DEVELOPMENT OF TECHNOLOGICAL CAPABILITIES IN CHINESE ENERGY SERVICE COMPANIES

By

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Doctor of Philosophy

ASTON UNIVERSITY

September/2017

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PhD in Management

Development of technological capabilities in Chinese Energy Service Companies (ESCOs)

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Year of Submission: 2017

This PhD investigation aims at identifying technological capability development of Chinese Energy Service Companies (ESCO) from the perspective of drivers, factors, process of technological capabilities development and product portfolio.

This PhD investigation addresses four research questions:

1. Why have Chinese ESCOs developed their technological capabilities?
2. Which and how do factors affect Chinese ESCO's technological capabilities?
3. How have Chinese ESCOs developed technological capabilities?
4. How do case companies compare to US ESCOs in terms of product portfolio?

ESCOs are an effective market-mechanism to help a country to achieve the target of energy conservation. After nearly 30 years' development, China has the largest ESCO market in the world. The development of ESCO industry in China is however still in its early stages. Technological capability is one of key barriers to its progress in China.

The key research strategy was based upon multiple case studies in a qualitative approach which was supplemented by secondary data analysis. Within-case analysis and Cross-cases analysis were employed as key data analysis methods for this investigation.

Six Chinese ESCOs of different sizes and locations were analysed through four dimensions of technology capabilities, namely: investment, production, linkage, and innovation. While the findings ratify the impact of these four dimensions on the company's technological capabilities, they had to be refined in accordance to the characteristics of service industry. An ESCO will manage each dimension and develop its technological capabilities based on the company's business strategy, business model, products and services.

This PhD thesis will help companies to identify the factors within the four dimensions of technological capabilities. This should allow them to gradually develop initiatives to improve their products and services.

Keywords: ESCO, technological capability, China.

Acknowledgements

The most important decision in my life was to get married. Four years ago, I made the second most important decision in my life when I started my PhD at Aston University.

I have studied in Aston University and lived in Birmingham for four years. During this period, my life has changed a lot. I have made lots of good friends. I went to Orlando, Florida and Vienna to attend conferences and presented my research work to researchers from around the world. I was most excited about having my first child in 2016. I have enjoyed my everyday life at Aston University and in Birmingham.

I must give credit to everyone who has supported me throughout this time.

First of all, I must thank Dr Breno Nunes, who accepted me as his PhD student and took me to the United States and Austria to attend IAMOT conferences. He taught me how to present my work confidently. I appreciate his help during my PhD study period.

I also need to thank Kirit Vaidya, whose professional advice provided new insights into my PhD investigation, enabling me to move closer and closer to my destination.

I would also like to thank the people who provided help with my qualitative research. Without their help, it would have been impossible for me to complete this task.

In all my life achievements, I am gratitude for the support from my family. Thanks all of you, and special thanks to my father Weiguo Qiu, who funded my PhD study in the UK.

I leave my final and biggest thanks to my wife, Na Zhang, for always being loving and encouraging, and supporting me to carry on my study. I will love her forever.

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List of Abbreviations

ESCO-Energy Service Company

EPC- Energy Performance Contracting

IEA-International Energy Agency

SME-Small and Medium Enterprise

SOE-State Owned Enterprise

FYP- Five-year-plan

DSM- Demand Side Management

NDRC-National Development and Reform Commission

MoF-Ministry of Finance

SAT-Administration of Taxation

MIIT-Ministry of Industry and Information Technology

Note: All the case companies are Chinese enterprises and all the data collection was conducted in China. Therefore, the currency used in this thesis is RMB (1 RMB equivalent to 0.112 pound, referenced by currency rate on 25th /09/2017).

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Chapter 1 Introduction

This chapter starts with a brief introduction to energy consumption and energy efficiency in China and the current status of the ESCO (energy service company) industry in China. Then, the research questions for this thesis are introduced, with explanations of their context, reasons and relevance. The objectives of this thesis are outlined and the contributions of the study are presented. Finally, this chapter presents the structure of the thesis as well. This thesis mainly focuses on the study of technological capability development in an emerging service industry – the ESCO industry. The methodology is predominantly qualitative and the research strategy used is multiple case studies. Various research methods were employed, including secondary data analysis, observations and interviews.

1.1 Energy consumption and energy efficiency in China

China's energy consumption and energy structure

The topic of energy efficiency has been in focus in both developed and developing countries for decades. In particular, some large energy consumers, their energy consumption, and energy structure have been of interest not only to their own countries, but also other countries. China is one of the world's largest emerging economies, with a population of 1.4 billion and approximately 19 percent of population of world. In 2015, China had the second-largest GDP in the world and the second-highest growth rate, 6.9 percent (Financial Times). Even though China's economic growth has slowed in recent years, it has maintained a fast-growing economy for several years.

The rapid economic growth and large population have driven China's overall energy demand, which has led to huge amounts of energy being imported and consumed, and serious associated environmental problems. China became the world's largest contributor of carbon dioxide emissions in 2007(IEA, 2016). In 2010, it overtook United States as the world's largest energy consumer. China is an energy-dependent economy, so energy is a limiting factor to the country's output growth (Yuan et al., 2008; Guan et al., 2008). Several studies have been conducted regarding energy consumption and economic growth in China (Wang et al., 2011a; Wang et al., 2011b; Pao, Fu & Tseng., 2012; Li and Leung, 2012; Omri, 2012). The results of existing studies show that energy consumption, carbon dioxide emissions and economic growth appear to be strong related.

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Figure 1: Energy consumption of selected countries in 2016. (Source: The World Bank)

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Figure 2: Energy consumption of China from 1990-2016. (Source from Global Energy Statistical Year Book 2017).

China's energy consumption has grown rapidly compared to other countries. From 1990 to 2010, it increased from 870 million tons to 2615 million tons. China's energy consumption in 2016 was 1.4 times that of the US. To support such large amounts of energy consumption, China not only actively produces energy, but also obtains fossil energy from imports. According to an analysis by the Institute of Energy Research in 2015, China became the world's largest coal producer and oil importer in 2013. According to a report from the US Energy Information

Administration, China’s oil consumption growth accounted for approximately 43 percent of the world’s oil consumption growth in 2014.

Figure 3: China's energy production from 1990-2016. (Sources from Global Energy Statistical Year Book 2017).

Economic growth has an impact on energy consumption and carbon dioxide emissions. As an emerging export-oriented manufacturing country, China’s energy consumption will continue to increase in order to guarantee its economic growth. The decreasing of energy consumption will impact the coastal and central regions in China, which have high manufacturing and population intensity (Li and Leung, 2012). Hence, the important point is how to optimise energy structure, decrease energy consumption per GDP unit, improve energy efficiency and reduce unnecessary energy wastage (Pao et al., 2012).

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Figure 4: China's energy consumption structure, 1985-2015. (Source from PR web)

China's energy consumption structure is a key factor that has led to huge energy consumption and carbon dioxide emission. According to data from China's National Bureau of Statistics, total energy consumption in the country reached 4.26 billion tons coal equivalent in 2014. Coal energy consumption is 4.17 billion tons in 2014 (China statistical year book 2016). The heavy reliance on coal in China is due to abundant coal resources, low cost of coal production, light control of coal prices and a lack of environmental awareness for decades (Crompton and Wu, 2005). Oil consumption is 0.52 billion tons and gas consumption is 186.9 billion cubic meters, while fossil energy consumption represents nearly 88 percent of the country's total. Hydropower, wind power, solar power and other non-fossil energy accounted for 12 percent Industrial energy consumption is 2.96 billion tons of coal equivalent, which represents 69.5 percent of the country's total energy consumption. Production-related emissions have made the largest contribution to this increase (Guan et al., 2008). Such energy consumption structure is one of the factors that impact carbon dioxide emission and environmental pollution. The heavy reliance on fossil energy, especially coal and an insufficient supply of electricity and oil will hamper the development of China' economy (Yuan et al., 2008). Zhang and Cheng (2009) noted that reducing consumption of coal and fossil fuel and increasing the utilisation of clear energy and gradually reforming and upgrading the energy consumption structure will be active ways to reduce carbon dioxide emission. Li et al., (2011) predicted that, in China, gas will become an important substitution for coal in some parts of primary energy consumption. Because gas is cleaner and generally more efficient than coal, the demand for gas will rise quickly in the future. In addition to energy structure, per capita GDP growth, production structure, efficiency and technology, capital investment and growth in exports are all factors that impact CO_2 emissions in the short and long term (Guan et al., 2008).

Figure 5: CO2 emissions of China, 1990-2016. (Source: Global Energy Statistical Year Book 2017)

China's energy consumption and CO_2 emissions are unlikely to be reduced significantly and may even continue to increase in the short run. Economic growth, urbanisation, and a growing population will increase the energy consumption. China has signed the Paris Agreement and joint Kyoto Protocol and has tried to achieve the objectives of CO_2 emission through upgrading the energy consumption structure, production structure, penetrating advanced energy efficient technologies and formulating and issuing more efficient energy policies. However, it seems impossible for China to achieve its objectives in the short term. Wang et al. (2016) predicted that China's carbon emissions will reach a peak in 2025. Nuclear energy will be a substitute for coal, the proportion of which in the country's total energy supply will decline rapidly. Nevertheless, the proportion of non-fossil energy in the country's primary energy supply will remain slightly lower than 20 per cent.

China's energy efficiency

Having recognised the increasingly prominent problems of energy consumption, energy structure and green gas emission, energy efficiency has gained an important place in the policy agendas of developed and developing countries. It has been linked to commercial and industrial competitiveness and energy security and environmental benefits (Patterson, 1996; Philip, 2009). As the largest energy consumer and CO_2 emitter, China's energy efficiency has been viewed as an important issue that researchers, governments and social classes have focused on for decades. Numerous studies have also shown that China has only harnessed a small portion of its energy efficiency potential (Price et al., 2002; Lu, 2007; Yang, 2008; Li and Colombier, 2009; Feng et al., 2010). China's government has also paid attention to energy efficiency, realising that it not only affects the environment and energy security, but also the sustainable development of China's economy in the future (Hu and Wang 2006; Han et al., 2007; Zhou, Levine & Price., 2010).

From 1970–2001, China implemented a series of programs to limit the growth of energy demand. The energy consumption per unit of GDP decreased 5 percent per annum during this period. The main policies, programs, and approaches included seriously monitoring industrial energy use, financial incentives, providing energy conservation service through more than 200 energy conservation centres around China, education and training of energy conservation concepts, and research and development of energy conservation technologies and projects (Sinton and Fridley, 2000; Zhou et al., 2010).

However, energy consumption increased by 3.8 percent per year from 2005 to 208. Accordingly, the Chinese government set a target to reduce energy consumption by 20 percent during its 11th five-year plan (FYP) from 2006–2010. In order to achieve this objective, a package of policies and approaches were launched and implemented. A medium- and long-term plan was formulated that involved establishing a system of monitoring, evaluating, and reporting of energy intensity; reducing production from inefficient industrial process, facilities, technologies; and encouraging high-tech industry and upgrading energy-intense industries. “Ten-key projects” were set up to reduce energy consumption in industry, buildings, and other energy-intensive industries through subsidies to help enterprises adopt new energy efficiency technologies. The “Top 1000 enterprises energy conservation action” was established to strengthen and accelerate energy conservation for high energy consumption enterprises. Other initiatives included strengthening energy data collection, establishing a national energy conservation centre, promoting energy efficiency and conservation in government agencies, and expanding media programs in order to train energy conservation professionals. In addition, in 2007 the state council issued a comprehensive work plan for energy conservation, restructuring energy agencies in central government, revising the Energy Conservation Law and adjusting energy pricing, tax and fiscal policies (Zhou, Levine & Price., 2010).

To review the effectiveness of energy conservation policies and programs in the 11th five-year plan, the target of energy conservation was basically achieved. Energy intensity decreased by 19.06 percent, compared to the target of 20 percent. The most saving contributions were made by the "Ten key energy conservation projects", the "1000 enterprises programs", and the 'Obsolete Capacity Retirement Program". This shows that energy conservation policies and programs have played a significant role in energy conservation in China (Lo and Wang,2013; Lo, 2014; Bi et al., 2014).

In China's 12th FYP (2011–2015), energy conservation continues to be a national priority. New energy conservation policies and programs were announced by the central government (Lo and Wang, 2013). According to the effectiveness of energy conservation policies and programs, changes are introduced based on small steps, trial and error. These are a continuation of 11th FYP. The key elements of the 11th FYP were remained. Energy efficiency improvement in the industry sector is still in focus and regulations are still the policy instrument. However, energy conservation targets and programs were more practical in the 12th FYP than in the 11th FYP. According to 12th FYP, the target of energy intensity reduction is 16 percent, 4 percent lower than in the 11th FYP. The targets also vary among the different provinces and regions. Apart from this, sectorial energy conservation targets were introduced. Based on the modified "Energy conservation technology fund", it is easier for enterprises to apply for subsidies. The limitations of energy conservation technologies list have been removed and funding was increased for the central and western regions of China. The assessment of energy intensity will be conducted annually. The most important point is that a new policy of developing the energy services industry in China has been formulated by National Development and Reform Committee (NDRC) (Lo and Wang 2013; Hong et al., 2013).

According to Yuan et al. (2011), "Achieving the national energy intensity target was anything but smooth and orderly." As China was still 50 percent more energy-intensive (Energy consumption per GDP) than IEA countries in 2014. Energy markets will continue to be affected as China drives to improve its intensity in the coming decades. However, according to the International Energy Agency's (IEA) "Energy efficiency market report in 2016", China's energy intensity improved by 30 percent from 2000–2015. Energy efficiency across China's major energy-consuming sectors improved by 19 per cent, which is higher than efficiency improvements in countries belonging to the IEA. The report also points out that China's efforts regarding energy efficiency are accelerating. The 13th FYP (2016–2020) targets a 15 per cent improvement in energy intensity.

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Figure 6: China's energy intensity from 1990-2016 (Source: Global Energy Statistical Year Book 2017).

China has made some achievements in energy conservation through energy conservation policies and programs in its 11th and 12th FYPs. Nevertheless, there are still problems and barriers to energy efficiency in China. First of all, energy consumption structure is a key problem. Without reforming and upgrading the energy consumption structure, it might be impossible to achieve energy conservation fundamentally (Zhou, Levine & Price ., 2010; Cui et al., 2014). Secondly, according to the assessment of energy conservation policies and programs in the 11th FYP, most of energy conservation contributions have been made by the 1000 enterprises that were listed in in “Ten key programs”. However, these enterprises only represent a small proportion of Chinese enterprises. The overlap of the “Top 1000 enterprises energy conservation action” is small and limited (Lo and Wang, 2013). Thirdly, the differences of energy efficiency among different sectors are obvious. Energy conservation policies have focused on the industrial sector, which has the largest energy conservation potential. Hence, energy conservation is more successful in the industrial sector than in other sectors (He et al., 2013; Hong et al., 2013; Wang and Wei 2014; Xu et al., 2014). Laustsen (2008) claimed that, in China, energy saving by energy efficiency in new buildings will have larger and faster impact on economy and result in larger energy saving than in developed countries. Improving energy efficiency in other sectors such as transportation, building and services will help China achieve its energy conservation targets (Kong, Lu & Wu, 2012; Chang et al., 2013; Wang et al., 2014; Allouhi et al., 2015). Fourth, there are energy efficiency differences in China's various areas and regions; for example, the coastal area performs better in energy efficiency than the central and western regions (Kong, Lu & Wu, 2012; Wang, Wei & Zhang., 2013; Wang and Wei 2014).

Apart from the above-mentioned factors, barriers to energy efficiency include local government awareness, policy execution, consumer awareness, financial barriers to energy conservation, informational barriers, energy conservation technology and energy prices (Kostka and Hobbs 2012; Kostka, *Moslener & Andreas*, 2013; He et al., 2013; Wang, Wei & Zhang, 2013). Wang, Wei & Zhang. (2013) noted that the differences of energy efficiency among difference areas are due to local government, consumer awareness and heterogeneities of production technologies. Local government does not pay enough attention to building energy efficiency, while limited finance for building energy efficiency and weak policy execution are other barriers to building energy efficiency. Feng et al. (2010) also noted that even through China has implemented a series measures to energy conservation, consumer awareness, energy price and government policies and programs are still barriers to energy efficiency in China.

To address the problems and barriers to energy efficiency in China, energy efficiency policies and programs have been modified and adjusted in the 12^{th} FYP in order to further improve energy efficiency implementation in China. The introduction of the energy service industry was viewed as an effective approach to solve existing problems and barriers such as financial, technical, informational barriers. Promoting the concepts of energy conservation and reducing the differences of energy efficiency in regions and sectors are important. In order to promote and develop ESCO industry and EPC programs in China, the government has also issued a series of policies, incentives, subsidies and tax preferences. In order use these policies and benefits effectively, the government has formulated a systemic regulation and supervision framework

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Figure 7: The government authorities related to ESCOs in China from Yuan et al. (2016)

The National Development and Reform Commission (NDRC) is responsible for the recognition and examination of qualifications of ESCOs. The Ministry of Finance (MoF) and the State of Administration of Taxation (SAT) are responsible for the management of financial incentives and implementation of preferential tax policies. The Ministry of Industry and Information

Technology (MIIT) is responsible for providing a recommended list of ESCOs for industry and information sectors (Yuan et al., 2016). Such a regulation and supervision framework or system ensures that limited resources could be used for EPC projects that make significant contributions to energy conservation. However, extremely complicated process and standards also make it difficult for most of the ESCOs to enjoy these benefits.

Energy efficiency and conservation have been identified as national priorities for decades. Energy efficiency polices have played a significant role in energy conservation and gradually improve and modified in practice. However, high reliance on energy efficiency policy will limit the development of energy conservation in the future. Attempts have been made to promote and develop energy conservation through appropriate economic instruments, such as the creation of energy service company. Energy conservation policies and regulations will continue to have a central place in energy conservation for the next five years at least.

1.2 Research questions

Energy efficiency has been recognised by China's government and society, which influences the country's economic growth and sustainability. The ESCO industry has also been identified as an effective way to help China achieve its targets of improving energy intensity and reducing carbon emissions. However, the study of the ESCOs industry remains limited.

The research questions of this PhD thesis were developed first by identifying a gap in the literature on ESCO industry. Existing studies of the ESCO industry in China, which has the world's largest ESCO market, are limited. In order to continually promote the development of ESCO industry, researchers such as Kastka and Shin (2013), Da-li (2009), and Vine (2005) have already recognised that technology is a key barrier to the development of the ESCO industry. However, there is little research into this problem of how to develop ESCOs' technological capability to remove this barrier.

Secondly, in terms of studies of technological capability, existing studies have focused on the manufacturing industry, with limited literature on technological capability development of service-intensive industry. Moreover, there is no literature identifying four dimensions of technological capability and their links between each other.

Based on the gap in literature on ESCO industry and technological capability development, four research questions were developed that aim to be answered in this investigation. The research questions are presented below, with a brief explanation about the relevance of each.

RQ1: Why have Chinese ESCOs developed technological capabilities?

Technological capability plays an important role in the business performance and competitiveness of companies. However, a pilot study of technological capability development in ESCO industry is important in order to identify what drives ESCOs to develop technological capability. This research question also identifies the importance of technological capability in terms of ESCO industry.

In addition, through in-depth semi-structure interviews with key informants from the case companies' management teams, The research identifies the importance of technological capabilities to ESCOs and main drivers to develop technological capabilities.

RQ 2: Which and how do factors affect Chinese ESCOs' technological capabilities?

Answering this question is a complicated task. First of all, the dimensions of technological capability need to be identified. Based on the literature, Lall (1992) identified three dimensions of technological capability (investment, production and linkage). Kim (1999) postulated another three dimensions: investment, production, and innovation. The potential factors affecting firms' technological capability were identified through discussing the existing literature. Through interviews with informants and secondary data analysis, the key factors affecting ESCOs' technological capability development were identified and also the links between technological dimensions were recognised, explained and discussed.

RQ3: How have Chinese ESCOs developed their technological capabilities?

This research question regards the process of technological capability development of Chinese ESCOs. Based on a literature review, a number of studies about the process of technological capability development were conducted with technology trajectory theory and a focus on the manufacturing industry (Utterback and Abernathy, 1978; Kim, 1980; Lee et al., 1988; Jin and Zedtwitz, 2008). In the ESCO industry, which is technology- and service-intensive, participants describe the process of technological capability development.

RQ4: How do case companies compare to American ESCOs in terms of product portfolio?

Even though China currently has the world's largest ESCO market, the United States has the most mature ESCO market, with nearly 40 years of development history. Chinese ESCOs aim to provide comprehensive energy conservation services and products to customers to help them achieve energy efficiency. Product portfolio is tangible manifestation of company's technological capability. Technological capability not only affects the types of products and services of ESCOs but also the complexity of services. Therefore, this question aims to investigate the case companies' number and type of products and services and further, identify company's technological capability.

To answer this question, secondary data analysis was applied. The products and services provided by case companies were obtained from secondary resources. The products and services provided by US ESCOs will be collected from the ESCOs' websites of all the ESCOs registered by the US Energy Department.

1.3 Objectives of the thesis

Considering the context of the research problems and questions raised for investigation, there are three main objectives of this thesis. The first is to understand the technological capability development of the ESCOs industry, which involves its drivers, factors affecting its development, and the process of development and its product portfolio. The second objective of the thesis is to create a framework with which to analyse the factors affecting the dimensions of technological capability and identify the relations between them. The third one is expanding study of technological capability, redefining the dimensions and identifying relations between dimensions of technological capability in ESCO industry.

1.4 Relevance and contributions of the thesis

Theoretical contributions

First, this thesis will expand the study of the ESCO industry in China and address the problem of technological capability development for the ESCO industry. A framework for analysing the factors affecting technological capability development of ESCOs will be developed and applied for case study analysis.

Second, this thesis extends the study of technological capability to a service-intensive industry. Due to the differences of characteristics between manufacturing and service industries, the dimensions of technological capability have been identified and redefined based on the context of service industry. Moreover, the dimensions of technological capability do not exist independently of the context. Therefore, the relations between the dimensions of technological capability will be identified based on cross-case studies.

Practical contributions

The ESCO industry is both finance- and technology-intensive. Through cross-case analysis, ESCOs can determine the key dimensions and factors affecting technological capability development and understand the process of technological development. When ESCOs build up and improve and develop their technological capability, they can analyse the factors and dimension affecting technological capability through the framework proposed in this thesis.

Government plays an important role in ESCO development. Governments can use the results of this thesis to exploit a series of measures and formulate appropriate policies and subsidies to help ESCOs identify the importance of technological capability and further accelerate the development of technological capability.

1.5 Structure of this thesis

This thesis consists of 10 chapters. Chapter 1 introduces the thesis, including the research context, research questions, objectives of the thesis and relevance and contributions. Chapter 2 is the literature review chapter, which includes five sections: (1) introduction, (2) technological capability, (3) literature on product portfolio, (4) ESCO industry, and (5) chapter summary.

Chapter 3 presents the conceptual framework for the thesis, which is created based on existing studies of technological capability. Chapter 4 presents the methodology of this thesis, illustrating why qualitative multiple case studies have been selected as the appropriate research method and outlining the case selection, data collection and analysis.

Chapters 5, 6 and 7 present case studies of small, medium-size and large ESCOs in China, respectively. All three chapters start by introducing the case companies' profile and technological capability, followed by case study analysis that involves answers to the research questions proposed in section 1.2.

Chapter 8 presents an analysis and discussion of cross-case analysis. It identifies the similarities and differences between the case companies are identified and discusses and summarises the findings of the case studies. The key factors affecting technological capability and process of technological capability are then proposed. Chapter 9 presents the secondary data analysis of product portfolio of ESCOs and shows the findings of comparative analysis between Chinese ESCOs with US ESCOs.

Chapter 10 concludes the thesis. In this chapter, the revised framework is presented, the dimensions of technological capability are redefined, and the theoretical and practical contributions are illustrated. Limitations of this research and future research opportunities also presented.

1.6 Chapter summary

This chapter has introduced this thesis and highlighted the importance of energy efficiency and the ESCO industry. Taking advantage of introduction of research context, the research questions and problems were introduced and explained and the structure of the thesis was outlined briefly.

The next chapter will present the literature review of this thesis and discuss the theoretical lens for this investigation.

Chapter 2 Literature review

2.1 Introduction

This chapter provides an overview of the literature related to technological capability development, product portfolio management and the current research related to development of the ESCO industry. The findings and results reported in relevant literature are critically reviewed and discussed.

Section 2.2 presents a review of the literature related to technological capability development. This research aims to investigate the technological capability development of ESCOs in China. The existing literature focuses on the study of technological capability development of manufacturing industry. Therefore, through reviewing the literature on technological capability development, I obtained a theoretical lens for this investigation.

Section 2.3 provides a literature review regarding product portfolio management, which reflects company's technological capability development. The literature of portfolio management provided insights into how a company can manage its product portfolio and which factors affect a company's product portfolio. It can helps address the research questions regarding which factors affecting ESCOs' technological capability.

Section 2.4 discusses the existing literature related to the ESCO industry. This research aims to investigate the ESCO industry in China. Reviewing the literature related to ESCO enabled me to obtain an overview of development of ESCOs industry around the world and in China, which is used to identify the limitations in research on the ESCO industry.

Section 2.5 summarises the literature review, which involves theoretical lens and research gap of existing research in technological capability development and the ESCO industry.

The main literature sources used to find relevant literature included online databases, such as Google Scholar, EBSCO and Science Direct. Despite some classic studies in terms of technological capability, the literature is mainly drawn from journals between 2000 and 2016. Because the ESCO industry is an emerging and scarce area of study, some necessary institutional and governmental market study reports have been obtained from governmental or ESCO association websites.

2.2 Technological capability development

The research of technological capability development has a long research history. Some classic scholars have drawn a picture of technological capability development for manufacturing industry in developed countries. Some emerging studies of technological capability have provided new insights, especially those regarding newly industrialised and less developed countries. In section 2.2, the literature review links to several key aspects of technological capability. Section 2.2.1 identifies different definitions of technological capability and key dimensions of technological capability. Section 2.2.2 introduces and discusses different views of process of technological capability development. Section 2.2.3 reviews the literature on technology transfer, which involves channels and spillover of transfer technology and identifying the main factors that affect transfer and spillovers. Section 2.2.4 reviews literature that is relevant to technological learning and focusing on absorptive capacity of firm and discusses factors that affect firms' absorptive capacity. Section 2.2.5 introduces technological innovation and illustrates that technology transfer, absorptive capacity and technological innovation is an integral process. Section 2.2.6 provides a summary of this part of the literature review.

2.2.1 Introduction to technological capabilities

Industrialisation is driven by the development of technological capabilities, which play a strategic role in the competitiveness of firms, industries and even countries (Kim, 1980; Kim, 1987; Kim, 1999; Lall, 1992; Bell & Pavitt 1992; Kumar, Kumar & Persaud, 1999; Wu, 2014). The terms "technology" and "technological capability" have been mentioned and emphasised since the mid-20th century. Technology is the application of scientific knowledge and skills to the establishment, operation, improvement and expansion of production facilities (Lall, 1987).

There are a variety of definitions of technological capabilities, depending on the aims of the researchers. In a narrow sense, technological capabilities refer to the capabilities to execute all technical functions entailed in operating, improving and modernising a firm's production facilities (Lall, 1992). Kim (1980, 1997) argued that technological capabilities could be used interchangeably with "absorptive capacity" in developing countries; that is, absorbing existing knowledge, assimilating it and generating new knowledge. Kim focused on the research aspect of technological learning and believed that effective technological learning requires strong absorptive capacity. Jin and Zedtwitz (2008) offered a more comprehensive definition, in which technological capabilities are the capabilities to make effective use of technical knowledge and skills, not only in an effort to improve and develop products and processes, but also to improve existing technology and to generate new knowledge and skills in response to the competitive business environment.

The ESCO industry is a service industry that has been described as a non-productive endeavor (Golpek, 2015). As a service-oriented industry, the ESCO industry has its own specific characteristics (goods, customers, inventory, labor, location and operation), which are different from those of the manufacturing industry. Therefore, the tendency of previous definitions of technological capabilities to focus on their tangible characteristics may limit the extent to which those definitions can be usefully applied in the service sector. Therefore, I propose a broader definition of technological capability that takes due account of business intangibles and of technological value for customers.

Thus, technological capability can be defined as the capability of an organisation to make effective use of organisational resources and learning skills in identifying, developing, improving, providing, protecting and monitoring technologies and solutions to create value for its clients and to strengthen its competitive position in the market (Qiu, Nunes & Vaidya, 2016).

There are two levels of technological capabilities: firm-level technological capabilities and national technological capabilities. The former is defined in the preceding paragraph. National technological capabilities are not just the sum of individual firm-level technological capabilities; they are synergies between individual firm-level technological capabilities (Lall, 1992).

This thesis aims to investigate the process and factors affecting the development of technological capability at the firm level through in-depth case studies of ESCOs in China. Therefore, I will discuss the key dimensions of a firm's technological capability.

In terms of firm-level technological capability, there are three important dimensions. The first is investment capabilities, which refer to the skills needed to identify, prepare, obtain technology for, design, construct, equip, staff and commission a new facility (Lall, 1992). The second is production capabilities, which involves basic skills of quality control, operation and maintenance; more advanced skills of adaptation, improvements, or equipment "stretching"; and most advanced skills of research, design and innovation (Dahlman, Ross-Larson & Westphal, 1987; Lall, 1992; Kumar, Kumar & Persaud, 1999; Seo, Kim & Choi, 2015). Linkage capabilities are the skills that are used to transfer knowledge, skills and technologies to suppliers, subcontractors, consultants, service companies and research institutions (Mathews 2006; Zhou & Wu, 2010; Fu, Pietrobelli & Soete, 2011; Tseng & Chen, 2014). Kim (1999) revealed that three key dimensions of technological capabilities are production, investment and innovation. The explanations from Kim (1999) of production and investment capabilities are similar but very brief. In terms of production capabilities, Kim did not include advanced demands such as adaptation, improvement, research, design and innovation. However, innovation capabilities are outlined individually as one of the key dimensions that consists of the ability to create and carry new technological possibilities through to economic practice (Zhou & Wu, 2010). Moreover, linkage capability is not considered a key element in technological capability. Hence, combining the existing literature reveals four dimensions that are involved in technological capability:

- Investment capability: Abilities required for identifying new and potential technologies and knowledge and preparing and allocating necessary and limited resources such as equipment, funds, experts and staff, for technological capability development (Lall, 1992).
- Production capability: Numerous capabilities required to operate and maintain production facilities and further adopt, assimilate and improve existing or mature technologies, and increase accumulation of knowledge (Lall, 1992; Kumar, Kumar & Persaud, 1999; Seo, Kim & Choi, 2015).
- Linkage capability: Capabilities used to transfer knowledge, skills and technologies to or from external actors such as suppliers, subcontractors, consultants, service companies and research institutions (Mathews, 2006; Zhou & Wu, 2010; Fu, Pietrobelli & Soete, 2011).
- Innovation capability: Abilities to create and carry new technological possibilities through to economic practice (Kim, 1999).

2.2.2 Process of technological capability development

Studies of the process of technological capabilities development have been expanded from industrialised countries to newly industrialised and emerging industrialised countries and from developed economies to developing economies (Utterback & Abernathy, 1975; Kim, 1980; Utterback & Kim, 1985; Lee, Bae & Choi, 1988; Kim, 1999; Gao, 2003; Mathews, 2006). According to the evidence of technology development from developed countries, Utterback and Abernathy (1975) expressed that, in advanced countries, industries and companies develop along a technology trajectory that involves three stages: fluid, transition and specific. Firms in new technology from advanced countries employ a fluid pattern of innovation, which means the rate of radical product and technology innovation is high, but the emerging technologies and products are crude, expensive and unreliable. These new technologies and products are just used to respond quickly and effectively to changes in the market and technology (Utterback & Abernathy, 1978). Then, with the better understanding of market demand, the stage transitions to dominant product design and mass production methods, adding competition in price as well as product performance. Production capability and scale assume greater importance to scale economies.

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Figure 8: Technology trajectory (Source: Kim, 1999)

In the “specific” stage, the focus of innovation shifts to incremental process improvements and greater efficiency. Firms are less likely to undertake radical innovations, becoming increasingly vulnerable in their competitive position. Later, they pursue the lower cost of standardised products and move production to developing countries. With significant changes to the technological and economic paradigm, this trajectory cannot be applied universally; nonetheless, it is meaningful for the study of building technological capabilities in newly industrialised countries (Kim, 1999).

Considering the rapid development of newly industrialising and emerging industrialising countries, there has been extensive research conducted on the process of technological development in these countries (Kim, 1980; Lee, Bae & Choi, 1988; Kim 1999; Kumar, Kumar & Persaud , 1999; Kim & Nelson, 2000; Gao, 2003; Jin & Zedtwitz, 2008). Based on Utterback and Abernathy's (1975) model, Kim (1980) developed a model involving acquisition, assimilation and improvement, which is used to describe the process of technological capabilities development in developing economies. Kim's model expresses that, in developing countries, the state of technological capability is developed from mature technologies to growing and emerging technologies. Most developing countries remain at the stage of mature technologies, with only a few reaching the stage of emerging technologies. Between the different stages, there are clear boundaries and technological capability must develop from one stage to the next without skipping any. The R&D activities of firms from developing countries focus on mature technologies acquisition and assimilation, not emerging technology innovation. To support this model with further evidence, studies such as Kim (1997) and Kim (1999) have been conducted.

However, some researchers disagree with the above model. Lee et al. (1988) illustrated that the three-stage technology trajectory in developing countries does not just happen at the specific stage with mature technologies, but also in transition stage. When firms in developing countries successfully complete the acquisition and assimilation of mature technologies in the transition stage, they will elevate to higher-level foreign technologies by learning through substantial investment in R&D activities. Gao (2003) found a similar phenomenon and stated that Kim's model is not applicable to China's telecommunication industry. Gao suggested that firms deviated from the assumed way of technological capability development and started to develop their own proprietary technology early in order to improve technological capabilities more effectively. Jin and Zedtwitz (2008) extended Kim's model to four stages, adding a complementary stage of recessive technology and illustrating that the boundaries among the different stages are unclear. Firms in developing countries concurrently acquire mature, growing and emerging technologies and concurrently invest in R&D of mature, growing, and emerging technologies.

Apart from this, Mathews (2002; 2006) presented a "3Ls" (linkage, leverage and learning) model based on the resource-based view to explain technological capability development when emerging economies employ a catch-up strategy. Those studies showed that firms in developing economies should link with foreign firms in various ways, such as FDI, franchising and cooperation contracts, and then leverage resources through these linkages to improve their capabilities. Finally, they learn by repeating the process of linkage and leverage. This model tends to be applied by enterprises in developing countries to develop technological capability through overseas expansion and to guide firms in developing economies how to acquire and employ technological capabilities internationally. This model mentions the importance of linkage capabilities in technological capability development.

Existing studies of the process of technological capability development are mainly extended and modified based on technology trajectory theory. The major research objects are traditional and emerging manufacturers, which focus on technological capability development from perspective of technology development. Little attention has been devoted to emerging technologies and service-intensive industries. In addition, considering the process of technological capability development, little research has touched upon the aspects of investment and linkage capabilities, or how to promote and develop these capabilities.

The present study sought to investigate the technological capability development of ESCOs in China. Therefore, the process of technological capability development in newly industrialising countries is taken into careful consideration. Based on the studies of Gao (2003) and Jin and Zedtwitz (2008), high-tech enterprises in China have already implemented R&D to develop their own proprietary technologies. They have focused not only on mature technologies but also emerging technologies. In addition, Mathews's (2002; 2006) "3Ls" model points out the importance of linkage, leverage and learning capacity for companies that implement a catch-up strategy. As an emerging industry in a newly industrialising country, a study of the technological capability development of ESCO industry in China must consider companies' linkage, leverage and learning capacities.

2.2.3 Technology transfer and diffusion in developing countries

Technology transfer is fundamental to the process of technological capability building, particularly in developing countries. Technology acquisition and diffusion both accelerate the productivity growth in participating countries (Lall, 1993; Bin, 2000; Hoekman, Maskus & Saggi, 2005; Archibugi & Pietrobelli, 2003; Hu, Jefferson & Jinchang, 2005). In terms of international technology transfer, there are various conventional and unconventional channels. International trade in goods, equipment, intellectual property, FDI (wholly owned subsidiary, joint venture), licensing and human capital turnover are all considered as conventional channels. When sectors or countries begin catching up, cooperation R&D, endogenous technology creation and acquisition of firms from advanced countries are viewed as unconventional channels (Damijan et al., 2003; Damijan, 2003; Hoekman, Maskus & Saggi., 2005; Keller, 2010; Lema & Lema 2012). Gallagher (2014) and Gallagher and Zhang (2013) conducted research on cleaner energy technologies transfer and provided a typology of mechanisms for the cross-border flow of cleaner energy technologies, showing how cleaner energy technologies transfer from conventional channels to unconventional ones (See Table 1).

Table 1: A typology of mechanism for the cross-border cleaner energy technology transfer (Sources:

Gallagher, 2014 & Gallagher & Zhang, 2013).

Mechanism	Variation(s)	
Turnkey contracts	Could include contracts with foreign providers for installation and/or operation of technology	Conventional Mechanism
Equipment or goods trade	Imports of equipment or other technologies from foreign providers	
Licenses		
International strategic alliances or joint ventures	Can be formalized as joint venture	
Foreign direct investment to invest in or purchase a domestic firm, or to establish a new wholly-owned firm in foreign country	Could be wholly-owned, or a joint venture with contract provisions related to transfer of technology to the joint venture	
Migration of people for work or education	Could be entrepreneur, financier, consultant, or a formal full-time employee who has worked or been educated in another country	
Contract with a foreign research entity where IP is to be shared or wholly owned by the investor	Could be a contract with a university lab, a government lab, or a for-profit firm	
Collaborative R&D	Research partnerships with foreign entities with shared IP arrangements	
Purchase of a foreign firm to acquire technology (M&A)	Could be a merger with a foreign firm	
Open sources	Including exhibitions, conferences, books, papers, patent documents	
Bi- or multi-lateral technology agreements among governments	Could include private participation, may include support for capacity building or "tied aid"	Unconventional mechanism

FDI is often considered as the most attractive channel for technology transfer, particularly from advanced economies to emerging economies (Sinani & Meyer 2004). Saggi (2002), Hoekman, Maskus & Saggi (2005) and Damijan et al. (2003) illustrated that FDI provides the most important and cost-efficient channel of direct international transfer and intra-industry knowledge spillover, especially tacit knowledge in developing countries. International technology transfer through FDI undoubtedly improves the productivity growth of firms in host countries (Chuang & Hsu, 2004). According to studies of FDI and regional innovation capability, using evidence from China, FDI has a significant positive impact on the overall regional innovation capacity and the intensity of FDI is positively associated with innovation efficiency in the host region, even though the innovation efficiency depends heavily on regional absorptive capacity (Fu, 2008). Nonetheless, FDI is not significant for technology spillover in host countries; FDI just provides vertical impacts to backward (from buyer to supplier) and forward (from supplier to buyer) linkages. These impacts improve productivity growth and reduce input costs. However, little horizontal impacts have occurred in developing countries (Blalock & Gertler, 2008; Hu, Jefferson & Jinchang, 2005; Damijan, 2003; Damijan et al., 2003). According to the research of technology transfer of US multinationals, multinational enterprises in the US contribute to productivity growth only in developed countries, but not in less developed countries. Less developed countries cannot benefit from technology transfer from US multinationals because they lack a minimum human capital threshold level (Bin, 2000). In addition, multinationals do not transfer more complex and advanced technologies to subsidiaries where they acquire a majority share (Damijan, 2003). Proprietary technologies that are transferred through foreign equity participation are largely independent of market-mediated technology transfer. The presence of foreign investment and foreign expertise does not enhance arm's-length market-mediated (Hu, Jefferson & Jinchang, 2005). Moreover, in the study of multinational firms and technology transfer, Glass and Saggi (2002) revealed that workers from host countries who work for multinational firms could access and acquire superior technologies. However, multinationals may prevent local firms from hiring their workers and thus gaining access to their knowledge by paying a wage premium.

International trade in goods, equipment and contractual agreement is another important channel for international technology transfer (Sinani & Meyer, 2004; Acharya & Keller, 2009). Through international trade, embodied technologies will be transferred across national borders. These technologies and knowledge are usually explicit (Kim, 1999). However, Damijan et al. (2003) pointed out that the latest and most valuable technologies are not available on license because of fears of technology leakage and protection of intellectual property rights.

Inter-firm cooperation is another effective way to obtain knowledge and skills from external firms (Cavusgil, Calantone & Yushan, 2003). Knowledge transfer is processed through cooperation by formal and informal paths. Nevertheless, Kim and Kim (1985) found that most critical knowledge was transferred free of charge from abroad through informal mechanisms rather than through formal collaboration with foreign firms.

Considering technology transfer, technology spillover and diffusion are crucial aspects, which means that firms from host countries could benefit from technologies transferred from advanced countries. Nevertheless, many factors can shape technology diffusion in host countries. These factors can be classified into national-level and firm-level factors. Gallagher and Zhang (2013) presented four factors that shape cleaner energy technology diffusion: (a) a large and stable domestic market attracts technology transfer and diffusion; (b) public policy; (c) complementary assets, which refers to infrastructures or capabilities required to support the successful commercialisation and marketing of a technological innovation; and (d) the players and globalisation of science and technology. Cavusgil Calantone & Yushan (2003) studied tacit knowledge transfer and illustrated that inter-firm collaborative experience, frequency of interaction, closeness of relationships and firm size determine the extent of tacit knowledge transfer. Fu, Pietrobelli and Soete (2011) pointed out international technology diffusion can only be delivered with parallel indigenous innovation efforts, modern institutional, governance structures and conducive innovation systems.

In terms of public policy, Saggi (2002) argued that trade policy, FDI policy and protection of intellectual property rights shape technology transfer and diffusion. Developing countries usually implement active policies to stimulate learning and improve access to knowledge and technology (Caselli & W.J.C, 2001; Archibugi & Pietrobelli, 2003; Hoekman, Maskus &Saggi, 2005; Reiter & Steensma 2010; Keller, 2010; De La Tour, Glachant, & Ménière 2011; Qiu & Wang, 2011). Based on firm-level factors, firms' absorptive capacity, intensive of R&D and human capital are crucial for firms to get significant benefits from technology transfer (Bin, 2000; Keller, 2004; Bruno & Lichtenberg 2001; Saggi 2002). A study of technology transfer in Estonia found that technology spillovers depend on the recipient firm's size, its ownership structure and its trade orientation (Sinani & Meyer, 2004). Frank, Ribeiro and Echeveste (2015) pointed out that personnel, technological, work design and external environment subsystems influence knowledge transfer. Dechezleprêtre, Glachant and Ménière (2013) argued that local technological capability discourages technology transfer for clean technology transfer. Moreover, Mowery and Oxley (1995) examined the role of national innovation systems in inward technology transfer and illustrated that national innovation systems strengthen national absorptive capacity and this capacity relies primarily on investment in scientific and technical training and economic policies. National trade regulation and government intervention are of secondary importance.

2.2.4 Technological learning

In developing countries, based on the existing literature, the acquisition of technological capabilities is an effective ways to develop technological capabilities. This acquisition is actually a process of technological learning (Kim, 1997a; Kim, 1999). Technological learning is a dynamic process that is affected by various variables (Fu, Pietrobelli, & Soete, 2011; Malerba & Nelson, 2011). Kim (1999) presented an integrative model to analyse technological learning.

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Figure 9: Technological learning (Source: Kim,1999).

Effective technological learning requires strong absorptive capacity, which refers to firms' abilities to recognise the value of new and external information and assimilate it and further apply it to commercial practice (Schmidt, 2010; Volberda, Foss, & Lyles, 2010; Spithoven, Clarysse & Knockaert, 2011). Prior knowledge base and intensive efforts are two key elements in building absorptive capacity (Cohen & Levinthal, 1990). Prior knowledge base can be obtained from technology transfer. Knowledge involves explicit and tacit knowledge. Most knowledge is tacit in order to raise its knowledge accumulation (Goffin & Koners 2011; Chang, Gong, & Peng, 2012). Compared with explicit knowledge, tacit knowledge is much more important to firms' technological capability (Kim, 1997a; Kim and Nelson., 2000). The individual tacit and explicit knowledge could transmit to organisational knowledge through expeditious learning. Additionally, externally evoked crises and proactively constructed crises stimulate the intensity of efforts of absorbing knowledge (Kim 1998). In this model, technological learning is recognised as an organisational system.

Absorptive capacity was viewed as a central element in the system. This term has been defined in various literatures. For instance, Cohen and Levinthal (1990) postulated that absorptive capacity is a firm's ability to value, assimilate and apply new knowledge into business practice. Mowery and Oxley (1995) defined it as a set of skills to deal with transferred tacit knowledge and modify it. Kim (1997a) stated that absorptive capacity is the capacity to learn and solve problems. Zahra and George (2002) defined it as a set of organisational routines and processes by which firms acquire, assimilate, transform and exploit knowledge to produce a dynamic organisational capability.

Absorptive capability is intangible and can be generated in various ways; it might be created as a byproduct of firms' R&D investment or enterprises' operation. Of course, some firms also invest in building up absorptive capability directly. Cohen and Levinthal (1990) claimed that absorptive capabilities can best be developed through an examination of the cognitive structures that underlie learning.

Understanding absorptive capacity starts with identifying the multi-dimensionality of the absorptive capacity construct (Volberda, Foss & Lyles., 2010). The theories of dimensions of absorptive capacity construct began with Cohen and Levinthal's (1990) well-known dimensions of recognition, assimilation and exploitation. Zahra and George (2002) presented four dimensions: acquisition, assimilation: transformation and exploitation; identifying potential absorptive capacity which makes firms acquire and assimilate external knowledge; and realising that absorptive capacity involves transformation and exploitation. Realised absorptive capacity reflects a firm's capacity to leverage and employ externally obtained knowledge. Potential absorptive capacity and realised absorptive capacity play different but complementary roles. Potential capacity helps sustain firms' competitive advantage with greater flexibility in reconfiguring their resource bases. Realised absorptive capacity helps achieve a competitive advantage through innovation and product development. Camisón and Forés (2010) argued that potential and realised absorptive capacity are simultaneous processes, the tacit knowledge that is acquired and assimilated might not be transformed directly. The tacit knowledge will be accumulated and used over a period time in order to better match the current market condition. Moreover, Lane, Koka & Pathak.. (2006) postulated three dimensions: exploratory learning refers to recognising and understanding new external knowledge; transformative learning refers to the assimilation of valuable external knowledge; and exploitative learning refers to the application of assimilated external knowledge. Todorova and Durisin (2007) valued Zahra and George's (2002) reconceptualisation and suggest returning to the component capabilities instead of the subsets of potential and realised absorptive capacity. In addition, the literature refines knowledge transformation and represents an alternative process linked to assimilation by multiple paths. It proposes power relationships that influence both the valuation and the exploitation of new knowledge as another contingency factor.

Building up absorptive capacity is a long-term process that is not only based on organisational cognitive structures, but also on an organisation's efforts and experience in business practices. In terms of companies from emerging economies, based on their process of technological development, they build up absorptive capacity through acquisition, assimilation, transformation and exploitation, and focused on R&D efforts. Taking advantage of R&D, they develop mature and emerging technologies and further accumulate knowledge. R&D is the main process of transforming and exploiting assimilated external knowledge. Cohen and Levinthal's (1990) concept has had a certain impact on today's absorptive capacity development. However, researchers such as Zahra and George (2002) and Todorova and Durisin (2007) have provided a more comprehensive process of absorptive capacity building.

To build and develop absorptive capacity, firms are motivated by external drivers and internal drivers. Cohen and Levinthal (1990) argued that a firm's environment is a central component in determining the incentives for investing in absorptive capacity. Volberda et al. (2010) noted that contextual factors affect firms' absorptive capacity. However, despite the firms' environment, industry environment (competitiveness), regulatory environment (that is, intellectual property rights) and knowledge environment (that is, knowledge produced by corporate and non-corporate sources, social integration mechanisms) should be adequately considered when analysing external drivers (Lane et al. 2006). Hippei (1988) pointed out firms are ought to develop a broad and active internal and external network, individuals' awareness of others' capabilities and knowledge which are benefit for prior knowledge enhancement further permits the assimilation and exploitation of new knowledge. Mowery and Oxley (1995) argued that absorptive capacity is depend on investment in scientific and technical training and economic policies.

In terms of internal drivers, organisation structure, policies, R&D, processed within organisations that affect technology transfer, diffusion, formalisation, integration and creation are viewed as important internal drivers (Zahra & George, 2003; Vega-Jurado, *Gutiérrez-Gracia & Murakoshi.*, 2008; Volberda, Foss & Lyles., 2010). Individual cognition, as the basis of a firm's absorptive capacity, is a critical internal driver of absorptive capacity. Individual cognition provides prior knowledge; without prior knowledge, it is difficult for an organisation to recognise new knowledge and further fail to absorb it (Cohen & Levinthal, 1990). Lane, Koka & Pathak., (2006) noted that a firm's strategy is another necessary internal driver of absorptive capacity; it plays a role in determining which areas of knowledge are valuable, assimilated and applied.

The two faces of R&D are learning and innovation. In developed countries, firms generally obtained prior knowledge through "learning by researching". In developing countries, firms mainly acquire and accumulate prior knowledge through "learning by doing" (Lall, 1992; Kinoshita, 2000). Intense R&D investment is a critical element in building and developing absorptive capacity (Cohen & Levinthal, 1990; Kim, 1999; Zahra & George 2002; Lane, Koka & Pathak., 2006; Todorova & Durisin 2007). However, Schmidt (2010) found that R&D intensity does not influence absorptive capacity for intra- and inter-industry knowledge significantly, and suggested that firms can influence the absorptive capacity to exploit external knowledge by encouraging individuals' involvement in a firm's innovation projects. Figure 10 presents the internal and external factors that affect absorptive capacity.

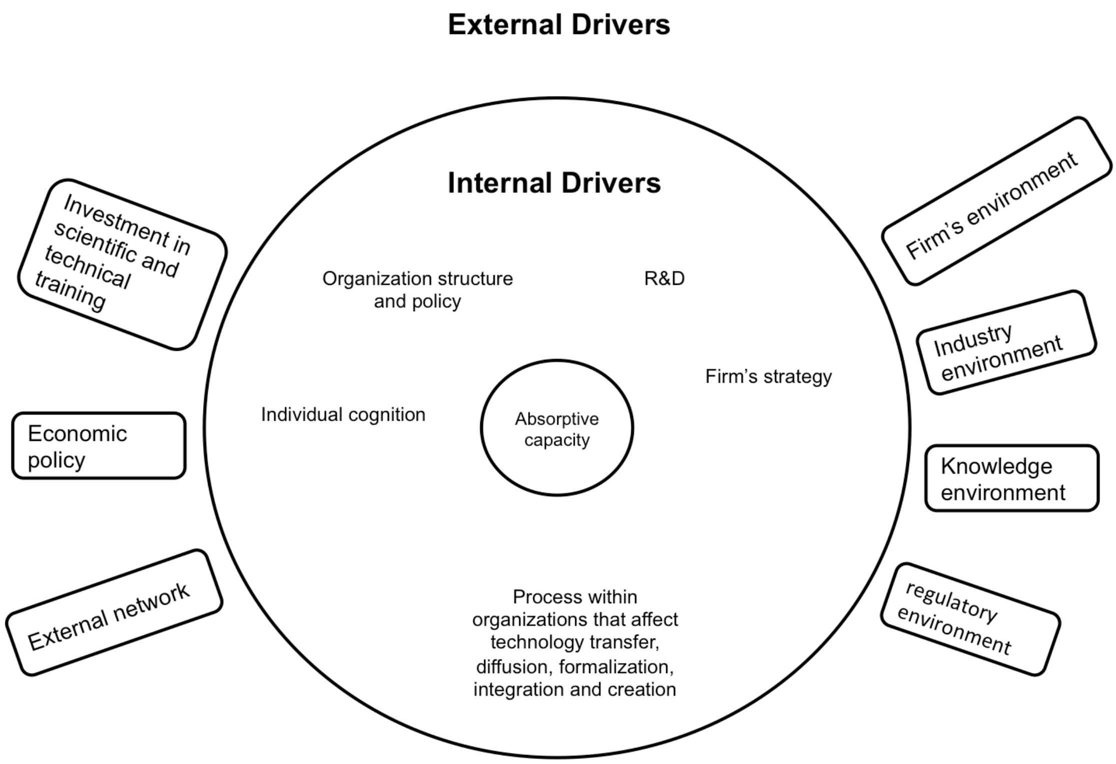

Figure 10: External and internal drivers for firm's absorptive capacity (Created based on the literature review)

Absorptive capability plays a critical role in the innovation, collaboration, technological development and innovation of SMEs. Liao, Welsch & Stoica., (2003) stated that if SMEs have well-developed capabilities in external knowledge acquisition, intra-firm and inter-firm knowledge dissemination and adopting a more proactive strategy, the responsiveness of growth-oriented SMEs is expected to increase. Nonetheless, there is no doubt that SMEs have limitations in accessing resource, such as little or no R&D investment, poor organisational and cognition structure and poor external network (Liao, Welsch & Stoica., 2003; Gray, 2006; Muscio, 2007). Hence, Spithoven, Clarysse & Knockaert.. (2010) found that SMEs operate in traditional sectors, often have little or a relatively low level of absorptive. It is very difficult to build absorptive capacity without external industrial assistance. However, the capability of SMEs to conduct collaboration with external actors such as universities, other firms and the technology transfer centre is impacted by the SMEs' absorptive capabilities (Muscio, 2007). Gray (2006) found that age, education, and size of SMEs significantly influences firms' acquisition and assimilation of knowledge. However, small companies with 15-plus employees with higher educational levels and clear growth objectives have the ability to absorb and use new relationships between each dimension of absorptive capacity and the SME's performance. Consequently, building and developing absorptive capacity in SMEs, particularly those in developing countries, involves more constraints than in large enterprises. Building and developing absorptive capacity requires a huge amount of investment and long-term persistence, sometimes without being very effective. Therefore, SMEs in developing countries often face a dilemma in terms of absorptive capacity development.

2.2.5 Technological innovation

Innovation is a concept that Thompson (1965) defined as the generation, acceptance, and implementation of new ideas, knowledge, processes, products and services. Innovation has been broadly studied and deemed as one of the main drivers of economic growth in the 20th and 21st centuries. The development of (regional and firm-level) innovation capabilities plays an important role in building competitiveness in both developed and developing countries (Abernathy & Utterback, 1978; Kim & Kim, 1985; Fu, 2008; Zahra, Ireland & Hitt., 2000). Technological innovation is generally identified as the generation of new products and services. The studies of technological innovation capabilities focus on the domains of product and process. Innovation capability is one of the critical components of technological capability (Kim, 1980; Kim, 1997a; Kim, 1999). Regardless of technology transfer, technology learning and absorptive capacity, to building and developing these capabilities should create and strengthen innovation capability.

There have been many studies of technology transfer and innovation capability (Krugman, 1979; Cavusgil, Calanton & Yushan., 2003; Mowery & Oxley, 1995; Liu & Buck 2007). Mowery and Oxley (1995) studied the relationship between technology transfer and national innovation system and emphasised that national innovation systems strengthen technology transfer. Lee (1996) examined the emerging technology transfer role that US universities are expected to play and found that universities play a crucial role in technology transfer and industrial innovation. Cavusgil Calanton & Yushan., (2003) demonstrated that tacit knowledge transfer through inter-firm cooperation makes a significant contribution to firms' ability to develop great innovation capability. Grimpe and Hussinger (2013) revealed that formal and informal technology transfer from universities to industries contributes to higher innovation performance. Li (2011) conducted research of external knowledge, absorptive and innovation capabilities in Chinese state-owned enterprises and found that obtaining foreign technology through importing does not accelerate innovation in Chinese state-owned high-tech enterprises, unless in-house R&D is also conducted. Purchasing domestic technology has a favorable direct impact on innovation because firms find it easy to absorb domestic technology.

Innovation is one of the key outcomes of absorptive capacity. The ability of absorptive capacity to exploit external knowledge is a critical component of innovation capability (Cohen & Levinthal, 1990). A large amount of existing research into absorptive capacity and innovation has revealed that absorptive capacity plays a positive role in innovation development and performance (Liao et al., 2010; Li, 2011; Spithoven, Clarysse & Knockaert., 2010; Kostopoulos et al,, 2011; Robertson, Casali & Jacobson., 2012; Ritala and Hurmelinna-Laukkanen, 2013). Zahra and George (2002) demonstrated that realised absorptive capacity is likely to influence firm performance through product and process innovation. Ritala and Hurmelinna-Laukkanen (2013) examined why some firms get better benefits than others from collaborating with their competitors in innovation and indicated that firms' potential absorptive capacity (knowledge acquisition from external sources) and appropriability regime (innovation and core knowledge protection) are relevant in improving the innovation outcomes of collaborating with its competitors. Kostopoulos et al. (2011) argued that absorptive capacity contributes to innovation directly or indirectly in different time spans. Spithoven, Clarysse & Knockaert.,(2010) indicated that absorptive capacity is a pre-condition to open innovation. Companies that lack absorptive capacity need to seek alternative way to conduct inbound open innovation. Firms need to invest in internal R&D, training and recruiting good educational personnel in order to conduct an open approach to innovation. Liao et al. (2010) found that absorptive capacity plays a critical role as a mediator between external knowledge and innovation. Absorptive capacity moderates the relationship between properties of knowledge and innovation performance (Wang & Han, 2011). Schmidt (2010) showed that the determinants of absorptive capacity differ with respect to the type of knowledge (knowledge from a firm's own industry, knowledge from other industries and knowledge from research institutions) absorbed for innovation activities.

Technology transfer and absorptive capacity are considered important components in the building and development of technological innovation capability. Technological innovation requires external sources from external actors. Technology transfer provides channels and opportunities of spillover that enable firms to obtain explicit and tacit technology and know-how from external domestic or international actors. In order to receive better benefits from external sources than those obtained from technology transfer, firms need to invest and build well-developed absorptive capacity. Well-developed absorptive capacity effectively recognises, assimilates and transforms knowledge, but also exploit these new knowledge for firm's innovation. Therefore, technology transfer, absorptive capacity and innovation are considered as a process and cannot definitely be studied separately.

2.2.6 Summary on technological capability development

According to the literature review regarding the introduction of technological capabilities, there are four key dimensions of technological capabilities – investment, production, linkage and innovation capabilities – which are outlined through combining various studies. The existing literature about the process of technological capability development mainly contributes to the process of technology development, but it weakens upstream parts of the process such as investment and linkage. Apart from this, most studies have focused on manufacturing, telecommunications and high-technology sectors. Few studies have addressed the problems in the energy and service sectors. There are many differences between manufacturing and service sectors. For example, the ESCO industry is a technology- and finance-intensive industry and its main products are intangible and personalised. ESCOs are responsible for the operation, maintenance and performance of projects over a period of time. Hence, technological capability will be affected by many more factors than a traditional manufacturing industry.

Technology transfer is the fundamental process for firms' technological capability building. Reviewing the literature of technology transfer revealed discussions of conventional and unconventional channels of technology transfer and factors affecting technology transfer and spillover. The extant studies focus on technology transfer and spillover between firms in developing and developed countries. However, quite a lot of technology transfer has happened between firms and industries domestically, which should be considered.

Technology transfer provides prior knowledge to firms for absorptive capacity building. Absorptive capacity is a central component of technological learning, to review the literature about absorptive capacity, is useful to understand construction of absorptive capacity and factors affecting firms' absorptive capacity. Absorptive capacity is important for technological capability development, but there are many barriers to build and develop absorptive capacity in terms of companies in developing countries, especially SMEs. Apart from external environmental construction and support, organisational willingness and efforts are elements that have been identified.

Technological innovation is an important dimension of a firm's technological capability. Through reviewing the literature of technological innovation, technology transfer and absorptive capacity are important components for technological innovation. Technological innovation needs external sources and strong learning capacity. Technology transfer provides external sources and technological opportunities for technological innovation. Well-developed absorptive capacity provides enough ability to acquire, assimilate, transform and exploit these external sources in order to conduct technological innovation.

The next part of the literature review will involve literature in terms of product portfolio management.

2.3 Product portfolio

Product portfolio management not only helps companies achieve their strategic goals, but also improve their performance and competitiveness. In particular, senior management has realised the importance and significance of portfolio management (Cooper, Edgett & Kleinschmidt , 2011). Product portfolio is about making strategic choice, allocating limited and scarce resources, selecting projects and dealing with balance (Cooper, Edgett & Kleinschmidt , 1999, Cooper, Edgett & Kleinschmidt, 2011). Portfolio management is more than a rational decision process; it is a dynamic decision process. Martinsuo (2013) revealed that portfolio management needs to be applied appropriately to each situation. It is not something can be considered as static. Since companies' active product (R&D) projects are constantly being upgraded and revised, this process includes new project evaluation, selection and prioritisation; acceleration and elimination of existing projects; and resource allocation and reallocation (Cooper, Edgett & Kleinschmidt, 1999).

Cooper, Edgett & Kleinschmidt (1997) noted that portfolio management and project selection is fundamental to success; therefore, companies should ensure that they make correct choices and have effective portfolio management processes (corporate planning, strategy development at the business unit level, new product processes, and portfolio review). Tolonen et al. (2015) revealed that companies do not consistently understand and utilise product portfolio management, as a concept and a tool for strategy implementation and performance management.

So far, the literature has presented various methods for portfolio management, such as financial models and indices, options pricing theory, strategic fit approach, probabilistic financial models, scoring models, analytical hierarchy approaches, behavioural approaches, value maximisation, balanced portfolio and mapping approaches. The main approaches are strategic fit, value maximisation and balanced portfolio (Cooper, Edgett & Kleinschmidt, 1999; Mikkola, 2001; *Rothaermel ,Hitt & Jobe, 2006; Kumar, Ajjan & Niu, 2009*).

Strategic fit refers to whether the product development is aligned with business strategy, whether resources are aligned with business strategy, the number of product resources in product development and the value of strategic investment in product development (Barczak Griffin & Kahn, 2003). Dickinson, Thornton & Graves. (2001) revealed that companies need to continually invest in technology projects. However, resource limitations required organisations strategically allocate resource for product and technology projects. Klingebiel and Rammer (2014) also showed that the resource allocation strategy of an organisation affects its innovation portfolios. According to Cooper, Edgett & Kleinschmidt (2004)'s benchmark study of innovation strategy and related impact on business performance, high-performance companies focus on innovation and technology strategy. The best-performing companies direct a larger portion of their product development capabilities to new product development than the worst-performing companies. The best businesses prefer strategic fit approaches (Cooper, Edgett & Kleinschmidt , 2011).

The most commonly used method is value maximisation (Cooper, Edgett & Kleinschmidt, 2011). It considers more about market attractiveness by product; market size, potential and growth; size of financial opportunities; sales turnover; the costs of product and sold; expected commercial value and net present value; gross margin, net margin, profitability, net profit; internal rate of return and the number of high-value and high-return projects (Tolonen et al., 2015). This approach uses a series of quantitative data to analyses the performance of business and further direct the product portfolio management. However, Cooper, Edgett & Kleinschmidt. (1999) noted that the worst-performing companies normally apply this approach.

A balanced portfolio refers to the considerations of short- and long-term product and development activities; the balance of high/low-risk products and development activities; the balance of technology; the size of a portfolio and resource availability from sales and marketing, R&D, technical, operations and services to develop and maintain the portfolio (Tolonen et al., 2015). McNally, Durmuşoğlu & Calantone (2013) examined three dimensions of new product portfolio management and noted that balance only matters for new product development and performance as increasing balance is associated with improved performance. The interesting finding from that study is that strategic fit shows an insignificant but negative relationship with performance. However, Eggers (2012) highlighted the importance of prior experience in portfolio management and noted that long-term strategy is the most effective at maximising product development outcomes.

In addition, multiple methods are the optimal choice. According to different companies and stages of development, multiple methods will deliver the best results by combining various approaches (Cooper, Edgett & Kleinschmidt, 1999). Beringer, Jonas & Kock. (2013) conducted a study of behaviour of internal stakeholders and its impact on portfolio management. Their study showed that stakeholder behaviour and stakeholder management are key success factors within project portfolio management. The effect of intensity of engagement of senior managers on success of portfolio is not clearly positive and has a negative impact on strategic portfolio structuring and project portfolio system establishment.

Considering the product/projects portfolio management in practice, the decision-making about product/project portfolio selection is political and path-dependent, and less planned and rational (Kester, Hultink & Lauche, 2009). Top managers and project and portfolio managers play crucial roles in how portfolio management plays out in everyday practice (Martinsuo & Lehtonen, 2007; McNally, Durmuşoğlu & Calantone ., 2009). Portfolio management should be applied appropriately to the situation. Project type (product development project or service development project) is necessarily taken into account in selecting portfolio management (Blomquist & Müller, 2006).

In terms of product/project portfolio management in context, previous studies have found that certain factors affect the success of product/project portfolio management. These factors are summarised as organisational complexity, degree of innovativeness, contextual dynamics and organisational governance, type and managerial context (Blomquist & Müller, 2006; Müller, Martinsuo & Blomguist, 2008; Teller et al., 2012). In addition, risks, uncertainties and changes in the project portfolio or its context should be considered in portfolio management (Martinsuo, 2013). The projects in the portfolio may share the risk, which is increasingly relevant to the business (Olsson, 2008). Because it is impossible to avoid the changes and uncertainties of the environment, portfolio management should be dynamic (Petit & Hobbs, 2010).

Based on empirical research, Martinsuo (2013) argued that product/project portfolio management should be considered as negotiation and bargaining and structural reconfiguration. Project/portfolio managers' and top managers' actions and managerial decision making involves negotiation and bargaining should be considered as part of the existing framework when studying portfolio management. In addition, the surroundings of a business and its portfolio are changing and evolving, which implies that the uncertainties will influence the success of portfolio management. In order to deal with these uncertainties and possibilities, structural reconfiguration should be taken into account.

Product/project portfolio management as a process for and between people and organisations, besides its service to strategy and products within one organisation, plays a crucial role in companies' competitiveness. In order to develop competitive products and services, companies should evaluate and select potential products and services, rationally allocate limited resources and make rational decisions. However, portfolio management is also strictly affected by companies' technological capability – a point that has not been discussed in past research. This element should be taken into account in existing product/project portfolio management frameworks. Because portfolio management is not only affects company's new product development and R&D but also innovation of the company (Mikkola, 2001; Killen, Hunt & Kleinschmidt, 2008) .

Summary of product portfolio

Portfolio management is closely related company's performance and success from perspectives of new product development, R&D and innovation. Previous research has addressed these problems by using various methods. However, technological capability is manifestation of product portfolio which is not involved by existing research. It affects company's product development, R&D and innovation. In other words, company's portfolio management is limited by company's technological capability

2.4 Development of ESCO industry

Study of the ESCO industry, as an emerging industry, is scarce but very informative. Section 2.4.1 introduces the concept of an energy service company and energy performance contracting (EPC). Section 2.4.2 discusses development of the ESCO industry around the world, before section 2.4.3 provides an overview of relevant research of the ESCO industry in developed countries, with particular focus on the United States. Section 2.4.4 reviews current studies of the ESCO industry in developing countries, emphasising China, as a typical example. Section 2.4.5 illustrates and discusses barriers to developing ESCO industry in developed and developing countries. Section 2.4.6 provides suggested removal measures mentioned in the existing literature and section 2.4.7 then discusses the limitations of existing literature of development of the ESCO industry. Section 2.4.8 presents a short summary of literature review of development of ESCO industry.

2.4.1 ESCO and Energy Performance Contracting

ESCO was introduced in North America in the 1980s and spread from there. Against the background of the 1970s oil crisis, Canada and US identified a pressing need for mechanisms or third-party entities to improve energy efficiency (Fraser, 1996; Vine, Murakoshi &Nakagami, 1998; 1999; Vine, 2005; Bertoldi, Rezessy & Vine, 2006). Since then, ESCOs and a new market-oriented mechanism – energy performance contracting (EPC) – was established and widely used to conduct energy efficiency projects. Researchers and institutions provide differ but similar definitions of ESCO. An ESCO is a public or private company that develops, installs and finances comprehensive performance-based projects to energy consumers (Goldman & Dayton, 1996; Stuart et al., 2014; Lee et al., 2003). Larsen, Goldman & Satchwell. (2012) showed that ESCO provides energy-efficiency-related and other value-added service based on performance contracting as its core business part. Painuly et al. (2003) defined an ESCO as an organisation that can provide technical, commercial and financial services for energy efficiency projects. An ESCO is viewed as a commercial entity that provides comprehensive energy efficiency solutions to energy consumers based on performance contracting. There is no prototypical ESCO, because of diversity of shapes, sizes and ownerships. Most ESCOs have capability and skills of project development, engineering and design, feasibility analysis, energy analysis, general contracting, financing, project and construction management, equipment installation, risk management, monitoring, training, operations and maintenance and administrative services (Vine, Nakagami & Murakoshi, 1999). The US Department of Energy provides a relatively comprehensive definition, stating that "ESCOs develop, design, build, and fund projects that save energy, reduce energy costs, and decrease operations and maintenance costs at their customers' facilities. In general, based on the performance contracting ESCOs act as project developers for a comprehensive range of energy conservation measures and assume the technical and performance risks associated with a project."

ESCO implements energy efficiency projects based on EPC, a new market-oriented mechanism that is used to implement an energy efficiency project. EPC is a negotiated contract between ESCO and an energy consumer (customer). EPC established a contractual and specific energy-saving goal and an agreed business model. Based on this contract and agreed model, ESCOs provide services and products such as energy conservation technologies and products, equipment, financing, installation and maintenance to its customers. EPC has been incorporated into various business models, such as the share-saving models, the guaranteed saving model, the energy-cost trust model and the finance lease model (Qin et al. 2017). In any EPC project, the ESCO and the energy user must select an appropriate business model; this is a critical element that leads to successful implementation of an EPC project.

“Shared saving” and “guaranteed saving” are the most basic and accepted models that are applied in EPC projects. Shared savings models refer to ESCO financing for the energy efficiency projects from its own capital or external financial institutes, such as banks or fund companies. During the project period (normally three to five years; a large project may last 10 years), the ESCO and the customer will share the energy cost saving based on a negotiated proportion. When the project is over, all the energy conservation products or equipment will belong to the energy user and the energy user will benefit from all the energy savings. Guaranteed savings models refer to customers’ financing for the projects from third-party institutions such as bank or other finance agencies. The ESCO simply arranges the fund and guarantees the performance based on the contracts. The ESCO will guarantee a certain level of energy saving. If the actual energy cost saving is lower than the guaranteed level, the ESCO will pay the difference. When the actual energy cost saving is over the guaranteed level, the ESCO and the user will share the excess. The main difference between the two schemes is that the ESCO takes financing and performance risks in shared savings contracts, but in the guaranteed savings contracts, the ESCO just takes performance risks (Painuly et al., 2003; Qin et al., 2017).

Figure 12: Guarantee saving model from Qin et al. (2017).

In order to select an appropriate EPC model and evaluate the success of an EPC model, a series of critical evaluation criteria should be considered. First of all, the ESCO has the ability to estimate accurate energy saving potential through investigating the energy user's energy consumption equipment, production process and production management process. Secondly, Price et al. (2011) explained that measurement and verification of energy savings form the basis of formulating an energy-saving plan. To give accurate measurement and verification, it is necessary to have a qualified third party with advanced measurement technologies to review the energy saving plan and its outcomes. Thirdly, the level of energy saving requirement of energy user affects the EPC project. If energy user has higher energy saving requirement, the investment of technologies and equipment will increase, which will also increase the risk of project. The fourth criterion is the financial condition of energy users. EPC project need a large amount of initial investment; energy users with good financial condition will decrease the risk of the EPC project. Fifthly, if energy users have technical experience, they can improve and upgrade existing equipment and technologies through internal sources. Otherwise, doing this through the ESCO will reduce the cost and risk of energy saving retrofit (Yik & Lee, 2004; Xu & Chan, 2011). Sixthly, the ESCO should have technical ability, which is key factor for EPC project. The ESCO is required to have technical ability to assess energy saving and advanced energy saving technologies and expertise (Price et al.,, 2011). The seventh criterion is the credibility of the ESCO and energy users. Due to EPC projects normally having relatively long contract periods, the credibility of the ESCO and energy users directly affects the EPC projects and finance from financial institutions. The two final criteria are national policy and financial service. Kostka and Shin (2013) and Lu and Shao (2016) pointed out that national policies such as financial policies and subsidies play important in role in long-cycle EPC projects. EPC projects require large amounts of investment to support them; hence, how to effectively access to financial capital becomes key factor in implementing a successful EPC project. Xu, Chan & Qian. (2011) summarised that the EPC team, client, ESCO and other related departments who are directly or indirectly involved in this work can all significantly influence the success of EPC projects.

2.4.2 Development of ESCO industry around the world

The ESCO industry has been rapidly introduced to other developed and developing countries since the 1990s (Vine, 2005). Vine (2005) conducted an international survey regarding the ESCO industry in 38 countries outside the US to examine the level to which the ESCO industry has developed internationally. Six of these countries built up their first ESCO in the 1980s, 27 in the 1990s, and the other five in the 21st century. Thirteen countries established ESCO associations to promote the development of the ESCO industry. The sectors targeted by ESCOs from key countries are residential, commercial, industrial, municipal and agricultural. Apart from these, this survey also addressed the key barriers to ESCO development and the future of ESCO industry in particular countries.

Today, the ESCO market is developing rapidly. The markets are more developed in some places, such as China, the US and the European Union. India's market has developed well because it is government-driven (IEA Energy Efficiency Market Report, 2016). According to the IEA's "Energy Efficiency Market Report" (2016), the global ESCO market was valued at approximately USD 24 billion in 2015. China has the largest market, which accounts for 55 percent, followed by the United States.

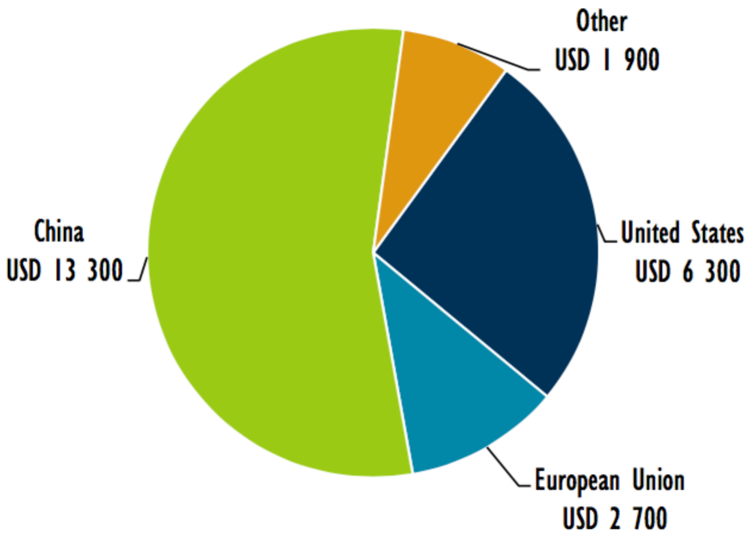

Figure 13: ESCO Revenue by regions, 2015, US dollars (Source: IEA Energy Efficiency Market Report 2016).

According to the same report, China had 5426 ESCOs as of 2015, employing 607,000 people. The United States had 114 ESCOs registered by the US Energy Department as of 2016. In terms of the development of the ESCO market in the European Union, most of the EU markets have grown since 2010, but only few have remained stable, such as Austria, Estonia, Finland and Luxembourg. Some have remained embryonic, such as Malta, Cyprus and Lithuania, while others, including Hungary and Sweden, have declined.

Most of the ESCOs in China, the US and the EU are SMEs. In the EU market, most of the ESCOs are small engineering and construction companies. Some are utilities that have opened up new business towards energy service. In the US, most of the ESCOs are small and medium-size ESCOs, but a number of “super ESCOs” exist in the market. In China, although small and medium-sized private ESCOs account for about 90 percent of the total, large-size ESCOs took about 70 per cent of market share (China Energy Service Company Market

Report by IFC).

To China's ESCO industry, policy is an important driver of growth. In the US, policy and funding are considered the key drivers of growth (IEA Energy Efficiency Market Report, 2016). In the EU, regulations on energy efficiency obligations or Demand Side Management (DSM) are the main drivers of growth.

Overlook for energy service company market globally, more and more companies acquired ESCOs and entered the market.

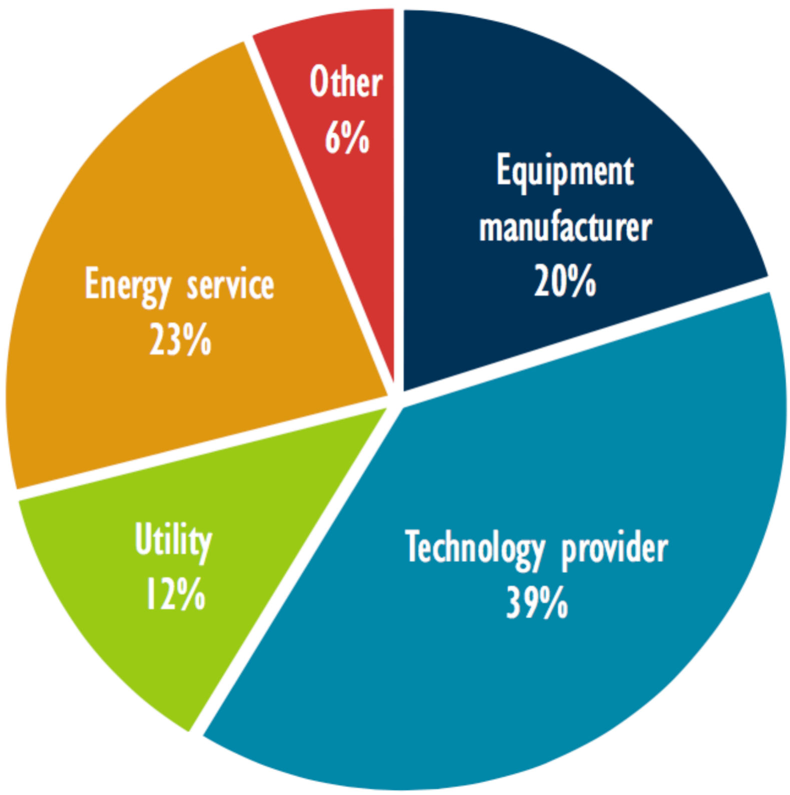

Figure 14: Share of energy efficiency service enterprises acquired, classified by sector of the acquirer, 2000–2015 (source: IEA Energy Efficiency Market Report, 2016).

Companies from other sectors entered the market through acquisition. The technology provider takes 39 percent of total acquisitions, the energy service such as energy provider takes 23 percent and the equipment manufacturer takes 20 percent. This trend leads to many “super ESCOs”. For example, super ESCOs in the US include energy suppliers such as EDF and manufacturers such as Philips lighting; these companies entered the market through acquired ESCOs or established their own ESCOs as subsidiaries. The large companies mainly enter the market through acquiring companies across different sectors of ESCOs.

2.4.3 Development of ESCO industry in developed countries

ESCOs are considered as important entities to improve energy efficiency and ESCOs have already made significant contributions to improving energy efficiency in developed and some developing countries (Vine, Nakagami & Murakoshi, 1998; 1999; Vine, 2005; Goldman et al., 2005; Bertoldi, Rezessy & Vine, 2006). In terms of studies of ESCO industry, relatively more have focused on developed countries. As one of the pilot countries that has developed the ESCO industry, the ESCO industry in Canada is unique. Taking advantage of a series of efficient measures such as government support, accreditation process, open books and utility programs, Canada built up a mature and unique ESCO industry (Fraser, 1996). Vine, Nakagami & Murakoshi . (1998) studied the opportunities and challenges of the ESCO industry in Japan and showed that the ESCO industry has great market potential there, but faces cultural and financial barriers. In order to develop ESCO industry, the Japanese government is supposed to accelerate the development of ESCO industry following practical strategies. ESCOs in Japan also develop through joint ventures with market players from the US. Polzin, Flotow & Nolden. (2016) studied EPC and ESCOs in Germany and showed that, through EPC outsourcing municipalities retrofitting, the barriers, cost and risk will be decreased. Hannon, Foxon & Gale. (2013) studied the co-evolutionary relationship between ESCO and the existing energy system and examined how ESCOs develop with the various dimensions of the energy system (that is, eco-systems, institutions, user practices, technologies and business models) to provide insight into how ESCOs help shape the future UK energy system. The study suggests that institutional and technological changes within the UK energy system provide a more favorable selection environment for ESCOs and eventually cause the ESCO model to proliferate at the expense of the EUCO model. Pätäri and Sinkkonen (2014) conducted a two-round Delphi study in Finland to increase understanding of business models employed by ESCOs and identify the main barriers to its business development. They found that little is known about ESCOs and their service in Finland, and that the uncertainly surrounding the business affects customers' inclination to invest in projects. Hence, the findings suggest that in order to develop ESCOs, businesses need to emphasise both the visible and invisible benefits. Bertoldi, Rezessy & Vine. (2006) reviewed and analysed the current status of ESCOs industry in Europe and presented a long-term strategy for accelerating ESCOs in EU. Together, the above literature indicates that the ESCO industry differs significantly from country to country. The combination of legislation on the ESCO industry fosters business expansion across the EU.

In the nearly 35 years since the ESCO industry was established in North America, relatively mature and complete market and economic utilities have developed. The ESCO industry in the US is viewed as a success model. The US created a mature and comprehensive market for ESCOs from legislation, regulation, accreditation, incentive and policy (Goldman et al., 2005). The ESCO industry in the US has been successful at rapid market penetration and mobilisation, but there are only 30–40 active ESCOs in that country. Most of the ESCOs in the US are small and medium-sized companies. Based on data from the US Department of Energy, there were 114 qualified ESCOs in that country in 2016. There has been comprehensive research into market trends and growth of the US ESCO industry. Goldman et al. (2002) studies US ESCO industry using the NAESCO Database Project from 1990–2000. Hopper et al. (2007) conducted a survey of the US ESCO industry to identify its market growth and development from 2000–2006. Satchwell et al. (2010) conducted a similar survey using data from 2008–2011, while Stuart et al. (2013) studied the current size and market potential with data from 1990–2011. Stuart et al. (2016) conducted the most recent study of market trends within the US ESCO industry using data from 1990–2016.

Figure 15: Report and projected ESCO industry revenue (nominal): 1990-2017 (Source: Stuart et al., 2016).

During 1990s, the ESCO industry in the US grew at an annualised rate of 24 percent (Goldman et al., 2005), and 7 percent per year between 2006 and 2008. Researchers estimate the annual growth rate will be 24 percent between 2009 and 2011. According to the US. Energy Service Company (ESCO) Industry: Recent Market Trends (Stuart et al., 2016), which is prepared for Office of Energy Efficiency and Renewable Energy Federal Energy Management Program, ESCO industry revenues appeared to flatten between 2011 and 2014. In 2011, the total revenue of ESCO industry in US was $5.263 billion; in 2014 it was $5.275 billion. Although growth was negligible, ESCOs' total annual industry revenues is expected to be approximately $7.6 billion in 2017, which equates to an average annual growth rate of 13 percent from 2015–2017. Even through, from 2010 to 2017, the U.S ESCO projected revenue is fluctuating growth. Stuart et al. (2013) predicted ESCO industry revenue in 2020 would be $10.6–15.3 billion, which means that the ESCO industry in the US will retain its market potential for the next three years.

The main market segments of ESCO industry in US are "MUSH" (municipal and state governments, universities and colleges, K-12 schools and hospitals); utility residential programs; Public housing; C&I (commercial and industrial); and federal.

Aston University

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Figure 16: ESCO industry revenue by market segment (Source: Stuart et al. 2016).

According to the most recent study conducted by Stuart et al. (2016), the main market segments for ESCOs are: state/local (25.4 per cent of the total revenue), K-12 schools (23.5 per cent), and federal (20.7 per cent). The proportion reaches nearly 70 per cent of total revenue. In 2008, state/local accounted for 23 percent, K-12 schools 22.4 per cent, and federal 15.4 per cent. In 2011, state/local was 24 percent, federal was 21.4 per cent, and K-12 was 19.4 per cent. The proportions of these three main market segments increased slightly from 2008–2014. In particular, state/local retained a relatively high proportion of total revenue from 2008–2014.

Since the ESCO industry in the US is considered a successful prototype, it provides some lessons. The first is the rapid market penetration and mobilisation in the field. Secondly, the most successful ESCOs in US make efforts to become “integrators” by implementing complex and large projects and further develop technologies in complex and multi-dimensions. Thirdly, successful ESCOs provide comprehensive solutions, not just energy efficiency, to their customers. Finally, ESCOs have the potential to interact with customers with more creativity than utilities by offering packages of comprehensive energy services, different fuels, varieties of pricing plans, and other creative ideas including energy efficiency and load management services, as the market develops and grows (Vine, Nakagami & Murakoshi., 1999). Moreover, comprehensive surveys and investigations of the US ESCO industry have identified the following characteristics of the US ESCO industry have been identified (Stuart et al., 2013; Stuart et al., 2016).

- Public and institutional markets accounted for large proportion of ESCO industry revenue; in 2011, the number was 84 percent.
- More projects of medium and large ESCOs rely on federal programs than is the case for small ESCOs.
- Customers of larger ESCOs tend to use third-party financial advisors more frequently than customers of small-to-medium-sized ESCOs.
- The main technology and project is energy efficiency, which takes about 75 percent of total revenue.
- Large ESCOs’ share of total industry revenue is large, but has been decreasing since 2011.
- Share of revenue by ESCO size varies for different market segments.

The lessons from US ESCOs industry could be used as a reference by other countries. However, the lessons are not universal. The successes of ESCO industry in US are based on government policy, legislation, features of energy consumptions and so on. Some countries, especially developed ones, are likely to be more suitable to accept these lessons and benefit from them.

2.4.4 The development of ESCO industry in developing countries.

The ESCO industry is expected to play an important role in promoting energy efficiency outside the US (Vine, 2005) because developing countries have tremendous potential to increase energy efficiency (Painuly et al., 2003). Based on the international survey of ESCOs conducted by Vine (2005), many developing countries established ESCOs and ESCO associations and have already started to promote ESCO or interest in promoting ESCO in their countries. Painuly et al. (2003) studied how to finance ESCOs in developing countries and focused on various approaches to financing energy efficiency projects. Painuly et al. pointed out the importance of government again in promoting the ESCO industry. South Korea has been studied as a successful developing country case. The research in this country has focused on the current status and barriers of South Korean ESCO industry and highlighted the importance of government for promoting and overcoming barriers (Lee et al., 2003). Okay et al., (2008) studied the ESCO industry in Turkey, another developing country. The ESCO industry has struggled to develop in Turkey and various barriers and limitations need to be removed there.

Brazil, as the biggest emerging economy in Latin America, started its process to develop ESCO industry; there are about 30 active ESCOs in Brazil, but most of them are small and independent companies and large companies have not shown any interest in this industry (Poole & Geller, 1997).

China, as the largest emerging economy, established its pilot ESCOs in 1998 with support from the World Bank and the Global Environment Facility. China currently has the largest ESCO industry of any developing country, and a relatively well studied ESCO industry and EPC. The expansion of ESCO industry is rapid in terms of the number of ESCOs and employees in the ESCO industry (Da-li, 2009). According to IFC's China ESCO Market Studies Report, in 2011 there were 2339 registered ESCOs operating in China, which employed 378,000 people. According to Energy Management Contract Association (EMCA) Statistics, by 2015, 5426 ESCOs were registered by the National Development and Reform Commission (NDRC) and 607,000 people were employed by the ESCO industry. The investment of EPC projects also increased significantly.

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Figure 17: Turnover and EPC investment in the ESCO market in China (source: IEA 2016)

From 2006 to 2015, the investment in EPC projects increased from USD200 million to USD16.7 billion. According to industry analysis of the current situation and market trends of China's ESCO industry, from China industry information web, total revenue of the ESCO industry in China increased from ¥8.36 billion (USD1.28 billion) in 2010 to ¥312.7 billion (USD48.1 billion) in 2015, an annual growth rate of 30.19 percent.

However, compared with the huge market potential, the ESCO industry is still in a nascent stage. The scale for individual companies is generally small and most ESCOs can be categorised as SMEs or even micro-enterprises (Vine, 2005). According to the IFC Market Study Report, by 2011, 48 percent of ESCOs' total assets were less than ¥10 million (USD1.54 million), and only about 10 percent of ESCOs had total assets of ¥60 million (USD9.23 million) or more. Some studies have indicated that the Chinese ESCO business model has "serious limitations and is unlikely to lead to large-scale implementation of energy efficiency projects in China" (Stuart et al., 2014).

ESCO industry is a technology intensive industry. ESCOs provide energy conservation services through applying a series of energy conservation technologies IFC's report presents the main energy conservation technologies distributions in China's EPC projects from 2010–2011. Figure xx presents the main technologies used by China's ESCOs.

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Figure 18: Technology distribution of EPC projects in 2010-2011 in terms of investment amount (source: IEC China ESCO Market Study Report).

The technologies of waste heat and pressure recovery, boiler and heating system and motor system are major energy conservation technologies that, together, comprise 77 percent of investment. Green lighting and central air conditioners account for only 7 percent, while energy management total only 1 percent of total investment. All of the major energy conservation technologies belong to the area of industry energy conservation because the largest manufacturing economy in China, industry energy conservation, has the largest market potential.

2.4.5 Key barriers to developing ESCO industry

Even though the ESCO industry has had success in some developed and developing countries, it still faces many barriers. Some barriers are jointly faced by developed and developing countries, while others are differ according to the countries' circumstances (Vine, 2005). Vine, Murakoshi & Nakagami. (1998) showed that the development of the ESCO industry in Japan mainly faces institutional, financial and cultural barriers. Particularly, joint ventures between Japanese and US ESCOs create cultural risks for both sides. Vine, Nakagami & Mutakoshi. (1999) illustrated that, in the evolution of ESCOs in the US, the ESCOs should focus on the relationship among utility users and companies, even though this could become a constraint that prevents the evolution. According to the international survey of ESCOs conducted by Vine (2005), the literature classifies key barriers to the development of ESCO industry into two categories. The key barriers to end users, which include financing, perception of risk, information/awareness/knowledge, EPC expertise, access to equipment and technology, administration, reliability and credibility. The other category refers to key policy barriers such as a lack of supporting policies and legislation, framework and regulations, low energy prices and significant political and economic uncertainty. Other literature also presents similar barriers to the development of the ESCO industry in other countries (Poole & Geller, 1997; Vine, Murakoshi & Nakagami, 1998; Lee et al., 2003; Painuly et al., 2003; Goldman, 2005; Bertoldi, 2006; Da-Li, 2009; and Kastka & Shin, 2013; Bertoldi & Boza-Kiss, 2017; Kindström, Ottosson & Thollander, 2017). In terms of development of the ESCO industry, financing is a crucial barrier, which is common in developed and developing countries. In most developing countries and some developed countries, institutional barriers, market barriers, and credibility barriers seriously affect the development of ESCO industry. Vine, Nakagami & Mutakoshi. (1999) showed that in the evolution of the ESCO industry in US, relations among utility users, companies and ESCOs might face a crucial barrier in future. Okay and Akman (2010) argued that the accretion of scientific, technological and financial know-how (innovation potential) in ESCO markets is important. Kastka and Shin (2013) also pointed out that technological barriers have hampered the development of the ESCO industry. Wang, Wang & Zhao. (2008) expressed that energy-saving industries in China are not well developed because of a lack of experience and energy-saving technology and management regarding high-energy consumption and low-efficient economic development pattern. Biermann (2001) illustrated that decreasing energy prices are the main barriers to developing ESCOs in the UK. Even though ESCO industries in different countries face common and different barriers, Vine (2005) argued that sustained efforts by other parties in society, not only ESCOs, are required to overcome these.

2.4.6 Removal measures toward barriers to development of ESCO industry

Most of the literature regarding the development of the ESCO industry has presented removal measures to overcome the existing barriers in order to promote ESCO industry and foster its development. Vine (2005) provided relatively comprehensive recommendations based on his survey of 38 countries' ESCO industries outside the US. The literature presents 10 ways to foster development of the ESCO industry internationally, including developing qualified energy managers; ensuring ESCO provides qualified and reliable service; creating more information for financial institutes and developing funding resources; standardising contracts and measurement; promoting EPC locally and regionally; conducting ESCO demonstration projects, like joint ventures with well-developed ESCOs internationally; developing third-party financing networks; and establishing equipment-leasing organisations. These recommendations are valid for most developed and developing countries. Bertoldi, Rezessy & Vine. (2006) argued that in terms of development of the ESCO industry in Europe, launching an accreditation system for ESCOs and developing a Europe-wide TPF network are necessary approaches to develop ESCO industry. Okay and Akman (2010) noted that developing scientific, technological and financial know-how will accelerate the development of the ESCO industry. Da-li (2009) claimed that state-owned ESCOs are responsible for promoting EPC and the ESCO industry; therefore, governments should rationalise energy prices and remove or reduce subsidies. Government plays important role in creating a regulation framework that includes industry-related policies. Legislation, financing networks, accreditation systems, standardisation for mergers and acquisitions and trust business environment. Da-li (2009) also noted that ESCOs need to develop their own capability in order to provide qualified service and products. Almost all researchers agree that, in terms of the development of ESCOs, government should play an important role, both for developing and developed countries (Fraser, 1996; Poole & Geller, 1997; Biermann, 2001, Okay et al., 2008). And these recommendations relate to the creation of a relatively comprehensive market and business environment for ESCOs.

2.4.7 Limitations of existing literature of development of the ESCO industry

The existing literature on the ESCO market is scarce but extremely informative (Okay et al., 2008). Studies of ESCO industry in developed countries are more comprehensive than studies of ESCO industry in developing countries. Especially, the studies of US ESCO industry are very comprehensive and timely. Regarding China, as the largest developing economy, the largest consumer of energy and the nation with the largest ESCO industry, studies of the ESCO industry are scarce. In particular, comparing China's energy conservation market potential and scale of ESCO industry with that of the US, China has absolutely larger market potential and industry scale. Hence, expanding the study of ESCO industry of China is more worthwhile in order to study development of ESCO industry in developing countries.

The existing studies on the ESCO industry have mainly involved market size and potential, market trends, current status, barriers and removal measures in developed and developing countries. In terms of the research field of developing the ESCO industry, the existing literature focuses on identifying barriers to the development of ESCOs and measures for removing them from a macro-perspective, such as how to improve awareness among financing institutions, utility users and society overall; how to build up a regulation framework, accreditation system, financing network, trust business and market environment, taking advantage of government support and efforts.

Only a few studies have argued that ESCOs should develop their own capability to provide qualified service and products (Da-li, 2009). Research on the ESCO industry cannot just address the commercial and financial functions of ESCOs. Some of the existing literature mentions technological barriers, but not to any great extent. Technology drives ESCOs (Biermann, 2001). Okay and Akmam (2010) also emphasised that innovation is an important element that fosters the development of ESCO. According to the successful case of the ESCO industry in South Korea, some ESCOs have done well considering their size and technological capabilities. However, those ESCOs usually have limitations in terms of available technologies and financial resources (Lee et al., 2003). Da-li (2009) also argued that foreign ESCOs usually come to China with energy-efficient technologies. Technological capability is an important research field and needs to be addressed. It directly affects whether ESCOs can provide quality services and products. A lack of technological capability will also lead to chain reactions, which will influence the development of the ESCO industry.

2.4.8 Summary on ESCO industry

This part of the literature review includes the ESCO industry-related research in developed and developing countries. The existing literature on the ESCO industry is scarce and there not many papers have been published in top journals, although some conference papers provide informative sources. The existing literature touches upon the development of ESCO industry internationally. Studies of the ESCO industry in the US and China are particularly reviewed. These studies involve the current status of ESCO industry, market trends and potentials, barriers to its development and removal measures. Unfortunately, there are still research gaps in this field. The recent studies of ESCOs in developing countries is scarce. The existing studies are unilateral and ignore the impact of ESCOs' technological capability. Some researchers have recognised the importance of technological capability and noted that technological risk is a crucial risks that ESCOs and customers take. Hence, focus on studying technological capability development of ESCO industry is urgent and valuable.

2.5 Chapter summary

Chapter 2 has presented a relatively comprehensive literature review, which is relevant to this thesis. Four main topics have been discussed, related to technological capability development, product portfolio management, energy consumption and efficiency in China, and ESCO industry development.

Technological capability development is a hot topic that has been in focus for many years. Especially, researchers have paid attention to technological capability development in emerging economies since the 1970s. However, some research questions still need to be addressed or investigated in more depth. For example, what factors affect companies' investment, production, linkage and innovation capabilities further more affect companies' technological capability and how these factors affect these capabilities. In addition, according to the existing studies, most of the research objects are traditional or high-tech manufacturing. However, the proportion of service industries in the economy has continued to increase. The study of technological capability development in service industry in emerging economies is limited and scarce.

Energy consumption and efficiency are issues that all countries must address. For a variety of reasons – including energy and energy consumption structure, huge population, large size of industry sector and low energy efficiency – China has become the world's largest energy consumer and carbon dioxide emitter. China has attempted to reduce its energy consumption and improve energy efficiency through regulations, taxes, policies, and a series of administration measures since the 1970s. Government has always been at the centre of energy efficiency in China. The ESCO industry and EPC, market mechanisms that make significant contributions to energy efficiency, have been applied in many countries for nearly 40 years. The introduction of ESCO industry and EPC implies that China has also attempted to achieve energy efficiency through economic measures.

The development of ESCO industry in China has been rapid. However, compared with its huge energy conservation potential, the ESCO industry in China is still in a nascent stage. Existing studies have identified a number of constraints to its development. The ESCO industry is a finance- and technology-intensive service sector. Due to the specific characteristics of this industry, technological capability plays a significant role in its development and comparativeness. However, few studies have addressed the problems.

For the reason that, the main gaps in the literature of study of ESCO industry refer to that 1) Organisational and external factors affecting technological capability development in ESCO industry and even service industry at firm level. 2) How ESCOs develop technological capability at firm level

According to the existing literature relevant to technological capability, a conceptual framework is created. The next chapter will present this conceptual framework about the factors affecting technological capability development. All components of the framework will be introduced and explained in detail.

CHAPTER 3 Conceptual framework of factors affecting technological capability development

To answer the research question “How do Chinese ESCOs develop technological capabilities?” The phenomenon of technological capability development of ESCOs industry has been explored from two perspectives, factors that affect the ESCOs’ technological capability and the process of capability development.

According to the empirical literature research related to definitions of technological capabilities, there are main four dimensions of firm-level technological capabilities: investment capability, production capability, linkage capability and innovation capability (Lall, 1992; Kim, 1980; Kim, 1999).

***Investment capabilities*：** The abilities required to establish new production facilities and expand capacity, such as identifying, preparing and obtaining technology for design, construction, equipment and staff. Investment capabilities are shaped by the firms’ size, finance capability, government policies, organisational managerial capability, profitability and a series of other factors. Investment capabilities determine the capital costs and scale of projects, product portfolio, selection of technologies and equipment, R&D expenditure and allocation of other organisational resources (Lall, 1992).

Moreover, based on the company’s ability to recognise technological opportunities, its investment capability has two levels: basic and advanced. Basic level means the company has the knowledge and ability to recognise the technological opportunities and equipment that can be used in production or improve production efficiency. If a company has knowledge accumulation or strong absorptive capacity, the company stays at advanced level of investment capability. The company not only effectively recognises the potential technologies or equipment, but also evaluates them in terms of cost efficiency and extensibility. The advanced level of investment capability provides a base and opportunities for company's innovation.

Production capabilities: Numerous capabilities require operating and maintaining production facilities and further adaptation, improvement, design and research (Lall, 1992; Kim, 1999). There are also two levels of production capability: basic and advanced. The basic level of production capability means the company has knowledge and know-how about how to use the technology or equipment to production or provide service to customer. The advanced level of production capability means the company has deep knowledge about the technologies or equipment. The company not only knows how to use the technologies and equipment, but also how to assimilate and improve the technologies and equipment.

Linkage capabilities: Capabilities are used to transfer knowledge, skills, technologies and know-how to or from external actors such as suppliers, subcontractors, consultants, service companies and research institutions. Linkages are created through formal and informal ways (Hippei, 1988; Cavusgil, Calantone & Yushan, 2003; Mathews, 2002; Mathews, 2006; Gupta

& Barua, 2016).

A company's linkage capability is reflected in three stages. The first is pure linkage, which means that a company simply has connections with external actors. In this stage, company creates or strengthens its social network. The second stage is leverage, which means the company can leverage sources from external actors such as universities, suppliers, partners and competitors to develop its technological capability; these resources include open sources. The third stage is the company's ability to acquire technologies through linkages. When the company has already built up linkages and found effective measures to leverage resources, it needs the ability to acquire and absorb technologies and know-how. This ability might be developed through production and R&D of the company.

Innovation capabilities: This refers to the ability to create and carry new technological possibilities through to economic practice (Kim, 1999). These technological possibilities involve technologies, process, products and services (Lawson & Samson, 2001). The innovation activities are mainly divided into incremental innovations and radical innovation. Most of companies are from developing countries and conduct incremental innovation through R&D. The main R&D activities are technology absorbing, improvement and integrating.

Table 2: Definition of dimensions of technological capability

Capability	Definition	References
Investment	Abilities required for establishing new production facilities and expanding capacity such as identifying, preparing and obtaining technology for design, construction, equipment and staff.	Dahlman, Ross-Larson & Westphal. (1987) Lall (1992) Kim (1999) Voudouris et al. (2012)
Production	Numerous capabilities required to operate and maintain production facilities and achieve further adaptation, improvement, design and research	Lall (1992) Bell & Pavitt (1995) Kim (1999) Kim (2004) Flor and Oltra (2005)
Linkage	Capabilities are used to transfer knowledge, skills and technologies and know-how to or from external actors such as suppliers, subcontractors, consultants, service companies and research institutions.	Hippei (1988) Lall (1992) Kumar, Kumar &Persaud. (1999) Cavusgil, Calantone & Yushan., (2003)
Innovation	Ability to create and carry new technological possibilities through to economic practice	Kim (1999) Lawson & Samson (2001) Morrison, Pietrobell & Rabellott (2008) Slater, Mohr & Sengupta. (2014)

To build and develop firm-level technological capabilities, firms in developing countries need to acquire external resource through technology transfer through conventional and unconventional channels from international or domestic actors (Lall, 1993; Damijan, Ross-Larson & Westphal., 2003; Gallagher & Zhang, 2013; Gallagher, 2014). The key factors affecting technology transfer and spillover are public policy, complementary assets, marketing of a technological innovation (Gallagher & Zhang, 2013), inter-firm collaborative experience, frequency of interaction, closeness of relationships, firm size (Cavusgil, Calantone & Yushan , 2003), indigenous innovation efforts, modern institutions governance structures, conducive innovation systems (Fu, Pietrobelli, & Soete, 2011), government policy, absorptive capacity, intensive R&D, human capital (Saggi, 2002), personnel, external environment subsystems (Frank, Ribeiro, & Echeveste, 2015), ownership structure (Sinani & Meyer, 2004), and investment in scientific and technical training (Mowery & Oxley, 1995).

To benefit from technology transferred from external actors, firms need to build up a strong absorptive capacity, which involves recognising, assimilating, transforming and exploiting knowledge (Cohen & Levinthal, 1990; Kim, 1997a; Zahra & George, 2002). The key factors affecting absorptive capacity are prior knowledge accumulation and intensity of efforts. Technology transfer provides a source for firms' knowledge accumulation. Intensity of efforts requires external evoked crises (market, technology, and government) to stimulate it, and organisational management, such as strategy setting, resources allocation, and personal recruitment and training (Cohen & Levinthal, 1990; Kim 1999; Camisón & Forés, 2010).

There are two key outcomes of technology transfer and absorptive capacity: performance and innovation (Cohen & Levinthal, 1990; Zahra & George, 2002; Todorova & Durisin, 2007). In terms of technological capability development, innovation is an important element to consider. Studying the process of technological innovation, technology transfer and absorptive capacity are critical components embedded in the innovation process. In addition, R&D investment and R&D experience are key factors that affect a company's innovation capability.

According to the empirical literature investigation, A conceptual framework to study the factors affecting firms' technological capability was created.

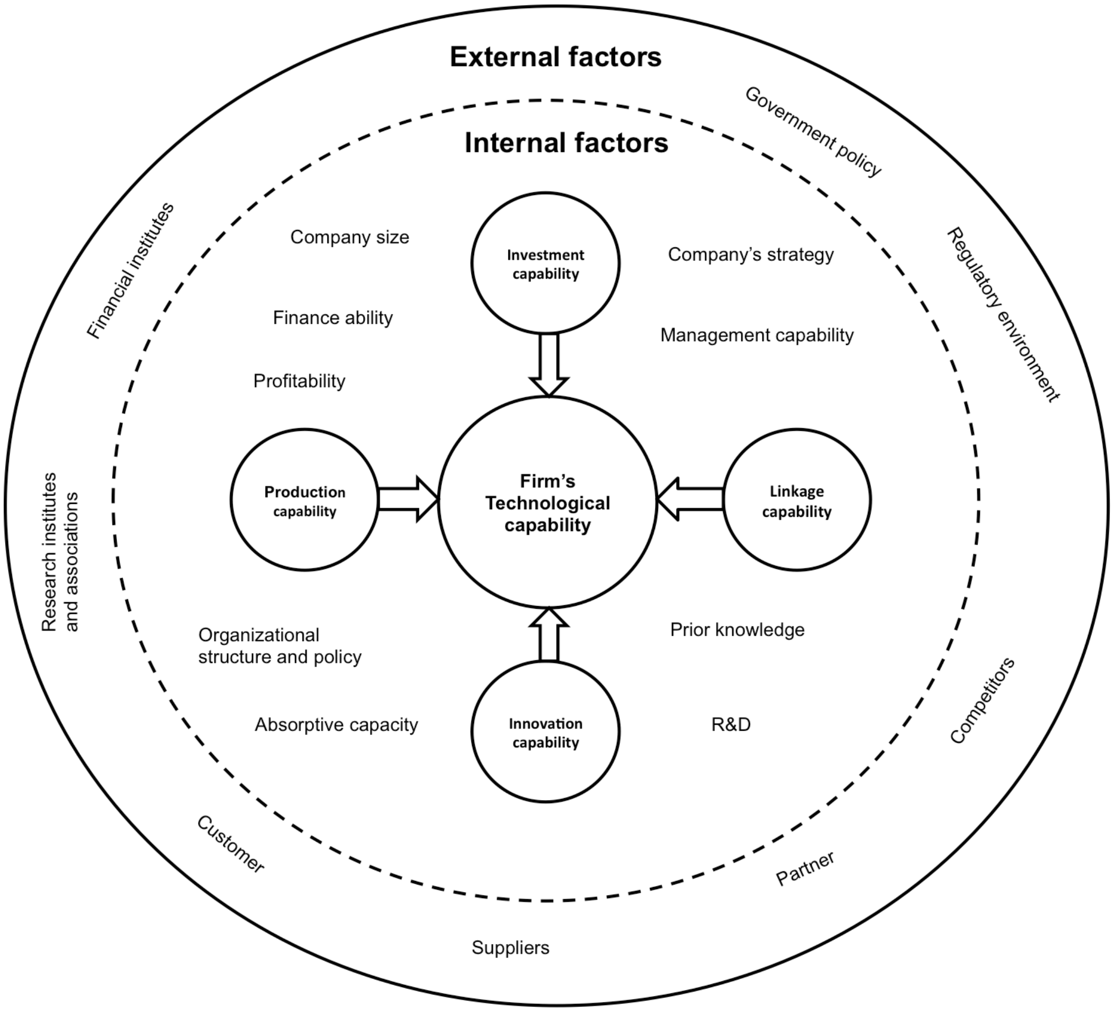


Figure 19: Conceptual framework: Factors affecting technological capability of ESCO industry.

The conceptual framework shows that investment capability, production capability, linkage capability and innovation capability all contribute to a firm's technological capability; these are viewed as the four key dimensions of technological capability and all are affected by internal and external factors.

These potential factors are obtained from the literature on technological capability, technology transfer, absorptive capacity, technology innovation and the ESCO industry. The internal factors mainly involve the company's size, strategy, finance ability, organisational structure and policy, absorptive capacity, prior knowledge profitability and management ability. The external factors involve government policy, regulatory environment, suppliers, partners, competitors, customer, financial institutes and research institutes and associations. The potential internal and external factors might affect one of more dimensions of technological capability. Some potential factors might not seriously affect the dimensions of technological capability. The conceptual framework and potential factors will be revised after the case studies.

Additionally, no literature has addressed the links between the four dimensions of technological capability. However, there might be relations between the four dimensions. For example, a company's production capability to use or even absorb technologies will increase prior knowledge, which provides a base for a company's innovation. A company's investment capability also directly affects its innovation capability through R&D investment and technical staff and equipment that will be used in R&D. Innovation capability also impacts the company's production capability through technology improvement and development, which improves production efficiency and quality. Linkage capability affects a company's investment, production and innovation capabilities through providing technology opportunities, resources and technical supports from external actors.

Therefore, the relations between the four dimensions of technological capability will be a proposition for this investigation. The relations between each dimension will be identified through case studies of six ESCOs in China.

Product portfolio is tangible manifestation of company's technological capability. As a technology-intensive sector, ESCOs' technological capability affects company's products and services from aspects of volume, variety, complexity. Investigating the internal and external factors affecting company's technological capability development, aims to study the effects between technological capability and product portfolio.(See Figure 20)

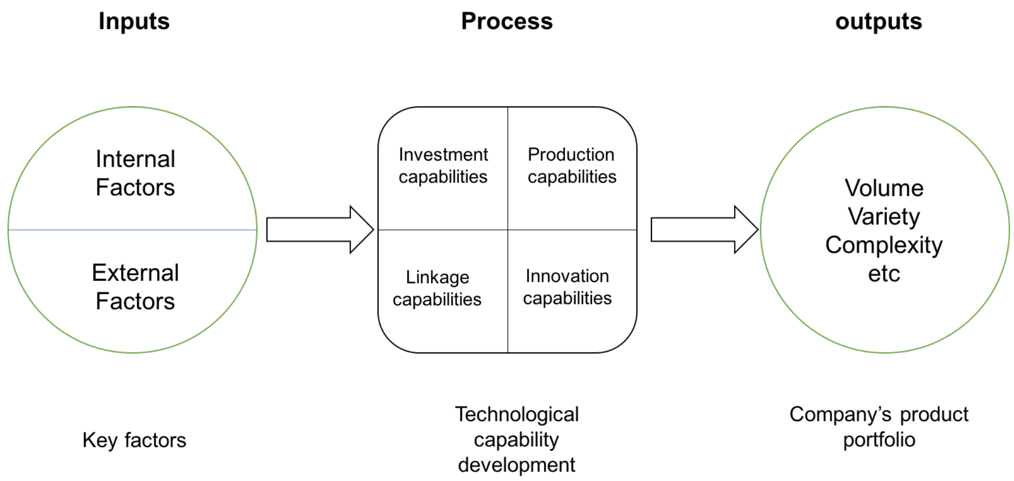


Figure 20: Product portfolio research framework

This chapter presents a conceptual framework of analysing factors that affect the technological capability of the ESCO industry. Based on a literature review, the potential internal and external factors affecting the four dimensions of technological capability were given. In addition, a proposition about the relations between the four dimensions of technological capability was proposed. Product portfolio is the tangible manifestation of company's technological capability.

A research framework is designed, which aims to identify the company's technological capability through investigating product portfolio of ESCOs. The next chapter will present the research methods applied for this investigation.

Chapter 4 Research method and process

This chapter explains the research methodology and describes the research process in detail. Section 4.1 briefly introduces the qualitative and quantitative research design, before section 4.2 explains the choice of the qualitative case study as a research strategy and section 4.3 illustrates the case selection criteria. Section 4.4 introduces and describes the research design and process. Sections 4.5 and 4.6 describe the data collection and analysis and then section 4.7 explains the criteria for assessing the quality of the empirical research. Finally, section 4.8 concludes and present a case study template.

4.1 Qualitative and quantitative methods

Determining an appropriate research methodology is a crucial element in a research study, especially a doctoral one. The methodology involves entire process of study, which refers to theoretical underpinnings and spanning, data collection and analysis and developing the solutions to research questions. Methodology refers to how the research will be conducted in order to answer the research questions and create original and relevant knowledge. The methodology is actually a combination of techniques used to enquire into a specific situation (Easterby-Smith, Thorpe and Jackson, 2008). Research methods are split broadly into quantitative and qualitative methods. A combination of qualitative and quantitative methods – a mixed approach – can also be used when a research question requires both methods to be answered (Kothari, 2004).

Qualitative research is empirical research where the data are not in the form of numbers (Punch, 1998) and is grounded in a philosophical position, which is broadly “interpretivist”. It is concerned with how the social world is interpreted, understood, experienced, or produced based on the generation of data that are flexible and sensitive to the social context in which they are produced (Mason, 1996). Normally, qualitative researchers conduct research in their natural settings, attempting to make sense of or interpret phenomena in terms of the meanings people bring to them (Denzin and Lincoln, 2005). Qualitative research is almost always associated with “why?” questions that reference its emergence in motivational research. Researchers can use such interrogative strategies to get to “deeper” levels (Barnham, 2015). Because it can be time-consuming to collect qualitative data, data is usually collected from a smaller sample than quantitative approaches. Even though qualitative data collection is time-consuming and expensive, the information obtained is richer and has a deeper insight into the phenomenon. The main methods for collecting qualitative data are interviews with individuals, focus groups, observations and action research.

Quantitative research is the systematic empirical investigation of observable phenomena via statistical, mathematical, or computational techniques. Bryman and Bell (2015) defined quantitative research as “entailing the collection of numerical data and exhibiting the view of relationship between theory and research as deductive, a predilection for natural science approach and as having an objectivist conception of social reality.” Bryman (1989) noted that the quantitative approach is infused with positivism, which is an approach to the study of people who commend the application of the scientific method. The quantitative search for “facts” can be usefully thought of as a series of “what?” questions (Barnham, 2015). The quantitative data collection methods rely on random sampling and structured data collection instruments that fit diverse experiences into predetermined response categories. The main quantitative data-collecting strategies involve experiments, observing and recording well-defined events, obtaining relevant data from management information systems and administering surveys with closed-ended questions.

In order to underpin better understanding of qualitative and quantitative research methods, Table 3 summarises and displays the key differences between positivism and interpretivism based on 10 key features: the ontology, epistemology, research object, approach, method and location of the researcher, based upon findings, data and researcher reflexivity.

Table 3: Key differences between positivism and interpretivism (Punch, 1998).

Features	**Positivism**	**Interpretivism**
Ontology	Reality exists objectively	The reality exists outside the human mind, but it becomes meaningful to human beings only through their intentionality.
Epistemology	The researcher and the researched are independent. It is possible for human mind to know reality as it is.	The researched is not independent of the researcher. Knowledge of the world is intentionally constituted

Research object	The research object has inherent qualities that exist independent of the researcher.	The research object is interpreted in the light of meaning structure of a persons' lived-in experiences.
Approach	Objective	Subjective
Method	Statistics, content analysis, mathematical models, simulations,	Hermeneutics, phenomenology, etc.
Location of researcher	Researcher is distant.	Researcher is close.
Based upon	A priori and theory test	Emergent themes and theories
Findings	Generalisation	Contextual understanding
Data	Hard and reliable data	Rich and deep observations, narratives, descriptions
Researcher reflexivity	Research results can be reproduced. Researcher can remove the influence of subjectivity through the rigor of the method.	Researchers recognise and include the implications of their subjectivity.

4.2 Qualitative case study research

Despite the considerations of qualitative and quantitative research approaches, choosing and setting an appropriate research strategy is crucial to conduct a successful social research.

Based on various researchers' disciplines and research objectives, there are a variety of research strategies, including experiments, surveys, archival analyses, histories and case studies. Each strategy has advantages and disadvantages and selection of the appropriate research strategy depends on three conditions: (1) the type of research questions, (2) the control a researcher has over actual behavioural events and (3) the focus on contemporary as opposed to historical phenomena.

Table 4: Relevant situations for different research strategies (Yin,2003).

Research strategy	**Form of research question**	**Requires Control of Behavioural event?**	**Focus on Contemporary events?**
Case study	How, Why	No	Yes
Survey	Who, What, Where, How many, How	No	Yes
Experiment	How, Why	Yes	Yes
Archival analysis	Who, What, Where, How many, How	No	Yes/No
History	How, Why	No	No

Yin (2003) defined a case study as "an empirical inquiry, which investigates a contemporary phenomenon within its real-life especially when the boundaries between phenomenon and not clearly evident." A case study may be the preferred research strategy when "how" and "why" questions are being raised, when the researcher has little control over events and when the investigator's focus is on a contemporary phenomenon. A researcher who chooses case study as a research method must believe that contextual conditions might highly pertinent to the phenomenon of study.

Qualitative case study was selected as an appropriate research method for the present study because this research aims to investigate a contemporary phenomenon: technological capability development of an emerging industry – the ESCO industry in China. The research questions of this investigation are as follows: (1) Why have Chinese ESCOs developed technological capabilities? (2) Which and how factors have affected Chinese ESCOs' technological capabilities? (3) How have Chinese ESCOs developed technological capabilities and (4) How do the case companies compare to American ESCOs in terms of their product portfolios? These are all "how" and "why" questions that aim to address the objectives of this investigation.

The ESCO industry is still an emerging industry, although the concept and development of ESCO industry is being promoted and accelerated by many countries, which are making effort to establish a mature ESCO industry and comprehensive ESCO market. Therefore, the development of the ESCO industry is a contemporary phenomenon. The case study method covers both the phenomenon of interest and its context, producing a large number of potentially relevant variables and rich information. Moreover, the study on technological capability development in the ESCO industry is in its very early stages and the research is scarce but informative. Therefore, interpretive research is closely connected to empirical reality, which makes it appropriate to explore contemporary phenomenon of technological capability development in the ESCO industry, rather than the positivist approach. In terms of interpretive research of technological capability development in ESCO industry, the research is conducted in-depth following interpretive traditions. As one of the outcomes of this study, the research provides propositions about the management practices of technological capability development in the ESCO industry. These propositions provide further research opportunities, which can be tested in positivist ways.

This research adopted a qualitative interpretive approach. Empirical data were collected based on words from informants' introductions, descriptions and explanation and secondary data such as projects report, cooperation agreements and so on. Furthermore, data analysis of this research did not involve quantitative procedures.

This investigation belongs to the study of technology and operation management. Case study research has been widely used in operation management research. Barratt, Choi and Li. (2011) examined the state of qualitative case studies in operations management through reviewing 204 qualitative case studies from five top operations management journals – Decision Sciences, International Journal of Operations and Production Management, Journal of Operations Management, Management Science, and Production and Operations Management – between 1992 and 2007. Their investigation noted that the trend of using qualitative case study is increasing and that there have been meaningful and significant contributions to the field of operations management, especially theory building. They also found that research protocols for conducting inductive case studies are much better developed than the research protocols for conducting deductive case studies. This investigation meets all the criteria of qualitative case study; therefore, qualitative case study is appropriate research strategy for this investigation.

Applying case study as a research strategy involves the use of the all-inclusive method and several approaches to data collection and analysis (Yin, 2003). Case study research from an interpretive perspective starts with a review of existing technological capability development and ESCOs industry literature, followed by numerous qualitative data collection approaches and an analysis of data.

There are a variety of sources for obtaining evidence for case study research. Generally, documentation, archival records, questionnaires, interviews and observations are the main sources. For the present study, the main sources were interviews, observations and documentation. Data collection from multiple sources makes an in-depth understanding and study of a phenomenon from different angles and may increase the variety of the research findings.

The present research involved more than one single case; therefore, the study must apply a multiple-case design. The evidence from multiple cases is often considered more compelling. Therefore, the overall study is regarded as being more robust. Yin (2013) noted that multiple case studies and subsequent cross-case analyses were conducted to increase the external validity of the research. In terms of this research, six case studies were conducted in six different companies. In multiple case studies, every case should serve a specific purpose within the overall scope of injury. In order to be able to compare findings from multiple cases, the selection of case should follow the criteria which are designed. The criteria will be presented in following sections.

Having identified qualitative case study as the proposed research method, the next section will introduce and explain criteria of selection of companies and key informants in case study research.

4.3 Selection of case study companies

The selection of companies to be investigated was driven by the main research interest, which is to study the phenomenon of technological capability development of the ESCO industry in China. Hence, six Chinese ESCOs were selected to conduct this research.

Based on official statistics, there were 5426 ESCOs in in China as of 2015, most of which were private SMEs. To ensure the quality of cases, the companies were selected from the group of ESCOs recorded by the National Development and Reform Commission (NDRC) and members of the ESCO Committee of China Energy Conservation Association (EMCA). All of 5426 ESCOs satisfied these two criteria. In order to further narrow the range and improve the quality of cases, four further criteria were applied.

(1) The companies that were selected have at least three years' business experience and have successfully implemented at least five energy conservation projects. This requirement ensures that the case companies are active ESCOs in China, thus providing useful information for this study.

(2) The case companies should be domestic ESCOs that are recorded by the NDRC. This criterion was set because the present study aims to examine domestic ESCOs, not foreign-owned ESCOs.

(3) Size: two small-size, two medium-size and two large. This criterion helped obtain comprehensive information from ESCOs in different sizes.

(4) The case companies came from different locations – one small, medium and large ESCOs from a first-tier city; the other case companies are from second-tier cities. This is because location is a consideration that is taken into account for affecting ESCOs' technological capability development.

The small and medium-sized companies satisfied all the criteria above, but the two large companies are both from a first-tier city, the Chinese capital of Beijing, where most of the State Owned Enterprise (SOE) ESCOs' headquarters are located. In addition, the small company that comes from a second-tier city has business and technologies that just involve the energy conservation domain of LED lighting.

To classify a different scale of ESCOs, the number of employees was applied as a classification criterion.

Table 5: Criteria for company scale classification (source: China National Bureau of Statistics)

	Unit of measurement	Small	Medium	Large
Number of employees (x)	Person	10-100	101-300	More than 300
Total Asset (Y)	10,000 RMB	100-8,000	8,001-120,000	More than 120,000

Naturally, the choice of companies that could be studied was limited, for a number of reasons. First, in order to ensure the quality of case companies, seven criteria were set. The number of companies that could satisfy all or most of these criteria was limited. Second, not many companies are ready to give access to an external researcher, especially the principal researcher, who came from a foreign university. Therefore, the case selection was initially quite time-consuming. Nearly 40 companies were contacted, but only eight were willing to provide access to the researcher and two refused to allow interviews with members of their management team. Therefore, the six companies were selected from eight ESCOs.

The following companies were selected for the case studies:

Case 1: Beijing Visible Energy Saving Technology Corporation is a small private ESCO located in Beijing. The company was founded in 2010 with registered capital of 5 million RMB. The number of employees is 48. The company provides a full range of energy conservation service and focuses on industrial and building energy conservation.

Case 2: Qingdao East-Bay New Energy Co., Ltd, is another small private ESCO and is located in Qingdao, a second-tier city. The company was founded in 2010 with registered capital of 10 million RMB and has 20 employees. The company provides a full range of energy-saving lighting solutions.

Case 3: Beijing Sinowise Technology Co., Ltd. is a medium-sized private ESCO located in Beijing. It was founded in 2010 with registered capital of 22 million RMB and currently has between 100 and 150 employees. This ESCO provides a relatively full range of energy conservation service and solutions for industrial energy conservation.

Case 4: Hangzhou Ditree Energy Conservation Technology Co., Ltd., another medium-sized private ESCO, is located in Hangzhou, a second-tier city. It was founded in 2005 with registered capital of 20 million RMB and has 100–150 staff. The ESCO focuses on industrial and building energy conservation.

Case 5: CECEP Industrial Energy Conservation, Ltd. Co. is a large state-owned ESCO located in Beijing. The company is one of the wholly owned subsidiaries of the China Energy Conservation and Environment Protection Group. The company was founded in 2010 with registered capital of 971.93 million RMB and has 970 employees. This ESCO focuses on industry energy conservation.

Case 6: State Grid Energy Saving Service, Ltd. Co. is a large state-owned ESCO located in

Beijing. This ESCO belongs to State Grid, the largest electricity provider in China. The company was founded in 2013 with registered capital of 4.6 billion RMB and has approximately 7000 staff. This company focuses on providing energy conservation technologies and solutions to the electric industry. The company is also involved in transport energy conservation, building conservation and industry conservation.

In addition to the consideration of companies selected for multiple case studies, the selection of key informants for interview is also required to satisfy two criteria:

(1) The interviewees have to have worked for the companies for at least three years.

(2) The interviewees must work in the management team and have knowledge about companies' strategy, current technologies, products, services and so on.

To satisfy these two criteria, three interviewees were selected from small and medium –sized case companies. In terms of large case companies, each company just provided 2 two key informants to attend interviews. This meant that there a total of 16 interviewees were selected to join in this research.

The next section will introduce the research design and process for this study.

4.4 Research design and process

Yin (2003) stated: “Every type of empirical research has an implicit if not explicit, research design. The design is the logical sequence that connects the empirical data to a study’s initial research questions, and ultimately, to its conclusions.” This research was designed based on the replication approach for multiple case studies, as described by Yin (2003). According to the replication approach, each case study is analyzed separately, then cross-case analysis was conducted through comparison based on findings from the individual case study in order to draw the final conclusions. Finally, secondary analysis was conducted of the case company’s product portfolios and that of American ESCOs. Figure 21 illustrates the research process and research design of this study.

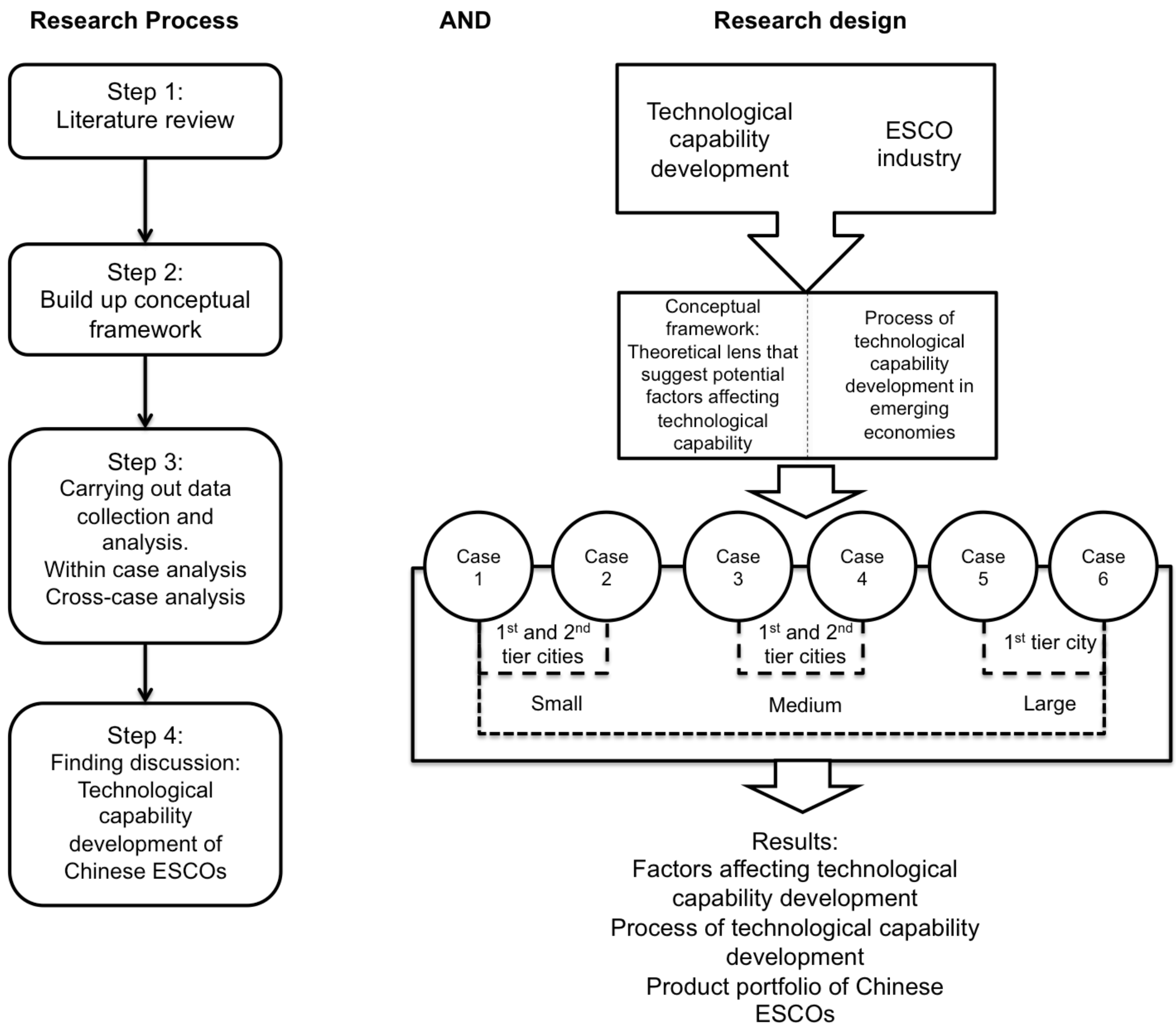


Figure 21: Research process and research design

As Figure 21 shows, the research process mainly involved four steps. The entire research process lasted for four years. The necessary ethical approval was obtained from the Aston Business School Research Ethics Committee. Before gaining permission to access to the case companies, a cover letter was sent to every case company and every interviewee (see the appendix). Every company and interviewee understood the research objectives of this research and the importance of their participation. All interviewees were given a research consent form (see the appendix A).

The first step in the research process involved a review of literature relevant to technological capability development and ESCO industry development. In step 2, based on the literature, a conceptual framework about factors affecting the firm's technological capability was developed. In step 3, multiple case studies were prepared. Case selection, contacting companies that satisfied the criteria, data collection protocol design and empirical investigation were undertaken. The semi-structured questionnaire was designed based on the elements from conceptual framework, such as dimensions, factors and process.

The interviews are started with identifying case company's technological capability and further investigate the dimensions of company's technological capability. And then, the interview questions will focus on the factors affecting case company's technological capability. The interviewees will provide the key factors firstly. And then, according to the factors from the conceptual framework, the interviewer will mention the other potential factors and consult interviewee's opinions.

During the empirical investigation in step 3, the data analysis was carried out in an iterative way, iterating between data collection and data analysis. When data collection finished for one case, a case study report was completed and preliminary data analysis was finished. Due to the fact that all the data collected from interview and documentation were in Chinese, a large amount of time was required to do the translation. To ensure accuracy, two translation software packages were applied to compare the translated results with those of the researcher. Data analysis includes analysis of each case separately (within-case analysis' and cross-case analysis). Considering the different locations and company scales, case 1 was compared with case 2 and case 3 was compared with case 4 for location consideration. Case 1 was compared with case 3 and case 2 was compared with case 4 for size consideration. Cases of small-and medium-size companies were compared with cases of large companies for size and ownership consideration. In step 4, the results from multiple case studies addressing the research questions were presented and discussed. The results include the theoretical framework that identified factors affecting technological capability in ESCO industry in China and identified the process of technological capability development. Finally, the role of government in technological capability development was illustrated.

4.5 Data collection: method and process

The data collection includes visits of six companies and 16 interviewees from three cities. There are four case companies: Case 1 (small ESCO), Case 3 (medium-size ESCO), and Cases 5 and 6 (large ESCOS from Beijing). Case 2 is a small ESCO located in Qingdao. Case 4 is a medium-sized ESCO located in Hangzhou. There were two rounds of data collection, the duration of each varying from five to seven days. The second round of data collection was conducted by telephone.

Evidence for case studies normally comes from six sources: documents, archival records, interviews, direct observation, participant observation and physical artifacts (Yin, 2003). In the present study, qualitative evidence was collected from interviews, documentation and observations.

Interviews: Semi-structured, open-ended, individual, face-to-face interviews were applied to collect primary qualitative data. Applying semi-structured interview enables the interviewer to clarify and follow up with questions on research questions related to the reasons for technological capability development, factors affecting technological capability and the process of technological capability development of each case company. Before the interview, semi-structured questionnaires were developed based on the research questions. In order to obtain effective and useful information from interview, the interviewer should acquire information about the case companies from companies' websites, news and annual reports.

In this research, 16 key informants were interviewed. Twelve interviews were conducted for small and medium-size ESCOs; three in each case company. A further four interviews were conducted for the two large ESCOs, with each case company providing two participants. The interviews lasted between 40 and 90 minutes. During the interviews, recording and intensive notes were taken and fully transcribed. Only nine of the interviewees allowed the interview to be recorded.

Direct observation: Observational evidence is often useful in providing additional information about the topic under study. In this research, observation of meeting and other communication between employees, managers and customers were applied. In addition, observations of the working environment were also mentioned. Taking advantage of information obtained from observations, the researcher was better able to understand the factors affecting the company's technological capability development.

Documentation: Several cooperation documents, internal and external published materials and annual reports provided by case companies. The documentation enabled the researcher to learn about the case companies' current market performance, energy conservation technologies, patents and networks.

In the second round, data collection took place by telephone. Telephone interviews lasting 15–30 minutes were conducted with each case company. The main purpose of secondary round data collection is obtaining supplementary data and further discussing the relations between four dimensions of technological capability. Table 6 describes the details of data collection for each case study.

Semi-structured questionnaire is designed for development of conceptual framework. Therefore, the main questions are related to company's technological capabilities, factors affecting company's technological capabilities, the relations between four dimensions of technological capabilities and process of technological capability development. Table 7 shows the links between questionnaire and conceptual framework development. The specific research questions of questionnaire, see Appendix D.

Table 6: Main steps in data collection process

Data collection steps	Case 1 Beijing Visible	Case 2 Qingdao East-bay	Case 3 Beijing Sinowise	Case 4 Hangzhou Ditree	Case 5 CECEP Industrial	Case 6 State Grid energy saving
Initial contact and arrangement	May–July 2015	May–July 2015	August 2015	May–July 2015	September 2015	September 2015
Visit location	Beijing office. 5 days in October 2015	Qingdao office 7 days in December 2015	Beijing office 4 days in October 2015	Hangzhou office 6 days In November 2015	Beijing office 4 days in November in 2015	Beijing office 7 days in December 2015
Review of case report for internal validity	February–April 2016	February–April 2016	March 2016	April 2016	May 2016	April 2016
Additional data collection	Phone interview September 2016	Phone interview September 2016	Phone interview September 2016	Phone interview October 2016	Phone interview October 2016	Phone interview October 2016

Role of interviewees	CEO, Senior manager, Director of R&D	General manager, Project manager, Director of design department	Assistant of senior manager, Senior manager, Director of strategic investment department	Senior manager, Director of R&D, Director of financial department	Director of strategic investment department, Deputy director of technology management department	Deputy director of engineering department, Project manager
Number of interviewee	3	3	3	3	2	2
Total number of interviews	Face-to-Face: 3 Telephone: 1	Face-to-Face: 3 Telephone: 1	Face-to-Face: 3 Telephone: 1	Face-to-Face: 3 Telephone: 1	Face-to-Face: 2 Telephone: 1	Face-to-Face: 2 Telephone: 1
Total hours for interview	5 hours	4.5 hours	3.5 hours	5 hours	3 hours	3 hours

Table 7: Links between semi-structured questionnaire (in appendix D) and conceptual framewrok

Aspects links to conceptual framework	Semi-structured questions	Explanation
Dimensions of technological capabilities	RQ1b, c, d and e	These questions are aim to identify the dimensions of company's technological capabilities and company's strategy for developing these dimensions
Factors affecting technological capabilities	RQ2 a	This question is designed to investigate the key factors affecting companies' technological capabilities
Factors affecting each dimensions of technological capabilities	RQ2 b and c	These two questions aim to investigate the factors affecting each dimensions of technological capabilities and further identify how the factors affect them.
Relations between each dimension	RQ2 d	This question is designed for identifying the links between each dimension.
Process of technological capabilities development	RQ3 c, d and e	These research questions aims to investigate and identify the process of technological capability development of companies. Further explore how companies develop their dimensions of technological capabilities

4.6 Data analysis process and techniques

In terms of this research, qualitative data were collected for multiple case studies. Therefore, qualitative data analysis was conducted to answer the questions, which are investigated.

> “Qualitative data analysis is a process of the description, classification and interconnection of phenomena with the researcher’s concepts. First, the phenomena under study needs to be described precisely. The researcher needs to be able to interpret and explain the data; therefore a conceptual framework needs to be developed and data classified. After that, concepts can be built and connected to each other.” (Graue, 2015)

Data analysis in this research aimed to identify the factors that affect companies’ technological capability and the process of technological capability development. Based on a review of literature relevant to technological capability development, a conceptual framework about factors affecting firm’s technological capability has been developed (see chapter 3).

Data analysis involved qualitative data analysis techniques suggested by Miles and Huberman (2013), Yin (2003) and Strauss and Corbin (1998). In this research, within-case analysis and cross-case analysis were conducted using several steps. The following sections will introduce the processes and techniques used in within-case analysis and cross-case analysis.

4.6.1 Within-case analysis

With regard to within-case data analysis, all the data collected from interviews were fully transcribed. All the interviewees and the principal researcher are Chinese, so the interviews were conducted in Mandarin and intensive notes were also taken in Chinese. Given that semi-structured and open-ended interviews were applied and the interviewees lacked experience in interviews, the full content of each interview was rich but largely redundant. The data were processed and streamlined before being developed into a case report where the themes related to the research questions were highlighted and organised into different sections. The developed case reports not only involved data from interviews, but also data from observations and documentation.

The case reports were then sent back to the interviewees, who had another opportunity to add further information or correct possible inaccuracies inherent to the method. The case reports were completed in Chinese so that the interviewees could read and understand them. Once feedbacks had been obtained from the interviewees, the case reports and other data collected were translated into British English by the principal researcher. To ensure and increase the accuracy of the translation, the results of translation were tested with two translation software tools: Google Translate and Whitesmoke.

There are mainly three phases in terms of within-case data analysis.

Identification: This phase mainly involves reading through intensive interview notes or transcripts and collected documents and identifying factors affecting ESCOs' technological capability development. For example, according to the transcripts and notes of three interviews and documents from Case 1, there were 13 factors that affected Case 1's technological capability. A list of these factors affecting technological capability was created and these factors were categorised as internal or external.

Classification: According to the conceptual framework, there are four key dimensions to technological capability (investment capability, linkage capability, production capability and innovation capability). The factors, which were identified in phase 1, were classified into these four dimensions. For example, in Case 1, "personal relationship" was deemed as an important factor affecting a firm's linkage capability. "Company's financing ability" is the factor affecting firms' investment capability. "Customer's knowledge capture" is the factor affecting firms' production capability and "R&D investment" affects firms' innovation capability.

Influence: This phase involves identifying how these factors affect four key dimensions of technological capability through detailed activities and explanation from interviewees. For example, In Case 1, the CEO had a good personal relationship with a manager from a Japanese ESCO. Hence, through licensing, Case 1 obtained its core energy conservation technology and started its business in China from 2010.

4.6.2 Cross-case analysis

Cross-case analysis aimed to compare and explain similarities, contradictory findings and complementary findings in the studied companies. A comparison technique was based on listing seminaries and differences between cases, and included the comparison of findings and factors across cases.

Despite this, location and companies' size were taken into considerations to conduct comparative analysis. Case companies from first-tier cities were compared with case companies from second-tier cities and SMEs were compared with large-size companies. Figure 22 displays a cross-case analysis of this investigation.

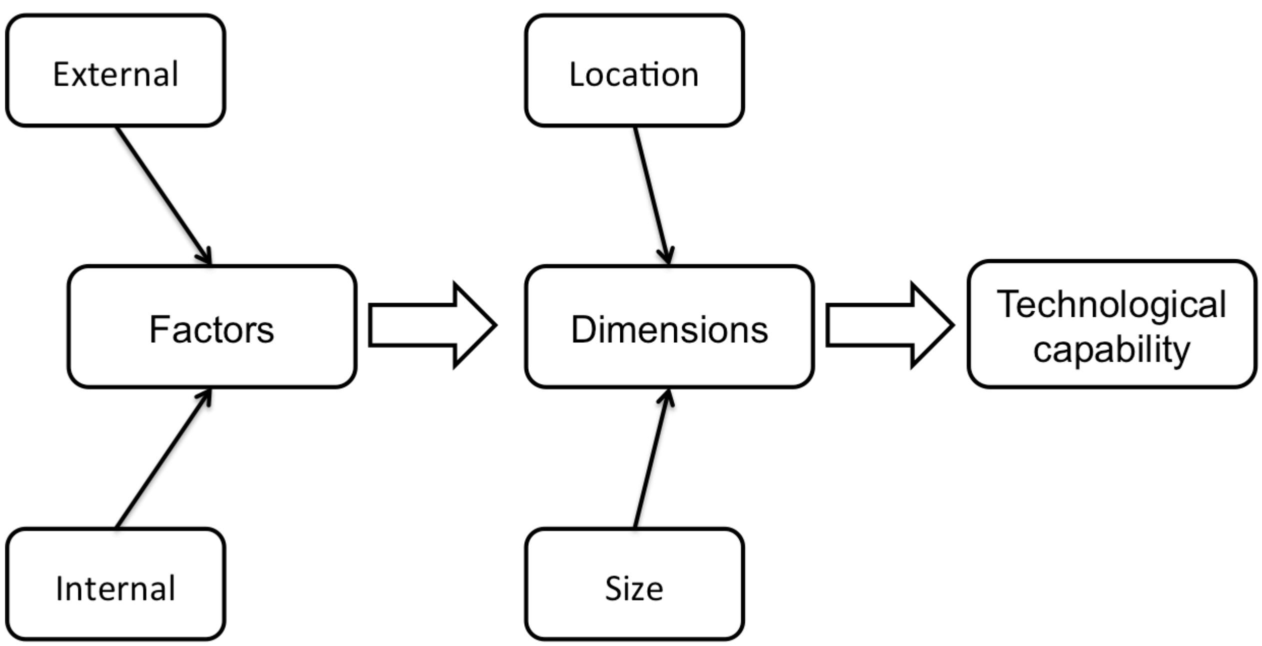


Figure 22: Cross-case analysis.

4.6.3 Secondary data analysis

Secondary data analysis was conducted to answer the question of “How do case companies compare to American ESCOs in terms of product portfolio?” The types of products and number of products and services or the case companies were compared with those of American ESCOs. The size of the companies is taken into consideration.

The next section will introduce the criteria commonly used to access quality of empirical research and further explain how this research satisfies these criteria.

4.7 Quality of the empirical research

A qualitative case study is deemed as “subjective”. With increasing use of the case study method, concerns have been raised among the academic community about bringing the necessary rigor to make qualitative methodologies relevant and acceptable. Several books have discussed how to ensure the quality of qualitative case studies (Yin, 2003; Bryman 2008; Eisenhardt, 1989; Miles and Huberman, 2013). Four tests – construct validity, internal validity, external validity and reliability – have been commonly used to establish the quality of any empirical social research (Yin, 2003).

Construct Validity

Construct validity refers to establishing the correct operational measures for the concepts being studied (Yin, 2003).

Construct validity can be addressed in the present study by data triangulation, when data is collected from multiple sources but aims to corroborate the same fact or phenomenon (Yin, 2003). Gathering evidence from multiple sources provides multiple measures of same phenomenon and ensures stronger substantiation of constructs and hypotheses (Eisenhardt, 1989).

The design of questionnaire is strong based on literature. Additionally, the supervisors provided feedback regarding to the questionnaire and plan of data collection before the data collection. Moreover, Semi-structured questionnaire is applied in order to strength the construct validity of this research.

Internal validity

Internal validity refers to establishing a causal relationship, whereby certain conditions are shown to lead to other conditions, as distinguished from spurious relationships (Yin, 2003). The internal validity was addressed in this investigation through three tactics: semi-structured questionnaires, data triangulation and robust data analysis procedures.

Besides enhancing construct validity of this research, the use of semi-structured questionnaires allowed the researcher to link factors to key dimensions of technological capability and process of technological capability development. In addition, the multiple sources of data collected for this research, emails and phone contacts with key informants for feedbacks of case reports also address the internal validity.

External validity

External validity prefers to establish the domain to which findings of the study can be generalised.(Yin, 2003)

The use of a multiple case study strategy strengthens the generalizability of this research. The design of multiple case studies and cross-case analysis were undertaken.

In addition, the cases were selected from ESCOs with different sizes and in different locations. Cases 1 and 2 are small private ESCOs, while Cases 3 and 4 are medium-size private ESCOs, and Cases 5 and 6 are large ESCOs. Cases 1, 3, 5 and 6 are located in a first-tier city (Beijing), while Cases 2 and 4 are located in two different second-tier cities in China.

Reliability

Reliability demonstrates that the operations of a study, such as the data collection procedures, can be repeated with the same result (Yin, 2003). The objective of such test is to ensure that an investigator following the same procedures as described by earlier investigator and conducting the same case study would obtain the same findings and results. This test aims to minimise the amount of errors and biases in the study.

To ensure consistency in applying procedures for data collection and analysis, a case protocol was developed for each case in the present study. Data collection was guided by this protocol to identify factors affecting the ESCOs' technological capability. In addition, semi-structured interviews were designed and applied to collect primary data. Most of the interviews were audio-recorded; when this was not possible, intensive notes were taken.

4.8 Chapter summary

This chapter has introduced and explained various aspects of research methodology applied in this investigation. For the research questions identified, a qualitative case study was applied as an appropriate research strategy for this study. The case selection and criteria were explained and the research process and design were displayed and illustrated. In addition, data collection instruments, data analysis processes and techniques were also explained. To ensure the quality of this qualitative case study, tactics were applied to address construct, internal, external validity, and reliability was also explained.

The next three chapters will present the within-case analysis of the individual case, starting from the small ESCOs (Beijing Visible and Qingdao East-bay), then the medium-size ESCOs (Beijing Sinowise and Hangzhou Ditree), and finally the large ESCOs (CECEP and State Grid Energy Saving).

Chapter 5 Findings from small ESCOs in China

5.1 Case study of Beijing Visible Energy Saving Technology Corporation

5.1.1 Company background

Company Profile

Beijing Visible Energy Saving Technology Corporation (also referred to in this thesis as Visible Corp) is a small-size ESCO that was founded by its CEO who had graduated from Kyoto University in 2010. The CEO now has more than 10 years of experience in energy management and energy conservation. The CEO is also an international registered senior energy auditor, which is certified by the registered senior energy efficiency assessment division, international registered senior energy manager and energy measurement and management division of the American Certified Association.

The registered capital of Visible Corp is 5 million RMB and the company has 48 employees. By the end of October of 2015, its annual sales reached 19 million RMB. Taking advantage of professional management, competitive technological advantage and good market performance, Visible Corp became a listed company in the “New over-the-counter market”, which refers to an “Agency Share Transfer System”. The “New over-the counter market” is a special system in China. If an SME has good market performance or potential, it can be financed through selling its equity.

However, equity trading is limited to between enterprises. Taking advantage of this system, through two private placements of 900,000 shares, Visible Corp financed 13.5 million RMB for technology upgrades, service optimisation and market expansion. In April of 2015, in order to achieve market expansion, Visible Corp built a subsidiary in Hefei. In October 2015, to expand its market and technological resources, Visible Corp acquired 51 per cent of another ESCO's equity. Hence, Visible Corp held another subsidiary in Guizhou. In addition, Visible Corp founded its own independent R&D centre in Xi'an in 2014.

Visible Corp was registered by NDRC and is also a member of EMCA. Visible Corp was awarded a series of qualifications and titles, such as "national high-tech enterprises", "Zhongguancun high-tech enterprises" and "the most entrepreneurial potential enterprise" because of its energy efficiency analysis system, which it introduced from overseas, and its "4W" energy efficiency analysis system, which was developed by independent R&D and can help energy consumption enterprises find "who, where, when and what", leading to energy inefficiency.

During the past five years, Visible Corp has successfully implemented 17 energy conservation projects (See Table 8).

Table 8: Projects implemented by Visible Corp

Number of projects	**Energy saving sectors**	**Key products, services and technologies**
Comprehensive Energy Management		
5 projects	Building energy saving, industry energy saving	"4W" (energy efficiency analysis system Energy efficiency management centre; Energy auditing and measurement
Energy-saving consultancy assignments		
8 projects	Building and industrial	Energy auditing
Air conditioning energy saving retrofitting		
3 projects	Building and industrial	Air conditioning smart management system
Lighting energy saving retrofitting		
1 project	Public infrastructure	LED lighting technology

Visible Corp focuses on industrial energy saving and mainly provides comprehensive energy management and consultation services to its customers. The comprehensive energy management refers to a package of services that includes energy auditing, energy-saving potential analysis, project design, project financing, energy-saving product procurement, project implementation, and maintenance. The consultancy service mainly involves energy auditing, energy efficiency analysis and project design. The energy management centre is a comprehensive energy management system that was developed by Visible Corp and involves various energy-saving technologies that help customers reduce energy consumption and improve energy efficiency and further reduce energy cost.

Visible Corp wants to expand its business and improve its market performance through providing comprehensive energy solutions to energy users. Hence, its business involves 12 services (see Figure 23).

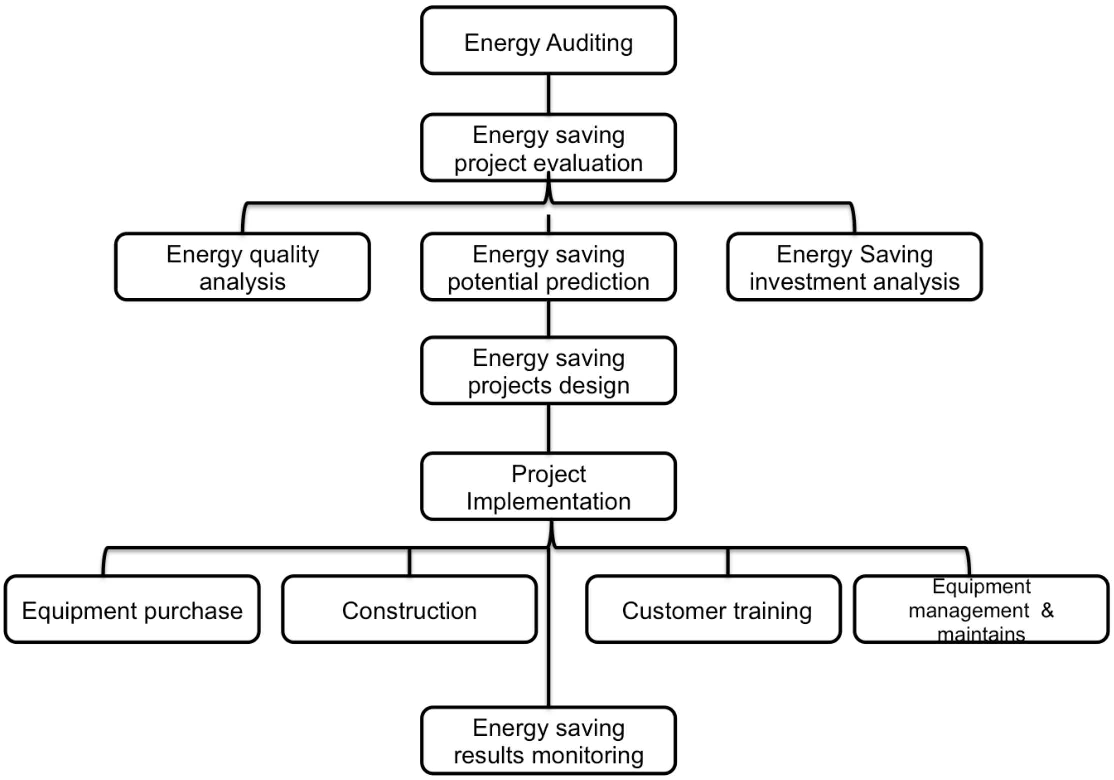


Figure 23: Services provided by Visible Corp.

These services constitute the company's product portfolio. The existing portfolio was formulated gradually, started from energy saving project design, and expanded up- and down-stream. Initially, Visible Corp employed a third-party company to undertake energy auditing and energy-saving project evaluation. During the stage of project implementation, Visible Corp only undertook equipment purchase, staff training and equipment management and maintenance before 2012. In 2013, the company built a small construction team with just five employees.

Visible Corp's personnel are divided into three key teams. The first, the management team, is responsible for operation management, linkage creation and maintenance, potential technologies searching, and finance. The second, the marketing team, is responsible for expanding the business to more cities and acquiring more energy conservation projects. The target customer group of Visible Corp main involves small and medium manufacturing enterprises. With the promotion and supporting policy by government, more and more companies entered this market, most are small-size companies that aim to provide energy-saving services to small and medium-sized industrial energy consumers. Hence, the competitiveness among SMEs is much more intensive than that faced by large ESCOs. Trying to seize the market becomes particularly important. The CEO thinks the most important team is the R&D department, which is responsible for building Visible Corp's competitive advantage: its technology. As a small-size company, Visible Corp set up its R&D department with huge potential risk and financial pressure. In order to minimize the impact on the whole company, and to take advantage of lower property and technical staff costs, the R&D department was established in Xi'an, which is located in western China. In 2015, 13 technical staff worked for the R&D department. The director of R&D has a PhD in industrial automation with 10 years R&D experience in a world-leading industrial automation company.

Company's technological capability

Visible Corp pursues R&D and innovation and considers technological capability to be its core competitive advantage. To build technological capability, Visible Corp built its independent R&D department in Xi'an. All the technical staff who work for the R&D department are software, mechanical and electrical engineers. The department is leaded by a PhD with rich R&D experience. A Japanese expert in energy conservation technology was invited as a consultant to provide technical support for improvement of a "Visible energy analysis system" and a "4W" energy efficiency analysis system. In addition, the CEO and the project director both have technical knowledge in energy-saving industry. The core expert team was formed by these four people.

Through overseas energy conservation technology introduction, R&D, and domestic energy-saving technologies transfer, Visible Corp obtained a series of advanced and mature domestic energy-saving technologies. Table 9 shows the energy saving technologies obtained and applied by Visible Corp.

Table 9: Energy saving technologies applied by Visible Corp.

Technology	Main application areas	Source of technology	Level of technology
Visible energy management center	Industrial, building energy saving	Foreign technology transfer	Domestic advanced
'4W' Energy efficiency analysis system	Industrial, building energy saving	R&D	Domestic advanced
Energy management system cloud platform	Industrial energy saving	R&D	Domestic advanced
Cold storage technology	Air conditioning retrofit	Domestic transfer	Domestic mature
Large temperature difference technology	Air conditioning retrofit	Domestic transfer	Domestic mature
Frequency conversion technology	Air conditioning retrofit	Domestic transfer	Domestic mature
Heat recovery technology	Air conditioning retrofit	Domestic transfer	Domestic mature
Natural cold source utilization technology	Air conditioning retrofit	Domestic transfer	Domestic mature
Fresh air system heat recovery technology	Air conditioning retrofit	Domestic transfer	Domestic mature
Led lighting technology	Lighting retrofit	Domestic transfer	Domestic mature

In order to obtain technical support from external institutes, Visible Corp focuses on building extensive linkages with suppliers, partners, and government department and research institutes. Visible Corp built up a strategic partnership with the Chinese Academy of Science, Tsinghua University, Beijing Energy Saving and Environment Protection Centre.

Visible Corp currently has one utility model patent in energy management system in the cement industry. It also has 13 software development copyrights. They are:

- Visible Energy Management Centre: Energy Efficiency Management Software
- Visible Energy-Saving Certification Management Software
- Visible Energy-Saving Chart Display Software
- Visible Energy-Saving Chart Comparative Analysis Software
- Visible Energy-Saving Monitoring Analysis and Management Software
- Visible Energy Management Centre: Alarm Management Software
- Intelligent Control System for Air Compressor Software
- KS Energy Efficiency Management Platform
- Visible Energy-Saving Calculation Formula Software
- KS Fan Water Pump Intelligent Control System software
- Visible Energy Management Centre: Energy-Saving Potential Management Software
- Visible Energy-Saving Data Conversion Software

5.1.2 Why has Visible Corp developed technological capability?

Company's development strategy

Visible Corp's development strategy is to become one of the "Top 100 ESCOs in China" within five years, before 2020. To achieve this goal, company wants to provide comprehensive and professional energy service to customers from various provinces through advanced energy conservation technologies that the company has developed. To this end, Visible Corp also set up a technological capability development strategy, which is "Combined with foreign advanced energy-saving ideas and technology, develop appropriate energy conservation technologies for Chinese energy consumers. Focus on independent R&D and innovation". Visible Corp developed its own proprietary energy conservation technology – a "4W" energy efficiency analysis system –

in 2012 and established its R&D centre in Xi’an city in 2014.

> *“In order to achieve our technological capability development strategy, the company has invested over 8 million RMB in technological capability development. In addition, 70 per cent of the staffs are technical and R&D staff. The company has also built up broad linkages with research institutes and universities in order to get technical support to develop technological capability.” (Senior manager of Visible Corp)*

Improving company’s competiveness

Developing technological capability helped Visible Corp improve its market performance and build up technological advantage. In Beijing, there are nearly 500 ESCOs registered by NDRC. With the promotion of ESCOs, more and more players have entered this market, most of them being SMEs. In addition, the proportion of large and super ESCOs is only about 10 per cent of total ESCOs, but they accounted for approximately 70 per cent of the energy saving market. Hence, market competition is more intensive for SMEs. Developing technological capability is an effective way to compete with small and medium-sized ESCOs. For example, Visible Corp has already mastered several domestic advanced energy conservation technologies and developed its own proprietary technology. Apart from these, Visible Corp has already accumulated some technical knowledge and R&D experience.

> *“As a small-sized ESCO, we currently have no advantages of scale, capital and brand. However, we have technological advantage. Visible Corp was built up based on the energy conservation concept and technology from overseas. Hence, technological*

capability is our key competitive advantage in the industry. Apart from these, technological capability is not easy to be caught up by new entrants." (CEO of Visible Corp)

Government intervention

The Chinese central government and the Beijing local government have established a series of policies and incentives to encourage SMEs to develop technological capability. In addition, the regulations of energy efficiency for high-energy consumption enterprises are becoming incresngly strict. To help customers meet the energy efficiency regulations, Visible Corp has continued to invest in energy conservation technology development. Because the government have not set up separate incentive policies for technological capability development of ESCOs, it is very difficult to compete for incentives with the large high-tech companies or companies with rich R&D experience. Visible Corp does not currently receive any incentives for technological capability development.

"The incentives provided by government are highly dependent on what kind of patents and software copyright are applied for. Due to some limiting factors, Visible Corp has not developed technologies and software that make significant contributions. Hence, the company has not received any incentives for technological capability development. However, we focus on the qualifications issued by government. Because these are reflections and confirmation of the firm's technological capability, this is also one of the important criteria for customer choosing ESCOs." (CEO of Visible Corp)

Visible Corp's development strategy is the most important driver of its technological capability.

Through developing technological capability, the company has built up its technological advantage, which is good for improving its competitiveness in small and medium-size ESCOs. Visible Corp benefited from government's qualifications for ESCOs' technological capability. Nevertheless, Visible Corp has not obtained any incentives for technological capability development. The government's regulations for energy efficiency have pushed Visible Corp to improve its technological capability and develop more effective energy conservation technologies to help customers to meet regulations.

5.1.3 Which factors affect Visible Corp's technological capability development?

Interviews with three key informants and documentary sources revealed 13 key factors that affect Visible Corp's technological capability development. These factors were classified into internal and external factors. Then, according to the conceptual framework, there are four key dimensions: investment, linkage, production, and innovation capabilities for firm's technological capability. The factors affecting these four dimensions were identified and the results are presented in Table 10.

Table 10：Key factors affecting Visible Corp technological capability(“**+**” supportive, “**−**” unsupportive).

Key Factors	Technological capability			
	Investment capability	Production capability	Linkage capability	Innovation capability
Internal				
Company’s financing ability	+			
Company’s market performance	+			
Technical staff		+		
R&D experience				−
R&D investment				−
Personal relationship			+	
Management team	+		+	+
Absorptive capacity		+	+	
External				
Government intervention	+		+	
Suppliers		+		
Research institutes & associations		+		
Customer		−		
Innovation environment				−

According to Table 10, there are eight internal factors and five external factors that affect a firm’s technological capability. Each factor not only affects one dimension, but also affects two or more dimensions of technological capability, either supportive or unsupportive.

5.1.4 How factors affect firm's technological capability

This section describes and explains the factors affecting a firm's technological capability, as perceived by the interviewees. First, four dimensions of technological capability of Visible Corp was explained and then how the factors affect these four dimensions was illustrated separately.

Investment capability

The investment capability of Visible Corp refers to preparing enough funds to investment in technological capability development through a company's profitability and accessing external financial resources. Secondly, the company is able to identify technology opportunities and make appropriate investment decisions in terms of energy conservation projects and technologies. So far, Visible Corp has been successfully financed through the capital market. The total financing amount is 13.5 million RMB. In 2015, annual sales reached 19 million RMB. The investments in technological capability were not fixed annually. From 2010–2015, the total investment in technology transfer and R&D reached over 8 million RMB, and R&D accounted for 60 per cent of the total investment. Visible Corp focused on industrial energy conservation. Therefore, the company focused on investing in industrial energy conservation technologies and projects. So far, Visible Corp has successful transferred and developed three industrial energy conservation technologies as its core technologies. In Visible Corp, the members of management team are all technical experts in energy conservation technology. They are responsible for seeking information about potential energy conservation technologies, potential technology evaluation, and investment decision-making.

According to interviewees' explanations, there are four key factors that affect Visible Corp's investment capability. These four factors all supportively affect the company's investment capability.

Company's financing ability: A company's financing ability refers to its ability to access external financial resources. Visible Corp has built up effective financing channels with commercial banks, such as Minshen Bank, and has been successfully financed through the stock market. Because the return periods of energy-saving projects are normally long, it is very difficult to get bank loans and venture capital. Visible Corp recently applied successfully for a 3 million RMB energy conservation project loan from Minshen Bank. Visible Corp mainly finances through SMEs equity trading platform in order to ensure stable and long-term investment in technological capability development. For example, Visible Corp has successfully financed 13.5 million RMB through equity trading and 30 per cent of the funds have been invested in R&D.

Company's market performance: A company's market performance directly affects its investment capability. Visible Corp' investment in technology transfer and R&D highly depends on the company's profits. Visible Corp has successful implemented 17 small and medium energy conservation projects. The average net profit rate is 25 per cent, which means Visible Corp has enough funds to develop technological capability. Due to relatively good market performance, Visible Corp has the confidence to increase its investment in R&D. The CEO expressed that the company successfully implemented five energy conservation projects in 2014. Therefore, at the end of 2014, the company decided to increase its investment in R&D and built up an R&D centre in Xi'an.

Management team: The management team significantly affects a company's investment capability in terms of accessing external financial resources, obtaining technological information, evaluating technological opportunities, and investment decision-making. Visible Corp has a professional financial advisor who is responsible for financing. The CEO and the director of R&D often take part in activities regarding energy conservation in order to obtain technological information. The CEO of Visible Corp travels to Japan every year to attend the ESCO summit in order to collect and learn new energy conservation concepts and trends. The management team of Visible Corp also makes appropriate decision-making for technological capability development. For instance, from 2011–2012, the management team decided the focus of technological investment is the improvement of existing core technology. In 2014, the management team decided to build up its own R&D department and therefore employed a number of experienced R&D staffs. In 2014 and 2015, management team decided to focus on new energy conservation technology transfer in building energy conservation.

Government intervention: The Chinese Government has promoted ESCO and EPC concepts to the whole society. It has especially encouraged commercial banks to collaborate with ESCOs and provide loans to EPC projects. Taking advantage of these interventions, Visible Corp could obtain a loan for an EPC project, which would indirectly help the company reduce its financial pressure and improve its ability to investment in technological capability. In addition, the government provided a SMEs equity trading platform, which enables Visible Corp to obtain an effective long-term financing channel to obtain financial support. Moreover, the government reduced a 6 per cent tax in terms of energy-saving projects, which increases the firm's profits and indirectly improves its investment capability.

Production capability

The interviewees indicated that Visible Corp mainly provided energy-saving consultations and energy-saving solutions through its energy management system. The company mainly provided energy conservation projects. The tangible products or equipment used in the energy-saving projects were purchased from renowned suppliers directly such as Omron, Schneider and Mitsubishi Electric. These products and equipment are standard, such as sensors, meters, and inverters. Unlike the manufacturing industry, Visible Corp does not have a large amount of manufacturing equipment and inventory, which need to be operated and maintained. Based on the characteristics of Visible Corp, its production capability mainly refers to absorb transferred technologies. The company takes advantage of absorbed and independent developed energy conservation technologies and professional knowledge in energy evaluation and auditing to help customers evaluate energy-saving potential, design energy conservation projects, and implement, monitor and maintain projects during the contract period. Normally, energy conservation projects are customized according to customers' requirements and contexts. Therefore, the main inputs include energy conservation products, energy efficiency analysis and management system, and technical staffs. Apart from these, customers play an important role in production capability. Customers undertake projects' daily operation and maintenance based on the designed management and operation programmes.

Technical staff, absorptive capacity, suppliers and research institutes and associations are supportively affective Visible's production capability. However, customers' knowledge capture is a key factor unsupportive to company's production capability. To date, the level of capability of Visible Corp is inefficient to produce a positive impact.

Technical staff: Technical staff, as one of the main inputs in production, significantly affects Visible Corp's production capability. Visible Corp has 15 experienced technical staff, who are responsible for absorbing technologies and designing and delivering energy conservation projects to customers. The most important role of technical staff is training customers how to operate and maintain the entire system. Taking advantage of experienced technical staffs and standardised programmes, technical staff can deliver projects effectively.

> *"In order to ensure the effectiveness of training, the company conducts staff training in energy technology knowledge and communication skills and has developed manuals and courses for customers. Technical staff will provide training courses to customers according to the designed program." (Vice manager of Visible Corp)*

Absorptive capacity: A company's absorptive capacity positively affects its production capability. Visible Corp has successfully absorbed seven domestic energy conservations technologies and one international energy conservation technology. It has also undertaken improvements to such absorbed energy conservation technologies as natural cold sources utilisation technology and cold storage technology. Visible Corp has five years' experience in technology absorption and improvement. Its absorptive capacity is particularly strong in areas of air conditioning retrofitting and energy efficiency analysis. The CEO indicated that Visible Corp's strong absorptive capacity is good for absorbing transferred technologies effectively and increasing technology accumulation, which provides more comprehensive energy conservation solutions for more customers.

Suppliers: Suppliers affect Visible Corp's production capability positively. To deliver energy conservation projects, besides energy efficiency analysis and management system and intensive technical staffs input, certain tangible products are necessary, such as LED lights, frequency converters and sensors. Visible Corp does not produce these products so it purchases them from reliable and well-known suppliers such as Omron, Schneider, Philips and Mitsubishi Electric. For example, in terms of industrial energy conservation projects, a large amount of sensors and frequency converters will be used in a project. In order to ensure the quality and reliability of its projects, Visible Corp purchases sensors from Schneider and frequency converters from Mitsubishi Electric.

Research institutes and associations: Research institutes and associations affect Visible Corp's production capability when it improves its energy conservation technologies and designs energy conservation projects. For example, when Visible Corp wanted to improve its Visible Energy Management system and increase its functionality, an expert from Tsinghua University suggested adding cloud technology to the existing energy management system. Visible Corp could collect and analyse different users' energy consumption data in the same industry and provided industrial standard reference energy consumption. Based on this suggestion, Visible Corp independently developed an Energy Management System Cloud Platform. However, the impact of research institutes and associations for production capability is limited for Visible Corp.

Customer: Customers undertake the daily operation and maintenance of energy conservation projects. The technical staff of Visible Corp arranged visual energy saving concept training, system operation training and energy efficiency analysis method training for customers. However, the customers' abilities regarding knowledge capture are different. So far, about 60 per cent of the company's customers have been small and medium-sized traditional manufacturing enterprises, whose staff lack of energy efficiency awareness and education. For example, Visible Corp implemented an energy conservation project for a medium-sized iron and steel manufacturing company in Hebei in 2014, whose workshop staff had only graduated from junior high school. Therefore, Visible Corp extended its training time from three days to five days and the company's technical staff stayed with customers for two weeks for monitoring and advising. Despite this, issues also arose because of operational errors.

Linkage capability

In terms of Visible Corp's linkage capability, the interviewees indicated that Visible Corp built up broad linkages with research institutes, government departments, EMCA, competitors, customers and suppliers in order to transfer technology/knowledge and provide technical support and consultations. There are main two types of linkages: formal linkages and informal linkages. Formal linkages were built up through purchasing contracts and collaborative agreements. Informal linkages were highly dependent on personal relationships, known in China as "Guanxi". Through purchase contracts, collaborative agreements and equity acquisition, Visible Corp built up formal linkages with suppliers, customers, and competitors. Linkages with research institutes and government departments were considered informal linkages.

Generally, it is easy to transfer technology/knowledge and leverage resources through formal linkages. However, informal linkages are also very important. Visible Corp transferred its core energy conservation technology through licensing from a Japanese ESCO. The CEO also invited the developer of this technology to come to China for two weeks to introduce technology. The company also transferred some air conditioning retrofit technologies through an acquired competitor. Technical staff of Visible Corp were sent to the acquired company for one month to work with technical staff from the acquired company together to absorb transferred technologies. The company has built up informal linkages with Tsinghua University and the Chinese Academy of Science, and the Energy Saving and Environment Protection Centre in order to obtain technical supports and consultations.

Four key factors affect a company's linkage capabilities, according to interviewees: personal relationship, management team, government intervention and absorptive capacity.

Personal relationship: "In China, personal relationship plays an important role in any social activities" (vice manager of Visible Corp). The CEO and vice manager of Visible Corp have good personal relationships with some research institutes and government department, such as Tsinghua University, the China Academy of Science and the Beijing Energy Saving and Environment Protection Centre. Taking advantage of personal relationship, Visible Corp built up informal linkages with these institutes. For example, when Visible Corp developed its "4W" Energy efficiency analysis and management system, a professor from the Department of Computer

Science at Tsinghua University provided suggestions for software architecture. However, Visible Corp has not yet conducted any formal collaboration with research institutes and associations in terms of technology development.

Management team: The management team positively affects a company's linkage capability. Visible Corp's management team prefers to build up linkages with external actors. In addition, the management team is good at maintaining these linkages. Particularly, the CEO and vice manager of Visible Corp build up informal linkages through attending activities related to energy conservation and ESCO. At the same time, the management team is good at increasing the company's visibility through television interviews and charitable activities.

Government intervention: Government encourages inter-firm communication and collaboration through conference organisation and EMCA, which holds an energy saving technology and green technology conference in Beijing every year. This provides an opportunity for ESCOs to learn about domestic and international advanced energy saving technologies and products. At the same time, it provides opportunities for ESCOs to communicate and build up informal and formal linkages. In addition, the website of EMCA also updates the recent technologies and products of member companies. Through conference held by EMCA in 2013, Visible Corp built up linkages with a competitor that it later acquired in 2015.

Absorptive capacity: After five years of technology absorbing, improving and innovation, Visible Corp has already built up its absorptive capacity, which means that it is able to absorb technology and know-how through linkages. However, Visible Corp's absorptive capacity was built up based on prior knowledge and Visible Corp's intensive efforts in an energy efficiency analysis system. Therefore, the absorptive capacity is limited for Visible Corp.

Innovation capability

Visible Corp focuses on innovation capability development. The firm built up its own R&D department in Xi'an and employed a PhD as director of this R&D department. Visible Corp focused on improving transferred technologies and developing its own proprietary technologies through independent R&D. Visible Corp currently has one utility model patent and 12 software copyrights (introduced in section 5.2), which means that the certainly has innovation capability. According to data collected from interviews, there are five key factors that Visible Corp's innovation capability positively or negatively. These are discussed below.

R&D experience: R&D experience was deemed as a key factor that negatively affects a company's innovation capability. Visible Corp started its R&D at the end of 2012, meaning it had approximately four years of R&D experience as of the time of this study. Initially, Visible Corp's main R&D activities were improving absorbed mature energy conservation technologies. However, due to the lack of knowledge about energy conservation, R&D staff still lack the R&D experience necessary to develop advanced energy conservation technologies through independent R&D. The R&D department still focuses on improving the “4W” energy efficiency analysis and management system.

R&D investment: The director of R&D believed that R&D investment is another key factor limiting the company’s innovation capability. From 2014–2015, Visible Corp invested approximately 8–10 per cent of its annual sales in R&D. However, the annual sales of Visible Corp in 2014 and 2015 were 15 million and 19 million RMB, respectively, which means the investment in R&D was only about 3 million RMB. The director of R&D expressed that the investment in R&D is still small, especially for new technology development, meaning that stable and long-term investment is necessary. Visible Corp is going to develop new energy conservation technologies in industrial energy conservation. The limited investment in R&D become one of key factors affecting this. The R&D centre was built in Xi’an, also because of the cost. While it is easier to recruit experienced and skilled R&D staff in Beijing than in Xi’an, the cost of labour is two to three times higher in the capital.

Management team: The management team of Visible Corp set up an explicit technological development strategy: “Focus on independent R&D efforts to become an innovator in energy-saving industry”. The management team allocated advantage sources into the R&D department. The management team focused on incremental innovation at the current stage to improve existing technology. The CEO of Visible Corp expressed that the management team decided to try to conduct radical innovation to develop advanced energy conservation technology through collaborative R&D with Tsinghua University.

Innovation environment: Governments have actively encouraged and promoted innovation but also created an innovation environment for enterprises. Under such circumstances, Visible Corp is willing to attempt innovate; however, the CEO expressed that there are still a lot of deficiencies in the existing innovation environment.

> *"Governments' support for innovation to SMEs is not sufficient. In terms of SMEs, it is very hard to conduct radical innovation. Most of the innovations are incremental. Nevertheless, the incentives of innovation focus on radical innovation. Secondly, in China, most R&D personnel are in universities and research institutes. It is very difficult for SMEs to conduct collaborative innovation or R&D with universities and research institutes. Finally, the effective investment in innovation of energy-saving technologies is rare." (CEO of Visible Corp)*

5.1.5 How has Visible Corp developed its technological capability?

Visible Corp has made efforts to develop its technological capability and to be an innovator in the energy conservation industry. This section illustrates the main process of technological capability development of Visible Corp. Visible Corp currently implements energy-saving projects based on its core energy-saving technology – the Visible energy management centre and a series other technologies – which were developed based on the Visible energy management concept. Figure

24 was created based on interviewee' descriptions and shows the main process of technological development.

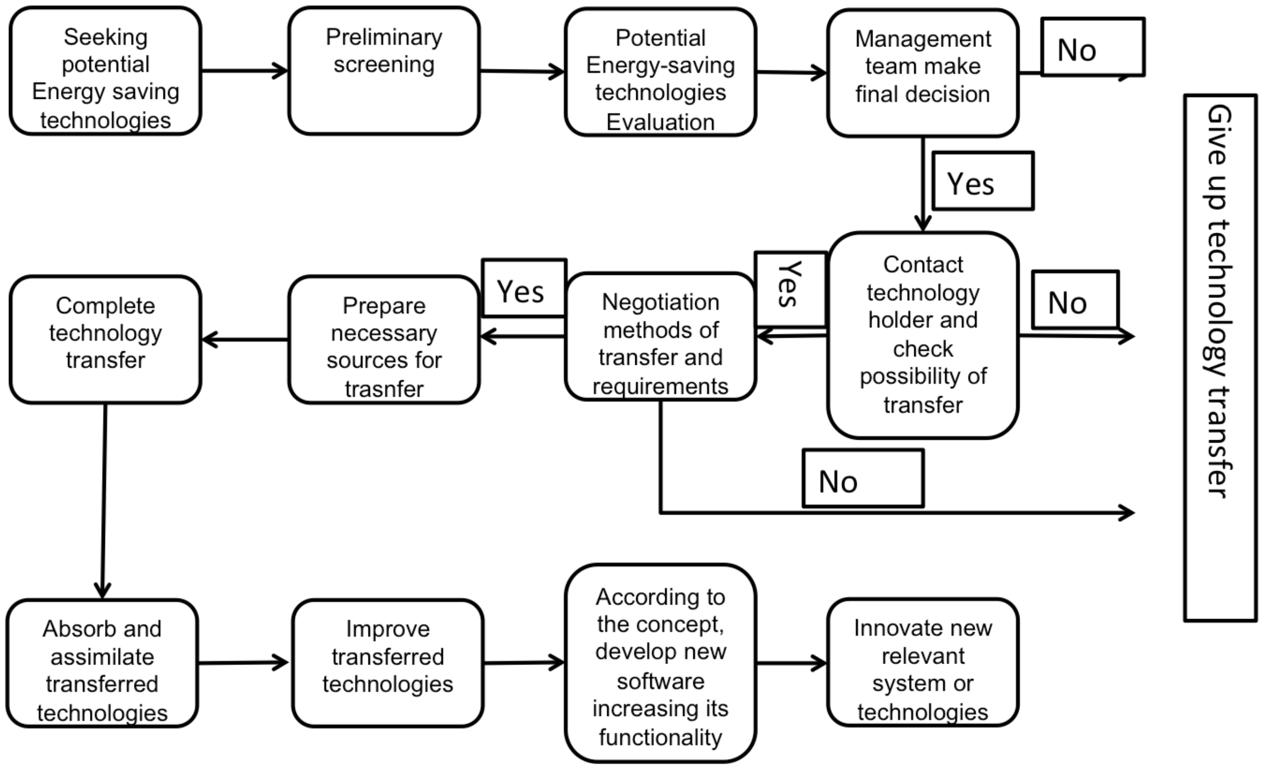


Figure 24: Process of technological capability development of Visible Corp.

The interviewees described and explained the process of the company's core technology development. There were three main phases: (1) seeking and obtaining, (2) absorption and assimilation, and (3) improvement and innovation.

Phase 1: Seeking and Obtaining

During the CEO's study period in Japan, she focused on energy-saving technologies through participating in activities relevant to energy-saving technologies, ESCOs, and energy efficiency and environment protection. In one event, the CEO learnt about Visible energy management technologies and had a conversation with the developer of this technology, a Mr Datingkangyan. Through the conversation, the CEO learnt more about the "Visible energy saving concept and the management system". She then brought this new concept and basic information about this technology to China and consulted experts from the Beijing Energy Saving Centre and Tsinghua University. According to experts' consultations and preliminary assessment, the Visible energy-saving management system is not only a new energy-saving concept in China but also an advanced energy-saving technology. Experts believed that this technology could be widely applied in Chinese energy-saving area.

After obtaining suggestions from experts, the CEO went back to Japan and made contact with Mr Datingkangyan. After several communications, Mr Datingkangyan agreed to transfer this technology to China through a licensing agreement. The CEO expressed that:

> *"At that time, the company had not been founded. After Mr Datingkangyan agreed to transfer this technology, I went back to China and founded Visible Corp. Due to the business having just started, there was not much money. Obtaining the technology through a licensing agreement was the most safe and appropriate way for me."(CEO of Visible Corp)*

Phase 2: Absorption and Assimilation

After the CEO brought the Visible energy management technology back to China, she organised a technical team to learn and absorb this technology. However, the firm and technical team were too young to conduct technology absorption. So, the CEO went back to Japan again and invited the developer of Visible Energy Management as a distinguished expert. In this way, Visible Corp absorbed and assimilated the technology rapidly. The technology was also adjusted according to the Chinese energy users' context and applied in an energy-saving project.

Phase 3: Improvement and Innovation

The Visible Energy Management Technology was a mature technology in Japan at the time. However, the CEO thought the Visible energy-saving concept was advanced in comparison with technologies in use in China at the time and had the potential to expand and improve. In order to further strengthen the company's technological capability and further improve existing energy-saving technologies, the CEO invited a PhD with R&D experience to join the company and built up an R&D department in Xi'an to conduct independent R&D. Through integrating software development and technology, Visible Corp developed a "4W" Energy efficiency analysis system and an energy management cloud system. Before new R&D projects started, the CEO had consulted with experts for suggestions.

Apart from these three phases, Visible Corp has also tried to obtain some domestic mature energy-saving technologies in other energy-saving area in order to enrich its product and service portfolio and strengthen its technological capability.

“We have been looking for new potential energy-saving technologies from Japan and China. In order to provide comprehensive energy-saving solutions to different industries, rich technology accumulation is necessary. It is impossible for Visible Corp to increase this through independent R&D and innovation because our R&D and innovation capability are so limited.” (Director of R&D)

5.1.6 Summary

This chapter has presented and discussed the analysis and results of the Visible Corp case study. Thirteen key internal and external factors affecting Visible Corp’s technological capability have been identified according to interviewees’ considerations. According to the conceptual framework, these factors separately affect four dimensions of the firm’s technological capability.

In terms of motivations for technological capability development, the main drivers for Visible Corp to develop its technological capability are its development strategy, improving its competitiveness and government intervention. The company’s development strategy and improving its competitiveness are the most important motivations driving Visible Corp’s technological capability development. Government intervention provides the motivation for Visible Corp to develop its technological capability.

Conceptual framework

Dimensions	Internal factors	External factors
Investment capability Production capability Linkage capability Innovation capability	Company size Finance ability Profitability ability Organizational structure and policy Absorptive capacity R&D Prior knowledge Company's strategy Management capability	Financial institutions Research institutions and associations Customer Supplier Partner Competitors Government policy Regulation environment

Factors affecting Visible Corp's four dimensions of technological capability

Dimensions	Internal factors	External factors
Investment capability	Company's financing ability Company's market performance Management team	Government intervention
Production capability	Technical staff Absorptive capacity	Research institutes & associations Supplier Customer
Linkage capability	Personal relationship Management team Absorptive capacity	Government intervention
Innovation capability	R&D investment R&D experience Management team	Innovation Environment

Figure 25: Factors affecting Visible Corp's four dimensions of technological capability.

Visible Corp has strong focus on its investment capability development. Its investment capability was affected by four internal and external factors: the company's financing ability, market performance, management team, and government intervention supportively. Through building up investment capability, Visible Corp established R&D centre and conduct innovation activities. Therefore, Investment capability facilitates company's current production and investment capabilities.

Visible Corp doesn't pay much attention to its production capability. Its production capability is in a line with company's size. Technical staff, absorptive capacity, suppliers and research institutes and associations supportively affect its production capability. However, the existing customer is deemed as an unsupportive factor. Through improving production capability, Visible Corp not only raises its capital for investment but also accumulated knowledge for incremental innovation.

Visible Corp is willing to establish linkages with broad organizations. Its linkage capability is supportively affected by government intervention, personal relationship, management team and absorptive capacity. However, its linkage capability is in nascent stage, which means that Visible Corp's linkage capability doesn't play significant role in development of other three dimensions of technological capability.

Visible Corp's innovation capability is affected by four key factors: R&D experience, R&D investment, innovation environment, and management team. Its innovation capability facilitates its production capability directly.

In terms of the process of Visible Corp's technological capability development, the company basically followed a "classic model", which refers to acquisition, absorption, and assimilation and further improvement. However, Visible Corp has invested a lot in building its innovation capability through setting up an R&D department, employing a number of R&D staff, and conducting a large amount of incremental innovation.

Section 5.2 will present the data analysis and results of another small ESCO case study:

East-Bay.

5.2 Case study of Qingdao East-Bay New Energy Co. Ltd.

5.2.1 Company background

Company profile

Qingdao East-Bay New Energy Co. Ltd (referred to as East-Bay in this thesis) is a small private ESCO that was founded in 2010 by its chairman. East-Bay is a professional ESCO that focuses on high-powered LED integrated packages, the design and sale of LED lighting products, and energy-saving lighting retrofits. The headquarters of East-Bay are located in Qingdao, an eastern coastal second-tier city in China. In order to better serve customers and expand its market, East-Bay set up branches and customer service offices in Beijing, Shanghai, Yixing, Mianyang, Hong Kong and Dongguang. Its business and services mainly cover the eastern coastal area of China.

East-Bay's registered capital is 10 million RMB and it employs 38 people, 20 of whom work at the headquarters in Qingdao. The headquarters mainly consists of the Marketing, Engineering, Design and Finance Departments. There is one general manager and a vice manager, who are responsible for management and operation of the company. The chairman of East-Bay is responsible for marketing and social network building. The organisational structure is simple, but the division of responsibilities is not explicit; the management is relatively loose. In 2015, the total revenue of East-Bay was approximately 9 million RMB. East-Bay is not a LED manufacturer but, through equity acquisition, became a shareholder of a local LED product manufacturer. Currently, all of the LED lighting products for sale all provided and manufactured by this partner enterprise.

Qingdao East-Bay is registered by NDRC. Having undergone five years of development, albeit without any significant development in company size, East-Bay has successfully implemented 24 LED lighting retrofit and construction projects. The company's main customers are local governments. Nineteen of the projects were medium-sized and large public facilities and commercial building energy-saving lighting retrofit and construction projects. Table 11 lists the main energy-saving projects conducted by East-Bay.

Table 11: Main energy-saving projects implemented by East-Bay.

Projects	**Energy-saving area**	**Main products and services**
Qingdao Zhongtie Centre	Commercial building Energy-saving lighting construction	Lighting design and construction; LED lighting products
Qingdao Ocean University	Campus and building exterior lighting retrofits	High-power LED lighting products and solar LED lighting products
Zhejiang Huzhou changdao park	Public facilities energy-saving lighting retrofit	Lighting design; solar LED lighting products and normal LED lighting products
Xi'an Ancient City	Public facilities energy-saving lighting retrofit	Lighting design, Solar LED lighting and normal LED lighting products
Wuhan Qingshan Peace Park	Public facilities energy-saving lighting retrofit	Lighting design, Solar LED lighting and normal LED lighting products
Jiangsu Wuxi Xihui Park	Public facilities energy-saving lighting retrofit	Lighting design, Solar LED lighting and normal LED lighting products
Dongguan Renmin Park	Public facilities energy-saving lighting retrofit	Lighting design, Solar LED lighting and normal LED lighting products
Dongguan Humen Park	Public facilities energy-saving lighting retrofit	Lighting design, Solar LED lighting and normal LED lighting products
Qingdao Wusi Square	Public facilities energy-saving lighting retrofit	Lighting design, Solar LED lighting and normal LED lighting products; High-power LED lights
Qingdao Sea Bridge	Public facilities energy-saving lighting construction	Lighting design; high-power lighting products
Shangri-La Hotel, Qingdao	Commercial building internal and external lighting retrofit	Lighting design; high-power lighting products and normal LED lighting products

East-Bay's main business is providing comprehensive energy-saving lighting solutions to customers, but it prefers to implement energy-saving lighting design, construction and retrofit projects for public facilities. Through energy-saving lighting projects implemented within five years, East-Bay accumulated rich experience in terms of lighting design, construction and retrofit. The energy-saving lighting projects is a complex process, because East-Bay not only just provide LED lighting products and service of construction and installation, but also overall and partial lighting design, which takes into account style, energy efficiency and function. Figure 26 shows the general process of an energy-saving lighting project.

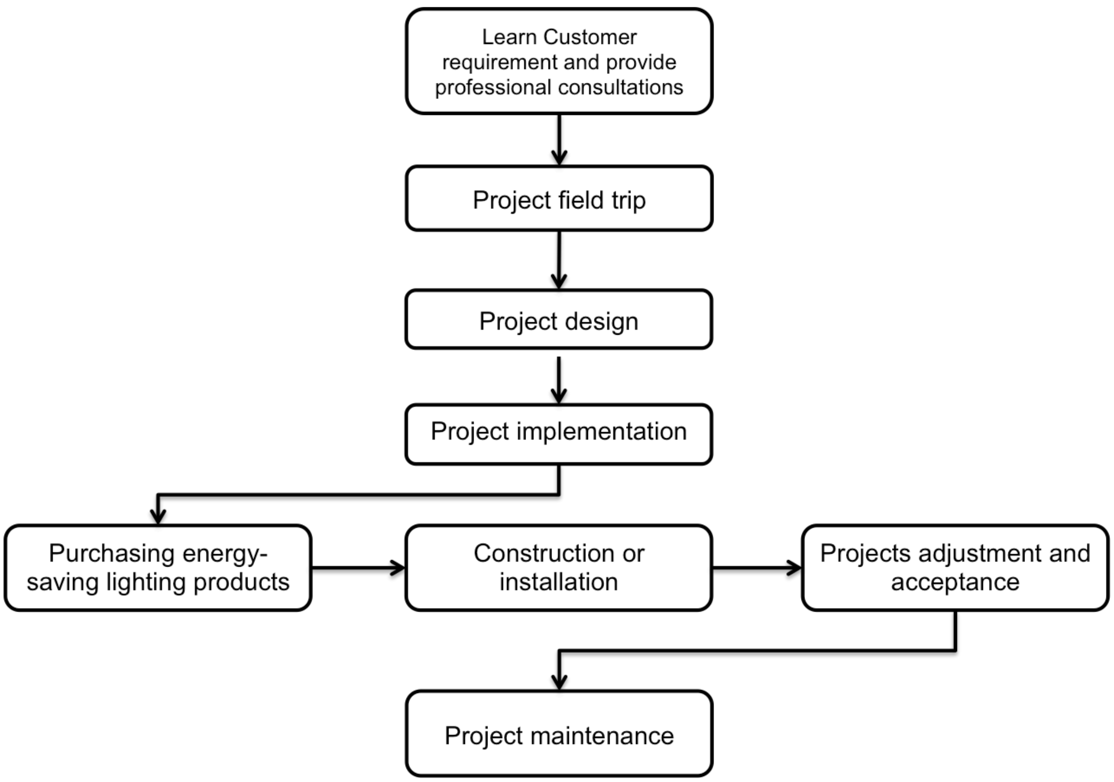


Figure 26: General process of an energy-saving lighting project.

The process of an energy-saving project mainly involves five categories of products: consultation, project design, provision of energy-saving products, construction and installation of energy-saving lighting projects, and maintenance. Two departments of East-Bay, the Design Department and the

Engineering Department, are responsible for project design, energy-saving projects preparation, construction and installation, and maintenance.

Company's technological capability

East-Bay does not have any LED products production technologies. At the same time, unlike some ESCOs, East-Bay has not developed an energy management system, focusing solely on energy-saving lighting projects. Its technological capability is mainly reflected in two aspects: lighting product design and lighting project design. In terms of the former, East-Bay focuses on products' exterior design. Through design, it increases its lighting range, decreases lighting energy wastage, and further improves energy efficiency. In terms of overall lighting project design, the company focuses on a project's overall plan and layout. Generally, projects need to satisfy four requirements: illumination, style, energy efficiency, and stability and reliability. East-Bay currently has a design department that consists of eight staff; four are responsible for product design and the other four are responsible for lighting project design. However, all of the staff members in the design department usually communicate with each other because lighting project design sometimes requires product design to support. In terms of project design, East-Bay also relies heavily on technical support from one local university. Through service contracts, the university provides project design services to East-Bay.

Apart from this, the technological capability of East-Bay is also reflected in relatively comprehensive and domestic advanced lighting products used in China. East-Bay currently provides 50 kinds of lighting products, which can be used in interior and outdoor lighting, private, public and commercial lighting. All of the products are divided into eight series and the main products include LED bulbs, LED fluorescent lamps, LED fluorescent tubes, LED ceiling lamps, LED track lights, LED spotlights, LED downlights, LED bucket lights, LED PAR lamps, and other series of LED energy-saving lamp. The main lighting technologies used in these products include LED lighting technology, secondary imaging lighting technology, imported COB lighting technology, and imported CREE LED technology, The interviewees indicated that the core LED lighting part – light-emitting chips – were imported from international companies from the United States and Japan. Some LED lighting elements were purchased from large domestic LED manufacturers. East-Bay and its partner do not yet have core LED lighting technologies.

East-Bay's technological capability relies heavily on its partner's technological capability. East-Bay has built up a long-term collaboration with Qingdao Ocean University and had a collaborative contract for lighting products and project design. In addition, through equity acquisition, East-Bay built up a linkage with an LED lighting product manufacturer in Qingdao that had nearly 10 years of LED lighting product production experience and 150 staff. The partner LED manufacturer has its own R&D department and has undertaken R&D activities for couple of years. However, not all of the R&D activities were relevant to core LED lighting technologies. Apart from these, this manufacturer strictly enforces the IS09001: 2008 international standard quality management system.

5.2.2 Why has Easy-Bay not developed technological capability?

According to the interviewees' explanation and direct observation, East-Bay does not have a strong willingness to develop its technological capability; this section will examine why this is the case.

The interviewees indicated that East-Bay does not currently have strong technological capability. East-Bay is not a LED lighting product manufacturing enterprise; its main business is LED product sales. Hence, the company does not have LED lighting products manufacturing technologies. Secondly, the products provided by East-Bay do not have obvious technical advantages. Finally, East-Bay is a small ESCO with just five years of business experience, which means it is very risky to invest in technological capability development.

The interviewees expressed that East-Bay's lack of willingness to develop technological capability is due to its current business strategy, core competitive advantage and strong governmental policy support.

Current business strategy: East-Bay's main current businesses are LED lighting product sales and energy-saving lighting construction and retrofit. The company has focused on the local market.

East-Bay does not have plans to expand its business to other energy-saving area and other regions in China. So far, 70 per cent of its customers have come from the Shandong province. The vice manager expressed that there is no significant requirement for technological capability development. We focus more on marketing and relationship building. Therefore, every year, there is a fixed fund for customer relation maintenance.

Company's core competitive advantage: Technological capability is not actually considered the company's competitive advantage at present. East-Bay's competitive advantages are local brand awareness, rich experience of energy-saving lighting projects' implementation and good relationship building.

> *"So far, the ESCOs that provide energy-saving LED lighting projects have similar LED lighting products. There are no significant differences in products' quality and technology with similar prices. The existing products could satisfy customers' requirements. Hence, ESCOs' brand awareness, price, and project experience become serious considerations. Apart from this, our main customers are governments and commercial entities. Therefore, good relationship building with customers is also considered an more important advantage." (Manager of East-Bay)*

Strong governmental policy support: In recent years, local government has made efforts to promote energy efficiency, energy saving, and ESCOs. Under these circumstances, it is easy to ignore the importance of technological capability. The East-Bay manager indicated that due to high subsidies for energy conservation to energy users who implemented energy-saving projects, customers also ignore the consideration of ESCOs' technological capability, especially given that the technical difference of LED lighting products is not significant. Apart from this, there is currently no specific regulation for lighting energy consumption. Government just called the commercial buildings and public facilities to implement energy-saving lighting retrofit.

5.2.3 Which factors affect the company's technological capability development?

The interviewees indicated that 10 key factors affect East-Bay's technological capability development. Seven internal factors and three external factors affect East-Bay's investment, production, linkage and innovation capabilities.

Table 12: Key factors affecting Easy-Bay's technological capability ("**+**" Supportive, "**−**" Unsupportive).

Key Factors	Technological capability			
	Investment capability	Production capability	Linkage capability	Innovation capability
Internal				
Company's financing ability	−			
Company's market performance	−			
Technical staff	−	+		
Design department				−
R&D investment				−
Personal relationship			+	
Management team	−	+	+	−
External				
Government intervention			+	
Research institutes & associations		+		+
Supplier		+		−

5.2.4 How factors affect firm's technological capability

This section illustrates the specific factors that affect the investment, production, linkage and innovation capabilities of East-Bay, based on the interviewees' explanations.

Investment capability

East-Bay's investment capability mainly refers to its abilities to obtain enough financial resources from external financial institutes and use its own capital and external funds to invest in its production capability. Apart from these factors, the company's investment capability is also reflected in its ability to recognize potential LED lighting technologies and products and make appropriate investment decisions in order to purchase appropriate LED lighting products and employ high-quality technical staff for project design and implementation. Currently, East-Bay relies mainly on private capital and bank loans for investment, although bank loans only account for approximately 7 million RMB. Apart from this, East-Bay has not built up other financing channels. The main investment in technological capability is technical staff recruitments. East-Bay has not acquired and developed any LED lighting technologies. In addition, the company's technical staffs are responsible for recognising and evaluating potential LED products. In order to complete this job, East-Bay employed two electrical engineers. So far, investment capability of East-Bay is limited.

East-Bay's investment capability is affected by four key factors, all of which unsupportively affect the company's ability and willingness to invest in technological capability development.

Company's financing ability: East-Bay's major financing method is currently bank loans, but only small parts of projects can apply for loans from commercial banks. Therefore, East-Bay must use its own capital to invest energy conservation projects. The investment in projects consumes a lot of funds – about 60 per cent of total assets. Thus, given the limited ability to finance from external financial institutes, the company's funding has been scarce and it has not had enough money to invest in technological capability development. In 2014 and 2015, East-Bay could only invest 200,000 RMB in new product design.

Company's market performance: East-Bay has successfully implemented 24 small and medium energy-saving lighting projects. However, due to cross-profits, the rate of energy-saving lighting projects is only about 35 per cent, which is lower than industrial energy conservation projects and means the profitability is not very good. Thus, in 2015, East-Bay only implemented two small energy-saving lighting projects and sales of LED lighting products decreased by 35 per cent compared with 2014. Accordingly, East-Bay has had minimal willingness to invest in technological capability.

Technical staff: East-Bay has four technical staff members responsible for identifying and evaluating energy-saving products. All of these technical staff are university graduates with minimal work experience. The manager expressed that when their technical staffs identified LED lighting products, they only focused on a series of technical parameters of the products, such as illumination, product life and energy consumption. However, price, product appearance, product working environment and customers' requirements also need to be considered. Normally, experienced technical staffs will comprehensively consider all the factors based on their work experience and projects' characteristics. So far, the technical staffs from East-Bay lack such experience.

Management team: The management team is responsible for product portfolio, product purchase, resource allocation and investment decision-making. The target markets of East-Bay are public and commercial facilities. Hence, the product portfolio mainly consists of LED lighting products that are used outdoors. In addition, the core department of East-Bay is the design department; accordingly, the design department was allocated the most technical staff and capital resources. There are 20 employees working for East-Bay, of which eight technical staff work in the Design Department. Because the management team has not had any ambition to expand the business and develop technological capability, there has been very little investment in technological capability.

Production capability

East-Bay focuses on develop its production capability. East-Bay's production capability of East-Bay mainly reflects three aspects: providing appropriate project design, providing appropriate and quality energy-saving lighting products, and providing effective and quality project implementation and maintenance. To ensure these, firstly, East-Bay has professional and experienced technical staff for project design and technical supports for technical design from the local university. Secondly, East-Bay has chosen good-quality and appropriate LED lighting products according to different uses of different environments from domestic and international LED lighting brands like Philips, OSRAM, Nichia and Cree. Finally, East-Bay carries out strict construction quality management and uses experienced and qualified staff for project implementation. In order to help customers maintain the projects, East-Bay has built up service offices in several cities in eastern China.

The following four key factors supportively affect East-Bay's production capability.

Technical staffs: In terms of project implementation and maintenance, East-Bay employs experienced technical staff to supervise and guide the construction and maintenance of projects during the contract period. When East-Bay started its business, it employed four technical staff who had at least five years of experience in project implementation. The company then employed another six technical staffs for project implementation and maintenance. After three years' training, all of the technical staff have at least three years experience of project implementation. The project manager of East-Bay stated:

> *"We focus on the quality and training of technical staff because they directly affect the quality and effectiveness of project. So far, our technical staff have rich experience in small and medium-sized lighting energy conservation projects."(Manager of East-Bay)*

Management team: The management team of East-Bay have adopted a series of measures to ensure the quality of projects.

1) Strictly control the quality of procurement products.
2) Formulate construction standards and execute them strictly.
3) Hire a qualified construction team and provide short-term training.
4) Provide real-time supervision and guidance.

5) Make timely return visits and checks.

Research institutes and associations: East-Bay received technical supports for project design through a service contract with the local university. For some medium-sized energy saving projects or projects with high design requirements, East-Bay normally asks the university to undertake the project design. For example, when East-Bay undertook a lighting energy-saving project for a 1.5 km long tunnel, the customer proposed a higher energy-saving requirement, meaning that East-Bay had to meet the requirement of lighting while reducing the quantity of energy-saving lighting products. Professors from the university helped East-Bay complete the project design. Through painting the wall of tunnel with special reflective material and adjusting angle of exposure, the quantity of lighting products was reduced by 15 per cent.

Suppliers: The suppliers of East-Bay provides some conventional and standard LED lighting products. In order to reduce the cost, the partner provides some LED lighting products; therefore, whether the partner can produce quality products directly affects East-Bay's production capability. The partner is a qualified LED lighting products manufacturer with 15 years of lighting product production. Moreover, the partner strictly applies the IS09001: 2008 international standard quality management system.

Linkage capability

East-Bay didn’t established broad linkages with external organisations. However, East-Bay built up formal linkage with China Ocean University through a collaborative service contract. Besides providing a consultation service, the university also helps the firm’s project design. In addition, East-Bay created linkage with its partner, a LED lighting product manufacturer, through equity acquisition. Now East-Bay has taken 20 per cent equity of that manufacturer. The formal linkages started from personal relationships between the chairman of East-Bay and external actors. Taking advantage of these formal linkages, East-Bay leveraged design capability from Ocean University and LED lighting product production capability from the partner manufacturer. According to the interviewees’ explanations, the linkage capability of East-Bay was affected by two key factors: company size and personal relationships.

Personal relationship: To date, the formal linkages that East-Bay has built up have been highly dependent on the chairman’s personal relationships. Both formal linkages were transformed from informal linkages that were built up by personal relationships. Before East-Bay built up a formal collaborative linkage with China Ocean University, the firm had experienced a long period of establishing and maintaining its informal linkage with the university. East-Bay even rented an office building inside the university as its headquarters.

> *“East-Bay has limited ability to build up linkages with a large LED product manufacturer. Our partner is a medium-sized manufacturer and its owner is our chairman’s friend. In order to collaborate effectively, the owner of our partner*

> *agreed to sell 20 per cent of equity and we became a shareholder of a LED lighting product manufacturer. We can leverage the partner's factory to produce LED lighting products designed by ourselves." (Manager of East-Bay)*

Management team: The management team has focused on creating and maintaining linkages. Every year, the management team allocates part of funds for linkage maintaining. The chairman and manager of East-Bay often visit customers, partners and professors from university in order to maintain good relations with them.

Government intervention: Local government encourages the local university to collaborate with local companies in order to help local companies with their production and innovation. Therefore, East-Bay has the opportunity to build up formal linkage with local university and obtain long-term technical support. The manager expressed that even though the chairman has good relationship with professors at the university, building up formal linkages with the university would involve obtaining consent from university management. Government's appeals have helped East-Bay obtain this consent.

Innovation capability

East-Bay is not a manufacturer and nor is it a ESCO that has its own energy management system. Hence, East-Bay does not have technologies for LED lighting product production or advanced energy-saving technologies. East-Bay conducted energy-saving projects based on mature LED lighting technologies and products. In terms of innovation capability, East-Bay has undertaken some product and project design, but its investment in innovation capability has been very limited. The company only has a small design department, with eight employees. In terms of product and project design, especially project design, East-Bay obtained strong technical support from the local university. Therefore, East-Bay has relative weak innovation capability.

Five factors seriously affect East-Bay's innovation capability, and four of these negatively affect the company's innovation capability. Only research institutes and associations positively affect the company's innovation capability.

Design department: In East-Bay, only the design department has undertaken some innovation work related to product and project design. The design department of East-Bay is small and has limited ability to innovate. Even though the design department completed the design of several new products, none of these new products have achieved the standards necessary to apply for patents.

R&D investment: The investment in product design is not fixed and is minimal. From 2010–2013, the company invested about 300,000 RMB in new product design. From 2014–2015, the company further reduced its investment in product design. Approximately 200,000 RMB has been used in designing new products.

Management team: The management team does not believe that developing or improving innovation capability is important to the company at this stage. Hence, the firm has not allocated many resource to building or developing innovation capability. The manager revealed that developing innovation capability is a long journey for East-Bay. Intensive competition and an unstable market have made East-Bay reluctant to make long-term investments.

Research institutes and associations: In terms of product and project design, China Ocean University has provided consultations and technical supports to East-Bay. This technical support has involved technical experts, advanced product design software and a laboratory. The manager provided an example about the Qingdao Lao mountain tunnel energy-saving lighting retrofit:

> *"Normally, when designing a tunnel energy-saving lighting project, an ESCO will replace LED energy-saving lighting products to achieve energy saving because the main features of LED lighting products are high illumination, long product life and low heat energy. In order to increase energy saving, East-Bay undertook a cooperative design with the university for this project. Through designing the angle of exposure and new reflective coating on the tunnel wall, this project reduced the quantity of LED lighting products used in this project by 15 per cent. This new concept of tunnel lighting retrofit was rapidly spread around the whole province." (Manager of East-Bay)*

Suppliers: East-Bay will design some products based on customers' specific requirements. The company's suppliers is responsible for producing these designed products. However, the partner has limited ability to produce all designed products. For example, the design department designed a LED lighting product that integrates the solar and wind power supplying system. However, due to the partner's limited processing technology, this product cannot be produced according to the design.

5.2.5 How has East-Bay developed its technological capability?

As mentioned above, East-Bay focuses on LED lighting products sales and energy-saving lighting construction and retrofit projects. East-Bay is not a manufacturer and therefore does not have LED lighting products production technologies. In addition, East-Bay has not developed an energy management system, which is a current mainstream energy conservation technology.

East-Bay's technological capability is reflected in a relatively rich product range and mature project design. However, the company is not currently willing to develop its technological capability.

In terms of the process of technological capability development, the interviewees did not provide detailed explanations and descriptions. The manager just expressed that East-Bay has been trying to seek advanced lighting products and update the existing products.

Based on the limited information, the process of technological capability development of East-Bay is simple. East-Bay develops its technological capability through seeking advanced energy efficiency lighting products and updating the existing products. Then, through collaboration with the university, it provides good project design. East-Bay's technological capability depends heavily on suppliers, its partner and the university. In other words, East-Bay's technological capability developed once its suppliers', suppliers' and university's technological capability developed.

5.2.6 Summary

This session has presented and discussed the analysis and results of the East-Bay case study, along with 10 key internal and external factors affecting East-Bay's technological capability. These factors separately affect, either supportively or unsupportively, four dimensions of the firm's technological capability.

In terms of motivations for technological capability development, East-Bay does not have a strong willingness to develop its technological capability. According to interviewees' explanations, the company's core competitive advantage is marketing. Based on the existing technological capability, East-Bay has good market performance in the local market. In addition, the current business model and strong government support for ESCOs and the energy conservation industry has weakened the importance of technological capability.

Conceptual framework

Dimensions	Internal factors	External factors
Investment capability Production capability Linkage capability Innovation capability	Company size Finance ability Profitability ability Organizational structure and policy Absorptive capacity R&D Prior knowledge Company's strategy Management capability	Financial institutions Research institutions and associations Customer Supplier Partner Competitors Government policy Regulation environment

Factors affecting East-Bay's four dimensions of technological capability

Dimensions	Internal factors	External factors
Investment capability	Company's financing ability Company's market performance Management team Technical staff	
Production capability	Technical staff Management team	Research institutes & associations Suppliers
Linkage capability	Personal relationship Management team	Government intervention Supplier
Innovation capability	R&D investment Management team Design department	Research institutions and associations Suppliers

Figure 27: Factors affecting Easy-Bay's four dimensions of technological capability.

East-Bay's investment capability was unsupportively affected by four factors: the company's financing ability, market performance, technical staff and management team. East-Bay has not built up effective financing channels with external financial institutes and therefore has limited funds to invest in technological capability development. Moreover, the worsened market performance has also reduced the management team's willingness to develop technological capability. Therefore, Easy-Bay's investment capability limited its innovation capability.

East-Bay focuses on its production capability and paying much attention to it. Its production capability was affected by four key factors: technical staff, management team, its suppliers, and research institutes and associations supportively. East-Bay's production capability directly affect its investment capability and innovation capability.

East-Bay has built up formal linkages with the local university and an LED lighting products manufacturer. The linkage capability of East-Bay was affected by personal relationships, management team and government intervention; all of these factors foster the development of linkage capability. Its linkage capability plays important role in production capability development.

East-Bay has very weak innovation capability. There are five key factors affecting its innovation capability. The first four – technical staff, design department, management team and supplier – are all constraints, while research institutes and associations made supportive contribution to the company's innovation capability. East-Bay's innovation capability limited company's production capability.

Overall, East-Bay focuses on its production and linkage capability, which it has already built up effectively. Through linkage capability, East-Bay has leveraged resources from the university and partner to help it improve its production capability. In addition, East-Bay currently has a low willingness and ability to develop and improve its investment and innovation capability.

East-Bay's lack of willingness to develop technological capability means that its process of technological capability is limited to seeking advanced LED lighting products to update its existing product portfolio.

East-Bay is not a good case for a technological capability study; however, the ESCO industry in China has a number of small-size ESCOs that might have a similar context to East-Bay. Therefore, the study of East-Bay is also useful for overviewing the entire ESCO industry in China.

5.3 Chapter summary

This chapter has presented a data analysis of case studies of small-size ESCOs. Visible Corp is an ESCO that has a strong willingness to develop technological capability, while East-Bay is less enthusiastic in this area.

Thirteen factors affect Visible Corp’s four dimensions of technological capability. Regarding East-Bay, 10 key factors affecting its technological capability were identified, most of which unsupportively influence the company’s technological capability. Visible Corp has strong focuses on its investment and innovation capability development. While, East-Bay just focused on developing its production and linkage capabilities.

Visible Corp has an explicit process of technological capability. It has already developed its own proprietary energy conservation technology – the “4W” energy efficiency analysis system. Moreover, Visible Corp has made efforts to absorb new energy conservation technologies in building and industrial energy conservation. East-Bay has not introduced its process of technological capability development. So far, the company has just developed its technological capability through upgrading its existing LED lighting product portfolio.

The next chapter will present data analysis and results of case studies of medium-size ESCOs in China.

Chapter 6 Findings from medium ESCOs in China

6.1 Case study of Sinowise (Beijing) Technology Co., Ltd.

6.1.1 Company background

Company Profile

Sinowise (Beijing) Technology Co., Ltd. (also referred to here as Sinowise) is a medium-sized ESCO. Sinowise was founded in 2009 by its chairman and is located in Beijing, with a subsidiary company in KunMing. By the end of 2016, Sinowise involved 25 natural person shareholders and a foreign investment enterprise, East Honour Investments Limited. The company has registered capital of 27.56 million RMB and approximately 180 employees.

Sinowise is one of first batch of ESCOs to be registered by NDRC in 2010. Sinowise is also a recommended ESCO by the Ministry of Industry and Information Industry. The company’s focus is providing comprehensive energy-saving solutions for the steel manufacturing industry. After seven years of development, Sinowise has become one of the few domestic companies to engage in high-temperature and high-pressure gas power generation. Sinowise has become a leading domestic ESCO that invests in blast furnace gas, waste heat and other power generation projects with the EPC model. So far, Sinowise’s main customers have been medium- and large-sized steel manufacturers.

As a professional ESCO, Sinowise has a relatively comprehensive organisational structure: a board of directors, a management office and eight divisions. The responsibilities of each department are clear. The board of directors involves 26 members and has set up a Strategic Development Committee and a Compensation and Assessment Committee. The management office consists of a general manager, a vice general manager, an executive vice manager and a financial director. The eight business departments are Marketing, Finance, Human Resources, Strategic Management, International Marketing, Operation Centre, Enterprise Promotion, and Technical. The Technical Department is the largest, with nearly 90 employees.

Sinowise provides comprehensive energy-saving services for its customers. These services mainly involve consultation, project financing and energy-saving project design, implementation and maintenance. Figure 28 displays the main services that Sinowise provides.

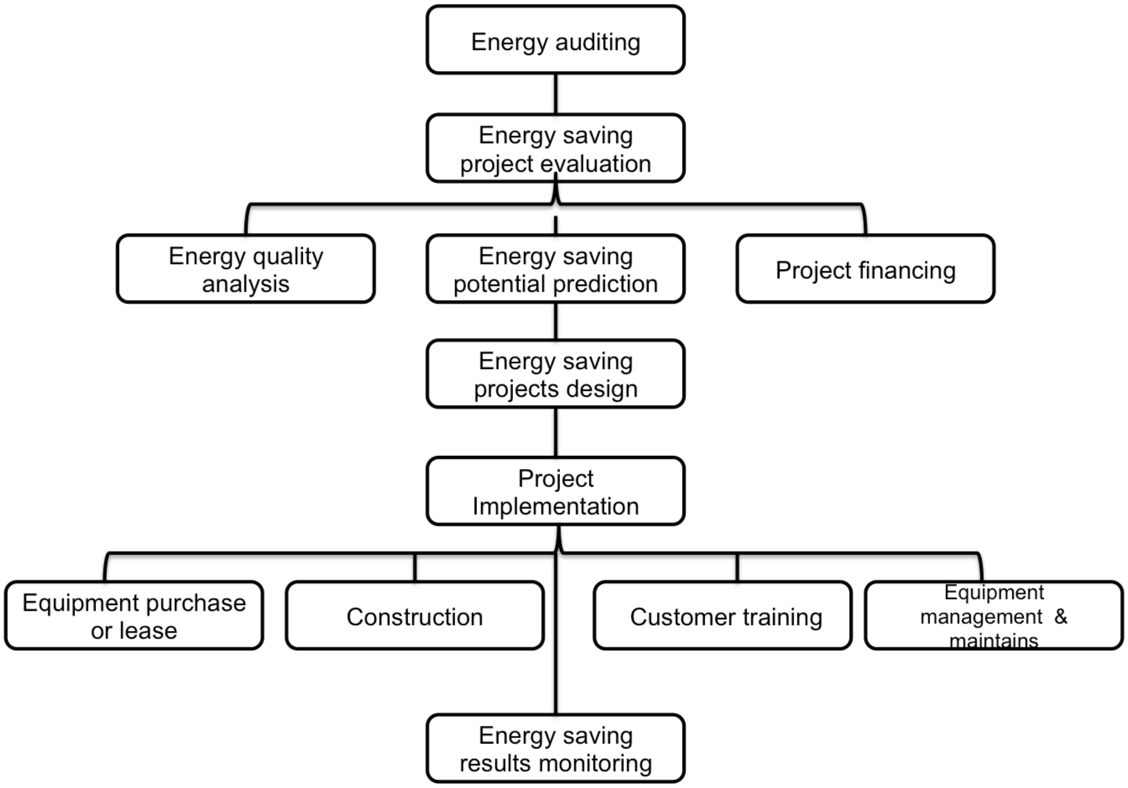


Figure 28: Main services provided by Sinowise.

After seven years of development, Sinowise has successful implemented more than 20 energy conservation projects and has completed 2 billion RMB of EPC project financing, with two projects having investments of more than 800 million RMB. Taking advantage of strong technological capability, professional project implementation, advanced management and good service, Sinowise completed its projects 100 per cent on schedule, with a one-time yield of 100 per cent, a 100 per cent project quality pass rate, and a return rate on time close to 100 per cent. In 2016, Sinowise ranked ninth in the Top 100 Chinese ESCOs. In industrial energy-saving areas, Sinowise obtained a '5A' in an assessment of ESCOs' comprehensive ability. Sinowise was also named as the 'Best Chinese ESCO', 'China's green capital leader enterprise', 'China's 3A creditability enterprises', 'EMCA excellent member' and 'Most growth ESCOs in China'.

Sinowise's success in energy conservation business is highly due to its mature business model and reliable collaborative partners. Figure 29 displays the business model applied by Sinowise.

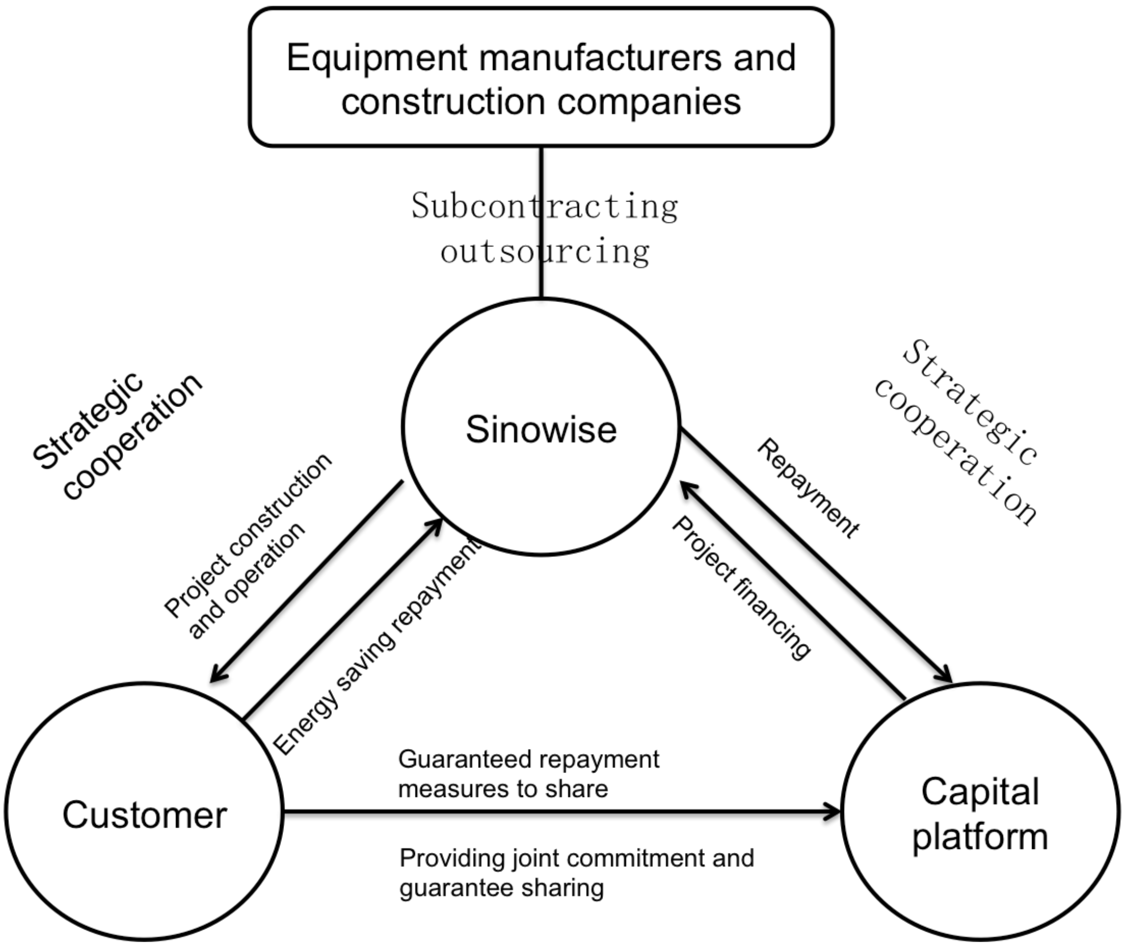


Figure 29: Business model applied by Sinowise.

Taking advantage of this business model, Sinowise built up a triangular relationship with capital platform and customers in order to guarantee that project financing, implementation and repayment can be completed successfully and to minimise the risks during the contract period. At the same time, through subcontracting outsources, Sinowise could have a professional equipment manufacturer and project implementation team. It is impossible for a medium-sized ESCO to build up equipment manufacturing capability and project implementing capability by itself to implement large energy conservation projects.

All of these projects that were implemented by Sinowise rely on three main technologies: waste heat and energy recycling and utilisation; biomass power generation, and an enterprise energy management system. Table 13 shows the energy conservation projects implemented by Sinowise from 2011–2016.

Table 13：Energy-saving projects implemented by Sinowise from 2011–2016.

Number of projects	Application industries	Main energy-saving technologies
5	Iron and steel manufacturing enterprises; cement building material manufacturing enterprises	Waste heat electric power generation
2	Iron and steel manufacturing enterprises	Waste heat energy comprehensive utilisation: heating
5	Iron and steel manufacturing enterprises	Blast furnace gas electricity generation
6	Iron and steel manufacturing enterprises; electrolytic aluminium industry	Energy management centre
6	Iron and steel manufacturing enterprises	Sintering desulfurisation, dust removal; photovoltaic power generation

Sinowise focuses on providing energy-saving solutions to the iron and steel manufacturing and building material manufacturing industries. These industries have high energy consumption and high carbon dioxide emission and therefore have higher energy-saving potential than other industries. To date, the energy-saving projects undertaken by Sinowise have helped enterprises save 250 million RMB annually in energy costs. Four further large energy-saving projects are under construction. Based on good market performance, Sinowise has made efforts to expand its business and build up linkages with external actors through investment. Sinowise has successfully completed investment in seven enterprises, which involves competitors and an equipment leasing company.

Company's technological capability

Sinowise focuses on independent R&D and energy-saving technology improvement and integration. The company has a relatively large technical department with approximately 90 technical staff, all of whom have related education background and work experience. Sixty per cent of the technical staff are undergraduates and the remainder are postgraduates. The technical staff include electrical engineers, mechanical engineers, software engineers, equipment engineers, thermal power engineers, project construction engineers, and photovoltaic power generation experts. In addition, Sinowise has relatively rich technology accumulation about waste heat and energy utilisation, biomass power generation and energy management in the iron and steel manufacturing industry and the building material manufacturing industry.

Sinowise currently focuses on three energy-saving areas: waste heat and energy recycling and utilisation, comprehensive biomass utilisation, and energy management systems. Table 14 shows the main energy-saving technologies used in these energy-saving areas.

Table 14： Main energy-saving technologies used by Sinowise.

Energy-saving areas	**Main technologies**
Waste heat and energy recycling and utilization	Blast furnace gas power generation technology
	Sintering Waste Heat Power Generation Technology
	Sintering waste heat supply steam technology
Biomass comprehensive utilization	Biomass power generation technology
	Biomass extraction technology
	Biomass charcoal technology
Enterprise energy management system	Energy consumption data collection and analysis technologies
	Energy consumption prediction technologies

Sinowise has applied various methods of obtaining and developing energy-saving technologies. Through technology acquisition and collaboration with competitors and customers, Sinowise obtained mature technologies that it transferred from other domestic ESCOs and customers. Through independent R&D, Sinowise developed its energy management system and improved and upgraded mature technologies transferred from competitors and customers.

Sinowise is qualified as a ‘National high-tech enterprise’ and a ‘Zhongguancun high-tech enterprise’. Sinowise has already developed and applied five utility model patents and 11 software development copyrights and achieved six qualifications for computer information system integration. Table 15 shows the patents and software copyrights owned by Sinowise.

Table 15： Patents and software copyrights owned by Sinowise.

Type	Reference number	Name
Utility model patent	2016211173598	A Remote Monitoring and Management System for Straw Storage Warehouse
Utility model patent	2016211169889	A Feeding System for Straw Biogas Project
Utility model patent	201621118398X	A device for stably controlling low temperature corrosion of gas boiler preheater
Utility model patent	2016211184291	A device for stabilizing and improving the temperature of the furnace AQC furnace from the cooler
Utility model patent	2016211184287	A system for improving waste heat recovery during sintering cooling
Software copyrights	2013SR075547	Steelmaking Quality Management System
Software copyrights	2013SR075598	Barcode Recognition Sample Management System
Software copyrights	2013SR075582	Material inspection management system
Software copyrights	2013SR075594	Anti - counterfeiting System for Iron and Steel Enterprises
Software copyrights	2011SR074690	Energy management center
Software copyrights	2011SR062441	Steel factory factory modeling management system
Software copyrights	2011SR062511	Operation and management system of equipment for iron and steel enterprises
Software copyrights	2011SR062508	Energy cost information management
Software copyrights	2011SR061876	Energy efficiency analysis information management
Software copyrights	2011SR062158	Standard Management System for Energy Efficiency in Iron and Steel Enterprises
Software copyrights	2010SR063441	Energy management information system

6.1.2 Why has Sinowise developed technological capability?

Company's development strategy

Sinowise was ranked ninth in the 'Top 100 ESCOs in China', its main customers are enterprises from the north of China. Sinowise plans to expand its business to the south of China and build up the brand throughout the country. To achieve its objectives of business development, Sinowise needs strong technological capability as supports. For large energy conservation projects, ESCO's technological capability is an important consideration. Therefore, Sinowise has focused on technological capability development and increasing its investment in technological capability year by year. The number of technical staffs is also increasing from 2012; so far, the investment in technological capability has reached 50 million RMB.

> *'Our business is highly reliant on technological capability and financing capacity. Based on our business model, Sinowise built up reliable and stable financing capacity. In terms of technological capability, we set up technological capability development strategy to absorb domestic and international mature energy-saving technologies in the iron and steel manufacturing and building material manufacturing industries, improve the technologies and develop our own energy management system by our own R&D.' (Senior manager)*

Improve company's competiveness

Although Sinowise has already built up its technological capability, its main customers are medium and large iron and steel manufacturers that are also large ESCOs' target customers. Compared with large ESCOs, Sinowise's technological capability needs to be further improved. The assistant vice manager expressed that Sinowise normally undertakes energy-saving projects for iron and steel manufacturers and building material manufacturers. Because the projects are relatively large, our competitors are competitive ESCOs in these sectors. Sinowise has to build up, keep and improve its technological capability, financing capacity and service. In large energy-saving projects, customers take all these aspects into serious consideration. Therefore, Sinowise has focused on establishing linkages with financing institutes to improve its financing capacity, and with competitors to improve its technological capability.

Government intervention

Sinowise's technological capability is an important consideration in terms of ESCOs' assessment by government. Governments usually focus on recommending and supporting ESCOs with strong technological capability and huge growth potential. Secondly, increasingly strict government regulations on high-energy consumption industries have pushed Sinowise to develop its technological capability. Sinowise's main customers are high-energy consumption enterprises, which were the focus of governments. Therefore, the regulations to these industrial are stricter than other industries.

> *'We choose high-energy consumption enterprises as our main customers because the*

energy-saving potential of these enterprises are large. Nevertheless, these enterprises have become the focus of central and local government in terms of energy conservation. In order to help customers satisfy government's increasing energy-saving requirements, Sinowise has to keep improving its technological capability. Therefore, Sinowise not only undertakes energy conservation technology absorption but also develops new energy conservation technologies through independent R&D.' (Senior manager)

6.1.3 Which factors affect Sinowise's technological capability development?

According to the data obtained from three interviewees and documentations, there are 12 key factors (seven internal and five external) that affect Sinowise's technological capability (see Table 16).

Table 16: Key factors affecting Sinowise's technological capability ("**+**" supportive, "**−**" unsupportive)

Key Factors	Technological capability			
	Investment capability	Production capability	Linkage capability	Innovation capability
Internal				
Company's financing ability	**+**		**+**	
Company's market performance	**+**			
Technical staff	**+**	**+**		
R&D investment				**+**
R&D experience				**−**
Personal relationship			**+**	
Management team	**+**			**+**
Absorptive capacity	**+**	**+**		
External				
Government intervention	**+**			**+**
Customer		**−**		
Supplier		**+**		
Competitor	**+**			

6.1.4 How factors affect Sinowise's technological capability

This section describes and explains the factors that affect Sinowise's technological capability, as perceived by interviewees. After explaining Sinowise's four dimensions of technological capability, attention turns to how certain factors affect these four dimensions.

Investment capability

Sinowise has already built up its investment capability and has a dedicated strategic investment department and professional financing team. The professional financing team consists of 28 staff who are responsible for financing for investment of energy-saving projects and technological capability development. The strategic investment team are responsible for investment evaluation, investment decision-making and resource allocation. In terms of technological capability investment, the strategic investment team make investment decisions based on the technical department's suggestions about technology acquisition, new technology and software development. Sinowise has a team consisting of five experienced technical staffs who are responsible for identifying and evaluation potential energy conservation technologies.

Company's financing ability: Sinowise joined the ESCO financing platform which consisted of financial institutions such as commercial banks, funding companies and venture capital firms. As a '5A' credit enterprise, Sinowise finds it relatively easy to obtain finance from this platform, unlike bank loans from commercial banks, which can only be used for energy-saving projects. Sinowise obtained funds from funding companies to invest in technology acquisition and R&D. To date, Sinowise has obtained 30 million RMB from funding companies to invest in technological capability development.

Company's market performance: Sinowise has very good market performance, which ensures the company has good profits. The investment in technological capability relies heavily on the company's profit. In addition, good market performance means Sinowise has the confidence to increase its investment in technological capability. From 2012 to 2015, the rate of investment in technological capability increased by 5 per cent totally.

Technical staff: Sinowise has employed various technical staff in industrial energy-saving area. Besides a number of software engineers, Sinowise also has electrical engineers, mechanical engineers, thermal power engineers, civil construction engineers, biogas comprehensive utilisation experts and photovoltaic power generation technicians. The vice manager expressed that when Sinowise acquired waste heat power generation technologies, the company organised a technical team to evaluate these technologies. This team consists of one electrical engineer, one mechanical engineer and two thermal power engineers. Diversified technical staffs comprehensively evaluated the potential energy conservation technology within four weeks.

Management team: Sinowise's management team consisted of experienced management staff with strong professional backgrounds. The firm has a professional financing team, a strategic investment department and a technical department. The management team could legitimately prepare and allocate resources for technological capability development.

> *The assistant of senior manager gave an example. In 2013, Sinowise wanted to recruit 10 new staffs for its marketing and technical departments. At that time, the technical department urgently needed biogas technical staff to start a biomass comprehensive*

utilisation project. The salaries of technical staff are much higher than those of marketing staff. Finally, management team decided recruit five technical staff for the technical department and only two staff for the marketing department.

Absorptive capacity: Sinowise has relatively rich experience in absorbing waste heat and energy recycling and utilisation, biomass comprehensive utilisation, and energy management systems. Sinowise has already successfully absorbed and improved 10 energy conservation technologies in waste energy utilisation and biomass utilisation. Therefore, when the company invested in the energy-saving technologies relevant to these technologies, it was able to undertake quick evaluations for potential technologies depending on its absorptive capacity.

Government intervention: In order to promote energy conservation and accelerate the development of the ESCO industry, governments encourage financial institutes to provide financial support to energy-saving projects. The finance platform was founded with policy support from the government. Therefore, Sinowise could obtain enough funds for investment in technological capability. In addition, Sinowise obtained a 200,000 RMB reward from the local government in 2014 because of the development of its Energy Management Centre.

Competitor: Competitors have not only pushed Sinowise to increase investment in technological capability development but also provided potential energy-saving technologies or new energy-saving concepts. Sinowise acquired biomass gasification and liquefaction separation technology from a competitor in 2013. Sintering desulfurisation dust removal technologies were obtained by Sinowise through technology exchange with competitors.

Production capability

Sinowise's production capability mainly refers to using transferred energy conservation technologies to implement energy conservation projects and further absorbing these technologies. In terms of projects construction and implementation, Sinowise does not have a construction and implementation team. Through subcontracting outsourcing, Sinowise uses professional partners to implement projects. The technical staff of Sinowise are just responsible for supervision and guidance and for absorbing and developing energy conservation technologies. In order to ensure the quality of projects, the technical staff also provide training to customers and maintenance work. There is a technical team that consists of 20 technical staffs to do this work.

Technical staff: The technical staff are diversified and experienced. Currently, 30 technical staff are responsible for absorbing transferred energy conservation technologies. All employees have at least three years' experience in technology absorption. In addition, technical staff who are responsible for project implementation supervision, customer training and project maintenance were selected from experienced employees who have experience in at least three energy conservation projects.

Absorptive capacity: To absorb transferred technologies, Sinowise needs to build up its absorptive capacity. Sinowise has built up absorptive capacity in waste heat and energy recycling and utilisation, biomass utilisation and energy management systems. In so doing, Sinowise has effectively absorbed technologies relevant to these three energy-saving areas.

Customer: Customers' knowledge capture affects the performance of energy-saving projects. After the customer training, customers are responsible for the daily operations of the projects. Sinowise provides training courses to customers and, according to the customer's context, will adjust its training courses such as training time. However, due to the limitations of customer's knowledge capture, some non-standard operations leads to poor project performance, which means the actual energy saving cannot meet expectations. This issue often appears in medium-sized iron and steel manufacturers.

Supplier: The suppliers of Sinowise provide equipment and project implementation services. The quality of equipment and projects implementation will directly affect the quality of the entire energy-saving project. In order to avoid such risks, Sinowise has chosen qualified equipment manufacturers and an implementation team as long-term collaborative partners. The existing partners have already co-operated with Sinowise for four years.

Linkage capability

Sinowise has built up broad linkages with financial institutions, equipment manufacturers, customers, EMCA and other domestic ESCOs. Based on Sinowise's business model, the company has established strategic partner relationships with financial institutions and customers. Initially, Sinowise obtained its core energy-saving technology: blast furnace gas power generation from its customer, an iron and steel manufacturer. Sinowise currently focuses on building formal linkages with competitive ESCOs and energy-saving equipment and product manufacturers. Sinowise actively participates in activities related to ESCOs and energy conservation and has invested in seven companies, including five ESCOs, one equipment leasing company and one project implementation company, and become shareholders of these companies.

Company's financing ability: To conduct energy-saving projects through EPC, the most important element is the company's financing ability. Sinowise has a strong financing ability than other small and medium-sized ESCOs. Some ESCOs would like to collaborate with Sinowise to conduct large energy-saving projects. In the process of collaboration, Sinowise was able to obtain technologies from other ESCOs. This kind of linkage is not long but is very effective. The vice manager said, 'Some ESCOs try to implement large energy conservation project through cooperation with us. They want to take advantage of our financing ability. We want to get the opportunity for technology transfer through such cooperation. Hence, we normally cooperate with ESCOs with specific and relevant energy-saving technologies."

Personal relationship: When the company was first established, building up linkages with customers, equipment manufacturers and financial institutions was highly dependent on personal relationships. The linkages built up through personal relationship were unstable and ineffective, but they were very important for Sinowise to start a business and obtain technologies at that time. The assistant vice manager expressed that Sinowise's first customer is also the company's core energy-saving technology provider. At that time of 2010, the founder of Sinowise had a good personal relationship with the factory director of the Tangshan Guofeng iron and steel manufacturer, which had relatively backward waste heat power generation technology. The manufacturer gave Sinowise an opportunity to collaborate to improve this technology. After the improvement, Sinowise successful transferred and absorbed this technology. So far, after several rounds upgrades and improvements, this technology has become one of Sinowise's core technologies.

Innovation capability

Sinowise's innovation capability refers to (1) improving and integrating existing energy-saving technologies and (2) independently developing an energy management system. Sinowise has already undertaken R&D activities. Through a series of software developments, Sinowise has successfully and independently developed an energy management system for iron and steel manufacturing and building material manufacturing enterprises. The annual investment in R&D is approximately 5–10 per cent of sales revenue. In 2015, the investment of R&D reached 10 million

RMB. The director of strategic investment department expressed that Sinowise's investment in R&D is larger than most small and medium-sized ESCOs.

R&D investment: Sinowise has continued to invest in R&D since it was founded. Sinowise's annual sales income is approximately 150–200 million RMB and its cross-profit rate is around 45 per cent. Every year, the company invests about 5–10 per cent of its sales income in technological capability development, half of which is for R&D. The director of the Strategic Investment Department expressed that, compared with other small and medium-sized ESCOs, Sinowise's amount of investment in R&D is large.

R&D experience: When Sinowise was founded, the company started developing its proprietary energy conservation technology "Energy Management System". Since then, Sinowise has developed 10 software packages for industrial energy conservation. Thus, the company has accumulated rich R&D experience in software development in energy conservation. However, in terms of waste energy recovery and utilisation, Sinowise just absorbed several technologies relevant to this area. Sinowise did not make any significant improvement for the absorbed technologies, and therefore lacks R&D experience in waste energy recovery and utilisation.

Management team: Sinowise's management team has recognised the importance of establishing and developing innovation capability. Therefore, the management team has allocated the company's advantage resources to R&D and innovation.

> *'In order to encourage our staff to conduct R&D and innovation, the management team also set up a reward system for significant contributions in R&D and innovation. The technical staff or group that makes significant contributions to R&D or innovation, such as their R&D resulting in successfully applied patents or software copyrights will receive a reward of 5000–20,000 RMB. This reward system effectively mobilize the enthusiasm of the staff to conduct R&D and innovation.' (Senior manager)*

Government intervention: National and local governments encourage ESCOs to develop new energy-saving technologies. Governments' policies and guides have provided a good environment for innovation. Secondly, local governments have provided rewards for company innovation. Sinowise received a 200,000 RMB reward for developing an 'Energy Management centre'. In addition, governments have pushed the company to develop its innovation capability through certifications such as the Notional High-tech Enterprise and Zhongguancun High-tech Enterprise. Only companies with high technological capability can qualify as high-tech enterprises.

6.1.5 How has Sinowise developed its technological capability?

The senior manager is responsible for the technical department provided a detailed explanation of Sinowise's process of technological development. Sinowise focuses on energy-saving technology improvement and integration and independent developing an energy management system through software development. Sinowise focuses on industrial energy-saving, especially in the iron and steel industry. Therefore, the energy-saving technologies that were absorbed, improved and integrated by Sinowise were technologies relevant to energy saving of the iron and steel industry.

So far, the company has basically completed the development of an energy management system. The improvement, upgrade and update will be continued. The technical department will further explore the potential of existing energy-saving technologies and undertake improvement and integration. The senior manager expressed that Sinowise is going to try to conduct radical innovation to develop advanced technologies for waste heat and energy utilisation in 2017. Figure 30 was created according to interviewee's descriptions and explanations and shows the process of technological capability development of Sinowise.

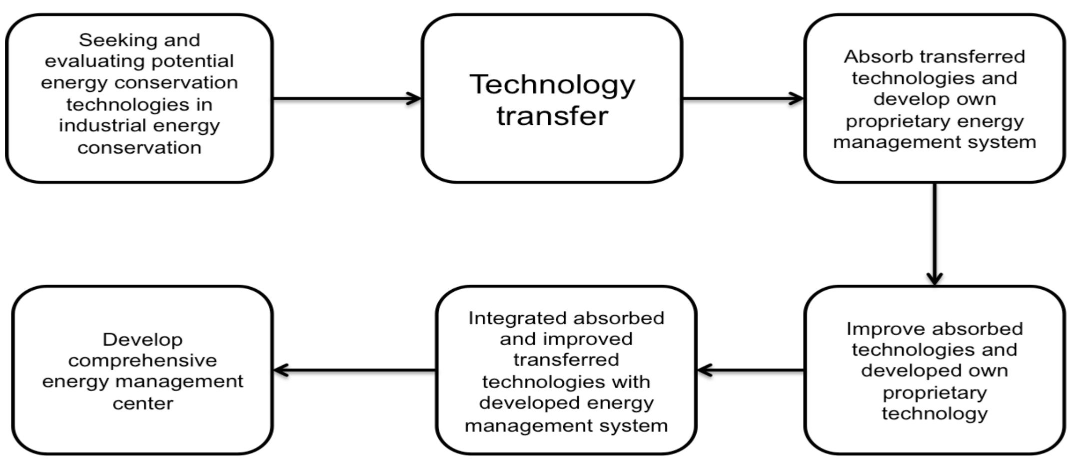


Figure 30: Sinowise's technological capability development process.

Sinowise's technological capability process mainly involves three stages.

Stage 1

In the first stage, the company focuses on seeking potential energy-saving technologies, especially at the beginning of business. In this stage, there are many factors that need to be taken into account, especially for SMEs. The considerations involve what kind of energy-saving technology the company prefers, what level of technology the company prefers (mature, domestic advanced, international advanced), the potential for technology transfer, and the company's ability to transfer target technology (financial ability, absorptive capacity). When Sinowise was first founded, the founder of company had an explicit direction about obtaining mature technology in energy conservation of the iron and steel industry.

Stage 2

In the second stage, Sinowise focused on absorbing transferred technologies and start to develop its own proprietary energy conservation technology Energy Management System. Sinowise organised a group that spent six months developing this system, which is used in iron and steel manufacturing enterprises. At the same time, the technical department made efforts to explore the potential of existing technologies and improve the technologies. Furthermore, Sinowise integrated relevant energy-saving technologies and its own Energy Management System. For example, Sinowise integrated blast furnace gas power generation technology, waste heat and steam power generation technology, and waste steam heating technology into a comprehensive waste heat and energy utilisation system.

Stage 3

Sinowise continued its efforts in independent R&D and developed a series of software packages, before integrating and absorbed energy conservation technologies and developing the Energy Management Centre, which involves a package of energy conservation technologies. Sinowise has been making efforts to improve this technology gradually and has sought to expand this technology to other industries.

6.1.6 Summary

In this section, the analysis and results of the Sinowise case study were presented and discussed. Sinowise is a medium-sized ESCO with relatively strong technological capability and good market performance.

The company has a strong willingness to develop its technological capability because of its need for business development, for improvement of its competiveness, and government intervention. Sinowise considers technological capability to be a core competitive advantage. According, the company's investment in technological capability has been increasing year by year. In order to keep its market position and expand its business to south of China, technological capability development is recognised as an effective approach. Government intervention has driven Sinowise to develop technological capability through a series of rewards and certifications. Even though government intervention was seen as a passive driver, it significantly accelerated the company's technological capability development.

Twelve factors were identified as affecting Sinowise's four dimensions of technological capability; see Figure 31.

Conceptual framework

Dimensions	Internal factors	External factors
Investment capability Production capability Linkage capability Innovation capability	Company size Finance ability Profitability ability Organizational structure and policy Absorptive capacity R&D Prior knowledge Company's strategy Management capability	Financial institutions Research institutions and associations Customer Supplier Partner Competitors Government policy Regulation environment

Factors affecting Sinowise's four dimensions of technological capability

Dimensions	Internal factors	External factors
Investment capability	Company's financing ability Company's market performance Management team Technical staff Absorptive capacity	Government intervention Competitor
Production capability	Technical staff Absorptive capacity	Customer Suppliers
Linkage capability	Personal relationship Company's financing ability	
Innovation capability	R&D investment R&D experience Management team	Government intervention

Figure 31: Factors affecting Sinowise's four dimensions of technological capability.

From the perspectives of preparing financial resources for investment and for technological capability development, Sinowise has built up a relatively complete investment capability and has a technical team responsible for recognising and evaluating potential energy conservation technologies. So far, Sinowise's investment in technological capability development has been large. Seven factors were identified as supportively affecting the company's investment capability. Sinowise thinks their investment capability directly affect its innovation capability.

In terms of production capability, there were five key factors to focus on. Sinowise built up its production capability through organising technical staff to absorb transferred energy conservation technologies and developed its own proprietary energy management system, applying professional project implementation companies and comprehensive customer training and maintenance service. Technical staff, absorptive capacity and its suppliers supportively affect Sinowise's production capability. However, due to the limitation of customer's knowledge capture, this factor unsupportively affects the company's production capability. The development of Sinowise's production capability facilitates the development of investment, linkage and innovation capability.

Sinowise has established formal linkages with external parties such as partners, financial institutes and competitors. Personal relationships and the company's financing ability were deemed as key factors that positively affect Sinowise's linkage capability at present. Through collaboration with partners and competitors, Sinowise has not only obtained a professional project implementation team and the ability to produce equipment used in energy-saving projects, but also opportunities to transfer energy conservation technologies. Sinowise's linkage capability directly influencese its investment capability and further its innovation capability.

Sinowise has undertaken incremental innovations for many years, focusing not only focuses on improving and integrating mature energy-saving technologies, but also on independent R&D. Three key factors were identified as affecting Sinowise's innovation capability. R&D investment and government intervention accelerated the development of Sinowise's innovation capability. However, limited R&D experience is a main constraint for new energy conservation technology development. Sinowise's innovation capability influence its production capability.

Sinowise focuses on all four dimensions of technological capability. The company has not only built up effective financing channels but also has good market performance and profitability. The experienced and diversified technical staff ensure that the company is able to recognize, exploit and absorb technologies. Taking advantages of linkages with suppliers, Sinowise enhanced its production capability through its suppliers' quality energy conservation equipment, products and professional project implementation team. Sinowise's investment and efforts in innovation capability are relatively large. Sinowise not only has several utility model patents and software copyrights, but has also developed its own proprietary technology in its early stage through integrating a series of absorbed and developed energy conservation technologies.

In terms of Sinowise's process of technological capability development, the company basically followed the path of acquisition, absorption and further improvement. However, Sinowise has established R&D and innovation capability, undertaking independent R&D and developing its own proprietary technology once the company was established. Even though Sinowise only conducted incremental innovation, rather than radical innovation, it has successful applied five utility model patents and 11 software copyrights.

6.2 Case study of Hangzhou Ditree Energy-saving Technology, Ltd.

6.2.1 Company background

Company profile

Hangzhou Ditree Energy-saving Technology, Ltd. (referred to here as Ditree) was founded in 2005 by its CEO, who had worked for Zhengjiang University Network Corporation as technical assistant to the president for five years. In 2005, the company's name was Hangzhou Ditree Technology, Ltd. and its main businesses were computer engineering, software development, system integration and network security. In 2011, the company changed its name to Hangzhou Ditree Energy-saving Technology, Ltd. In the same year, Ditree became an ESCO is registered by NDRC and the Zhejiang Provincial Government. Moreover, Ditree was selected by the Ministry of Industry and Information Technology to be on its recommended 'energy-saving service company' list.

Ditree is a professional medium-sized ESCO that focuses on energy-saving products and technologies development and providing EPC energy-saving projects to energy consumers. It has 83 employees and registered capital of 20 million RMB. In 2015, the company's annual sales income reached 65 million RMB. Ditree has a board of directors, a management office and seven specific business units managed by five vice managers, one chief engineer and a financial director. The seven business units are the Industrial Energy-saving Division, the Building Energy-saving Division, the Lighting Energy-saving Division, the Heat Energy-saving Division, R&D, a financial centre and an executive office.

Ditree is an ESCO which is recognised by government, customers and investors. Table 17 shows the major events in Ditree's process of development.

Table 17: Major events in Ditree’s development process.

Time	EVENT
2006	Ditree’s R&D team accessed to invention patent
2008	Ditree was named as “Zhejiang province innovative enterprise”
2009	Ditree was named as “ Zhejiang the most growth potential SMEs”
2010	The company obtained GB / T19001-2008 idt ISO9001: 2008 quality management system certification The company received a well-known domestic venture capital firm Song Wo capital investment Company was identified as “Hational high-tech enterprise” The company received "AAA grade credit enterprise" grade certificate
2011	Ditree became recorded ESCO by NDRC Ditree became recorded ESCO by Zhejiang province Ditree became recommended ESCO by Ministry of Industry and Information Technology
2012	The company won the top ten science and technology enterprises in Hangzhou
2013	The company won the 2013 annual hundred ESCOs
2014	The company became the core member of Shanghai Environmental Energy Exchange
2015	The company successfully listed the new three board

Ditree provided energy-saving projects for industrial and building energy conservation. Ditree applied EPI (energy process intergradation) technology, high-voltage and high-power frequency control devices, balanced filter savers, and gasoline dual purpose industrial boiler technologies to provide energy conservation solutions to iron and steel manufacturing enterprises and building material manufacturing enterprises. Ditree also applied LED lighting technology to provide energy-saving services for commercial buildings. So far, the company’s main customers have been small and medium-sized manufacturers and medium-sized commercial buildings. Ditree provides comprehensive energy service to its customers. However, due to a lack of technical personnel, Ditree has employed a third party to conduct an energy auditing and energy-saving potential evaluation. Figure 32 displays the comprehensive energy-saving services provided by Ditree.

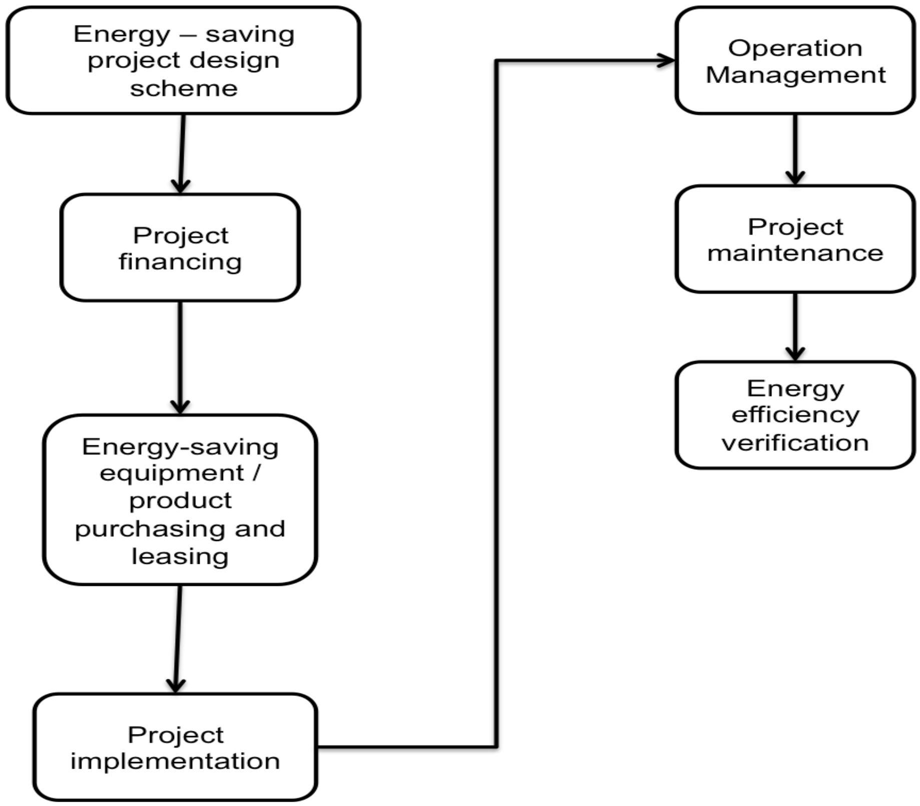


Figure 32: Main energy conservation services provided by Ditree.

Taking advantage of technologies in industrial and building energy conservation, Ditree has successfully implemented 19 small and medium-sized energy conservation projects for iron and steel manufacturers, building material manufacturers, commercial buildings and public infrastructure. The most popular energy conservation technology used in industrial energy conservation is EPI energy optimisation of an industrial circulating water system developed by Ditree. LED lighting technology and central air conditioning frequency conversion technology are the most popular technologies that Ditree has applied for building energy conservation. Table 18 shows the energy-conservation projects implemented by Ditree from 2010–2015.

Table 18: Energy conservation projects implemented by Ditree from 2010–2015.

Project name	Energy conservation areas	Main technologies
Shuicheng Iron and Steel Group	Industrial energy conservation	EPI Energy Optimization of Industrial Circulating Water System
Sichuan Meiqing Cyanamide Ltd	Industrial energy conservation	EPI Energy Optimization of Industrial Circulating Water System
Chende shengfeng Iron and Steel Ltd	Industrial energy conservation	EPI Energy Optimization of Industrial Circulating Water System Fan frequency conversion system optimization
Chuanhua Group Ltd	Industrial energy conservation	EPI Energy Optimization of Industrial Circulating Water System
Xinyu Iron and Steel Ltd	Industrial energy conservation	EPI Energy Optimization of Industrial Circulating Water System
Maanshan Iron & Steel Co., Ltd	Industrial energy conservation	EPI Energy Optimization of Industrial Circulating Water System
Hangzhou advanced Fuchun Chemical Co., Ltd	Industrial energy conservation	EPI Energy Optimization of Industrial Circulating Water System
Zhejiang Xue Yongxing Spandex Co., Ltd	Industrial energy conservation	EPI Energy Optimization of Industrial Circulating Water System
Shandong Dongyue Polymer Co., Ltd.	Industrial energy conservation	EPI Energy Optimization of Industrial Circulating Water System
Zhejiang Hengxin Electric Power Co., Ltd.	Industrial energy conservation	EPI Energy Optimization of Industrial Circulating Water System
Xiaoyi Xing'an Chemical Co., Ltd	Industrial energy conservation	EPI Energy Optimization of Industrial Circulating Water System
Ningxia Jinning Aluminum Magnesium New Material Co., Ltd	Industrial energy conservation	Fan frequency conversion system optimization
Zhejiang University of Finance and Economics，xiasha compus	Building energy conservation	LED lighting Central air conditioning frequency conversion technology
FAW Jiefang Automobile Co., Ltd.	Building energy conservation	LED lighting
Tongjiang County Jiangnan town lights transformation	Public infrastructure energy conservation	LED lighting
Hangzhou Canal Street	Public infrastructure energy conservation	Building energy station
Yuhang people home	Building energy conservation	Led lighting and HVAC retrofit
Hangzhou seventh people hospital	Building energy conservation	Central air conditioning frequency conversion technology
Hangzhou Baima Lake Jianguo Hotel	Building energy conservation	Central air conditioning frequency conversion technology

According to the projects, nearly two-thirds of projects are industrial energy conservation projects and 95 per cent of industrial energy conservation projects applied the EPI industrial circulating water system. By the end of 2015, after nearly 10 years of development, Ditree's total assets reached 70 million RMB. At the same time, Ditree also became a well-known ESCO in Zhejiang Province.

Company's technological capability

Ditree has already built up its own technological capability. In 2006, Ditree established its R&D department and by the end of 2015, there were 30 technical staffs worked for the R&D centre. Approximately 30 per cent of the technical staff are software engineers, 20 per cent are electrical engineers, and the remaining 50 per cent consist of mechanical engineers, product designers and technical staff for energy-saving measurement. All of the technical staff have at least three years of relevant work experience.

Ditree focuses on collecting domestic and international mature energy-saving technologies and increasing its technological accumulation and then independent R&D. From 2006 to 2012, Ditree tried a number of R&D projects. Through collaborative R&D with a university, Ditree obtained an invention patent for EPI liquid efficient delivery technology. Through independent R&D, Ditree successfully applied for five utility model patents and a software copyright. Although Ditree invested in a number of R&D projects during that period, only a small proportion were successful.

In order to provide a comprehensive energy-saving service to customers in different industries, Ditree had started to collect mature domestic and international energy-saving technologies in industrial energy conservation and building conservation. So far, Ditree has six industrial energy conservation technologies and nine building energy conservation technologies; see Table 19.

Table 19: Energy conservation technologies applied by Ditree.

Category	Energy saving technology	Level of technology
Industrial energy conservation technologies	Balanced filter reactance Saver	Domestic mature
	New high efficiency gas and powder dual - use boiler	Domestic advanced
	Hydropower and Hybrid Power Saving Technology for Cooling Tower	Domestic mature
	Energy Saving Technology of Ternary Flow Sintering	Domestic advanced
	Energy Optimization of Industrial Circulating Water System	Domestic advanced
	High - voltage high - power frequency control device	Domestic mature
Building energy conservation technologies	Energy efficiency management service platform	Domestic mature
	Energy Saving Technology of Water - cooled Central Air Conditioning System	Domestic mature
	Dynamic Ice Storage Energy Saving Technology	Domestic mature
	Energy Saving Technology of Air - cooled Air Conditioning System	Domestic mature
	Energy station	Domestic mature
	LED lighting	Domestic mature
	Elevator electric energy feedback device technology	Domestic mature
	Modular centralized steam supply system	Domestic mature
	Distributed photovoltaic power station	Domestic mature

Most of the energy conservation technologies applied by Ditree are mature domestic technologies, especially in building energy conservation. In industrial energy conservation, Ditree obtained three domestic advanced energy-saving technologies through independent and collaborative R&D.

6.2.2 Why has Ditree developed its technological capability?

Company's development strategy

Ditree has been attempting to become a well-known ESCO in Zhejiang Province and throughout China. The company would like to expand its business and be one of the "Top 100 ESCOs in China". To achieve these objectives, Ditree must develop its technological capability and master more and more energy conservation technologies in industrial and building energy conservation. To this end, Ditree has set up clear technological development strategies, although it has made changes to these strategies. From 2006 to 2013, Ditree had focused on independent R&D and innovation and tried to develop domestic and even international advanced energy conservation technologies in industrial energy conservation. The company did reach some achievements, such as EPI technology, during this period. However, the company also paid a huge price of 10 million RMB investments. In 2013–2015, Ditree changed its business development strategy to provide energy conservation service to building and public infrastructure. Therefore, its technological development strategy also changed to collect mature or advanced building energy conservation technologies, improve them and further integrate them in order to get more business from building energy conservation market. The vice manager of Ditree said:

'We have maintained our technological investment every year; from 2010–2015, we invested 25 million RMB in technological development, but from 2013 we have made more investment into technology transfer instead of independent R&D. This is because in recent years, more and more ESCOs, with strong technological capability, have entered the industrial energy conservation market. Therefore, we changed our technological development strategy in order to meet our new business development strategy.'

Improving company's competiveness

After China's 11th FYP, more and more ESCOs entered the market, leading to increasingly intense competition. The number of ESCOs in Zhejiang Province increased by seven times within five years. Compared with new entrants, Ditree has built up a technological capability that is hard to catch. However, Ditree does not own many domestic advanced energy conservation technologies or the ability to develop emerging energy conservation technologies. Therefore, Ditree must keep its investment in technological capability development and employ more R&D staffs to develop and improve its own proprietary technologies.

'With more and more competitive ESCOs entering the market, our domestic advanced technologies gradually became mature technologies. Ditree is not able to develop another new and advanced technology at present. Therefore, Ditree tried to transfer more mature industrial and building conservation technologies in order to increase its technologies accumulation and R&D experience for R&D and innovation in the future.' (Director of R&D)

Government intervention

Ditree was named as a ‘National high-tech enterprise’ in 2011, but must maintain and develop its technological capability in order to keep this honorary title. At the same time, as a registered ESCO by NDRC and a recommended ESCO by the Ministry of Industry and Information Technology, Ditree must develop its technological capability in order to be a technical competitive ESCO; otherwise, Ditree will be removed from the list of NDRC registered ESCOs. The vice manager expressed that all the honorary titles, certificates and qualifications are important considerations for customers when choosing an ESCO. If lost these, Ditree would face significant marketing problems.

6.2.3 Which factors affect Ditree’s technological capability development?

Even though Ditree has built up its technological capability, there are 10 factors (seven internal and three external) that currently affect its technological capability development. Most of the factors were identified as unsupportively impacting Ditree’s investment, production, linkage and innovation capabilities; see Table 20.

Table 20: Factors affecting Ditree's technological capability ("**+**" supportive, "**−**" unsupportive).

Key Factors	Technological capability			
	Investment capability	Production capability	Linkage capability	Innovation capability
Internal				
Company's financing ability	**−**			
Technical staff	**+**	**+**		
R&D investment				**−**
R&D experience				**−**
Personal relationship			**+**	
Management team	**+**	**+**		**−**
Absorptive capacity		**−**	**+**	
External				
Research institutes and associations				**+**
Customer		**−**		

6.2.4 How do the factors affect the firm's technological capability?

This section described and explains the factors affecting Ditree's technological capability, as perceived by interviewees. First, four dimensions of technological capability of Ditree were explained, followed by a separate illustration of how the factors affect these four dimensions.

Investment capability

Ditree has not built up a strong investment capability from the perspective of financing and amount of investment. First of all, the company has not had effective financing channels to access external financial resources for investment in technology transfer and R&D. The investment for technological capability mainly comes from the company's profit. Every year, Ditree invests 3 per cent of its sales income in technological capability. For example, in 2015, Ditree's sales income was 60 million RMB and its investment in technological capability is 2 million RMB. Therefore, the investment in technological capability development is limited. However, Ditree employs a number of technical staff, who are diversified and experienced. Therefore, when Ditree identifies potential energy conservation technologies, technical staff can effectively and comprehensively evaluate these technologies. Three factors affected Ditree's investment capability: the company's financing ability negatively affected its investment capability, while technical staff and management team were factors that positively accelerated the development of the company's investment capability.

Company's financing ability: Ditree tried to obtain financing in various ways. In 2010, the company received a 3 million RMB investment from a well-known domestic venture capital firm called Song Wo Capital. Then, in 2015, Ditree successfully became a listed company of 'New third board' and tried to finance through inter-firm equity transaction. However, by the end of 2016, no transaction had taken place. Moreover, Ditree only obtained limited short-term loan from commercial banks for energy conservation projects. Ditree's limited ability to finance has meant it has not had enough funds to invest in R&D.

Technical staff: Ditree has a number of technical staff with nearly 10 years of experience each.

Some employees have had work experience in iron and steel manufacturing enterprises, while others include software engineers, mechanical engineers and electrical engineers. When technical staff identify and evaluate potential energy conservation technologies, they can undertake the evaluation more comprehensively and effectively.

Management team: The management team is responsible for setting up technological development strategy, investment decision-making and allocating resources for technological capability development. From 2006–2012, the management team allocated much more resources for independent R&D and innovation. From 2012–2015, the management team focused on allocating resources for technology transfer. The senior manager said:

> *'The resources of Ditree are very limited and even tense, so the management team must reasonably allocate resources to the right place. Because of failed decision-making, the company lost lots of money from 2006 to 2012. Therefore, the management team changed its investment direction to transfer domestic mature technologies to expand the company's business at present.' (Senior manager of Ditree)*

Production capability

Ditree's production capability refers to absorbing transferred energy conservation technologies and using these technologies to implement energy conservation projects and help customers save energy and reduce emissions. In addition, Ditree has also collaborated with an electrical components manufacturer and a professional project implementation company. The electrical components manufacturer helps Ditree produce products developed by Ditree. The project implementation company helps Ditree to implement projects. Ditree purchased some standard product used in projects, such as frequency converters and servomotors, from famous suppliers Mitsubishi and Panasonic.

In order to ensure the quality and operation of projects, technical staff from Ditree supervise the implementation of entire project and provide technical guidance in the field. After the project implementation, Ditree sends five technical staffs to the customer's enterprise to provide training and guidance.

Five factors influence Ditree's production capability. Technical staff and management team are the factors that facilitate the company's production capability, whereas customer and absorptive capacity are negative factors that influence Ditree's production capability.

Technical Staff: Ditree has approximately 40 technical staffs, 30 of them work for the R&D department. The technical staffs of Ditree are experienced and diversified. The company has software engineers, electrical engineers, mechanical engineers and normal technical staffs. The director of R&D expressed that when the company undertook technologies absorption, the experienced and diversified technical staff are good at accepting different kinds of mature energy conservation technologies from industrial and building conservation. Especially, in terms of absorption of building energy conservation technologies, electrical engineers play a significant role in absorbing these mature technologies.

Management team: In order to provide quality projects, the management team developed a series of norms and operation processes, which the project implementation company complied with when implementing projects. At the same time, Ditree also trained its technical staffs in how to transfer knowledge to customers effectively. The management team developed a standard training course for customers, although technical staff could adjust the course according to customer's context.

Absorptive capacity: Even though Ditree has successful absorbed more than 10 energy conservation technologies, the company only has experience about absorbing energy conservation technologies in the industrial area. Due to a lack of knowledge about building energy conservation technologies, all of the building energy conservation technologies that were absorbed and assimilated were mature domestic technologies. The director of R&D said:

> *'It is much easier for the company to absorb these domestic mature technologies. The absorption was efficient and involved low time and money cost. At the same time, the obtained technologies could be rapidly applied by the company to implement energy-saving projects. If we have strong absorptive capacity, we will definitely try to absorb advanced domestic energy conservation technologies.' (Director of R&D)*

Customer: Customer's knowledge capture and ability to conduct daily project operation will affect the effectiveness of energy-saving projects. Ditree usually provides regular visits and maintenance for the energy-saving projects, although customers are responsible for daily operation and maintenance after the training that Ditree provides. Due to customers' weak knowledge capture capacity, the amount of energy saving is less than expected. The senior manager expressed:

> *'Some customers complained that the saving energy is less than expected. Actually, most of these problems were caused by non-standard operation… Moreover, the conflicts between energy-saving projects and customer's staff affect the company's production capability. An example occurred when we implemented a boiler retrofit project through our gas and power dual use technology, to improve the combustion efficiency of coal. Before the retrofit project, the staff who operated the boiler could sell insufficient combustion of cinder for 50 RMB per ton. Our retrofit project harmed personal interests. Therefore, the staff intentionally disturbed standard operation or even damaged the equipment.'(Senior manager of Ditree)*

Linkage capability

Since Ditree was established, the firm has tried to build up linkages with research institutes, local governments, suppliers, customers and competitors. After 10 years of development, Ditree has established formal linkage with Zhejiang University and successfully conducted collaborative R&D. Ditree has also built up formal linkages with the Hangzhou Energy Conservation Centre, suppliers and four competitors through cooperation agreements. Through linkages with competitors, Ditree successfully transferred or exchanged seven energy conservation technologies.

Taking advantage of collaborative R&D, Ditree leveraged the National Advanced Fluid Laboratory and fluid mechanics experts from Zhejiang University. During the period of collaborative R&D, Ditree sent a technical team to the university and worked together with technical staff and experts for four months. All of the R&D work has been finished at the university.

Moreover, Ditree also established some informal linkages by means of a personal relationship. Two domestic mature building conservation technologies have been transferred based on the informal linkages with competitors. According to the interviewees' explanations, there are two key factors that affect the company's linkage capability.

Personal relationship: Most of linkages established by Ditree started from personal relationships. The CEO of Ditree has good and broad personal relationships with research institutes, suppliers and competitors. For example, the CEO has five years of work experience at Zhejiang University. Therefore, when Ditree established linkage with Zhejiang University and conducted collaborative R&D, the CEO's personal relationship played an important role. Moreover, personal relationships also reduce the costs of establishing linkages.

The director of R&D provided an example of this. When Ditree transferred the energy-saving technology of Ternary Flow Sintering from another ESCO through technology acquisition, the acquisition price was 20 per cent lower than the market price and the whole technology acquisition was completed within one week. Such efficient technology acquisition with lower price was due to a good personal relationship between the CEO of Ditree and the general manager of another ESCO. Apart from this, the technology transfer party sent two technical staff to Ditree and provided two days' introduction and illustration about the technology.

Absorptive capacity: Ditree has good absorptive capacity for absorbing and improving energy conservation technologies in industrial conservation. Taking advantage of rich experience of absorbing several domestic advanced industrial energy conservation technologies, Ditree built up good absorptive capacity. By means of this absorptive capacity, Ditree effectively obtained and absorbed technologies through linkages.

Innovation capability

From 2006 and 2012, Ditree tried to become an innovator in industrial energy conservation technologies. The company focused on independent R&D, even conducting radical innovation through collaborative R&D with the university. During that period, Ditree built up some innovation capability. However, from 2013–2015, the company changed its focus to collecting and absorbing domestic mature energy conservation technologies in order to increase technology accumulation. During this period, Ditree's innovation capability did not improve greatly. So far, Ditree's main innovation activities have been to improve existing technologies and to integrate them into a whole system.

Interviewees identified seven key factors that affect Ditree's innovation capability. Interviewees focused on internal factors and indicated that six internal factors affect the company's previous, current and even future innovation capability.

R&D investment: Ditree's annual investment in R&D is only 1–1.5 million RMB. Half of the investment in technological capability development was allocated to technology transfer and absorption. Limited R&D investment leads to limited R&D activities. In 2014 and 2015, there were no R&D activities to develop new energy conservation technologies. The director of Ditree's financial department expressed that, due to the company's general market performance, there was not a lot of money to allocate to R&D. The company will only be able to increase its investment in R&D if Ditree obtains external financed or has a significant improvement in its market performance.

R&D experience: The technical staff of Ditree were experienced and diversified. Nevertheless, most of the technical staff lack of sense and practical experience to innovation. The technical staffs were good at absorbing transferred technologies and improving these technologies, although most of these improvements were not significant. In addition, from 2013–2016, the main R&D activities of R&D department were absorbing transferred mature technologies and integrating technologies. The R&D department did some incremental innovation work to improve some mature technologies, but no significant innovation work was undertaken. Therefore, Ditree did not accumulate R&D experience during these three years.

Management team: Because the management team changed its technological capability development strategy, there were not a lot of resources to allocate to innovation. This change directly affects the improvement of innovation capability. The vice manager expressed:

> *'In recent years, we changed our strategy to technological capability development. Therefore, most of the resources and investment were used to collect and acquire numbers of energy conservation technologies in building energy conservation. We want to increase the quantity of our energy technologies and enrich our product portfolio, taking advantage of this way. Therefore, the input of innovation was reduced. Nevertheless, through technology absorption, our knowledge accumulation is increasing, which is good for our innovation in future. So, it is hard to say that our innovation capability didn't improve.'(Vice manager)*

Research institutes and associations: The local university has a large amount of excellent R&D resources, including R&D talents, experts, equipment and laboratories. The director of R&D expressed that if the company can obtain effective support from universities or other research institutes, it will definitely strengthen the company's innovation capability. For example, through collaborative R&D, Ditree developed an advanced energy-saving technology, although this is the only advanced technology the company has developed so far. The senior manager expressed that the university's support will greatly strengthen the company's innovation capability. However, if it wants to get effective supports from the university, the company requires a lot of capital to make the investment. Ditree is not currently able to conduct this kind of collaboration.

6.2.5 How has Ditree developed its technological capability?

Ditree started to develop its technological capability in 2005. However, the company faced numerous challenges in the process of development. The initial success led to overconfidence in independent R&D; the resulting failure helped the firm understand itself better and change its technological development strategy.

This section has discussed and illustrated the different processes of Ditree's technological capability development during different periods. The director of the R&D department detailed introduced and explained the current process of technological capability development.

2005–2012

During this period, Ditree focused on independent R&D and innovation. Therefore, Ditree's technological capability building up started with collaborative R&D with Zhejiang University to develop an advanced energy-saving technology for industrial circulating water. Ditree then started to undertake independent R&D to develop energy-saving technologies for industrial energy conservation. However, no significant energy-saving technologies were developed during these years. During this period, Ditree expanded its business by obtaining another three industrial energy-saving technologies through technology transfer.

From 2013–2015

During this period, Ditree focused on collecting and absorbing domestic mature energy-saving technologies for building energy conservation. Through technology acquisition, project cooperation with competitors and technical staff flowing, Ditree obtained nine building energy conservation technologies, which it then absorbed and assimilated and, in some cases, integrated. Taking advantage of technology transfer, Ditree increased the quantity of its energy-saving technology and its knowledge accumulation. Finally, Ditree developed its first energy management platform for a heating supply system. Figure 33 is the current process of technological capability development, which was created according to director of R&D's description and explanation.

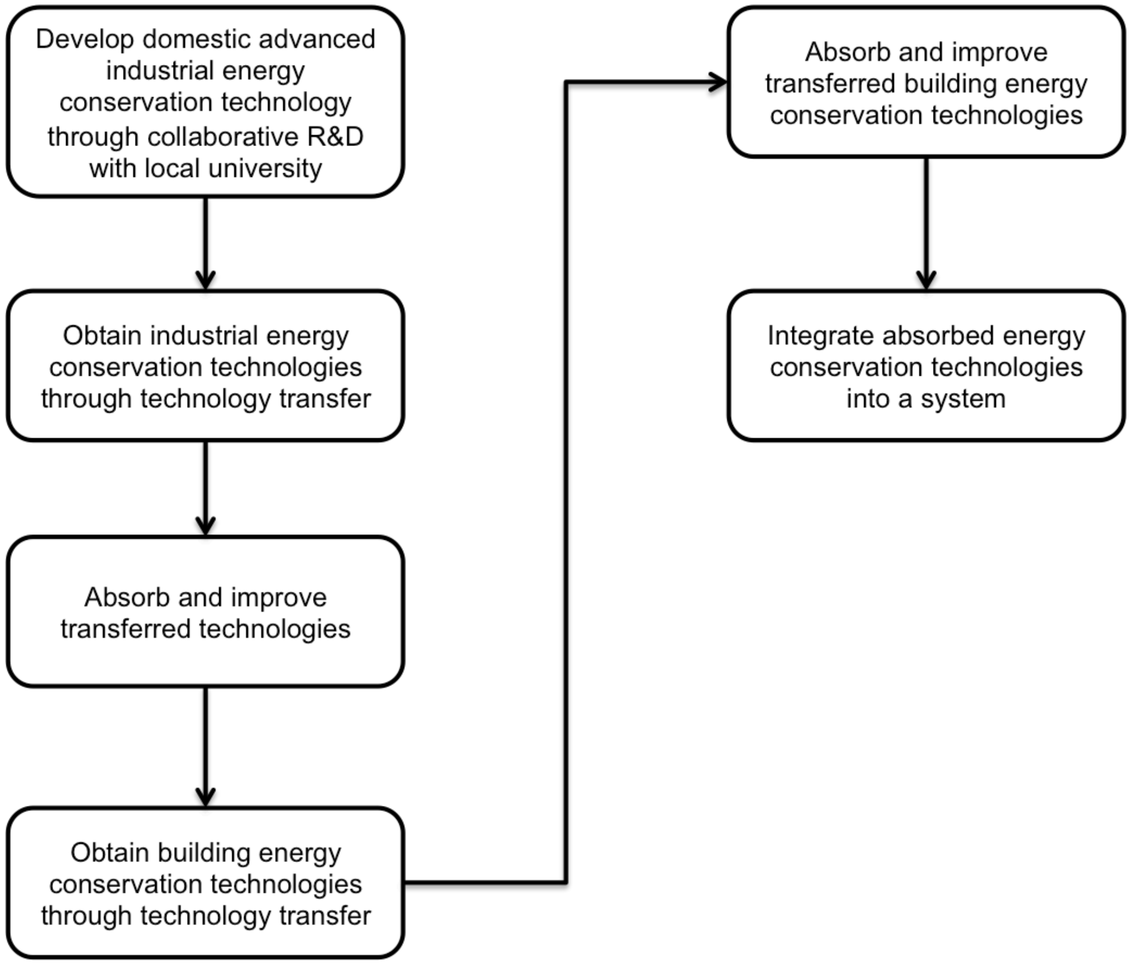


Figure 33: Ditree's process of technological capability development.

The process of technological capability development is relatively simply. Unlike other ESCOs, Ditree did not invest a lot into improving these mature technologies. Moreover, Ditree has tried to undertake innovation again by developing its own energy management platform.

6.2.6 Summary

This section has presented and discussed the analysis and results of the Ditree case study. As a medium-sized ESCO with more than 10 years' business history, Ditree has already built up its own technological capability.

Ditree wants to expand its business and improve its competiveness through technological capability development. Technological capability is the company's competitive advantage, and new ESCOs will find it difficult to catch up in this regard. Government intervention is another driver that motivated Ditree to develop its technological capability. In order to keep the honorary titles and certifications issued by government, Ditree has to develop its technological capability over time.

According to the data analysis, 9 key factors were identified as affecting Ditree's technological capability development. These factors supportively or unsupportively influence the dimensions of technological capability; see Figure 34.

Conceptual framework

Dimensions	Internal factors	External factors
Investment capability	Company size Finance ability Profitability ability Organizational structure and policy Absorptive capacity R&D Prior knowledge Company's strategy Management capability	Financial institutions Research institutions and associations Customer Supplier Partner Competitors Government policy Regulation environment
Production capability		
Linkage capability		
Innovation capability		

Factors affecting Ditree's four dimensions of technological capability

Dimensions	Internal factors	External factors
Investment capability	Company's financing ability Technical staff Management team	
Production capability	Technical staff Management team Absorptive capacity	Customer
Linkage capability	Personal relationship Absorptive capacity	
Innovation capability	R&D investment R&D experience Management team	Research institutes and associations

Figure 34: Factors affecting Ditree's four dimensions of technological capability

Investment capability was deemed as the most influential dimension of technological capability. Three key factors were identified affecting investment capability. Limited financing ability has hindered Ditree's investment in technological capability. However, due to diversified and experienced technical staff, Ditree has been able to identify and evaluate potential energy conservation technologies. The limited investment capability of Ditree directly affects company's production and innovation capability.

Ditree's production capability was seen as another one of the most important dimensions of technological capability, which was affected by four factors. Ditree provides energy conservation services through applying absorbed and developed energy conservation technologies. There is a technical team responsible for absorbing transferred technologies. In addition, Ditree purchases equipment and products from renowned international suppliers and has found a qualified manufacturer to help it produce energy-saving products. In order to ensure the quality of projects, Ditree set up a series of norms and operation processes for project implementation, customer training and project maintenance. Therefore, Ditree's production capability directly affects its investment capability.

Ditree has built up formal linkages with a local university, suppliers and competitors. Taking advantage of these linkages, Ditree successfully completed collaborative R&D with the university and technology transfer with the competitors. Two factors positively affect Ditree's linkages capability. One is personal relationships, which help Ditree build up broad informal and formal linkages. The other is Ditree's absorptive capacity, which helps the company effectively obtain and absorbed technologies transferred through these linkages. The linkage capability influences the development of production and innovation capabilities.

In terms of innovation capability, Ditree used to focus on developing innovation capability though independent R&D and collaborative R&D. However, from 2013, the company changed its technological capability strategy to collect and absorb numbers of mature domestic technologies to increase its technology stock and improve its knowledge accumulation. Four factors were identified.

R&D investment, R&D experience and management became main constraints to innovation capability, while research institutes and associations have facilitated Ditree's innovation capability. Ditree doesn't have strong innovation capability. However, its current innovation capability facilitates its production capability development.

Currently, Ditree focuses solely on production capability. In its early stage, Ditree focused on investment, linkage and innovation capability but after changing its business and technological capability development strategy, the company shifted its focus to absorbing building energy conservation technologies. Moreover, most of the company's building energy conservation technologies were from open sources, which are mature energy conservation technologies.

Ditree had different process of technological capability during different time periods. From 2006–2012, Ditree implemented independent R&D and collaborative R&D to develop advanced energy-saving technologies. From 2013–2015, the company focused on collecting, absorbing and assimilating number of mature energy-saving technologies to improve its technological capability. In 2016, Ditree tried to achieve innovation by developing software in the form of an energy management system for heating supply system.

6.3 Chapter summary

This chapter has presented data analysis and results of case studies of two medium-sized ESCOs in China. Sinowise and Ditree have both built up their technological capability and developed their own proprietary energy conservation technologies at an early stage. However, many factors still positively and negatively affect both the technological capability of both companies.

Twelve factors affect Sinowise's technological capability; mostly positively. Nine factors were identified for Ditree, although most of these are constraints to the company's technological capability.

Sinowise and Ditree both have clear process of technological capability. Sinowise developed its own proprietary energy conservation technology and gradually improved this technology. Through integrating absorbed and developed energy conservation technologies, Sinowise developed an energy management centre that involves a series of energy conservation technologies. Moreover, Sinowise is trying to develop domestic advanced energy conservation technologies through radical innovation. Ditree, on the other hand, developed one domestic advanced energy conservation technology through collaborative R&D, but changed its technological capability development strategy from 2013, focusing more on collecting and absorbing building energy conservation technologies. The R&D investment has been reduced and there were only a few R&D activities from 2013 to 2015.

The next chapter will present data analysis and results of case studies of large-size ESCOs in China.

Chapter 7 Findings from large ESCOs in China

7.1 Case study of CECEP Industrial Energy Conservation Co., Ltd

7.1.1 Company background

Company profile

CECEP Industrial Energy Conservation Co., Ltd (referred to as CECEP IEC in this thesis) is a holding subsidiary of China Energy Conservation and Environmental Protection Group (CECEP). CECEP is the only state-owned central enterprise whose main businesses are energy conservation and environmental protection. CECEP currently has 543 sub-enterprises, including 27 wholly owned and holding subsidiaries, six of which are listed companies. Its business has expanded to 60 regions and countries. CECEP group is the largest state-owned energy conservation group in China and is also the largest investor in energy conservation projects in China, either..

CECEP IEC is a large ESCO that focuses on industrial energy conservation in China and other developing countries. It was established in December of 2010 in Beijing with registered capital of 50 million RMB. By the end of 2013, the registered capital of company had reached 970 million RMB, and by the end of 2014, the total assets of the company had reached 4.69 billion RMB. There were 971 employees working for CECEP IEC by the end of 2015. CECEP IEC has five wholly owned subsidiaries, four holding subsidiaries and seven branches around China. By the end of 2014, the total installed capacity of the projects was 599.3 MW. In 2013 and 2014, CECEP IEC was ranked first in the list of 'Top 100 Chinese ESCOs'.

The company applies professional management and has an explicit organisational structure and divisions of responsibilities. The company has a board of directors, board of supervisors, management team and 12 departments. The Infrastructure Management and Safety Production Supervision and Management departments are responsible for infrastructure safety. The Waste Heat Power Generation Management, Company Management, and Strategic Investment departments are responsible for investment and operation. The Product Sales, Market Development, and Technology Management departments are responsible for marketing. The Community Work Group, Finance Management, HR Management, and Integrated Management departments are responsible for the integrated management of the company.

As one of the largest ESCOs in China, CECEP IEC focuses on providing energy conservation services for high-energy consumption industrial enterprises. It mainly engages in industrial energy-saving project system integration, core equipment manufacturing, energy-saving project investment, and construction, project implementation and operation and management. CECEP IEC provides comprehensive energy solutions for high-energy consumption enterprises through energy-saving diagnosis, assessment, technological transformation, operation and financing.

CECEP IEC applied different businesses models and serve for different customers. Its main customers are large domestic and foreign manufacturers and its main businesses models involve energy performance contracts (EPC), build-operate-transfer (BOT), build-owning-operate (BOO) and build-transfer (BT). Based on these businesses models, CECEP IEC has already successfully provided energy conservation services for PetroChina, Chongqing Iron and Steel, Lafarge, Taiwan Glass Group, Chuanwei Group and a series of customers from the metallurgy, petroleum and petrochemical, building materials and chemical industries.

CECEP IEC has implemented 21 large energy conservation projects in 10 provinces. By the end of 2015, total project investment had exceeded 12 billion RMB. Seven energy conservation projects were key projects that were focused on by national and local governments. Table 21 shows the key projects implemented by CECEP IEC.

Table 21: Key energy conservation projects implemented by CECEP IEC.

Energy conservation projects	Amount of energy saving or energy generation	Main energy saving technologies
Lu'an Thermal Power Project	Steam 4.656 million tons Generating capacity of 870 million kWh annual	Waste heat steam supply Waste heat power generation
Ningxia Aetai coalbed methane power generation project	Power generation 32.4MW annual	Coal mine gas power generation
Chongqing Sanfeng Project	Power generation 353.5MW annual	Gas - steam combined cycle power generation CDQ waste heat generation
Chuanwei project	Power generation 30MW annual. Saving 9,6000 tons of standard coal annually Reduced 250,000 tons of carbon dioxide emissions annually	CDQ power generation Sintering waste heat power generation
Lafarge Cement Waste Heat Power Generation Project	Power generation 27MW annual Saving 6,6000 tons of standard coal annually Reduced 195,000 tons of carbon dioxide emissions annually	Cement waste heat power generation
Table glass kiln waste heat power generation project	Power generation 24MW annual Saving 3,4000 tons of standard coal annually Reduced 91,000 tons of carbon dioxide emissions annually	waste heat power generation
"West - East Gas Pipeline" Compressor Station Energy - saving Project	n/a	Gas turbine waste heat generation

CECEP IEC’s four competitive advantages are as follows:

- Technological advantage: Rich technology accumulation, core industrial energy conservation technologies, and product and technology integration.
- Project management advantage: Rich experience in project construction management and operation, especially for large industrial energy conservation projects.
- Resource integration advantage: Providing whole process of systematic solutions, which involve project consulting, design, construction, investment, and financing
- Branded advantage: Has a good business reputation and a wide range of social impact, cooperation channels.

Company’s technological capability

CECEP IEC is a national high-tech enterprise that has 400 distinct technical staff positions. The technical management department at the company's headquarters has 100 technical staff working in research and development. CECEP IEC not only has various engineers but also a technical experts group that involves 30 experts in industrial energy conservation. The technical management department was established at the end of 2015.

Through technology transfer, in-house R&D and collaborative R&D, CECEP IEC owns 120 utility model patents and invention patents. As one of China's largest ESCOs, CECEP IEC has the most patents in industrial energy conservation in China.

CECEP IEC not only develops energy conservation technologies but also develops and manufactures core energy-saving products and equipment for industrial energy conservation. Besides a series of waste heat and comprehensive energy utilisation technologies, the company has developed four core industrial international advanced energy-saving technologies: the Real-time Online Condenser Cleaning & Enhanced Heat Transfer System, Recovery of Carbide Furnace Tail Gas and Renovation of Lime Kiln, Energy-Saving Technology of Permanent Magnet Eddy Current Flexible Transmission, and Comprehensive Energy-saving Technology of Industrial Boiler System.

Even though CECEP IEC has only six years of business history, it has very rich technology accumulation. Taking advantage of its strong capital and financing ability, the company acquired a number of medium and large ESCOs in recent years in order to obtain energy-saving technologies and experienced technical staff. The company has also built up linkages with domestic and internationally renowned research institutes, universities and companies for technology communication and collaborative R&D. The company has established close industrial and technology cooperative relationships with Daqing Oilfield, GE Gas, Mitsubishi Heavy Industries, Kobe Steel, Albert, Tianjin University, Beijing University of Science and Technology, and dozens of organisations.

Since CECEP IEC was established, it has applied explicit business and technological development strategies. In view of the common problems and key issues in the field of industrial energy saving, the company has actively carried out technical research activities and cooperation in production and research. In terms of technological development strategy, the company has vigorously promoted the introduction of technology, absorption, assimilation and innovation, and integration of technology innovation. From 2011–2014, CECEP IEC focused on introducing and absorbing transferred technologies in order to enrich its technology and know-how accumulation. Since 2015, the company has been focusing on enhancing cooperation with domestic research institutes and domestic and international companies in order to conduct collaborative R&D to develop international advanced industrial energy-saving technologies.

7.1.2 Why has CECEP IEC developed its technological capability?

Company's development strategy

CECEP IEC has clear business development and technological capability development strategies, which it has maintained since it was established. The company has been making efforts to become the leading ESCO in industrial energy conservation. The director of the Strategic Investment Department expressed that 'In order to attain our current market position and keep this position, we have to keep and improve the company's competitive advantages, such as branded advantage, capital and finance advantages and technological advantages.' CECEP IEC focuses on market share, energy conservation investment revenue, but also on technology accumulation and advanced energy conservation technologies. Hence, CECEP employs a large number of technical staff and experts and has invested more than 300 million RMB in technology transfer and R&D.

Improving the company's competiveness

Around 30 large ESCOs can be viewed as the main competitors to CECEP IEC. In addition, some competitive medium ESCOs have started to implement large energy conservation projects (that is projects with investment of over 1 billion RMB). The director of the Strategic Investment Department expressed that 'With some big companies from other industries entering this market, the market competition between large ESCOs has become more and more intense. These new entrants have capital and finance advantage and branded advantage. Compared with them, CECEP IEC's only advantage is project implementation experience and technological capability. Therefore, technological capability is an important competitive advantage for the company.'

Government intervention

As a state-owned central enterprise, CECEP IECis heavily affected by government policies. The central government wants the company to be a representative ESCO to promote the development of entire energy service industry. Hence, the central government has a higher requirement for the company's technological capability. CECEP IEC needs to build up strong technological capability and has significant advantages in technological capability in the energy service industry. The director of the Strategic Investment Department expressed that 'Central government is the owner of CECEP. The objective of building up CECEP is very clear: it is to establish a representative ESCO with strong capabilities and large scale in order to show an attitude and ability to the outside.' That is one of the main reasons why CECEP IEC has 120 patents in just six years of history.

7.1.3 Which factors affect CECEP IEC's technological capability development?

The interviewees provided their opinions about key internal and external factors that affect the company's technological capability. All of the identified key factors affect the company's investment, production, linkage and innovation capabilities. Table 22 shows these key factors.

Table 22: Factors affecting CECEP IEC's technological capability ('**+**' supportive, '**−**' unsupportive).

Key Factors	Technological capability			
	Investment capability	Production capability	Linkage capability	Innovation capability
Internal				
Company's financing ability	+			
R&D investment			+	+
R&D experience				−
Technical staff	+	+	+	
Management team	+	+	+	+
Absorptive capacity		+	+	+
External				
Government intervention	+		+	+
Research institutes &associations				+
Companies from other industries				+
Competitor				+

The interviewees identified a total of 10 key factors, six of which were internal and four of which were external.

7.1.4 How do the factors affect the CECEP IEC's technological capability?

In this section, the factors affecting firm's technological capability are described and explained. First of all, four dimensions of company's technological capability are introduced and explained separately, followed by a description of the factors that affect the company's investment, production, linkage and innovation capabilities.

Investment capability

CECEP IEC has very strong investment capability. Its investment capability not only reflects a strong capital and financing ability to invest in technological capability, but also the ability to recognise, evaluate and select technical staff, energy-saving technologies, and energy conservation products and equipment.

First, CECEP IEC has an advantage in terms of preparing funds for investment in technological capability. The company has obtained funds mainly from commercial banks, its own capital and its parent company's financial support, CECEP. In addition, due to its good market performance, the company has strong profitability. To date, the company's investment in technological capability has exceeded 300 million RMB and this number will continue to increase over the next five years. So far, the company has already successfully obtained approximately 200 energy-saving technologies.

In terms of recognising and assessing potential energy conservation technologies, CECEP IEC not only has knowledge about which energy conservation technologies are suitable for its customers and business but also about which technologies can be improved and integrated with existing technologies in order to create an integrated technological system or package to implement energy conservation projects.

Company's financing ability: CECEP IEC is a large ESCO with total assets reaching 4.6 billion RMB. Taking advantage of this large capital, it is relatively easy for the company to obtain bank loans from commercial banks. In addition, adequate funding supply ensures that the company is able to invest in large energy conservation projects. Therefore, the company's market performance and profitability is good. The director of the Strategic Investment Department expressed that:

> *'Even though the investment in technological capability is only about 2–3.5 per cent of annual sales income, the amount of investment can reach 50–100 million RMB annually. This amount of investment normally does not include the expense of company acquisition. The annual investment in technological capability development is very large in terms of the ESCO industry.'(Director of the Strategic Investment Department)*

Technical staff: The company has a large amount of high-quality technical staff, most of whom have graduated from renowned universities in China and experienced a rigorous review and selection process. Therefore, the technical staff of the company have professional knowledge and good working and learning abilities. Through acquisition, the company also absorbed a number of experienced technical staffs. Through communication, training and cooperation, these technical staff have acquired knowledge about industrial energy conservation technologies. The company has built up its ability to recognise and evaluate potential technologies over the last two years, 2010-2012.

Management team: The management team decided the direction and amount of investment. In recent years, the management team has focused on acquiring technologies in order to increase technology accumulation. Therefore, a large amount of investment in technological capability was allocated to technology transfer. The investment in R&D and innovation accounts for approximately 40 per cent of the total investment in technological capability development. The director of Strategic Investment Department expressed that:

> *'Every year, we will develop an investment plan that involves how much we invest in technological capability development, the proportion of technology transfer, R&D, innovation and technical staff enrolment. This plan will also be reviewed and confirmed by the board of directors. The management team implements and adjusts specific investment activities, and therefore directly affects the company's investment capability.' (Director of the Strategic Investment Department)*

Government intervention: Increasingly strict government policies and regulations regarding industrial energy consumption have pushed CECEP IEC to develop its technological capability. In addition, the government has specific requirements for state-owned enterprises regarding technological capability development. The government asks state-owned ESCOs not only to lead investment in energy conservation projects but also to develop advanced energy conservation technologies and projects. In order to meet these requirements, CECEP IEC has increased its proportion of investment in R&D and innovation.

Production capability

The production capability of CECEP IEC has two main aspects. One is using energy conservation technologies to provide energy conservation service to its customers, and the other is core energy conservation projects and equipment manufacturing. CECEP IEC not only effectively uses transferred technologies to implement energy conservation projects and produce energy conservation products and equipment; it also absorbs these technologies in order to improve and integrate them.

In recent years, CECEP IEC has focused on absorbing and assimilating transferred technologies. The technology management department assumes responsibility for this work. In addition, the company has its own projects implementation team with rich project experience, which ensures the quality of energy-saving projects from the perspectives of project design, construction and maintenance. According to interviewees' explanation, three key factors affect the company's production capability.

Technical staff: The company has a large number of high-quality and diversified technical staffs. One hundred technical staff work in the Technology Management Department and another 300 ones work for subsidiaries. The technical staffs in the Technology Management Department are responsible for absorbing different energy-saving technologies. The director of that department said:

> *'Our technical staff have very good learning capability to make up for the lack of experience. Normally, our technical staff have six to eight months of work experience and could become*

experienced in technology absorption and assimilation. Moreover, most of our technical staff are young. They dare to challenge the absorption and assimilation of more complex and advanced energy-saving technologies. This helps the company accumulate knowledge about complex and advanced energy conservation technologies.'(Director of Technology Management Department)

Management team: The company set up a Safety Production and Supervision Management department in order to ensure the safety, quality and efficiency of project implementation and production. The project manager stated that this department arranges a technical team for every project, supervises the project implementation and prepares a report for every project. The project manager's work is supervised by this department. Moreover, the management team has focused on technology absorption, dedicating a large amount of resources to this, including technical staff, training courses, expert introduction and funds. The director of the Technology Management Department expressed that in the department has 40 technical staff responsible for absorbing transferred technologies. At the same time, these technical staffs are also responsible for diffusing these absorbed technologies to other technical staffs.

Absorptive capacity: CECEP IEC has 120 patents and has mastered more than 150 energy-saving technologies. However, most of the patents and technologies were obtained from company or technology acquisition. Through absorption of transferred technologies, the company has been increasing its knowledge accumulation and building up its absorptive capacity. CECEP IEC is able to recognise, absorb, transform and exploit energy conservation technologies.

'Recent years, the company has focused on technology transfer through technology and even company acquisitions. The quantity of transferred technologies has increased rapidly. Even though our company has only six years of history, our technology and knowledge accumulation has increased quickly. Therefore, we have built up our absorptive capacity with our intensive efforts.' (Director of Strategic Investment Department)

Linkage capability

CECEP IEC has built up formal linkages with research institutes, competitors, customers and internationally renowned companies from other industries. The company has established formal linkages through acquisition, cooperation agreements, project collaboration and collaborative R&D. The company has focused more on building up formal linkages rather than informal linkages. The director of the Strategic Investment Department said that the informal linkages were unstable and unreliable. It is very difficult to conduct effective cooperation based on informal linkages.

CECEP IEC effectively leveraged resources based on these formal linkages. First of all, through company acquisition, the company not only acquired energy-saving technologies, production facilities and technical staff, but also the linkages that were built by the acquired companies. Secondly, through collaborative R&D with research institutes and renowned companies from other industries, the company leveraged resources such as technical experts, advanced laboratory and test equipment, R&D personnel and rich R&D experience. However, the improvement of the company's technological capability is very limited. Finally, through project cooperation, the company normally leveraged energy-saving technologies or implementation teams from cooperating companies. Because CECEP IEC has already built up its absorptive capacity, the company has been able to effectively use and absorb the transferred technologies through these linkages.

There are five key factors that affect the company's linkage capability, all of which positively affect the company's linkage capability.

R&D investment: CECEP IEC has built up formal linkages with well-known companies and domestic universities through collaborative R&D. In most of these collaborations, CECEP IEC has borne all the R&D costs, which requires a huge amount of R&D investment to support. Between 2013 and 2015, the company's investment in collaborative R&D was approximately 50 million RMB.

Technical staff: The technical staffs of CECEP IEC have rich experience in absorbing industrial energy conservation technologies, especially for technologies of waste management. Therefore, when the company acquired a new company, the technical staffs could effectively absorb the transferred energy conservation technologies.

Management team: Generally, the management team has decided which company or organisation will be contacted and how to establish linkages with other organisations. In different development periods, the management team makes different decisions about linkage establishment with different organisations in different ways. The director of strategic investment department stated:

> *'Initially, the company focused on established linkages with domestic competitors, universities and famous companies to undertake technology transfer and collaborative R&D. From 2014, when the company successfully transferred a series of energy conservation technologies and implemented large energy conservation projects with these technologies, CECEP IEC began to contact internationally renowned companies in order to collaboratively develop international advanced energy conservation technologies and products.'(Director of Strategic Investment Department)*

Government intervention: The Chinese Government has encouraged ESCOs to establish linkages with other organisations and promote the development of the ESCO industry. Moreover, the government has encouraged ESCOs to conduct inter-firm technical communication and cooperation. As a state-owned ESCO, the company must actively respond to and implement the government's policies. Therefore, the company has also established broad linkages with a number of domestic competitive ESCOs for technical communication and cooperation.

Innovation capability

Taking advantage of strong capital, finance ability, brand, broad linkages and state-owned enterprise, CECEP Industrial Energy Conservation has strong innovation capability. First of all, the company has 120 utility model and invention patents. Even though 80 per cent of the patents came from acquisition, the company has already undertaken incremental and radical innovation.

The company itself does not have strong competency in terms of independent R&D. However, through company acquisition, CECEP IEC has acquired not only technologies but also some R&D teams and R&D talents who have experience and ability in innovation. Moreover, through collaborative R&D with universities and domestic and international famous companies, the company has successfully conducted radical innovation and developed advanced energy-saving technologies and products.

To date, the company's main independent R&D activities have been energy conservation technologies integrations, which belong to incremental innovation. The radical innovations depend heavily on help and support from universities and outside organisations. The annual investment in innovation capability development is not fixed. However, according to interviewees' explanations, the annual investment in innovation is approximately 20–30 million RMB. The interviewees indicated that there are 11 key factors (six internal and five external) that affect the company's innovation capability.

R&D investment: Radical and incremental innovation both require a large amount of investment support. CECEP IEC's investment in R&D is large. From 2010–2015, the investment in R&D was approximately 120 million RMB, with around 60 per cent used for in-house R&D and the remainder used for collaborative R&D. The director of strategic investment department said:

'The investment of R&D is relatively large. We just focus on industrial energy conservation

technologies. Hence, our investment is also very focused. It ensures our company has good innovation capability in industrial energy conservation.'(Director of Strategic Investment Department)

R&D experience: Most of the company's technical staff have graduated from renowned universities and are young and energetic. Through nearly five years' training, they have accumulated some experience about technology absorption. However, they also lack experience about R&D, which is one of the company's limitations. The current R&D technical staff are particularly limited when it comes to developing advanced energy conservation technologies; however, they have a strong willingness to innovation. The director of technology management department said:

'I am very confident about this young team. These young technical staffs and R6D talents have good academic backgrounds, learning and working ability. Their ideas are open and flexible. They have a sense of innovation, which is important for the company's innovation capability development. They just lack experience from practice. I believe that if we give them three years, they will become a very good R&D team.' (Director of Technology Management Department)

Management team: The company's management team decided seasonal and annual work focuses of technological capability development. For example, in 2011–2013 the management team focused on increasing technology accumulation and building up absorptive capacity, and therefore made a smaller investment in innovation capability. From 2014–2015, the management team decided to try to develop advanced energy-saving technologies through collaborative R&D; therefore, a large amount of investment was allocated into collaborative innovation.

Absorptive capacity: CECEP IEC has successfully transferred a number of mature and advanced industrial energy-saving technologies. Through absorbing these transferred technologies, the company has increased its prior knowledge and built up its absorptive capacity. The absorptive capacity of CECEP IEC provides support for incremental innovation related to improving and integrating absorbed energy conservation technologies.

Government intervention: The government asked CECEP IEC to be a leading ESCO with strong technological capability and make contributions to the development of energy-saving technologies and products. Therefore, the company has had to focus on develop innovation capability in order to respond government's requirements. As director of Strategic Investment Department indicated, 'As a state-owned central ESCO, in terms of government policies and appeals, the company has to implement and respond better than other private companies.'

Research institutes & associations: CECEP IEC built up formal linkages with Tianjin University and University of Science & Technology Beijing to conduct collaborative R&D. To date, the collaborative R&D has focused on both incremental innovation and radical innovation. Especially, in terms of integration of complex energy-saving technologies, universities have provided important technical support.

Companies from other industries: CECEP IEC has collaborated with domestic and internationally renowned companies to conduct radical innovation to develop advanced industrial energy conservation technologies and products. In such collaboration, the technical support relied heavily on outside companies; therefore, companies from other industries seriously affect the company's radical innovation.

Competitor: CECEP IEC increased its technology stock and improved its technological capability through company and technology acquisitions. Competitors were the first choice for acquisition; through acquisition, the company obtained some good R&D team and R&D talents. These resources have helped CECEP IEC build up its innovation capability in short time. The director of technology department said:

> *'We selected some good and experienced R&D talents from acquired companies to join in the technology management department to lead different R&D groups or direct some R&D activities. They made a great contribution to young R&D talents training and R&D capability establishment.' (Director of Technology Management Department)*

7.1.5 How has CECEP IEC developed its technological capability?

Since the company was established, CECEP IEC has made efforts to develop technological capability through technology transfer and independent and collaborative R&D. After six years of development, the company has built up a strong technological capability and has 120 utility model and invention patents. In terms of process of technological capability development, the company followed the path of technology introduction, technology absorption, technology assimilation and technology integration. Moreover, the company also started to conduct radical innovation to develop domestic and international advanced industrial energy conservation technologies and products through collaborative R&D with internationally renowned companies. Figure 35 was created according to interviewees' introduction and explanation, which display the general process of technological capability development.

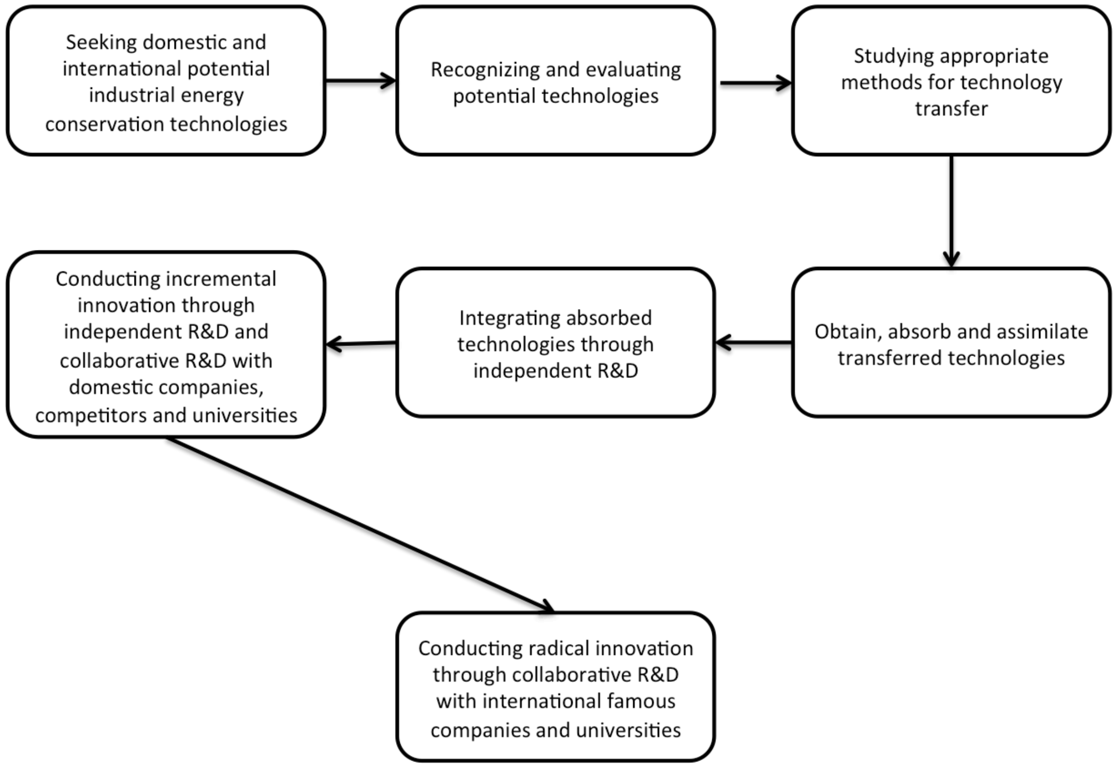


Figure 35: The process of technological capability development of CECEP IEC.

The process of technological capability development of CECEP IEC basically followed the classical path of absorbing, improving and developing. However, there were some differences that need to be mentioned.

First of all, most of the technologies were transferred from domestic organisations, not from companies in developed countries. Some industrial energy conservation technologies were obtained from open sources as well. CECEP focuses on inter-firm technology transfer within China.

Secondly, even though the company focused on absorbing transferred technologies, it also undertook incremental innovation through in-house R&D and collaborative R&D with domestic universities, customers and competitors. The company invested a lot of resources in R&D development and incremental innovation annually. The main incremental innovation activities involve technology improving, equipment retrofit and technology integration.

Thirdly, the company did not focus on obtaining technologies from companies in advanced countries. This strategy has meant, firstly, it is very difficult to obtain emerging technologies from foreign companies. Secondly, the foreign energy conservation technologies might not be exactly suit Chinese energy consumption enterprises. Therefore, in order to leverage the foreign companies' R&D resources, CECEP IEC has focused on developing advanced technologies through collaborative R&D with famous companies in advanced countries.

Finally, the company did not follow a step-by-step method. In other words, the company has developed its technological capability through absorbing and assimilating technologies, conducting incremental innovation and radical innovation at the same time. Taking advantage of incremental innovation, CECEP IEC has rapidly started its business and improved its production capacity. Taking advantage of radical innovation, CECEP IEC built up technical advantage in industrial energy conservation technology.

7.1.6 Summary

In this section, the analysis and results of CECEP IEC case study are presented and discussed.

CECEP IEC is a young and large ESCO. Although it only has six years of business history, it has already built up its technological capability, owns 120 patents, and has mastered approximately 150 industrial energy conservation technologies. Since the company was established, it has focused on developing technological capability and invested a huge amount of resources in R&D.

In terms of motivations of technological capability development, the company's development strategy, market competition and government intervention were identified to drive company's technological capability development. As a large state-owned ESCO, it has the ambition of becoming the leading ESCO in China. Technological capability is deemed as its crucial competitive advantage. Competition between large ESCOs has been increasing due to the entry of large companies from other industries into the market. Compared with these new entrants, the company's advantage of technological capability is hard to be copied. Moreover, government intervention plays a more important role in motivating company's technological capability development, mainly because it is a state-owned central enterprise.

There are 10 key internal and external factors that affect the company's technological capability be identified (see Figure 36).

Conceptual framework

Dimensions	Internal factors	External factors
Investment capability Production capability Linkage capability Innovation capability	Company size Finance ability Profitability ability Organizational structure and policy Absorptive capacity R&D Prior knowledge Company's strategy Management capability	Financial institutions Research institutions and associations Customer Supplier Partner Competitors Government policy Regulation environment

Factors affecting CECEP IEC's four dimensions of technological capability

Dimensions	Internal factors	External factors
Investment capability	Company's financing ability Management team Technical staff	Government intervention
Production capability	Technical staff Management team Absorptive capacity	
Linkage capability	R&D investment Technical staff Management team Absorptive capacity	Government intervention
Innovation capability	R&D investment R&D experience Management team Absorptive capacity	Government intervention Research institutes and associations Companies from other industries Competitors

Figure 36: Factors affecting CECEP IEC's four dimensions of technological capability.

CECEP IEC has strong investment capability. Four key factors supportively affect the company's investment capability. It not only has effectively channels to obtain external financial resources but also has good market performance and profitability. In terms of recognising and evaluating potential energy conservation technologies, CECEP IEC also has rich knowledge and technical staff to support it. CECEP IEC's investment capability support its huge investment in production, linkage and innovation capabilities.

The company's production capability is supportively affected by three key factors. The company's management team focuses on technology absorption, while the technical staff and absorptive capacity make effective utilisation and absorption of transferred technologies. In addition, CECEP IEC has its own project implementation and construction company and energy efficiency product and equipment manufacturing company. In order to ensure the quality, safety and efficiency of project implementation and products and equipment manufacturing, the management set up specific departments to supervise and guide production activities. Company's production capability provides prior knowledge for company's innovation.

CECEP IEC built up formal linkages with customers, competitors, universities and well-known domestic and international companies. Taking advantage of these formal linkages, the company successfully transferred hundreds of energy-saving technologies. Moreover, based on these formal linkages, the company leveraged resources for R&D and innovation. The company's absorptive capacity ensures that the company effectively absorbs technology and know-how from these linkages. Five key factors supportively affect the company's linkage capability; four of these are internal factors. Company's existing linkage capability support company's innovation capability development.

The company has invested a lot in developing its innovation capability. It has conducted incremental innovation through independent and collaborative R&D. Moreover, the company has also started to conduct radical innovation through collaborative innovation with well-known domestic and international universities and companies. Eight key factors affect the company's innovation capability. Seven of these factors supprotively affect the company's innovation capability, but R&D experience is still a barrier to innovation capability. Therefore, company's innovation capability just affects company's production capability directly.

CECEP IEC developed its technological capability following a path similar to Kim's model. The company initially focused on absorbing and assimilating technologies and then integrated absorbed technologies for incremental innovation. However, the company conducted all these activities to develop its technological capability, which involves radical innovation at the same time. The company did not follow a step-by-step method. Based on the numbers of patents owned by the company, the process of technological capability is effective.

7.2 Case study of Guowang Energy Conservation Service Co., Ltd

7.2.1 Company background

Company profile

Guowang Energy Conservation service Co., Ltd (referred to hereafter as Guowang) is another large state-owned ESCO, which was established in January of 2013. Guowang is a wholly owned subsidiary of China State Grid, which is China's largest enterprise for grid operation. State Grid has about 1.66 million employees and is ranked no. 2 in the Top 500 enterprises in the world (Fortune magazine 2016).

In order to respond to government policies about promoting energy conservation and development of ESCOs, State Grid deployed capital, technical personnel and project implementation personnel to establish Guowang. Before Guowang was established, State Grid had a department for energy conservation technologies and project development for electric power generation, delivery and new energy generation. The establishment of Guowang is an attempt by a super company from another industry to enter energy service industry.

Guowang is one of the largest ESCOs in China. Taking advantage of its parent company, its registered capital reached 4.6 billion RMB and total assets reached 16.1 billion RMB in 2015. The company employs approximately 7000 people and has seven functional departments and two business units. Moreover, Guowang also manages six subsidiaries from its parent companies: Guoneng Biomass Power Generation Group Co., Ltd, Guowang Green Energy Co., Ltd., Guowang (Beijing) Energy Conservation Design and Research Institutes Co., Ltd, Chongqing Chuandong Electric Power Group Co., Ltd, Guotai Green Energy Co., Ltd. and Beijing Biomass Energy Technology Centre Co., Ltd. Of these, Guoneng Biomass Power Generation Group Co., Ltd. is the world's largest processional enterprise for biomass comprehensive development and utilisation. Chongqing Chuandong Electric Power Group Co., Ltd. is a listed company that provides direct financing channel for the company.

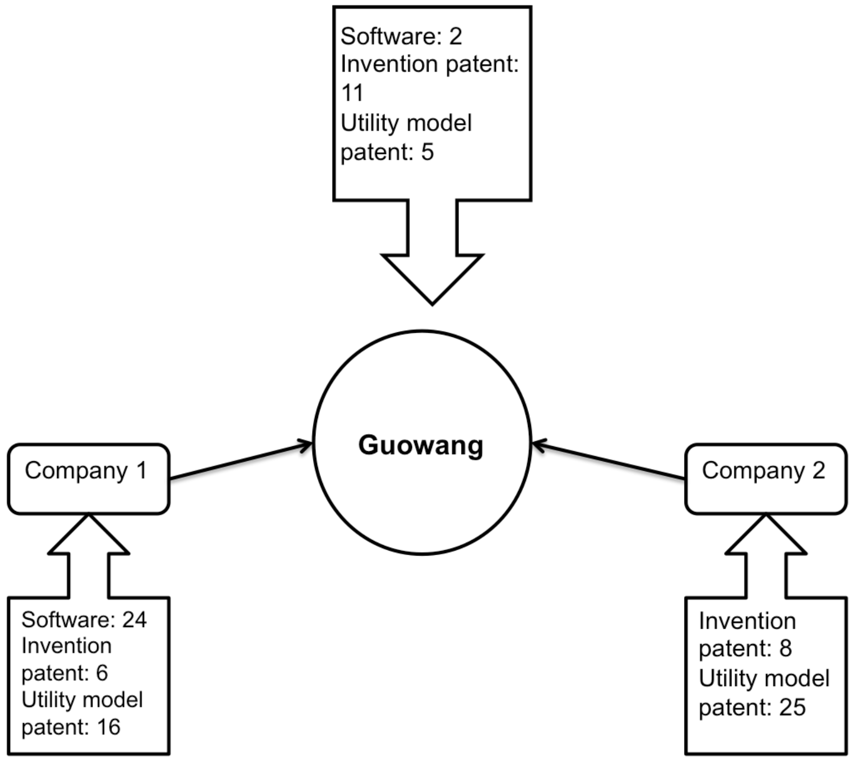
The company has focused on energy conservation services, clean energy comprehensive development and utilisation, power environmental protection, international business four dimensions. Guowang has also focused on developing technologies for energy conservation and clean energy development. Guowang aims to provide comprehensive energy service for customers, mainly from the electricity industry but also the transportation, building and industrial. So far, Guowang's main and biggest customer is its parent company, State Grid.

Guowang is an ESCO, which provides advantages in terms of capital, brand, technological capability and projects design and implementation. However, it is also a young ESCO with just four years of business history. By the end of 2016, it had conducted several large energy conservation projects in the electricity industry, but very limited numbers of projects in other industries. While Guowang aims to provide energy conservation services for different companies from different industries, it has so far seemed to be dedicated to its parent company, State Grid.

Company's technological capability

By taking advantage of its parent company, and because most of its employees had been transferred from the parent company with at least three years of experience, Guowang had relatively strong technological capability when it was established. The company has thousands of technical staffs and hundreds of R&D staffs, who were separated into different departments and managed companies.

Guowang has rich energy conservation technology and knowledge accumulation in terms of energy conservation in electricity industry. These technologies mainly involve power transmission loss reduction technologies, biomass comprehensive utilisations technologies, wind power generation technologies, photovoltaic power generation technologies and a series of thermal power generation energy-saving technologies. Moreover, the company transferred and developed a series of building and industrial energy conservation technologies. Most of the energy conservation technologies in the electricity industry were taken over from the parent company. At the same time, the company also conducted radical innovation to develop advanced energy conservation technologies in the electricity industry through independent R&D and collaborative R&D. Figure 37 displays the energy conservation technologies owned by different companies that were managed or owned by Guowang.



Company 1: Guowang (Beijing) energy conservation design and research institutes Co., Ltd
Company 2: Guoneng biomass power generation group Co., Ltd

Figure 37: Patents owned by Guowang.

Nearly one hundred of patents and software copyrights relevant to energy conservation. Guowang's Technology Department is responsible for absorbing and developing technologies for energy conservation. Guowang (Beijing) Energy Conservation Design and Research Institute helped Guowang Energy Conservation Service Co. Ltd. develop some software for its energy management system. Guoneng Biomass Power Generation Group Co., Ltd. brought a number of advanced technologies for biomass utilisation.

The main entity for energy conservation technology development is Guowang's R&D department.

Guowang (Beijing) Design and Research Institute, which was established in 1999, has worked for the parent company for technologies and product design and development for nearly 17 years. Since Guowang Energy Conservation Service Co. Ltd., was established, according to the parent company's arrangement, Guowang (Beijing) Energy Conservation Design and Research Institute changed its R&D direction to energy conservation technology development in various industries.

Guowang's Technology Department is not big, with just 80 technical staff. The department is still expanding; according to the initial design, the department should have 200 technical staff by the end of 2018.

7.2.2 Why has Guowang developed its technological capability?

Company's development strategy

Guowang aims to become a competitive ESCO, which provides energy conservation services to various energy consumption enterprises from various industries. Guowang's main customers are still companies in the electricity industry, the largest of which is its parent company. In order to achieve its business objectives, Guowang must develop its technological capability in terms of energy conservation. Moreover, Guowang's technological capability development strategy also indicated that it is absorbing and developing energy conservation technology in industrial and building energy conservation in order to increase energy conservation technology accumulation and further improve its technological capability.

Improve company's competiveness

As the subsidiary of a super company, Guowang has many competitive advantages, such as capital, brand, technical staff and technological capability. However, Guowang lacks experience in energy conservation project implementation and energy conservation technologies and products in other industries. In addition, Guowang's main competitors are medium and large ESCOs that have at least five years' business history. In order to compete with medium and large ESCOs in industrial and building energy conservation, Guowang must develop its energy conservation technologies in industrial and building conservation to improve its competiveness and further expand its business to other industries.

Government intervention

As a large state-owned ESCO, Guowang actively responds to government policies. In order to respond to government policies related to promoting and developing energy conservation technologies, Guowang must improve its technological capability. The deputy director of Guowang's Engineering Department stated:

> *'Our parent company is a state-owned central enterprise, so government policies seriously affect parent company's development. As a wholly owned subsidiary, Guowang is very reflective to government's policies, too. The government wants the parent company to build up a competitive and leading ESCO in the industry. Therefore, the government wants Guowang to be competitive in scale, brand, technological capability, project implementation and investment.' (Director of Engineering department)*

7.2.3 Which factors affects Guowang's technological capability development?

Guowang has already built up strong technological capability in terms of technologies for electricity industry and biomass comprehensive utilisation. The interviewees talked at length about energy conservation technologies for industrial and building energy conservation. There are nine key factors that affect Guowang's technological capability development; see Table 22.

Table 23: Key factors affecting Guowang's technological capability ('**+**' supportive, '**−**' unsupportively).

Key Factors	Technological capability			
	Investment capability	Production capability	Linkage capability	Innovation capability
Internal				
Company's financing ability	**+**			
Technical staff	**−**	**+**		**−**
R&D investment				**+**
R&D experience				**−**
Management team	**+**		**−**	**+**
Absorptive capacity		**−**	**−**	**−**
External				
Research institutes & associations		**+**		**+**
Government intervention	**+**			
Supplier		**+**		

Six of these factors were internal and three were external. Most of the factors supportively affect

Guowang's technological capability. However, absorptive capacity is a factor that unsupprotively affects the company's production, linkage and innovation capability.

7.2.4 How do factors affect the Guowang's technological capability development?

In this section, each dimension of technological capability of Guowang is introduced and then explained in detail.

Investment capability

Guowang has the ability to access external financial resources such as bank loans. In addition, the capital of Guowang is large and, based on its existing business, the company has good profitability. Therefore, Guowang has enough funds to invest in developing its technological capability. Moreover, Guowang has a number of experienced technical staff and experts who are responsible for recognising potential energy conservation technologies, products and equipment. However, Guowang lacks knowledge about energy conservation in manufacturing and building industries. Therefore, there are some barriers to evaluating the potential energy conservation technologies in other industries. So far, Guowang's annual investment in technological capability is approximately 80 million RMB, most of which is used for R&D.

Company's financing ability: Guowang has strong financing ability. So far, Guowang has obtained a 7 billion RMB bank loan from 7 commercial banks. Adequate bank loans mean that

Guowang has good cash flow. The company could use its profits to invest in technological capability. The project manager said:

‘Adequate funding support ensures that the company has enough money to conduct large energy conservation projects and has good profitability. The investment in technological capability only takes about 5-10 per cent of the company’s net profit every year. Therefore, company has the ability to increase its investment in technological capability if required’.(Project manager)

Technical staff: Nearly 70 per cent of technical staffs come from the parent company or other subsidiaries of parent companies. These technical staffs have at least three years of work experience. Most of the technical staff have rich experience and knowledge in electrical engineering. Therefore, the technical staff have the ability to recognise the energy conservation technologies that are relevant to electricity. However, in terms of most of energy conservation technologies in industrial and building energy conservation, current technical staff have limited knowledge to recognise and further evaluate them.

Management team: The management team decides the direction of investment in technological capability. The management team makes the investment decisions after reviewing the R&D Department’s reports or considering the parent company’s instructions. So far, the management team has decided to expand its business to building energy conservation. Therefore, the management team has allocated investment and technical staff for transferring, absorbing and developing energy conservation technologies in building energy conservation. The management team has also recruited a number of technical staff for industrial and building energy conservation in recent years.

Government intervention: The government has asked Guowang to expand its business to industrial and building energy conservation areas, rather than just focusing on energy conservation in electricity industry. It also provides comprehensive energy services to different customers from different industries. Taking advantage of the company's capital, technological capability and brand, it aims to develops effective and advanced energy conservation technologies for energy consumption enterprises in China. Therefore, Guowang increased its investment in R&D to develop building and industrial energy conservation technologies.

Production capability

The production capability of Guowang mainly refers to absorbing and assimilating transferred energy conservation technologies for industrial and building industries. So far, Guowang has focused on absorbing and assimilating energy conservation technologies for industrial and building industries in order to increase its energy conservation technology and knowledge accumulation and improve its technological competiveness. Approximately 40 technical staff were supposed to do this job, but Guowang just absorbed and assimilated some mature and a few of advanced domestic energy conservation technologies in industrial and building energy conservation. In particular, the company absorbed a series of building and industrial energy conservation technologies that are relevant to electricity.

Technical staff: Most of the technical staff from the parent company have rich experience in electricity industry. In terms of energy conservation, this is a new dimension for them, especially energy conservation for industrial and building industries. Therefore, when the technical staff absorb and assimilate energy conservation technologies in industrial and building industries, they normally choose mature technologies. Alternatively, they absorbed energy conservation technologies relevant to the electrical area. In addition, technical staffs have rich experience in project implementation and construction; however, for energy conservation projects in industrial and building industries, Guowang has only conducted eight small and medium projects. The experience of project implementation and construction for energy conservation in industrial and building industries is limited.

Absorptive capacity: Guowang has rich knowledge accumulation about energy conservation in electricity industry. However, it has very limited knowledge and know-how regarding industrial and building energy conservation. Therefore, the absorptive capacity of the company has not been completely created. This has limited the company to absorbing various and advanced industrial and building energy conservation technologies.

> *'So far, in terms of building energy conservation technologies, the company just absorbs and assimilates LED lighting and air conditioning retrofitting technologies. In terms of industrial energy conservation, the company mainly absorbed a series of motor frequency conversion technologies and sintering utilisation technologies. These technologies are mature technologies, which were widely used by many medium and large ESCOs.' (Project manager)*

Research institutes and associations: Due to a lack of knowledge and technical staff of industrial and building energy conservation, Guowang obtained technical support from research institutes for absorbing advanced energy conservation technologies. At the same time, the company also invited experts from research institutes to provide training course for company's technical staff in order to provide introductions of energy conservation in different industries. The deputy director of engineering department said:

> *'The company has already invited six professors from the China Architecture Research Institute and China Electric Power Research Institute to provide 30 training courses to our existing technical staff. Because most of our technical staff have limited understanding and knowledge about energy conservation, the professors have focused on the building energy conservation concept and the most popular solutions that were widely used by most of the ESCOs. These training courses are useful for our technical staff to absorb energy conservation technologies and project implementation in the building industry.''*(Deputy Director of Engineering Department)

Supplier: Guowang has absorbed and developed building energy conservation technologies.

However, the company does not manufacture products that are used in building energy conservation projects, such as LED lights, temperature sensors or frequency converters. In order to ensure the quality of projects, Guowang purchases these products from international suppliers such as GE, OSRAM, Omron and Panasonic.

Linkage capability

Guowang has built up linkages with a number of subsidiaries of parent company, but has not built up broad linkages with external organisations. So far, Guowang has established formal linkages with China Electric Power Research Institute and China Architectural Design Institute. Moreover, Guowang is a member of EMCA. The deputy director of engineering department expressed that ‘At present, the company has no need to build up broad linkages with external organisations. And the parent company thinks build up broad linkages with external organisations is a threat to the company’s security.’ In addition, due to the lack of absorptive capacity, some building and industrial energy conservation technologies were obtained from open resources. These technologies are mature technologies that are widely used by small and medium ESCOs.

Management team: Guowang’s management team decided to manage its linkages with external organisations. As a state-owned ESCO, the company has some advanced core technologies, which were seriously protected. In terms of technology transfer and technology exchange, the management team has strict regulations, which is why the company did not build up broad linkages with external organisations. The deputy director of engineering department stated:

> *‘Our parent company takes responsible for nearly 95 per cent of China’s grid operation. Therefore, our parent company has some very advanced core technologies, which are deemed as national security technologies. In order to develop energy-saving technologies for power transmission, several national security technologies were transferred to our company. Therefore, our company focuses more on technical confidentiality and technical protection. Our management team seriously complies with the requirements of the parent company and has set up strict regulations for establishing linkages with external organisations.’(Deputy Director of Engineering Department)*

Absorptive capacity: Guowang has built up linkages with some research institutes for technical support or collaborative R&D. However, due to its lack of absorptive capacity, it is difficult for Guowang to obtain know-how through this linkage. Research institutes conducted most of collaborative R&D projects by themselves, with Guowang only responsible for investment. No technical staffs from Guowang have joined the R&D projects.

Innovation capability

Guowang’s innovation capability is reflected in two aspects: energy conservation technologies in the electricity industry and energy conservation technologies in industry and building industry. In terms of the former, the company has strong innovation capability and can undertake radical innovation to develop advanced energy conservation technologies. With regard to the latter aspect, the company focuses on technology improvement and undertaking incremental innovation. According to the data of patents, all the invention patents refer to energy conservation technologies in the electricity industry. Guowang developed several energy management systems for industrial and building industries, and all of the patents of industrial and building energy conservation are utility model patents. Six factors can be identified as key factors that affect the company's innovation capability.

Technical staff: In terms of energy conservation technology innovation in electricity industry, Guowang has numbers of experienced and skilled R&D staff who have already conducted R&D projects in the electricity industry for many years. Therefore, Guowang has strong innovation capability in the area of electricity and has undertaken radical innovations in this area. However, in terms of energy conservation technology innovation in the industrial and building industries, the company lacks relevant professional staff and the existing technical staff lack experience in innovation in those areas.

R&D investment: Guowang has maintained its the amount of R&D investment every year at approximately 50 million RMB. However, in 2013–2014, 70 per cent of R&D investment was used to develop energy conservation technologies in the electricity industry and biomass utilisation. Only 30 per cent of R&D investment was used to improve and develop energy conservation technologies in the building and industrial industries. In 2015, Guowang allocated 60 per cent of its R&D investment to improving and developing energy conservation technologies in industrial and building industries.

R&D experience: R&D experience negatively affects the company's innovation capability to improve and develop energy conservation technologies in industrial and building energy conservation. In 2015, the company started to focus on R&D in industrial and building energy conservation. Hence, Guowang actually has less than two years' experience with R&D. In addition, most of the absorbed energy conservation technologies were obtained from open resources. It is not good for Guowang to accumulate knowledge and know-how or R&D.

Management team: The management team decided the direction for innovation and is responsible for resource allocation. When Guowang was newly established, the management team focused on developing energy conservation technologies in the electricity industry and undertaking radical innovation. From 2015, the management team decided to absorb and develop energy conservation technologies in the industrial and building industries. Therefore, a large amount of resources were allocated to undertake incremental innovation for industrial and building energy conservation.

Absorptive capacity: Due to the relatively rich knowledge accumulation of energy conservation in the electricity industry, Guowang undertook radical innovation for energy conservation technologies in electricity industry and successfully obtained 11 invention patents. The company lacks absorptive capacity regarding energy conservation in other industries. Even though the company has also tried to undertake incremental innovation to develop energy conservation in other industries, there are only five utility model patents obtained for industrial and building energy conservation technologies. The project manager said:

> *'Absorptive capacity seriously affects efficiency and quality of innovations. Although Guowang has a number of experienced R6D staff, they faced lots of problems when they developed energy conservation technologies for industrial and building industries. For example, they have little knowledge about manufacturing and commercial buildings. They need lots of time to learn the target sectors in order to increase knowledge accumulation.'(Project Manager)*

Research institutes and association: Due to a lack of knowledge about energy conservation in other industries, seeking external technical support is the most direct and efficient way to improve innovation capability. In order to develop energy conservation technologies for the building industry, Guowang built up a collaborative relationship with the China Architectural Design Institute. The company conducted collaborative R&D to develop energy-saving technologies of large commercial building lighting and cooling. At the same time, the research institute designed a specific course for technical staff from Guowang to introduce energy consumption and conservation for commercial building. The project manager stated:

> *'The research institute did not just provide technical support for innovation but also some training for technical staff. According to our management team requirements, the research institute designed and provided some courses for recent innovation projects. These courses helped our technical staff improve the efficiency of innovation."(Project Manager)*

7.2.5 How has Guowang developed its technological capability?

In order to provide comprehensive energy conservation services to different energy consumption enterprises from different industries, Guowang has been making efforts to absorb various energy conservation technologies and trying to conduct incremental innovation to develop energy conservation technologies in the industrial and building industries.

According to interviewees' descriptions and explanations, the company has developed its technological capability from two aspects. One is by developing energy conservation technologies in electricity industry and the other is by absorbing and developing energy conservation technologies in industrial and building industries. In terms of different energy conservation technologies from different industries, the company applied different approaches and processes.

In terms of energy conservation technologies in electricity industry, the parent company had many years of R&D experience to develop these kinds of technologies before Guowang was established. When Guowang was established, the task of developing energy conservation technologies in the electricity industry was distributed to Guowang. At the same time, some energy conservation technologies and a number of R&D staff and technical staff were assigned to Guowang. Therefore, Guowang has an experienced R&D department with which to develop energy conservation technologies in the electricity industry. The company is currently focusing on undertaking radical innovation to develop advanced energy conservation technologies and products in the electricity industry.

Guowang has little knowledge about energy conservation technologies in the industrial and building industries. Therefore, besides employing some technical staff who have some knowledge about industrial and building energy conservation, the company has focused on absorbing and assimilating mature technologies and trying to undertake incremental innovation to improve absorbed mature technologies and develop some simple energy conservation technologies in the industrial and building industries.

The project manager said that ‘the company developed energy conservation technologies starting with developing an energy management system. The company has experience in software development; therefore, developing software is relatively easy and the R&D cycle is short. The energy management system can be easily applied in energy conservation projects. So far, the company has developed an ‘energy service operation management platform’ and a ‘building energy efficiency monitoring and management platform’. The deputy director of the Engineering Department described and explained the general process of industrial and building energy conservation technology development. Figure 38 shows the process.

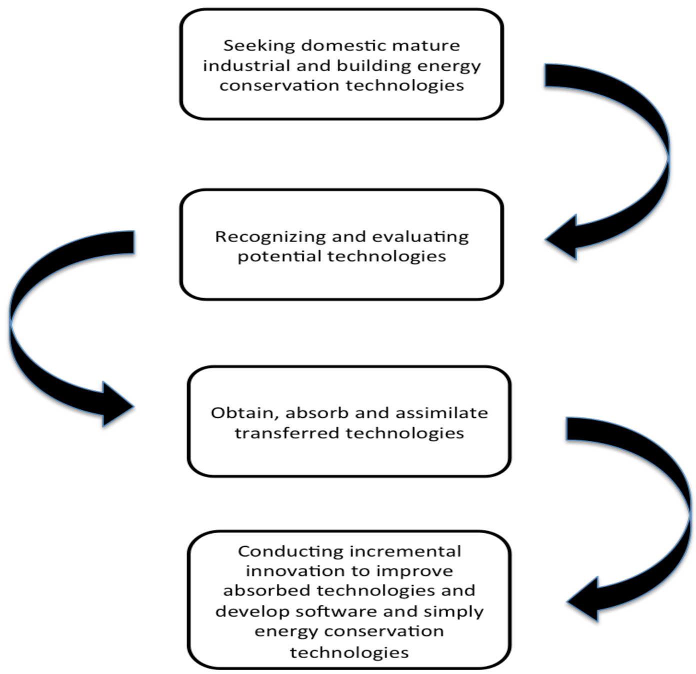


Figure 38: Guowang's process of industrial and building energy conservation technology development.

This process is about the development of industrial and building energy conservation technologies. So far, the company has focused on improving its technological capability through developing energy conservation technologies in the industrial and building industries.

In addition, Guowang (Beijing) Energy Conservation Design and Research Institute has played an important in role in the company's technological capability development. The research institute helped the company develop energy management software and some LED energy-saving lighting products. In terms of energy conservation in electricity industry, the research institute successfully developed 19 kinds of software.

7.2.6 Summary

Guowang is a subsidiary of a super state-owned enterprise. Taking advantage of its parent company's advantages, Guowang was established with a large amount of capital and thousands of employees. The company focused on energy conservation in the electricity industry, with the parent company being its main and largest customer. Guowang aims to become an ESCO in order to provide comprehensive energy solutions to different energy consumers from different industries. Therefore, the company has been marking efforts to absorb and develop energy conservation technologies in industrial and building industries.

The company has relatively strong technological capability and good market performance, especially in the electricity industry. Guowang directly and indirectly owns and controls hundreds of patent and software copyrights; nearly 40 per cent of these are invention patents. However, most of technologies are energy conservation technologies in the electricity industry. The energy conservation technologies for other industries represent only a very small proportion. In other words, Guowang has strong technological capability in terms of energy conservation in the electricity industry.

In terms of motivations for technological capability development, the firm's development strategy, market competition and government intervention are the main drivers of its technological capability. Unlike other firms, government intervention plays much more important role in Guowang's technological capability development.

Nine factors affect Guowang's technological capability development: six internal factors and three externals; see Figure 39.

Conceptual framework

Dimensions	Internal factors	External factors
Investment capability Production capability Linkage capability Innovation capability	Company size Finance ability Profitability ability Organizational structure and policy Absorptive capacity R&D Prior knowledge Company's strategy Management capability	Financial institutions Research institutions and associations Customer Supplier Partner Competitors Government policy Regulation environment

Factors affecting Guowang's four dimensions of technological capability

Dimensions	Internal factors	External factors
Investment capability	Company's financing ability Management team Technical staff	Government intervention
Production capability	Technical staff Absorptive capacity	Research institutions and associations Supplier
Linkage capability	Management team Absorptive capacity	
Innovation capability	R&D investment R&D experience Technical staff Management team Absorptive capacity	Research institutes and associations

Figure 39: Factors affecting Guowang's four dimensions of technological capability.

Guowang has a very strong investment capability from the perspective of financing ability and amount of investment in technological capability. In particular, the annual investment in technological capability development is approximately 80 million RMB. Moreover, the company has a number of experienced technical staff to recognise and evaluate potential energy conservation technologies in the electricity industry. However, in terms of industrial and building energy conservation technologies, the technical staffs only have the ability to choose the appropriate technologies that can be used in the energy conservation projects. Therefore, its investment capability facilitates the development of production and innovation capability.

Guowang's production capability is reflected in two areas. The first is using energy conservation technologies to implement energy conservation in the electricity industry. In this area, Guowang has strong production capability. The second area is using and absorbing energy conservation technologies to implement energy conservation in industrial and building industries. In this area, the company's absorptive capacity has become the main barrier to the company's production capability. Its production capability directly provides capital for investment in innovation capability development.

Due to Guowang's specific situation, the company has set out strict regulations for establishing linkages with external organisations. Guowang has just build up formal linkages with two research institutes in order to get technical supports for radical and incremental innovation. Therefore, Guowang does not have strong linkage capability. But, its existing linkages with external research institutes and association provide supports for companies' development of production and innovation capabilities.

Guowang has built up its innovation capability. Because Guowang has taken on a number of experienced R&D staff and R&D resources from its parent company, the company has undertaken radical innovation to develop advanced energy conservation technologies in the electricity industry. On the other hand, due to the lack of related technical staff and knowledge accumulation, the company has recently undertaken incremental innovation to develop simple energy conservation technologies for the industrial and building industries. Guowang's current innovation capability helps the company expand its business to building and industrial energy conservation field and further improve its production capability.

Guowang is currently focusing on absorbing and developing technologies for industrial and building energy conservation. The process of technological capability is very simple. Through absorbing and improving its mature domestic technologies, the company has increased its knowledge accumulation and technology stock. Then, by taking advantage of experienced technical staff from its parent company and rich software development experience, the company has developed an energy management platform for the building and industrial industries. However, these technologies developed by Guowang were not advanced technologies with simple functions.

7.3 Chapter summary

This chapter has presented data analysis and results of case studies of two large state-owned ESCOs in China. CECEP IEC and Guowang have both built up their technological capability and developed their own proprietary energy conservation technologies. Both of these ESCOs have hundreds of patents and software copyrights, many of which are invention patents. However, CECEP IEC has focused on industrial energy conservation and Guowang has focused on energy conservation in the electricity, industrial and building industries.

There are 10 key factors that affect CECEP IEC's technological capability, nine of which have a positive effect; only R&D experience is deemed as a barrier to innovation capability.

Guowang's technological capability was affected by nine key factors. Due to its recent focuses on industrial and building energy conservation, technical staff and absorptive capacity became main constraints to the company's investment, production and innovation capabilities.

CECEP IEC and Guowang have both focused on their investment and innovation capability. CECEP IEC has also focused on linkage capability and built up broad linkages with external actors. Due to its parent company's regulations, Guowang has only built up formal linkages with two research institutes and has not created any informal linkages.

CECEP IEC's process of technological capability is very explicit. The company started by transferring and absorbing industrial energy conservation technologies. Through technology transfer and absorption, the company accumulated technology, knowledge and know-how and has further gradually built up its absorptive capacity and undertaken incremental innovation to improve and integrate absorbed technologies. In order to develop advanced industrial energy conservation technologies, CECEP IEC invested a large amount of funds in collaborative R&D with domestic research institutes and well-known international companies.

Guowang has two paths for developing its technological capability. The first is electricity industrial energy conservation technology development and the second is industrial and building energy conservation technology development. In terms of electricity industrial energy conservation technology development, Guowang already has rich technology, knowledge and R&D experience accumulation. Therefore, Guowang focuses solely on improving its existing technologies and developing new technologies through R&D. In terms of industrial and building energy conservation technologies, Guowang focuses on absorbing technologies and has sought to develop energy management software for industrial and building energy conservation.

The next chapter will present the results and analysis of the cross-case study. The results of the comparative case study will also be presented and illustrated.

Chapter 8 Cross-case analysis and results

This chapter presents and discusses a cross-case analysis of the six case companies. Section 8.1 presents the similarities and differences between the case companies. Section 8.2 discusses why case companies have to develop their technologies capability. In section 8.3, the factors affecting case companies' technological capability are presented in the form of a table. The four dimensions of technological capability of different case companies are discussed and the key factors affecting case companies' technologies are further illustrated. Section 8.4 presents discussions about processes of technological capability.

8.1 Similarities and differences between the studied cases

To consider the similarities between studied cases, as explained in section 4.3, the six studied cases comply with the following criteria, which guided the case study selection:

(1) All of the case companies were domestic ESCO, which were recorded by NDRC.

(2) All of the case companies have at least three years' business experiences and have successfully implemented five energy conservation projects.

In terms of the difference between case companies, the case companies were selected from differently sized companies from different location, see Table 24.

Table 24：Main differences between case companies.

Company size	Location	Company name
Small	1st tier city	Visible Corp
	2nd tier city	East-Bay
Medium	1st tier city	Sinowise
	2nd tier city	Ditree
Large	1st tier city	CECEP IEC
	1st tier city	Guowang

The small and medium-sized companies satisfied the above criteria above, but the two large companies are both from a first-tier city: Beijing.

To consider the differences between cases, company size and locations are selected as important variables that influence the company's technological capability.

Locations

China has significant regional differences in terms of economy development, market, entrepreneurship, innovation and so on. Besides companies' internal factors that affect technological capability development, the innovation environment is deemed as an important element that affects companies' TC development. Based on the 'Chinese urban innovation and entrepreneurial environment rankings in 2015', which were issued by Inspiration Innovation Institute of Tsinghua University, six eastern cities are ranked in the top 10. Government support, industrial development, human environment, development environment, financial support, intermediary service, market environment and innovation awareness might affect the regional innovation environment.

Beijing

The cases of Visible Corp, Sinowise, CECEP IEC and Guowang are all located in the Chinese capital of Beijing, which is a first-tier city. Beijing is a megacity with a population of 21.7 million. Beijing is not only China's political, cultural and educational centre, but also an international exchange and innovation centre. There are 90 colleges and universities and 80 research institutes located in Beijing. In 2015, 165,000 people graduated from these universities and research institutes. In 2015, Beijing's real GDP per capita was 106,284 RMB and the average annual salary is 85,032 RMB. In terms of the ESCO industry, there are 448 energy service companies recorded by the National Development and Reform Commission (NDRC). In addition, there are many energy-saving and environmental protection institutes, such as the Beijing Energy Saving and Environmental Protection Centre and the EMCA (Energy Management Contract Association).

Qingdao

Qingdao is one of the second-tier cities in the eastern part of China, with a population of 9.04 million. Qingdao is the most developed city in the Shandong province. In 2015, its real GDP per capita was 102,519 RMB and the average annual salary was 67,968 RMB. There are 24 colleges and universities and 25 research institutes located in Qingdao. In Shandong province, there 284 energy service companies are recorded by the NDRC.

Hangzhou

Hangzhou is one of the second-tier cities in the eastern part of China; it is the capital of the Zhejiang province and has a population of 9.01 million, real GDP per capita of 112,268 RMB (as of 2015) and an average annual salary of 85,164 RMB. There are 44 colleges and universities located in Hangzhou. In terms of ESCO industry, there are 157 energy service companies recorded by NDRC in Zhejiang province.

Qingdao and Hangzhou are both second-tier cities with similar economy, market and innovation environments. Table 25 presents the above information in table form.

Table 25: Comparisons between case companies' locations

Location	**1st Tier cities**	**2nd Tier cities**	
	Beijing	Qingdao	Hangzhou
Population	21.7 millions	9.04 million	9.01 million
No. of universities	90	24	44
No. of research institutes	80	25	N/A
No. of ESCOs	448	284 in Shandong province	157 in Zhejiang province
Average salary (Annual)	85,032 RMB	67,968 RMB	85,164 RMB

Company size

According to the Ministry of Industry and Information Technology, National Bureau of Statistics, the NDRC, and the Ministry of Finance 'on the issuance of SMEs plan type standard notice' (Ministry of Associated Enterprises [2011] No. 300), in terms of the leasing and business services sector, the criteria for classification is as shown in Table 5.

Visible Corp and East-bay are small ESCOs, Sinowise and Ditree are medium-sized ESCOs, and CECEP IEC and Guowang are large ESCOs. Nevertheless, some case companies do not completely meet these standards above because ESCO industry is an emerging industry. For example, Ditree's total assets are approximately 67 million RMB, which falls below the threshold for a medium-size company.

Moreover, there are many other differences between the companies, such as their histories, energy conservation areas and company types. These differences could lead to different results in cross-case analysis. Table 26 summarises these differences between the studied companies.

Table 26: Similarities and differences between studied cases

ESCO	Visible	East-Bay	Sinowise	Ditree	CECEP IEC	Guowang
Foundation time	2010	2010	2010	2005	2010	2013
Company size	Small	Small	Medium	Medium	Large	Large
Company type	Private	Private	Private	Private	State-owned	State-owned
Location	Beijing	Qingdao	Beijing	Hangzhou	Beijing	Beijing
Registered capital	5 million RMB	10 million RMB	22 million RMB	20 million RMB	971 million RMB	4.6 billion RMB
No. of employees	38	20	100–150	100–150	About 970	About 7000
Energy conservation area	Industrial and building	Building	Industrial and building	Industrial and building	Industrial	Industrial, building and electricity
No. of projects	17	11	24	19	21	8
No. of patents/ software	12	N/A	16	9	120	97
Types of innovation	Incremental innovation	No Innovation	Incremental innovation	Incremental innovation	Incremental innovation & Radical innovation	Incremental & Radical innovation

8.2 Why have ESCOs developed technological capability?

Technological capability plays an important role in a company's competitiveness; this has been recognised by five of the six case companies, with East-Bay being the exception. According to the results of within-case studies, five of the companies believed they have to develop their technological capability because of their business development strategies, willingness to improve competiveness and government intervention. Figure 40 displays motivations for technological capability development.

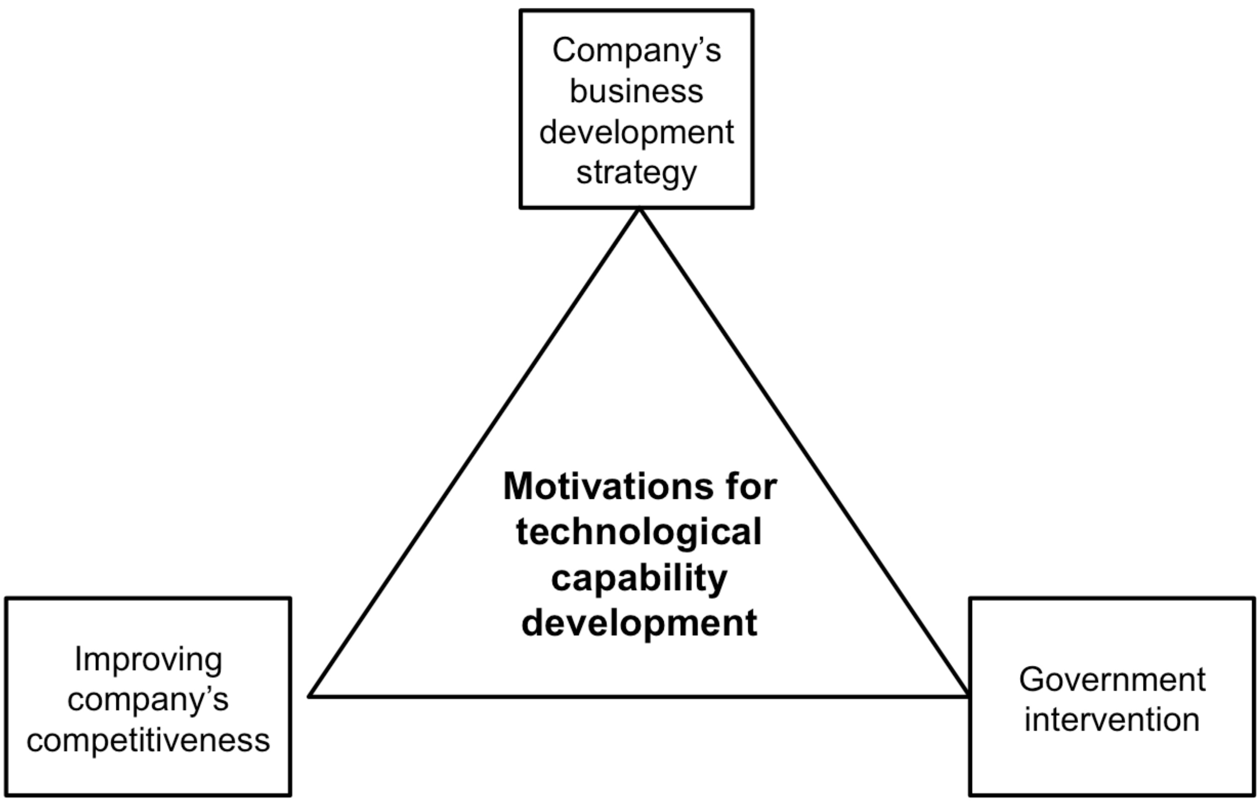


Figure 40: Motivations for technological capability development.

Companies' business development strategy

Visible, Sinowise, Ditree, CECEP IEC and Guowang have already developed clearly business development strategies and practical technological capability development strategies. These companies have placed technological capability in a strategic position. Visible Corp, Sinowise and Ditree would like to be domestic ESCOs that provide comprehensive energy services through a series of effective energy conservation technologies. As large ESCOs, CECEP IEC and Guowang have the aim of becoming the leading ESCOs in China and competitive ESCOs in the world, providing energy services to domestic and international customers.

To achieve these strategic objectives, developing technological capability was a crucial aspect. Therefore, these companies set up practical technological capability development strategies according to their context and gradually built up and developed their technological capability through a large amount of investment in technological capability and technical efforts such as R&D. Moreover, Ditree even adjusted its technological capability development strategy in the process of company's development. Consequently, the company's development strategy is one of the key motivations for technological capability development.

Improving company's competiveness

During the 11^{th} and 12^{th} FYP periods in China, central and local government have enhanced the promotion and support for development of ESCO industry. Within this context, the numbers of ESCOs have shown explosive growth, with most of new entrants being small and medium-sized ESCOs. The main competitors of Visible Corp, East-Bay and Ditree are small and medium-sized ESCOs. Therefore, the market competition has become increasingly intensive. Some large enterprises from other industries also tried to enter this industry; these companies became the main competitors of Sinowise, CECEP IEC and Guowang. Therefore, the competition in ESCO industry for large ESCO has also been increasingly intensive since the 11^{th} FYP.

In order to maintain their market positions and further improve their market performance and profitability, the case companies see technological capability as one of their core competitive advantages. There are three main reasons for this: (1) Experienced ESCOs have usually already built up technological capability through a large amount of time and money investment; (2) It is very difficult to build up technological capability and it is also difficult for new entrants to catch up; (3) Technological capability is an important element for customers to take into account when choosing an ESCO.

Developing technological capability is an effective way to respond to increasingly fierce market competition. Hence, the case companies thought that improving companies' competiveness was a key driver to developing technological capability.

Government intervention

The ESCO industry is policy-driven in China. Central and local governments have fostered companies' technological capability development through issuing qualified certificates and cash rewards. The case companies expressed that they have focused on qualified certificates issued by governments. Visible, Sinowise, Ditree and CECEP IEC were all qualified as 'national high-tech enterprises'. Visible and Sinowise also qualified as 'Zhongguancun high-tech enterprises' by local government. Small and medium-sized ESCOs expressed that it is difficult to obtain cash rewards because of limited technological capability. However, large ESCOs received government rewards for technological capability development.

ESCOs focused on the qualifications issued by central and local governments because when customers choose an ESCO, these qualified certificates are seriously taken into consideration. Most energy consumers know little about ESCOs and their energy conservation technology and technological capabilities. Energy consumers can initially learn about and identify an ESCO by means of these issued certificates by governments. ESCOs also initially show their technological capability mainly through these certificates.

In order to obtain and hold these qualified certificates, ESCOs must continually develop their technological capability. Governments regularly check and evaluate companies' technological capability and, according to the results, either withdraw or renew the certificates. Therefore, governments push ESCOs to develop their technological capability.

In addition, compared with small and medium-sized private ESCOs, large state-owned focused more on government intervention. In terms of governments' policies, large ESCOs respond to them much more actively. Therefore, large state-owned ESCOs consider government intervention to be a more important motivation.

However, according to the analysis of East-Bay, government intervention can also have a negative impact on a company's willingness to develop its technological capability. Overly radical policies for promoting and encouraging ESCOs' development lead ESCOs to ignore the importance of technological capability development at current stage. Due to these policies, large numbers of new entrants enter the market and conduct energy-saving projects with lagging and mature energy saving technologies in order to obtain government subsidies for energy saving. These ESCOs do not have a long-term plan for development, so government intervention can also play negative role in technological capability development.

8.3 Key factors affecting companies' technological capability

According to results from data analysis of six case ESCOs, a number of internal and external key factors affect a company's investment, production, linkage and leverage capabilities, as identified by the six case companies. Table 27 integrates the results from the six studied companies and shows all the key factors affecting companies' technological capability.

Table 27: Integrated key factors affecting ESCOs' technological capability. ("**+**" supportive, " **—** " unsupportive**)**

Key factors affecting company's Technological capability	**Studied ESCOs**					
	Small		Medium		Large	
	1st Tier	2nd Tier	1st Tier	2nd Tier	1st Tier	1st Tier
	Visible Corp	East-Bay	Sinowise	Ditree	CECEP IEC	Guowang
Investment Capability						
Company's financing ability	**+**	**—**	**+**	**—**	**+**	**+**

Company's market performance	+	—	+			
Technical staff		—	+	+	+	—
Management team	+	—	+	+	+	+
Absorptive capacity			+			
Government intervention	+		+		+	+
Supplier		+				
Competitors			+	+		
Production Capability						
Technical staff	+	+	+	+	+	+
Management team		+		+	+	
Absorptive capacity	+		+	—	+	—
Research institutes & associations	+	+				+
Customer	—		—	—		
Supplier	+	+	+	+		+
Linkage Capability						
Company's financing ability			+			
R&D investment					+	
Technical staff					+	
Personal relationship	+	+	+	+		
Management team	+	+			+	—
Absorptive capacity	+			+	+	—
Government intervention	+	+			+	
Research institutes & associations						
Innovation Capability						
R&D investment	—	—	+	—	+	+
Design department		—				
Technical staff						—
R&D experience	—		—	—	—	—
Management team	+	−	+	−	+	+
Absorptive capacity					+	—
Government intervention			+		+	
Research institutes & associations		+		+	+	+
Innovation environment	—					
Competitor					+	
Supplier		—				
Companies from other industries					+	

According to Table 27, various factors affect the companies' four dimensions of technological capability, to varying degrees. For example, only East-Bay thought that is partner influenced its investment capability. Visible Corp and Guowang recognised supplier as a factor that affects production capability but the other companies did not. Only CECEP IEC thought competitors and companies from other industries have an impact on their companies' innovation capability. Personal relationship only affects the linkage capability of small and medium-size ESCOs but not large ESCOs.

Additionally, each factor may affect ESCOs positively or negatively based on the ESCO's size and headquarters location. For instance, a company's financing ability and government intervention only had a supportive effect on the investment capability of ESCOs from first-tier cities, and unsupportively affected the investment capability of ESCOs from second-tier city. Customers had a unsupportive impact on the production capability of small and medium-size ESCOs but no impact on large ESCOs. In order to summarise and generalise the factors affecting ESCOs' technological capability, only factors that were identified by three or more case companies were recognised as key factors affecting companies' technological capability. Table 28 shows the summarised key factors affecting companies' four dimensions of technological capability.

Table 28: Key factors affecting four dimensions of technological capability.

Dimensions	Internal factors	External factors
Investment capability	Company's financing ability Company's market performance Technical staff Company size Management team	Government intervention Headquarter location (Business context)
Production capability	Technical staff Management team Absorptive capacity	Research institutes & associations Supplier Customer
Linkage capability	Company size Personal relationship Management team Absorptive capacity	Government intervention
Innovation capability	Company size R&D investment R&D experience Management team	Research institutes &associations Headquarter location (Business context)

There are 14 key factors (nine internal and five external) that affect ESCOs' technological capability. Compared with conceptual framework, there are 18 potential factors affect company's technological capability. In terms of internal factors, company's financing ability and company's market performance only affects investment capability. Technical staff is one of the key factors that affects investment and production capabilities. R&D investment and R&D experience have a significant influence on innovation capability. Company size mainly has an impact on investment, linkage and innovation capabilities. Personal relationship affects the linkage capability of ESCOs. Management team was deemed as key factor that affects all four dimensions of technological capability. Company's absorptive capacity not only influences production capability but also linkage capability.

The external factors mainly involve government intervention, research institutes and associations, partners, customers and headquarters location. Government intervention seriously affects investment and linkage capabilities. Research institutes and associations play roles in production and innovation capabilities. Headquarter location is a factor that mainly affects ESCOs' innovation capability. Partners and customers have an impact on ESCOs' production capabilities.

8.4 How the factors affect company's technological capability

According to the data analysis of six case companies, the key factors affecting company's four dimensions of technological capability have been identified and generalised (see Table 8.5). These factors positively or negatively affect company's technological capability. In this section, four dimensions of technological capability of ESCO will be explained, followed by a discussion and explanation of how the key factors affect the four dimensions of technological capability of different case companies.

Investment capability of ESCOs

In terms of case companies' investment capability, there are two main aspects. One is company's ability to access external financial resources and prepare necessary other resources for technological capability development. The other aspect is the company's ability to recognise and evaluate potential energy conservation technologies based on its prior knowledge and technical staff in order to make appropriate investment decisions.

As a service sector, unlike the manufacturing industry, for example, ESCOs do not need to invest in manufacturing equipment and facilities. ESCOs focus on investment in potential energy-saving technologies, technical staff and R&D. Therefore, the ability to recognise and evaluate potential energy conservation technologies becomes particularly important.

Large ESCOs have a significant advantage over medium-sized ESCOs in terms of access and preparing financial resources for investment in technological capability. The amount of investment that large ESCOs make is much greater than that of small and medium-sized ESCOs. Recognising and evaluating potential energy conservation technologies is mainly based on the company's prior knowledge and ability of technical staff. Therefore, small and medium-sized ESCOs with rich knowledge accumulation about energy conservation technologies or experienced and qualified technical staff also have ability to effectively recognise and evaluate potential energy conservation technologies. Visible Corp and Sinowise are medium-sized ESCOs that have implemented energy conservation projects for industrial energy conservation. Guowang is a large ESCO that only started industrial energy conservation in 2014. Even though Guowang has much more technical staff than that of Visible Corp and Sinowise, the latter companies have an advantage over the former in terms of recognising and evaluating industrial energy conservation technologies because of their five years of accumulated knowledge and experience. Additionally, if a large ESCO also has rich knowledge accumulation about energy conservation technologies, as is the case with CECEP IEC, that company not only has an advantage in terms of the amount of investment, but also a stronger ability to recognise and evaluate industrial energy conservation technologies than Visible Corp and Sinowise.

ESCOs from first- tier cities built up more effective financing channels than those from second-tier cities and therefore have strong financing ability. In addition, the market performance of ESCOs from first-tier city is better than that of ESCOs from second-tier cities. Therefore, the amount of investment in technological capability of ESCOs from a first-tier city is larger than that of ESCOs from second-tier cities. Visible Corp has a stronger ability than East-Bay to recognise and evaluate energy conservation technologies. However, there is not much difference between Sinowise and Ditree in this regard.

Generally, there are six key factors that affect ESCOs' investment capability: company size, company's financing ability, company's market performance, technical staff, management team and government intervention.

Company size: Company size is recognised as a key factor affecting investment capability. It affects the funds for investment in technological capability but also quantity and quality of technical staff employed. In terms of SMEs, company size is a constraint for investment capability. For large ESCOs, company size becomes their advantage for investment capability; in other words, a larger company relatively leads to stronger investment capability.

Company's financing ability: A company's financing ability is a key factor that affects its investment capability; this was identified by five of the case companies. A company's financing ability refers to its ability to obtain financial support through various financial channels for technical capability investment. A company's finance ability directly affects its level of investment in technological capability. Visible Corp, Sinowise, CECEP IEC and Guowang all believed that their financing ability positively affected their investment capability because these companies have already built up effective financing channels with financial institutes. East-Bay and Ditree did not build up effective financing channels with financial institutes. Hence, financing ability became one of the key constraints to investment capability.

Company's market performance: This factor was recognised by Visible Corp, East-Bay and Sinowise. Visible Corp and Sinowise thought their company's market performance not only improved their profitability but also enhanced their willingness to invest in technological capability and further improved their competiveness and expand their business. Therefore, a company's market performance positively influences its investment capability. However, company's market performance became a barrier to the investment capability of Easy-Bay. Due to poor market performance in recent years, East-Bay not only has limited funds to invest in technological capability but also lacks the confidence to make investments in technological capability. The company has allocated most of its funds to marketing.

Technical staff: East-Bay, Sinowise, Ditree, CECEP IEC and Guowang identified technical staff as a key factor affecting their company's investment capability. East-Bay and Guowang thought that technical staff negatively affected their investment capability. East-Bay has a very limited number of technical staff. Guowang has huge number of technical staff, but its technical staff lack knowledge accumulation about energy conservation technologies in manufacturing and building industries. Therefore, these two companies found that they have a barrier to effective evaluate energy conservation technologies. Sinowise, Ditree and CECEP IEC focused on industrial energy conservation. All of these companies have at least five years' business history and have a number of experienced technical staff to recognise and evaluate potential energy conservation technologies. In addition, their technical staffs are diversified, which means that the staff foster their investment capability.

Management team: All of the studied companies identified management team as a key factor affecting company's investment capability. The management team establishes the companies' business and technological development strategies and allocates organisational resources for investment in technological capability development. Five of case companies thought their management team positively affects the company's investment capability. Only East-Bay thought its management team negatively affects investment capability; this is because the management team not only failed to set a clear technical development strategy, but it also allocated limited resources to technological capability development.

Government intervention: Government intervention, as one of key factors affecting investment capability, was recognised by four case companies from first-tier cities. Government intervention affects company's investment direction and investment willingness. The four case companies thought government intervention positively affects their investment capability. Firstly, central and local government promoted ESCOs to financial institutes and encourage them to cooperate with ESCOs and invest in energy conservation projects. Secondly, governments push ESCOs to develop technological capability through a series of qualifications. Thirdly, governments applied a series of rewards and subsidies to help ESCOs invest in technological capability. However, small and medium-sized ESCOs benefit from the first two interventions and large ESCOs benefit from all three interventions.

Production capability of ESCOs

The ESCO industry is a service industry. In contrast to enterprises in manufacturing industry, ESCOs mainly provide intangible products to their customers. Most of ESCOs do not have manufacturing facilities. ESCOs provide services based on professional knowledge in energy conservation and specific energy conservation technologies.

The production capability of case ESCOs mainly refers to applying and absorbing energy conservation technologies and providing reliable and high-quality energy conservation projects to its customers. During the contract period, companies must ensure the operation of energy conservation projects and that they have achieved their expected energy savings. To some extent, an important aspect of production capability of ESCOs is the company's absorptive capacity. An ESCO's production capability depends heavily on its technical staff.

In terms of production capability, there is not much difference between compared small and medium-sized ESCOs and large ESCOs. Production capability depends heavily on the company's prior knowledge accumulation, project experience and technical staff. Large ESCOs have a large number of qualified technical staffs, rich project experience and professional project implementation teams. Therefore, they have strong production capability. Small and medium-sized ESCOs do not have professional project implementation teams but, through cooperation with professional project implementation companies, are able to deliver high-quality energy conservation projects. The ability to apply and absorb energy conservation technologies depends on companies' technical staff and absorptive capability. East-Bay and Ditree only have the ability to apply energy conservation technologies, while Visible Corp and Sinowise are able to absorb some transferred energy conservation technologies. Although Guowang is a large ESCO, its lack of absorptive capacity to industrial and building energy conservation technologies means it has limited ability to absorb energy conservation technologies in industrial and building energy conservation.

ESCOs from first-tier cities have stronger production capability than those from second-tier cities. However, the difference is not significant. ESCOs from first-tier cities find it easier than their counterparts in second-tier cities to recruit high-quality technical personnel, and the cost of employing quality technical personnel is also higher. According to data analysis of the studied ESCOs, ESCOs from first-tier cities have advantage in quantity and quality of technical personnel. Moreover, ESCOs from first-tier cities have absorbed more energy conservation technologies and implemented more energy conservation projects than ESCOs from second-tier cities. Therefore, ESCOs from first-tier cities have more knowledge accumulation and project experience than ESCOs from second-tier cities.

There are six key factors that affect companies' production capability: technical staff, management team, absorptive capacity, research institutes and associations, partners, and customers.

Technical staff: All case companies recognise technical staff as a key factor that positively influences company's production capability. Technical staff affects a company's ability to apply and absorb energy conservation technologies and deliver high-quality and reliable energy conservation projects to customers. In terms of technical staff, ESCOs focus on four main aspects: specialisation, diversification, experience, and knowledge transfer (that is, the ability to provide effective training to customers).

Specialisation refers to technical staff having professional knowledge in energy conservation. Technical staffs are trained through professional institutes that provide energy conservation courses, knowledge, assessment and certifications. Alternatively, technical personnel obtain energy conservation knowledge through work experience in ESCOs. Therefore, specified energy conservation technical personnel are scarce.

Diversification**:** ESCOs provide comprehensive energy conservation service and need to apply and absorb variety of energy conservation technologies. Therefore, ESCOs need diversified technical personnel. The main technical staffs have involved software engineers, electrical engineers, energy auditors and assessors, mechanical engineers and construction engineers.

Experience: Experienced technical staff will improve the efficiency of technology absorption and ensure the quality and efficiency of energy conservation projects. So far, experienced technical personnel have been the industry’s scarcest resources.

Knowledge transfer: It is important to provide effective training to customers. Technical personnel must have a good ability to transfer knowledge to customers effectively, and must therefore also have good communication skills.

Management team: East-Bay, Ditree and CECEP IEC all stated that their management team positively influences their production capability. The management team allocates appropriate resources to production capability, formulates production to ensure the quality and efficiency of project implementation and maintenance, and arranges a specific team or department to guide and supervise the project of implementation and maintenance.

Absorptive capacity: Five of the six case companies identified absorptive capacity as a key factor that affects ESCOs' production capability. Company's absorptive capacity is relevant to a company's ability to absorb transferred energy conservation technologies. Visible Corp, Sinowise and CECEP IEC initially built up their absorptive capacity. However, Ditree and Guowang felt that their absorptive capacity is a barrier to absorbing energy conservation technologies.

Research institutes & associations: Visible Corp, East-Bay and Guowang recognise that research institutes and associations positively affect their production capability. When companies find that they have limited ability to absorb external energy conservation technologies, they might seek help from research institutes or associations. Alternatively, if an ESCO has limitations in designing projects, it may also seek technical support from research institutes and associations. Visible Corp and Guowang seek technical support when they have limited ability to absorb energy conservation technologies. East-Bay asked a local university to help it undertake project design work.

Customer: Visible Corp, Sinowise and Ditree – three small and medium-sized ESCOs – identified that customers affect a company's production capability. Because customers are responsible for the day-to-day operation and maintenance of energy conservation projects, they affect the quality and reliability of the projects. Customers' learning ability, awareness of energy conservation and responsibility are taken into consideration. Visible Corp, Sinowise and Ditree all focused on industrial energy conservation. Their main customers are small and medium-sized manufacturers. Hence, their customers have limited ability for knowledge capture. Conducting energy conservation projects for large enterprises will usually minimise the negative impacts on energy conservation projects. From this aspect, large ESCOs normally conduct large energy conservation projects with large enterprises. Therefore, customers are not considered by large ESCOs as a factor that affects production capability.

Partner: East-Bay, Sinowise and Ditree identified partners as a key factor affecting companies' production capability. These three companies rely heavily on their partners to help them produce energy conservation products and equipment and implement energy conservation projects. Because large ESCOs have their own ability to produce energy conservation products and equipment and project implementation, they do not considered partners to have a significant effect on production capability.

Linkage capability of ESCOs

Linkage capability of ESCOs main refers to a company's ability to establish linkages with external organisations in order to transfer technology, obtain technical support, absorb know-how, conduct collaborative R&D or leverage necessary resources for technological capability development.

In terms of linkage capability, informal and formal linkages are the two main types of linkages that are established by case ESCOs. Informal linkage refers to a kind of oral or private agreement that is established and highly dependent on personal relationships. It is like a simply connection with external actors. This kind of linkage is popular for small and medium-sized ESCOs. ESCOs could obtain some technical support, consultations and information based on informal linkages. However, it is very hard to conduct technology transfer, collaborative R&D and leveraging resources through these informal linkages. Informal linkages can be upgraded into formal linkages.

Formal linkages are generally established through acquisition, licensing, joint venture or cooperation contract. This kind of linkage is much more reliable and effective than informal linkages. Competitive small and medium-sized ESCOs and large ESCOs prefer to establish formal linkages with external organisations. Taking advantage of these formal linkages, ESCOs could transfer technologies, conduct collaborative R&D, receive effective technical supports and leverage necessary resources for technological capability development.

Small and medium-sized ESCOs established broad informal linkages with external organisations such as universities, research institutes, competitors, and suppliers to a greater extent than large ESCOs. The ability of small and medium-sized ESCOs to build up linkages depends heavily on personal relationship, whereas large ESCOs prefer formal linkage establishment and normally build up linkages through acquisitions and cooperation contracts.

There is no significant difference in the linkage capability of ESCOs from first-tier cities and those from second-tier cities. They all built up formal and informal linkages with their stakeholders, which indicates that a company's location does not affect its linkage capability.

Linkage capability of ESCOs was affected by five key factors: company size, personal relationship, management team, absorptive capacity and government intervention.

Company size: All of the case companies noted that company size is an important factor that affects the formal linkage establishment. Company size is a crucial element that is considered by external organisations. External organisations prefer to establish formal linkages with stronger and competitive ESCOs; in other words, it is easier for a larger company to establish formal linkages than for a smaller ESCO.

Personnel relationship: all small and medium-sized ESCOs identified personal relationships as a key factor affecting linkage capability. It mainly has a positively effect on informal linkage establishment for small and medium-sized ESCOs, which have limited ability to build up formal linkages with external organisations and therefore attempt to build up broad informal linkages in order to obtain technical support. Establishing broad informal linkages with external organisations depends largely on personal relationships. This kind of relationship is called 'Guanxi' in China (Xin and Pearce, 1996; Park and Luo, 2001). Because large ESCOs prefer formal linkages, they did not really consider personal relationships.

Management team: Visible Corp, East-Bay, CECEP IEC and Guowang all claimed that management team affects linkage capability. The first three of these companies built up linkages with external actors because of their management teams' decisions. The management team of these companies would like two build up broad linkages with external actors in order to obtain technical support and information for technological capability development. Guowang's management team set up strict regulation for linkage establishment with external actors. Therefore, Guowang just built up linkages with two research institutes.

Absorptive capacity: ESCOs' absorptive capacity affects a company's ability to absorb technologies and know-how through the linkages. This factor was recognised by Visible Corp, Ditree, CECEP IEC and Guowang. The first three of these companies thought their absorptive capacity positively affects their linkage capability because they successfully absorbed technologies and know-how through established informal and formal linkages. Guowang has built up formal linkages with research institutes but, due to its lack of absorptive capacity to energy conservation technologies, almost did not absorb any know-how through the linkages.

Government intervention: Three companies – Visible Corp, East-Bay and CECEP IEC – identified government intervention as a key factor affecting linkage capability. Central and local governments encourage ESCOs build up linkages with each other in order to promote and exchange energy conservation technologies. To achieve this objective, governments provided platforms, conferences and summits to ESCOs in order to provide opportunities for energy-saving technology exchange and transfer, and cooperation between ESCOs and companies from other industries. Therefore, government intervention plays an important role in a company's linkage capability.

Innovation capability of ESCOs

Innovation capability refers to the ability to create and carry new technological possibilities through to economic practice (Kim, 1999). However, in terms of ESCOs' innovation capability, it mainly refers to the company's ability to improve and integrate transferred technologies and further conduct incremental and radical innovation. Moreover, considering a company's innovation capability, its willingness to innovation should also be taken into account.

All six case ESCOs conducted incremental innovation to improve or integrate mature or domestic advanced energy conservation technologies. Large ESCOs also conducted radical innovation through in-house and collaborative R&D to develop advanced energy conservation technologies.

Large ESCOs have significantly stronger innovation capability than their small and medium-sized counterparts. Large ESCOs have advantages in terms of the amount of investment in innovation, quantity and quality of technical personnel, scale of R&D department, and technical support from external research institutes and associations and other organisations. Moreover, small and medium-sized ESCOs just have the ability to undertake incremental innovation. In addition, large ESCOs undertake incremental and radical innovation at the same time. Large ESCOs have more patents, which involve utility model and invention patents. Small and medium-sized ESCOs only have utility model patents.

ESCOs from first-tier cities have stronger innovation capability than ESCOs from second-tier cities based on the numbers of patents owned by ESCOs. Nevertheless, ESCOs from first- and second-tier cities, with the exception of East-Bay, all have a strong willingness to develop innovation capability.

The innovation capability of ESCOs is affected by five key factors: R&D investment, R&D experience, management team, headquarters location, and research institutes and associations.

R&D investment: All of the case companies considered R&D investment to be a key factor that affects their innovation capability. Visible Corp, East-Bay and Ditree felt that R&D investment is a key barrier to innovation capability, while, Sinowise, CECEP IEC and Guowang felt that R&D investment positively affects its innovation capability. Large ESCOs have especially high investment in innovation capability; Sinowise's investment in this area is greater than Visible Corp's and Ditree's.

R&D experience: Five out of the six case companies acknowledged that R&D experience is a negative factor that influences their innovation capability. Case companies of all sizes felt that they lack R&D experience: small and medium-sized ESCOs lack R&D experience to improve and integrated domestic complex and advanced energy conservation technologies, while large ESCOs lack R&D experience to develop international emerging energy conservation technologies. Even though these ESCOs lack R&D experience, they have already successfully undertaken a number of incremental and radical innovations.

Management team: Management team is another key factor affecting innovation capability; all of the studied companies recognised this. The management team decides the direction of innovation and allocates resource for innovation capability development. The innovation capability of a company can only be improved and developed if the management team makes appropriate decisions about innovation and allocates the necessary resources to innovation. Case companies from first-tier city thought their management team positively affects their innovation capability. East-Bay and Ditree, which come from second-tier cities, thought the management team negatively affects their innovation capability. This is because their management teams did not focus on developing innovation capability and allocated limited resources into innovation capability.

Headquarters location: ESCOs' locations also affect their innovation capability. Based on the number of patents and software copyrights applied by case companies, those companies from first-tier cities have more patents and software copyrights than those from second-tier cities. This is mainly because the case companies from first-tier cities find it easier to employ high-quality R&D and technical personnel. Another reason is innovation environment, which involves innovation facilities and investment in science.

Research institutes & associations: Four of the case companies considered this to be a key factor affecting their innovation capability. In China, research institutes and associations have a huge amount of quality R&D personnel and resources. Research institutes and associations provide consultation, technical support and collaborative R&D to ESCOs when they undertake innovation. Large ESCOs in particular undertake collaborative R&D with research institutes and associations to develop international advanced energy conservation technologies or products through radical innovation. In terms of small and medium-sized ESCOs, research institutes and associations provide necessary but limited consultations and technical support when they undertake incremental innovation to improve and integrate existing technologies.

8.5 Links between four dimensions of company's technological capability

According to the within-case analysis, not all the case companies focus on developing all four dimensions of technological capability at the same time. ESCOs preferentially choose one or more dimensions according to company's requirements and current capabilities.

Table 29 shows the dimensions which are preferentially selected by case companies.

Table 29: Dimensions focused by case companies.

Size	Case company	Dimensions
Small	Visible Corp	Investment; Linkage; Innovation
	East-Bay	Production; Linkage
Medium	Sinowise	Investment; Production; Innovation
	Ditree	Investment; Production
Large	CECEP IEC	Investment; Production; Linkage; Innovation
	Guowang	Investment; Production; Innovation

ESCOs focus on developing one or more dimensions of technological capability at the same time. The process is gradually. The dimensions of technological capability also have links between each other. Some links are admitted by all case companies, such as investment capability affects innovation and production capabilities, Innovation capability influences production capability, production capability affects investment capability.

Nevertheless, some links are just identified by some case companies. Visible Corp, Ditree, CECEP IEC and Guowang think linkage capability facilitates their innovation capability. East-Bay, Ditree, CECEP IEC and Gowang recognised that their companies' linkage capability also affects production capability. The main reasons of these differences are about company size, existing linkage capability and main resources for innovation investment and company's profitability.

8.6 Process of technological capability development of ESCOs in China

All six case companies have similar processes of technological capability development. Even though ESCO industry is an emerging technology-intensive service industry, ESCOs follow similar process of technological capability development of manufacturing industry.

The ESCOs in this study started to build up their technological capability by absorbing and assimilating domestic and international mature energy conservation technologies. Through technology absorption and assimilation, the ESCOs increase their technology stock and knowledge accumulation. The companies then tried to improve these absorbed technologies and increase their functionality, mainly through independent R&D. Moreover, ESCOs also tried to integrate various energy conservation technologies into a system. In fact, ESCOs have already tried to undertake incremental innovation. Some large ESCOs have also undertaken radical innovation through independent and collaborative R&D to develop international advanced energy conservation technologies or products.

In terms of incremental innovation, ESCOs of all sizes have started to develop their own proprietary energy conservation technologies from software development. Four of the studied companies developed their own energy management system or platform as their proprietary technology; see Figure 41.

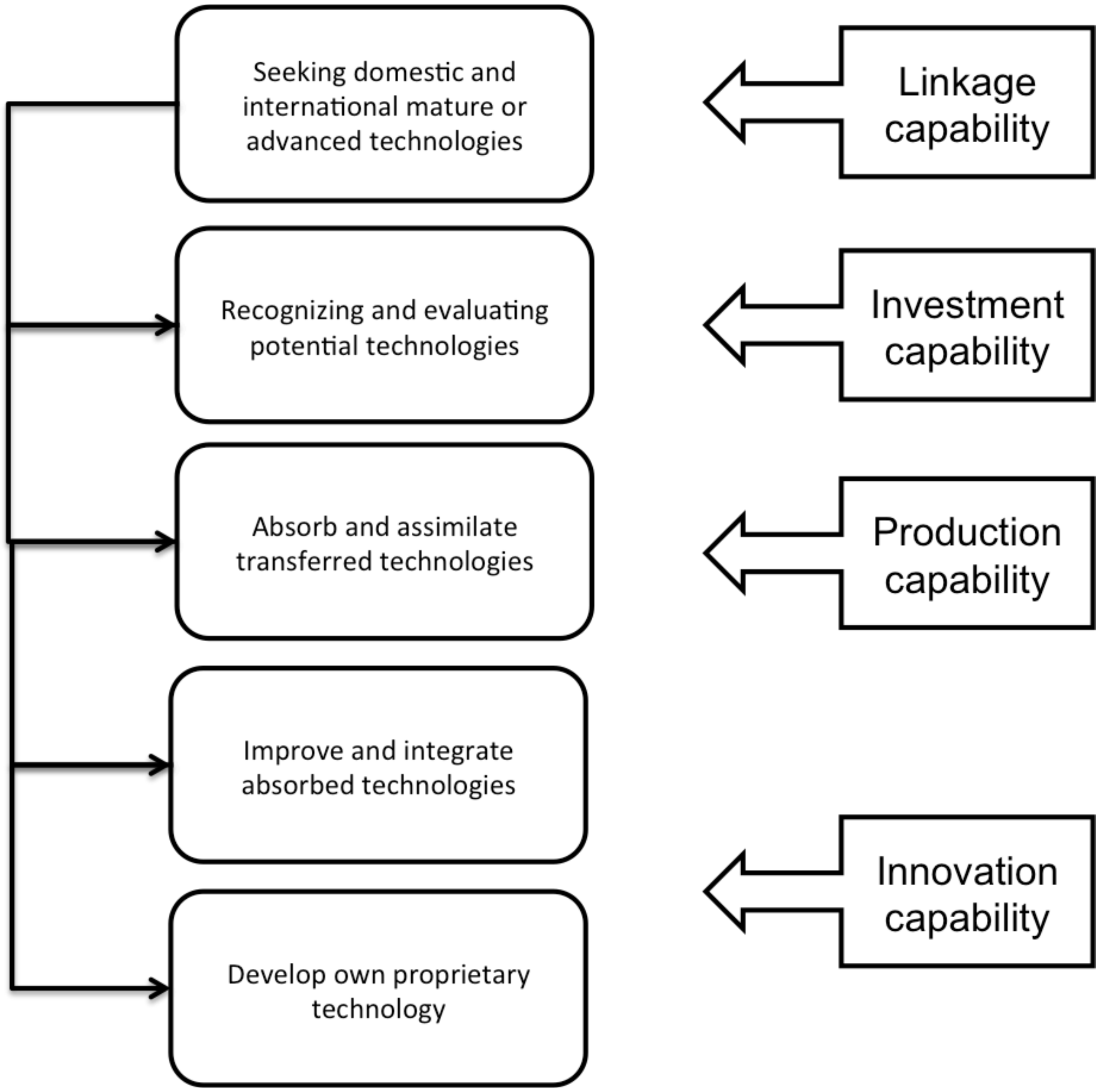


Figure 41: Generalised process of technological capability development of ESCOs in China.

Small and medium-sized ESCOs usually start by seeking and absorbing domestic and international mature technologies. These technologies are easy to absorb and assimilate and can be rapidly used in energy conservation projects. Large ESCOs have strong capital and large numbers of technical staff. The companies tried to transfer domestic and international mature and advanced technologies at the beginning of their business. ESCOs prefer to absorb energy conservation technologies in industrial and building conservation. They normally tried to transfer and absorb technologies in similar energy conservation areas first and then transfer and absorb technologies for other energy conservation areas or industries.

Through absorbing various energy conservation technologies in same or similar energy conservation area, ESCOs accumulated some knowledge and then tried to improve and integrate the absorbed technologies. In this stage, ESCOs actually undertake incremental innovation through independent R&D. In this stage, the R&D department accumulated a large amount of experience for innovation.

The ESCOs started to develop their own proprietary technology very early. Normally, once they had successfully absorbed one or two energy conservation technologies, they started to develop the energy management system or platform. These systems or platforms were continually improved, along with technology absorbing and improvement. Large ESCOs started to develop international advanced energy conservation technologies or products through collaborative R&D when they initially built up their technological capability and had some knowledge accumulation. However, taking advantage of collaborative R&D, there is not much improvement for independent R&D because ESCOs usually just provided funds for collaborative R&D projects.

8.7 Chapter summary

This chapter has presented and discussed cross-case analysis and results of the six studied cases.

The similarities and differences between studied cases were presented first. All the studied cases satisfy the criteria of case selection. The main differences are company size and location.

In terms of motivations for technological capability, company's business development strategy, improving company's competiveness and government intervention were identified as key drivers for technological capability development of ESCOs in China. Company size and location did not significantly affect the drivers for technological capability development.

In terms of company's technological capability, company size definitely affects company's technological capability in terms of investment, linkage and innovation capabilities. Location also impacts the companies' technological capability but the effect is not obvious.

All the factors perceived as key factors affecting company's technological capability in six studied cases. Some factors were identified by all cases, while other specific factors were only identified by one or two of the studied cases. Through comparison and combination, the generalised and summarised 14 key factors affecting four dimensions of technological capability were presented. ESCOs preferentially developed the dimensions of technological capability. Each dimension of technological capability has links between each other.

Even though ESCO industry is an emerging service industry, ESCOs have a similar process of technological capability development to companies in the manufacturing industry. ESCOs focused on absorbing transferred technologies and improving and integrating them in order to increase their technology stock and knowledge accumulation. However, ESCOs started to develop their own proprietary technology very early. Additionally, large ESCOs have already undertaken radical innovation to develop international advanced energy conservation technologies or products.

This chapter has presented the cross-case analysis and results. The following chapter will present a secondary analysis of the product portfolio of ESCOs in China.

Chapter 9 Product portfolio of Chinese ESCOs

This chapter presents the product portfolio of Chinese ESCOs from the perspective of the types and number of products and services that each of the case companies provides. Through secondary data analysis, The product portfolio of case companies in different sizes are compared and then, the portfolios against those of American ESCOs (the global "benchmark" for the ESCO market) are also contrasted. Data for US ESCOs' product portfolios was obtained from an investigation of 112 qualified American ESCOs by the US Department of Energy in 2016 (Qiu, Nunes & Vaidya, 2017).

9.1 Products and services of ESCO

ESCO provides comprehensive energy conservation products and services to energy consumers from various industries. There are 11 main products involved in an ESCO's product portfolio, with each product consisting of a series of specific services. Not every ESCO provides the all 11 products, which means that each ESCO has its own product portfolio based on its business, strategy, size and technological capability. In addition, each ESCO also provide different specific services in terms of each product. Because of complexity and cost of services. For example, Visible Corp and East-Bay both provide consulting. However, Visible Corp provides services for energy-saving measurement and verification, energy quality analysis, energy-saving project evaluation, energy-saving potential prediction, energy conservation project design, and energy-saving investment analysis. East-Bay, by contrast, provides services of energy conservation project design, energy-saving potential prediction, and energy-saving investment analysis. Table 30 shows the products and services that each of the studied ESCOs provides.

Table 30: Products and services provided by ESCOs.

Product	SERVICES
Lighting and HVAC retrofit	Energy saving lighting retrofit; Heating and air conditioning system energy-saving retrofit
Consulting	Energy saving measurement and verification; Energy-saving project evaluation; Energy quality analysis; Energy conservation project design; Energy-saving potential prediction; Energy-saving investment analysis
Energy management	Energy quality optimization; Energy usage monitoring and analysis, Energy wastage control
Process management	Optimization of production processes
Facility engineering	Production facilities transformation; Equipment retrofit and product design
Waste management	Waste gas, steam and heating power utilisation; Recycled water; Wastewater Emissions Treatment
Renewable energy generation and providing	Solar energy; Wind energy; Tidal energy power generation and comprehensive utilisation
EPC	Share-saving model, Guarantee-saving model; Build and transfer model; Build own and operate model
Electrical vehicle	Charge station installation; battery technology R&D
Building/infrastructure construction	Building and infrastructure construction and retrofit
Energy efficiency product production	Energy efficiency product and core equipment design, development and manufacturing

The comparisons of product portfolio between different case companies will be based on the products listed in Table 30. The comparison of the product portfolios of Chinese ESCOs with those of the US ESCOs is also based on the products listed in Table 30.

9.2 Product portfolio of Chinese small-size ESCOs

Visible Corp focuses on industrial energy conservation. Therefore, its main customers are traditional manufacturers and products are relevant industrial energy conservation. In order to provide comprehensive energy conservation services, Visible Corp’s main products involve energy consulting, energy management, process management, facility engineering, and EPC.

Taking advantage of its professional technical staff in energy conservation and developed energy management and analysis software, Visible Corp provides relatively comprehensive services for each product. However, Visible Corp has employed professional project construction companies for project installation and construction.

Visible Corp has five main products, each of which consists of a number of technical staff and a series of energy conservation technologies. Based on Visible Corp's core energy conservation technologies, the company focused on energy management, consulting, and process management. In terms of EPC, Visible Corp applies Share and guarantee saving models.

East-Bay is an ESCO that was developed from a LED lighting products distributor. East-Bay currently focuses on LED lighting energy-saving projects for commercial buildings and public infrastructures. East-Bay provides a series of LED lighting products and also LED energy-saving products design and production.

To date, East-Bay's main products have involved lighting and HVAC (heating, ventilation and air conditioning) retrofit, facility engineering, EPC, and energy efficiency product production. East-Bay employs a project construction company to provide project installation. The energy efficiency product production relies on its partner. The LED lighting products provided by East-Bay are relatively rich. There are about 30 kinds of LED lighting products for interior and exterior use. However, in terms of energy conservation services, East-Bay has only four products.

In terms of lighting and HVAC retrofit, East-Bay focuses solely on lighting retrofit. East-Bay's facility engineering refers to LED lighting products design. The company applies share energy-saving models.

Visible Corp's product portfolios are richer than those of East-Bay, due to the two company's different locations and target customers. Visible Corp is located in a first-tier city and East-Bay is located in a second-tier city. Visible Corp focuses on industrial energy conservation, while East-Bay focuses on lighting retrofit in building energy conservation. See Table 31 for a description of the two companies' product portfolios.

Table 31: Product portfolios of Visible Corp and East-Bay.

Company	Location	Main product areas	No. of Products	Products
Visible Corp	1st tier city	Industrial energy conservation	5	Energy consulting Energy management; Process management; Facility engineering; EPC
East-Bay	2nd tier city	Building energy conservation	4	Lighting retrofit; Facility engineering; Energy efficiency products production; EPC

9.3 Product portfolio of Chinese medium-size ESCOs

Sinowise focuses on industrial energy conservation. Its main customers are medium-sized and large iron and steel manufacturers and building material manufacturers. Therefore, the energy conservations products provided by Sinowise focus on consulting, energy management, process management, facility engineering, EPC, and waste management.

According to Sinowise's energy conservation technologies, the company focuses on energy management, process management, and waste management. Its core energy conservation technologies are relevant to energy management and waste energy comprehensive utilisation. Sinowise does not have a project installation and construction team, so the company employs a project construction company to help it with project implementation. At the same time, by taking advantage of outsourcing, Sinowise provide products of facility engineering. Sinowise has applied share and guarantee energy saving models; however, nearly 80 per cent of the projects apply a shared energy-saving model.

Ditree focuses on industrial energy conservation and building energy conservation. Its main customers involve small and medium-sized manufacturers and commercial buildings and public facilities. Hence, the products and services provided by Ditree are relatively comprehensive and include energy consulting, energy management, process management, facility engineering, EPC, waste management, lighting, and HVAC retrofit and energy efficiency product production.

Ditree provides project installation and construction, energy consulting, and energy efficiency product production through outsourcing. The company focuses on waste management, process management, and facility engineering. In terms of energy management, Ditree only developed its energy management system in 2015. Ditree provides share and guarantee energy-saving models.

Ditree's product portfolio is more comprehensive than Sinowise's. Ditree focuses on both industrial and building energy conservation domains. Therefore, although Ditree is located in a second-tier city, it has more products than Sinowise, which is located in a first-tier city. However, Sinowise provides energy consulting based on its own technical staff. Ditree relies heavily on partners. Table 30 shows the product portfolios of the two companies.

Table 32: Product portfolio of Sinowise and Ditree

Company	Location	Main product areas	No. of Products	Products
Sinowise	1st tier city	Industrial energy conservation	6	Energy consulting; Energy management; Process management; Facility engineering;; Waste management; EPC
Ditree	2nd tier city	Industrial and Building energy conservation	8	Energy consulting; Energy management; Process management; Facility engineering; ; Waste management; Lighting and HVAC retrofit; Energy efficiency product production; EPC

9.4 Product portfolio of Chinese large ESCOs

CECEP IEC focuses on industrial energy conservation. Its main customers are large manufacturers and it implements large energy conservation projects. Its products focus solely on industrial energy conservation. CECEP IEC's product portfolio involves energy consulting, energy management, process management, facility engineering, EPC, waste management, renewable energy generation and provision, building and infrastructure construction, and energy efficiency product production.

CECEP IEC has a number of branches and subsidiaries. Therefore, the company not only has numbers of technical staff for energy consulting, process management, energy management, facility engineering and waste management, but also a professional project implementation team that is responsible for project installation and construction. In addition, CECEP IEC has a subsidiary for producing core energy efficiency equipment. CECEP IEC applies various EPC models, such as share and guarantee energy saving models, a build and transfer model, and a build-own-operation model.

Guowang focuses on energy conservation for grid systems and renewable energy generation and provision. Guowang has also expanded its business to building energy conservation. Guowang's main customer is its parent company State Grid. The product portfolio mainly involves lighting/HVAC retrofit, process management, facility engineering, EPC, renewable energy generation and providing, building and infrastructure construction and energy efficiency product production.

Guowang has a professional project implementation company, technical team, R&D department and the world's largest biomass power generation company. Hence, it focuses on renewable energy generation and providing, and energy saving for the national grid. Lighting/HVAC retrofit has been part of its business offering for only two years, but its services involve lighting and air conditioning retrofit. Therefore, Guowang provides a total of seven products.

CECEP IEC focuses only on industrial energy conservation and all of its products are provided for traditional manufacturing. Guowang's main customer is its parent company, so its product portfolio focuses more on very narrow domain about grid energy saving and renewable energy generation and providing. Guowang started to provide service of lighting/HVAC retrofit in order to expand its business. However, the product portfolio of CECEP IEC is much richer than that of Guowang. Table 33 presents the product portfolios of these two companies.

Table 33: Product portfolios of CECEP IEC and Guowang.

Company	Location	Main product areas	No. of Products	Products
CECEP IEC	1st tier city	Industrial energy conservation	9	Energy consulting; Energy management; Process management; Facility engineering; EPC; Waste management; Energy efficiency product production; Building and infrastructure construction; Renewable energy generation and providing
Guowang	1st tier city	Industrial and Building energy conservation	7	Process management; Facility engineering; EPC; Building and infrastructure construction; Lighting and HVAC retrofit; Energy efficiency product production; Renewable energy generation

9.5 Comparisons of product portfolios of case companies

Different case companies have different numbers of products and services and types of products and services. These differences are due to company size and company's domains of energy conservation. Table 34 shows the number of products and services that each case company provides.

Table 34: Numbers of products provided by case companies.

Company size	Location	Company name	Numbers of products
Small	1st tier city	Visible Corp	5
	2nd tier city	East-Bay	4
Medium	1st tier city	Sinowise	6
	2nd tier city	Ditree	8
Large	1st tier city	CECEP IEC	9
	1st tier city	Guowang	7

As the table shows, the various companies provide different numbers of products. Large ESCOs provided more comprehensive products than small and medium-size ESCOs. However, the number of products and services provided also depends on the company's energy conservation domains, main customer groups, linkage capabilities and business strategy. For example, Ditree is a medium-size ESCO and it offers more products and services than Guowang, a large-size ESCO; this is because Guowang's main customer is its parent company, and its product portfolio is therefore linked closely to the requirements of its parent company. In addition, Sinowise and Ditree are both medium-size ESCOs, but the number of products and services provided by Ditree is more than that of Sinowise. This is mainly because Ditree focused on industrial and building energy conservation, while Sinowise focuses solely on industrial energy conservation.

Table 35: Types of products and services provided by case companies.

Products and services	Small-size ESCOs		Medium-size ESCOs		Large ESCOs	
	Visible Corp	East-Bay	Sinowise	Ditree	CECEP Industrial	Guowang
Lighting and HVAC retrofit		o		o		o
Consulting	o		o	o	o	
Process management	o		o	o	o	o
Facility engineering	o	o	o	o	o	o
Energy management	o		o	o	o	
EPC	o	o	o	o	o	o
Building and infrastructure					o	o
Energy efficiency product production		o		o	o	
Waste management			o	o	o	o
Renewable energy generation and providing					o	o

As Table 35 shows, the case companies mainly provide 11 types of products. However, no case company's product portfolio covers all of these products. CECEP IEC provides nine products. Products such as consulting, process management, energy management, facility engineering, EPC, and waste management are provided by at least four of six case companies. Among them, EPC and facility engineering are the products provided by all case companies.

Some products are provided by two or three case companies, such as lighting/HVAC retrofit, energy efficiency product production, building and infrastructure construction and renewable energy generation and providing. Among them, only large case companies provide building and infrastructure construction and renewable energy generation and providing services.

9.6 Comparisons of product portfolio between Chinese ESCOs and American ESCOs

The United States is one of the earliest countries to start an ESCO business and build an ESCO market. After nearly 50 years' of development, the US now has the most mature ESCO market in the world. The US Department of Energy's study of the product portfolios of 112 qualifying US ESCOs revealed, among other things, the size, number of products and services, and types of products and services of each ESCO.

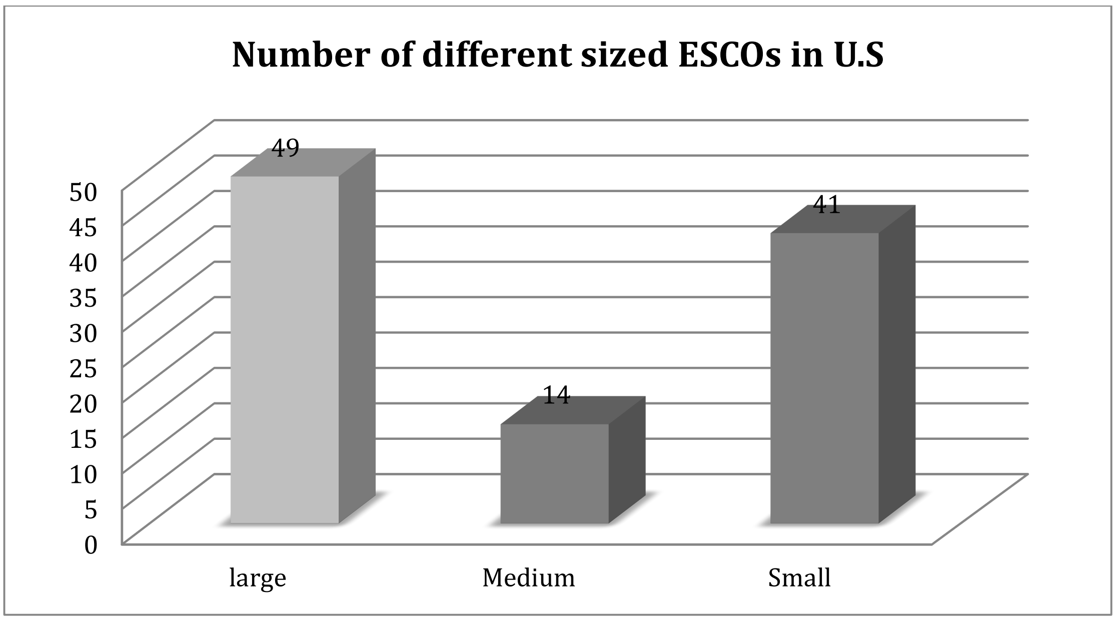


Figure 42: Sizes of US ESCOs

A total of 112 qualified as ESCOs, according to the US Department of Energy's study. In China, 5426 ESCOs are registered by the NDRC, and 90 per cent of these are SMEs (IEA: Energy Efficiency Market Report 2016). Although the number of ESCOs in China is much larger than that of the US, the proportion of large ESCOs in the US (44 per cent) is higher than that of China. This could be because ESCOs in the US tend to become super-ESCOs (Vine et al. 1999). In China, the number of ESCOs has been increasing quickly; from 2011–2015, the number of registered

ESCOs increased by 3087. Most of new market entrants are private small and medium-size ESCOs. Hence, the proportion of small and medium-size ESCOs is much higher than that of the US.

Table 36: Number of products and services of ESCOs in the US.

Number of Products & Services					
	Average	Max	Min	Median	Mode
Total	4.57	10	2	4	5
Large size	4.76	10	2	5	5
Medium size	4.29	8	2	3	3
Small size	4.44	8	2	4	4

As Table 36 shows, the average number of products and services of ESCOs in the US is 4.57. The number of products provided by the small case study companies in this study is similar to the overall figure of US ESCOs. The number of products provided by the medium-sized and large case study ESCOs studied herein is higher than that of US ESCOs. However, some ESCOs in the US provide 10 types of services, compared to nine for the case companies studied herein. In terms of small-sized ESCOs, such companies in the United States provide eight products, compared to a maximum of five products for the case companies.

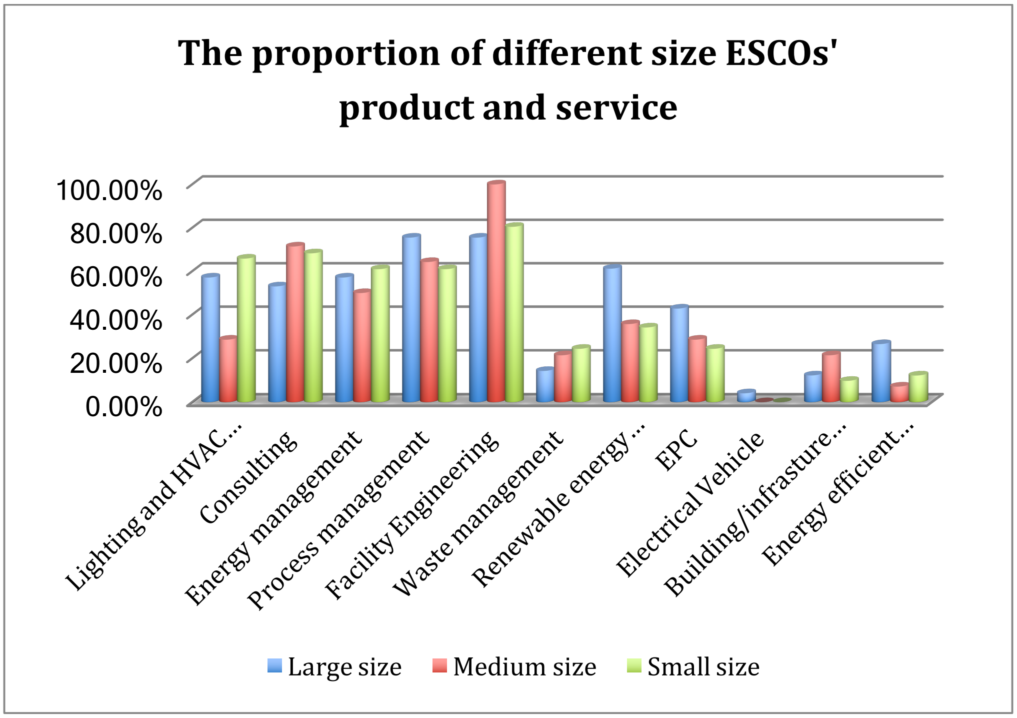


Figure 43: The proportion of different size ESCOs' products and services in the US

According to Figure 43, lighting/HVAC retrofit, consulting, energy management, process management and facility engineering are the most common services provided by US ESCOs. For the Chinese case companies, the most common services are consulting, energy management, process management, facility engineering, EPC and waste management. Lighting/HVAC retrofit is common for ESCOs in the US but not for case companies in China. Waste management is common for case companies in China but not for ESCOs in the US; this is because the case companies focuses more on industrial energy conservation. ESCOs in the US focus on building energy conservation. In addition, the main customers of the case companies are traditional manufacturers. The main customer group of ESCOs in the US are “MUSH” (municipal and state governments, universities and colleges, K-12 schools and hospitals), utility residential programs, public housing, C&I (commercial and industrial), and federal.

In terms of case companies, no ESCOs provide products related to electrical vehicles. In the US, the proportion of renewable energy generation and providing of large ESCOs is very high; only large case companies provide this service. In terms of energy efficiency products production, ESCOs in the US are similar to the case companies in China. In the US, the proportion of building and infrastructure construction of medium-size ESCOs is higher than that of large and small-size ESCOs. In terms of the Chinese case companies, however, only the large companies provide this service. Additionally, the proportion of EPC of ESCOs in the US is not very high, less than 50% of total U.S ESCOs. while all the case companies in China provide this product.

9.6 Chapter summary

The United States is the ‘benchmark’ ESCO market, with nearly 50 years of development history. China has the largest ESCO market with most ESCOs and revenue. There are similarities and differences between ESCOs in the US and the case companies in China in terms of product portfolios.

In terms of number of products and services of ESCOs, case companies have advantages in the number of products, while small and large ESCOs in the US have advantages in terms of the maximum number of products and services. Of the case companies, only CECEP IEC provides nine products, while several ESCOs in the US provide 10 products. In terms of small-size ESCOs, the maximum number is eight products for US ESCOs and five for the case companies.

Case companies in China and US ESCOs provide various types of products and services. Consulting, energy management, process management and facility engineering are most common services for case companies and ESCOs in the US. However, the case companies focus on industrial energy conservation, so there are four case companies that provide waste management services. ESCOs in the US focus on building energy conservation, so the proportion of lighting/HVAC retrofit is much higher than that of case companies. On the whole, in terms of number of products provided by ESCOs and types of products provided by ESCOs, Chinese ESCOs are slightly different from ESCOs in the US.

Although case companies have similar product portfolio with U.S ESCOs, due to the characteristics of ESCOs industry, the complexity of services which involved in products is different. According to the analsyis of case companies products and services. Company's technological capability play an important role in the complexity, effectiveness and cost of services. On the other words, ESCOs' product portfolio and services reflect companies' technological capability.

Next Chapter will provide conclusions for the whole thesis.

Chapter 10 Conclusions

This chapter summarises the main findings and results of this thesis and discusses the contributions that the study makes to the body of knowledge, business practice and government intervention. I start by revising the conceptual framework for the study, which was created based on empirical research. A theoretical framework is proposed in section 10.1, before section 10.2 presents the main findings of the product portfolio of Chinese ESCOs. In section 10.3, the importance of technological capability development of ESCO is taken into consideration, and the theoretical contributions of this thesis are illustrated in section 10.4. Business practice contributions are explained in section 10.5. Section 10.6 presents limitations of this research and, finally, areas for further research are given in section 10.7.

10.1 Conceptual framework: Revised

10.1.1 Redefinition of four dimensions of technological capability in ESCO industry

According to my empirical research, a conceptual framework to investigate the factors affecting companies' technological capability development was proposed in chapter 3. First of all, investment, production, linkages and innovation capabilities are the four key dimensions of company's technological capability that are accepted by manufacturing and service industries. Each of these dimensions was explained in section 2.1.1. These explanations were proposed according to the previous studies of company's technological capability in manufacturing industry. Nevertheless, the ESCO industry is a service industry that has specific industrial characteristics. Therefore, this section starts by revising and discussing the explanations of these four dimensions of technological capability.

Investment capability: The investment capability of ESCOs not only refers to company's financing ability to access external financial resources in order to satisfy the requirement of investment for technological capability development, but also to the ESCOs' ability to recognise and evaluate potential energy conservation technologies. To build up this ability, ESCOs rely not only on prior knowledge of energy conservation but also on diversified and experienced technical staff. Therefore, ESCOs not only recognise and select potential energy conservation technologies but also appropriate technical staff. Moreover, ESCOs have different levels of knowledge, which will seriously affect their investment capability. ESCOs not only have knowledge about which product, equipment or technologies can be used in energy conservation projects, but also rich knowledge about cost efficiency and improvement potential of product, equipment and technologies. The large ESCOs or small and medium-sized ESCOs with rich technologies absorption experience will build up the ability to effectively recognise, evaluate and select potential products and technologies.

Production capability: ESCOs' production capability relies heavily on technical staff and their absorptive capacity. The production capability of ESCOs refers to absorbing and exploiting energy conservation technologies and providing energy conservation projects to customers. The technical staff at ESCOs are responsible for absorbing energy conservation technologies, exploiting energy conservation technologies, selecting qualified energy conservation products and equipment, designing and implementing energy conservation projects, customer training, and project maintenance. The main inputs of ESCOs' production capability are energy conservation technologies and technical staff. Therefore, recruitment and training of technical staff are important for ESCOs' production capability. In addition, ESCOs' production capability was strongly affected by customers; for example, the customers' knowledge capture, awareness of energy conservation and operational ability of workers.

Linkage capability: This refers to the ability of ESCOs to build up informal and formal linkages with external actors such as customers, competitors, suppliers, research institutes and associations, financial institutes, and government departments. Taking advantages of linkages, ESCOs receive technical and financial support from external actors. In order to obtain technical supports and leverage resource for effective development of technological capability, ESCOs require absorptive capacity and also financial support. Visible Corp, Sinowise and Ditree created connections with external actors, such as suppliers, competitors and research institutes. These connections are more likely oral agreements or personal relationships. East-Bay, CECEP IEC and Guowang have the ability to leverage resources to enhance or develop technological capability through formal linkages, such as outsourcing contracts, collaborative R&D contracts, and mergers and acquisitions. Only CECEP IEC has the ability to absorb technology and know-how through linkages. Small and medium-sized ESCOs normally stay in the first and second stages. Large ESCOs can leverage and further absorb technology and know-how to develop technological capability.

Innovation capability: This refers to ESCOs' ability to improve and integrate absorbed energy conservation technologies. Moreover, the company's innovation capability also reflects in developing mature and advanced energy conservation technologies through in-house or collaborative R&D. So far, all of the studied ESCOs have implemented incremental innovation through improving and integrating domestic and international mature energy conservation technologies to improve their technological capability and further expand their business and improve their market performance. Large ESCOs undertake incremental innovation and also radical innovation through in-house and collaborative R&D. Large ESCOs develop domestic advanced energy conservation technologies, products and equipment through in-house R&D or collaborative R&D with local research institutes. At the same time, through collaborative R&D with foreign companies, large ESCOs have tried to develop international emerging energy conservation technologies. The collaborative R&D relies heavily on a large amount of R&D investment, which only large ESCOs can afford.

The new explanations of the four dimensions of technological capability are quite different from the previous ones in terms of investment, production and linkage capabilities. Due to the characteristics of energy conservation projects, ESCOs are responsible for the full cost of projects; therefore, the cash flow of ESCOs is tight. ESCOs need strong financing ability in order to obtain the funds they need to invest in technological capability. Apart from this, ESCOs focus on investment in energy conservation technologies and technical staff. In terms of production capability, the main products of the ESCO industry are intangible services. ESCOs do not need large amounts of manufacturing equipment and manufacturing facilities. Transaction are not instant, which means that the services normally last a period of time. ESCOs and customers keep close connections during this period of time. ESCOs must ensure the performance of services during contract period. The main inputs of production of ESCOs are energy conservation technologies and technical staff, which means they are labour-intensive. In terms of linkage capability, both informal and formal linkages should be taken into account. It is important to establish linkages with external actors, not just for skills, knowledge and technology transfer but also for consultations, collaborative R&D and resource leverage.

10.1.2 Relations between four dimensions of technological in ESCO industry in China

There are links between four dimensions of technological capability in the ESCO industry in China. Each dimension directly or indirectly affects other dimensions.

Firstly, we found that ESCOs in China are currently focusing on investment capability because investment capability directly affects companies' production and innovation capabilities. R&D investment was deemed as a key factor affecting companies' innovation capability.

ESCOs' production capability was considered an important approach to accumulate companies' prior knowledge and know-how and further build up absorptive capability. In addition, production capability also affects ESCOs' market performance. Therefore, ESCOS' production capability influences the companies' three other dimensions of technological capability.

Some ESCOs have focused on linkage capability and have sought to obtain technical supports or opportunities of technology transfer and collaborative R&D through these linkages. Hence, linkage directly affects ESCOs' production and innovation capability.

Innovation capability was focused on by those ESCOs that deem technological capability as their competitive advantage. Innovation capability only affects ESCOs' production capability directly. It is also linked to ESCOs' investment capability but not to an obvious degree. Figure 44 shows the relations between dimensions of ESCOs' technological capability.

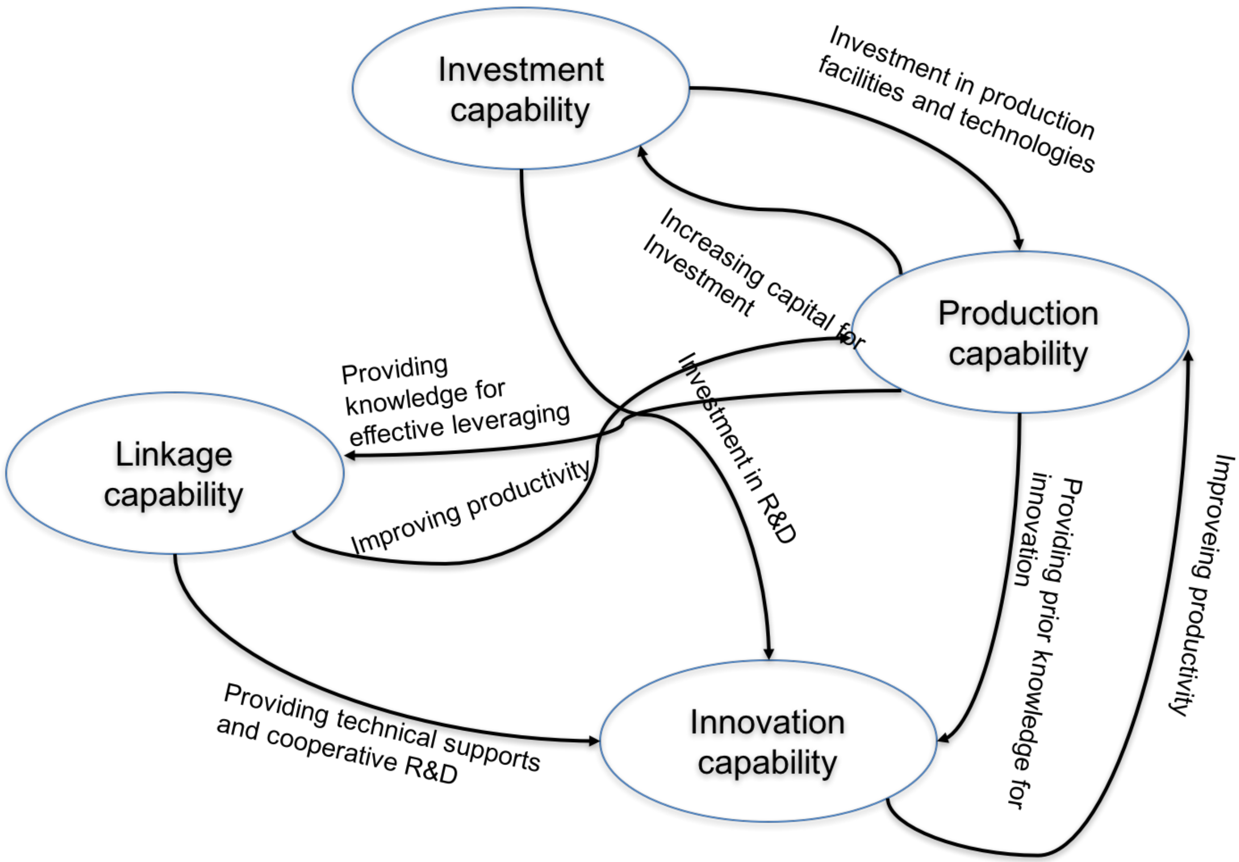


Figure 44: Relations between four dimensions

Apart from these, ESCOs do not have to focus on all four dimensions of technological capability. Based on ESCOs' business and technological development strategy, ESCOs could focus on one or more dimensions. Small and medium-sized ESCOs focused more on investment, production and innovation capability. However, these three dimensions of technological capability of small and medium-size ESCOs are limited. Small and medium-sized ESCOs take advantage of outsourcing to compensate for their limited production capability. However, compared with large ESCOs, there are significant differences in amount of investment and innovation capability.

Large ESCOs have focused on four dimensions of technological capability. However, large ESCOs have significant advantages in investment, production and innovation capability. In terms of linkage capability, large ESCOs will build up formal and effective linkages with external actors according to their requirements. The linkages built up by large ESCOs might not be broad, but large ESCOs are able to leverage resources to develop their technological capability. Unlike small and medium-sized ESCOs, most of the linkages that were built up through personal relationships are simply connections. It is very hard to leverage resources or absorb technologies and knowledge by these linkages.

Moreover, when ESCOs develop technological capability, small and medium-sized ESCOs can develop investment and production capability priority. Taking advantage of strong capital and scale, large ESCOs focus on developing linkage and innovation capability priority. However, for those super-ESCOs that have just entered the market, it is necessary to start by developing investment and production capability. The dimension of priority development depends heavily on ESCOs' business development strategy, current market performance, size, market competition, customers' requirements and government policy.

10.1.3 Theoretical framework

According to the conceptual framework, the factors affecting technological capability were limited. Therefore, the conceptual framework is revised based on the results of data analysis. Figure 43 shows the revised conceptual framework.

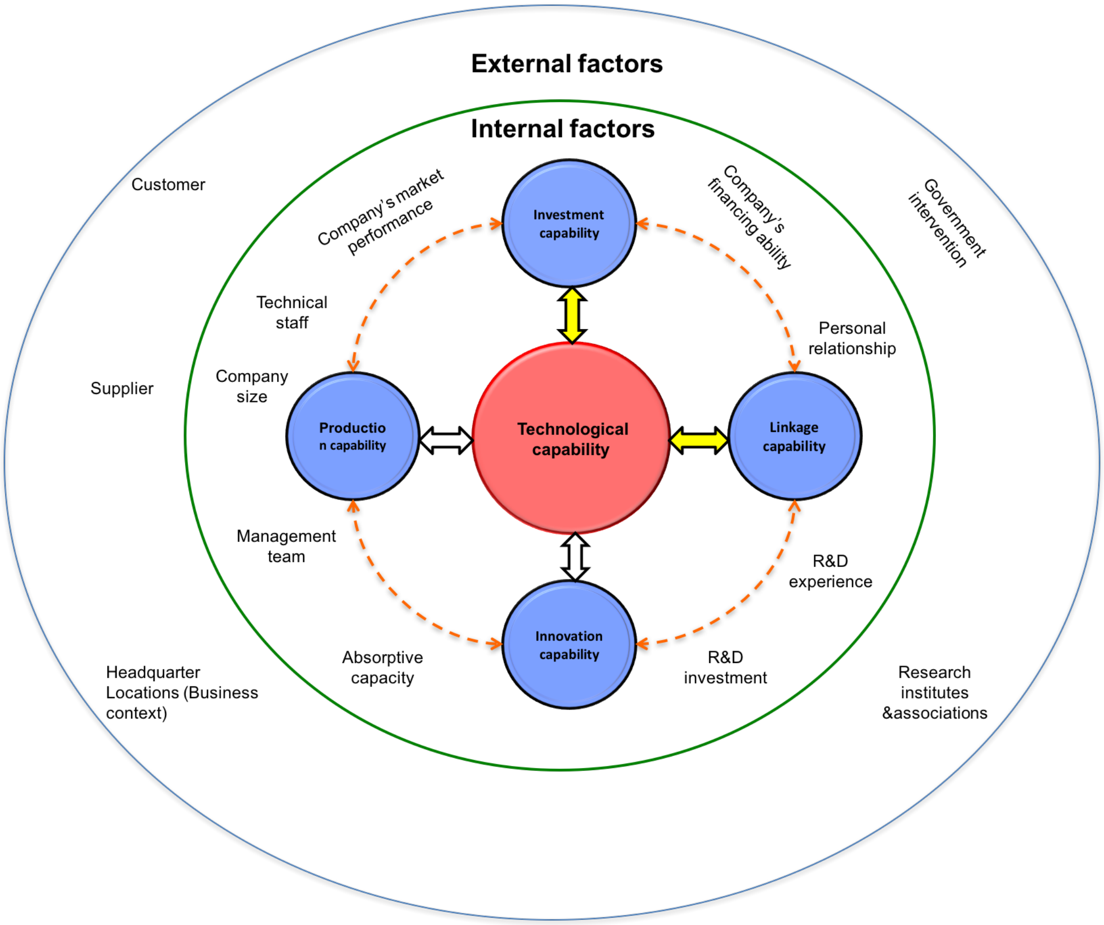


Figure 45: Theoretical framework for factors affecting technological capability

Compared with conceptual framework, the key factors affecting company technological capability are refined. Figure 46 displays the comparison of key factors affecting four dimensions of technological capability between conceptual and theoretical frameworks. According to conceptual framework, there are 10 internal and 8 external key factors affecting companies' four dimensions of technological capability. However, based on the data analysis, in terms of ESCOs industry, there are 9 internal and 5 external key factors affecting ESCOs' four dimensions of technological capability. Apart from these, the internal factors in conceptual framework, like profitability, management capability, R&D are replaced by company's market performance, management team and R&D investment and experience. The external factor from conceptual framework, like government policy and regulation environment are replaced by government intervention. The differences between factors from conceptual framework and theoretical framework are explained in the chapter of cross-case analysis.

Conceptual framework: Key factors affecting four dimensions of technological capability

Dimensions	Internal factors	External factors
Investment capability Production capability Linkage capability Innovation capability	Company size Finance ability Profitability ability Organizational structure and policy Absorptive capacity R&D Prior knowledge Company's strategy Management capability	Financial institutions Research institutions and associations Customer Supplier Partner Competitors Government policy Regulation environment

Theoretical framework: Key factors affecting four dimensions of technological capability

Dimensions	Internal factors	External factors
Investment capability	Company's financing ability Company's market performance Technical staff Company size Management team	Government intervention Headquarter location (Business context)
Production capability	Technical staff Management team Absorptive capacity	Research institutes & associations Supplier Customer
Linkage capability	Company size Personal relationship Management team Absorptive capacity	Government intervention
Innovation capability	Company size R&D investment R&D experience Management team	Research institutes &associations Headquarter location (Business context)

Figure 46: Comparison of key factors affecting four dimensions of technological capability between conceptual and theoretical frameworks.

Moreover, conceptual framework doesn't' shows the links between four dimensions of technological capability. Through cross-case analysis, theoretical framework displays that four dimensions of technological capability have connections between each other.

10.2 Product portfolio of Chinese ESCOs

This investigation studied product portfolios of Chinese ESCOs through secondary analysis and provide insights about ESCOs' technological capability's impacts to companies' product portfolio from perspectives of types and numbers of products and services. Large ESCOs provide more products than small and medium-size ESCOs; however, some medium-size ESCOs also provide comprehensive products through outsourcing or cooperation with partners. The number of products was affected less by location than by the energy conservation areas that the ESCOs focused on.

Five of the six case ESCOs provide consulting, process management, facility engineering, energy management and EPC services. Waste management was only provided by medium and large ESCOs. The products of building and infrastructure construction and renewable energy generation are only provided by large ESCOs.

The types of products that the case ESCOs provide are similar to those of American ESCOs. However, lighting/HVAC retrofit is a popular product provided by US ESCOs, but only three of the case companies provide this product. This is because most of the case ESCOs focus on industrial energy conservation. US ESCOs focus on building energy conservation. In addition, a small number of US ESCOs provide products for electrical vehicles. However, no case companies provide this product. The number of products provided by case ESCOs is higher than that provided by US ESCOs. However, the maximum number of products provided by US ESCOs is 10, while only one large case ESCO provides nine products.

Case studies implies that although companies provide same type and number of products and services, the differences between companies' technological capability affect the complexity of products and services in ESCO industry.

10.3 Considering the importance of technological capability development in the ESCO industry

As one of objectives of this study, identifying importance of technological capability of this emerging industry in China is crucial. Since the concept of ESCO was introduced into China in the end of 1990s, ESCO industry developed for nearly 20 years in China. However, during the 11th and 12th FYP periods, ESCO industry stepped into the high-speed development stage.

In order to establish and develop the ESCO industry to help China achieve its objectives of energy saving as soon as possible, central and local governments issued a series of policies and measures to promote ESCO industry to the whole society and foster the development of ESCOs. Within this context, the numbers of ESCOs and investment in energy conservation projects have increased rapidly. Most attention has focused on how to promote this industry instead of how to develop it healthily and sustainably.

Competitive ESCOs recognised the importance of technological capability development and started to build up and develop their own technological capability. When they set up their business development strategies, technological capability has been placed in a strategic position, although marketing remains their priority. Some ESCOs, such as East-Bay, have not yet focused on technological capability. Depending on some mature energy conservation technologies, ESCOs can conduct energy conservation projects and obtain subsidiaries from local and central governments. The requirement of technological capability development does not seem to be so urgent.

As an industry that implements energy conservation projects and disseminates and develops energy conservation technologies, ESCOs have the responsibility to develop their technological capability. Moreover, with the development of industry and improvement of market and policy, only competitive ESCOs will survival in an increasing competitive market. With energy consumers' deepening their understanding of energy conservation, ESCOs' technological capability will be seen as one of the most important considerations. Government policy support will not be always radical. The development of industry will ultimately depend on the market. Therefore, the importance of technological capability cannot be ignored.

Finally, the ESCO industry is an important one in terms of helping China make industrial structure adjustment and upgrades, and to achieve further sustainable development. ESCOs develop technological capability in order to spread and develop advanced energy conservation technologies and products that are suitable for Chinese industrial characteristics. Additionally, actively developing technological capability can help adjust energy utilisation structure, improve energy efficiency and further reduce energy consumption and carbon dioxide emission. The implications of technological capability development are far-reaching. Therefore, not only ESCOs but also energy consumers and governments should recognise the importance of technological capability when accelerating the development of the ESCO industry.

10.4 Theoretical contributions

The originality of this thesis resides in its different angle of analysing technological capability in service industry in developing countries, particular in China. It contributes to the field of energy efficiency and technology management through a better understanding of technological capability development in ESCO industry in China.

The first theoretical contribution is an expansion of the study of technological capability development by creating a theoretical framework for analysing the key dimensions of technological capability and factors that affect ESCOs' technological capability development. So far, a number of researchers have defined technological capability and proposed dimensions of technological capability based on the context of manufacturing industries. Lall (1992) proposed three dimensions of technological capability: investment, production and linkage. Kim (1999) identified another three dimensions of technological capability: production, investment and innovation.

This thesis contributes the study of four dimensions of technological capability in service industry. There are differences in characteristics between manufacturing and service industries. In this thesis, investment, production, linkage and innovation have been confirmed and notified as four key dimensions of technological capability based on ESCO industry. The explanations of these four dimensions are re-defined according to the characteristics of ESCO industry. In addition, this framework also identifies the relationship between the four dimensions of technological capability in the Chinese ESCO industry.

The second theoretical contribution is expansion of the understanding of technological capability development in the service industry from the perspective of process of technological capability development in ESCO industry. A number of scholars have studied the process of technological capability in developed and developing countries, including Utterback and Abernathy (1975), Kim (1980), Lee et al. (1988), Gao (2003), Mathews (2006) and Jin and Zedtwitz (2008). According to different enterprises in different countries during different time periods, researchers provided different propositions for process of technological capability. The present thesis has provided the propositions of a process of technological capability for an emerging service industry in a fast developing country: China. This finding can be used as a reference by ESCOs in other countries with similar contexts to China.

The final contribution that this thesis makes to theory is by expanding the study of technological capability in China. Previous studies of technological capability development in China have focused on manufacturing industries. This thesis has provided a pilot study of technological capability in the ESCO industry in China. It is a first attempt to expand the study of technological capability development from manufacturing industry to service industry in China.

10.5 Practical contributions

This study is closely connected to business practice and a number of implications can be derived from this thesis. The thesis has investigated ESCOs with different sizes, locations and business histories. The results can be used by small, medium-sized and large ESCOs with little or rich business experience in China when they analyse their technological capability development.

First of all, this thesis helps ESCOs recognise the importance of technological capability. When ESCOs set up business development strategy, technological capability should be placed in a strategic position for consideration. Company's size and headquarter location (business context) are also need to be considered when develop technological capability.

The second practical contribution is to help government recognise the supportive and unsupportive effects of existing policies on ESCOs' technological capability development. Governments should formulate specific and appropriate policies for SMEs and large ESCOs in different locations. In addition to promoting the ESCO industry and energy conservation projects, government should recognise the importance of technological capability development for fostering the sustainable development of the ESCOs industry. Taking advantage of the technological capability development of ESCOs, government could achieve the national objectives of energy efficiency and carbon dioxide emission reduction and further achieve sustainability. Through improving ESCOs' technological capability, ESCOs could provide more comprehensive product portfolio and more complex energy conservation technologies in order to improve the efficiency and reduce the cost of energy conservation.

The third practical contribution of this study is that it has identified and analysed the factors that affect technological capability when ESCOs develop their own technological capability. The theoretical framework can serve as a guide to holistic view of technological capability establishment and development. According to the framework, ESCOs can start to gradually establish or develop their investment, production, linkage and innovation capabilities and further build up and develop their competitive technological capability. Taking advantage of competitive technological capability, ESCOs could improve their market performance and profitability and further improve companies' competiveness in the industry.

Finally, the 'stories' of the case companies can have practical contribution, which means that new players could obtain experience about technological capability development from these companies. This can help new players set up an appropriate technological development strategy and choose an appropriate method to establish and develop their own technological capability effectively.

10.6 Limitations

In this thesis, conclusions were drawn from an investigation of six different ESCOs in China. Even though these ESCOs came from different locations, sizes and with different business histories, they are all domestic ESCOs. This investigation did not involve joint-venture ESCOs and foreign ESCOs in China.

Secondly, all of the studied ESCOs are from China. The development of ESCO industry was studied within a specific national context. Therefore, the results are strongly related to industry and location, so they can only be applied by ESCO industries in countries with a similar context with China and are not suitable for ESCO industries in developed countries.

In this investigation, the choice of multiple case study approach provided breadth, although this came at the expense of a deeper investigation in each case. Ideally, more time spent in each studied company will provide a better understanding of technological capability development. In addition to a limited amount of time, the number of interview of each case is also limited. There are three formal interviews for each small and medium-sized ESCO, but only two interviews for each large sized ESCOs, which leads to limited information being obtained from large-sized ESCOs. This limited time and access necessitated the choice of data collection with “key informants”. Additionally, personnel from different organisational functions may have different views of the technological capability development, which may affect the generalisation of the results. However, this effect is minimised through cross-case analysis. Moreover, all of the interviews were conducted in Chinese, and even though the principal researcher is frequently in English and Mandarin, some Mandarin is hard to translate into English accurately.

The data analysis techniques also had certain limitations. In terms of secondary data analysis, all the data are presented in print or electronic documents, which means there are few errors in the data analysis. In primary data analysis, however, errors that are embedded in any inductive-deductive reason process could have occurred in the process of interpreting the data, especially for the cases where the interview could not be audio-recorded. In order to minimise the effect, all the case reports were sent back to interviewees and feedback was obtained.

10.7 Opportunities for further research

This investigation is the first attempt to study technological capability in the ESCO industry and in the service industry. Therefore, there is opportunity to explore and expand the study to other areas. This can be done n different sectors or through different research methodologies.

Expanding the study of technological capability development beyond ESCO industry

As mentioned in the previous section, this investigation is closely related to industry and location. In terms of studying the technological capability development of the ESCO industry, it can be expanded to ESCO industry in different countries such as other developing countries and even developed countries. Additionally, further investigations could involve all types of ESCOs in China, such as joint-venture ESCOs and wholly owned foreign ESCOs. FDI normally plays an important role in technology transfer and technological capability development in developing countries.

In terms of study of technological capability, further investigation could expand the study of technological capability to other service industries. The ESCO industry is a technology- and finance-intensive emerging service sector. Many specific industrial characteristics affect the results of the study. In order to generalise the results for whole service industry, more studies of technological capability in some traditional service sectors are necessary.

Finally, there are research opportunities for the studies of technological capability of ESCO industry in other locations, or even other countries. There are more than 5000 ESCOs in China, located in various first-, second- and third-tier cities. This investigation selected ESCOs from one first-tier city and two second-tier cities. In terms of ESCOs from other first- and third-tier cities, further investigations are needed. In addition, while the present investigation focused on the ESCO industry in China, the ESCO industry has also developed quickly in other developing countries, such as India. As the fastest growing developing country, India's ESCO industry should also be focused on and studied as one of the main ESCO markets in the world.

Applying different research methodologies

This thesis used a qualitative multiple case study research approach, which provided enough breadth and depth understanding of technological capability development in ESCOs industry. It provided insights for this exploring investigation.

According to the results and research questions raised in this investigation, more research methods can be applied in order to develop and address new research questions.

For example, according to the dimensions of technological capability development proposed in this research, further research could focus on investigating the relationship between these four dimensions. The results will help companies develop their technological capability more effectively.

In this thesis, 14 key factors affecting company's technological capability were identified through qualitative analysis. Further investigation could examine these factors through quantitative analysis.

Finally, in order to evaluate the technological capability of ESCOs, a quantitative data analysis is necessary. The patent data can be used to evaluate ESCOs' technological capability and innovation capability.

Addressing the above research limitations would enhance our knowledge and practice in the energy sector, which will help deal with the important global challenges of energy efficiency and sustainability.

Reference

Abernathy, W. and J. M. Utterback (1978), Patterns of Industrial Innovation, Technology Review, June/July, 80(7), pp 41–48.

Archibugi, D, & Pietrobelli, C (2003)，The globalization of technology and its implications for developing countries. Windows of opportunity or further burden?, Technological Forecasting & Social Change, 70(9), pp. 861-883

Acharya, R, & Keller, W (2009)，Technology transfer through imports, Canadian Journal Of Economics, 42(4), pp. 1411-1448

Andrew Satchwell, Charles Goldman, Peter Larsen, Donald Gilligan and Terry Singer (2010)，A Survey of the U.S. Energy Service Company (ESCO) Industry: Market Growth and Development from 2008 to 2011, Lawrence Berkeley National Laboratory and National Association of Energy Service Companies

Allouhi, A., El Fouih, Y., Kousksou, T., Jamil, A., Zeraouli, Y. and Mourad, Y. (2015), Energy consumption and efficiency in buildings: current status and future trends, Journal of Cleaner Production, 109, pp.118-130.

Bryman, A. (1989). Research Methods and Organization Studies. Unwin Hyman Press.

Bell, M, & Pavitt, K (1992), Accumulating Technological Capability in Developing Countries, The World Bank Economic Review, 6, Supplement 1, p. 257

Bell, M. and Pavitt, K., (1995), The development of technological capabilities. Trade, technology and international competitiveness, 22(4831), pp.69-101.

Bin, X (2000), Multinational enterprises, technology diffusion, and host country productivity growth, Journal Of Development Economics, 62(2), pp. 477-493

Bruno van Pottelsberghe de la, P, & Lichtenberg, F (2001), Does Foreign Direct Investment Transfer Technology across Borders?, The Review of Economics and Statistics, 83(3), pp. 490-497

Biermann, A., (2001) ESCOs in the liberalised domestic UK energy markets—barriers to establishing ESCOs and possibilities to overcome them in the UK energy markets. Proceedings of the 2001 ECEEE Summer Study, European Council for an Energy-Efficient Economy, Paris, Vol. 2, France, pp. 437–446.

Barczak G., A. Griffin and B. Kahn, (2003), Perspective: trends and drivers of success in NPD, practices: results of the 2003 PDMA best practices study, Product Innovation Management, 26 (1) (2009), pp. 3–23

Bertoldi, P., Rezessy, S. and Vine, E. (2006), Energy service companies in European countries: Current status and a strategy to foster their development, Energy Policy, 34(14), pp. 1818–1832.

Blomquist, T. and Müller, R., (2006), Practices, roles, and responsibilities of middle managers in program and portfolio management, Project Management Journal, 37(1), p.52.

Blalock, G, & Gertler, P (2008), Welfare gains from Foreign Direct Investment through technology transfer to local suppliers, Journal Of International Economics, 74(2), pp. 402-421

Barratt, M., Choi, T., and Li, M. (2011). Qualitative case studies in operations management: Trends, research outcomes, and future research implications, Journal of Operations Management, 29, 4, pp. 329–342.

Beringer, C., Jonas, D. and Kock, A., (2013), Behavior of internal stakeholders in project portfolio management and its impact on success. International Journal of Project Management, 31(6), pp.830-846.

Bi, G.B., Song, W., Zhou, P. and Liang, L. (2014), Does environmental regulation affect energy efficiency in China's thermal power generation? Empirical evidence from a slacks-based DEA model, Energy Policy, 66, pp.537-546

Börjesson, S., Elmquist, M. and Hooge, S., (2014), The challenges of innovation capability building: Learning from longitudinal studies of innovation efforts at Renault and Volvo Cars. Journal of Engineering and Technology Management, 31, pp.120-140.

Bryman, A. & Bell, E. (2015). Business research method. Oxford: Oxford Univ. Press, 2015.

Barnham, C. (2015). Quantitative and qualitative research, International Journal of Market Research, 57, 6, pp. 837–854.

Bertoldi, P. and Boza-Kiss, B. (2017). Analysis of barriers and drivers for the development of the ESCO markets in Europe. Energy Policy, 107, pp.345-355.

Cohen, W. M. and D. A. Levinthal (1990), Absorptive Capacity: A New Perspective on Learning and Innovation, Administrative Science Quarterly, 35, 128–152..

Cooper, R. G., Edgett, S. J., & Kleinschmidt, E. J. (1997), Portfolio management in new product development: Lessons from the leaders, Research-Technology Management, 40(5), pp. 16-28.

Cooper, R. G., Edgett, S. J., & Kleinschmidt, E. J. (1999), New product portfolio management: practices and performance. Journal of product innovation management, 16(4), pp. 333-351

Caselli, F. and II, W.J.C. (2001), Cross-country technology diffusion: The case of computers. National bureau of economic research.

Charles A. Goldman, Julie G. Osborn, and Nicole C. Hopper, LBNL Terry E. Singer, NAESCO (2002), Market Trends in the U.S. ESCO Industry: Results from the NAESCO Database Project, Energy Analysis Department, Environmental Energy Technologies Division Ernest Orlando Lawrence Berkeley National Laboratory University of California Berkeley, CA 94720 (1990-2000)

Cavusgil, S, Calantone, R, & Yushan, Z (2003), Tacit knowledge transfer and firm innovation capability, Journal Of Business & Industrial Marketing, 18(1), pp. 6-21

Cooper. R.G., S.J. Edgett, E.J. Kleinschmidt (2004), Benchmarking Best NPD Practices-II, Research Technology Management, Industrial Research Institute Inc, pp. 50–59

Chuang, Y.C. and Hsu, P.F. (2004), FDI, trade, and spillover efficiency: evidence from China's *manufacturing sector, Applied Economics, 36(10), pp.1103-1115.*

Crompton, P. and Wu, Y. (2005), Energy consumption in China: past trends and future directions, Energy economics, 27(1), pp.195-208.

Camisón, C. and Forés, B. (2010), Knowledge absorptive capacity: New insights for its conceptualization and measurement, Journal of Business Research, 63(7), pp.707-715..

Cooper, R., Edgett, S., & Kleinschmidt, E. (2011), Portfolio management for new product development: results of an industry practices study. R&D Management, 31(4), pp. 361-380.

Chang, Y. Y., Gong, Y., & Peng, M. W. (2012). Outsourcing knowledge transfer, assisted absorptive capacity and subsidiary performance. Journal of Management, 55 (4), pp.927-948.

Clausen, T.H. (2013), External knowledge sourcing from innovation cooperation and the role of absorptive capacity: empirical evidence from Norway and Sweden. Technology Analysis & Strategic Management, 25(1), pp.57-70.

Chang, Y.T., Zhang, N., Danao, D. and Zhang, N. (2013), Environmental efficiency analysis of transportation system in China: A non-radial DEA approach, Energy policy, 58, pp.277-283.

Cui, Q., Kuang, H.B., Wu, C.Y. and Li, Y. (2014), The changing trend and influencing factors of energy efficiency: the case of nine countries, Energy, 64, pp.1026-1034

“China Energy Statistical Yearbook 2016”, published by National Bureau of Statistics of the People’s Republic of China. < http://www.stats.gov.cn/tjsj/tjcbw/201706/t20170621_1505833.html> accessed on 2nd of July, 2017.

“China Statistical Yearbook 2016”, published by National Bureau of Statistics of the People’s Republic of China. < http://www.stats.gov.cn/tjsj/tjcbw/201610/t20161018_1410756.html>, accessed on 10th/11/2016

Dahlman, C.J., Ross-Larson, B. and Westphal, L.E. (1987), Managing technological development: lessons from the newly industrializing countries. World development, 15(6), pp.759-775.

Dickinson, M, Thornton, A, & Graves, S (2001), Technology portfolio management: optimizing interdependent projects over multiple time periods, IEEE Transactions On Engineering Management, 4, p. 518-527

Damijan, J, Knell, M, Majcen, B, & Rojec, M. (2003), Technology Transfer through FDI in Top-10 Transition Countries: How Important are Direct Effects, Horizontal and Vertical Spillovers?, Enterprise In Transition: International Conference Proceedings: 2003, pp. 1-23

Damijan, JP (2003), The Role of FDI, R&D Accumulation and Trade in Transferring Technology to Transition Countries: Evidence from Firm Panel Data for Eight Transition Countries, Economic Systems, 27(2), pp. 189-204

Denzin, N. K. & Lincoln, Y. S. (2005). The Sage Handbook of Qualitative Research, Third Edition, Sage

Da-li, G. (2009), Energy service companies to improve energy efficiency in china: Barriers and *removal measures, Procedia Earth and Planetary Science, 1(1), pp. 1695–1704*

De La Tour, A., Glachant, M., & Ménière, Y. (2011). Innovation and international technology transfer: The case of the Chinese photovoltaic industry. Energy Policy, 39(2), pp.761-770.

Dechezleprêtre, A., Glachant, M., & Ménière, Y. (2013). What drives the international transfer of climate change mitigation technologies? Empirical evidence from patent data. Environmental and Resource Economics, 54(2), pp.161-178.

Eisenhardt, K.M. (1989). 'Building theories from case study research'. Academy of Management Review, 14, 4, pp. 532–550.

Easterby-Smith, K., Thorpe, R., and Jackson, P.R. (2008). Management Research, third edition, Sage.

Eggers, J. P. (2012), All experience is not created equal: learning, adapting, and focusing in product portfolio management. Strategic Management Journal, 33(3), pp. 315-335

Elizabeth Stuart, Peter H. Larsen, Charles A. Goldman and Donald Gilligan. (2013), Current Size and Remaining Market Potential of the U.S. Energy Service Company Industry, Lawrence Berkeley National Laboratory and National Association of Energy Service Companies

"Energy efficiency market report" (2016), IEA.

Elizabeth Stuart, Peter H. Larsen, Juan Pablo Carvallo, Charles A. Goldman, and Donald Gilligan. (2016), U.S. Energy Service Company (ESCO) Industry: Recent Market Trends, Energy Analysis & Environmental Impacts Division, Electricity Markets & Policy Group, Lawrence Berkeley National Laboratory and National Association of Energy Service Companies. 1990-2016

Fraser, M. (1996), What makes the Canadian ESCO industry unique?, Proceedings of the 1996 Summer Study on Energy Efficiency in Buildings, American Council for an Energy Efficient Economy, Vol. 10, Washington, DC, pp. 39–45.

Flor, M. and Oltra, M.J., (2005), The influence of firms' technological capabilities on export performance in supplier‐dominated industries: the case of ceramic tiles firms. R&D Management, 35(3), pp.333-347.

Fu, X. (2008), Foreign Direct Investment, Absorptive Capacity and Regional Innovation Capabilities: Evidence from China, Oxford Development Studies, 36, 1, pp. 89-110

Feng, Dianshu, Benjamin K. Sovacool, and Khuong Minh Vu. (2010), The barriers to energy efficiency in China: Assessing household electricity savings and consumer behavior in Liaoning Province, Energy Policy 38, no. 2, pp. 1202-1209.

Fu, X., Pietrobelli, C. and Soete, L. (2011), The role of foreign technology and indigenous innovation in the emerging economies: technological change and catching-up, World development, 39(7), pp.1204-1212.

Frank, A. G., Ribeiro, J. L. D., & Echeveste, M. E. (2015). Factors influencing knowledge transfer between NPD teams: a taxonomic analysis based on a sociotechnical approach. R&D Management, 45(1), pp.1-22.

Glass, A.J. and Saggi, K. (2002), Multinational firms and technology transfer. The Scandinavian Journal of Economics, 104(4), pp.495-513

Goldman, C.A., Osborn, J.G., Hopper, N.C. and Singer, T.E., (2002). Market trends in the US ESCO industry: results from the NAESCO database project (No. LBNL-49601). Lawrence Berkeley National Lab.(LBNL), Berkeley, CA (United States).

Gao, X. (2003), Technological capability catching up: follow the normal way or deviate, Ph.D. Thesis, MIT Sloan School of Management

Goldman, C.A., Hopper, N.C., Osborn, J.G. and DeepDyve, I. (2005), Review of US ESCO industry market trends: An empirical analysis of project data, Energy Policy, 33(3), pp. 387–405.

Gray, C. (2006), Absorptive capacity, knowledge management and innovation in entrepreneurial small firms, International Journal of Entrepreneurial Behavior & Research, 12(6), pp.345-360

Guan, D., Hubacek, K., Weber, C.L., Peters, G.P. and Reiner, D.M. (2008), The drivers of Chinese CO 2 emissions from 1980 to 2030, Global Environmental Change, 18(4), pp.626-634.

Goffin, K., & Koners, U. (2011). Tacit knowledge, lessons learned and new product development. Journal of Product Innovation Management, 28 (2), pp.300-318.

Global Energy Statistical year book 2017, < https://yearbook.enerdata.net>, accessed on 11th/04/2017.

Grimpe, C. and Hussinger, K. (2013), Formal and informal knowledge and technology transfer from academia to industry: Complementarity effects and innovation performance, Industry and innovation, 20(8), pp.683-700.

Gallagher, K.S. and Zhang, F. (2013), Climate Technology & Development Case study: Innovation and Technology Transfer Across Global Value Chains: Evidence from China's PV Industry.

Gallagher, Kelly Sims. (2014), The Global Diffusion of Clean Energy Technologies: Lessons from China. Cambridge, MA: MIT Press (forthcoming)

Gölpek F. (2015), Service Sector and Technological Developments, Procedia - Social and Behavioural Science, Volume 181, 11 May 2015, pp. 125–130

Graue, C. (2015), Qualitative Data Analysis', International Journal Of Sales, Retailing & Marketing, 4, 9, pp. 5–14.

Gupta, H. and Barua, M.K., (2016). Identifying enablers of technological innovation for Indian MSMEs using best–worst multi criteria decision making method. Technological Forecasting and Social Change, 107, pp.69-79.

Hippel, E. von. (1988), The Sources of Innovation, New York: Oxford University Press.

Hoekman, B, Maskus, K, & Saggi, K. (2005), Transfer of technology to developing countries: Unilateral and multilateral policy options, World Development, Vol. 33, Iss. 10, pp. 1587-1602

Hu, A, Jefferson, G, & Jinchang, Q (2005), R&D and Technology Transfer: Firm-Level Evidence from Chinese Industry, Review Of Economics And Statistics, 87(4), pp. 780-786

Hu, J.L. and Wang, S.C. (2006). Total-factor energy efficiency of regions in China. Energy policy, 34(17), pp.3206-3217.

Hopper, N., C. Goldman, D. Gilligan, T. Singer, D. Birr. (2007), A Survey of the U.S. ESCO Industry: Market Growth and Development from 2000 to 2006. Lawrence Berkeley National Laboratory 62679. May.

Han, Z.Y., Fan, Y., Jiao, J.L., Yan, J.S. and Wei, Y.M. (2007), Energy structure, marginal efficiency and substitution rate: An empirical study of China. Energy, 32(6), pp.935-942.

Holste, J. S., & Fields, D. (2010). Trust and default knowledge sharing and use. Journal of Knowledge Management, 14 (1), pp.128-140.

Hannon, M. J., Foxon, T. J., & Gale, W. F. (2013), The co-evolutionary relationship between Energy Service Companies and the UK energy system: Implications for a low-carbon transition, Energy Policy, 61, pp 1031-1045.

He, F., Zhang, Q., Lei, J., Fu, W. and Xu, X. (2013), Energy efficiency and productivity change of China's iron and steel industry: Accounting for undesirable outputs. Energy Policy, 54, pp.204-213.

Hong, L., Zhou, N., Fridley, D. and Raczkowski, C. (2013), Assessment of China's renewable energy contribution during the 12th Five Year Plan, Energy Policy, 62, pp.1533-1543.

Hansen, U.E. and Ockwell, D., (2014). Learning and technological capability building in emerging economies: The case of the biomass power equipment industry in Malaysia. Technovation, 34(10), pp.617-630.

IFC China ESCO market study report: China Energy Service Company (ESCO) Market Study, International Finance Corporation, World Bank Group. Industry analysis of current situation and market trend of China 's ESCO industry (2016) from China industry information web.

Jin, J., & Von Zedtwitz, M. (2008). Technological capability development in China's mobile phone industry. Technovation, 28(6), 327-334.

Krugman, P (1979), A Model of Innovation, Technology Transfer, and the World Distribution of Income, Journal Of Political Economy, Vol. 87, No. 2, pp. 253-288

Kim. L. (1980), Stages of development of industrial technology in a developing country: A model, Research Policy, Vol. 9, iss. 3, pp 254-277

Kim, L. and Y. Kim. (1985), Innovation in a Newly Industrializing Country: A Multiple Discriminant Analysis, Management Science, 31(3), pp: 312–322

Kim, L. and C. J. Dahlman. (1992), Technology Policy for Industrialization: An Integrative Framework and Korea's Experience, Research Policy, 21, pp 437–452

Kokko, A., R. Tansini, MC. Zejan. (1996), Local technological capability and productivity spillovers from FDI in the Uruguayan manufacturing sector, The Journal of Development Studies, Vol. 32, iss. 4, pp. 602-611

Kim, L. (1997a), Imitation to Innovation: The Dynamics of Korea's Technological Learning. Harvard

Business School Press: Boston, MA.

Kim, L. (1997), The Dynamics of Samsung's Technological Learning in Semiconductors, California Management Review, Vol. 39, No. 3, pp. 86-100

Kim, L. (1998), Crisis Construction and Organizational Learning: Capability Building in Catching-up at Hyundai Motor, Organization Science, 4, pp. 506

Kim, L. (1999), Building Technological Capability for Industrialization: Analytical Frameworks and Korea's Experience, Industrial And Corporate Change, 8, 1, pp. 111-136,

Kumar, V., Kumar, U. and Persaud, A. (1999), Building technological capability through importing technology: the case of Indonesian manufacturing industry, The Journal of Technology Transfer, 24(1), pp.81-96.

Kim, L., Nelson, R.R. (Eds.) (2000), Technology, Learning, and Innovation: Experiences of Newly Industrializing Economies, Cambridge University Press, Cambridge.

Kinoshita, Y. (2000), R&D and technology spillovers via FDI: Innovation and absorptive capacity, William Davidson Institute Working Paper No. 349

Kim, L. (2001), The dynamics of technological learning in industrialization, International Social Science Journal, Vol. 53, Iss. 168, pp 298-308

Keller, W. (2004), International technology diffusion, Journal of economic literature, 42(3), pp.752-782.

Kim, L., (2004), The multifaceted evolution of Korean technological capabilities and its implications for contemporary policy. Oxford Development Studies, 32(3), pp.341-363.

Kothari, C. R. (2004). Research methodology: Methods and techniques. 2nd edition, New Age International.

Killen, C.P., Hunt, R.A. and Kleinschmidt, E.J., (2008). Project portfolio management for product innovation. International Journal of Quality & Reliability Management, 25(1), pp.24-38.
Kodama, T. (2008), The role of intermediation and absorptive capacity in facilitating university–industry linkages—An empirical study of TAMA in Japan, Research Policy, 37(8), pp.1224-1240.

Kumar, R., Ajjan, H. and Niu, Y., (2009). Information Technology Portfolio Management: Literature Review, Framework, and. Global, Social, and Organizational Implications of Emerging Information Resources Management: Concepts and Applications: Concepts and Applications, p.446.

Kester, L., Hultink, E.J. and Lauche, K., (2009), Portfolio decision-making genres: A case study, Journal of engineering and technology management, 26(4), pp.327-341.

Keller, W. (2010). International trade, foreign direct investment, and technology spillovers. Handbook of the Economics of Innovation, 2, pp.793-829.

Kostopoulos, K., Papalexandris, A., Papachroni, M. and Ioannou, G. (2011), Absorptive capacity, innovation, and financial performance, Journal of Business Research, 64(12), pp.1335-1343

Kostka, G. and Hobbs, W. (2012), Local energy efficiency policy implementation in China: Bridging *the gap between national priorities and local interests, The China Quarterly, 211, pp.765-785.*

Kong, X., Lu, S. and Wu, Y. (2012), A review of building energy efficiency in China during "Eleventh Five-Year Plan" period, Energy policy, 41, pp.624-635.

Kostka, G. and Shin, K. (2013), Energy conservation through energy service companies: Empirical analysis from china, Energy Policy, 52, pp. 748–759.

Kostka, G., Moslener, U. and Andreas, J. (2013), Barriers to increasing energy efficiency: evidence from small-and medium-sized enterprises in China. Journal of Cleaner Production, 57, pp.59-68.

Klingebiel, R, & Rammer, C, (2014), Resource allocation strategy for innovation portfolio management, Strategic Management Journal, 35, 2, pp. 246-268

Kindström, D., Ottosson, M. and Thollander, P. (2017). Driving forces for and barriers to providing energy services—a study of local and regional energy companies in Sweden. Energy Efficiency, 10(1), pp.21-39.

Lall. S. (1987), Learning to Industrialize: The Acquisition of Technological Capability by India, Springer.

Lee, J., Z.T. Bae and D.K. Choi. (1988), Technology Development Processes: A Model for a Developing Country with a Global Perspective, R&D Management, 18, 235–250

Lall, S. (1992), Technological capabilities and Industrialization, World Development, Vol. 20, No. 2, pp. 165-168

Lall, S. (1993), Promoting technology development: the role of technology transfer and indigenous effort. Third World Quarterly 14 (1), pp. 95–108.

Lee, Y.S. (1996), Technology transfer and the research university: a search for the boundaries of university-industry collaboration. Research policy, 25(6), pp.843-863.

Lawson, B. and Samson, D., (2001), Developing innovation capability in organisations: a dynamic capabilities approach, International journal of innovation management, 5(03), pp.377-400.

Liao, J., Welsch, H. and Stoica, M. (2003), Organizational absorptive capacity and responsiveness: an empirical investigation of growth-oriented SMEs, Entrepreneurship Theory and practice, 28(1), pp.63-85.

Lee, M.-K., Park, H., Noh, J. and Painuly, J.P. (2003), Promoting energy efficiency financing and ESCOs in developing countries: Experiences from Korean ESCO business, Journal of Cleaner Production, 11(6), pp. 651–657.

Lane, P. J., B. R. Koka, S. Pathak. (2006), The reification of absorptive capacity: A critical review and rejuvenation of the construct. Academy of Management Review, 31(4), pp. 833–863

Liu, X. and Buck, T. (2007), Innovation performance and channels for international technology spillovers: Evidence from Chinese high-tech industries, Research policy, 36(3), pp.355-366.

Lu, W. (2007), Potential energy savings and environmental impacts of energy efficiency standards *for vapor compression central air conditioning units in China, Energy Policy, 35 (3), pp. 1709–1717*

Laustsen, J. (2008), Energy efficiency requirements in building codes, energy efficiency policies for new buildings. International Energy Agency (IEA), pp.477-488

Li, J and M. Colombier. (2009), Managing carbon emissions in China through building energy efficiency, Journal of Environmental Management, 90 (8), pp. 2436–2447

Liao, S.H., Wu, C.C., Hu, D.C. and Tsui, K.A. (2010), Relationships between knowledge acquisition, absorptive capacity and innovation capability: an empirical study on Taiwan's financial and manufacturing industries. Journal of Information Science, 36(1), pp.19-35

Li, X. (2011), Sources of external technology, absorptive capacity, and innovation capability in Chinese state-owned high-tech enterprises, World Development, 39(7), pp.1240-1248

Li, J., Dong, X., Shangguan, J. & Höök, M, (2011) Forecasting the growth of Chinese natural gas consumption, Energy, 2011, 36(3), pp. 1380-1385

Larsen, P.H., Goldman, C.A. and Satchwell, A. (2012), Evolution of the U.S. Energy service company industry: Market size and project performance from 1990–2008, Energy Policy, 50, pp. 802–820.

Lema, R. and Lema, A. (2012), Technology transfer? The rise of China and India in green technology sectors, Innovation and Development, 2(1), pp.23-44.

Li, R. and Leung, G.C. (2012), Coal consumption and economic growth in China, Energy policy, 40, pp.438-443

Lo, K. and Wang, M.Y.(2013), Energy conservation in China's Twelfth Five-Year Plan period: Continuation or paradigm shift?, Renewable and Sustainable Energy Reviews, 18, pp.499-507.

Lo, K. (2014), A critical review of China's rapidly developing renewable energy and energy efficiency policies, Renewable and Sustainable Energy Reviews, 29, pp.508-516.

Lu, Z, & Shao, S. (2016), Impacts of government subsidies on pricing and performance level choice in Energy Performance Contracting: A two-step optimal decision model, Applied Energy, 184, pp. 1176-1183

Mowery, D. C , & Oxley, J. E. (1995), Inward technology transfer and competitiveness: The role of national innovation systems. Cambridge Journal of Economics. 19(1): pp 67-93

Mason, J (1996). Qualitative Researching, London, Sage.

Mikkola J.H. (2001), Portfolio management of R&D projects: implications for innovation management, Technovation, 21 (7), pp. 423–435

Matthews, J. A. (2002), Competitive Advantages of the Latecomer Firm: A Resource-Based Account of Industrial Catch-Up Strategies, Asia Pacific Journal Of Management, 19(4), p467-488

Matthews, J. A. (2006), Catch-up strategies and the latecomer effect in industrial development, New Political Economy, Volume 11, Issue 3, p313-335

Muscio, A. (2007), The impact of absorptive capacity on SMEs' collaboration, Economics of Innovation and New Technology, 16(8), pp.653-668.

Martinsuo, M. and Lehtonen, P., (2007), Role of single-project management in achieving portfolio management efficiency, International journal of project management, 25(1), pp.56-65.

Müller, R., Martinsuo, M. and Blomquist, T., (2008), Project portfolio control and portfolio management performance in different contexts. Project management journal, 39(3), pp.28-42.

Morrison, A., Pietrobelli, C. and Rabellotti, R., (2008), Global value chains and technological capabilities: a framework to study learning and innovation in developing countries. Oxford development studies, 36(1), pp.39-58.

McNally, R.C., Durmusoglu, S.S., Calantone, R.J. and Harmancioglu, N., (2009), Exploring new product portfolio management decisions: The role of managers' dispositional traits, Industrial Marketing Management, 38(1), pp.127-143.

Malerba, F. and Nelson, R., (2011), Learning and catching up in different sectoral systems: evidence from six industries, Industrial and Corporate Change, 20(6), 1 December 2011, pp,1645–1675

McNally, R. C., Durmuşoğlu, S. S., & Calantone, R. J. (2013), New product portfolio management decisions: antecedents and consequences. Journal of Product Innovation Management, 30(2), pp: 245-261.

Martinsuo, M., (2013), Project portfolio management in practice and in context, International Journal of Project Management, 31(6), pp.794-803.

Miles, M.B., Huberman, A.M., and Saldana, J. (2013). Qualitative data analysis. Sage.

Nelson, R. R. and S. G. Winter. (1982), An Evolutionary Theory of Economic Change, Harvard University Press: Cambridge, MA, p. 134

Nelson, R. R. (1994), The Co-evolution of Technology, Industrial Structure, and Supporting Institutions, Industrial and Corporate Change, 3(1), pp. 47–63

Okay, E., Okay, N., Konukman, A.E.Ş. and Akman, U. (2008), Views on turkey's impending ESCO market: Is it promising?, Energy Policy, 36(6), pp. 1821–1825.

Olsson, R., (2008), Risk management in a multi-project environment: An approach to manage portfolio risks, International journal of quality & reliability management, 25(1), pp.60-71.

Okay, N. and Akman, U. (2010), Analysis of ESCO activities using country indicators, Renewable and Sustainable Energy Reviews, 14(9), pp. 2760–2771.

Omri, A. (2013), CO 2 emissions, energy consumption and economic growth nexus in MENA countries: evidence from simultaneous equations models, Energy economics, 40, pp.657-664

Patterson, M.G. (1996), What is energy efficiency?: Concepts, indicators and methodological issues, Energy policy, 24(5), pp.377-390.

Poole A & Geller, H. (1997), The Emerging ESCO Industry in Brazil, American Council for an Energy Efficient Economy, Washington, DC (1997)

Punch, K. (1998). Introduction to Social Research: Quantitative and Qualitative Approaches. London, Sage.

Park, S.H. and Luo, Y.,(2001). Guanxi and organizational dynamics: Organizational networking in Chinese firms. Strategic management journal, 22(5), pp.455-477.

Price, L., J. Sinton, E. Worrell, D. Phylipsen, H. Xiulian, L. Ji. (2002), Energy use and carbon dioxide emissions from steel production in China, Energy, 27 (5) (2002), pp. 429–446

Painuly, J.P., Park, H., Lee, M.. and Noh, J. (2003), Promoting energy efficiency financing and ESCOs in developing countries: Mechanisms and barriers, Journal of Cleaner Production, 11(6), pp. 659–665.

Philip, A. S., (2009), China's ongoing energy efficiency drive: origins, progress and prospects, Energy Policy, 37 (4), pp. 1331–1344

Petit, Y. and Hobbs, B., (2010), Project portfolios in dynamic environments: sources of uncertainty and sensing mechanisms. Project Management Journal, 41(4), pp.46-58.

Price, L., Levine, M.D., Zhou, N., Fridley, D., Aden, N., Lu, H., McNeil, M., Zheng, N., Qin, Y. and Yowargana, P. (2011). Assessment of China's energy-saving and emission-reduction accomplishments and opportunities during the 11th Five Year Plan. Energy policy, 39(4), pp.2165-2178.

Pao, H.T., Fu, H.C. and Tseng, C.L. (2012), Forecasting of CO 2 emissions, energy consumption and economic growth in China using an improved grey model, Energy, 40(1), pp.400-409.

Pätäri, S., & Sinkkonen, K. (2014), Energy Service Companies and Energy Performance Contracting: is there a need to renew the business model? Insights from a Delphi study, Journal of Cleaner Production, 66, pp. 264-271.

Polzin, F., von Flotow, P., & Nolden, C. (2016), What encourages local authorities to engage with energy performance contracting for retrofitting?, Evidence from German municipalities. Energy Policy, 94, pp. 317-330.

Qiu, L. D., & Wang, S. (2011). FDI Policy, Greenfield Investment and Cross-border Mergers. Review of International Economics, 19(5), pp.836-851.

Qiu, P., Nunes, B., and Vaidya, K. (2016), Technological capability development in China's energy service company industry, IAMOT 2016 conference proceeding.

Qin, Q, Liang, F, Li, L, & Wei, Y (2017), Selection of energy performance contracting business models: A behavioral decision-making approach, Renewable And Sustainable Energy Reviews, 72, pp. 422-433

Rothaermel, F.T., Hitt, M.A. and Jobe, L.A., (2006). Balancing vertical integration and strategic outsourcing: effects on product portfolio, product success, and firm performance. Strategic management journal, 27(11), pp.1033-1056.

Reiter, S. L., & Steensma, H. K. (2010). Human development and foreign direct investment in developing countries: the influence of FDI policy and corruption. World development, 38(12), pp.1678-1691.

Robertson, P.L., Casali, G.L. and Jacobson, D. (2012), Managing open incremental process innovation: absorptive capacity and distributed learning. Research policy, 41(5), pp.822-832

Ritala, P. and Hurmelinna‐Laukkanen, P. (2013). Incremental and radical innovation in cooperation—The role of absorptive capacity and appropriability, Journal of Product Innovation Management, 30(1), pp.154-169

Strauss, A. and Corbin, J. (1998). Basics of qualitative research: Procedures and techniques for developing grounded theory. Sage Publication.

Sinton, J., Fridley, D. (2000). Status report on energy efficiency policy and programs in China: recent and related developments, LBNL Report, Lawrence Berkeley National Laboratory, Berkeley, CA

Saggi, K (2002), Trade, Foreign Direct Investment, and International Technology Transfer: A Survey, The World Bank Research Observer, 17(2), p. 191-235

Sinani, E, & Meyer, K (2004), Spillovers of technology transfer from FDI: the case of Estonia, Journal Of Comparative Economics, 32(3), pp. 445-466,

Spithoven A, B. Clarysse, M. Knockaert (2010), Building absorptive capacity to organise inbound open innovation in traditional industries, Technovation, Vol. 30, Issue 2, February 2010, pp 130-141

Satchwell. A, C. Goldman, P. Larsen, D. Gilligan, T. Singer, (2010) A Survey of the U.S. ESCO Industry: Market Growth and Development from 2008 to 2011, https://emp.lbl.gov/sites/all/files/report-lbnl-3479e.pdf

Schmidt, T. (2010), Absorptive capacity—one size fits all? A firm‐level analysis of absorptive capacity for different kinds of knowledge, Managerial and Decision Economics, 31(1), pp.1-18

Shan, J. and Jolly, D.R., (2013), Technological innovation capabilities, product strategy, and firm performance: The electronics industry in China. Canadian Journal of Administrative Sciences, 30(3), pp.159-172.

Stuart E, Larsen PH, Goldman CA, Gilligan D.(2013) Current size and remaining market potential of US ESCO industry. LBNL report, https://emp.lbl.gov/sites/all/files/lbnl-6300e_01.pdf

Stuart, E., Larsen, P.H., Goldman, C.A. and Gilligan, D. (2014), A method to estimate the size and remaining market potential of the U.S. ESCO (energy service company) industry, Energy, 77, pp. 362–371.

Seo, J.H., Kim, J.O. and Choi, W.S. (2015), The Effects of Commercialization Capability in Small and Medium-sized Businesses on Business Performances: Focused on Moderating Effects of Open Innovation. Journal of Management and Strategy, 6(2), p.70.

Stuart E, Larsen PH, Goldman CA, Gilligan D.(2016) U.S. Energy Service Company (ESCO) Industry: Recent Market Trends, LBNL report. https://emp.lbl.gov/sites/default/files/esco_recent_market_trends_30sep2016_1.pdf

Slater, S.F., Mohr, J.J. and Sengupta, S., (2014), Radical product innovation capability: Literature review, synthesis, and illustrative research propositions. Journal of Product Innovation Management, 31(3), pp.552-566.

Thompson. V. A., (1965), Bureaucracy and Innovation, Administrative Science Quarterly, Vol. 10, No. 1,pp. 1-20

Todorova, G., B. Durisin. (2007), Absorptive capacity: Valuing a reconceptualization, Acad. Management Rev. 32(3), pp 774–786

Teller, J., Unger, B.N., Kock, A. and Gemünden, H.G., (2012), Formalization of project portfolio management: The moderating role of project portfolio complexity, International Journal of Project Management, 30(5), pp.596-607.

Tseng, C.H. and Chen, L.T. (2014), Determinants of subsidiary's technological capability–examining the roles of subsidiary–local supplier linkage, Journal of Business & Industrial Marketing, 29(5), pp.374-386

Tolonen, A., Shahmarichatghieh, M., Harkonen, J., & Haapasalo, H. (2015), Product portfolio management–Targets and key performance indicators for product portfolio renewal over life cycle. International Journal of Production Economics, 170, pp. 468-477.

Utterback, J. M. and W. J. Abernathy (1975), A Dynamic Model of Process and Product Innovation, Omega,, 3, pp. 639–656.

Vine, E.L., Murakoshi, C. and Nakagami, H. (1998), International ESCO business opportunities and challenges: A Japanese case study, Energy, 23(6), pp. 439–447.

Vine, E., Nakagami, H. and Murakoshi, C. (1999), The evolution of the US energy service company (ESCO) industry: From ESCO to super ESCO, Energy, 24(6), pp. 479–492.

Vine, E. (2005), An international survey of the energy service company (ESCO) industry, Energy Policy, 33(5), pp. 691–704.

Vega-Jurado, J., Gutiérrez-Gracia, A. and Fernández-de-Lucio, I. (2008), Analyzing the determinants of firm's absorptive capacity: beyond R&D. R&D Management, 38(4), pp.392-405.

Volberda, H, Foss, N, & Lyles, M. (2010), Absorbing the Concept of Absorptive Capacity: How to Realize Its Potential in the Organization Field, Organization Science, Vol. 21, No. 4, pp. 931-951

Voudouris, I., Lioukas, S., Iatrelli, M. and Caloghirou, Y., (2012), Effectiveness of technology investment: Impact of internal technological capability, networking and investment's strategic importance. Technovation, 32(6), pp.400-414.

Wang, G., Wang, Y. and Zhao, T. (2008), Analysis of interactions among the barriers to energy saving in china, Energy Policy, Vol.36, Iss 6, pp 1879–1889.

Wang, C. and Han, Y. (2011), Linking properties of knowledge with innovation performance: the moderate role of absorptive capacity. Journal of Knowledge Management, 15(5), pp.802-819

Wang, S.S., Zhou, D.Q., Zhou, P. and Wang, Q.W. (2011a), CO 2 emissions, energy consumption and economic growth in China: a panel data analysis, Energy Policy, 39(9), pp.4870-4875.

Wang, Y., Wang, Y., Zhou, J., Zhu, X. and Lu, G. (2011b), Energy consumption and economic growth in China: A multivariate causality test. Energy Policy, 39(7), pp.4399-4406

Wang, Q., Zhao, Z., Zhou, P. and Zhou, D. (2013), Energy efficiency and production technology heterogeneity in China: a meta-frontier DEA approach, Economic Modelling, 35, pp.283-289.

Wang, K., Wei, Y.M. and Zhang, X. (2013), Energy and emissions efficiency patterns of Chinese regions: a multi-directional efficiency analysis, Applied Energy, 104, pp.105-116

Wang, Z., Feng, C. and Zhang, B. (2014), An empirical analysis of China's energy efficiency from both static and dynamic perspectives. Energy, 74, pp.322-330.

Wu, J. (2014), Cooperation with competitors and product innovation: Moderating effects of technological capability and alliances with universities. Industrial Marketing Management, 43(2), pp.199-209.

Wang, K. and Wei, Y.M. (2014), China's regional industrial energy efficiency and carbon emissions abatement costs, Applied Energy, 130, pp.617-631

Wang, Y.F., Li, K.P., Xu, X.M. and Zhang, Y.R. (2014), Transport energy consumption and saving in China, Renewable and Sustainable Energy Reviews, 29, pp.641-655

Wang, Z., Zhu, Y., Zhu, Y., and Shi, Y. (2016). Energy structure change and carbon emission trends in China. Energy, 115, 369-377.

Xin, K.K. and Pearce, J.L.(1996). Guanxi: Connections as substitutes for formal institutional support. Academy of management journal, 39(6), pp.1641-1658.

Xu, P.P., Chan, H.W. (2011), Barriers to Implementation of Energy Performance Contracting (EPC) Mechanism, MISBE2011. In: Proceedings of the International Conference on Management and Innovation for a Sustainable Built Environment, 20—23 June 2011, Amsterdam, Netherlands.

Xu, P., Chan, E.H.W. and Qian, Q.K. (2011), Success factors of energy performance contracting (EPC) for sustainable building energy efficiency retrofit (BEER) of hotel buildings in China. Energy Policy, 39(11), pp.7389-7398.

Xu, X., Zhao, T., Liu, N. and Kang, J. (2014), Changes of energy-related GHG emissions in China: an empirical analysis from sectoral perspective, Applied Energy, 132, pp.298-307.

Yin, R. K. (2003) Case study research: design and method, Third edition, Sage Publication.

Yik. F.W.H. and W.L. Lee. (2004), Partnership in building energy performance contracting, Building Resarch Information, 32 (3), pp. 235–243

Yang, M. (2008), China's energy efficiency target 2010, Energy Policy, 36 (2) (2008), pp. 561–570

Yuan, J.H., Kang, J.G., Zhao, C.H. and Hu, Z.G. (2008), Energy consumption and economic growth: evidence from China at both aggregated and disaggregated levels, Energy Economics, 30(6), pp.3077-3094

Yuan, J, J, Kang, C, Yu and Z, Hu. (2011), Energy conservation and emissions reduction in China—progress and prospective, Renewable and Sustainable Energy Reviews, 15 (2011), pp. 4334–4347

Yuan, X, Ma, R, Zuo, J, & Mu, R. (2016), Towards a sustainable society: the status and future of energy performance contracting in China, Journal Of Cleaner Production, 112, pp. 1608-1618

Zhang, X.P. and Cheng, X.M. (2009), Energy consumption, carbon emissions, and economic growth in China. Ecological Economics, 68(10), pp.2706-2712.

Zahra, S, Ireland, R, & Hitt, M. (2000), International Expansion by New Venture Firms: International Diversity, Mode of Market Entry, Technological Learning, and Performance, The Academy of Management Journal, 43(5), pp. 925-950

Zahra. S A and George G. (2002), Absorptive capacity; A review reconceptualization, and extension, Academy of management review, Vol. 27, No. 2, pp185-203

Zhou, K.Z. and Wu, F.(2010), Technological capability, strategic flexibility, and product innovation, Strategic Management Journal, 31(5), pp.547-561.

Zhou, N., Levine, M.D. and Price, L. (2010), Overview of current energy-efficiency policies in China, Energy policy, 38(11), pp.6439-6452.

Appendix

Appendix A：Consent form for interview

[1]

Aston University
Birmingham

Consent Form - Interviews

Capability development of domestic ESCOs in China

Peng Qiu, PhD student, Email:[redacted]

Please initial box

I confirm that I have read and understood the information sheet provided for the above study and have had the opportunity to ask questions. ☐

I understand that my participation is voluntary and that I am free to withdraw at any time without having to give a reason. ☐

I agree to take part in the above study. ☐

I agree that the information and opinions I provide for this study may be stored in a secure form and may be used for this study and for future research. ☐

Please tick box

Yes No

I am willing to be interviewed by the researcher for up to 90 minutes.
I also confirm my agreement for the interview to be audio-recorded. ☐ ☐

I confirm that I have read and understood the information sheet and freely consent to participating in the study. I have been given adequate time to consider my participation and agree with the conditions of participation in the study. ☐ ☐

[1] Version number： 2014/15 date：20/08/2015

Appendix B：Data collection schedule

Aston University

Principle Researcher: Peng Qiu
Institution: Operation and information management group, Aston business school
Research Title: Developing Capabilities of Domestic ESCOs in Chinese Energy Service Sector

Data Collection Schedule

Time	Case	Location	Main activities
Week 1	Case 1	Beijing	Access to the case company; Conduct a conversation with CEO of the firm; Collect secondary data; Conduct interview with first participant; Arrange other interviews
Week 2	Case 1	Beijing	Conduct interview with two or three participants; Collect supplementary secondary data; Process primary data; Send contents of interview to participants for verifying
Week 3	Case 2	Hangzhou	Access to the case company; Conduct a conversation with CEO of the firm; Collect secondary data; Conduct interview with first participant; Arrange other interviews
Week 4	Case 2	Hangzhou	Conduct interview with two or three participants; Collect supplementary secondary data; Process primary data; Send contents of interview to participants for verifying
Week 5	Case 3	Beijing	Access to the case company; Conduct a pilot conversation with Director of R&D; Collect secondary data; Conduct interview with first participant; Arrange other interviews
Week 6	Case 3	Beijing	Conduct interview with two or three participants; Collect supplementary secondary data; Process primary data; Send contents of interview to participants for verifying
Week 7	Case 4	Beijing	Access to the case company;

			Conduct a conversation with CEO of the firm; Collect secondary data; Conduct interview with first participant; Arrange other interviews
Week 8	Case 4	Beijing	Conduct interview with two or three participants; Collect supplementary secondary data; Process primary data; Send contents of interview to participants for verifying
Week 9	Case 5	Non-Beijing	Access to the case company; Conduct a conversation with CEO of the firm; Collect secondary data; Conduct interview with first participant; Arrange other interviews
Week 10	Case 5	Non-Beijing	Conduct interview with two or three participants; Collect supplementary secondary data; Process primary data; Send contents of interview to participants for verifying
Week 11	Case 6	Non-Beijing	Conduct a conversation with CEO of the firm; Collect secondary data; Conduct interview with first participant; Arrange other interviews
Week 12	Case 6	Non-Beijing	Conduct interview with two or three participants; Collect supplementary secondary data; Process primary data; Send contents of interview to participants for verifying

Appendix C: Information sheet for interviews

Principal researcher: *Peng Qiu*
Email: [redacted]
Mobile phone: [redacted]
Supervisory team:
Breno Nunes (Email: [redacted])
Kirit Vaidya (Email: [redacted])
Address: *Aston Business School, Aston University, Birmingham, UK - B4 7ET*

Information Sheet for Potential Participants—Interview

Your valuable voluntary participation in this research will make an impact

Study title: Developing Capabilities of Domestic ESCOs in the Chinese Energy Service Sector

We are grateful for your interest in assisting us in this research project. This document offers a brief overview of the project, its objectives, benefits and the nature of your participation if you agree to participate. Please note that participation in this project is voluntary and participants are able to withdraw from the research at any time without giving a reason.

My name is Peng Qiu, a doctoral student at Aston Business School, Aston University, Birmingham, B4 7ET, UK. My study is about the development of capabilities of Chinese energy service companies (ESCOs.).

You are being invited to take part in a research study as an interviewee. Before you decide whether or not to take part, it is important for you to understand why the research is being done and what it will involve. Please take time to read the following information carefully.

- **What is the purpose of the study?**

The aim of this study is to explore why and how Chinese energy service companies develop their technological capabilities. The study requires investigation of internal and external factors that affect firms' capability development and whether and how the process of capability development differs between companies of different sizes and characteristics (whether private wholly Chinese owned, joint-ventures with foreign partners or wholly foreign-owned). Apart from contributing to knowledge on the capability development of emerging economy companies, the study results could guide domestic energy service companies in developing their technological capabilities and the Chinese government and governments in other countries in developing effective policies to support the development of ESCOs.

- **Why have I been invited to participate?**

As an experienced manager/director in an ESCO, you have knowledge of the firm's technological capability and its current and future technological strategy. The study needs contributions based on such knowledge. There will be 17 other people, a few from your company and the rest from other companies participating in this study.

- **Do I have to take part?**

  It is entirely up to you to decide whether or not to participate in the study. Once you have decided to participate you will be given an information sheet to keep. You will still be able to withdraw at any time without giving a reason. Your voluntary participation is of vital significance to the research. The results of the study may contribute to improved performance of Chinese ESCOs and future development of Chinese energy service industry.

- **What will happen to me if I take part?**

  You will be interviewed by me for between 45 and 60 minutes. The interview will be arranged to take place at a time and place convenient to you. During the interview you will be asked questions and invited to share your ideas on your company's technological strategy and status, issues related to technological capability and plans for future capability development.

- **What are the possible benefits of taking part?**

1. During your participation in the research and that of others from your company, you will have an opportunity to discuss with the principal researcher and colleagues the technological capabilities of your company and future strategy.
2. At the end of the study you will have access to a report on the findings of which will include an appraisal of capability development strategies in the sector and the role of government policy.

- **Will what I say in this study be kept confidential?**

  There will be no need for personal information of a sensitive nature to be collected as a part of the study. Any personal information collected will be encoded and stored securely and password protected. All company information provided by you will be anonymised when used in the doctoral thesis or other publications unless express permission is provided by you and the company to use names. No one but the principal researcher will be able to access these data. To fulfill the requirements for the academic audit of research, the data generated by the research will be retained in accordance with Aston University's policy on Academic Integrity. It will be kept securely either in paper and/or electronic forms for a period of five years after the completion of the research project. Hence, the potential risk for participants of loss of confidentiality is low.

- **What will happen to the results of the research study?**

  The research will be presented in the principal researcher's PhD thesis. The research results might also be used in academic papers published by the principal researcher. As the participant in this research, if you would like to be informed of the research findings, please contact me (email: [redacted]). I will be happy to send an electronic copy of report on the research findings.

- **Who is organising and funding the research?**

  The principal researcher, Peng Qiu, is conducting this research as an Aston University doctoral student under supervision of Aston Business School staff (see the top of this document for their names). Mr. Qiu is a student in the Operations and Information Management Group, Aston Business School, Aston University.

- **Who has reviewed the study?**

  This research study has been reviewed and given a favorable opinion by the Aston University Research Ethics Committee.

- **What if there is a problem?**

  If you have any concerns or complaints about anything to do with this study, please raise them with the principal researcher or research supervisors whose details are at the top of this document and they will do their best to answer your questions and deal with your concerns. If they cannot help and you still have worries about the way in which the study has been conducted, you should contact the Secretary of University Research Ethics Committee, Mr John Walter, at [redacted] or telephone [redacted]

Thank you for taking the time to read this information sheet. If you are willing to participate, please contact me.

Yours sincerely

Peng Qiu[1]

[1] Version number: 2014/15 Date: 20/08/2015

Appendix D Semi-structured questionnaire

Shall we start with a brief introduction about you?

How long have you been in this company?

What is your role and responsibilities here?

Is there any previous work or study experience that you would like to highlight about yourself?

Could you please tell me about how your company competes in the market?

What is your key competitive advantage against your competitor?

How would you describe the current company strategy?

RQ 1 Why has your company developed technological capability?

a. Do you think technological capability is important to your company? Why?

b. What is your view about your company's technological capability? (Dimensions)

c. Which aspects of your company's technological capability are well developed or under developed?

d. Do you have a strategy for technology management (development, application, etc)?

e. Has your company had always the same technology strategy? How different was it 5 years ago? And, how about 10 years ago?
If there were significant changes, could you tell me why your company adopt a new strategy?

f. Beside the company's strategy, do you think is there any other drivers to the company to develop technological capability?
What are they?
Why do you think they motivate company's technological development?

RQ 2 The factors that affects technology capability development- company level

a. Is there any factors seriously affect your company's technological capability?
What are they?

b. What aspects do these factors affect? (Dimensions)

c. How do they affect company's technological capability? Could you please give me some examples?

d. Do you think are there any links between the aspects of company's technological capability? (Second round)

RQ 3 How has your company developed technological capability?

a. Can you please tell me more about the current energy conservation technologies that your company applies?

b. Could you tell me what are the key technologies that best represent your companies' technological process?

c. Are they mature or advanced technologies in the industry?

d. Could you tell me more about the backgrounds of obtaining or developing these technologies?

e. Normally, how does your company develop technologies? Can you please give me an example? Could you explain the reason for developing a particular technology?

PROMPT (e.g. developing by yourself or obtain from overseas companies? Domestic partners, imitating competitors, suppliers, customers, etc)

Thanks your adequate answers and unique opinions. Finally, could you talk about any plan for technological capability development in the next five years?

Can we quickly summaries the key points of this interview now?

Finally, to finish this interview, is there anything I did not ask you that you think is worth telling me?