyst Perspective
Incomplete Information	Prescriptive measures	Law, regulation, and standard on energy saving, energy saving target, energy efficiency strategies	*	√	√
		Policies on information disclosure	*	√	○
		Building energy performance benchmarking	-		
		Policies on credit system improvement	-		
		Compulsory building energy audit for all commercial buildings	*	√	○
	Supportive measures	Building energy information sharing platform	*	√	○
		Enterprise qualification	-		
		Third-party assessment	*	√	√
		Pilot and successful EPC cases	*	√	√
		Standard EPC contract	*	√	√
		Advertising	*	√	√
		Energy insurance	-		
Market Power	Prescriptive measures	Policies on improving existing financing system using potential energy savings as pledge	*	√	x
		Policies on credit system improvement	-		
	Economic measures	Government subsidies	*	√	○
	Supportive measures	Play the role of industry association	-		
Externalities	Prescriptive measures	Law, regulation, and standard on energy saving, energy saving target, energy efficiency strategies	*	√	√
		Energy consumption quota	-		
		Building energy performance benchmarking	-		
		Energy/carbon tax	-		

	Economic measures	Specific tax credit, exemption, deduction	-		
		Government award	-		
		Government subsidies	*	√	○
	Supportive measures	Education	*	√	√

Note: * = the policy is applied in the case.

- = the policy is not applied in the case.

√ = the policy achieved the policy objective.

X = the policy did not achieve the policy objective.

○ = the policy achieved the policy objective partially.

Overall, Chongqing's policies on conducting CBEER by EPCs are summarised in Figure 10-2. Prescriptive measures (regulation on building energy efficiency and EPCs) and economic measures (subsidies) directly improved the uptake of EPCs in the market. The aspect of frequency under the conceptual framework of transaction costs increased directly. The issues of externalities and market power were addressed partially. The supportive measures included four parallel systems: energy information system, market service system, technology support system, and education system. They played a great role in supporting EPC development by sharing information, reducing risks, improving financing access, and improving technical skills and awareness of energy efficiency. The aspect of uncertainty has been decreased and the aspect of asset specificity has been improved. The issues of incomplete information, market power and externalities were addressed partially.

From the perspectives of participants in the case, two objectives (reduce market imperfection and decrease transaction costs) were achieved. From the perspectives of the analysts, two objectives were achieved partially. Some policies had some good effects on the existing market; however, they did not fully move the market towards a more competitive approach. Transaction costs were decreased in somehow, but could be decreased further by fully achieving a more competitive market. Chongqing was the most successful city in achieving the targeted results in this pilot program, because Chongqing not only carried out the program more quickly than the other pilot cities but also incentivised and cultivated the CBEER market at the same time. The following sections provide detailed analysis and discussion.

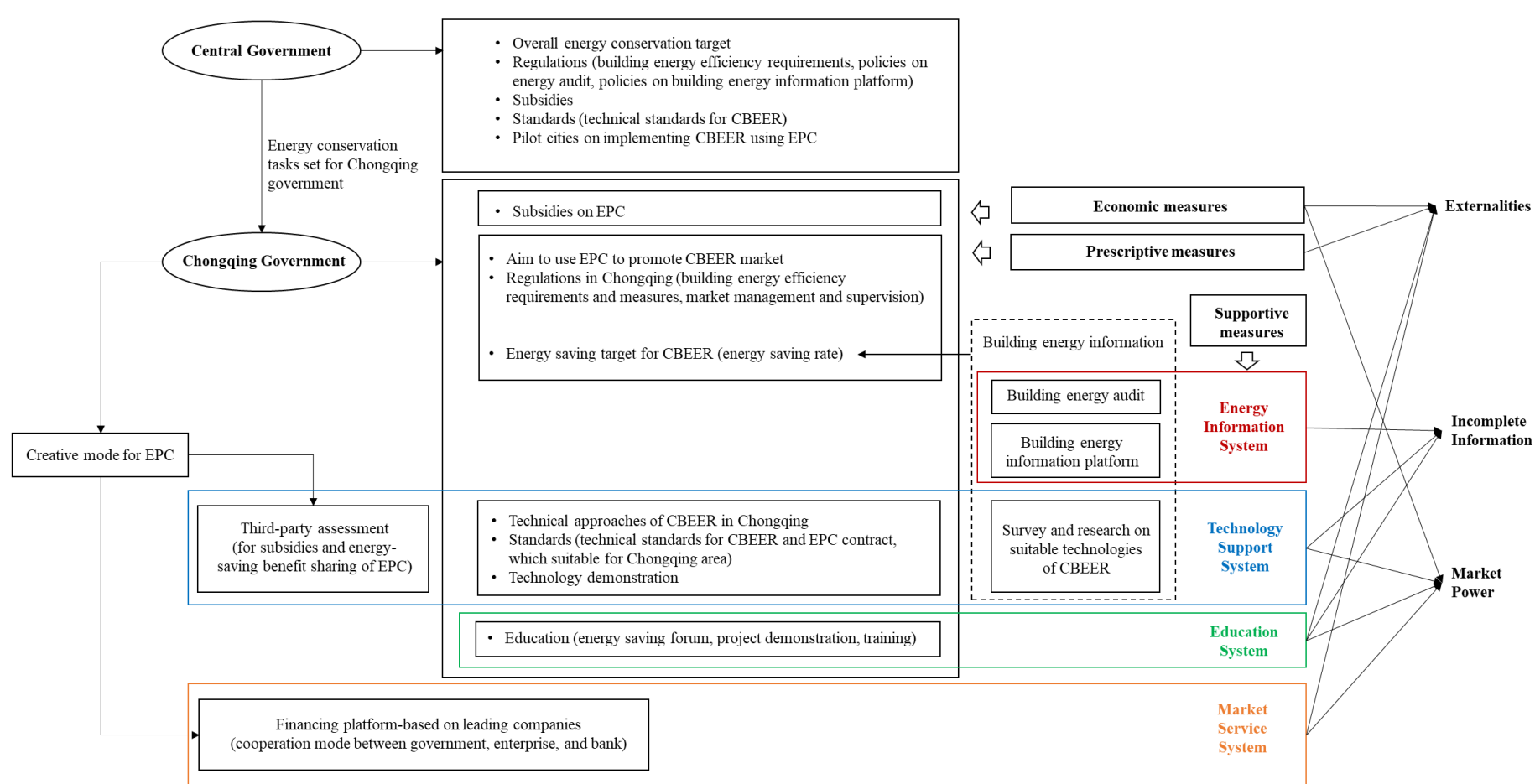


Figure 10-2 Roadmap of Chongqing's successful experience of conducting CBEER by EPCs

(1) Regulation played an overall role in improving the frequency of transactions and addressed the issue of externalities of energy consumption

The central government played an overall role in dealing with externalities of energy consumption by setting the energy saving regulations. The Five-Year Plan is critical for regulating the energy saving targets. Energy efficiency has become one of the key performance indicators for the local government. Therefore, Chongqing government followed the task set by the central government and established policies and strategies for implementing EPCs in practice. The guidance of Chongqing government was targeted on using EPCs to promote CBEER. The regulations set by the Chongqing government directly influenced the local ESCOs and building owners to use EPCs. ESCOs and building owners stated that they feel more confident when the central and local governments have those regulations, and they are more willing to conduct CBEER and take up EPCs. According to the conceptual framework of transaction costs, the frequency of transactions has been improved directly. As a result, the externalities of consuming energy are addressed. However, some building owners and ESCOs showed their concerns on the continuation of these policies. It is particularly strongly reflected in the subsidy policy. Especially for the building owners, it would be better to inspire their desire for CBEER or for using EPCs from their own motivation. Policy continuity is discussed in the next section.

(2) Subsidies are critical for motivating the initial EPC market by improving the frequency of transactions and decreasing externalities through decreasing costs of transaction but face the problem of continuity

Subsidies in Chongqing were designed to use EPCs to conduct CBEER, which attracted a lot of investment in EPC projects (this was verified from the government through private communication, but no data were released). As EPCs are a new concept to the CBEER market in Chongqing, connecting the subsidy level or subsidy allocation with EPC application directly promoted the interests of stakeholders. Meanwhile, linking the subsidy level proportionally to energy savings was effective to encourage CBEER projects to pursue greater energy savings within a single retrofit. Subsidies paid in several instalments are good for retrofit quality management (Hou et al. 2016). The Chongqing government paid the subsidy in two main instalments: one when the retrofit was

completed and approved and one when the projects had been operated for a defined period. Thus, there was no subsidy paid when the project had just started. It puts forward a higher requirement for the financing ability of ESCOs. Therefore, this type of instalments of subsidies requires the government to build a better financing environment for the enterprises. Subsidies actively affect promoting EPC projects and in particular attracted building owners and small ESCOs according to the interview results. Most building owners and smaller ESCOs stated that subsidies are their driving force for using EPCs. The costs of financing and the contract period decrease, which limits risks for ESCOs. According to the conceptual framework of transaction costs, subsidies in Chongqing improved the frequency of transaction of CBEER by EPCs directly. From the perspective of reducing the costs of transaction, subsidies could directly deal with the issue of market power caused by high financial cost and the issue of externalities caused by low uptake of CBEER.

The above perspective shows how subsidies contribute to EPC success in Chongqing. However, they are still an external factor influencing EPC investments. It has a similar problem that regulations face that the interest in EPCs easily disappears if these policies are discontinued. After subsidies from central and local governments stopped, some ESCOs no longer undertook EPC projects. Especially for some small-size ESCOs that strongly rely on subsidies, they have weak ability to face financial problems when the subsidies stopped. According to interviews with the government and ESCOs (there is no accurate data), they stated that the number of ESCOs that still maintain EPC business decreased substantially when the central government stopped the subsidies in 2016. Many small-size ESCOs quit the market (private communication). However, the number of EPC projects and CBEER is still increasing. Therefore, subsidies played a great role in the EPC market, but it requires long-term and internal motivation to stay in the market.

(3) Energy information systems are critical for addressing the issue of incomplete information but are not applied widely at the project level

Energy information systems including building energy audits and building energy information platforms aided access to information. From the government perspective, by getting complete information, it is possible to design more targeted policies. Indeed, under this energy information system, Chongqing government was able to set a practical

target for energy savings of CBEER. Also, based on the building energy information, the Chongqing government was able to design a target technology roadmap and demonstrated feasible technologies of CBEER, which could serve as references for the market. Based on the targeted energy efficiency technologies, EPC projects could be implemented more specifically, and the stakeholders could get more certain energy saving benefits. As privately-owned commercial buildings are very sensitive to the cost of energy consumption (as the energy price for commercial buildings set by the government is higher than for other types of buildings), the targeted technologies of CBEER make CBEER and EPCs more attractive in the market. At the same time, energy saving rate related subsidies for EPCs make EPCs more popular in CBEER and the energy saving potential has been tapped to a large extent.

However, the above information on building energy is only available to the government and ESCOs could not get that information to conduct EPC projects. For the buildings that installed energy platforms, building owners have significant problems in maintaining and using the platforms. Although the central government offered financial subsidies to build the building energy information platforms, without continuous investments in maintenance of the platforms, their roles are limited. Some advanced ESCOs have an ability to build their own building energy monitor platform and tend to use it when they conduct retrofits. For the projects installing a building energy monitor platform, both the building owners and ESCOs stated they are beneficial and increase their willingness to conduct EPCs. From the perspective of transaction costs, it increases a great amount of asset specificity for transaction parties. Although the costs of construction are higher than for the projects without building energy information platforms, the issue of incomplete information is well addressed. The transaction costs decrease accordingly. The policy of information disclosure is still waiting to be further implemented. A widely used building energy information platform is still waiting for further implementation. If information sharing is still restricted to the government level, full market competitiveness is not achieved.

(4) Third-party energy assessment for EPCs is helpful for decreasing the uncertainties of the projects to address the issue of incomplete information

It is challenging to quantify operation-related energy savings; therefore, the retrofit energy savings are also hard to assess and verify. This makes EPCs difficult to implement because EPCs use the actual energy savings as benefits. The Chongqing government used third-party auditors to conduct energy assessment for building owners and ESCOs as a reference to share energy saving benefits. It also acts as evidence for applying subsidies. It reduces a great number of uncertainties on energy saving benefit sharing under EPCs. All the ESCOs and building owners stated having the third-party energy assessment meant they had less concerns on dealing with conflicts on determining energy savings in the future. This limits conflicts between building owners and ESCOs and makes EPCs more attractive.

Meanwhile, the Chongqing government paid for the costs of energy assessment of commercial buildings for the building owners and ESCOs under EPCs. There are three institutions authorised by the Chongqing government for conducting energy assessment. These institutions have a high degree of authority and uniformity to assess energy savings. The investment in third-party assessments by the government directly decreases the uncertainty of transactions, and the transaction costs decreased accordingly. Third-party assessment is a guarantee for the contracting parties if the actual energy savings are controversial. Some ESCOs and building owners even prefer to use the energy savings assessed by the third party than the actual energy savings. Although this is far away from the essence of EPCs, in the initial EPC market, it is a practical way to limit risks and develop the market. Third-party assessment is necessary when the EPC market has not been fully developed, especially when there are huge problems related to incomplete information.

(5) Cooperation mode between government, enterprises and banks as a financing platform to address the issue of market power and externalities but the issue of market power still exists

A cooperation mode of implementing EPCs was designed to offer financing necessity including the financial support and energy saving assessment to ESCOs. It is a new design on the financing platform by the Chongqing government linking government, enterprises and banks together. A government interviewee from Chongqing stated the EPC market development in Chongqing is tightly related to the cooperation between government, enterprises and banks. Their initial vision is to make use of this mode to develop the market. Some subsidies offered by the Chongqing government are linked to this platform. This improves the frequency of transaction directly as it can solve the financial problems of ESCOs to some extent. Meanwhile, this financing platform also reduced the asset specificity of transactions for ESCOs, especially the small-size ESCOs.

This creative cooperation mode gives great support on financial issues for ESCOs addressing market power. Figure 10-3 summarises how this cooperation mode works. The red arrows represent the capital flow during the cooperation. The green arrows represent the information flow during the cooperation. This mode provides leadership for leading ESCOs. It tries to solve two issues of barriers to EPCs: the financial problem and the comprehensive service capacity of ESCOs.

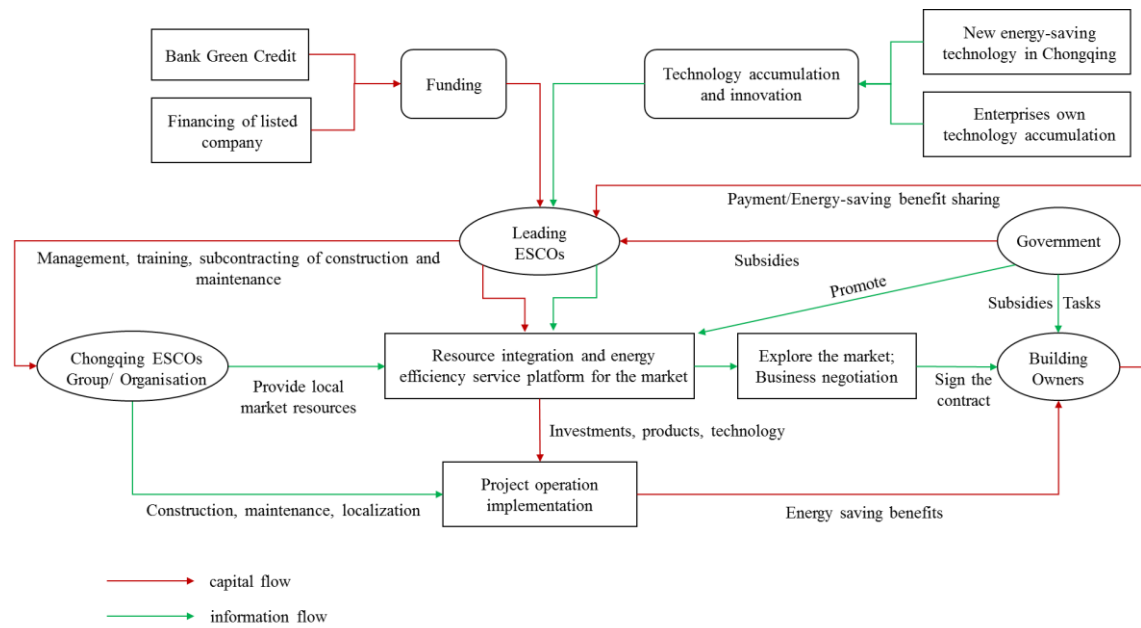


Figure 10-3 Cooperation mode between government, enterprises and banks

The effect was to really promote the initial market and attract many small ESCOs to enter the market. However, it did not directly solve the issue of market power related to access to finance. The leading ESCOs played a critical role in this cooperation mode of the financing platform, thus they maintain more power than the smaller ESCOs. The entry level to enter the EPC market is still very high. Although many ESCOs entered the market

by following the leading ESCOs, they were still in a weak position in the market. The leading ESCOs have great influence on the market. In the early stage, there many ESCOs flooded into the market. After a while, without government endorsement and especially as subsidies decreased, the small ESCOs disappeared from the market (this finding is from interviews with leading ESCOs and government). Although the government was trying to intervene in the market by addressing the issue of access to finance, the approach they adopted only solved the symptoms but not the actual problem. This cooperation mode of financing platform did not support these small companies in the long term.

10.3. Case Two: EPC Experience of Changning District in Shanghai

10.3.1. Background of the Case

Shanghai municipal and Changning district governments are firmly committed to developing a low-carbon city, and achieving their carbon-intensity reduction targets was one of the top priorities in their 12th Five-Year Plan (World Bank 2013). This case focuses on the EPC experience in Changning district of Shanghai. As Changning district is part of Shanghai municipality, the background information of the EPC experience is introduced from Shanghai municipality to Changning district.

(1) Background of EPC experience in Shanghai

Shanghai is located in the southeast China. Similar to Chongqing, Shanghai is one of the four direct-administered municipalities in China. It is China's largest economic centre and the most attractive location for foreign investment in China. Shanghai's building stocks are increasing exponentially and energy consumption from commercial buildings is increasing rapidly. The commercial sector has only 37% of the total area, but consumes around 70% of the total energy of the whole building stock in Shanghai (Jiang & Tovey 2010; Kung 2014). The city is striving to become a global centre for finance, trade and technological innovation by 2035, while at the same time transitioning to a "low-carbon city".

Conducting CBEER to decrease energy consumption and carbon emissions is one of the main methods under the aim of developing a “low-carbon city” in the building sector. To reduce energy use of commercial building, the Shanghai government has implemented a series of policies related to measurement, audit, disclosure and reduction of energy consumption (Sherlock et al. 2020). In the 12th Five-Year Plan (2011–2015) a city-wide building energy monitor online platform was built to monitor the energy consumption of 1,288 commercial and public buildings. This platform enabled Shanghai to identify 4 million square metres of inefficient commercial and public buildings for further retrofits (Sherlock et al. 2020).

Similar to Chongqing, Shanghai was listed as one of the first key pilot cities for energy conservation renovation of public buildings program (see Section 10.1). In this program, the Ministry of Housing and Urban-Rural Development (MOHURD) and the Ministry of Finance (MOF) set the task for the Shanghai government. The final completed energy efficiency area of public buildings should be no less than 4 million square metres and the energy consumption per unit area of public buildings should be reduced by more than 20%. Under this program Shanghai could access a special fund of 80 million CNY from the national finance for energy conservation and emission reduction. Similar to Chongqing, 67% of Shanghai’s pilot projects have been identified mainly through market channels (Hou et al. 2016).

The department responsible for EPCs in Shanghai is the Economic and Information Technology Commission, Shanghai (EITC), which is in charge of industrial energy conservation. EPCs were originally used mainly in industry, and were later introduced into building energy efficiency retrofits. Shanghai’s EPC policies were issued by the EITC and have been maintained in recent years. The main policy issued by the EITC is “Shanghai Municipal Special Support Measures for Industrial Energy Conservation and Energy Performance Contract Project [2017] No. 220”, jointly issued by Shanghai Municipal Economic and Information Technology Commission, Municipal Development and Reform Commission and Municipal Finance Bureau.

(2) Background of EPC experience in the Changning District

Changning district is one of 16 districts in Shanghai and located in the central west area. It covers an area of 38.30 square kilometres and has a resident population of 693,700. It is an established district with mostly commercial buildings and few industrial activities. At the forefront of Shanghai's effort to transition to a "low-carbon city", its vision is to "transform Changning into a leading low-carbon district anchoring to green growth as the engine for the competitiveness of the district". Changning district sought to achieve this vision by leveraging international expertise and piloting innovative policies and programs, yet to be implemented anywhere in the country. By 2015, the carbon intensity in Changning district had been reduced by 17% compared to 2010 (Sherlock et al. 2020). By 2020, the Changning district planned to have retrofitted a total of 1.5 million square metres of existing commercial and public buildings. The target has been achieved as scheduled.

World Bank – Global Environment Fund offered support for Changning's energy efficiency policies. This fund (2013–2018) helped set up a dedicated management office – Changning Low Carbon Office, to provide assistance and advice for the implementation of energy efficiency policies (Sherlock et al. 2020). This office is directly supervised by Changning District Development and Reform Commission and has carried out research projects in building energy efficiency benchmarking and disclosure, commercial and public building energy commissioning and management, methods to promote successful existing building energy efficiency retrofit case studies, and innovative green finance mechanisms (Sherlock et al. 2020). Changning district did not conduct the energy conservation work on the CBEER and EPCs separately but did them as a whole. From the perspective of the Changning government, the role of EPCs and the other similar market mechanisms would develop naturally if a more sustainable environment for CBEER was developed.

10.3.2. Policy Implementation

(1) Prescriptive measures

(a) Prescriptive low-carbon target

Changning district's CBEER and EPC projects were implemented under the prescriptive policy of the low-carbon target for buildings. Following China's building energy administration structure, Changning district's building energy efficiency target was designed based on Changning district's low-carbon target according to the Chinese national energy and greenhouse gas emission reduction target and Shanghai's low-carbon target.

To set the energy efficiency target, the Changning government invited the World Bank and an international consulting firm and cooperated with the Shanghai Energy Conservation Supervision Centre. Based on the data gathered from the energy consumption monitoring platform (ECMP) and a carbon dioxide (CO₂) abatement cost curve the above departments developed, the Changning government could set CO₂ abatement targets and identify prior actions and various options of CO₂ mitigation in the commercial sector. The final energy efficiency target in Changning district was set to reduce current energy consumption of at least 100 existing commercial buildings by 18%. The energy efficiency target and strategies offered the market a direction of CBEER.

(2) Economic measures

(a) Subsidies based on the central demonstration program

Under the policies of central government, with a 80 million CNY central subsidy from the demonstration program, the Shanghai government offered a local subsidy at a rate of 1:1 to the central subsidy. Shanghai's policy linked the subsidy intensity directly to the energy saving rate and compared the energy performance of projects after retrofits to Shanghai's commercial building energy efficiency standard for the construction of new buildings (DGJ08-107-2012). The subsidy amount was 35 CNY/m² when the energy saving rate was over 20% for non-EPC projects; and 40 CNY/m², when the energy saving rate was over 20% for EPC projects (Hou et al. 2016). The subsidy amount was 80 CNY/m², when the retrofits meet or exceed the requirements of the energy efficiency

standard DGJ08-107-2012 for new buildings. However, it is difficult to meet the requirements and no projects received the 80 CNY/m² level of the subsidy. For the projects that could achieve the same level of energy savings, by setting a different subsidy for non-EPC and EPC projects, the Shanghai government could promote EPCs.

Based on the survey results from Hou et al. (2016), 67% of demonstration projects completed in Shanghai had been implemented by EPCs. Similar to Chongqing, Shanghai's subsidy was paid in two instalments. In contrast to Chongqing, the first 50% of the subsidy was paid after the retrofit application was approved, and the second 50% of the subsidy was paid after the completion of the retrofit and M&V by a third party.

(b) Overall incentive policies in Shanghai

The Shanghai government regulated general energy conservation plan for commercial buildings, then based on these regulations offered subsidies for energy efficiency technologies, CBEER demonstration projects, EPC projects and credits for tax for the enterprise's energy saving work. The details are summarised in Table 10-2.

Table 10-2 Overall building energy efficiency and EPC policy in Shanghai

No.	Policies	Type
1	Regulations of Shanghai Municipality on Energy Conservation	Regulation
2	Regulations of Shanghai Municipality on Building Energy Conservation	Regulation
3	Procedures of Shanghai Municipality for the Administration of Special Funds for Energy Conservation and Emission Reduction	Subsidy
4	Interim Measures of Shanghai Municipality for Special Support to Building Energy Efficiency Projects	Subsidy
5	Measures of Shanghai Municipality for the Special Support and Implementation of Retrofitting Technologies of Energy Conservation and Emission Reduction	Subsidy
6	Measures of Shanghai Municipality for the Support of Special Funds for the Development of Renewable and New Energy	Subsidy
7	Shanghai Municipal Special Support Measures for Industrial Energy Conservation and Energy Performance Contract (EPC) Project	Subsidy
8	Procedures of Shanghai Municipality for the Special Support and Implementation of Energy Performance Contract Projects	Subsidy
9	Rational Use of Energy Guide for Large-scale Commercial Buildings	Standard
10	Shanghai Municipal Work Plan for Accelerating the Promotion of High-efficiency Electric Machines and Promoting the Remanufacturing of High-efficiency Electric Machines	Regulation
11	Detailed Rules of Shanghai Municipality for Accelerating the Promotion of High-efficiency Electric Machines and Promoting Remanufacturing of High-efficiency Electric Machines	Subsidy
12	Notice on the Identification and Management of Special Equipment for Energy Saving and Water Saving, Environmental Protection and Production Safety and the Credit of Enterprise Income Tax	Tax
13	Announcement in Accelerating Shanghai's Commercial and Public Buildings Monitoring System	Regulation
14	Shanghai's Guide to Energy Efficiency Operation for Large-scale Commercial Buildings	Regulation

(c) Target incentive policies in Changning district

In order to increase the acceptance of the stakeholders of the overall existing building energy efficiency targets and improvement plans, Changning government conducted an evaluation of a range of practical rewards and punishment measures on the stakeholders of CBEER. Table 10-3 shows the evaluation results of the target stakeholders of each policy.

Table 10-3 Possible government incentive policies for different stakeholders

Government Incentive Policies		Stakeholders			
		Building Owners	ESCOs	Financial Institution	Tenant
Rewards	Subsidies	√			
	Technical support and education	√	√	√	√
	Green Energy Efficiency Award	√			√
	Low interests/ increase credit limits		√	√	
	Tax incentive	√	√		
	Simplify the permit application process	√	√		
Punishment measures	Administrative penalties and fines for non-compliance	√			
	High utilities/additional charge	√			√
	Blacklist	√			

Based on the above evaluation, Changning government also allocated special funds for energy conservation and emission reduction from its management funds to support CBEER. These special funds regulated a package of economic policies applied in Changning district. In the special funds, one support policy is “the Management Method of the Special Funds for Low-Carbon Development in Shanghai Changning District”. This policy could be valid for five years. The contents supported by the special funds are summarised in Table 10-4. The special funds are offered as two categories: subsidies and awards.

Table 10-4 Special funds for energy conservation and emission reduction in Changning district

Policies	Description
Subsidy for energy audit	The annual subsidy for energy audits of commercial buildings that consume more than 2,000 CNY/tce* should not exceed 80,000 CNY. For buildings with energy consumption between 500 and 2,000 tce, the subsidy should not exceed 40,000 CNY. Buildings undergoing energy audits in 2012 and 2013 should be reimbursed in full for audit costs; and the subsidy should be reduced gradually over the following few years.
Subsidy for energy saving and emission reduction amount or investment	A financial subsidy of 100 CNY/tce is provided based on the actual audited energy savings. If the energy efficiency of the building is improved significantly, a subsidy of 25% of the energy efficiency investments can be offered to the enterprise through audit, and the amount of this subsidy for a single project is not more than 2.5 million CNY.
Subsidy for incentive demonstration project	According to the innovation of the project or the energy efficiency level of the equipment and system operation, a one-time incentive subsidy ranging from 20,000 CNY to 250,000 CNY will be provided for a single project.
Subsidy for interrupted operation from a retrofit	If the normal business is interrupted for 6 months or more and it is caused by the implementation of CBEER, 30% of the actual rent loss caused by the retrofit can be compensated, but the maximum amount of subsidy for a single project is not more than 1 million CNY.
Subsidies for fundamental work to build the low-carbon demonstration area	It provides subsidies for the establishment of an online monitoring system for building energy efficiency data, for evaluation and assessment, and for low-carbon research. It also provides subsidies of 1,000 CNY/tce for other low-carbon projects in low-carbon demonstration areas.
Subsidy for individual energy efficiency technical retrofitting projects	Subsidies are set for boiler and envelop retrofits, HVAC and lighting system retrofits, renewable energy applications, green roof projects.
Subsidy for EPC projects	Subsidies for EPC projects shall be provided based on the amount of energy savings. The subsidy standard is 500 CNY per unit energy saving, and a one-time subsidy equal to 15% of the actual energy saving investment shall be provided. For the projects that obtain municipal special incentive funds, Changning district government should give matching funds at a ratio of 1:1. The total subsidy for a single project should not exceed 2 million CNY. For pilot projects that meet more than 55% of the existing building energy efficiency renovation standards and have building area for a single unit of more than 20,000 square metres, subsidies should be given on a per unit building area basis.
Award for demonstration projects of CBEER	For the use of energy efficiency building envelope structure, renewable energy or new technology, and after retrofits the energy saving rate reaching 55%, and after examination the projects are selected as the demonstration projects of CBEER in Changning district, the projects shall be given a reward of not more than 250,000 CNY.
Award for advanced institution and individuals	The relevant departments, energy-using units and property managers of Changning District who have made remarkable achievements in promoting CBEER, energy saving management and reducing energy consumption should be rewarded. In addition, the special fund also provides 200,000-250,000 CNY for each demonstration project or advanced personnel as recognition and reward.

Note: tce stands for tonne of coal equivalent.

(3) Supportive measures

(a) Energy consumption monitoring platform

The commercial building energy consumption monitoring platform (ECMP) played an important role for the Changning government in collecting data to set the energy efficiency target. This platform was officially put into operation in July 2011 and covered over 100 commercial buildings. This platform included information on building characteristics (location; type and function; building size; construction year; occupancy), building energy data (total energy consumption; energy consumption by end-uses/system and by fuel type) and other information on water consumption and retrofitting information.

(b) Benchmarking and disclosure on commercial building energy

Changning district has been leading policies related to benchmarking and disclosure for identifying potential buildings for retrofits (Sherlock et al. 2020). Buildings would be ranked for energy performance based on Shanghai's Guide to Energy Efficiency Operation for Large-scale Commercial Buildings and categorised by building types. Outcomes would be disclosed on the government website. Building owners would then receive their energy bills and ranking results. This policy has incentivised motivation of energy conservation to some extent.

(c) “Pre-review and filling” policy assisting the application of subsidies and loans

Policy “pre-review and filling” is an innovative administrative process designed by the Changning government to manage EPC projects. After the evaluation and approval of the declared EPC projects by the government (showing the projects have energy saving potential), the applicants (ESCOs) sign the filing form with the government (register the record in the government). The subsidies could be paid by the government through the financial institution to the applicants. It is a guarantee for both ESCOs and the financial institutions, which is considered a policy offering financial support.

(d) Voluntary cooperation project to promote CBEER and EPC

In 2016, Changning district committed to be the first pilot project for the Better Buildings Challenge program in China (Sherlock et al. 2020). This is a comprehensive voluntary energy efficiency program launched in cooperation between the China Association of Building Energy Efficiency, Lawrence Berkeley National Laboratory and the Energy Foundation. Through this program, Changning district aimed to achieve 20% energy savings in the commercial building sector within 10 years and disclose building energy performance data. The targets are developing at least five energy-efficient demonstration projects in Shanghai, 15 case studies using EPCs on building retrofits and 20 CBEER projects with over 20% energy savings (Sherlock et al. 2020).

Meanwhile, Changning district government cooperated with the International Bank for a project “Reconstruction and Development/Global Environment Facility Green Energy for Low Carbon City”. This project provided loans of USD 100 million, combined with an additional USD 146 million from institutional investors, which brought great opportunities and financial support to CBEER.

10.3.3. Analysis and Discussion

The previous section introduced policies implemented in Changning. Comparing the case of Changning to the incentive mechanism proposed in Chapter 9 (Figure 9-5), of the 20 policies proposed in the incentive mechanism, 10 policies have been implemented in practice and received a positive response from the market. Table 10-5 summarises which policies proposed in the incentive mechanism have been implemented in practice and classifies them according to the type of market imperfections.

This section evaluates Changning’s successes and shortcomings in meeting its two primary objectives: dealing with the issue of market imperfections from three perspectives of incomplete information, market power and externalities; and decreasing transaction costs from three perspectives of asset specificity, uncertainty and frequency. The evaluation of the policy achievements in dealing with market imperfections from two perspectives (participant perspectives and analyst perspectives) is summarised together in Table 10-5. The validation of the proposed incentive mechanisms can be derived from the analysis and discussion.

Table 10-5 Comparison of case in Changning with proposed incentive mechanisms

Policy Objective 1: Reduce Market Imperfection	Proposed Incentive Mechanism		Case in Changning	Does the Policy Achieve the Policy Objective	
				Participant Perspective	Analyst Perspective
Incomplete Information	Prescriptive measures	Law, regulation, and standard on energy saving, energy saving target, energy efficiency strategies	*	√	√
		Policies on information disclosure	*	√	○
		Building energy performance benchmarking	*	√	○
		Policies on credit system improvement			
		Compulsory building energy audit for all commercial buildings	*	√	○
	Supportive measures	Building energy information sharing platform	*	√	○
		Enterprise qualification			
		Third-party assessment			
		Pilot and successful EPC cases	*	√	√
		Standard EPC contract			
		Advertising	*	√	√
		Energy insurance			
Market Power	Prescriptive measures	Policies on improving existing financing system using potential energy savings as pledge	*	√	x
		Policies on credit system improvement			
	Economic measures	Government subsidies	*	√	○
	Supportive measures	Play the role of industry association	*	√	√
Externalities	Prescriptive measures	Law, regulation, and standard on energy saving, energy saving target, energy efficiency strategies	*	√	√
		Energy consumption quota			
		Building energy performance benchmarking	*	√	√
	Economic measures	Energy/carbon tax			
		Specific tax credit, exemption, deduction			
		Government award	*	√	○
		Government subsidies	*	√	○
	Supportive measures	Education	*	√	√

Note: * = the policy is applied in the case.

- = the policy is not applied in the case.

√ = the policy achieved the policy objective.

X = the policy did not achieve the policy objective.

○ = the policy achieved the policy objective partially.

Overall, Changning district's policies on conducting CBEER and EPCs are summarised in Figure 10-4. A prescriptive measure (building energy efficiency target) guided the market and improved the willingness of conducting CBEER. The issue of externalities was addressed partially. During this process of implementing the policies, EPCs became known by the market. Economic measures (subsidies) played the most important role in improving the uptake of EPCs in the market by directly increasing the frequency of transactions. The issues of externalities and market power were addressed accordingly. Supportive measures in Changning included two systems: market service system and information disclosure system. The market service system is an administrative mechanism called "pre-review and filing" to offer financial support to ESCOs through financial institutions. It was designed to improve access to finance. The issue of market power is addressed accordingly. The information disclosure system is the most successful practice to deal with the issue of incomplete information.

These policies aimed to address the identified market imperfections. From the perspectives of participants in the case study, the two objectives (improve market imperfection and decrease transaction costs) were achieved. From the perspectives of analysts, the two objectives were achieved partially. According to the market investigation, the willingness to use EPCs substantially improved and stakeholders in the market showed their positive attitudes towards the development of the EPC market, however there is still more to do to realise a more competitive market and many shortcomings still exist. Following is the detailed analysis and discussion.

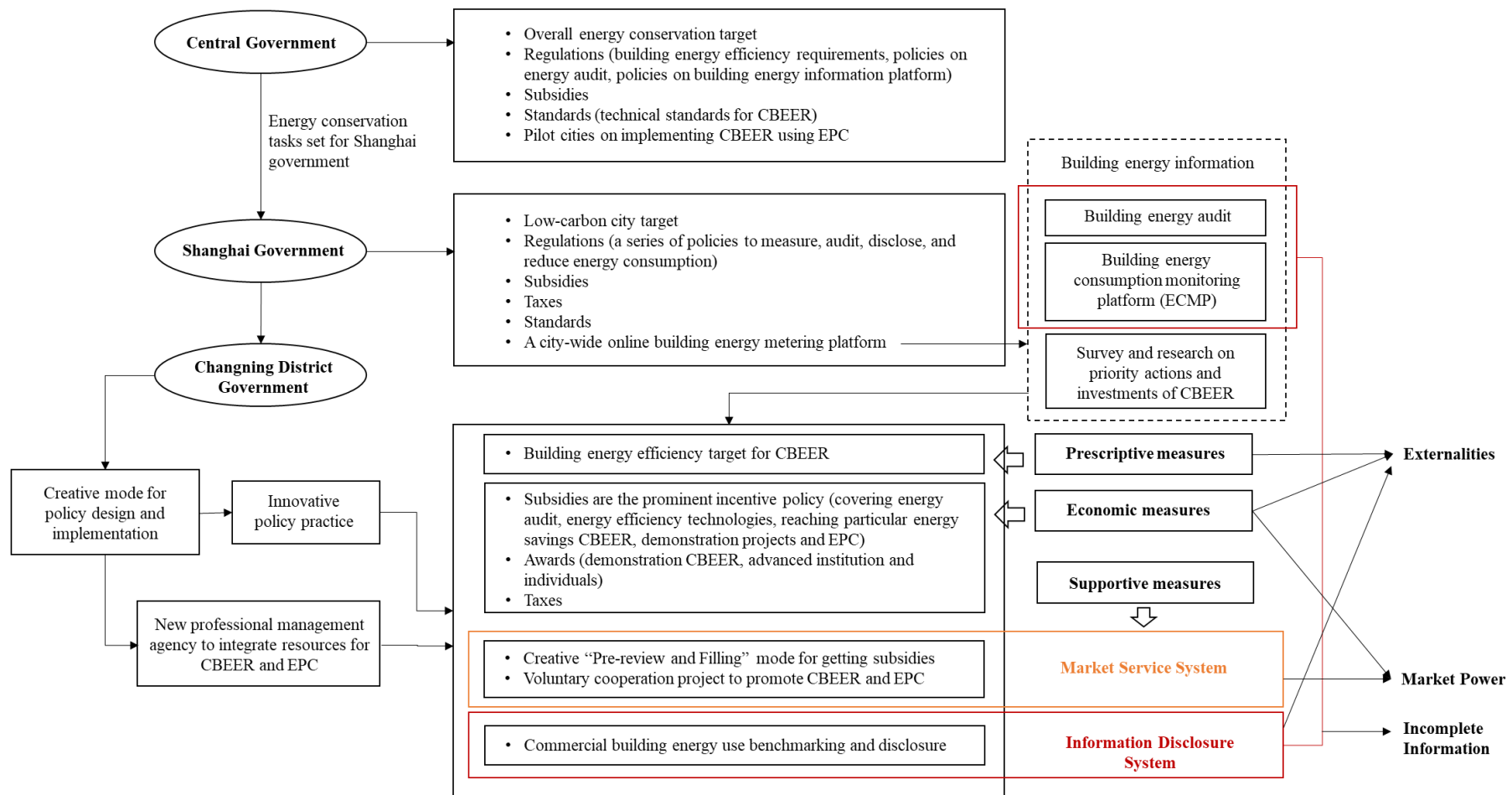


Figure 10-4 Roadmap of Changning district's experience of conducting CBEER and EPCs

(1) Subsidies as the major economic measures played the most important role in promoting the CBEER market in Changning to address the issues of externalities

Subsidies were set directly to improve the frequency of conducting CBEER. The performance of subsidies is already evident in the accelerating growth of EPC projects. There are various subsidies offered in Changning as introduced in the last section. These subsidies addressed many perspectives on CBEER including energy audit, energy efficiency technologies, and energy efficiency effect, and covered almost all the stages of CBEER projects. To motivate all types of stakeholders, some awards were set together with the subsidies. Subsidies offset part of the costs of CBEER. By decreasing the costs of CBEER, the financial costs were decreased. As a result, the market power decreased accordingly for the ESCOs. With subsidies, building owners' willingness to conduct CBEER substantially increased, which decreased the externalities caused by the building energy consumption accordingly. Meanwhile, some awards were set to reward tenants who had performed well during CBEER. They aimed to solve the split incentive problem of externalities. As a result, the above measures increased the frequency of transactions accordingly.

Although Changning district and Shanghai government set subsidies for using EPCs, they did not separate the EPCs from CBEER significantly. Subsidies were offered for both the EPC and non-EPC projects. The goal was to build a good environment for CBEER. Then, EPCs could play their role naturally. Indeed, by improving the environment of CBEER, more building owners became more familiar with EPCs than before. Without having adequate access to finance by the ESCOs, the uptake of EPCs was still limited. Subsidies were limited compared to the costs of CBEER. This is discussed in the next part.

(2) “Pre-review and filling” made some progress on access to finance, but still did not fully address the issue of market power

In contrast to the practice of Shanghai and other domestic government subsidies, Changning's subsidies adopted the system of “pre-review and filing” which functioned as a kind of government endorsement to offer financial support to EPC projects. The aim of this policy design is to deal with the problem of access to finance. Under “pre-review and filling”, the projects that passed the government review could get subsidies through

a financial institution. It was a trial for using the future energy saving benefits to apply for loans from banks under government endorsement.

From the perspectives of ESCOs, the probability of getting access to financial support is improved under this policy because the pre-review filling system gives financial institutions more confidence to lend money to the ESCOs. It is good practice to build a more friendly financing environment and, as a result, it improves the possibility of the implementation of EPCs. By this “pre-review and filling” mode, the frequency of transactions is increased. The market power problem related to access to financial support seems to be addressed partially.

The above success is built on the subsidies offered by the government. According to the investigation in the market, except for getting subsidies through banks, ESCOs rarely get loans from banks based on the future energy saving benefits. Although this policy is to improve the attention of financial institutions on the potential of CBEER to produce energy saving benefits, the financial institutions are reluctant to use it. There are two reasons: the risk of EPC projects and limited energy saving benefits of CBEER compared to investment in new constructions. Therefore, if the issues of incomplete information and the financing system are not improved, the problem of access to finance remains far from resolved. As a result, the issue of market power is still present.

(3) Building information disclosure system is critical for the energy efficiency market development in Changning by improving the issue of incomplete information and externalities

The building information disclosure system in Changning is advanced compared to those of other cities in China, and it received much positive feedback from independent experts, government and ESCOs. The system covers all kinds of methods to gather information and disclosure.

Firstly, the building energy consumption monitoring platform offered basic information for the government to understand the actual energy consumption of commercial buildings. At the beginning, based on energy audits and real data gathered from the platform from 100 existing commercial buildings, the Changning government found commercial buildings with great energy saving potential and identified priority mitigation

options. Through the completion of CBEER of the 100 existing commercial buildings, based on the real-time data, the Changning government was able to continually improve the policies and provide better guidance to CBEER. Meanwhile, with the data gathered from the platform and statistical data, the Changning government cooperated with financial institutions like the World Bank to gain finance support, and with research institutions to work out good ways to offer services to the market. As a result, the government integrated all kinds of resources for building owners and ESCOs. As a centre of information gathering, it can assist to integrate and share information between the stakeholders, and limit the information gap between stakeholders.

Similar to Chongqing, the building energy consumption monitoring platform could not be used by ESCOs and building owners. Thus, the government played a role as a monitor and a medium for introducing CBEER or EPCs to building owners. Information was shared by the government. From the perspective of the government, although this platform has not been used widely between ESCOs and building owners, it supports energy audits and other information disclosure methods, for example, building energy use benchmarking and disclosure. However, without sharing information within projects, the potential of the platform is not realised. Therefore, some ESCOs installed building energy information monitor platforms by themselves to monitor building energy consumption to maintain buildings. In conclusion, the contribution of the building energy information platform is agreed by the stakeholders, but how to fully use the platform to address the issue of incomplete information needs to be discussed further.

As mentioned above, comprehensive building energy audits and commercial building energy benchmarking and disclosure worked together to deal with the issue of incomplete information. According to interviews, building energy audits are beneficial for both building owners and ESCOs by improving the knowledge about the current energy situation of the buildings and decreasing the probabilities of asymmetric information. However, without wide use of energy audits as a prescriptive measure, few building owners were willing to perform them, although ESCOs were very supportive of this policy.

The policy of commercial building energy use benchmarking and disclosure is a new approach for limiting the information gap on building energy consumption. From the perspective of the government, ranking the energy consumption of buildings is a way to let building owners know about the level of energy efficiency of their buildings, which could push them to do CBEER. This policy not only improves the issue of incomplete information but also deals with the issue of externalities. According to the investigation, building owners were concerned whether the government would use the benchmark to punish them if their building energy consumption was shown to be high. Some building owners were concerned that, if they were ranked last, they would think about doing CBEER or face punishment. From this perspective, the policy of energy use benchmarking has great potential to incentivise the market.

10.4. Further Discussion and Recommendations

Sections 10.2 and 10.3 introduced the experience where governments implemented EPC projects in specific contexts and analysed the effects of the policies. Overall, the two cases show high alignment with the proposed incentive mechanisms in Chapter 9, and hence provide strong support to the incentive mechanisms. Both the two cases were trying to address market imperfections and the frequency of transactions directly improved in the market. Under the current policies, the EPC market was developed to some extent but did not fully achieve its potential. The shortcomings are shown from the analysis. Although from the perspectives of participants the two cases achieved the two policy goals, from the perspectives of analysts, the two policy achievements were only partial. Therefore, this section further discusses how the policies or strategies proposed in the incentive mechanism could better facilitate the market. Some considerations of applying the policies and strategies are discussed.

10.4.1. Subsidies Incentivised the Initial EPC Market in the Short

Term: Energy/Carbon Tax is a Substitute Economic Measure in the Long Term

In both the cases, governments used subsidies to attract stakeholders' attention to conduct EPCs. The purpose was to deal with the issue of externalities. By implementing subsidies, the number of EPC projects increased directly because subsidies are a "pull-type" policy, which can improve investments in energy efficiency directly (Merrill & Sintov 2016). Still, there are some flaws in subsidies. Firstly, direct subsidies have an inevitable rebound effect because they can just reduce energy prices in the end. Secondly, direct subsidies do not meet the principle of cost-effectiveness because they require investment from the government sector. Thirdly, the process of allocating subsidies to a specific project requires careful evaluation and verification procedures by the government to evaluate the energy saving effect, which brings additional costs.

From the government perspective, subsidies can help develop the market at the very beginning. When the market is mature, it knows about the benefits of EPCs, and should function by itself. However, when some subsidies from central government stopped, a few small ESCOs no longer undertook EPC projects and the willingness to use EPCs decreased substantially. Although the EPC projects are still increasing, the growth rate is now very slow. It can be seen that subsidies are helpful as a short-term market incentive.

From the perspective of boosting demand, clear assignment of responsibilities of building energy conservation is the long-term goal. Motivating the basic demand for energy efficiency and financing access are the major concerns. It suggests the need for other policies focusing on a long-term effect.

The incentive mechanism proposed two policies belonging to the economic measures which could be a substitute for subsidies in the long term: energy/carbon tax and a specific tax credit, exemption or deduction. As tax policies are newly suggested in the sector for building energy conservation, they were not implemented in the two cases. The benefits of a carbon tax have been verified through an economic model (China Environmental-Energy-Economy Analysis) by researchers Jia & Lin (2020) and practice in many countries and also for dealing with similar problems (Metcalf 2021). These research show

that in the long term, a carbon tax may have strong emission reduction capacity and high relative emission reduction efficiency. The main problem of a carbon tax is about who should be in the taxation system and the measurement of the tax rate”. The concept of a carbon tax has relatively unified understanding across the industry, but the carbon tax rate should adapt to local conditions. By collecting an energy tax on energy, the price of energy would increase, and consumption would go down to a new equilibrium with a higher price and a smaller quantity traded. An opposite method is not setting a carbon tax for building owners or building users. A tax exemption policy could be set for the companies who do energy efficiency, which would cause similar benefits to the market. Especially under EPC mechanism, ESCOs take the responsibility of building owners to manage energy consumption, and a tax exemption for ESCOs is also an appropriate incentive for these companies.

10.4.2. Strengthening the Role of Demand-pull Policies to Address the Issue of Externalities to Better Achieve the Role of the Market

In the two cases, the prescriptive measure “law, regulation, and standard on energy saving, energy saving target, energy efficiency strategies” initiated energy efficiency retrofits and the EPC mechanism to address the issue of externalities. Under China’s current governance system, the government has more power to lead the market than the market itself. Therefore, in the two cases, it was the government support that led the market to embrace the concept of energy efficiency. Under the overall energy conservation target by the central government, local governments could develop the specific energy saving target and strategies to incentivise the market. However, in order to incentivise the market to move in a more competitive direction, it is not enough to only rely on regulations of energy saving targets. More focused demand-pull policies are needed for the market.

The previous section mentioned two demand-pull policies from economic measures: short-term subsidies and long-term energy/carbon taxes. Of the prescriptive measures, building energy performance benchmarking proposed in the incentive mechanism has potential. A building energy performance benchmark was implemented in the case of Changning. Although this policy is just being implemented and is just at the stage of gathering data, it is still making a great contribution to attract the attention of building

owners for energy conservation. The future issue of disclosure of the results of benchmarking is still facing a great challenge. There is a need to discuss how to disclose information properly at an operational level. However, widely conducting building energy audits is a premise.

Energy consumption quotas could theoretically offer a clear baseline of the energy consumption to the building owners. Facing the challenge of exceeding the energy consumption quota, building owners could either be charged a carbon tax/fees or conduct CBEER. However, it is hard to set if there is not enough data from buildings. It asks the government to master the detailed building energy consumption information and then design a reasonable scheme based on the form of energy usage, type of buildings, business situation and other factors. The premise is exhaustive energy audits for most buildings. It is also a stop-gap measure if it is implemented without linking taxes together, as it would move the market decisively away from the perfectly competitive model that the government is implicitly aiming for.

10.4.3. Information Disclosure is Critical to Improve Incomplete

Information: Energy Audits and Building Energy Information Sharing Platform Need to be Used Widely in Projects

To deal with the issue of incomplete information, the policies on information disclosure contribute the most in the two cases. Building energy performance benchmarking, energy audits and building energy information platforms are the three major measures. Policy on building energy performance benchmarking was discussed in the last section. In contrast to the incentive mechanism, the other two policies were implemented as supportive measures not prescriptive measures in the two cases.

The local governments in the two cases used policies on extensive building energy audits to get more precise information on buildings. It had good effects according to the two cases, as the stakeholders could better understand the energy situation and the government could design energy targets. The uncertainties of transactions were decreased according to the shorter negotiation time before signing the contract. Transaction costs decreased accordingly. However, this policy is not compulsory in the overall market. The policy

was implemented in demonstration projects or a particular area. To incentivise the overall market, it is necessary to implement this policy compulsorily.

Building energy information platforms were helpful methods in the two cases to implement the policies on information disclosure. However, the data gathered from the platforms are used mostly by the government. The platforms are not used widely at the project level. Another problem identified related to maintaining the building energy information platform as it requires continuous investment. Although the government helps construct building energy information platforms, the success of information disclosure depends on the maintenance of platforms and the involvement of stakeholders. In the two cases, the local governments set energy efficiency targets based on the detailed building energy information gathered from platforms and technological verification. Asset specificity increased, and uncertainty decreased directly. Transaction costs decreased accordingly.

Comparing these two policies to the policy of building energy performance benchmark and disclosure, it can be seen the latter is more powerful to push the market, while energy audits and building energy information platforms are the foundation to the policy of benchmark and disclosure.

10.4.4. Market Power is Still Significant in the Market: the Finance System Urgently Needs to Be Improved

Improving the financing system is important to reduce market power, while it asks for the improvement from the essence of the problem, the existing creative modes are only developed on the endorsement of the government, the competitiveness of the market has not been fully used.

To deal with the issue of market power, both governments used subsidies to attract building owners and ESCOs to use EPCs. ESCOs took these subsidies as financial supports offered by the government. Although they helped ESCOs reduce the financial pressure and reduced costs at the early stage of the project, the subsidies did not solve the basic problem of access to capital for energy efficiency.

Meanwhile, both governments designed new modes to develop a financing platform to improve access to finance by involving leading companies or offering endorsement. The new modes in both cases were trying to link financial institutions with EPC projects from an institutional design based on government endorsement. Although the transaction costs could be decreased accordingly, it is still separate from the nature of competitiveness. The subsidies offered by the government supported EPC projects through those financial institutions. Outwardly, the financial institutions participated in EPC projects. To some extent, the size of the market developed. However, without government endorsement, financial institutions still hesitate to lend to small-size ESCOs. Securities like fixed assets or business volume are still requested. In the short term it is suitable for the development of the initial market, but in the long term a policy of access to capital should be well developed.

Policies on improving existing financing systems using potential energy savings as a pledge proposed by the incentive mechanism offer a direction. The benefits of credit system improvement to deal with market imperfections were analysed in the last chapter. According to the investigation, the two cases did not involve credit system improvements because the development of a credit system in China is at an initial stage. It asks for a set of databases and initiatives that monitor and assess the trustworthiness of companies. Currently, there is a social credit system in China. The databases are managed by China's economic planner, the National Development and Reform Commission, the People's Bank of China and the country's court system. Most of the data is gathered from traditional sources such as financial, criminal and government records, as well as existing data from registry offices along with third-party sources such as online credit platforms. However, this system is not designed to determine creditworthiness when seeking to get loans from banks. Also, it is not available for all enterprises when evaluating their transaction parties. Therefore, this system is not functioning, and it urgently needs to be improved.

10.4.5. Supportive Measures to Limit Risks of EPC Projects to Improve Uncertainties of Transactions

Uncertain energy savings is one of most important barriers to the uptake of EPCs by building owners and the agreements to lend loans by the financial institutions. EPC projects are risky projects. Therefore, more supportive measures are needed to manage risks for EPC projects.

For the case in Chongqing, the government had various supportive measures on the uncertain energy savings. The local government used “third-party assessment” to support energy audit before the project and also creatively used post-audit by “third-party assessment” to solve the “energy efficiency gap” for the stakeholders for energy saving assessment and benefit sharing. The government offered great subsidies to third parties to offer energy assessment services for EPC projects. At the same time, the Chongqing government first designed a standard EPC contract as a reference for building owners and ESCOs, which was even published before the national contract sample format for building energy performance contract designed by the central government (CSTID & CABEE 2014). These two policies show high alignment with the incentive mechanism.

There are two policies (enterprise qualification and energy insurance) proposed in the incentive mechanism showing great potential, although they were not fully implemented in the current two cases.

Enterprise qualification is not new to evaluating the quality performances of subcontractors in the construction sector. For EPC projects in the two cases, at the current initial stage, most building owners were connected with ESCOs through local governments. At the very beginning of introducing the EPC mechanism to the market, there was a register system for ESCOs to send their information to the government based on the criteria set by the government. This policy has been stopped because the government is going to streamline and delegate power to let the market play its role. As the government winds down the transaction of EPC projects, an enterprise qualification system must be developed for the stakeholders to select transaction parties freely with more comprehensive information. The problem of “adverse of selection” could be addressed.

Energy insurance is a very new idea for limiting the “energy efficiency gap” on risky EPC projects. Although these two cases did not include this strategy, it would be good to have energy insurance to alleviate risks for stakeholders. The reason is insurance solutions may foster energy efficiency investments by transferring risks of energy savings to insurers (the previous section demonstrated the role of energy insurance). With energy insurance, the financial institutions would be more confident to give loans to ESCOs. A well-designed reliable insurance scheme for better risk management benefits both insurers and the insured (Niromandfam, Sadeghi Yazdankhah & Kazemzadeh 2020). Further research is needed for this.

10.5. Summary

This chapter analysed two cases to verify the incentive mechanism proposed in the last chapter. The policy successes of the case studies cover most of the policies put forward in the incentive mechanism in Chapter 9. The cases demonstrate high alignment with the proposed incentive mechanism, which provides strong support to the incentive mechanism. The two cases show evidence that at least some of the market barriers to EPCs can be successfully addressed by policy initiatives. Considering the initial situation of CBEER in China, subsidies, city level energy saving targets and building energy information platforms played a critical role in developing EPC markets. These policies in the two cases demonstrate the success in the short term to develop the EPC market. However, market competitiveness in the long run has not yet been demonstrated. At the same time, the two cases show shortcomings and the need to implement policies in the long term to address market imperfections. The EPC market is still far from being a monopolistic competition market. Energy taxes, energy audits, benchmarking and disclosure, and improving the existing financing system, which were proposed in the incentive mechanism, showed great potential to incentivise the market in a more competitive direction. To better address the EPC market barriers, further studies related to a particular policy at an operational level should be conducted.

Chapter 11 Conclusions and Future Research

11.1. Introduction

This chapter outlines the summary and conclusions of this research. It starts with a summary of the evolution of the research. It then presents research findings for the three research questions posed in the introduction. The research aim and objectives are reviewed to show the achievements of this research. A conclusion with major findings follows. Contributions to knowledge are discussed. The chapter concludes with descriptions of research limitations and suggestions for future research.

11.2. Summary of the Research

An energy performance contract (EPC) is a market mechanism designed to facilitate energy efficiency in the market. However, it faces significant hurdles and risks in the building sector compared to the manufacturing sector. Building energy efficiency, especially commercial building energy efficiency retrofits (CBEER), has great energy saving potential, but its full potential is not being realised. This research investigates why EPCs, as a theoretical successful mechanism, are not widely used in the CBEER market. It aims to identify the market barriers to CBEER under EPCs and explores ways of improving the current market situation in China.

The microeconomic theory of price is used as the basic theory to analyse market efficiency. Market imperfections are one explanation on why markets do not function efficiently. Against a background that the Chinese government is going to play a role in the market to promote energy efficiency, the theory of market imperfections is used to examine the nature of the energy efficiency market, in particular the use of EPCs. Institutional economics theory of transaction costs under Williamson's theoretical framework is used as a tool to design policies to incentivise the EPC market. The sector of commercial buildings is used for investigation.

The principal purpose of this research is to test whether the EPC market has the characteristics of market imperfections as defined in economic theory. This led to a review of two bodies of literature: theories of market imperfections and potential of market barriers including limitations of EPC market and risks of CBEER under EPCs. The literature reviews helped develop the first part of the research for theory testing: whether the EPC market conforms to the characteristics of market imperfections as defined in economic theory. This theory testing required two steps. The first step was to identify the overall market barriers (Chapter 6). The second step was to explore the reasons for those market barriers (Chapter 7) to see if they were caused by market imperfections in economic theory (Section 8.2). These two steps were accomplished by a multi-method approach: a questionnaire survey and semi-structured interviews. Both the questionnaire survey and interviews collected data from four groups: building owners, ESCOs, government, and independent experts. These two steps also linked to the first two research questions: what are the market barriers to the uptake of EPCs in the CBEER market; and what are the reasons limiting the uptake of EPCs in the CBEER market.

In terms of applying theories to explore the nature of the energy efficiency market, the theory of transaction costs under Williamson's theoretical framework offers an additional angle to reflect the market barriers. The literature review showed that there is a close link between theories of market imperfections (microeconomics) and the theory of transaction costs (institutional economics). Those market barriers caused by market imperfections present high transaction costs. Therefore, this research used the theory of transaction costs to monitor if the market imperfections could be dealt with appropriately by policy design.

This leads to the second part of the research for policy design: how to design policies properly to eliminate market imperfections to improve the uptake of EPCs. This policy design required three steps. The first step was to design theoretical policies addressing identified EPC market imperfections following theoretical deductive analysis based on literature review (Section 8.3). The second step was to collect empirical data from interviews to investigate potential policies and strategies for dealing with market barriers (Section 9.2). The potential policies and strategies were identified according to the conceptual framework of the theory of transaction costs. An incentive mechanism was then developed combining the theoretical analysis and interview findings (Sections 9.3 and 9.4). The last step was to conduct case studies to collect existing successful

experiences to verify the proposed incentive mechanism (Chapter 10). These three steps aimed to answer the third research question: how can the uptake of EPCs in the CBEER market be incentivised.

11.3. Review of the Research Questions

This section presents the key findings of the research to show whether and how it answers the three main research questions.

11.3.1. Research Question One: Market Barriers

The first research question: What are the market barriers to the uptake of EPCs in the CBEER market?

The first research question was explored through literature review and questionnaire surveys. From the literature review in Chapter 3, the overall market barriers were identified including the limitations of EPC market development (Chapter 3 Section 3.4) and risks of using EPCs (Chapter 3 Section 3.5). They guided the design of the questionnaire. From the questionnaire surveys, there were nine critical factors impacting the uptake of EPCs in the sector of commercial buildings (Chapter 6). These nine critical factors are:

- EPC costs and benefits
- the complexity of commercial building energy efficiency retrofits
- uncertainties of using EPCs
- building energy savings
- criteria for ESCOs to enter the EPC market
- policies and regulations
- financial support
- service quality of ESCOs
- EPC market development.

The above nine critical factors are listed by the level of importance. These nine factors impact the willingness to take up EPCs. The certainty of energy saving benefits by using EPCs is of most concern in the market. Financial difficulties are significant barriers

limiting ESCOs from using EPCs. In these nine factors, the four groups of participants (building owners, ESCOs, government and independent experts) had significantly different opinions on three factors: EPC costs and benefits, uncertainties of using EPCs, and criteria for ESCOs to enter EPC markets. These three aspects were examined in interviews to establish the imbalance of information between the groups of participants (the details are answered in research question two). Overall, the nine market barriers revealed the general situation of EPC market barriers, which led to the follow-up interviews to investigate the reasons limiting the uptake of EPCs in the CBEER market.

11.3.2. Research Question Two: Reasons Limiting Uptake

The second research question: What are the reasons limiting the uptake of EPCs in the CBEER market?

This research question was explored through 26 semi-structured interviews. There were five main themes identified by thematic analysis as contributing to the limitations of the uptake of EPCs in the sector of commercial buildings (Chapter 7). These five themes are:

- asymmetric information between ESCOs and building owners
- energy performance gap of BEER makes EPCs hard to implement
- high barriers for ESCOs to the entry of the EPC Market
- low motivation for commercial building owners
- limitations of initial national policies on the initial market

Theme 1 includes six aspects (see Section 7.2, Figure 7-2): i) inadequate information about existing buildings; ii) new concept and incomplete information of using EPCs; iii) the lagging facility management system in China; iv) incomplete contract; v) service quality of ESCOs; and vi) credit risk of building owners.

Theme 2 includes two aspects (see Section 7.3, Figure 7-3): i) technology issue; and ii) changes in building energy use.

Theme 3 includes two aspects (see Section 7.4, Figure 7-4): i) comprehensive service capability of BEER for ESCOs; and ii) financial capability.

Theme 4 includes four aspects (see Section 7.5, Figure 7-5): i) type of building owners; ii) split incentives; iii) long payback period; and iv) limited energy saving benefits.

Theme 5 includes four aspects (see Section 7.6, Figure 7-6): i) initial national subsidies limit EPC business model innovation; ii) building energy information platform is not fully developed; iii) financial system is far behind in using potential energy savings; and iv) discontinued national subsidies impact the initial market.

These five main themes exhibit the characteristics of market imperfections as defined in economic theory from three propositions: incomplete information, market power and externalities. The testing on how these themes connect with the theories of market imperfection was analysed in Chapter 8.

Incomplete information can answer part of the reasons for the low uptake of EPCs in the commercial building sector. There is inadequate information about existing buildings and the building energy operation situation, which makes setting a baseline for CBEER very hard. The lagging facility management system in China can also be blamed. Meanwhile, there is asymmetric information between ESCOs and building owners due to the complex relationships of EPC stakeholders. In addition, ESCOs are suffering from credit risks of building owners, and building owners are facing difficulties identifying the service quality of ESCOs. Lastly, changes of building energy use may cause uncertainties for ESCOs. Overall, the incomplete information causes great uncertainty about the costs and benefits of EPCs, brings a great number of risks related to uncertain energy efficiency performance to ESCOs and decreases the willingness of building owners to conduct CBEER by EPCs.

Market power is the second reason limiting the uptake of EPCs in the commercial building sector. The evidence in Chapter 7 reveals the high barriers for ESCOs to the entry of the EPC Market. There are two main issues related to this: access to capital and comprehensive service capability of ESCOs. These two problems cause great challenges to the great number of small-size ESCOs. As a result, many ESCOs do not undertake EPCs as their main business. Market power favours large ESCOs.

Externalities are the final reason limiting the uptake of EPCs in the commercial building sector. Low energy price is the most important reason leading to low motivation by building owners to conduct CBEER. Although EPCs can improve the motivation of building owners more than the normal CBEER without using EPCs, low energy price is a dominant reason for the low uptake of EPCs. As a result, building energy consumption would cause negative externalities to the environment and the public. Another type of externalities is caused by the activity of CBEER, in which the issue of separated incentives occurs. The separated ownership of commercial buildings contributes to this. Building users cannot receive the benefits from CBEER but they need to cooperate during the process of CBEER. Meanwhile, using EPCs makes this issue even worse due to the complex relationships between EPC stakeholders. There is a separated management right between facility managers, building owners and ESCOs. Furthermore, by using EPCs, more risks are transferred from building owners to ESCOs compared to the traditional CBEER. In the meantime, building owners tend to make use of ESCOs for additional work, which causes negative externalities to ESCOs.

Overall, the EPC market has the characteristics of market imperfections as defined in economic theory from three perspectives: incomplete information, market power and externalities. Those imperfections lead to significant market barriers in the uptake of EPCs for CBEER. The causes of market barriers of the uptake of EPCs are not only from the EPC itself. Some of the reasons (see Section 7.7) are from the inherent characteristics of CBEER but affect EPCs to a large extent.

11.3.3. Research Question Three: Incentivising EPC Uptake

The third research question: How can the uptake of EPCs in the CBEER market be incentivised?

As the EPC market is an imperfect market, the market cannot rehabilitate itself, and government intervention is necessary to improve the efficiency of the market by offering a good foundation for the CBEER market to address identified market imperfections. The third research question was explored through four steps: i) a theoretical analysis of solutions to EPC market imperfections in Chapter 8 Section 8.3; ii) an evaluation analysis through interviews to identify the potential incentive strategies by adopting the conceptual framework of transaction costs in Chapter 9 Section 9.2; iii) developing an

incentive mechanism for the EPC market; and iv) a validation of how the proposed incentive mechanism reduces market imperfections and facilitates the market in a more competitive direction by case studies.

Theoretically, there are three approaches in general to remedy market imperfections: regulation, subsidies and taxes. To address the market imperfection of incomplete information, regulations on screening and signalling could overcome the issue of incomplete information, where an information disclosure policy is a way to offer more complete information about existing buildings, building energy operation, benefits of EPCs, credit of building owners, and the service quality of ESCOs. To address the market imperfection of market power, regulation for improving the existing financing system can decrease the barriers to market entry by offering more access to capital for ESCOs. In addition, offering subsidies for market cultivation can directly increase the service ability and motivations of ESCOs. As a result, in the market of CBEER, there would be a greater number of ESCOs offering EPC services. To address the market imperfection of externalities, energy price is the most efficient policy tool to correct the distortion caused by the existing low energy price. Taxes are another price-type policy to charge the building owners for their high energy consumption. Both energy price and taxes aim to deal with the externalities caused by building operation and energy consumption. In parallel with price-type policies are the quantity-type policies, including legislation, regulation, standards and emission limits. These methods regulate energy conservation activities by setting rules, for example limitations of energy consumption in buildings.

Empirically, potential policies and strategies were investigated in the Chinese context through interviews. The three determinants of transaction costs under Williamson's framework (asset specificity, uncertainty, frequency) were used to monitor if the market imperfections could be dealt with appropriately by these strategies. Combining the theoretical policy design with the empirical findings from interviews, an incentive mechanism was developed for the EPC market addressing the identified three types of market imperfections. Overall, government plays the role of leader in the market. It aims to build a legal and sustainable environment for all the stakeholders in the market. From the whole building sector to CBEER and further EPC mechanisms, there are different targets.

In detail, the concrete policies and strategies are divided into three types: prescriptive measures, economic measures, and supportive measures.

In prescriptive measures, there are seven policies: i) law, regulation and standards on energy savings, energy saving target, and energy efficiency strategies of commercial buildings; ii) policies on improving the existing financing system using potential energy savings as a pledge; iii) policies on information disclosure; iv) policies on credit system improvement; v) building energy audit; vi) building energy performance benchmarking; and vii) energy consumption quota.

In economic measures, there are four policies: i) government subsidies; ii) energy/carbon tax; iii) specific tax credit, exemption, deduction; and iv) government award.

In supportive measures, there are nine policies: i) play the role of industry association; ii) building energy information sharing platform; iii) enterprise qualification; iv) third-party assessment; v) pilot and successful cases; vi) standard EPC contract; vii) advertising; viii) energy insurance; and viv) education.

The two cases studies about the successful Chinese EPC experience in Chongqing and Changning district in Shanghai showed high alignment with the proposed incentive mechanism, which provided strong support to the incentive mechanism. The proposed incentive mechanism shows great potential to reduce the market imperfections and decrease transaction costs and could help the market move in a more competitive direction.

11.4. Review of Aim and Objectives

This research has satisfied the aim and objectives specified in the introduction in Chapter 1. This research aimed to explore the way to incentivise the EPC market to achieve more regular use of EPCs in the commercial building sector in China. An incentive mechanism for the EPC market was developed in Chapter 9 Section 9.4 and was verified by empirical data from case studies to show the potential that this incentive mechanism could reduce market imperfections and move the market in a more competitive direction to further improve the uptake of EPCs in CBEER.

The six research objectives have been achieved as well and outlined as follows:

Objective One: To develop a theoretical framework to understand the current situation of the EPC market in commercial buildings

This objective has been achieved by the literature review in Chapters 2 and 3. The literature review in Chapter 3 identified that policy factors are the main driving force for the development of the EPC market. Limitations of the EPC market (in Section 3.4) show in the moral hazard in the landlord–tenant relationship, principal–agent problems, limited energy savings, and market credit environment. Risks of using EPCs (in Section 3.5) show in three external risks, such as market risks, and eight internal risks, such as project design risks. The limitations of the EPC market and risks of using EPCs point to the problem of market failures in economic theory. Therefore, theories of market imperfections under microeconomics and the theory of transaction costs within Williamson’s theoretical framework under institutional economics were reviewed in Chapter 2 as the theoretical foundation for this research. At the end of Chapter 3, in Section 3.5 a theoretical framework was developed for the future theory test and the application in analysing and improving the EPC market.

Objective Two: To study the empirical data from surveys to identify the overall barriers of the EPC market

This objective has been achieved by questionnaire surveys in Chapter 6 to explore the overall market barriers and critical factors impacting the uptake of EPCs in the CBEER market. The results and discussion were summarised in Section 11.3.1 Research Question One.

Objective Three: To study the empirical data from the questionnaire survey and interviews to test the existence of market imperfections

This objective has been achieved by the interviews in Chapter 6 to identify the main reasons contributing to market barriers identified in Objective two; and by theoretical analysis to test the existence of market imperfections. The results and discussion were summarised in Section 11.3.2 Research Question Two.

Objective Four: To analyse policy implications in the EPC market to deal with market imperfections

This objective has been achieved by theoretical deductive analysis in Chapter 8 Section 8.3 to identify the theoretical solutions to EPC market imperfections. The results and discussion were summarised in Section 11.3.3 Research Question Three.

Objective Five: To triangulate the empirical data from interviews to discuss an incentive mechanism in practice from the perspective of transaction costs in the Chinese context

This objective has been achieved by the interviews and theoretical deductive analysis in Chapter 9. Section 9.2 identified the potential incentive strategies to deal with market imperfections in the EPC market. By adopting the conceptual framework of transaction costs, the feasibility of the potential incentive strategies was analysed in Section 9.3 and then an incentive mechanism was developed for more regular use of EPCs in Section 9.4. The results and discussion were summarised in Section 11.3.3 Research Question Three.

Objective Six: To triangulate the case study's empirical findings to verify the proposed incentive mechanism

This objective has been achieved by case studies in Chapter 10. The experiences in the development of the EPC market under government intervention were introduced and analysed. The case studies tested the validity of the proposed incentive mechanism in Chapter 9 and demonstrated that the incentive mechanism could facilitate the EPC market to become more competitive by addressing market imperfections.

11.5. Conclusions

The overall working hypothesis that the EPC market in commercial buildings conforms to the characteristics of market imperfections defined in economic theory is supported by the results. The research shows that market imperfections reduce the volume of EPCs. The EPC market exhibits three types of market imperfections: incomplete information, market power and externalities.

Incomplete information has three perspectives: the asymmetric information between ESCOs and building owners; lack of knowledge of the existing buildings and building energy operation situation; and uncertainties due to changes of energy use during the implementation of an EPC. Information disclosure, particularly energy performance benchmarking, is the solution to the problem of incomplete information. With fully disclosed information, building owners and ESCOs can better make decisions during projects. The transaction costs can be decreased accordingly, and the benefits of EPCs can be shown.

Market power has two perspectives: difficulties of access to capital; and lack of comprehensive service capabilities of ESCOs. Reforming the existing financing system by using estimated energy savings as loan security is a way to decrease the costs for ESCOs entering the EPC market. Subsidies are offered for the development of service capabilities of ESCOs, which can directly increase the quantity of services offered by ESCOs.

Externalities has three perspectives: low energy price; separated incentives; and risk transferring to ESCOs. In the long term and focusing on the entire industry, reforming the existing energy price and developing energy taxes are ways to directly internalise the externalities. In the short term and focusing on only the energy efficiency market, regulations on energy consumption limits and subsidies to increase activities can directly increase the quantity of energy efficiency in the market.

The conceptual framework of transaction costs can help evaluate policies to reduce the costs of transaction of EPC projects and address the market imperfections.

11.6. Contributions of the Research

This section discusses contributions of the research with reference to past research and from three perspectives: contributions to theories (including theories of market imperfections and the theory of transaction costs); the knowledge of CBEER and EPCs; and practice.

11.6.1. Contributions to Theories

In this research, theories of market imperfections in microeconomic theory have been demonstrated to work to analyse the problem of barriers to the EPC market and to serve to derive policies that can make the EPC market more competitive. The theory of transaction costs in institutional economic theory has been used to design an incentive mechanism to help address market imperfections. The following is the detailed explanation.

The theory of market imperfections has been used to explain the market barriers for energy efficiency in the existing research, however the integrated characteristics of market imperfections are not fully described for the energy efficiency market. This research firstly reviewed theories of market imperfections from four perspectives: incomplete information, market power, externalities and public goods. These four hypotheses were set to test if the EPC market has the characteristics of market imperfections. Analysis of empirical data from questionnaire surveys and interviews showed that the EPC market conforms to characteristics of market imperfections in three perspectives: incomplete information, market power, and externalities. The barriers to the energy efficiency market in the commercial sector have been fully investigated by using formal models in economic theory. These three perspectives reveal the nature of the EPC market in a theoretical and holistic way.

Existing studies about the energy efficiency market have shown some market barriers present in a form of significant transaction costs in institutional economics, while the concept of transaction costs they used did not cover all the perspectives of market barriers in CBEER projects. Meanwhile, few of them use the conceptual framework of transaction costs to value the performance of the improvement of the market. The theory of transaction costs in this research has been used to analyse the policies and strategies that are designed to incentivise the EPC market. From the conceptual framework transaction costs of three determinants (asset specificity, frequency and uncertainties), the effect can be seen if the policies or strategies appropriately deal with identified market imperfections.

Furthermore, the existing research did not clearly elaborate the relationship between market imperfections in microeconomic theory and transaction costs under Williamson's theoretical framework in institutional economic theory when they are used to discuss the market barriers to energy efficiency. The boundary of the two approaches is unclear. This research analysed the linkage between market imperfections and transaction costs in theory and presented the linkage through empirical findings from interviews. As the perspectives of market imperfections were defined in economic theories behind the phenomenon of great market barriers, it is hard to observe the changes of the market after addressing the imperfections immediately, while transaction costs are more visible for the market stakeholders to see the difference of the market by fixing some existing problems. Considering the characteristics of market imperfections and transaction costs in economic theories, the conceptual framework of transaction costs was adopted as a tool to value the performance of the policies to see the reaction of the market. Chapter 9 showed how the policies and strategies address the market imperfections (microeconomics) and at the same time decrease the transaction costs (institutional economics) of EPCs.

11.6.2. Contributions to the Knowledge of CBEER and EPCs

This research shows the nature of CBEER market under EPCs. It helps answer the problem of the low uptake of EPCs in the commercial building sector in China. It offers deeper understanding of CBEER and EPCs in a holistic view. The great market barriers against EPCs confirm the three perspectives of market imperfections as defined in microeconomic theory. Those EPC market barriers present themselves also in high transaction costs defined in institutional economic theory. Some of the market barriers come from the inefficient environment of CBEER and some come from the EPC itself.

Although EPCs are designed to address some existing problems of CBEER, in such an imperfect environment, the potential of EPCs could not be completely achieved. The issue of externalities of energy consumption is the basic problem causing lack of motivation to conduct CBEER in the market. Although the EPC mechanism can internalise the externalities to some extent by decreasing costs of CBEER for building owners, there is still a great number of barriers that cannot be solved due to the major issues of incomplete information and market power. By identifying the reasons behind EPC market barriers, more targeted policies can be designed to address the market imperfections to better achieve the goal of an efficient market.

11.6.3. Contributions to Practice

After addressing the existing market barriers, this research puts forward a theoretical policy design as a reference to practice. Meanwhile, by investigating the potential policies and strategies from empirical interview data, an incentive mechanism targeted to the Chinese context was developed to offer more detailed solutions to deal with market barriers in practice. Successful Chinese experiences were reviewed by two case studies, which confirmed the benefits of the proposed incentive mechanism in dealing with existing market barriers. This incentive mechanism can be a reference for government for further policy design, which can contribute to not only the CBEER and EPCs, but the existing lagging facility management system, the whole energy conservation industry, the financing system, and more innovative modes of market mechanisms (for example, carbon trading in the building sector). The current EPC market is highly dependent on government subsidies. In such an initial market, it is helpful for developing the market and directly incentivising the quantity of energy efficiency services. However, the market cannot only rely on subsidies. This research offers the government a roadmap on how to develop a more efficient market by internalising the externalities and decreasing market power. For building owners and ESCOs, from this research they can better understand the EPC market, which can contribute to more reasonable decision making in the future. This research also offered suggestions to financial institutions, industry associations, and other third parties related to building energy efficiency.

11.7. Limitations of Research

This research has successfully identified the EPC market barriers in the sector of commercial buildings in China and revealed the nature of the EPC market. However, the research has limitations.

Firstly, there is a potential limitation related to the research scope. This research is set within the sector of commercial buildings and focused on the energy efficiency market in China to discuss the low uptake of EPCs. Therefore, the research can only investigate the characteristics of EPCs within the scope. Although there are many common problems in the whole sector of buildings, the sample of the data only covered the participants involved in energy efficiency activities under EPCs in the sector of commercial buildings.

There are also common problems in all EPC markets in different countries, but without enough data support, it is difficult to extend the research findings to EPC markets in other countries.

Secondly, there is sampling bias due to the limitations associated with the distribution of the questionnaires and the proportional number of ESCOs that failed to conduct EPC projects compared to the overall number of the respondents. This bias and accuracy of findings were examined when the themes were tested in the validation process associated with the follow-up interviews. Meanwhile, the sample size is small, and the coverage of the sample is not widely throughout the entire mainland China, which may affect the generalisation of finding in broader context in China. This bias has been examined when the sample distribution of places in the survey is consistent with the actual place distribution of EPC projects.

Thirdly, there is a potential limitation corresponding to language translation. As this research was conducted to investigate the Chinese EPC market, data was collected in China in Chinese. The research used questionnaires and interview questions which were translated from English to Chinese to collect data. The interviews were conducted in Chinese and transcribed into English and then analysed. The materials for the case studies were collected from both Chinese and English resources. The main contents of the Chinese resources were translated from Chinese to English. During the process of translation, some inaccuracies may have occurred despite the checks and controls outlined in the text. Those potential inaccuracies, however, do not influence the main content and findings of this research.

Fourthly, there is a limitation of access to data on policy changes. As controlled experiments in economics could not be made, the proposed incentive mechanism in this research was validated by two cases. To better analyse the contributions of different types of policies, more case studies of the effects of policy changes need to be conducted as policies develop over time.

It is also acknowledged that there were constraints related to time, distance and finance. However, the importance of the study remains, because the limitations do not weaken the findings, but provide space for further research.

11.8. Future Research

This research found that the EPC market is an imperfect market and discussed methods to remedy market imperfections. The focus is the overall EPC market. It shows an overall situation of the EPC market and offers a foundation for future research. Knowing the nature of the EPC market, for every component of the market, there is scope to discuss further. There are several further research directions that could be developed.

As mentioned in limitations of the research, focusing on the energy efficiency market, there are some common issues in the whole building sector and the EPC market in other countries. The findings in this research could be extended to a bigger scope. For example, are the formalised theories of market imperfections still suitable for residential buildings? Does the EPC market in Australia have the same characteristics as the EPC market in China? More comparative studies of the EPC market can be conducted in different types of buildings and different areas.

Considering each type of market imperfection identified in this research, there are a number of theories involved and more details can be explored. Addressing incomplete information, how does the economic principal–agent theory anticipate the efforts of information disclosure? Addressing market power, the research shows there are some large ESCOs in the market. An interesting topic is to establish how the leadership of ESCOs can motivate the energy efficiency market. Meanwhile, access to capital is a major problem contributing to market power. What is lacking in the existing financing system is worth exploring further. Although policies in this research have put forward proposals on how to improve the existing financial system and develop a credit system, it is necessary to examine how to improve the existing system at an operational level. Addressing externalities, although the research suggested the energy price can deal with the problem of externalities, it is worthy to further analyse the relationship between energy price and externalities based on more actual policies, and examine how energy price internalises externalities of EPCs in a more precise way by using appropriate economic models.

Considering the EPC mechanism itself, there are new research questions: under such an imperfect market, how to modify the business model of EPCs to make it more adaptable for the CBEER market; how to design and manage the contract of EPCs to control risks of EPC projects; and how the theory of incomplete contract can be used for better contract design and decision making for the contracting parties in EPC projects.

There is some research discussing the relationships between the EPC mechanism and public–private partnerships. Therefore, further research on how to adapt EPCs to public projects can be conducted. As in China, when the energy price in the public sector is subsidised by the government, does EPC apply as well?

In the EPC market, ESCOs take more responsibility than the building owners to conduct CBEER. To what extent could the responsibility for energy savings be set to internalise the externalities, which promote the uptake of EPCs. Meanwhile, under uncertain economic and market situations, how could the risks be allocated to better promote EPC projects for both building owners and ESCOs.

Considering the policy design, this research implies the concept of transaction costs. In future research, it may be worth quantifying transaction costs to measure whether the policy is effective in decreasing the transaction costs of EPC projects in a more direct way. Meanwhile, simulation models could be adopted to simulate the real context to see which type of policies could contribute more to the uptake of EPCs. Each type of policy identified in this research can be quantified to see improvements in the performance of the market.

This research has successfully tested the existence of market imperfections as defined in economic theories in the EPC market. It used qualitative empirical data to reveal the relationship between the EPC market barriers with market imperfections, however, it cannot value the degree of market imperfections. Therefore, further research could quantify the degree of market imperfections to take more precise actions to address those market imperfections.

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Appendices

Appendix 1 Letter of Ethics Approval

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Mail - Shiyu WAN - Outlook

HREC Approval Granted - ETH19-3793

Research.Ethics@uts.edu.au <Research.Ethics@uts.edu.au>

Mon 9/2/2019 2:21 PM

To: Grace Ding <Grace.Ding@uts.edu.au>; Shiyu WAN <Shiyu.WAN@student.uts.edu.au>; Research Ethics <research.ethics@uts.edu.au>

Dear Applicant

Thank you for your response to the Committee's comments for your project titled, "Energy Performance Contract in Imperfect Markets: a Study on Energy Efficiency Retrofits of Commercial Buildings in China". The Committee agreed that this application now meets the requirements of the National Statement on Ethical Conduct in Human Research (2007) and has been approved on that basis. You are therefore authorised to commence activities as outlined in your application.

You are reminded that this letter constitutes ethics approval only. This research project must also be undertaken in accordance with all UTS policies and guidelines including the Research Management Policy (<http://www.gsu.uts.edu.au/policies/research-management-policy.html>).

Your approval number is UTS HREC REF NO. ETH19-3793.

Approval will be for a period of five (5) years from the date of this correspondence subject to the submission of annual progress reports.

The following standard conditions apply to your approval:

- Your approval number must be included in all participant material and advertisements. Any advertisements on Staff Connect without an approval number will be removed.
- The Principal Investigator will immediately report anything that might warrant review of ethical approval of the project to the Ethics Secretariat (Research.Ethics@uts.edu.au).
- The Principal Investigator will notify the UTS HREC of any event that requires a modification to the protocol or other project documents, and submit any required amendments prior to implementation. Instructions can be found at <https://staff.uts.edu.au/topic/sub/Pages/Researching/Research%20Ethics%20and%20Integrity/Human%20research%20ethics/Post-approval/post-approval.aspx#tab2>.
- The Principal Investigator will promptly report adverse events to the Ethics Secretariat (Research.Ethics@uts.edu.au). An adverse event is any event (anticipated or otherwise) that has a negative impact on participants, researchers or the reputation of the University. Adverse events can also include privacy breaches, loss of data and damage to property.
- The Principal Investigator will report to the UTS HREC annually and notify the HREC when the project is completed at all sites. The Principal Investigator will notify the UTS HREC of any plan to extend the duration of the project past the approval period listed above through the progress report.
- The Principal Investigator will obtain any additional approvals or authorisations as required (e.g. from other ethics committees, collaborating institutions, supporting organisations).
- The Principal Investigator will notify the UTS HREC of his or her inability to continue as Principal

<https://outlook.office.com/mail/id/AAQkAGQ4YmUyMzAxLTczOTMlNGIxYi04NDMwLWEzMzcNTE1YmNhZQAQAAMo9v5l6ApJh59N5hp7vWs%...> 1/2

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Mail - Shiyu WAN - Outlook

Investigator including the name of and contact information for a replacement.

I also refer you to the AVCC guidelines relating to the storage of data, which require that data be kept for a minimum of 5 years after publication of research. However, in NSW, longer retention requirements are required for research on human subjects with potential long-term effects, research with long-term environmental effects, or research considered of national or international significance, importance, or controversy. If the data from this research project falls into one of these categories, contact University Records for advice on long-term retention.

You should consider this your official letter of approval. If you require a hardcopy please contact Research.Ethics@uts.edu.au.

If you have any queries about your ethics approval, or require any amendments to your research in the future, please do not hesitate to contact Research.Ethics@uts.edu.au.

Yours sincerely,

A/Prof Beata Bajorek
Chairperson
UTS Human Research Ethics Committee
C/- Research Office
University of Technology Sydney
E: Research.Ethics@uts.edu.au

REF: E38

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Appendix 2 Questionnaire Survey

The Survey for the Influential Factors of the Energy Performance Contract of Commercial Building Energy Efficiency Retrofit in China

Dear Sir/Madam,

Thanks for participating in this questionnaire survey and provide valuable opinions for the research. The purpose of this survey is to identify factors impacting the uptake of Energy Performance Contract (EPC) for commercial building energy efficiency retrofit (CBEER) in China. This survey is divided into four parts: general information of respondents, key factors impacting on the uptake of the EPC, the significance evaluation of risks and the improvements of the uptake of EPCs of CBEER in China.

This study has been approved by the University of Technology, Sydney Human Research Ethics Committee (Ethics approval No. ETH19-3793). The information obtained in this questionnaire survey will be used only for academic research, and the information provided will be kept confidential. The outcome of this research will not show any sensitive information about the personal details of participants. Any data referenced from the survey will be reported anonymously. If you have any queries or concerns, please contact either Shiyu Wan (shiyu.wan@student.uts.edu.au) or my supervisor Associate Professor Dr. Grace Ding (grace.ding@uts.edu.au).

Your opinions are very important to our research. Thanks again for your support!

Part 1 General Information

- (1) Which city do you work in? _____
- (2) Please indicate your highest educational qualification:
 - Secondary school
 - Undergraduate degree
 - Postgraduate Degree
 - PhD
 - Others (please specify) _____
- (3) What kind of organisation do you work for?
 - Education
 - Government
 - Professional institute
 - Development company
 - Facility Management Company
 - Energy Service Company

- Engineering consultant
 - Construction company
 - Design consultant
 - Supplier of building materials
 - Institute for Measurement & Verification
 - Others (please specify): _____
- (4) What is your profession? (Select all that apply)
- Public administration
 - Architecture
 - Mechanical & Mechatronic Engineering
 - Electrical Engineering
 - Water & wastewater engineering
 - Project management
 - Property management
 - Measurement & Verification
 - Marketing
 - Others (please specify): _____
- (5) What is your role in the organisation?
- Intern
 - General employee
 - Manager
 - Director
 - President
 - Others (please specify): _____
- (6) What is your professional qualification?
- Primary
 - Intermediate
 - Senior
 - Others (please specify): _____
- (7) How long have you been working in this organisation?
- 1 year or less
 - 2-5 years
 - 6-10 years
 - More than 10 years
- (8) How long have you been working in projects related to building energy efficiency?
- 1 year or less
 - 2-5 years
 - 6-10 years
 - More than 10 years

- (9) On a scale from 1 (extremely unfamiliar) to 5 (extremely familiar), please rate the level of familiarity with Energy Performance Contract (EPC). The more you know about EPC the higher you would rate it. The less you know about EPC the lower you would rate it.
- 1
 - 2
 - 3
 - 4
 - 5
- (10) How many EPC projects have you participated in?
- 0
 - 1
 - 2-3
 - 4-5
 - Over 5
- Note: If you select 0, please go to question 11, otherwise go to question 12.
- (11) Please specify that you have not participated in the EPC projects:
- No involvement at all
 - Not directly involved in EPC projects, but have participated in other EPC activities like policy design/research/scientific research/training
 - Others (please specify) _____
- (12) What type of activities did you participated in the EPC projects?
- Upgrade building envelope
 - Upgrade lighting system
 - Upgrade air condition system
 - Upgrade heating and cooling system
 - Upgrade distribution system
 - Develop building energy management system
 - Others (please specify) _____
- (13) What do you think of the current state of EPC in the building sector in China?
- Emerging
 - Growing
 - Mature
 - Declining
 - Not sure
- (14) How likely would you recommend EPC for building energy efficiency retrofits?
- Likely, please specify the reasons: _____
 - Not likely, please specify the reasons: _____

Part 2 Key Factors Impacting on the Uptake of EPCs of CBEER in China

- (1) Please select the degree of your acceptance of the following descriptions, according to your understanding of the uptake of EPCs in Commercial Building Energy Efficiency Retrofit (CBEER) in China. Please tick “√” in the corresponding box.

Where: 1 = strongly disagree, 2 = disagree, 3 = neutral, 4 = agree, 5 = strongly agree.

Items	Descriptions	1	2	3	4	5
Policy environment	The government has given great support to the uptake of EPCs in CBEER					
	Policies and regulations have given clear provisions on the application of EPCs for CBEER					
	Policies are the main motivation for the uptake of EPCs in CBEER					
	The subsidies and tax policies provided by the government play an important role in promoting CBEER using EPCs					
	Pilot EPC projects play an important role in promoting CBEER using EPCs					
	Green Finance Policy has great support on conducting an EPC project					
Popularity of EPCs	EPC is well known in CBEER					
Energy Service Companies	ESCOs can offer professional retrofit services including finance, design, construction, energy maintenance					
	The ability of energy service company has a great influence on the effect of energy savings					
	The service quality of ESCOs can be effectively guaranteed					
Benefits of EPCs	EPCs are useful for promoting commercial buildings conducting energy efficiency retrofit					
	EPC can ensure the energy saving effect of CBEER					
	EPC can effectively solve the financing problem of CBEER					
	EPC can guarantee stakeholders' energy saving benefits					
Contracts of EPC projects	Contracts of EPC projects clearly specify the rights and obligations for each contracting parties					
	The allocation of estimated energy savings and energy saving benefits can easily be verified					
	The contract period is clearly stipulated and measured					
	The contracts clearly define the measures for CBEER					
	The contracts clearly ensure the current baseline of building energy consumption					
	The contracts clearly define the potential energy savings for CBEER					
Commercial building energy efficiency retrofit	Building owners are responsible for investing CBEER					
	Building users can get more benefits on CBEER than building owners					

	Relationships for making decisions within CBEER are complicated					
	The recovery period of investment in CBEER is too long					
	The behaviour of the user has a great impact on energy efficiency					
	Technologies of CBEER cannot effectively guarantee the effect of energy savings					
	Measurement & Verification by a third party provides a very effective help to the energy saving assessment of CBEER					
	The building climate zone has a great influence on the energy saving potential of commercial buildings					
	The functional types of commercial buildings have a great impact on the owners' decisions for energy efficiency retrofit					
Building energy efficiency market	Low energy prices do not encourage demand for energy efficiency					
	Building energy savings are limited					
	There are a large number of building energy service companies engaged in EPC services					
	Building energy saving makes it easier to apply for a bank loan					
	Information platform for building energy information can help stakeholders explore building energy saving potential					

- (2) Please rank the following factors that limit the uptake of EPCs in order of importance – 1 being the most important to you. If there are other factors not involved, please add them in the table and rank them together. If the factors are equally important, please give them the same rank.

No.	Factors of limiting the uptake of EPCs	Ranking
1	Effectiveness and continuity of policies	
2	Uncertainty of EPC benefits	
3	Quality of energy service companies	
4	Low popularity of EPCs	
5	Complexity of CBEER	
6	Incompletion of the building energy market	
7	Complexity of applying EPCs	
8	Incomplete contract characteristics of EPCs	
9	Others (please specify)	

If you have other views on the uptake of EPCs in CBEER in China, please add in the space provided below:

Part 3 Significance Evaluation of Risks of EPC of CBEER in China

Please evaluate the significance of the following potential risks based on your work experience and knowledge, regarding whether to use EPC to conduct CBEER. If there are other risks not included, please add and evaluate the significance together.

Where: 1= extremely unimportant, 2= unimportant, 3= neutral, 4= important, 5= extremely important.

Items	Risk factors	1	2	3	4	5
Political and legal risk	Political adjustments					
	Update of technical standard					
Market risk	Falling market demands					
	Increasing market competition					
	Market price changes					
Economic risk	Increasing construction costs					
	Interest rate changes					
	Exchange rate changes					
	Changes in the electricity pricing mechanism					
	Fuel costs changes					
Project design risk	Insufficient information on existing building energy consumption and facility operation					
	Accuracy of potential energy saving estimation					
Management risk	Decision risks on choosing a suitable retrofit scheme					
	Changes of owner or facility management company of buildings					
Contract risk	Incomplete contracts					
	Inappropriate contracts					
Construction risk	Completion delay					
	Quality of subcontractors					
Technology risk	Poor actual energy saving performance					
	Inappropriate equipment sizes					
Operation risk	Degradation of equipment					
	Faulty operation					
	Frequent breakdowns					
	Unexpected consumption pattern					
Measurement & Verification risk	Modelling errors or imprecise model					
	Missing data or inconsistency of data					
	Imprecise metering					
Other (please provide)						

Part 4 Improvements of the Uptake of EPCs of CBEER in China

Please evaluate the significance of the potential improvements to the uptake of EPCs of CBEER in China. If there are other improvements not included, please add and evaluate the significance together.

Where: 1= extremely unimportant, 2= unimportant, 3= neutral, 4= important, 5= extremely important.

No.	Improvements	Significance				
		1	2	3	4	5
1	Compulsory regulation on building energy efficiency					
2	Subsidies on using EPCs					
3	Information disclosure on building energy consumption					
4	The rationality demonstration on the method of energy saving benefits allocation					
5	The rationality demonstration on energy saving audit/assessment					
6	Professional energy saving operation management					
7	Post EPC project evaluation					
8						

Thanks for participating !

If you are interested in participating in an interview about this research, please leave your information below so the researcher can contact you later.

- Your name: _____;
- Contact number: _____;
- Email address: _____.

If you are interested in this research and want to receive the outcome of this research, please leave your information below so the researcher can contact you.

- Email address: _____.

Appendix 3 Interview Guide

Guide to the Interviews

This interview aims to explore:

- The current situation of Commercial Building Energy Efficiency Retrofit (CBEER) under Energy Performance Contract (EPC) in China
- Limitations of the uptake of EPCs in CBEER in China
- Reasons for those limitations of the uptake of EPCs in CBEER in China
- Suggestions for incentivising EPC in CBEER in China

This is a face-to-face semi-structured individual interview. The whole process will last no more than 1 hour. Before the start of the interview, participants should be addressed protocols and to sign the consent form. Make sure all the participants understand the process of the interview and their rights and obligations. The willingness of participants will be respected and protected. The followings are the interview questions, those questions may be adjusted according to participants' responses and answers.

For the participants who know about EPC very well:

- (1) Have you participated in EPC projects? (If the answer is not, please turn to questions in the next part)
 - Could you please introduce the EPC project you have ever joined?
 - Why you choose EPC for energy efficiency retrofit?
 - What is your responsibility in this project?
 - What is the business model adopted in this project? What is the financial model? How long is the contract period?
 - What problems have you encountered in this project? And how you dealt with?
 - What lessons can be drawn from this project?
- (2) What do you think of the development of the EPC project in China? Especially for commercial building energy efficiency retrofit.
 - Why do you think EPC projects are doing well?
 - What do you think are the reasons for the limited use of EPCs in China?
- (3) Do you see any risks in using the EPC when conducting CBEER?
- (4) What measures do you think will lead to more people using EPCs for CBEER?

For the participants who know a little about EPC:

For these participants, they will be asked questions about building energy efficiency retrofit firstly, and then introduced EPC to them, lastly they will be asked attitude questions towards EPC.

- (1) Based on your experience in building energy efficiency retrofit, what do you think are the biggest difficulties in the process of building energy efficiency retrofit?
- (2) Based on your experience in building energy efficiency retrofit, do you think that building energy saving can be effectively guaranteed? Why?
- (3) (Introduce EPC to the participants, then ask them) Now that you've known EPC, are you willing to use this mechanism for CBEER in the future? If so, why? If not, why?
- (4) Do you see any risks in using the EPC for CBEER? (or what are your concerns about using this mechanism?)
- (5) What measures do you think will lead to more people using EPCs for CBEER? (or in what way can you or more people want to use EPC for CBEER?)

Appendix 4 Interview Questions for Each Group

Questions for Government

- (1) Under the background of the “13th Five-Year Plan” of “comprehensive work plan for energy conservation”, especially after the compulsory national policy “information of improving the energy efficiency of public buildings on the construction of key cities” came out, what impact do you think it may have on the development of EPCs in the building sector in China? Are there any opportunities for EPC development?
- (2) How is the EPC implemented in the building sector in the key cities? Are there any barriers?
- (3) What do you think are the reasons for the limited uptake of EPCs in the sector of commercial buildings compared with the industrial sector?
- (4) In the policy “interim measures for financial incentive funds for EPC projects”, the financial supports are only given to the EPC projects using shared saving business model, are there any special considerations?
- (5) There are some discussions on the Internet about the difficulties of getting financial supports for the previous EPC projects on building energy saving. What do you think of this?
- (6) How are the first two rounds of Pilot EPC projects? Will there be a post-evaluation for those projects?
- (7) After the abolition of the policy “interim measures for financial incentive funds for EPC projects”, what impact did it have on the implementation of EPC projects in the building sector, especially for commercial building?
- (8) How to play the market role of building energy conservation for promoting EPC? And are there any policies supporting for financing EPC projects?
- (9) What do you think of the building energy information service and disclosure mechanism that will help conduct EPC projects?
- (10) In the policy “information of improving the energy efficiency of public buildings on the construction of key cities”, it put forward “develop a public building energy saving information service platform for the stakeholders of government, the market, owners, financial institutions, and social groups”, how could this policy promote the development of EPCs?
- (11) In the policy “information of improving the energy efficiency of public buildings on the construction of key cities”, it put forward “the EPC projects should demonstrate the rationality of the energy saving benefit determination method and

energy saving verification method, and the demonstration results can be used as a reference for financing". Are there any guidelines on "energy saving benefit determination method and energy saving verification method"? How can that help develop EPC services?

- (12) Do you think there are any other measures to promote the uptake of EPCs for commercial buildings?

Questions for Independent Experts

- (1) What do you think of the development of the EPC project in China? Especially for commercial building energy efficiency retrofit.
- (2) Under the background of the “13th Five-Year Plan” of “comprehensive work plan for energy conservation”, what impact do you think it may have on the development of EPCs in the building sector in China? Are there any opportunities for the development EPCs?
- (3) What do you think are the reasons for the limited uptake of EPCs in the sector of commercial buildings compared with the industrial sector?
- (4) What do you think are the key factors influencing the uptake of EPCs for CBEER?
- (5) What do you think about how green finance policy can help CBEER using EPCs?
- (6) What do you think of the building energy information service and disclosure mechanism that will help conduct EPC projects?
- (7) What do you think are the difficulties of developing a building energy information platform?
- (8) What do you think about how a standard EPC contract helps using EPCs?
- (9) What do you think about how to avoid the risks of using EPCs?
- (10) After the abolition of the policy “interim measures for financial incentive funds for EPC projects”, what impact do you think it has on the implementation of EPC projects in building sector, especially for commercial building?
- (11) In the policy “information of improving the energy efficiency of public buildings on the construction of key cities”, it put forward “the EPC projects should demonstrate the rationality of the energy saving benefit determination method and energy saving verification method, and the demonstration results can be used as a reference for financing”. What are the difficulties of "energy saving benefit determination method and energy saving verification method"? What do you think can improve the accuracy of energy assessment of commercial buildings?
- (12) Do you think there are any other measures to promote the uptake of EPCs for commercial buildings?

Interview Questions for Building Owners

- (1) The following questions are set for participants who have joined EPC projects. So for these participants, they will be asked questions about their opinions on the development of EPC in the building sector firstly, and then more details on the EPC projects they have joined before, lastly they will be asked opinions of potential improvements of EPC.
- What do you think of the development of EPC projects in China? Especially for commercial building energy efficiency retrofit.
 - Why do you think EPC projects are doing well?
 - What do you think are the reasons of limiting the use of EPCs in China?
 - How did you know about EPCs?
 - How did you select Energy Service Companies?
 - Could you please introduce the EPC project you have ever joined?
 - Why you choose EPC for energy efficiency retrofit?
 - What's your responsibility in this project?
 - What is the business model adopted in this project? What's the financial model? How long is the contract period?
 - What problems have you encountered in this project? And how you dealt with?
 - What lessons can be drawn from this project?
 - What measures do you think will lead to more people using EPCs for CBEER?
- (2) The following questions are set for participants who have not joined EPC projects. So for these participants, they will be asked questions about building energy efficiency retrofit firstly, and then the reasons they did not use EPC, lastly they will be asked attitude questions towards EPCs.
- Based on your experience in building energy efficiency retrofit, what do you think are the biggest difficulties in the process of building energy efficiency retrofit?
 - Based on your experience in building energy efficiency retrofit, do you think that building energy saving can be effectively guaranteed? Why?
 - Why did you not use EPCs for CBEER?
 - Do you see any risks in using EPCs for CBEER? (or what are your concerns about using this mechanism?)
 - What measures do you think will lead to more people using EPCs for CBEER? (or in what way can you or more people want to use EPC for CBEER?)

Interview Questions for ESCOs

- (1) The following questions are set for participants who have joined EPC projects. So for these participants, they will be asked questions about their opinions on the development of EPC in the building sector firstly, and then more details on the EPC projects they have joined before, lastly they will be asked opinions of potential improvements of EPC.
- What do you think of the development of the EPC project in China? Especially for commercial building energy efficiency retrofit.
 - Why do you think EPC projects are doing well?
 - What do you think are the reasons for the limited use of EPCs in China?
 - Could you please introduce the EPC project you have ever joined?
 - Why you choose EPCs for energy efficiency retrofit?
 - What is your responsibility in this project?
 - What is the business model adopted in this project? What is the financial model? How long is the contract period?
 - What problems have you encountered in this project? And how you dealt with?
 - What lessons can be drawn from this project?
 - What measures do you think will lead to more people using EPCs for CBEER?
- (2) The following questions are set for participants who have not joined EPC projects. So for these participants, they will be asked questions about building energy efficiency retrofit firstly, and then the reasons they did not use EPC, lastly they will be asked attitude questions towards EPCs.
- Based on your experience in building energy efficiency retrofit, what do you think are the biggest difficulties in the process of building energy efficiency retrofit?
 - Based on your experience in building energy efficiency retrofit, do you think that building energy saving can be effectively guaranteed? Why?
 - Why did you not use EPCs for CBEER?
 - Do you see any risks in using the EPC for CBEER? (or what are your concerns about using this mechanism?)
 - What measures do you think will lead to more people using EPCs for CBEER? (or in what way can you or more people want to use EPC for CBEER?)

Appendix 5 Results of ANOVA Test on Four Groups

(1) ANOVA Test for Part 2 Questions

Statements	Comparison of Groups	Sum of Squares	df	Mean Square	F	Sig.
The government has given great support to the uptake of EPCs in CBBER	Between Groups	10.160	3	3.387	3.938	0.011
	Within Groups	78.261	91	0.860		
	Total	88.421	94			
Policies and regulations have given clear provisions on the application of EPCs for CBBER	Between Groups	0.178	3	0.059	0.076	0.973
	Within Groups	70.727	91	0.777		
	Total	70.905	94			
Policies are the main motivation for the uptake of EPCs in CBBER	Between Groups	1.011	3	0.337	0.329	0.804
	Within Groups	93.137	91	1.023		
	Total	94.147	94			
The subsidies and tax policies provided by the government play an important role in promoting CBEER using EPCs	Between Groups	3.762	3	1.254	3.568	0.017
	Within Groups	31.985	91	0.351		
	Total	35.747	94			
Pilot EPC projects play an important role in promoting CBBER using EPCs	Between Groups	1.537	3	0.512	1.127	0.342
	Within Groups	41.368	91	0.455		
	Total	42.905	94			
Green Finance Policy has great support on conducting an EPC project	Between Groups	1.868	3	0.623	0.946	0.422
	Within Groups	59.921	91	0.658		
	Total	61.789	94			
EPCs are well known in CBEER	Between Groups	2.097	3	0.699	1.034	0.381
	Within Groups	61.524	91	0.676		
	Total	63.621	94			
ESCOs can offer professional retrofit services including finance, design, construction, energy maintenance	Between Groups	3.821	3	1.274	3.127	0.030
	Within Groups	37.063	91	0.407		
	Total	40.884	94			
The ability of energy service company has a great influence on the effect of energy savings	Between Groups	1.694	3	0.565	1.482	0.225
	Within Groups	34.664	91	0.381		
	Total	36.358	94			
The service quality of ESCOs can be effectively guaranteed	Between Groups	3.260	3	1.087	2.357	0.077
	Within Groups	41.961	91	0.461		
	Total	45.221	94			
EPCs are useful for promoting commercial buildings conducting energy efficiency retrofit	Between Groups	1.053	3	0.351	0.745	0.528
	Within Groups	42.884	91	0.471		
	Total	43.937	94			
EPC can ensure the energy saving effect of CBEER	Between Groups	7.393	3	2.464	5.818	0.001
	Within Groups	38.543	91	.424		
	Total	45.937	94			
EPC can effectively solve the financing problem of CBEER	Between Groups	6.131	3	2.044	5.467	0.002
	Within Groups	34.017	91	0.374		
	Total	40.147	94			
EPC can guarantee stakeholders' energy saving benefits	Between Groups	3.332	3	1.111	2.800	0.044
	Within Groups	36.100	91	0.397		
	Total	39.432	94			
Contracts of EPC projects clearly specify the rights and obligations for each contracting party	Between Groups	10.065	3	3.355	7.399	0.000
	Within Groups	41.262	91	0.453		
	Total	51.326	94			
The allocation of estimated energy savings and energy saving benefits can easily be verified	Between Groups	4.213	3	1.404	3.312	0.024
	Within Groups	38.587	91	0.424		
	Total	42.800	94			
The contract period is clearly stipulated and measured	Between Groups	4.927	3	1.642	3.926	0.011
	Within Groups	38.063	91	0.418		
	Total	42.989	94			

The contracts clearly define the measures for CBEER	Between Groups	10.197	3	3.399	7.071	0.000
	Within Groups	43.740	91	0.481		
	Total	53.937	94			
The contracts clearly ensure the current baseline of building energy consumption	Between Groups	5.558	3	1.853	3.881	0.012
	Within Groups	43.432	91	0.477		
	Total	48.989	94			
The contracts clearly define the potential energy savings for CBEER	Between Groups	1.823	3	0.608	1.048	0.375
	Within Groups	52.767	91	0.580		
	Total	54.589	94			
Building owners are responsible for investing CBEER	Between Groups	5.468	3	1.823	2.027	0.116
	Within Groups	81.837	91	0.899		
	Total	87.305	94			
Building users can get more benefits on CBEER than building owners	Between Groups	2.165	3	0.722	0.932	0.428
	Within Groups	70.425	91	0.774		
	Total	72.589	94			
Relationships for making decisions within CBEER are complicated	Between Groups	3.953	3	1.318	2.116	0.104
	Within Groups	56.679	91	0.623		
	Total	60.632	94			
The recovery period of investment in CBEER is too long	Between Groups	5.280	3	1.760	3.100	0.031
	Within Groups	51.667	91	0.568		
	Total	56.947	94			
The behaviour of the user has a great impact on energy efficiency	Between Groups	0.385	3	0.128	0.441	0.724
	Within Groups	26.499	91	0.291		
	Total	26.884	94			
Technologies of CBEER cannot effectively guarantee the effect of energy savings	Between Groups	8.252	3	2.751	3.118	0.030
	Within Groups	80.275	91	0.882		
	Total	88.526	94			
Measurement & Verification by a third party provides a very effective help to the energy saving assessment of CBEER	Between Groups	1.161	3	0.387	0.686	0.563
	Within Groups	51.323	91	0.564		
	Total	52.484	94			
The building climate zone has a great influence on the energy saving potential of commercial buildings	Between Groups	1.080	3	0.360	0.632	0.596
	Within Groups	51.826	91	0.570		
	Total	52.905	94			
The functional types of commercial buildings have a great impact on the owners' decisions for energy efficiency retrofit	Between Groups	2.641	3	0.880	1.581	0.199
	Within Groups	50.685	91	0.557		
	Total	53.326	94			
Low energy prices do not encourage demand for energy efficiency	Between Groups	6.220	3	2.073	2.376	0.075
	Within Groups	79.401	91	0.873		
	Total	85.621	94			
Building energy savings are limited	Between Groups	0.612	3	0.204	0.181	0.909
	Within Groups	102.715	91	1.129		
	Total	103.326	94			
There are a large number of building energy service companies engaged in EPC services	Between Groups	0.821	3	0.274	0.494	0.687
	Within Groups	50.400	91	0.554		
	Total	51.221	94			
Building energy savings make it easier to apply for a bank loan	Between Groups	10.757	3	3.586	4.875	0.003
	Within Groups	66.927	91	0.735		
	Total	77.684	94			
Information platform for building energy information can help stakeholders explore building energy saving potential	Between Groups	8.270	3	2.757	3.980	0.010
	Within Groups	63.035	91	0.693		
	Total	71.305	94			

(2) ANOVA Test for Part 3 Questions

Risks	Comparison of Groups	Sum of Squares	df	Mean Square	F	Sig.
Political adjustments	Between Groups	3.119	3	1.040	2.905	0.039
	Within Groups	32.565	91	0.358		
	Total	35.684	94			
Update of technical standard	Between Groups	13.505	3	4.502	8.859	0.000
	Within Groups	46.242	91	0.508		
	Total	59.747	94			
Falling market demands	Between Groups	0.087	3	0.029	0.070	0.976
	Within Groups	37.850	91	0.416		
	Total	37.937	94			
Increasing market competition	Between Groups	7.240	3	2.413	5.169	0.002
	Within Groups	42.486	91	0.467		
	Total	49.726	94			
Market price changes	Between Groups	0.340	3	0.113	0.223	0.880
	Within Groups	46.144	91	0.507		
	Total	46.484	94			
Increasing construction costs	Between Groups	1.090	3	0.363	1.086	0.359
	Within Groups	30.447	91	0.335		
	Total	31.537	94			
Interest rate changes	Between Groups	4.480	3	1.493	2.894	0.040
	Within Groups	46.952	91	0.516		
	Total	51.432	94			
Exchange rate changes	Between Groups	8.514	3	2.838	5.977	0.001
	Within Groups	43.212	91	0.475		
	Total	51.726	94			
Changes in the electricity pricing mechanism	Between Groups	0.858	3	0.286	0.843	0.474
	Within Groups	30.869	91	0.339		
	Total	31.726	94			
Fuel costs changes	Between Groups	2.887	3	0.962	2.691	0.051
	Within Groups	32.545	91	0.358		
	Total	35.432	94			
Insufficient information on existing building energy consumption and facility operation	Between Groups	1.243	3	0.414	1.080	0.362
	Within Groups	34.905	91	0.384		
	Total	36.147	94			
Accuracy of potential energy saving estimation	Between Groups	1.430	3	0.477	1.266	0.291
	Within Groups	34.255	91	0.376		
	Total	35.684	94			
Decision risk on choosing a suitable retrofit scheme	Between Groups	0.809	3	0.270	0.719	0.543
	Within Groups	34.138	91	0.375		
	Total	34.947	94			
Change of owner or facility management company of buildings	Between Groups	0.580	3	0.193	0.539	0.657
	Within Groups	32.620	91	0.358		
	Total	33.200	94			
Incomplete contracts	Between Groups	1.684	3	0.561	1.729	0.167
	Within Groups	29.537	91	0.325		
	Total	31.221	94			
Inappropriate contracts	Between Groups	2.356	3	0.785	2.154	0.099
	Within Groups	33.181	91	0.365		
	Total	35.537	94			
Completion delay	Between Groups	0.658	3	0.219	0.490	0.690
	Within Groups	40.773	91	0.448		
	Total	41.432	94			
Quality of subcontractors	Between Groups	0.232	3	0.077	0.174	0.914
	Within Groups	40.400	91	0.444		
	Total	40.632	94			
Poor actual energy saving performance	Between Groups	3.551	3	1.184	2.976	0.036
	Within Groups	36.196	91	0.398		
	Total	39.747	94			
Inappropriate equipment sizes	Between Groups	1.053	3	0.351	0.915	0.437
	Within Groups	34.884	91	0.383		
	Total	35.937	94			
Degradation of equipment	Between Groups	3.309	3	1.103	1.987	0.122
	Within Groups	50.522	91	0.555		
	Total	53.832	94			

Faulty operation	Between Groups	4.144	3	1.381	3.031	0.033
	Within Groups	41.477	91	0.456		
	Total	45.621	94			
Frequent breakdowns	Between Groups	1.256	3	0.419	1.246	0.298
	Within Groups	30.575	91	0.336		
	Total	31.832	94			
Unexpected consumption pattern	Between Groups	1.626	3	0.542	1.192	0.317
	Within Groups	41.364	91	0.455		
	Total	42.989	94			
Modeling errors or imprecise model	Between Groups	3.515	3	1.172	2.853	0.042
	Within Groups	37.369	91	0.411		
	Total	40.884	94			
Missing data or inconsistency of data	Between Groups	0.845	3	0.282	0.850	0.470
	Within Groups	30.144	91	0.331		
	Total	30.989	94			
Imprecise metering	Between Groups	4.011	3	1.337	2.668	0.052
	Within Groups	45.610	91	0.501		
	Total	49.621	94			

(3) ANOVA Test for Part 4 Questions

Improvements	Comparison of Groups	Sum of Squares	df	Mean Square	F	Sig.
Compulsory regulation on building energy efficiency	Between Groups	2.810	3	0.937	2.082	0.108
	Within Groups	40.937	91	0.450		
	Total	43.747	94			
Subsidies on using EPCs	Between Groups	3.886	3	1.295	2.503	0.064
	Within Groups	47.103	91	0.518		
	Total	50.989	94			
Information disclosure on building energy consumption	Between Groups	0.495	3	0.165	0.295	0.829
	Within Groups	50.810	91	0.558		
	Total	51.305	94			
The rationality demonstration on the method of energy saving benefits allocation	Between Groups	0.511	3	0.170	0.380	0.768
	Within Groups	40.815	91	0.449		
	Total	41.326	94			
The rationality demonstration on energy saving audit/assessment	Between Groups	3.294	3	1.098	3.283	0.024
	Within Groups	30.433	91	0.334		
	Total	33.726	94			
Professional energy saving operation management	Between Groups	3.029	3	1.010	3.479	0.019
	Within Groups	26.403	91	0.290		
	Total	29.432	94			
Post EPC project evaluation	Between Groups	5.110	3	1.703	4.025	0.010
	Within Groups	38.511	91	0.423		
	Total	43.621	94			

Appendix 6 Results of Multiple Comparisons of Groups

(1) Multiple Comparisons of Groups for Part 2 Questions

Dependent Variable	Organisation group	Organisation group	Mean Difference	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
The government has given great support to the uptake of EPCs in CBBER	Independent expert	Government	-0.844*	0.345	0.016	-1.53	-0.16
		Building Owner	-0.604*	0.262	0.024	-1.12	-0.08
		ESCO	-0.040	0.260	0.878	-0.56	0.48
	Government	Independent expert	0.844*	0.345	0.016	0.16	1.53
		Building Owner	0.240	0.325	0.462	-0.41	0.89
		ESCO	0.804*	0.324	0.015	0.16	1.45
	Building Owner	Independent expert	0.604*	0.262	0.024	0.08	1.12
		Government	-0.240	0.325	0.462	-0.89	0.41
		ESCO	0.564*	0.234	0.018	0.10	1.03
	ESCO	Independent expert	0.040	0.260	0.878	-0.48	0.56
		Government	-0.804*	0.324	0.015	-1.45	-0.16
		Building Owner	-0.564*	0.234	0.018	-1.03	-0.10
The subsidies and tax policies provided by the government play an important role in promoting CBEER using EPCs	Independent expert	Government	-0.351	0.221	0.116	-0.79	0.09
		Building Owner	-0.456*	0.168	0.008	-0.79	-0.12
		ESCO	-0.058	0.166	0.728	-0.39	0.27
	Government	Independent expert	0.351	0.221	0.116	-0.09	0.79
		Building Owner	-0.106	0.208	0.613	-0.52	0.31
		ESCO	0.293	0.207	0.161	-0.12	0.70
	Building Owner	Independent expert	0.456*	0.168	0.008	0.12	0.79
		Government	0.106	0.208	0.613	-0.31	0.52
		ESCO	0.398*	0.149	0.009	0.10	0.69
	ESCO	Independent expert	0.058	0.166	0.728	-0.27	0.39
		Government	-0.293	0.207	0.161	-0.70	0.12
		Building Owner	-0.398*	0.149	0.009	-0.69	-0.10
ESCOs can offer professional retrofit services including finance, design, construction, energy maintenance	Independent expert	Government	-0.684*	0.238	0.005	-1.16	-0.21
		Building Owner	-0.402*	0.180	0.028	-0.76	-0.04
		ESCO	-0.329	0.179	0.070	-0.68	0.03
	Government	Independent expert	0.684*	0.238	0.005	0.21	1.16
		Building Owner	0.282	0.224	0.212	-0.16	0.73
		ESCO	0.355	0.223	0.115	-0.09	0.80
	Building Owner	Independent expert	0.402*	0.180	0.028	0.04	0.76
		Government	-0.282	0.224	0.212	-0.73	0.16
		ESCO	0.074	0.161	0.648	-0.25	0.39
	ESCO	Independent expert	0.329	0.179	0.070	-0.03	0.68
		Government	-0.355	0.223	0.115	-0.80	0.09
		Building Owner	-0.074	0.161	0.648	-0.39	0.25
EPC can ensure the energy saving effect of CBEER	Independent expert	Government	-0.758*	0.242	0.002	-1.24	-0.28
		Building Owner	-0.634*	0.184	0.001	-1.00	-0.27
		ESCO	-0.667*	0.183	0.000	-1.03	-0.30
	Government	Independent expert	0.758*	0.242	0.002	0.28	1.24
		Building Owner	0.123	0.228	0.591	-0.33	0.58
		ESCO	0.091	0.227	0.690	-0.36	0.54
	Building Owner	Independent expert	0.634*	0.184	0.001	0.27	1.00
		Government	-0.123	0.228	0.591	-0.58	0.33
		ESCO	-0.032	0.164	0.845	-0.36	0.29
	ESCO	Independent expert	0.667*	0.183	0.000	0.30	1.03
		Government	-0.091	0.227	0.690	-0.54	0.36
		Building Owner	0.032	0.164	0.845	-0.29	0.36
EPC can effectively solve the financing problem of CBEER	Independent expert	Government	-0.515*	0.228	0.026	-0.97	-0.06
		Building Owner	-0.527*	0.173	0.003	-0.87	-0.18
		ESCO	-0.021	0.172	0.904	-0.36	0.32
	Government	Independent expert	0.515*	0.228	0.026	0.06	0.97
		Building Owner	-0.012	0.215	0.957	-0.44	0.41
		ESCO	0.494*	0.214	0.023	0.07	0.92
	Building Owner	Independent expert	0.527*	0.173	0.003	0.18	0.87
		Government	0.012	0.215	0.957	-0.41	0.44

	ESCO	ESCO	0.506*	0.154	0.001	0.20	0.81
		Independent expert	0.021	0.172	0.904	-0.32	0.36
		Government	-0.494*	0.214	0.023	-0.92	-0.07
		Building Owner	-0.506*	0.154	0.001	-0.81	-0.20
EPC can guarantee stakeholders' energy saving benefits	Independent expert	Government	-0.615*	0.234	0.010	-1.08	-0.15
		Building Owner	-0.395*	0.178	0.029	-0.75	-0.04
		ESCO	-0.243	0.177	0.174	-0.59	0.11
	Government	Independent expert	0.615*	0.234	0.010	0.15	1.08
		Building Owner	0.220	0.221	0.322	-0.22	0.66
		ESCO	0.372	0.220	0.094	-0.07	0.81
	Building Owner	Independent expert	0.395*	0.178	0.029	0.04	0.75
		Government	-0.220	0.221	0.322	-0.66	0.22
		ESCO	0.152	0.159	0.340	-0.16	0.47
	ESCO	Independent expert	0.243	0.177	0.174	-0.11	0.59
		Government	-0.372	0.220	0.094	-0.81	0.07
		Building Owner	-0.152	0.159	0.340	-0.47	0.16
Contracts of EPC projects clearly specify the rights and obligations for each contracting parties	Independent expert	Government	-0.706*	0.251	0.006	-1.20	-0.21
		Building Owner	-0.814*	0.190	0.000	-1.19	-0.44
		ESCO	-0.774*	0.189	0.000	-1.15	-0.40
	Government	Independent expert	0.706*	0.251	0.006	0.21	1.20
		Building Owner	-0.109	0.236	0.647	-0.58	0.36
		ESCO	-0.068	0.235	0.773	-0.54	0.40
	Building Owner	Independent expert	0.814*	0.190	0.000	0.44	1.19
		Government	0.109	0.236	0.647	-0.36	0.58
		ESCO	0.040	0.170	0.813	-0.30	0.38
	ESCO	Independent expert	0.774*	0.189	0.000	0.40	1.15
		Government	0.068	0.235	0.773	-0.40	0.54
		Building Owner	-0.040	0.170	0.813	-0.38	0.30
The allocation of estimated energy savings and energy saving benefits can easily be verified	Independent expert	Government	-0.169	0.242	0.488	-0.65	0.31
		Building Owner	-0.327	0.184	0.079	-0.69	0.04
		ESCO	-0.558*	0.183	0.003	-0.92	-0.19
	Government	Independent expert	0.169	0.242	0.488	-0.31	0.65
		Building Owner	-0.158	0.229	0.490	-0.61	0.30
		ESCO	-0.389	0.228	0.091	-0.84	0.06
	Building Owner	Independent expert	0.327	0.184	0.079	-0.04	0.69
		Government	0.158	0.229	0.490	-0.30	0.61
		ESCO	-0.231	0.164	0.163	-0.56	0.10
	ESCO	Independent expert	0.558*	0.183	0.003	0.19	0.92
		Government	0.389	0.228	0.091	-0.06	0.84
		Building Owner	0.231	0.164	0.163	-0.10	0.56
The contract period is clearly stipulated and measured	Independent expert	Government	-0.580*	0.241	0.018	-1.06	-0.10
		Building Owner	-0.278	0.183	0.132	-0.64	0.09
		ESCO	-0.574*	0.182	0.002	-0.94	-0.21
	Government	Independent expert	0.580*	0.241	0.018	0.10	1.06
		Building Owner	0.302	0.227	0.187	-0.15	0.75
		ESCO	0.006	0.226	0.980	-0.44	0.45
	Building Owner	Independent expert	0.278	0.183	0.132	-0.09	0.64
		Government	-0.302	0.227	0.187	-0.75	0.15
		ESCO	-0.296	0.163	0.072	-0.62	0.03
	ESCO	Independent expert	0.574*	0.182	0.002	0.21	0.94
		Government	-0.006	0.226	0.980	-0.45	0.44
		Building Owner	0.296	0.163	0.072	-0.03	0.62
The contracts clearly define the measures for CBEER	Independent expert	Government	-1.108*	0.258	0.000	-1.62	-0.60
		Building Owner	-0.671*	0.196	0.001	-1.06	-0.28
		ESCO	-0.537*	0.195	0.007	-0.92	-0.15
	Government	Independent expert	1.108*	0.258	0.000	0.60	1.62
		Building Owner	0.437	0.243	0.076	-0.05	0.92
		ESCO	0.571*	0.242	0.021	0.09	1.05
	Building Owner	Independent expert	0.671*	0.196	0.001	0.28	1.06
		Government	-0.437	0.243	0.076	-0.92	0.05
		ESCO	0.134	0.175	0.445	-0.21	0.48
	ESCO	Independent expert	0.537*	0.195	0.007	0.15	0.92
		Government	-0.571*	0.242	0.021	-1.05	-0.09
		Building Owner	-0.134	0.175	0.445	-0.48	0.21
The contracts clearly ensure the current baseline of building energy consumption	Independent expert	Government	-0.714*	0.257	0.007	-1.23	-0.20
		Building Owner	-0.166	0.195	0.398	-0.55	0.22
		ESCO	-0.496*	0.194	0.012	-0.88	-0.11
	Government	Independent expert	0.714*	0.257	0.007	0.20	1.23
		Building Owner	0.548*	0.242	0.026	0.07	1.03

The recovery period of investment in CBEER is too long	Building Owner	Independent expert	0.166	0.195	0.398	-0.22	0.55
		Government	-0.548*	0.242	0.026	-1.03	-0.07
		ESCO	-0.330	0.174	0.061	-0.68	0.02
	ESCO	Independent expert	0.496*	0.194	0.012	0.11	0.88
		Government	-0.219	0.241	0.367	-0.70	0.26
		Building Owner	0.330	0.174	0.061	-0.02	0.68
	Independent expert	Government	-0.740*	0.280	0.010	-1.30	-0.18
		Building Owner	-0.544*	0.213	0.012	-0.97	-0.12
		ESCO	-0.379	0.212	0.076	-0.80	0.04
	Government	Independent expert	0.740*	0.280	0.010	0.18	1.30
		Building Owner	0.196	0.264	0.459	-0.33	0.72
		ESCO	0.361	0.263	0.174	-0.16	0.88
	Building Owner	Independent expert	0.544*	0.213	0.012	0.12	0.97
		Government	-0.196	0.264	0.459	-0.72	0.33
		ESCO	0.164	0.190	0.389	-0.21	0.54
Technologies of CBEER cannot effectively guarantee the effect of energy savings	Independent expert	Government	0.463	0.350	0.188	-0.23	1.16
		Building Owner	0.803*	0.265	0.003	0.28	1.33
		ESCO	0.565*	0.264	0.035	0.04	1.09
	Government	Independent expert	-0.463	0.350	0.188	-1.16	0.23
		Building Owner	0.340	0.330	0.305	-0.31	0.99
		ESCO	0.102	0.328	0.756	-0.55	0.75
	Building Owner	Independent expert	-0.803*	0.265	0.003	-1.33	-0.28
		Government	-0.340	0.330	0.305	-0.99	0.31
		ESCO	-0.238	0.237	0.318	-0.71	0.23
	ESCO	Independent expert	-0.565*	0.264	0.035	-1.09	-0.04
		Government	-0.102	0.328	0.756	-0.75	0.55
		Building Owner	0.238	0.237	0.318	-0.23	0.71
Building energy savings make it easier to apply for a bank loan	Independent expert	Government	0.866*	0.319	0.008	0.23	1.50
		Building Owner	0.854*	0.242	0.001	0.37	1.34
		ESCO	0.423	0.241	0.083	-0.06	0.90
	Government	Independent expert	-0.866*	0.319	0.008	-1.50	-0.23
		Building Owner	-0.012	0.301	0.969	-0.61	0.59
		ESCO	-0.443	0.300	0.143	-1.04	0.15
	Building Owner	Independent expert	-0.854*	0.242	0.001	-1.34	-0.37
		Government	0.012	0.301	0.969	-0.59	0.61
		ESCO	-0.431*	0.216	0.049	-0.86	0.00
	ESCO	Independent expert	-0.423	0.241	0.083	-0.90	0.06
		Government	0.443	0.300	0.143	-0.15	1.04
		Building Owner	0.431*	0.216	0.049	0.00	0.86
Information platform for building energy information can help stakeholders explore building energy saving potential	Independent expert	Government	-0.567	0.310	0.070	-1.18	0.05
		Building Owner	-0.250	0.235	0.290	-0.72	0.22
		ESCO	0.305	0.234	0.195	-0.16	0.77
	Government	Independent expert	0.567	0.310	0.070	-0.05	1.18
		Building Owner	0.317	0.292	0.281	-0.26	0.90
		ESCO	0.872*	0.291	0.004	0.29	1.45
	Building Owner	Independent expert	0.250	0.235	0.290	-0.22	0.72
		Government	-0.317	0.292	0.281	-0.90	0.26
		ESCO	0.555*	0.210	0.010	0.14	0.97
	ESCO	Independent expert	-0.305	0.234	0.195	-0.77	0.16
		Government	-0.872*	0.291	0.004	-1.45	-0.29
		Building Owner	-0.555*	0.210	0.010	-0.97	-0.14

*. The mean difference is significant at the 0.05 level.

(2) Multiple Comparisons of Groups for Part 3 Questions

Dependent Variable	Organisation group	Organisation group	Mean Difference	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
Political adjustments	Independent expert	Government	0.152	0.223	0.498	-0.29	0.59
		Building Owner	-0.376*	0.169	0.028	-0.71	-0.04
		ESCO	-0.104	0.168	0.537	-0.44	0.23
	Government	Independent expert	-0.152	0.223	0.498	-0.59	0.29
		Building Owner	-0.528*	0.210	0.014	-0.94	-0.11
		ESCO	-0.256	0.209	0.225	-0.67	0.16
	Building Owner	Independent expert	0.376*	0.169	0.028	0.04	0.71
		Government	0.528*	0.210	0.014	0.11	0.94
		ESCO	0.272	0.151	0.074	-0.03	0.57
	ESCO	Independent expert	0.104	0.168	0.537	-0.23	0.44
		Government	0.256	0.209	0.225	-0.16	0.67
		Building Owner	-0.272	0.151	0.074	-0.57	0.03
Update of technical standard	Independent expert	Government	-0.874*	0.265	0.001	-1.40	-0.35
		Building Owner	-0.948*	0.201	0.000	-1.35	-0.55
		ESCO	-0.363	0.200	0.073	-0.76	0.03
	Government	Independent expert	0.874*	0.265	0.001	0.35	1.40
		Building Owner	-0.073	0.250	0.770	-0.57	0.42
		ESCO	0.511*	0.249	0.043	0.02	1.01
	Building Owner	Independent expert	0.948*	0.201	0.000	0.55	1.35
		Government	0.073	0.250	0.770	-0.42	0.57
		ESCO	0.585*	0.180	0.002	0.23	0.94
	ESCO	Independent expert	0.363	0.200	0.073	-0.03	0.76
		Government	-0.511*	0.249	0.043	-1.01	-0.02
		Building Owner	-0.585*	0.180	0.002	-0.94	-0.23
Increasing market competition	Independent expert	Government	0.446	0.254	0.083	-0.06	0.95
		Building Owner	0.680*	0.193	0.001	0.30	1.06
		ESCO	0.153	0.192	0.427	-0.23	0.53
	Government	Independent expert	-0.446	0.254	0.083	-0.95	0.06
		Building Owner	0.235	0.240	0.331	-0.24	0.71
		ESCO	-0.293	0.239	0.224	-0.77	0.18
	Building Owner	Independent expert	-0.680*	0.193	0.001	-1.06	-0.30
		Government	-0.235	0.240	0.331	-0.71	0.24
		ESCO	-0.527*	0.172	0.003	-0.87	-0.19
	ESCO	Independent expert	-0.153	0.192	0.427	-0.53	0.23
		Government	0.293	0.239	0.224	-0.18	0.77
		Building Owner	0.527*	0.172	0.003	0.19	0.87
Interest rate changes	Independent expert	Government	-0.177	0.267	0.508	-0.71	0.35
		Building Owner	-0.421*	0.203	0.041	-0.82	-0.02
		ESCO	-0.561*	0.202	0.007	-0.96	-0.16
	Government	Independent expert	0.177	0.267	0.508	-0.35	0.71
		Building Owner	-0.243	0.252	0.337	-0.74	0.26
		ESCO	-0.384	0.251	0.130	-0.88	0.12
	Building Owner	Independent expert	0.421*	0.203	0.041	0.02	0.82
		Government	0.243	0.252	0.337	-0.26	0.74
		ESCO	-0.140	0.181	0.441	-0.50	0.22
	ESCO	Independent expert	0.561*	0.202	0.007	0.16	0.96
		Government	0.384	0.251	0.130	-0.12	0.88
		Building Owner	0.140	0.181	0.441	-0.22	0.50
Exchange rate changes	Independent expert	Government	-0.195	0.256	0.449	-0.70	0.31
		Building Owner	0.134	0.195	0.494	-0.25	0.52
		ESCO	-0.567*	0.194	0.004	-0.95	-0.18
	Government	Independent expert	0.195	0.256	0.449	-0.31	0.70
		Building Owner	0.328	0.242	0.178	-0.15	0.81
		ESCO	-0.372	0.241	0.126	-0.85	0.11
	Building Owner	Independent expert	-0.134	0.195	0.494	-0.52	0.25
		Government	-0.328	0.242	0.178	-0.81	0.15
		ESCO	-0.701*	0.174	0.000	-1.05	-0.36
	ESCO	Independent expert	0.567*	0.194	0.004	0.18	0.95
		Government	0.372	0.241	0.126	-0.11	0.85
		Building Owner	0.701*	0.174	0.000	0.36	1.05
Poor actual energy saving performance	Independent expert	Government	-0.532*	0.235	0.026	-1.00	-0.07
		Building Owner	-0.392*	0.178	0.031	-0.75	-0.04
		ESCO	-0.089	0.177	0.615	-0.44	0.26
	Government	Independent expert	0.532*	0.235	0.026	0.07	1.00

		Building Owner	0.141	0.221	0.526	-0.30	0.58	
		ESCO	0.443*	0.220	0.047	0.01	0.88	
	Building Owner	Independent expert	0.392*	0.178	0.031	0.04	0.75	
		Government	-0.141	0.221	0.526	-0.58	0.30	
		ESCO	0.302	0.159	0.060	-0.01	0.62	
	ESCO	Independent expert	0.089	0.177	0.615	-0.26	0.44	
		Government	-0.443*	0.220	0.047	-0.88	-0.01	
		Building Owner	-0.302	0.159	0.060	-0.62	0.01	
	Faulty operation	Independent expert	Government	-0.597*	0.251	0.020	-1.10	-0.10
Building Owner			-0.046	0.191	0.810	-0.43	0.33	
ESCO			-0.362	0.190	0.060	-0.74	0.02	
Government			Independent expert	0.597*	0.251	0.020	0.10	1.10
Government		Building Owner	0.551*	0.237	0.022	0.08	1.02	
		ESCO	0.236	0.236	0.320	-0.23	0.70	
		Building Owner	Independent expert	0.046	0.191	0.810	-0.33	0.43
Government			-0.551*	0.237	0.022	-1.02	-0.08	
ESCO			-0.316	0.170	0.067	-0.65	0.02	
ESCO		Independent expert	0.362	0.190	0.060	-0.02	0.74	
		Government	-0.236	0.236	0.320	-0.70	0.23	
		Building Owner	0.316	0.170	0.067	-0.02	0.65	
Modeling errors or imprecise model		Independent expert	Government	-0.636*	0.239	0.009	-1.11	-0.16
			Building Owner	-0.387*	0.181	0.035	-0.75	-0.03
			ESCO	-0.219	0.180	0.227	-0.58	0.14
	Government	Independent expert	0.636*	0.239	0.009	0.16	1.11	
		Building Owner	0.249	0.225	0.271	-0.20	0.70	
		ESCO	0.418	0.224	0.065	-0.03	0.86	
	Building Owner	Independent expert	0.387*	0.181	0.035	0.03	0.75	
		Government	-0.249	0.225	0.271	-0.70	0.20	
		ESCO	0.168	0.161	0.300	-0.15	0.49	
	ESCO	Independent expert	0.219	0.180	0.227	-0.14	0.58	
		Government	-0.418	0.224	0.065	-0.86	0.03	
		Building Owner	-0.168	0.161	0.300	-0.49	0.15	
*. The mean difference is significant at the 0.05 level.								

(3) Multiple Comparisons of Groups for Part 4 Questions

Dependent Variable	Organisation group	Organisation group	Mean Difference	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
The rationality demonstration on energy saving audit/assessment	Independent expert	Government	-0.446*	0.215	0.041	-0.87	-0.02
		Building Owner	-0.487*	0.163	0.004	-0.81	-0.16
		ESCO	-0.247	0.162	0.132	-0.57	0.08
	Government	Independent expert	0.446*	0.215	0.041	0.02	0.87
		Building Owner	-0.041	0.203	0.840	-0.44	0.36
		ESCO	0.199	0.202	0.328	-0.20	0.60
	Building Owner	Independent expert	0.487*	0.163	0.004	0.16	0.81
		Government	0.041	0.203	0.840	-0.36	0.44
		ESCO	0.240	0.146	0.103	-0.05	0.53
	ESCO	Independent expert	0.247	0.162	0.132	-0.08	0.57
		Government	-0.199	0.202	0.328	-0.60	0.20
		Building Owner	-0.240	0.146	0.103	-0.53	0.05
Professional energy saving operation management	Independent expert	Government	-0.442*	0.200	0.030	-0.84	-0.04
		Building Owner	-0.456*	0.152	0.004	-0.76	-0.15
		ESCO	-0.214	0.151	0.160	-0.51	0.09
	Government	Independent expert	0.442*	0.200	0.030	0.04	0.84
		Building Owner	-0.015	0.189	0.938	-0.39	0.36
		ESCO	0.227	0.188	0.230	-0.15	0.60
	Building Owner	Independent expert	0.456*	0.152	0.004	0.15	0.76
		Government	0.015	0.189	0.938	-0.36	0.39
		ESCO	0.242	0.136	0.078	-0.03	0.51
	ESCO	Independent expert	0.214	0.151	0.160	-0.09	0.51
		Government	-0.227	0.188	0.230	-0.60	0.15
		Building Owner	-0.242	0.136	0.078	-0.51	0.03
Post EPC project evaluation	Independent expert	Government	0.606*	0.242	0.014	0.13	1.09
		Building Owner	0.495*	0.184	0.008	0.13	0.86
		ESCO	0.115	0.183	0.532	-0.25	0.48
	Government	Independent expert	-0.606*	0.242	0.014	-1.09	-0.13
		Building Owner	-0.111	0.228	0.627	-0.56	0.34
		ESCO	-0.491*	0.227	0.033	-0.94	-0.04
	Building Owner	Independent expert	-0.495*	0.184	0.008	-0.86	-0.13
		Government	0.111	0.228	0.627	-0.34	0.56
		ESCO	-0.380*	0.164	0.023	-0.71	-0.05
	ESCO	Independent expert	-0.115	0.183	0.532	-0.48	0.25
		Government	0.491*	0.227	0.033	0.04	0.94
		Building Owner	0.380*	0.164	0.023	0.05	0.71

*. The mean difference is significant at the 0.05 level.

Appendix 7 Results of Principal Component Analysis

Total Variance (Factors of the Uptake of EPCs) Explained by Principal Component Analysis									
Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	9.158	26.936	26.936	9.158	26.936	26.936	5.355	15.750	15.750
2	3.280	9.646	36.583	3.280	9.646	36.583	2.758	8.111	23.861
3	2.425	7.132	43.715	2.425	7.132	43.715	2.723	8.008	31.869
4	1.976	5.810	49.525	1.976	5.810	49.525	2.380	7.001	38.870
5	1.670	4.911	54.435	1.670	4.911	54.435	2.353	6.921	45.790
6	1.616	4.754	59.190	1.616	4.754	59.190	2.249	6.614	52.404
7	1.546	4.546	63.736	1.546	4.546	63.736	2.123	6.243	58.647
8	1.185	3.484	67.220	1.185	3.484	67.220	2.084	6.129	64.776
9	1.077	3.168	70.388	1.077	3.168	70.388	1.908	5.612	70.388
10	0.894	2.628	73.016						
11	0.814	2.395	75.411						
12	0.783	2.304	77.715						
13	0.755	2.221	79.936						
14	0.715	2.103	82.040						
15	0.647	1.902	83.942						
16	0.613	1.803	85.745						
17	0.556	1.635	87.380						
18	0.479	1.410	88.789						
19	0.449	1.320	90.109						
20	0.429	1.260	91.369						
21	0.383	1.127	92.497						
22	.332	0.978	93.475						
23	0.299	0.879	94.354						
24	0.277	0.815	95.169						
25	0.250	0.737	95.905						
26	0.229	0.675	96.580						
27	0.210	0.617	97.197						
28	0.190	0.558	97.756						
29	0.169	0.496	98.252						
30	0.164	0.483	98.735						
31	0.128	0.377	99.112						
32	0.114	0.336	99.447						
33	0.097	0.286	99.733						
34	0.091	0.267	100.000						
Extraction Method: Principal Component Analysis.									