To cite this article: Qiu, P., Nunes, B., Vaidya, K., van de Kaa, G., & Greeven, M. (2022). Technological capabilities development model in Chinese energy service companies. *Journal of Cleaner Production*, vol 30, 1 January 2022.
DOI: https://doi.org/10.1016/j.jclepro.2021.129551

Technological Capabilities Development Model in Chinese Energy Service Companies

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Abstract

This paper investigates the energy service companies (ESCOs) in China from the perspective of technological capability (TC) development. The conventional capability development model of manufacturing in emerging economies has been adapted to examine the four dimensions of TC (investment, production, linkage and innovation) through a qualitative analysis of multiple case studies. Small and medium-sized private ESCOs can perform well based on investment and production capabilities to develop energy management software competence. Large state-owned ESCOs can develop more advanced linkage and innovation capabilities and serve large-scale businesses with more specialist services. For small and medium-sized ESCOs, competitiveness, customers and related business strategy are the primary drivers of TC development. These drivers are essential for large ESCOs, but government support and pressure are also important. The framework developed can be used to research ESCOs and other service providers in other developing countries.

Keywords: Chinese ESCOs, Technological capability, Energy efficiency

1. Introduction

For over three decades, China has been in the process of rapid industrial development and urbanization. China's energy consumption has increased dramatically since 2010 and is forecast to keep rising for the next several decades (Dong et al., 2017). China's consumption of primary energy increased 45.30% between 2009 and 2019, according to BP's Statistical Review of World Energy (BP, 2020). According to China Electricity Council, electricity consumption in China increased 78.81% in a decade (2010-2020) (CEIC, 2020). While energy has been a critical input for achieving rapid economic growth and social development, this has inevitably led to comparatively high CO2 and other harmful pollutants emissions. Nowadays, China's contribution to CO2 is higher than the combined emissions from Europe and the USA (Rapier, 2018). Therefore, increasing attention is being paid to improving energy efficiency to preserve competitiveness and meet broader environmental sustainability goals. Furthermore, with the risk of energy price increases, resource scarcity, and sustainability concerns, improving energy efficiency has been given high priority in China.

To address energy inefficiency and achieve the national energy conservation and sustainability objectives, China has developed a series of policies and measures. During the 11th and 12th five-year-plan periods (2006–2015), the Chinese government set explicit targets for energy saving in the short and long term. As part of policy initiatives, the energy services sector's role and performance were critical in improving energy efficiency and reducing the Chinese economy's energy intensity. The introduction of the energy service company scheme was an appropriate and effective way to help the government achieve the energy conservation objectives (Yuan et al., 2016; Zheng et al, 2018a).

Energy services companies (ESCOs) constitute the energy services sector which provides energy efficiency solutions to energy consumers, most commonly through energy performance contracts (EPCs) (Deng et al., 2015). ESCOs and EPCs have been instrumental in developing energy conservation technologies and reducing environmental impacts (Zheng et al, 2020). Taking advantage of support from the government through a series of initiatives in the form of incentives, subsidies, and tax concessions, China has founded the world's largest energy service market, accounting for 55% of the total energy service company revenue in the world (IEA, 2016).

However, compared with the current levels of energy consumption and, therefore, conservation potential, the energy service sector's development is still considered to be in its early stages (Liu et al., 2018; IEA, 2016). Existing studies mainly focus on ESCOs' current market status and market potential. For instance, Lee et al (2003) has investigated the barriers for ESCOs in Korea and how the government can operate as a market creator to remove barrier and promote better growth of ESCOs. The USA have experienced a steady growth until 2011 (Stuart et al., 2013) and almost tripled its size by 2020. Other parts of the world, like France and Germany, have shown similar patterns of growth (Stuart et al., 2014). Stuart et al. (2016) highlights how the share of revenue and market characteritics varies in different regions even when considering the USA alone.

Previous research has addressed several barriers for the development ESCO industry (Vine, 2005), including the financial and credibility barriers (Lee et al., 2003), policy problems (Okay et al., 2008), and infrastructure issues (Polzin et al., 2016). Despite of the those barriers, a combination of market forces and dedicated policy measure enabled the sector to grow (Bertold and Boza-Kiss, 2017). Nevertheless, lack of technical skills, technological competencies and efficient regulation still hinder further growth of ESCOs (Kangas et al., 2018). Worryingly, there are few investigations into the development and level of the technological capability (TC) of ESCOs. Thus, this paper is interested in responding to this gap.

China has been developing into innovation and technology-driven society, with many private enterprises taking the lead (Greeven, Yip and Wei, 2019). Chinese private enterprises have been on the path from incremental and limited business model innovation to radical and breakthrough technological innovation in the past decade (Greeven and Yip, 2019). While these include significant innovations in both the manufacturing and service sectors, the question arises to what extent the energy sector has developed such capabilities. While we have seen the emergence of green technology ventures such as water cleaning, air purification, and other related technology, developing the energy sector's technological capabilities to transition towards a more sustainable and energy-efficient approach has received limited attention.

Many studies in the context of China and sustainability have focused on green innovation performance of Chinese companies (Cheng, 2020), green consumer behavior (Wang, Wei, and Zhang, 2019; Yan, Keh, and Wang, 2019), and ecological accounting practices in China (Wang, 2019) among others. While the literature on technological capabilities is abundant and well-established in emerging countries' manufacturing sectors, the same cannot be said about service sectors and SMEs (Lin and Lai, 2021), particularly those driven by sustainability pressures such as the ESCo industry (Nurcahyanto and Urmee, 2020). Thus, this paper addresses the specific gap in the literature on understanding the TC development model in China's energy service sector and its contribution to developing effective energy conservation solutions.

More widely, it contributes to the limited literature on capability development in China's services, particularly in emerging economies in general. This paper addresses the question of "how have the Chinese ESCOs developed their technological capability?". The study investigates the drivers, dimensions, factors, and model of TC development in ESCOs in China to achieve this research's objectives.

2. Technological capabilities in service industries

Industrialization is driven by the development of technological capabilities, which play a strategic role in the competitiveness of firms, industries and countries. With the rise of digitally-enabled technologies, the ability to search, recognise, develop, adopt, and change or disseminate those technologies is becoming a critical capability in the service industry. This paper will draw on extant literature from the manufacturing sectors to identify important factors for TC development in service sectors.

For a paper on ESCOs, Jin and Von Zedtwitz (2008) offer a comprehensive definition: TC as a capability to make effective use of technical knowledge and skills not only to improve and develop products and processes but also to improve existing technology and generate new knowledge skills in response to the competitive business environment. We propose the use of their broader definition of technological capability because it considers business intangibles and encompasses the value created for customers by both goods and services.

In studies of manufacturing, researchers have found factors that affect firms' technological capabilities. Volberda et al. (2010) noted that contextual (external) factors affect firms' absorptive capacity. Lane et al. (2006) highlight the importance of the industry, regulatory and knowledge environments. Besides, scholars have mentioned significant factors: the external network, investment in science and economics, government subsidies and support, infrastructure, and national innovation systems (Mowery and Oxley, 1995; Doh & Kim 2014). Finally, energy efficient design and rebound effect should be taken into account besides the technological capability.

Articles that have focused on internal factors affecting TC have included prior knowledge Cohen & Levinthal, 1990, individuals' awareness of the capabilities and knowledge of others in their company (Zahra & George, 2002), R&D and organizational structures (Vega-Jurado et al., 2008), policy and industry environment (Volberda et al., 2010), amongst other processes within the organization that affect technology transfer, diffusion, formalization, integration and creation (Lin and Lai, 2021). Hansen and Ockwell (2014) point the use of learning mechanisms by firms. Consequently, the external and internal factors which could affect TC are summarised in Table 1 and 2.

Table 1: Potential external factors affecting TC

Factors	Supporting references
Industry environment	Lane et al. (2006)
Regulation environment	Volberda et al. (2010)
Knowledge environment	Zheng et al (2020)
External network	Tsai (2001) Lin and Lai (2021)
Government subsidy and support	Mowery and Oxley (1995)
Investment in scientific and technical training	Zhang & Gallagher (2016) Lin and Lai (2021)
Infrastructure	Doh & Kim (2014)
Financial institutions	Gan (2009)
Governance structure	Fu et al. (2011)
Modern institutions	Zheng et al (2018a)
Suppliers	De La Tour et al. (2011)
Competitors	
Research institutions and associations	Cohen & Levinthal (1990)

Table 2: Potential internal factors affecting TC

Factors	Supporting references
Organisational structure and policy	Volberda et al. (2010)
Firm's size	Cavusgil et al. (2003)
Individual cognition	Zheng et al (2020)
Prior knowledge	Cohen & Levinthal (1990）
R&D	Zahra & George (2003)
Learn mechanisms	Todorova & Durisin (2007) Schmidt (2010) Hansen and Ockwell (2014)
Firm's strategy	Lane et al. (2006)
Finance ability	Vine (2005)
Profitability	Pan et al (2018)
Organisational knowledge formulation	Vega-Jurado et al. (2008)
Social integration mechanism	Greeven et al (2019)
Personal, technical and work design	Frank et al. (2015) Park and Ghauri (2011)

3. ESCOs and their development in China

The ESCO and EPC concepts were introduced into China in 1998, with the World Bank and the Global Environment Facility support and help. Since then, the development of China's energy service sector has been dramatic, and China currently has the largest ESCO industry of any developing country (IEA, 2016). Gan's (2009) comprehensive study of the sector in China reports on the rapid growth in the number of companies and employees and provides an account of the barriers (market, institutional, financial and technological) against its development and how they are being addressed. Wang et al., (2016) also note the barriers, like economic incentives, appropriate technology and government's insufficient support to enforceable law and regulation.

In addition to the well-know external barriers (Vine et al., 1998), the complexity of ESCOs business models may limit the growth of the sector (Pätäri and Sinkkonen 2014). Most countries have experienced institutional and financial barriers, as well as perceptions of risk. Developing countries also have experienced barriers regarding information/awareness/knowledge, EPC expertise, access to equipment and technology, administration, reliability, and credibility (Vine, 2005). Other institutional factors, including nature itself (Zheng et al, 2020) and government and financial support (Nurcahyanto and Urmee, 2020; Zheng et al, 2018b), need to be accompanied by appropriate firm strategy and capabilities (Greeven et al, 2019; Pan et al, 2018;) for the industry to prosper. In a study on LED standardization in China, the Philippines, Thailand, Vietnam, and Indonesia, in an attempt to push a green technology to dominance, it is shown that the institutional infrastructure strongly influences the role of key stakeholders in the standardization process of a new technology (Van de kaa and Greeven, 2017,). Large scale implementation of energy efficiency projects in China are likely to be contingent on the institutional infrastructure support.

ESCOs in China are public (state-owned) or private companies that provide technical, commercial and financial services for energy efficiency projects. ESCOs are service providers and play critical roles in developing energy conservation technologies (Larsen et al., 2012; Stuart et al., 2014). However, there is no proto-typical ESCO, because of the diversity of shape, scope, size and ownership. Larsen et al. (2012) showed that ESCOs provide energy-efficiency-related and other value-added services based on performance contracting as their core business.

ESCOs implement energy efficiency projects based on EPCs, which are negotiated contracts specifying energy-saving goals and agreed business models between ESCOs and energy consumers (Deng et al., 2015). The various business models include the shared savings model, the guaranteed savings model, the energy-cost trust model, and the finance lease model (Qin et al, 2017).

Of these, *shared savings* and *guaranteed saving*s are the most basic and accepted models applied in EPC projects (Ouyang and Ju, 2017). The *shared savings* model means that the ESCO finances the energy efficiency project from its resources or external financing. During the project period (typically three to five years, although a large project may last ten 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 customer, and the customer will benefit from all the energy savings.

Guaranteed savings models are those where the customer finances the project via third-party institutions, such as banks or other finance agencies. The ESCO simply arranges the fund and guarantees the performance based on the contract. The ESCO guarantees a certain level of energy saving. If the actual energy cost saving is lower than the guaranteed level, the ESCO pays the difference. When the actual energy cost saving is over the guaranteed level, the ESCO and the customer will share the excess. The main difference between the two schemes is that the ESCO takes both the financing and performance risk in shared savings contracts, but in the guaranteed savings contracts, the ESCO just takes the performance risk (Lee et al., 2003; Qin et al., 2017).

As characterised by Qin et al (2017), in the *energy-cost trust* model, the ESCO rebuilds the energy system which the energy user finances during the contract period. At the end of the contract, the balance of funds belongs to the ESCO. Thus, if expenses are less than those specified in the contract, the ESCO will keep the surplus. Otherwise, the ESCO should compensate the energy user for any excess costs.

Qin et al (2017) explains that in *the finance lease model,* the ESCO rents equipment from the finance lease company to carry out the energy project and repays the lease by extraction from the energy-saving benefits.

Therefore, an ESCO's TC plays a significant role in the scope of service it can offer and specifies and fulfills its contracts; this further contributes to the company's credibility and competitiveness.

According to the International Finance Corporation's (IFC) China ESCO Market Studies Report, in 2011, 2,339 registered ESCOs were operating in China, which employed a total of 378,000 people. According to Energy Management Contract Association (EMCA) Statistics, by 2015, 5,426 ESCOs were registered by the National Development and Reform Commission (NDRC), and the ESCO industry employed 607,000 people. Between 2006 and 2015, turnover and investment in EPC projects has been dramatic, the latter increasing from USD200 million to USD16.7 billion (IEA, 2016).

However, such a high number of companies may not represent a healthy energy service sector. The scale for individual companies is generally small, and most ESCOs can be categorized as SMEs or even micro-enterprises (Vine, 2005). According to EMCA, 60% of ESCOs' registered capital was less than ¥10 million (USD1.54 million), and only about 20% of ESCOs' registered capital was over ¥50 million (USD9.23 million) in 2011 (Kostka and Shin, 2013). Moreover, in China, it is complicated for small companies with little capital to obtain loans or other financial support, which make many Chinese ESCOs incapable of developing technical skills and so they only provide low-end services, just selling products instead of creating energy efficiency solutions (Liu et al., 2018). 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).

Technological capability is one of the key barriers which needs to be addressed in China. Some of the existing literature mentions technological barriers, but not to any great extent. Only a few studies have argued that ESCOs should develop their capability to provide qualified services and products (Gan, 2009).. Okay and Akmam (2010) also emphasized that innovation is an essential element that fosters the development of ESCOs. Kangas et al. (2018) pointed out that technical skills, disinterest, and non-functional regulations are the main barriers faced by energy service companies in Finland.

4. Methodology

Qualitative multiple case studies were considered an appropriate research strategy to answer the research question since they provide detailed empirical descriptions of particular instances of a phenomenon typically based on various data sources (Yin, 2003). As indicated in the literature review section, few empirical studies have identified the role of TCs in service sectors and even fewer in the context of the energy sector. Although we can leverage insights from other industries, this study warrants a qualitative approach to identify key factors as emergent themes from carefully selected case examples. Case studies typically combine data collection methods, such as archives, interviews, questionnaires, and observations (Eisenhardt, 1989). Based on informants' introductions, descriptions, and explanations, empirical data was collected from secondary data such as project reports and cooperation agreements. This research's primary sources were collected from interviews with management team members, observations, and documentation. The depth of understanding that such multiple case studies provide is required for addressing the questions posed.

There were six case companies involved in this study. 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). The case selection criteria included that the companies should have a domestic registration, at least three years' business experience, and had successfully implemented at least five energy conservation projects. The case ESCOs were different-size organizations and in different tier cities. Table 3 provides the basic information about the case ESCOs.

Table 3: Basic information of case companies

Case ESCOs	Ownership	Size	No. of employees	Registered capital (RMB)	Location	Year founded	No. of interviews
S1	Private	Small	48	5 million	Beijing	2010	3
S2	Private	Small	20	10 million	Qingdao	2010	3
M1	Private	Medium	100-150	22 million	Beijing	2010	3
M2	Private	Medium	100-150	20 million	Hangzhou	2005	3
L1	State-owned	Large	950-1000	971 million	Beijing	2010	2
L2	State-owned	Large	7000	4.6 billion	Beijing	2013	2

All the interviewees selected for this investigation had at least three years' experience working for the senior management team and had knowledge of their company's strategy, current technologies, products, and services. Each interview lasted about 60 to 90 minutes and was audio-recorded. The researcher spent between 4-7 days in each company gathering data. All interviews were conducted in Mandarin then transcribed and translated to English. In total, 16 participants were interviewed. They listed the factors that affect their companies' TC which allowed us to class a factor as being critical. When recognised by three or more companies, a factor was included as affecting TC. As a result, 13 key factors were identified as affecting TC (See table 6-9). In addition to these, the location of the ESCO is also considered to be a key factor.

Case S1 interviewees included the CEO, senior manager, and directors of R&D. In case S2, the general manager, project manager, and director of the design department were interviewed. For case M1, personal interviews were conducted with the senior manager, the senior manager's assistant, and the strategic investment department director. In case M2, access was granted to the senior manager, director of R&D, director of the financial department. The interviewees in case L1 were the director of the strategic investment department and deputy director of the technology management department. Finally, the deputy director of the engineering department and the project manager in case L2 complete the interviewees' list for this study.

The investigation included within-case and cross-case analyses. In the within-case analysis, the data were processed and streamlined before being developed into case reports. The case reports included data from interviews, direct observations by the investigator and secondary data. In these reports, any time the interviewee mentioned external and internal influences on TC capacity and development these were highlighted and organized. Cross-case analysis compared and attempted to explain complementary and contradictory findings between the companies studied with respect to these influences. The cross-case analysis helped to avoid reaching premature and even false conclusions resulting from single case study information bias (Eisenhardt 1989). While this approach favours an in-depth exploration of factors and understanding of patterns in TC development, it has limitations for the generalisation of results as other quantitative approaches.

5 Results

5.1. Case description

The energy service sector is an emerging one in China, and its development is strongly influenced by government support and pressure. However, the development of business strategy in response to competition and increasing customers' requirements for improving energy efficiency influenced by regulation push ESCOs to develop and strengthen their TC. Drivers of TC development were classified as primary and secondary based on the role they played for technology development. Primary drivers are those that form the chief and primary reasons for companies to develop their TC. Secondary drivers are supplementary reasons that influence the reasons but would not be sufficient to develop TC. Table 4 summarises the findings. Primary drivers are the key influencing factors for technology capability development. Secondary drivers are additional factors that are important but not essential to promote behavioral change (e.g. weaker enabler).

Table 4： Main drivers of case study ESCOs' TC development

Case ESCOs	Primary drivers	Secondary drivers
S1	Business development strategy Improving competitiveness Customers' requirements	Government support Government pressure
S2	Business development requirements (Basic) Customers' requirements	Government support
M1	Business development strategy Improving competitiveness	Government pressure
M2	Business development strategy Customers' requirements Improving competitiveness	Government support Government pressure
L1	Government pressure Business development strategy Improving competitiveness Customers' requirements	Government support
L2	Government pressure Business development strategy Improving competitiveness	Government support Customers' requirements

Business development strategy and customers' requirements are considered to be primary drivers for TC by small ESCOs. S1 views TC as giving it a competitive advantage; therefore, improving competitiveness also becomes one of its primary drivers. As an ESCO, energy conservation technologies and products are fundamental components for business operations and development. S1 aims to become one of *China's top 100 ESCOs* in five years, taking advantage of its unique energy monitor and analysis system. S2 focuses on increasing its local market share based on its existing technologies and products. Hence, S2's primary driver is keeping its basic business development requirements. Both small-sized companies view government support as a secondary driver. The government has launched a series of policies, such as the *Energy conservation project subsidy*, which has directly increased stakeholders' willingness to implement energy conservation projects. Nevertheless, these policies are not closely linked with ESCOs' technological capability.

The latest government's certifications (such as the National High-tech Enterprise and Zhongguancun High-tech Enterprises) are however pushing ESCOs to develop their technological capability. Therefore, government pressure is still viewed as a secondary driver by S1, because the government's increasingly strict regulations for energy users increase demand for energy services. However, the effectiveness of the government's role is weakened by slower adoption of policies promoting the energy service sector and more stringent criteria for designating enterprises high-tech enterprises to attract support and incentives, making it difficult for smaller energy services companies providing essential services to qualify as high-tech.

Medium-sized ESCOs also consider the commercial drivers, business development strategy, and improving competitiveness to be the primary drivers for TC development. Both medium-sized ESCOs belong to *China's top 100 ESCOs*. Both these ESCOs have explicit and pragmatic business development strategies, aiming to expand their business to China's western and southern areas. In order to keep and strengthen their competitiveness, TC development is deemed a practical approach. Company M1 has its technological advantages in the steel manufacturing industry through waste heat recovery and energy management system technologies. Company M2 is developing its business based on its industrial circulating water energy-saving technology. For M1, customer requirements are not considered driving TC development, as the company believes all energy conservation needs of its customers are being met. Both medium-sized ESCOs think that government pressure is pushing them to develop TC. The pressure mainly comes from local government regulations and policies. M1 obtained a minimal government subsidy because of new technology development. Therefore, it explicitly recognizes the secondary importance of government support for TC development. The certifications issued by the government are also an encouragement.

The large case study ESCOs regard government pressure as a primary driver. Both L1 and L2 are state-owned enterprises and are highly affected by government policy and regulation. In particular, L2 was founded in response to government policies regarding energy conservation and emission reduction. As would be expected, state-owned ESCOs are more responsive to government policies. Additionally, the government requires state-owned ESCOs to maintain and strengthen their advantage in TC. Each large ESCO has over 100 patents, far more than private ESCOs and the business development strategy is another primary driver. Both large ESCOs compete in the domestic and international markets. Although large ESCOs have the technological advantage in the domestic market, they need to develop their TC to improve their competitiveness internationally. L1 and L2 both think government support is a secondary driver, affecting companies' TC development but not directly. The companies differ in their opinions regarding customers' requirements. L1 considers customers' requirements to be a primary driver for developing TC. L2 considers that satisfying customers' requirements is essential but not a key driver because its existing TC outperforms its customers' requirements.

In short, the results from this research shows that government support and pressure are still one of the key drivers for energy efficiency projects in China. This is compatible with results found by previous researchers in developed such as Finland (Kangas et al, 2018) and Spain (Peñate-Valentín et al, 2021) as well as in developing countries like Turkey (Okay et al, 2008), and Indonesia (Nurcahyanto and Urmee, 2020). Here, the paper shows that customers' voice and firm competitiveness are also gaining relevance for ESCOs to develop their TC. To some extent, this finding supplements the findings from Kangas et al (2018), in which customers' lack of knowledge could act as a barrier for ESCOs' capabilities development.

5.2 Dimensions of TC of Chinese ESCOs

The energy service sector has different business contexts and industry characteristics from manufacturing. As service- and technology-intensive enterprises, ESCOs generally have closer relationships with their customers and provide customized products and services. The four dimensions framework encompassing investment, production, linkage, and innovation capabilities has been used to examine the case study ESCOs' TC levels in this section - table 5 shows which dimensions were well-developed and under-developed in each case according to the perception of respondents. A dimension was considered well-developed when there was evidence of excellent/superior corporate outcomes using the dimension capabilities. For instance, S1 had built an R&D department (capability) and obtained 12 patents and software copyrights.

Table 5: Dimensions of TC developed by the case companies

Case ESCOs	Well-developed dimensions	Examples of evidence for well development dimensions from case interviews and observation	Under-developed dimensions	Examples of evidence for under-developed dimensions from case interviews and observation
S1	Investment capability Production capability Linkage capability	• Has built up finance ability and continuous investment in TC • 17 projects implemented • Cooperation agreements with universities in place, but no projects as of yet • Has built up R&D department and has 12 utility model patents or software copyrights	Innovation capability	• R&D department is currently unable to conduct complex energy-saving technology development projects
S2	Production capability Linkage capability	• 11 projects implemented • Cooperation with local university and implemented projects	Investment capability Innovation capability	• No practical finance ability and few investments in TC • No R&D department or investment in R&D •
M1	Investment capability Production capability Innovation capability	• Has built up finance ability and continuous fixed annual investment in TC • 24 projects implemented • Has built up R&D department and has 16 utility model patents or software copyrights	Linkage capability	• No effective linkages with suppliers or research institutions • Has less interest in cooperating with companies for TC development
M2	Production capability Linkage capability	• 19 projects implemented • Cooperation with university and one project for energy-saving technology development has been implemented	Investment capability Innovation capability	• Has built up finance ability but does not have continuous fixed annual investment in TC • Has built up R&D department and has 9 patents or software copyrights, but investment in R&D has been reduced.
L1	Investment capability Production capability Linkage capability	• Has built up finance ability and continuous increased investment in TC • 21 projects implemented • Cooperation with universities and international companies	Innovation capability	• Large R&D department; however, little impact on developing and patenting emergent energy technologies
L2	Investment capability Production capability Innovation capability	• Has built up finance ability and continuous increased investment in TC • 8 projects implemented • Large R&D department and has 97 patents or software copyrights. It has domestic advanced level of energy-saving technologies for power transmission.	Linkage capability	• Limited cooperation with universities and research institutes • Less willingness to build up broad linkages with external players

There are differences in the development of the dimensions of TC. The development levels are related to company size, business development strategy, government intervention and other business and regulation contexts. Most case companies have developed investment capability by initially growing their financial performance. S1 and M2 raise finance through selling equity for technology acquisition and R&D investment. M1, L1 and L2 finance through bank loans or corporate bonds. However, Yuan et al., (2014) find that there are barriers to getting a bank loan. Unlike manufacturing enterprises, ESCOs do not need heavy investment in equipment and production facilities. They focus on investing in technology acquisition and technical staff recruitment and training. Concerning the company's capacity to recognize and invest in necessary or potential resources needed for production, companies can get the necessary resources needed for production. However, only S1, L1, and L2 can recognize and invest in the technologies that have the potential to be improved or upgraded.

Production capability represents the essential dimension of TC to enable it to function. In every case, ESCO has developed its production capability to operate its business. ESCOs produce and provide tangible energy conservation products and intangible technologies (e.g., concepts, processes, software, and training). Established production capabilities depend on accumulated knowledge, technical staff, and S1, M1, M2, and L1 have special teams to deliver customer training sessions. Simultaneously, all the case companies have organized customer services and maintenance teams to regularly visit projects to ensure effective operation and performance projects. Absorptive capacity is a critical element for production capability development. S1, M1, M2, and L1 have built up the absorptive capacity to assimilate technologies in the process of production. S2 has basic production capability as a supplier of LED lighting products requiring the limited capacity to provide training to its customers. L2 has developed the required level of production capability. Its customers are professional electrical power providers, so it is much easier to deliver customer training and projects.

Linkage capability is a practical ability to transfer and absorb knowledge from other stakeholders (Qiu, 2018), and the government encourages ESCOs to build up linkages with stakeholders from various industries. ESCOs generally establish linkages with suppliers, customers, universities and research institutes, competitors, and companies in other industries. S1 has established formal linkages with international competitors and informal linkages with local universities. S2 has built up linkages with local universities. M2 prefers to establish effective linkages with universities. L1 and L2 have established formal linkages with universities and research institutes, companies in other industries, customers, suppliers, and international competitors. To transfer knowledge effectively from the linkages, ESCOs need to have absorptive capacity and particular types of linkages, such as personal relationships. S1 has established informal linkages with universities, from which it is difficult to transfer knowledge effectively. M2 has built up a formal linkage with a local university through cooperative R&D; M2 obtained Industrial circulating water energy-saving technology and trained its R&D team.

Innovation capability is an essential manifestation of TC required to develop new products and processes for enhancing performance and competitiveness. Most case companies have developed their innovation capabilities, though at different levels and having different approaches in conducting innovation activities. However, these case companies have mostly implemented incremental innovation, which means focusing on improving, upgrading, and integrating existing technologies to improve their production capability. S1 has improved the licensed energy consumption analysis technology and is attempting to embed cloud computing and AI technologies. M1 prefers to integrate open access energy conservation technologies with its self-developed software and develop an energy management system that involves energy consumption prediction (simulation), energy consumption monitoring, energy consumption analysis, energy cost management, and energy quality management. Only L1 has tried to make radical innovations to develop new and advanced energy conservation technologies and products. L1 has collaborated with Mitsubishi Heavy Industry to develop *Waste steam utilization technology under low pressure*. Additionally, L1 has also developed several domestic, advanced energy conservation products and technologies, such as the *Real-time online condenser cleaning and enhanced heat transfer system*, *Permanent magnet eddy current flexible transmission energy-saving technology* and *Oxygen-rich combustion energy-saving technology*. Although there is evidence of L1 and L2 carrying out radical innovation tentatively, L1’s innovation capabilitity is underdeveloped when considering their size.

The results from previous research focused primarily in financing aspects of ESCOs (Zhang et al, 2015). Naturally, the investment capability, alongside production, remains critical as shown in the results presented here. Moreover, the results provide a more detailed view and expand knowledge on linkage and innovation capabilities; nevertheless, they are in alignment with the findings from (Pätäri and Sinkkonen, 2014) and (Wang et al, 2018).

5.3 The key factors affecting the TC of ESCOs

In the investigation, the 16 interviewees listed the factors that affect their companies' TC (see Table 6-9). We identified a factor as being critical, only if at least three companies recognised it. As a result, 13 key factors are identified as affecting TC. In addition to these, the location of the ESCO is also considered to be a key factor. These factors affect one or more dimensions of TC supportively or unsupportively.

Table 6: Key factors affecting the TC Investment capability of Chinese ESCOs. Legend: ("+" supportive; "0" neutral/not mentioned; "-" unsupportive)

Key factors	S1	S2	M1	M2	L1	L2
Finance ability	+	–	+	–	+	+
Profitability	+	–	+	0	0	0
Technical staff	0	–	+	+	+	–
Firm's strategy	+	–	+	+	+	+
Absorptive capacity	0	0	+	0	0	0
Government subsidy and support	+	0	+	0	+	+
Firm size	–	–	+	–	+	+
Competitors	0	0	+	+	0	0

Table 7: Key factors affecting the TC Production capability of Chinese ESCOs. Legend: ("+" supportive; "0" neutral/not mentioned; "-" unsupportive)

Key factors	S1	S2	M1	M2	L1	L2
Technical staff	+	+	+	+	+	+
Firm's strategy	0	+	0	+	+	0
Absorptive capacity	+	0	+	—	+	—
Research institutes & associations	+	+	0	0	0	+
Customer	—	0	—	—	0	0
Supplier	+	+	+	+	0	+

Table 8: Key factors affecting the TC Linkage capability of Chinese ESCOs. Legend: ("+" supportive; "0" neutral/not mentioned; "-" unsupportive)

Key factors	S1	S2	M1	M2	L1	L2
Finance ability	0	0	+	0	0	0
Firm size	0	0	0	0	+	0
Technical staff	0	0	0	0	+	0
External network	+	+	+	+		
Firm's strategy	+	+	0	0	+	—
Absorptive capacity	+	0	0	+	+	—
Government subsidy and support	+	+	0	0	+	0
Research institutes & associations	0	0	0	0	0	0

Table 9: Key factors affecting the TC Innovation capability of Chinese ESCOs. Legend: ("+" supportive; "0" neutral/not mentioned; "-" unsupportive)

Key factors	S1	S2	M1	M2	L1	L2
R&D investment	—	—	+	—	+	+
Infrastructure	—	—	0	0	0	0
Technical staff	—	0	0	—	0	—
Prior knowledge	—	0	—	—	—	—
Firm's strategy	+	−	+	−	+	+
Absorptive capacity	0	0	0	0	+	—
Government subsidy and support	0	0	+	0	+	0
Research institutes & associations	0	+	0	+	+	+
Governance structure	—	0	0	0	0	0
Competitor	0	0	0	0	+	0
Supplier	0	—	0	0	0	0

Finance ability is a supportive factor affecting investment capability by case ESCOs from first-tier cities (Beijing). This is because case ESCOs in first-tier cities find it easy to acquire finance from external resources (Banks or fund companies). The firm's strategy is another supportive factor affecting investment capability recognized by five of the case companies. Government subsidy and support are deemed supportive factors affecting investment capability by case ESCOs from first-tier cities. The local government's support and pressure stimulate the development of investment capability.

The technical staff, the firm's strategy, absorptive capacity, research institutes and universities, customers, and suppliers are identified as crucial factors affecting the case companies' production capability. As the primary entity to implement energy conservation projects, technical staff affect the project's quality and efficiency. Customer satisfaction depends highly on the technical staff's performance. Absorptive capacity is a supportive factor only if companies have accumulated knowledge and experience and have built enough of it. Cases S1, M1, and L1 have focused on industrial energy conservation for over five years and have successfully assimilated and improved transferred technologies and put them into production. Research institutes and universities are supportive factors if ESCOs have established effective linkages with them. The customer's weak knowledge and capacity to implementing energy-saving projects are considered unsupportive factors. Most energy conservation projects require the customers' participation in daily operations and maintenance (Vine et al., 1999). However, according to the project records of M2, customer participation unsupportively affects the performance of projects. Most of the case ESCOs do not produce energy conservation products. Therefore, a reliable and qualified supplier has a powerfully positive effect on a project's performance. Five of the case companies think their suppliers provide quality products and services that support their projects' implementation and performance.

The external network, the firm's strategy, absorptive capability, and government subsidy and support are four key factors influencing ESCOs' linkage capability. The external network is only recognised by small- and medium-sized ESCOs as a supportive factor affecting their linkage capability. However, most of the external networks established by small- and medium-sized ESCOs are informal linkages; for example, S1 has built linkages with local universities, and M1 has established linkages with existing and potential customers. These informal linkages are difficult to translate into an effective transfer knowledge or technologies. S2 and M2 have built up formal linkages with local universities through cooperation contracts. These formal linkages are established initially based on personal relationships, and they prove to be more effective. The company's strategy includes deciding whether the company needs to build up linkage capability, linkages with which organizations, and establish these. S1's management team prefers to establish linkages with local research institutes and universities through informal cooperation agreements. S2 has built up a linkage with a local university through cooperation contracts. L1 has established linkages with domestic research institutes and universities through a cooperation contract and international companies through collaborative R&D contracts. However, L2 considers the company's strategy has limited its linkage capability development because of strict regulation and monitoring.

R&D investment, prior knowledge, the firm's strategy, and research institutes and universities are recognized as key factors affecting the case companies' innovation capability. The small- and medium-sized ESCOs consider their investment in R&D to be limited; this is owing to their company's size, financial ability, and profitability. The large ESCOs can keep a stable and long-term investment in R&D. L1's annual investment in R&D is over ¥ 50 million. R&D experience is an unsupportive factor by all the case companies, even though they have all conducted R&D for at least three years. Prior knowledge regarding R&D is still a barrier. This is particularly a concern, so when the ESCOs have acquired new technology and try to assimilate and improve it, they require additional time and investment costs because of the lack of accumulated knowledge. Four of the case companies think their organizations' strategies supportively affect their innovation capability. This is because S1, M1, L1, and L2 have explicit technological capability development strategies and have placed innovation capability development in a core position. S2 and M2 have focused on building and developing production capability. Research institutes and universities are considered supportive factors by the case companies that have established formal linkages with them. This is particularly the case for M2, as it developed its domestic advanced '*Industrial circulating water energy-saving technology'* through collaborative R&D with the local university.

In summary, while the birth and rapid growth of ESCOs was primarily driven by external factors as it was well-documented by previous authors; the results in this paper also supplement findings from other countries (e.g. Kangas et al, 2018), showing that further technological development and innovation for ESCOs is heavily dependent on internal factors, mainly technical (Pätäri and Sinkkonen, 2014) and networking skills (Wang et al, 2018).

6. Discussion

6.1 Dimensions of the TC of ESCOs

Most of the case ESCOs, have a basic level of investment capabilities. M1 and M2, for instance, invest in basic industrial and building energy conservation technologies to serve their main customers in the iron and steel industry. As an example of the more advanced level capability, S1 and L1 are at an advanced level. S1 has invested in energy analysis technologies with the potential to upgrade. This means the technology can be used in various sectors and serve different customers. L1 has also invested in more complex and advanced industrial energy conservation technology to help customers achieve energy savings above the government's existing regulations.

Small- and medium-sized ESCOs have developed well their production capabilities. However, they predominantly use existing technologies to implement their energy conservation projects.

Even though they assimilate, transform and even improve the existing technologies, these technologies are not the most advanced when considering the sector as a whole. The large ESCOs have advanced production capabilities because they have advanced domestic technologies and have already applied them to implement energy conservation projects.

Cases S1, S2, M2 and L1 have established advanced linkage capabilities with suppliers, customers, and international companies. They have effectively transferred technologies and developed their TC. However, M2, and L2 have only built up a basic level of linkage capabilities, which means that they can only leverage resources from external actors to implement projects rather than effectively complete knowledge transfer.

Most ESCOs – S1, S2, M2, and L1 – have only a basic innovation capability level. They have tried to improve existing energy conservation technologies through in-house R&D, but they have not conducted complex modifications through applied research and exploratory development. The large ESCO L2 have more advanced innovation capabilities. First of all, they can conduct collaborative R&D with leading international companies to develop advanced and even world-leading technologies. The R&D activities of the large ESCOs involve advanced technology development. According to the data analysis of the small and medium-sized ESCOs, it is challenging for them to improve and upgrade innovation capabilities.

Most case study companies have investment and production capabilities. Companies with advanced levels of TC also have linkage and innovation capabilities as well. In the ESCO industry, firms' production capabilities include linkage capability, because an essential component of their business is to transfer knowledge to their customers. Hence, the levels of TC can be classified as basic and advanced.

All the case ESCOs built up basic levels of investment and production capabilities required for starting their businesses. An essential feature of the sector is that ESCOs' projects involve services that require customers' participation as co-producers. Therefore, ESCOs need to develop a basic level of linkage capability from the beginning. However, to upgrade their TC, companies have to continuously develop their investment, production, and linkage capabilities to increase their knowledge accumulation and absorptive capacity. ESCOs could then gain advanced innovation capabilities to develop advanced energy-saving technologies or services, but most stay at a basic TC level, especially small-and medium-sized ESCOs. Only S1 and the large ESCOs have taken steps towards attaining more advanced capabilities.

6.2 A model of TC development

Five key drivers of TC development of ESCOs in establishing and developing investment, production, linkage and innovation capabilities were relevant. The business development strategy, customer requirements, and improved competitiveness were identified as primary drivers. The business development strategy was mentioned the most by the interviewees in affecting the companies' development of investment and linkage capabilities. For large state-owned ESCOs, government pressure and support were significant for fostering their innovation capabilities development. The large ESCOs qualified more easily for national subsidies and support than small and medium-sized. On the other hand, the large state-owned ESCOs have more pressure to comply with government regulations and policies. Currently, government intervention does not play a significant role in the TC development of small-and medium-sized ESCOs.

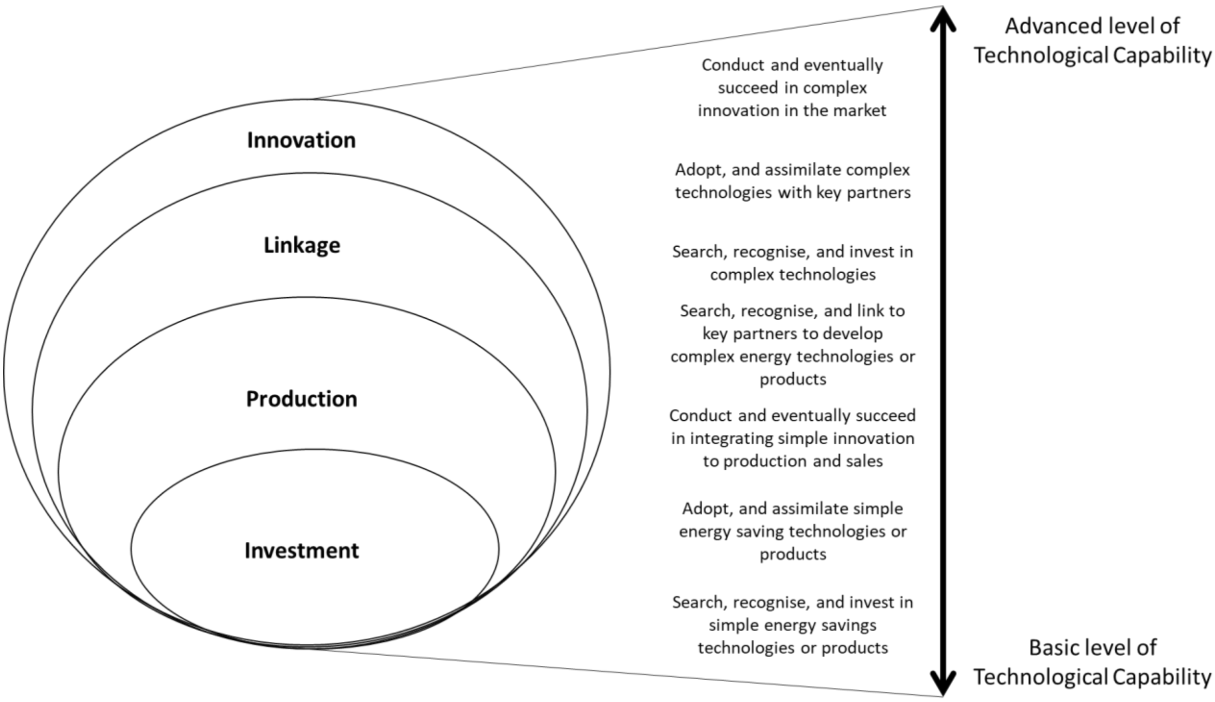

Figure 1： Model of ESCOs' TC development

Figure 1 shows the model of ESCOs' TC development. ESCOs start and develop their TC by recognizing and investing in basic and straightforward energy-saving technologies to support their production activities. Then, ESCOs adopt and assimilate energy-saving technologies through project implementation. At this stage, ESCOs start to conduct basic-level innovation. Small and medium-sized case ESCOs have developed energy analysis or management systems through software development. In this way, small- and medium-sized ESCOs develop their initial independent energy conservation technology relying on "open source" knowledge or linkage with specialist suppliers as in the case of S1. Nevertheless, the systems they develop and supply are simple, involving the basic functions of energy consumption data collection, monitoring and analysis. Their ability to survive and improve is consistent with the low entry barrier for firms with sufficient specialist knowledge.

With the development of business and knowledge accumulation through project implementation, ESCOs can invest in, apply, adapt, assimilate complex and even advanced technologies. Large ESCOs' innovation activities could then move to the next level, intermediate innovation, where ESCOs upgrade their initial developed technology or develop new energy analysis or management systems. Most ESCOs, mainly small- and medium-sized ESCOs, will stay at this level for a long time. However, large companies can move to having higher levels of innovation, taking advantage of their substantial capital and adoptive capacity.

A possible difference between the model of TC development in ESCOs and manufacturing companies is that the former could conduct innovation activities at an earlier stage. Even though ESCOs have a basic level of innovation capability, they start to develop their independent technology at an early stage of their business. Their independently developed technology is simple and basic, but they improve their innovation capability by developing their investment, production, and linkage capabilities.

6.3 Overcoming barriers for ESCOs development in China

Companies in the sector need to improve linkage and innovation capabilities. We have benchmarked Chinese ESCOs against American ones regarding their product portfolios, size, and market strategies. This allows us to provide some insights into overcoming barriers and thinking holistically about improving their competitiveness.

For instance, in the USA, the proportion of large ESCOs is higher than that in China. SMEs ESCOs in China may want to merge or create alliances in order to be able to have a more sophisticated product portfolio and the ability to win more significant and more complex projects.

Although smaller private enterprises drive the Chinese private sector, the limitations of developing relevant TCs are partly due to their small size. In different sectors, we have seen ecosystems of partnership emerging, and this may be a way forward for SMEs ESCOs without losing the agility of being a small flexible enterprise. A company that has been relatively successful in creating ecosystems of partnership within the energy sector is Envision (http://www.envision-group.com/en/).

The primary customer group of ESCOs in the US are “MUSH” (municipal and state governments, universities and colleges, K-12 schools and hospitals), residential programs, public housing, C&I (commercial and industrial), and federal. Chinese ESCOs can expand in this sector both nationally and internationally, particularly in neighboring countries such as India, Bangladesh, and Vietnam.

There is also a trend of ESCOs offering products related to electric vehicles. China has been adopting electric vehicles quite rapidly, creating opportunities as they become an untapped market for ESCOs. Total EV sales in China were 1.3 million, an increase of 8% compared to 2019, and 41% of all EVs sold worldwide (Huang et al, 2021). At large scale, new services such as battery swap stations may become viable; as well as battery reconfiguration for a second life in grid-connected storage and electrical tools for when the battery becomes obsolete for driving purposes (Hua et al, 2021).

7. Conclusions

China's rapid growth in developing green technologies is evident in several energy-related fields (de Paulo et al., 2020). This study contributes to how ESCOs in China are strategizing the development of their technological capabilities.

As opposed to the extant literature on government policies' influence on shaping the energy sector (Wang and Zhang, 2011; Van de Kaa and Greeven, 2017), this study shows that the ESCO's have been primarily driven by internal forces. Consequently, the findings suggest a significant role of internal organizational capability development independent from frequently temporary support policies. The findings suggest that the business development strategy, customer requirements, and improved competitiveness were primary drivers. Both internal and external factors drive the case ESCOs' TC levels and development. Nevertheless, internal drivers appeared to have played a role in accelerating TC's development in companies. This is a worthy topic for further investigation. Government policies (regulation, subsidies, and support) are mainly supplementary drivers in small- and medium-sized ESCOs, although they are more influential for larger companies.

This study also finds that ECSOs have developed their TC from building up basic investment and production capabilities to develop advanced levels of linkage and innovation capabilities gradually. Unlike other studies, it appears that they follow a gradual and incremental approach to developing innovation capabilities over time (Greeven et al, 2019).

Compared with manufacturing companies, ESCOs start to conduct basic levels of innovation activities at earlier stages. However, most ESCOs keep conducting activities at basic levels of linkage and innovation capabilities for a long time because of lack of critical mass in R&D investment, R&D experience, and absorptive capacity. Overall, the cases have in common that a lack of prior knowledge on technology prohibits developing more advanced innovation capabilities.

A possible area for future research would be to perform a survey to assess the product portfolio of ESCOs in China compared to other countries such as USA and Germany. This would expand the study of ESCOs from the perspective of technological capabilities and its energy efficiency benefits. Specifically, the effects of foreign or joint-venture ESCOs need to be studied alongside their commitment to build a more sustainable energy system in China.

In terms of contribution to practice, this paper is closely connected to business practice. ESCOs of different sizes, locations and business histories can benefit from the results presented in this paper.

First, this paper helps ESCO manager to recognise the importance of technological capability. When ESCOs set up business development strategy, technological capability should be placed in a strategic position for consideration. Companies should gradually establish or develop their investment, production, linkage, and innovation capabilities. For instance, headquarter location might be key to develop linkage and innovation capabilities. By building a competitive technological capability, ESCOs will improve their market performance and profitability, and become more competitive.

Second, governments can use the framework as well as the results in this paper to reflect how supportive and unsupportive their existing policies are 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 foster innovation towards more sophisticated product portfolios, which would help in achieving not only energy efficiency and decarbonisation goals but also other sustainable development goals.

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