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THE UNIVERSITY OF HULL

Sustainability transitions and leapfrogging in latecomer cities: a case of the diffusion of solar thermal energy in China

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By

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For my grandmother

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Abstract

Sustainability transition has been a burgeoning research field and political practice due to its focus on the systemic and fundamental transformation of existing main human sectors to curb global climate change. The present thesis aims to contribute to the literature by investigating the potential of latecomer cities in sustainability transitions through a geographical lens. Inspired by the multi-level perspective, economic geography, and leapfrogging research, the thesis proposes to understand sustainability transitions as consequences of power struggles between niche development and regime resistance, and latecomer cities may have a higher potential for sustainability transitions as they are less locked-in by existing regimes and niche actors could be more powerful to direct desired changes. These ideas are explored through a qualitative investigation of the popularisation of solar thermal energy in a latecomer city, Dezhou, in contrast to a more developed counterpart, Beijing.

Though the global and national landscape of green development has exerted unprecedented pressures on lower governance scales, it is interpreted and responded to differently at the local level. Unlike the development of other renewable energies, the popularisation of solar thermal energy in China is primarily driven by market forces. It is only recently that government's policies began to play a significant role. When this technology was encouraged to enter the urban market, it confronted many obstacles such as low technology profile, high-end consumer preferences, and conflict of interests among the main actors. However, these resisting factors have different purchase in cities at different development stages.

Dezhou's transition to solar thermal energy is an interactive consequence of weak regime resistance (i.e. suitable building infrastructure, less hostile market selection, and less institutional inertia) and strong niche development with a positive feedback loop among a powerful lead industry, supportive government, networked users, and motivated estate developers. These interactions are conditioned by place-specific contexts, as well as

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multi-scalar interactions, through which knowledge learning, interest coordination, and empowering are realised by key niche champions such as green entrepreneurs and governments at the local level.

The findings of this thesis suggest that the global landscape of green development is repositioning the role of less developed regions in sustainability transitions. Latecomer cities, though weak in technology innovation, demonstrate several advantages over developed cities in transition to decentralized energy systems, as they are generally less locked-in by incumbent unsustainable regimes, and green niche actors within them could be more powerful in directing transitions if they are able to meet economic interests at the local level and environmental benefits at the higher scales. Local scalar-transcending actors are of pivotal significance for latecomer cities to pursue green transitions because they are the key mechanism whereby external knowledge, resources, and legitimacy are brought in to sustain local transitions. This highlights the role of power and agency that has previously been overlooked in transition research. The thesis thus not only contributes to an in-depth understanding about why and how sustainability transitions take place in certain places, it also reveals the general potential of cities that are lagging behind in industrialisation and urbanisation in pursuing sustainability transitions. Based on this, policy implications are suggested for latecomer cities to achieve sustainability transitions.

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Declaration

I hereby declare that the work presented in this thesis is entirely my original work, except explicit attribution is made. None of this thesis has been previously submitted for any other award.

Signature:

Zhen Yu

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Abbreviations

BRT	Bus rapid transit
CPC	Communist Party of China
CPEC	Cadre performance evaluation system
CSTIA	China's solar thermal industrial association
DRC	Development and reform committee
EV	Electric vehicles
EWH	Electric water heater
FDI	Foreign direct investment
FYP	Five-year plan
GDP	Gross domestic production
GHG	Greenhouse gas
GPN	Global production network
GWH	Gas water heater
ICLEI	International Council for Local Environmental Initiatives
IEA	International Energy Agency
IPP	Intellectual property protection
ISES	International Solar Energy Society
MHURC	Ministry of housing and urban-rural construction
MIIT	Ministry of industry and information technology
MLP	Multi-level perspective
NDRC	National development and reform commission
NGO	Non-government organisation
NIC	Newly industrialising countries
NPC	National people’s congress
NSI	National system of innovation
OECD	Organization for Economic Cooperation and Development
OEM	Original equipment manufacturer

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PV	Photovoltaic
R&D	Research and development
RMB	Renminbi
SNM	Strategic niche management
SOE	State-owned enterprise
STRN	Sustainability transition research network
SWH	Solar water heater
TCE	Tonnes of coal equivalent
TIS	Technological innovation system
TM	Transition management
TNC	Transnational companies

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Chapter 1 Introduction

1.1 Research motivation

In recent decades, the primary sustainability challenge facing human society has gradually shifted from regional environmental problems such as pollution and ecological degradation to global climate change. Countries across the world are committed to clean technologies, innovation and renewable energy development, aiming to sustain economic growth and meanwhile curb the fear over global warming and energy security. The ideologies of ‘green growth’, as well as ‘ecological modernization’, are prevailing because they indicate the possibility of tackling environmental crisis without leaving the pathway towards modernization (Mol and Spaargaren, 1993). At the core of these ideologies is the faith in technology and innovation to tackle environmental problems (Roberts and Colwell, 2001). However, these have been criticized for merely focusing on a ‘technical fix’ through clean technologies (York, Rosa and Dietz, 2003), while neglecting technology’s side effects (e.g. the Fukushima nuclear accident in 2011) and the rebound effects (Binswanger, 2001), that is, a large amount of emission reduction is offset and even overcompensated by additional induced consumption due to technology development. Furthermore, compared to the main environmental concerns in the 20th century, such as water pollution, air pollution, and waste problems, which have been tackled well to some extent with incremental technological progress, global climate change is far more challenging in terms of scale and complexity, and thus calls for more fundamental and systematic changes in major human sectors such as energy, transportation, and buildings, covering both sides of production and consumption (Geels, 2013b).

However, system change is easier said than done because existing sectors are characterised by path dependence and lock-in (Åhman and Nilsson, 2008). Path dependence refers to the process in which future outcomes evolve as a consequence of its

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own historical choices. Path dependence does not imply that history determines present or future status, rather, it emphasises that:

> at each moment in historical time the suite of possible future evolutionary trajectories (paths) of a technology, institution, firm or industry is conditioned by (contingent on) both the past and the current states of the system in question. (Martin and Sunley, 2006:402)

In economics, path dependence can result from either technological 'lock-in' (David, 1985), dynamic increasing returns (Arthur, 1994), or institutional hysteresis (North, 1990). Dosi (1982) suggests that a particular technology is developed not only through the criteria such as feasibility (from a science perspective), marketability and profitability (from an economic perspective), but also through institutional factors that self-reproduce over time. As a consequence of path dependence, technology development follows particular technological paradigms that demonstrate a strong exclusion effect:

> The efforts and the technological imagination of engineers and of the organisations they are focussed in rather precise directions while they are, so to speak, "blind" with respect to other technological possibilities. (Dosi, 1982:153)

Established technologies are profoundly embedded in past socio-technical elements, such as user practices, infrastructures, complementary technologies, cultural meanings, institutional structures and policies (Rip and Kemp, 1998). The cumulativeness and path dependence of innovations discourage actors to look for opportunities outside their routines (Hoppe *et al.*, 2015). Consequently, existing sectors tend to experience incremental innovations, which are widely believed not sufficient to address current and future sustainability challenges (Markard, Raven and Truffer, 2012).

It is against this background that sustainability transition becomes a burgeoning field of research since the end of the 1990s. Sustainability transition entails not only the old technologies substituted by sustainable (or environmental) ones, but more importantly radical shifts in technology paradigms, including changes in markets, user practices, policy and cultural meanings (Geels 2004; Hoogma et al. 2005). The strength of

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sustainability transitions rests in analysing the co-evolution of these factors in a systemic perspective (Smith, Voß and Grin, 2010). So far, sustainability transitions research has yielded rich understandings of system changes in the main human sectors, especially in energy (e.g.Essletzbichler, 2012; Faller, 2012; Bridge *et al.*, 2013; Ornetzeder and Rohracher, 2013; Rohracher and Spath, 2013; Laes, Gorissen and Nevens, 2014); transportation (e.g. Egbue and Long, 2012; Geels, 2012; Whitmarsh, 2012; Berggren, Magnusson and Sushandoyo, 2014; Sengers and Raven, 2015), buildings (e.g. Rohracher, 2001; Beerepoot, 2007; Gibbs and O'Neill, 2015), food (e.g. Cohen and Ilieva, 2015; Konefal, 2015), and water infrastructures (e.g. Tàbara and Ilhan, 2008; Binz and Truffer, 2009; Domènech and Saurí, 2010). These research works have investigated sectoral transitions at various spatial scales and examined multiple aspects of social-technical systems, including culture, civil society, policy, governance, and institutions. Meanwhile, sustainability transitions research has begun to exert influence on several European countries' policy agendas, such as the Dutch Transition Management (Kemp and Loorbach, 2006), the UK's Low Carbon Transition and the German Energy Transition (Energiewende). Some international organisations also have started to embrace transition approaches in facilitating innovations and addressing global environmental issues (UNEP, 2011; OECD, 2015).

One of the major criticisms of sustainability transitions research is its lack of a geographical dimension (Coenen, Benneworth and Truffer, 2012a; Lawhon and Murphy, 2012; Raven, Schot and Berkhout, 2012; Binz, Truffer and Coenen, 2014). In many accounts, space and scale are absent or poorly conceptualised, resulting in limited understanding about where sustainability transitions take place and why they occur in specific places and not others (Truffer and Coenen, 2012; Gibbs and O'Neill, 2014b). Although there has been a growing interest in studying sustainability transitions in various geographical contexts, the focus has mainly been on post-industrialised European countries (Markard, Raven and Truffer, 2012). It is of value to examine whether this European theory can maintain its theoretical purchase when applied to rapidly

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industrialising countries, which may have different pathways to sustainability (Berkhout, Angel and Wieczorek, 2009b; Murphy, 2015). In particular, research into so-called 'leapfrogging' suggests that developing countries may have latecomer advantages and thus environmental problems associated with urbanisation and industrialisation could be avoided by leapfrogging to cleaner technologies from the outset (Perkins, 2003). Despite that some transitions literature has paid attention to the developing Asian context (e.g. Bai *et al.*, 2009; Rock *et al.*, 2009; Hess and Mai, 2014; Quitzow, 2015), there is still little understanding about whether and how rapidly developing countries can take latecomer advantages to achieve sustainability transitions in the context of fast urbanisation and industrialisation (Lachman, 2013). In addition, the majority of transitions research has focused on the national level, while the role of cities and regions is relatively neglected (Späth and Rohracher, 2010; Bulkeley *et al.*, 2013). Moreover, in the literature that does address transition at the urban scale, the focus is on world cities or developed western cities, while the role of cities in less developed economies is overlooked. Since such cities may not have the resources that developed/world cities have to mobilise, Hodson and Marvin (2010) advocate that future research should pay more attention to transitions in developing country/less developed cities.

As a contribution to this agenda, this thesis applies a contrasting case study of the popularisation of solar thermal energy in two Chinese cities. As the world's largest developing economy and largest carbon emitter, China's transitions to renewable energies not only caters to its national sustainability objectives, but may also significantly contribute to combating global warming through mitigating carbon emission and exporting transition experiences. In spite of its rapid economic growth in the past few decades, China is confronted with massive environmental problems and energy issues, mainly as a result of the "high input, high consumption and high emission" mode of industrialisation and urbanisation (Zhang, 2005:4). Though having a relatively low level of per capita emissions, China has surpassed the United States as the world's largest carbon emitter since 2008 (World Climate Report, 2008). Moreover, energy security is

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gaining pervasive attention as China has become the world's largest energy consumer (IEA, 2010). To address these challenges, other than upgrading its industrial structure and encouraging clean technologies, China is committed to altering its coal-dominated energy mix by promoting the development of renewable energy. In 2009, China pledged to reduce its carbon intensity by 40-45% by 2020 based on the level of 2005 and to increase the share of non-fossil sources of energy to 15% of its primary energy consumption. So far, China has been one of the world's leading countries in the renewable energy industry with the largest installed capacity in hydropower, wind, photovoltaic (PV) and solar heating in the world (REN21, 2015). In particular, China's production and consumption of solar thermal energy accounted for approximately 80% and 67% respectively of global capacity in 2012 (Mauthner and Weiss, 2014). Solar thermal energy has been applied in industry for heating, cooling and drying, but the most common usage is for solar water heaters (SWH) for residential and commercial use. A number of cities and regions have become the main manufacturing bases of China's solar thermal industry, but they show considerable differences in their adoption levels of solar thermal energy.

This research focuses specifically on the development of the solar thermal industry in Dezhou, but meanwhile, uses the case of Beijing as a contrast to make more sense. Compared with Beijing, Dezhou is a latecomer in industrialisation and urbanisation, but it has become a pioneer in solar thermal utilisation. Dezhou has an SWH cluster of national importance and an SWH installation rate[1] of 75.4% (Li *et al.*, 2011). These achievements led to Dezhou being designated both as China's Solar City and receiving wider international environmental recognition. Despite local developments in technology and installation, Dezhou has important links with Beijing, the technology centre of China's solar thermal industry. Both China's flat-plate and evacuated tube technology originated in Beijing, and Dezhou's SWH cluster has benefited substantially from Beijing's technology spillover. However, despite Beijing's key role as a centre of technological development and possession of a pioneering solar thermal industry cluster

[1] SWH installation rate refers to the percentage of households installing SWH in a place.

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in China, the market penetration of solar thermal energy is much lower - in Beijing's urban area, the SWH installation rate was less than 7% in 2009.

Drawing upon the multi-level perspective (MLP) framework (Geels, 2002), the primary objective of this study is to use an empirical analysis of the adoption of solar energy technologies by Chinese cities as a lens for investigating the dynamic and diversified relationships between regime and niche in sustainability transitions, thereby also pushing forward theoretical understanding of this key relation beyond existing literature and its various limitations (e.g. regarding questions of geography-place, scale, space and the city- and power).

This introduction starts by introducing the main transition theoretical framework MLP and existing research gaps, justifying my proposed framework to incorporate insights from economic geography and leapfrogging research in studying sustainability transitions in less developed cities and regions. It then proceeds to elaborate on the research objectives and research questions of this thesis. Section 1.4 illustrates the research design, including analysis framework and methodology. The structure of the thesis is outlined in the last section.

1.2 Theories and research framework

A sustainability transition is a "long-term, multi-dimensional, and fundamental transformation towards more sustainable modes of production and consumption" (Markard, Raven and Truffer, 2012:955). Rather than modifying existing products or adopting end-of-pipe technologies, a sustainability transition is a shift of the deep structure of one system to another (Geels, 2011). Sustainability transitions research aims to understand how to unlock the highly institutionalised and mutually reinforcing processes in existing systems, and create path-breaking transformations towards more sustainable systems (STRN, 2010). It is thus vital to understand how environmental innovations develop and how they challenge, reconfigure and replace established

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unsustainable systems. So far, two conceptual frameworks: the multi-level perspective (MLP) (Rip and Kemp, 1998; Geels, 2002) and technological innovation systems (TIS) (Jacobsson and Johnson, 2000; Bergek *et al.*, 2008), have been well elaborated in transition studies. The present thesis mainly resorts to the MLP approach, which is believed to have more consideration of the broader social, cultural and political factors that shape socio-technical transitions (Truffer and Coenen, 2012).

The MLP conceptualises transitions as shifts from one socio-technical configuration to a new one through the interaction of processes at three levels: landscape, regime and niche. The regime is the central concept in socio-technical transitions, referring to the "semi-coherent set of rules that orient and coordinate the activities of the social groups that reproduce the various elements of socio-technical systems" (Geels, 2011:27). In addition to formal, normative and cognitive rules, a regime is also comprised of material and technical elements and networks of actors and social groups (Verbong and Geels, 2010). A regime is characterised by path dependence and lock-in as a result of "a logic and direction for incremental socio-technical change along established pathways of development" (Markard, Raven and Truffer, 2012:957). A niche is a 'protected space' where path-breaking radical innovations emerge to challenge the incumbent regime (Rip and Kemp, 1998). Niches function as incubators, protecting new technologies from the selection pressure of existing systems. Niches are the seeds for transitions by possessing the potential to substitute existing technologies, alter user practices and change institutional structures, leading to a new regime, but they may also fail to survive in a harsh selection environment. Finally, the landscape is the collection of external factors which affect the dynamics of niches and regimes, but is unlikely to be influenced in reverse in the short run (Rip and Kemp, 1998). Changes in the landscape level are a major source of tensions in embedded regimes. Geels (2013:15-16) depicts the temporal transition processes from the interactions within and between the three levels:

> Niche innovations build up internal momentum through co-construction of heterogeneous elements in a stable configuration, through learning process

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> and price/performance improvements, and through support from powerful groups; changes at the landscape level create pressure on the regime; destabilisation of the regimes creates windows of opportunities for niche innovation.

The three levels refer to different degrees of stability, with niche being the most dynamic and landscape the most stable (Geels, 2011). The MLP provides a robust framework in delineating sustainability transitions through its ability to order and simplify the analysis of complex and large-scale system transformations (Smith, Voß and Grin, 2010).

One of the criticisms of the MLP is its treatment of space and scale (Späth and Rohracher, 2010; Raven, Schot and Berkhout, 2012). So far, little understanding has been developed about where transitions take place, why transitions unevenly unfold, or how the transition process could be shaped by spatial contexts (Gibbs and O'Neill, 2014b). Much MLP research treats space merely as a passive territorial container where niche, regime and landscape interact, risking reaching "oversimplified conclusions on isolated 'success factors' and 'barriers' that cannot be taken out of context" (Coenen, Benneworth and Truffer, 2012:970). Differences and linkages between scales are often overlooked, and the fact that localised activities and resources are subject to external pressures could be neglected if the relations between scales are ignored in the analysis. Therefore, Coenen and Truffer (2012) advocate that the MLP approach should focus more explicitly on territorial embeddedness and multi-scalarity. By contextualising territorial specificities, such MLP analysis will help to address the questions why environmental innovations are performing differently in different geographical settings and whether success in certain localities can be upscaled into mainstream regime practice. Also, more emphasis on multi-scalarity will help to explain global and trans-local dynamics and reveal how local actors and resources grow with their networks across scales (Murphy, 2015; Truffer, Murphy and Raven, 2015).

Concurring with Hansen and Coenen (2015), this thesis believes that the current contributions in the geography of transition primarily focus on the niche innovations in

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various spatial contexts while less attention has been paid to how regimes respond and how the variance of regimes across space contribute to the differences of the transition process. So too have niche-regime relations been neglected, as too much emphasis has been given to the bottom-up niche processes. Though the notion of regime conveys high homogeneity, there exist significant variations of regime structure between nations as well as between cities and regions (Späth and Rohracher, 2012). This thesis is concerned with two particular aspects of the geography of transitions – the potential for environmental innovations to 'leapfrog' in developing countries and the role of latecomer cities in sustainability transitions (Figure 1.1).

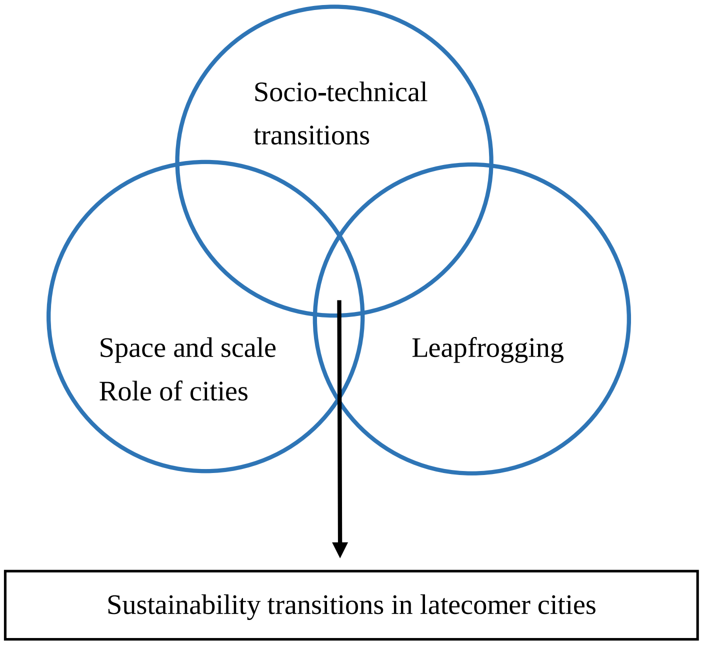

Figure 1.1 Research gaps identified in this research

First, linking leapfrogging analysis with a socio-technical transition perspective is believed to contribute to the emerging 'geography of transitions' literature (Binz *et al.*, 2012). Leapfrogging research implies the possibility that environmental problems in latecomer countries could be avoided by leapfrogging to more advanced and cleaner technologies from the outset (Perkins 2003; Goldemberg 1998). Latecomers do not necessarily follow the product life circle path of technology development. Instead, they

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may jump over some stages of technology development and even create their own individual pathways (Lee and Lim, 2001). Developing countries enjoy several latecomer advantages that may enable them to bypass the 'dirty' stage of economic growth through the use of cleaner production paradigms (Perkins 2003). While developed countries have largely been locked-in by existing less efficient technologies due to the non-recoverability of sunk investment, developing countries have yet to install significant capacity, allowing them to choose between new sustainable technologies. Path dependencies that lead to particular regimes in developed countries may not exist or are much weaker in latecomers since their infrastructures have not been fully established (Binz and Truffer, 2009). Another source of latecomer advantage is the so-called learning investment (Perkins and Neumayer, 2005). Developed countries bear the cost and risk of failure in the early stage of new technologies while developing countries take advantage of this accumulated learning to diffuse the innovations faster and at less cost. Lessons from forerunners can guide latecomers by means of both technology innovation and shared experience (Iwami, 2005).

Second, neither the transition nor the leapfrogging literature gives enough attention to the role of cities and regions. Transition studies have focused on the national level because cultures, infrastructures, regulations and institutions are mostly believed to be national phenomena (Geels, 2013b). Transitions approaches have said little about cities and whether the MLP can help to understand urban social-technical transitions (Hodson and Marvin, 2010; Mans and Meerow, 2012b). However, the current challenge of sustainability at the global scale can be substantially affected by urban transition processes. Focusing on the urban scale allows the development of sustainable demonstration policies and initiatives to be up-scaled to wider spatial scales. Cities can not only provide seedbeds for niche experiments (Geels, 2013b), but also:

> appear to bridge the niche-regime and provide 'social context' to integrate and implement socio-technical configurations which differ from the dominant regime and may be important for long-term transition processes (Späth and Rohracher, 2012:475).

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Hodson and Marvin (2010) argue that the proximity between actors, networks and places at the city scale makes it more likely to achieve low carbon transitions than at the national level. Geographic proximity enjoyed by the urban and regional scale facilitates the creation of social ties and network formations that are necessary for niche development (Coenen, Raven and Verbong, 2010). For instance, the growth of clean-tech clusters often requires knowledge transfer in various forms, such as employee mobility, entrepreneurial spin-offs and social networking with related industries, all of which have a bias toward the local scale (Boschma, Minondo and Navarro, 2013). Nonetheless, the extra-local relations with distant places and actors that contribute to local transition dynamics through the flow of knowledge, resources and technologies, should not be downplayed (Binz, Truffer and Coenen, 2016).

Despite the increasing interest in sustainability transitions at the urban level (Bai, Roberts and Chen, 2010; Späth and Rohracher, 2014b; Moloney and Horne, 2015; Affolderbach and Schulz, 2016), the role of smaller cities and less developed cities has been neglected. Large world cities have political aspirations to develop purposive system transitions, but what happens in cities that cannot mobilise similar resources? (Hodson and Marvin, 2010). While the major cities obviously have more impact on global environmental problems, small cities may also play a significant role as places of test-beds and experiments for new technologies or governance if some preconditions are met (Späth and Rohracher, 2010). Less developed cities do not necessarily have to grow to be technological innovation centres, but may provide supportive frameworks for the broad application of new sustainable technologies. Moreover, high-tech solutions such as solar PV and wind turbines have been the dominant focus of low-carbon transition in many countries, while the role of low-cost and low-tech alternatives is usually underrated (Tyfield, Jin and Rooker, 2010). High-tech innovations are undoubtedly important for low-carbon development, but the comparatively cheaper but 'good enough' low-tech innovations are also of global significance in sustainability transitions (Tyfield and Jin, 2010). These innovations not only are more affordable and thus available to the larger population of

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the world, but also could be ‘disruptive’ by redefining technologies and setting novel development paths (Christensen, 1997). In this respect, latecomer cities may enjoy a better position than developed cities in such transitions, since they usually face less resistance from incumbent actors or established technologies and meanwhile have more preferences to inexpensive low-carbon innovations.

1.3 Research objectives and questions

The leapfrogging literature has argued that regimes tend to be less ordered and stable in latecomer countries than developed countries because they are undergoing economic, social and demographic transformations, and their institutional and governance capacities have yet to be settled (Berkhout, Wieczorek and Raven, 2011). It is reasonable to assume that this principle may also be applied to the urban scale within a nation. As Raven *et al.*, (2012) argue, regimes can either have transnational features or remain subnational in their spatial reach, rather than merely sticking to the national scale. This thesis contends that cities can represent their own regimes (Hodson and Marvin, 2010). For cities in the same country, their landscape factors tend to be similar at the national and global level, but the regime factors and niche factors within them vary. Sustainability transition in a city can be viewed as a power struggle between regime resistance (incumbents) and niche development (challengers). Sustainability transition has a higher potential to happen in cities characterised by weak regime resistance and strong niche development. Thus, a less developed but growing city may have great potential for environmental leapfrogging. Green niche innovations could be more empowered in less developed regions because they may coincide with local development in terms of regional competitiveness and economic benefits (Essletzbichler, 2012). These hypotheses are explored in more depth in the thesis through the analysis of the authors’ empirical work in Dezhou and Beijing, where the institutional structures and key actors in the two cities that have influenced the diffusion of SWH are investigated.

Moreover, the thesis also seeks to contribute to the growing literature of the geography of

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transitions (Hansen and Coenen, 2015). To this end, it is vital to understand how space and scale influence sustainability transitions. Institutional structure and actor networks, advocated in institutional economic geography and relational economic geography respectively, have provided fruitful understandings of the spatial unevenness of economic activities. This thesis attempts to draw insights from these two lines of economic geography and develop a more practical framework to understand the geography of sustainability transitions. The thesis will explore how spatial context conditions transition practice; what factors facilitate or hinder sustainability transitions; how less developed cities can leapfrog to environmental sustainability; and how scale matters in transitions? Specifically, the research objectives and questions of this thesis are presented below:

- Objective 1: To contextualise sustainability transitions in urban-industrial China.

  - Research Question 1: What are the institutional contexts of China's sustainability transitions?

- Objective 2: To explore the facilitating and obstructing factors of sustainability transition in latecomer cities.

  - Research Question 2: Why and how do sustainability transitions occur in certain cities?
  - Research Question 3: What is the role of latecomer cities in sustainability transitions?

- Objective 3: To draw insights from economic geography for theoretical development and policy implications.

  - Research Question 4: How do space and scale matter in sustainability transitions?

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1.4 Research design

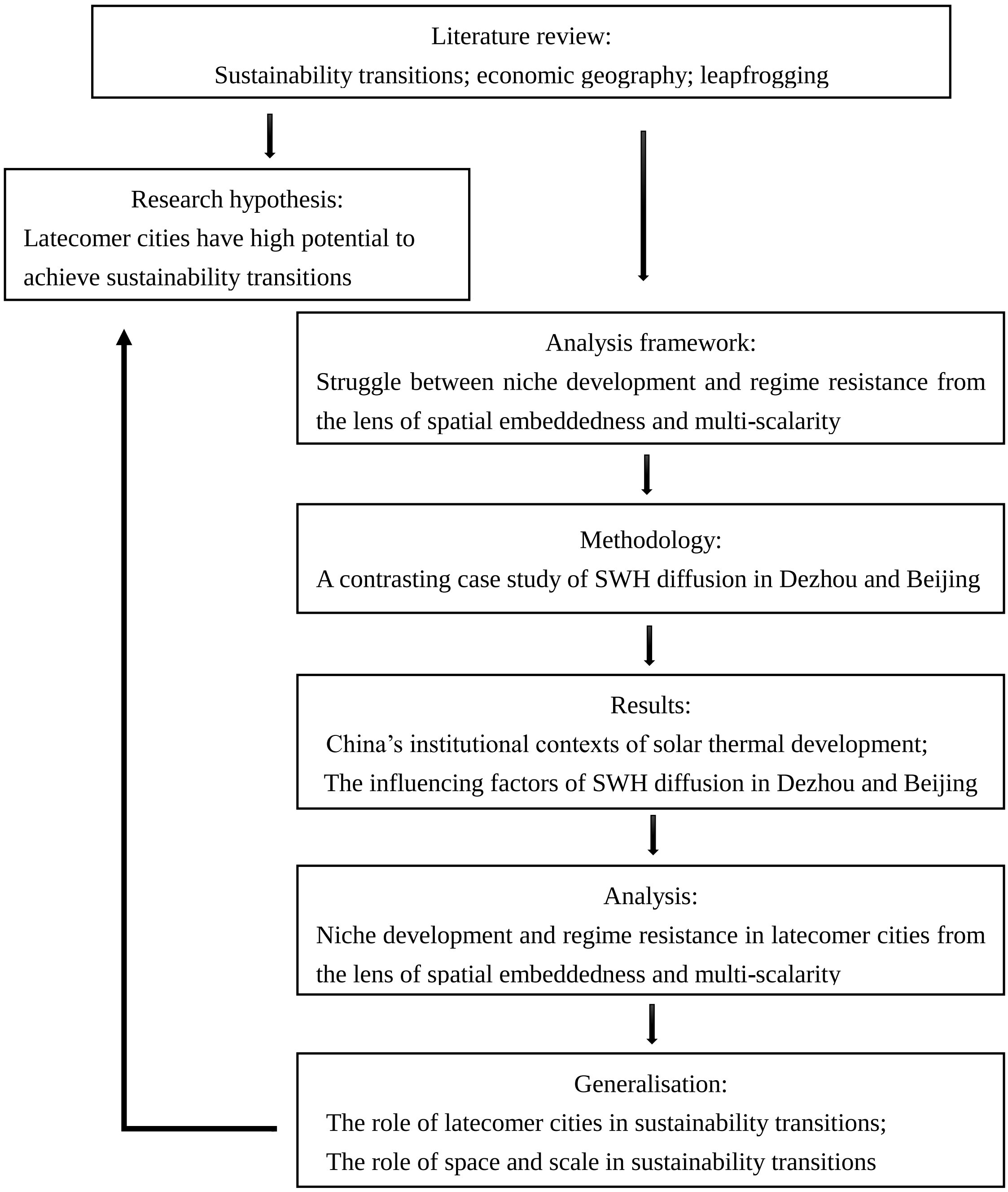

Figure 1.2 Research design of this thesis

Figure 1.2 illustrates the research design of this thesis. Based on an extensive literature review on sustainability transitions, economic geography and leapfrogging research, this thesis proposes to understand sustainability transitions as a power struggle between regime resistance and niche development. Using two contrasting cases of the

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development of solar thermal energy, the research will examine factors in both niche development and regime resistance in Dezhou and Beijing, as well as landscape factors at the national and global level. These factors are investigated through a qualitative methodology, including semi-structured interviews as the primary data source. The research results will display the institutional contexts of China's sustainability transitions, the social-economic contexts of Dezhou and Beijing, and the facilitating factors and obstructing factors of the development of solar thermal energy in each cities. Applying the analytical framework developed by this research, the thesis will analyse these results from a dynamic perspective of the interaction between niche development and regime resistance, both of which are understood through a geographical lens with a focus on spatial embeddedness and multi-scalar interactions. Hence, the thesis could contribute not only an interesting transition story of Dezhou, but also a more generalised implication about the role of less developed cities in sustainability transitions.

1.5 Structure of the thesis

Following this introduction, Chapter 2 provides a detailed literature review on sustainability transitions research. It introduces the four main theoretical frameworks in transition research and presents recent theoretical criticisms and developments. The identified research gap regarding the relative lack of a geographical perspective is elaborated. Drawing insights from economic geography and leapfrogging research, the chapter proposes a theoretical hypothesis concerning the role of less developed cities in sustainability transitions and a corresponding framework to analyse the empirical results.

Chapter 3 explains the methodology of investigating the sustainability transition in urban-industrial China, including philosophical bases, case selection, data collection and data analysis. The choice of each of the specific methods is justified and their limitations are identified.

Chapter 4 illuminates China's institutional contexts of the development of renewable

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energies in relation to its fast urbanisation and industrialisation. The focus is on the development of China's solar thermal energy. It summarises China's policy efforts in popularising the technology and exhibits the general problems and obstacles for this green technology in entering the urban market.

Chapter 5 reports the research results of why and how SWH popularisation has taken place in Dezhou but not to the same extent in Beijing. The factors influencing the SWH transition in Dezhou and Beijing are presented separately. Each case starts by introducing the geographical, social and economic contexts of the case study city, and then describes the facilitating and obstructing factors of SWH diffusion based on fieldwork. The relation between the two cities with regard to SWH development is also revealed.

Applying the developed analytical framework, Chapter 6 further analyses the empirical results in Dezhou and discusses the general role of latecomer cities in sustainability transitions. The discussion views sustainability transitions as the consequence of a power struggle between niche development and regime resistance, both of which are conditioned by place-specific contexts and multi-scalar interrelations.

Chapter 7 concludes the thesis by answering the research questions, summarising theoretical contributions to existing literature and suggesting practical implications for sustainability transitions in latecomer cities and regions. Lastly, the limitation of the research is reflected and avenues for future research are suggested.

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Chapter 2 Literature review and research framework

2.1 Introduction

This chapter aims to provide a more comprehensive literature review on sustainability transitions and leapfrogging, based on which the analysis framework for this research is proposed and justified. The chapter starts with introducing the concepts and characteristics of sustainability transitions in section 2.2. The next section elaborates the two main conceptual frameworks of technological innovation systems (TIS) and the multi-level perspective (MLP) in sustainability transitions research, and so are the two policy-oriented analysis frameworks, strategic niche management (SNM) and transition management (TM) introduced. The third section discusses researchers' studies on the question as to which factors facilitate or impede sustainability transitions. Following this, some criticisms and development of sustainability transitions research are presented and reviewed in section 2.4. Section 2.5 focuses on the growing body of work on the geography of transition studies and discusses how insights from economic geography could benefit existing transition studies. Section 2.6 provides a review of the leapfrogging research and section 2.7 specifically discusses the role of less developed cities in sustainability transitions, linking sustainability transitions with leapfrogging of latecomers. Finally, the theoretical framework is elaborated for this study and several suggestions for a future agenda are provided in the summary section.

2.2 Sustainability transitions

2.2.1 What is a sustainability transition?

The notion of transition was usually used in political economics before the 1990s, particularly as a way to depict the profound changes in some countries' economic and social systems. The collapse of the Soviet Union is deemed as a typical and significant transition from a planned economy to a market-oriented economy. The concept was then borrowed by other social sciences in the 1990s and socio-technical studies related the idea

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of transition with sustainable development to cater to the global environmental discourses of the time (Lachman, 2013), hence, the term socio-technical (sustainability) transition. A clarification between 'transformation' and 'transition' should be made. In the context of socio-technical transition, 'transformation' is now often seen as the phases or changes in small domains within 'transition' (Grin *et al.*, 2010; Pisano, Lepuschitz and Berger, 2014). As defined by Rotmans, Kemp and Asselt (2001:16), the transition is "transformation processes in which society changes in a fundamental way over a generation or more" or "a gradual, continuous process of change where the structural character of a society (or a complex sub-system of society) transforms". Transitions result from a set of connected changes that reinforce each other in different domains. A transition is generally composed of four different phases (Figure 2.1):

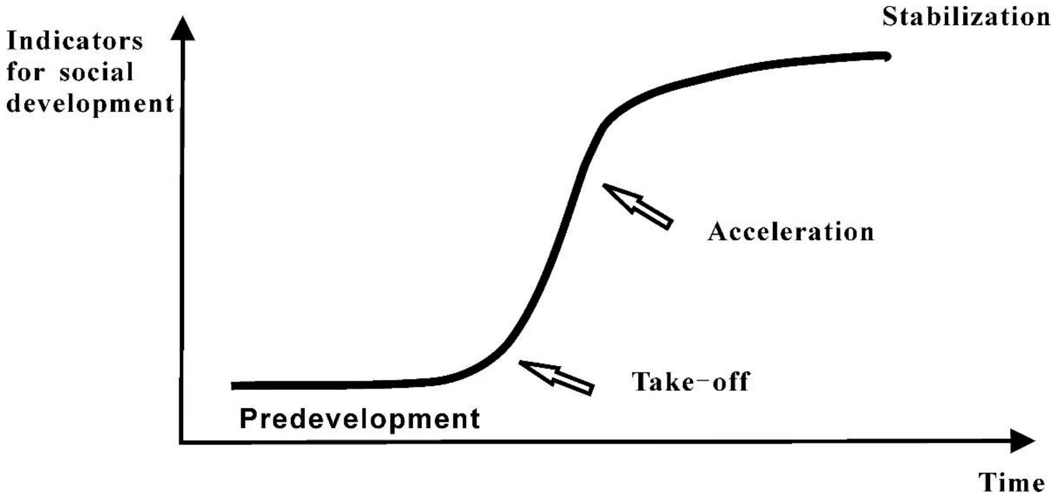

Figure 2.1 Four phases of a transition

Source: Rotmans, Kemp and Asselt (2001:17).

A) A predevelopment phase, the state of the system does not visibly change, remaining a dynamic equilibrium.

B) A take-off phase, the system begins to shift with changes in some domains.

C) A breakthrough phase, systematic change takes place as a result of the accumulation of socio-cultural, economic, ecological and institutional changes that react to each other. Collective learning, diffusion and embedding processes play important roles.

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D) A stabilisation phase, systematic change slows down and reaches a new dynamic equilibrium.

Socio-technical transition theory derives from a variety of disciplines such as evolutionary economics, innovation study, environmental economics and complex theory. A product or technology is viewed as a socio-technical phenomenon rather than a single artefact because it is highly interrelated with the social, economic and political contexts. Sectors such as energy, transport, and housing can be regarded as socio-technical systems, which consist of a set of actors (e.g. users, firms, policy makers), networks and institutions (e.g. norms, regulations), as well as material artefacts and knowledge (Geels, 2002; Markard, 2011). Geels's (2002) illustration of socio-technical configuration in personal transportation is a typical example (Figure 2.2). These system components are intensively interacting with and depending on each other, and if one of them is removed or changes, the other elements will change their characteristics accordingly (Hughes, 1987). A new technology, no matter how advanced it is, would not be widely accepted without the corresponding changes in user practices or institutions in favour of it. Therefore, a socio-technical transition means a fundamental changing process in socio-technical systems (Kemp, 1994). It entails radical changes in various system elements, including technologies, user practices, institutions, organisations, policies, and cultures, as well as the relations between them. As one of these elements shifts or is substituted by an emerging one, the induced tensions will cause pressures on other system elements to change consequently. If the pressure is pressing enough, the system may be transformed or reconfigured. Hence, the socio-technical transition is the co-evolutionary process of these system elements, and no actors have sufficient resources unilaterally to enable systems shift (Smith, Stirling and Berkhout, 2005).

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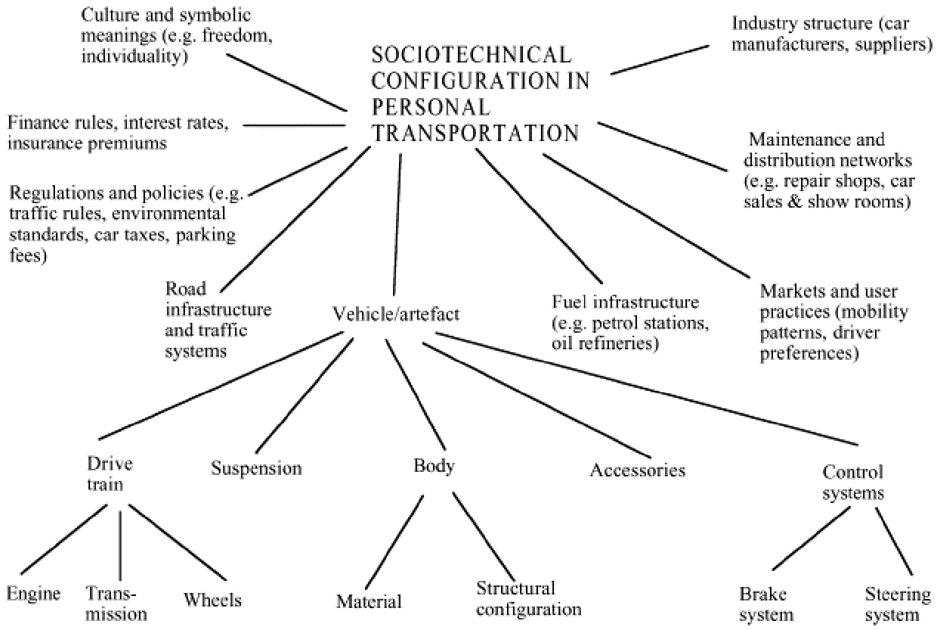

Figure 2.2 An example of socio-technical configuration

Source: Geels (2002:1258).

Apparently, a socio-technical transition emphasises the innovation of systems rather than changes in innovation systems. Smith, Voß and Grin (2010) provide convincing logics of broadening the perspective from innovation studies to socio-technical transition. First, as environmental and societal problems become increasingly challenging in human society, the purposes and outcomes of innovation no longer rest solely in economic concerns, there are needs to broaden its problem framing from the focus on promoting cleaner technologies towards innovating entire systems of production and consumption. Second, as the problem framing is broadened, so is the analytical framing, that is, "the set of considerations used to explain the emergence and success of innovation" (Smith, Voß and Grin, 2010:436). The analytical focus gradually shifts from end-of-pipe technologies at the firm level to cleaner production process across the lifecycle at the sector level (e.g. industrial ecology), to environmental economics (mainly advocating the internalisation of environmental externalities in product costs and prices), to greener innovation systems (recognising the role of institutions and networks in facilitating environmental innovations), and eventually to a system innovation perspective. System innovation implies:

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> the renewal of a whole set of networked supply chains, patterns of use and consumption, infrastructures, regulations, etc., that constitute the socio-technical systems which provide basic services such as energy, food, mobility and housing. (Smith, Voß and Grin, 2010:439)

The innovation system is concerned with the promotion of environmental goods and service into markets while the socio-technical transition aims to realise its 'societal functions'. The socio-technical transition towards sustainability is called a sustainability transition: a "long-term, multi-dimensional, and fundamental transformation process through which established socio-technical systems shift to more sustainable modes of production and consumption" (Markard, Raven and Truffer, 2012:956). It appeals for radical changes in human society's essential technologies of production, transport, and consumption (Kemp, 1994).

According to Geels (2011), some features of sustainability transition distinguish it from historical technological transitions. First, as sustainability and environmental aims mainly address public well-being, there are limited incentives for private sectors to commit to sustainability transitions. Therefore, sustainability transitions are usually purposive (Smith, Stirling and Berkhout, 2005) and public authorities and civil society will play the leading role (Elzen *et al.*, 2011). Second, the change in economic framework conditions, such as taxes and subsidies, is an indispensable part of sustainability transitions, because most sustainable solutions do not offer users direct economic benefits, and are often not able to compete with existing technologies in performance-price ratio. Third, sustainability transitions are most needed in some empirical sectors (e.g. transport, energy and housing). They are often characterised by large firms, who possess a lot of resources and powers but are less willing to take the initiative to achieve sustainability transitions. These features imply the multi-dimensional aspects of a sustainability transition. Though sustainability transition is of high societal relevance, it is a field of great complexities, as it involves large numbers of heterogeneous actors and interests in transition process (Markard, Raven and Truffer, 2012). The transition process is constantly accompanied by conflicts between winners and losers, as well as the shift in economic and political power.

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These conflicts can be either positive in opening up new pathways or counterproductive and even destructive (van den Bergh, Truffer and Kallis, 2011).

The last decade has witnessed the growth of sustainability transition as an emerging research field (Coenen and Truffer, 2012; Markard, Raven and Truffer, 2012; Lachman, 2013). This is demonstrated not only in the increasing publications of sustainability transitions in relevant journals (e.g. Research Policy, Technological Forecasting and Social Change, Journal of Cleaner Production, and Energy Policy) but also in its high impact in the academic community in terms of citations and attentions (see Markard *et al.*'s (2012) quantitative survey of sustainability transitions papers). Furthermore, there is an increasing number of scholars from various disciplines joining and contributing to the sustainability transitions community, particularly from innovation study, economics, public policy, geography, and sociology, etc. The Sustainability Transition Research Network (STRN, established in 2010), the International Conference of Sustainability Transition (IST, since 2009), and the new journal titled 'Environmental Innovations and Societal Transition' (EIST, launched in 2011) have been the three pillars of the sustainability transition research community. Besides the debates and progresses in conceptual approaches (e.g. Markard & Truffer 2008), sustainability transitions research has provided abundant empirical cases of radical changes in sectors such as energy, transport, food, housing and infrastructure (Markard, Raven and Truffer, 2012). Due to its strength in dealing with complex socio-technical changes, sustainability transition is not only being embraced by increasing number of academic researchers but also exerting growing influence on policy agendas at different governance levels.

2.2.2 Conceptual frameworks on transitions

According to the classification by Næss and Vogel (2012), there are three lines of research focus in transition theory. The first line of transition theory focuses on ex-post studies of historical transitions that usually span decades. As an influential representative of this line, Geels (2002; 2005; 2006) has interpreted several historical transitions from the

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multi-level perspective, such as from sailing ships to steamships (1780-1900), surface water to piped water and personal hygiene (1870-1930), and cesspools to integrated sewer systems in the Netherlands.With his colleagues, Geels also developed a typology of transition pathway to characterise different transitions (Geels and Schot, 2007; Geels *et al.*, 2015). The second direction in transition theory emphasises the complexity of societal systems and draws insights from complex systems theory to direct system dynamics towards sustainability (Loorbach and Rotmans, 2010). This perspective believes that historical transitions have often not led to a more sustainable society. Therefore, explicit normative orientations of sustainability are needed to foster sustainability transitions (Rotmans, Loorbach and Van der Brugge, 2005). Finally, represented by Smith *et al.*, (2005), the last line of transition theory attends to the governance perspective of transition, with more attention paid to power and agency that are missing in historical transitions analysis.

To promote sustainability transitions, it is critical to understand how environmental innovations develop and how they challenge, reconfigure or replace established systems (Geels, 2011). Therefore, the objective of sustainability transitions research is to understand how to unlock the highly institutionalised and mutually reinforcing processes in existing systems and create path-breaking transformations towards more sustainable systems (STRN, 2010). So far, two conceptual frameworks: the multi-level perspective (MLP) (Rip & Kemp 1998; Geels 2002; Geels 2004) and technological innovation systems (TIS) (Jacobsson and Johnson, 2000; Bergek *et al.*, 2008; Markard and Truffer, 2008), and two policy-oriented frameworks: transition management (TM) (Rotmans et al. 2001; Rotmans et al. 2005; Loorbach & Rotmans 2010) and strategic niche management (SNM) (Kemp, Schot and Hoogma, 1998; Smith, 2007), have been well elaborated in transition studies. The MLP provides a powerful framework in delineating sustainability transitions through its ability to order and simplify the analysis of complex and large-scale system transformations (Smith, Voß and Grin, 2010). Compared to MLP, TIS is more concerned with emerging technological innovations, but weaker in considering the

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broader social, cultural and political factors that shape socio-technical transitions (Truffer and Coenen, 2012). Given the focus of this research on the broader political and economic structures in China, I will mainly discuss the development of the MLP while giving brief introductions to TIS, TM and SNM as comparisons in the following section.

2.2.2.1 MLP

(1) Regime

The MLP conceptualises transitions as shifts from one socio-technical configuration to another through the interaction of processes at three levels: landscape, regime, and niche (Geels, 2002). Originating from evolutionary economics (Nelson and Winter, 1977), the regime is the key concept in socio-technical transitions. Rip and Kemp's (1998:338) seminal work defines a technological regime as:

> …the rule-set or grammar embedded in a complex of engineering practices, production process technologies, product characteristics, skills and procedures, ways of handling relevant artefacts and persons, ways of defining problems—all of them embedded in institutions and infrastructures. Regimes are intermediaries between specific innovations as these are conceived, developed and introduced, and overall sociotechnical landscapes.

Subsequently, the technological regime concept is extended to the socio-technical regime, which is a “semi-coherent set of rules that orient and coordinate the activities of the social groups that reproduce the various elements of socio-technical systems” (Geels, 2011:27). Note that the term regime is used rather than paradigm or system because it also refers to rules. The system refers to tangible and measurable elements while a regime implies intangible and underlying deep structures, such as beliefs, routines, paradigms, visions, social expectations and norms (Geels, 2011). Verbong and Geels (2010) identify three dimensions of socio-technical regimes: a) material and technical elements (e.g. resources and infrastructures); b) networks of actors and social groups (e.g. producers, industrial users, and households); and c) formal, normative and cognitive rules (e.g. regulations, belief system, guiding principles and behaviour norms). Smith and Raven (2012) also

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summarise six dimensions of the regime, exerting different selection pressures on path-breaking innovations (Table 2.1).

Table 2.1Main regime dimensions

Regime dimension	**Selection pressures**
Industry structure	Organisational networks, industry platforms, user-producer networks, shared industry routines, labour force, capabilities, etc.
Technologies and infrastructures	Technical standards, infrastructural requirements, etc.
Knowledge base	Formal research programs and groups, review procedures and preferences of established journals, paradigms, etc.
Users relations and markets	Market rules and institutions, user practices and preferences
Public policies and political power	Administrative regulations, policy goals, power relationships, policy guiding principles, etc.
Cultural significance and associations of the regime	Media laws and preferences, symbolic meanings of technologies, cultural value of innovation, etc.

Source: Smith and Raven (2012:1028).

A regime is characterised by path dependence and lock-in as a result of "a logic and direction for incremental socio-technical change along established pathways of development" (Markard, Raven and Truffer, 2012:957). These pathways occur in the interaction of sub-regimes, such as technology, culture, policy, market, science etc., which have their own dynamics and co-evolve with each other. Regimes contain coherences, shared values, and similarities on the one hand, but also varieties, disagreements, debates, and internal conflicts on the other hand (Geels, 2011). The main concern in sustainability transitions research is how to destabilise or reconfigure existing regimes towards the sustainable ones.

(2) Niche

A niche is a 'protected space' where radical innovation emerges for path-breaking from the incumbent regime (Rip and Kemp, 1998). Niches function as incubators, such as R&D laboratories, specific market segments, and demonstration projects, protecting new

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technologies from the selection pressures of existing systems (Kemp, Schot and Hoogma, 1998). There are three key processes in niche development: a) articulation of expectations and visions; b) social networking of heterogeneous actors; and c) social learning and articulation processes (Kemp, Schot and Hoogma, 1998; Geels and Raven, 2006). Through these processes, niche innovations may develop enough momentum to challenge the established regimes. Therefore, niches are the seeds for the transition by possessing the potential to substitute current technologies, alter user practices and change institutional structures, leading to a new regime, but they may also fail, which is more often expected.

Smith and Raven (2012) argue that the successful up-scaling of niche innovations consists of three types of processes: shielding, nurturing and empowering. Shielding is the process providing a bay where regime selection pressures are held off so that niche innovations can be further developed. This can be achieved through either providing passive space, i.e. generic space pre-existing deliberate mobilisation, or creating active space, i.e. deliberately created space by advocators to avoid selection pressure from the regime. Nurturing refers to the process that sustains the development of niche innovations. They emphasise the role of empowering process, in which niche innovations gain competitiveness in uncertain selection environments (empowering to fit and conform) or restructure prevailing selection environments to facilitate their growth (empowering to stretch and transform). There is an iterative relationship between the three processes:

> initial, passive protection enables early nurturing of the innovation, whose promise (if successful) empowers niche advocates to obtain more active protective measures, that assist in further nurturing, greater empowering, and eventually the institutionalisation of the innovation within a transformed selection environment. (Smith and Raven, 2012:1034)

This bottom-up perspective has triggered the development of the approach of strategic niche management (SNM), which aims to promote regime shift through deliberate creation and support of niches (Kemp, Schot and Hoogma, 1998).

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Divisions have been made between the market niche and technological niche (Schot and Geels, 2007). A market niche is the new application domain that is isolated from the mainstream market so that innovations can be implemented. It can be further divided into two types, the ones shielded or isolated from the incumbent socio-technical regime, and the ones operating within the regime. The isolated market can be achieved in the form of cognitive, social and spatial distance, e.g., in specific social groups or particular geographical areas. A technological niche is created based on the promise of future viability when market niches do not exist. New inventions keep being experimented with and developed in the protected space until they can compete or survive in the mainstream market. Since no market may currently exist, the government is often heavily involved for the perceived societal and collective aims or projected future demands. The replacement of the established regimes can be seen in two aspects: the stability of rules in niches, and the scale of niche, i.e., the population using the rules. Rules in market niches, either those within the regime or those isolated from the regime, tend to be stable, while those in technological niches are highly contested. Judging from whether the niche is internal or external to a regime, and whether rules operating in niches are stable or not, four types of niches are defined by Schot and Geels (2007): a) internal market niche: high stability and low protection/isolation from the regime; b) external market niche: high stability and high isolation; c) technological niche: low stability and high isolation; d) breakthrough niche: low stability and low protection. All these types of niche possess the potential to become new regimes.

(3) Landscape

The landscape is the collection of external factors which affect the dynamics of niches and regimes but are unlikely to be influenced in reverse in the short run (Rip and Kemp, 1998). Geels (2002:1260) defined landscape as a "set of heterogeneous factors, such as oil prices, economic growth, wars, immigration, broad political coalitions, cultural and normative values, environmental problems". The landscape is characterised by slow changes in the early MLP literature, but actually, the landscape can be more dynamic.

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Van Driel and Schot (2005) exemplify three types of landscape dynamics: a) factors that do not change or that change very slowly, such as physical climate; b) rapid external shocks, such as wars and financial crisis; and c) long-term changes in a certain direction, such as economic growth and population growth. For instance, growing environmental awareness is widely considered as a landscape process, causing pressures to existing unsustainable regimes, while creating opportunities for green niche innovations to develop from the bottom (Berkhout, Smith and Stirling, 2004). Nonetheless, the landscape can also sustain existing regime trajectories at times (Smith, Voß and Grin, 2010).

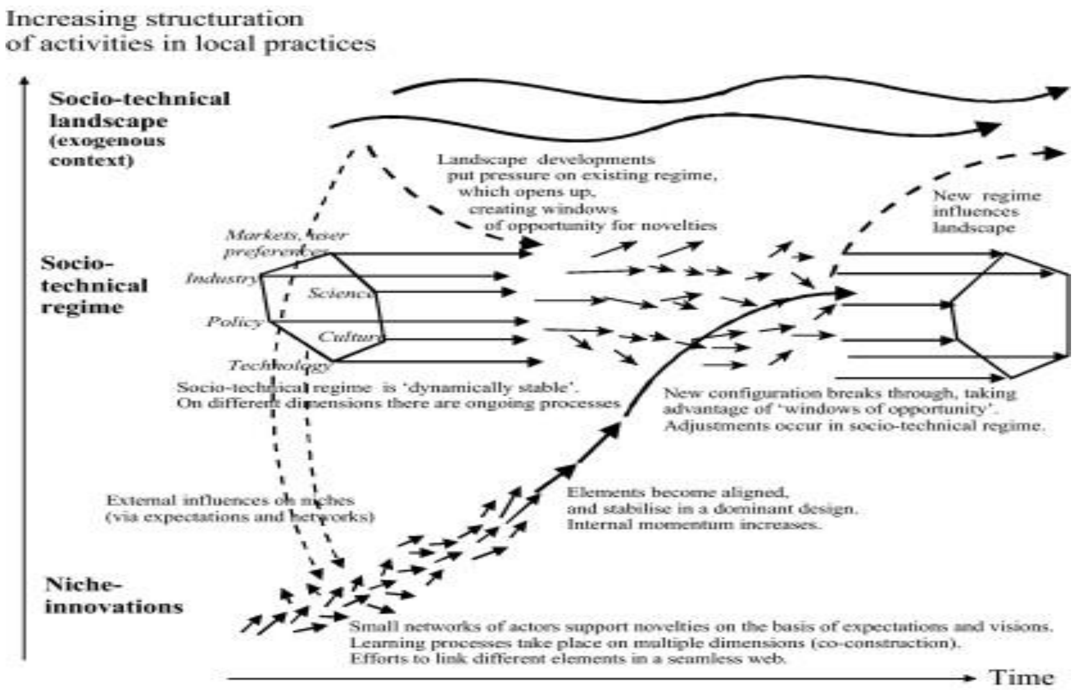

Figure 2.3 Multi-level perspective on socio-technical transition

Source: Geels (2011:28).

Changes at various levels alone are insufficient to bring transitions, vertical linkages and interactions between levels are essential (Bai *et al.*, 2009). A socio-technical transition happens when a) landscape changes exert pressure on regime and meanwhile provide legitimacy to niche activities; b) regimes destabilise as conflicts emerge within, creating windows of opportunities for niche innovations; and c) niche innovations gain momentum

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to challenge and replace regimes through articulating expectations, social learning, and mobilising heterogeneous actors (Geels, 2011) (Figure 2.3).

The MLP is believed to be a robust framework in delineating sustainability transitions because it "provides a relatively straightforward way of ordering and simplifying the analysis of complex and large-scale structural transformations in production and consumption demanded by the normative goal of sustainable development" (Smith, Voß and Grin, 2010:441-442). Other than successfully explaining many historical transitions (e.g. Geels, 2002; 2006; 2005; Turnheim and Geels, 2012), the MLP has been widely applied purposively to promote transitions in desired directions by assessing and diagnosing current ongoing transitions, such as the UK's low carbon policy (Kern, 2012), China's development of PV power generation (Liu and Shiroyama, 2013), and electric vehicles (EV) in Stockholm (Nykvist and Nilsson, 2015). The barriers and drivers of transition identified at the three conceptual levels (niche, regime and landscape) allow transition managers to consider the complex factors that are co-evolving and co-determining one another across macro-scale, meso-scale and micro-scale (Rock *et al.*, 2009). Furthermore, the framework has expanded from depicting sectoral systems to territorial systems, such as urban sustainability transitions (e.g. Næss and Vogel, 2012), which concern the system innovation of cities rather than simply in specific sectors.

(4) Transition pathway

The early MLP work has been criticised for placing too much emphasis on the role of technological niches in bringing regime transformation while ignoring the ongoing processes at the regime and landscape level (Berkhout, Smith and Stirling, 2004). In response to this, Geels and Schot (2007) developed the typology of transition pathways to differentiate the MLP by varying the timing and nature of interactions between levels, especially between niche innovations and landscape pressures. Given the same landscape pressure, the transition paths would be different between those with well-developed niches and those without. Four transition pathways are clarified:

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A) Transformation: moderate landscape pressure occurs when niche innovation is not fully developed; regime actors respond by reorientating their development paths and innovation activities.

B) De-alignment and re-alignment: sudden and large-scale landscape changes lead to the loss of faith among regime actors and, consequently, de-alignment among them; taking advantage of this opportunity, multiple niche innovations develop and compete until one of them dominates and leads to re-alignment of a new regime.

C) Technological substitution: the landscape exerts much pressure on regimes at the moment when niche innovation develops sufficiently; niche-innovations break through and replace the existing regime.

D) Reconfiguration pathway: well-developed symbiotic innovations are initially adopted by regime actors to solve local problems; subsequently, this incorporation causes further adjustments in the underlying architecture of the regime.

Table 2.2 Main actors and (inter)actions in transition pathways

Transition pathways	**Main actors**	**Type of (inter)actions**
Transformation	Regime actors and outside groups (social movements)	Outsiders voice criticism. Incumbent actors adjust regime rules (goals, guiding principles, search heuristics)
Technological substitution	Incumbent firms versus new firms	Newcomers develop novelties, which compete with regime technologies
Reconfiguration	Regime actors and suppliers	Regime actors adopt component-innovations, developed by new suppliers. Competition between old and new suppliers
De-alignment and re-alignment	New niche actors	Changes in deep structures create strong pressure on regime. Incumbents lose faith and legitimacy. emergence of *multiple* novelties. New entrants compete for resources, attention and legitimacy. Eventually one novelty wins, leading to restabilisation of regime

Source: adapted from Geels and Schot (2007: 414).

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Table 2.2 summarises the main actors and interactions in these transition pathways. These transition pathways are not exclusive to each other. Many transitions could be mixed with these pathways during the process because the status of landscape and niche innovation are both changing, so are the interactions between them, resulting in different pathways. For instance, Geels *et al.,* (2015) compare the low-carbon electricity transition in the UK and Germany (1990-2013) and find that the UK's renewable electricity development is dominated by incumbent actors while Germany's is characterised by new entrants. The UK's transition is found to be a mix between the 'transformation' and 'technological substitution' pathways, and the German transition mainly follows the ' technological substitution' pathway but also show features of the 'reconfiguration' and 'de-alignment and re-alignment' pathways.

2.2.2.2 SNM

New technologies often cannot compete against established technologies immediately because of the harsh selection environments and the technological problems themselves such as high cost and incompatibility with existing infrastructure. Mokyr (1990:291, cited in Schot and Geels, 2008) refers new technologies as 'hopeful monstrosities' because they enjoy a promising future on the one hand, but have a comparatively low performance at the moment on the other hand. It is particularly true for sustainable technologies, for instance, wind turbines and solar PVs, which cater to global environmental concerns but struggle to lower their cost and improve reliability so as to compete with conventional energies. Therefore, Strategic Niche Management (SNM) is introduced to realise the 'hopeful' potential of these innovations purposively (Kemp, Schot and Hoogma, 1998; Hoogma *et al.*, 2005). The SNM is defined by Kemp, Schot and Hoogma (1998: 186) as:

> the creation, development and controlled phase-out of protected spaces for the development and use of promising technologies by means of experimentation, with the aim of (1) learning about the desirability of the new technology and (2) enhancing the further development and the rate of application of the new technology.

In SNM, niches are not only the space protecting new technologies from the selection

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environment, but also the experimental arena for the co-evolution of technology, user practices and institutions (Schot and Geels, 2007, 2008). Rather than simply testing the viability of new technologies, SNM also aims to make institutional connections and adaptions for further development. Compared to a ‘technology push’ approach, SNM places emphasis more on the learning aspects of experimentation. It brings the knowledge and expertise of various actors into the technology development process and directs institutional changes in favour of the new technologies through an interactive process (Kemp, Schot and Hoogma, 1998).

The early SNM literature primarily focused on the internal process of niche development, addressing how technological niches can finally replace existing regimes. Three mechanisms of successful niche formation have been elaborated: the articulation of expectations and visions, learning process, and network formation (Kemp, Schot and Hoogma, 1998; Geels and Raven, 2006).

A) Articulation of expectations and visions. Positive expectations and visions are essential to the new technologies which face many uncertainties and resisting forces in their early development phase. Positive expectations create faith on new technologies’ promising future or perceptions of societal good among actors, and thus, more attention and resources are ‘pulled in’ to facilitate the technology development. Smith, Stirling and Berkhout (2005) identify five functions of visions: a) mapping a ‘possibility space’; b) a heuristic; c) a stable frame for target-setting and monitoring progress; d) a metaphor for building actor-networks and e) a narrative for focusing capital and other resources. Expectations and visions will be more influential in pushing niche formation if they are shared by more actors (more robust), based on facts and tests (more credible), with clear guidance (more specific), and coupled to certain societal goods (Kemp, Schot and Hoogma, 1998).

B) Learning process. It is not only about finding out the problems and possibilities of new

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technologies but also learning feedbacks and adaptions from multiple dimensions, including technical barriers, market and user preferences, cultural and psychological meaning, government policies, industry and production networks, infrastructure and maintenance, and societal and environmental effects. In addition to the accumulation of facts and data (i.e. first-order learning), the learning process could also contribute to niche development by enabling changes in cognitive frames and assumptions (i.e. second-order learning) (Hoogma, 2002, cited in Schot and Geels, 2008).

C) Network formation. Actors associated with established technologies are usually hostile to the rise of new technologies. Therefore, network formation around the new technologies with new actors (e.g. entrepreneurs) are particularly crucial for niche development. The network of interested actors will facilitate the interactions between stakeholders and mobilise necessary resources to help the new technology function in the desired way. To reach better outcomes, the network is expected to be both broad (i.e. involve multiple kinds of stakeholders and relative outsiders) and deep (i.e. have influential actors that can mobilise more resources within their own networks) (Hoogma, 2002, cited in Schot and Geels, 2008).

SNM's bottom-up process of niche formation provides a useful policy tool for real social experiments. The SNM literature has offered a clear guideline for interested stakeholders, particularly the governments, to manage the process through technological niche formation to market niche development and ultimately regime transformation. The suggested policy packages consist of five steps (Kemp, Schot and Hoogma, 1998): a) The choice of technologies; criteria for choosing promising technologies, such as, technological opportunities, economic returns, and organisational and institutional supports; b) The selection of an experiment; choosing a setting or space where the new technology could survive and its advantages are valued; c) The set-up of the experiment; suggested is to strike a balance between protection and pressure, neither too much protection nor pressure could bring desired experiment results; d) Scaling up the

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experiment; policy intervenes to support the experiments; e) The breakdown of protection; phase out protection when it is not necessary anymore.

Nevertheless, except for a few successful cases in actual pilot projects, SNM is not that useful as expected in pushing technology niches into market inches and ultimately regime replacement (Caniëls and Romijn, 2008). This might be explained by SNM's too great an emphasis on the internal process of niche development and its missing links with wider external processes (Schot and Geels, 2008). Niche formation is essential to technology substitutions, but it can hardly enable regime shift without broader changes at the regime and landscape level. In this respect, MLP is believed to function better in linking the internal and external processes of niche development (Schot and Geels, 2008).

2.2.2.3 TIS

Technological innovation system (TIS) is another conceptual building block of sustainability transitions research developed in the last two decades (Truffer, 2015), although there is an ongoing debate about whether TIS is useful for studying transitions (Markard and Truffer, 2008; Geels, 2011; Kern, 2015). Branching from the innovations system fields, TIS has focused on innovations in specific technological fields, which involve not only the micro level (e.g. technology, entrepreneurs, firms, and clusters) but also institutional and socioeconomic structures at the macro level. Carlsson and Stankiewicz's (1991) seminal work on technological system highlights the interaction of firms and other actors within particular institutional structures. They described a technological system as a "network of agents interacting in a specific economic/industrial area under a particular institutional structure and involved in the generation, diffusion and utilisation of technology" (p94). This system approach helps to understand why technology developments are often locked into relatively rigid technological trajectories because it emphasises that the rate and direction of technology changes are often determined by competition between various established systems, rather than competition between technologies (Hekkert *et al.*, 2007). Compared to the National Systems of

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Innovation (NSI) (Freeman, 1987; Lundvall, 1992), TIS is believed to involve a smaller number of actors, networks, and institutions on an aggregate level, making it less complex and thus, more useful for dynamic analysis (Hekkert *et al.*, 2007). Also, contrary to the regional or sectoral innovation systems approaches (Cooke, Gomez Uranga and Etxebarria, 1997; Malerba, 2002), TIS takes a specific technology as a starting point and emphasises that technology changes contain components across various geographical regions and sectors (Hekkert *et al.*, 2007).

The overall function of TIS is to develop, diffuse and utilise new technologies (products and services) and processes, through the interaction between its three structural components: actors, networks, and institutions (Bergek *et al.*, 2008). Actors of TIS range from private actors to public actors, from technology developers to technology adopters, including firms, regulators, financiers, universities, research institutes, associations, and consumers, etc. These actors do not necessarily share the same goal to promote a particular technology. Instead, there are often many conflicts and tensions among them that obstruct technology changes. Networks are the modes of transferring tacit and explicit knowledge. The information network may be conducive to identifying problems, finding solutions, and guiding the search, but may also constrain the actors' perception of other possibilities and other technology choices (Jacobsson and Johnson, 2000). Institutions in TIS are considered as the 'rules of the game', which can be distinguished between formal (or hard) institutions (e.g. law, regulations, and standards) and informal (or soft) institutions (e.g. norms, values, cultures and entrepreneurial spirit) (Smith, 2000). Another basic element of TIS is technological factors, including the features of artefacts (e.g. cost, performance, and aesthetics) and the infrastructure in which they are integrated (e.g. the charging stations for EVs).

The initial objective of TIS is to examine the performance of a particular technology field and discover the obstructing factors in the system so that policy recommendations could be made for improvement (Markard, Hekkert and Jacobsson, 2015). To this end, the

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earlier TIS literature has spent many efforts in identifying system imperfections or structural failures of TIS (e.g. Carlsson and Jacobsson, 1997; Smith, 2000). Klein Woolthuis, Lankhuizen and Gilsing (2005) reframe system failure frameworks and categorise them into four types: a) Infrastructure failure: for instance, underinvestment in R&D leads to the lack of physical and knowledge infrastructure. b) Institutional failure: this includes hard institutional failures (i.e. the formal institutions that hinder innovations) and soft institutional failures (i.e. the informal institutions such as political culture and social values). c) Interaction or network failure: a too strong network may lead to lock-in among main actors at the expense of new knowledge from other actors, while weak interaction prevents the cycle of learning and innovation. d) Capabilities failure: individual actors and firms lack the competencies and resources to adapt to new technologies. Identifying these structural failures is essential to effective policy interventions. However, as Bergek *et al.*, (2008) argue, it is difficult to assess a particular structural component without looking at its effects on the innovation process. Only by recognising its influences on the innovation process can we evaluate how ‘strong’ or ‘weak’ a structural element is.

Therefore, recent TIS literature has shifted the focus from system structures to innovation processes or functions, leading to more rich understandings of the dynamics of innovation systems. Among various contributions to the functional approach, Hekkert *et al.*'s (2007) and Bergek *et al.*'s (2008) identifications of system functions are probably the most influential ones. The main functions are:

A) Entrepreneurial experiments: entrepreneurs take risks to turn the potential new knowledge, networks, and markets into actions so that the reactions of the system can be learned.
B) Knowledge development: includes different types of knowledge (e.g. scientific, technological, market and production) through ‘learning by searching’ and ‘learning by doing’.

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C) Knowledge diffusion: the scale and intensity of networks affect how and to what extent knowledge is diffused.

D)Guidance of the search: the combined effect of visions, incentives, interests, expectations, and regulations etc., guides the selection of technologies towards particular directions.

E) Market formation: provide protected space (niche market) or incentive tax regimes for new technologies to compete with established technologies.

F) Resource mobilisation: financial and human capital, as well as complementary assets that are available to be used.

G)Legitimation: actors and institutions are allied to create legitimacy for new technologies to overcome their liability concern.

These functions are interdependent with each other. The fulfilment of a particular function usually involves the fulfilment of other functions. For instance, entrepreneurial activities require a certain knowledge base and resource mobilisation, and they can be motivated by market formation, legitimacy and expectations. A strong function fulfilment (e.g. an explicit guidance of search on renewable technologies by regulations) may induce a virtuous cycle among other functions, while poor performance of one function may also lead to a vicious cycle of the system functions (Hekkert *et al.*, 2007).

TIS has been widely used by transition scholars and contributes to a systematic understanding of the emergence of environmental innovations, renewable energy technologies in particular (e.g. Jacobsson and Bergek, 2004; Dewald and Truffer, 2012; Bento and Fontes, 2014; Palm, 2014; Wieczorek, Raven and Berkhout, 2015). The function approach has been a useful tool to assess TIS and locate system weaknesses, thus, effective policy interventions could be suggested to address them (Jacobsson and Bergek, 2011; Markard, Hekkert and Jacobsson, 2015). Nonetheless, TIS is also subject to some criticisms, such as lack of attention to context factors (Markard and Truffer, 2008; Bergek *et al.*, 2015), a missing spatial and geographical perspective (Coenen and Truffer,

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2012; Binz, Truffer and Coenen, 2014; Hansen and Coenen, 2015), and insufficient attention to agency and politics (Kern, 2015). Due to its bias towards system structures, TIS offers little understanding about what drives changes, and the evolution of functions. If these shortcomings are not addressed, TIS may remain as a 'diagnostic approach' rather than an explanatory approach (Kern, 2015). Regarding sustainability transitions, which is not what TIS was originally designed for, TIS is believed to be less useful than MLP in several aspects. First, TIS is more concerned with emerging technological innovations but is weaker in considering the broader social, cultural and political factors that shape socio-technical transitions (Truffer and Coenen, 2012). TIS places more emphasis on the supply side (e.g. firm and institution), while the MLP takes innovation, institution, and consumption into account. Second, TIS mainly concentrates on analysing system functions and discovering system weakness while overall system change is less considered (Smith, Voß and Grin, 2010; Geels, 2011). TIS provides less evidence and understanding of how emerging technologies replace the incumbent ones.

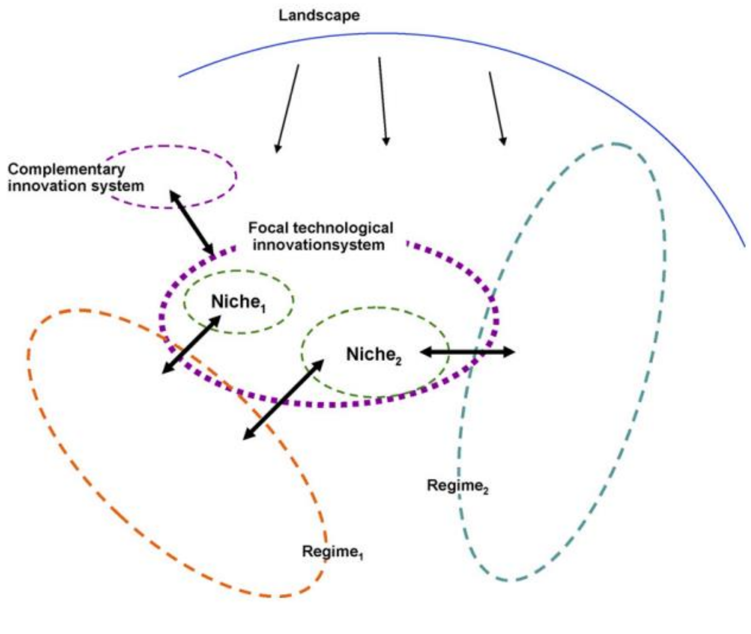

Figure 2.4 TIS and interactions with the conceptual elements of the MLP

Source: Markard and Truffer (2008:17).

Despite the ontological difference, there are many trade zones between MLP and TIS,

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such as the common conceptual ground and their theoretical roots in evolutionary economics. Some efforts, therefore, have been made to incorporate the insights of both MLP and TIS, so that each approach's weakness could be complemented in addressing sustainability transition (Markard and Truffer, 2008; Weber and Rohracher, 2012; Haley, 2015). Though both MLP and TIS are accused of not paying enough attention to agency, TIS is generally believed to provide a better understanding of roles and strategies played by different actors in the transition process than MLP. On the other hand, TIS focuses within systems without considering system environments, thus, it is less suited for dealing with strategic system transformations (Weber and Rohracher, 2012). Markard and Truffer (2008) made the first attempt to propose an MLP-TIS combined framework, in which the concept of system is seen as being somewhat between the niche and the regime. The four conceptual elements in their framework are: a) niche or application context, where radical innovations emerge and develop; b) a technological innovation system, characterized by emergent institutions and conjointly produced resources; c) socio-technical regimes, the dominant production structure and d) a landscape with parameters that influences regimes and innovation without being influenced in turn (Figure 2.4). It aims to consider more strategies and agency at the micro-level and the broad range of factors that influence innovation process. Though this seems attractive, the framework has not been empirically applied so far.

2.2.2.4 TM

Transition management (TM) is a governance approach that aims to achieve sustainability objectives through a deliberate process of visioning, learning and experimenting (Rotmans, Kemp and Asselt, 2001). The starting point of TM is acknowledging that society is becoming increasingly complex, in terms of the society itself, the problems facing it, and its governance (Loorbach, 2010). Sustainability transition is a highly complex process because "they are rooted in different societal domains, occur on varying levels, and involve various actors with dissimilar perspectives, norms, and values" (Loorbach, 2010:164). Facing such multi-domains, multi-levels and multi-actors,

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conventional governance approaches in current political systems are believed to be insufficient to offer satisfactory solutions. For instance, Kemp and Loorbach (2007) identify several key problems of current approaches in managing societal changes: a) lack of consensus among actors on the goals, solutions, and nature of problems (dissent); b) lack of cooperation and network management due to the distributed control over various actors with different interests and resources; c) lack of clarity about how to link short-term actions with long-term structural change; d) danger of being locked into particular solutions that may turn out to be not optimal in the long-run; and e) political myopia. As a new model of governance for sustainable development, TM views societal change as a result of interactions between multiple actors across different levels in a changing societal landscape (Kemp and Loorbach, 2007). The development of TM is based on five key principles (Rotmans *et al.*, 2001; Loorbach, 2007):

A) Long-term thinking; long-term objectives form the frame for short-term policies; short-term action is based on long-term goals through backcasting; objectives should be flexible and adjustable at the system level according to structural changes.

B) System thinking; focus on the system level that encompasses multi-domains, multi-actors, and multi-levels, rather than on processes.

C) Learning from niche experiments and reflexivity; learning by doing and doing by learning.

D) Trying to broaden the participation of various kind of actors so that different societal values and beliefs could be encompassed.

E) Keeping the options open to avoid lock-in.

The core idea of TM is to deliberately influence transition process through the participatory process of visioning, learning and experimenting. Both SNM and TM highlight the importance of experiments, but TM puts more stress on the role of strategic envisioning before experiments. Unlike other policy approaches, TM sets transition objectives based on long-term visions, rather than existing problems, barriers, and risks.

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Long-term visions function as the framework to formulate short-term objectives through backcasting. These visions are not fixed, rather, they are adjustable according to what has been learned from transition experiments. The multi-level framework of TM by Loorbach (2004, 2007) proposes that the governance of transition consists of four types of governance activities or levels (Table 2.3):

A) Strategic level: this level concerns the process of vision development, problem structuring, anticipation, long-term goal formulation etc. The focus is on the 'culture' of the societal system as a whole, such as norms, values, and relative importance for society.
B) Tactical level: the process of agenda building, negotiating and networking at sub-system level (e.g. a sub-sector); the main interest is in the structure (or regimes) of the system, such as rules, institutions, networks and infrastructure.
C) Operational level: the process of experimenting, project building and implementation; actions are often driven by individual interests, entrepreneurship, and innovations. It is important to link the random, emergent and uncertain processes at this level to broader agendas.
D) Reflexive level: the process of monitoring, assessing, and evaluation of ongoing experiments and societal changes. These activities can be realised either within existing institutions or by social participations, such as media and the internet that can effectively affect public opinions on policies. This level of activities relates to all the other three levels.

Table 2.3 Activities in transition management

TM types	**Focus**	**Problem scope**	**Time scale**	**Level**
Strategic	Culture	Abstract/societal system	Long term (30 years)	System
Tactical	Structure	Institutions/regime	Mid term (5-15 years)	Subsystem
Operational	Practices	Concrete/project	Short term (0-5 years)	Concrete

Source: adapted from Loorbach (2010:171).

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Different actors participate and specific instruments apply in each level. The interaction between actors at one level and interactions between levels enable transitions (Kemp and Loorbach, 2007). Operationally, systematic instruments have been developed to implement transition management in practice. This is illustrated in the so-called transition management cycle (Loorbach, 2004), which consists of following components (Loorbach, 2010:172):

> (1) structure the problem in question, develop a long-term sustainability vision and establish and organize the transition arena; (2) develop future images, a transition agenda and derive the necessary transition paths; (3) establish and carry out transition experiments and mobilize the resulting transition networks; (4) monitor, evaluate, and learn lessons from the transition experiments and, based on these, make adjustments in the vision, agenda, and coalitions.

A particularly useful concept here is the transition arena, which is "a small network of frontrunners with different backgrounds, within which various perceptions of a specific persistent problem and possible directions for solutions can be deliberately confronted with each other and subsequently integrated" (Loorbach, 2010:173). A transition arena is not an administrative platform or consultant body but a social network of frontrunners that have expertise, resources and networking, such as experts, networkers, and opinion leaders. It is an open process and provides space and favourable conditions for transition frontrunners to shape strategic visions by means of a strongly interactive process. More practically, transition management can be achieved through six steps: a) analysing the system; b) envisioning; c) exploring pathways; d) experimenting; e) assessing; and f) translating.

TM provides not only a prescriptive governance approach for operational policies but also a normative model by taking sustainability as the long-term goal (Loorbach, 2010). Its strength lies in the synthesis of both top-down (e.g. envisioning and agenda building) and bottom-up approaches (e.g. experimenting and learning in niches), which reinforce each other (Rotmans, Loorbach and Kemp, 2007). In practice, TM has been applied in

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some countries to develop transition policies, such as the Netherlands, the UK, and Belgium (Loorbach and Rotmans, 2010). TM was first introduced in the Dutch National Environmental Policy Plan (NMP4) as an official government policy in 2001. It is a result of an interactive process between NMP4 leaders and transition scholars, e.g., Jan Rotmans, René Kemp and Marjolein van Asselt. The transition experiments have been extensively carried out in the Netherlands in various sectors, such as energy, waste, and water. Particularly, Dutch transition management in energy has been viewed as the most successful (Kemp and Loorbach, 2006; Kern and Smith, 2008). TM is not only applied at the national level but also at the sectoral and regional level (Loorbach and Rotmans, 2010; Nevens *et al.*, 2013), albeit to a much lesser degree.

Nonetheless, TM is still limited to relatively few empirical cases and its usefulness is still debated and challenged in scientific research and policy arena. The central critique of TM is the possibility of deliberate system transitions, as many historical transitions have been proved to be unplanned and involving spontaneous processes (e.g. Geels, 2002). The theory of TM is still in the hypothetical stage because it may take decades to find out how transition managements work as most of the transition experiments have just started recently (Loorbach, 2007). It is admitted that deliberate interventions could positively facilitate societal changes (Meadowcroft, 2009), but transition management may only be effective in smaller domains or scales than it suggests. In practice, many projects may be labelled as transition management, but they are actually not much different from regular policies. The other criticism concerns the missing contexts in transition management. The transition is never simply a management task but involves many influencing factors both within and outside its contexts such as belief system and culture. Therefore, facing such complex societal systems, the 'manageability' of transition management is questioned. Besides, some argue that TM's building on guiding visions is problematic because visions are constantly contested (Berkhout, Smith and Stirling, 2004).

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2.3 What drives or impedes sustainability transitions

Apart from many contributions in conceptual debates, a large number of empirical studies have been conducted under the umbrella of sustainability transitions. Like the notion of sustainable development, sustainability transition has become a buzzword that is being used at various sectoral and spatial levels (Audet, 2014). One merit of the term sustainability transition is that it focuses on the particular socio-technical system rather than the triple balance of social, economic and environmental goals in sustainable development, making it more operational for empirical research and policy making. Indeed, recent years have witnessed an increasing literature addressing the sustainability transition of territorial systems at different scales, such as urban transitions (see Bulkeley and Betsill, 2005; Bai, Roberts and Chen, 2010; Hodson and Marvin, 2010; Nevens *et al.*, 2013; Moloney and Horne, 2015; Ernst *et al.*, 2016) and transition towns (Hopkins, 2010; Smith, 2011; Forrest and Wiek, 2014). This '*radical-ecocentrist*' discourse on transition highlights the role of local actors in envisioning and experimenting with practices toward a deep social, environmental and cultural transformation in specific spaces (Audet, 2014:47). Nonetheless, the majority of transition research primarily studies the development of eco-innovations (or low-carbon innovations, environmental innovations) in various sectoral domains (e.g. Verbong and Geels, 2007; Foxon, Hammond and Pearson, 2010; Essletzbichler, 2012; Moallemi *et al.*, 2014; Gibbs and O'Neill, 2015; Haley, 2015), usually at the national level. According to the literature survey by Markard *et al.*, (2012), the empirical topics of sustainability transitions research is dominated by renewable energy sources in the energy sector (36%), followed by transportation, water and sanitation, and food.

The core inquiry of these empirical research works is how environmental innovations take place and what factors facilitate or impede them to gain momentum in niches, adapt, grow and become mainstream (STRN, 2010). Due to the multi-dimensional and multi-level characteristics of sustainability transitions, Geels (2011: 38) argues that "it is unlikely that

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only one kind of causal factor or mechanism can explain entire transition processes." Transition scholars' explorations into the factors influencing sustainability transitions vary greatly in terms of perspectives, empirical domains, geographical areas and conclusions as well. There might not be common decisive factors of sustainability transitions, but it is acknowledged that there are some common factors influencing transition processes albeit their roles vary a lot according to the characteristics of sectors, geographical areas, as well as time periods. Since most empirical sustainability transition research takes the diffusion of eco-innovation (e.g. market penetration of renewable energies) as an indicator of transition, the following section provides a review of the common drivers and barriers of socio-technical transition of eco-innovations. Note that the study of eco-innovation also prevails in other fields such as economics, management, and policy sciences, but the transition approach differs from them in its systemic innovation perspective and conceptual frameworks mentioned above.

2.3.1 Obstructing factors

The notion of eco-innovations, low-carbon innovations, environmental innovations, green innovations, and ecological innovations have often been used interchangeably because they all possess the potential to bring about fewer adverse effects on the environment and more efficient use of resources (Hojnik and Ruzzier, 2016). Specifically, eco-innovation is defined as:

> the creation or implementation of new, or significantly improved, products, processes, marketing methods, organisational structures and institutional arrangements which lead to environmental improvements compared to relevant alternatives (OECD, 2009).

Though the definition includes organisational, social and institutional innovations, there is a strong preference towards technological progress in academic research and practice. Compared to other innovations, eco-innovations have two peculiarities. First, eco-innovations are attractive on the collective environmental criteria but usually inferior to their substitutes in terms of technological performance, for instance, higher cost and less stability of renewable energies. Second, there exists the 'double externality problem' of

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eco-innovations, that is, the knowledge externalities in the innovation phase and the environmental externalities during the diffusion phase (Rennings, 2000). Due to this double externality problem, firms and private actors have little incentive to develop eco-innovations. Among the earliest works on sustainability transition, Kemp *et al.,* (1998) distinguish several main factors that obstruct the utilisation of environmental technologies:

A) Technological factors: many eco-innovations are still in their early development phases, their functions and performances are not mature enough to satisfy user needs; eco-innovations are usually much more expensive due to high cost and small scale economy; another barrier is that they often have problems in fitting with existing infrastructures, or the required complementary technologies have not been well developed. Thus, new environmental technologies themselves are less attractive in terms of functions, cost, and compatibility. A typical example is the EV, which is currently expensive but also offers limited driving freedom, plus the charging infrastructure is ill-developed. Furthermore, though eco-innovations bring societal good in one aspect, it might also cause undesirable social or environmental effects, for instance, the waste problem of an EV's batteries.

B) Government policy and regulatory framework: although governments have been widely believed to be the most active actor in the development of eco-innovations, they might impede eco-innovations in two ways. As there are many technology options for sustainable goals, if governments do not give a clear message about the future need of specific technologies, manufacturers would be reluctant to invest in particular technologies due to uncertainty; on the other hand, if the governments guide the search to a particular technology too early, it might turn out being locked into a suboptimal technology.

C) Cultural and psychological factors: established technologies have been embedded in users’ cultural life and it is difficult for new technologies to replace them. To give an

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example, the value of flexibility and freedom attached to conventional automobiles has constituted a barrier to EV diffusion, not to mention the fact that they are also a symbol of social status.

D) Demand factors: this is much related to the technological factors of eco-innovations; on the one hand, consumers may not be able to pay for new technologies because of their high costs; on the other hand, consumers are usually not willing to pay for new technologies as there are a lot of risks involved. For instance, even though environmental awareness has contributed to EV adoption, it is still ranked behind cost and performance in purchase decisions (Egbue and Long, 2012). The required change in habits of users also imposes a hard time for new technologies.

E) Production factors: existing manufacturers have been locked-in to incumbent technologies due to scale economy and sunk cost; they are less willing to invest in eco-innovations because of the market and technological risks; new entrants often lack technological capacities and financial resources because financial institutions also tend to avoid risky projects.

F) Infrastructure and maintenance: a new radical technology often requires the modification of existing infrastructure, which is very difficult to change. The core problem is who takes the responsibility to develop the infrastructure and how the cost can be covered.

These factors do not act separately, but interrelate with and reinforce each other, leading to a strong inertia in technological changes. Many eco-innovations are subject to such a vicious circle: consumers have little faith in eco-innovations because of their technological problems such as high cost and incompatibility while producers blame the high cost on the lack of scale economy due to uncertain market demand. Therefore, the challenge of sustainability transition lies not only in the long-term change of technologies

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and infrastructures but also in ensuring that consumer criteria change at the same time (Kemp and van Lente, 2011).

2.3.2 Facilitating factors

A number of studies have been dedicated to the understanding about what drives eco-innovations (see the reviews by Bossle *et al.*, 2015 and Hojnik and Ruzzier, 2016). These factors are divided into either internal factors and external factors at the firm level (Bossle *et al.*, 2015) or technology push, market pull and regulatory push factors at the sectoral level (Rennings, 2000) (Figure 2.5). These factors play different roles in driving different environmental technologies, such as 'end-of-pipe' technology, process integrated technology and production innovations (Ekins, 2010). For instance, Cleff and Rennings (1999) find that environmental production innovations are significantly relevant to market pull effects, while 'end of pipe' and process-integrated technology are largely driven by regulation push factors.

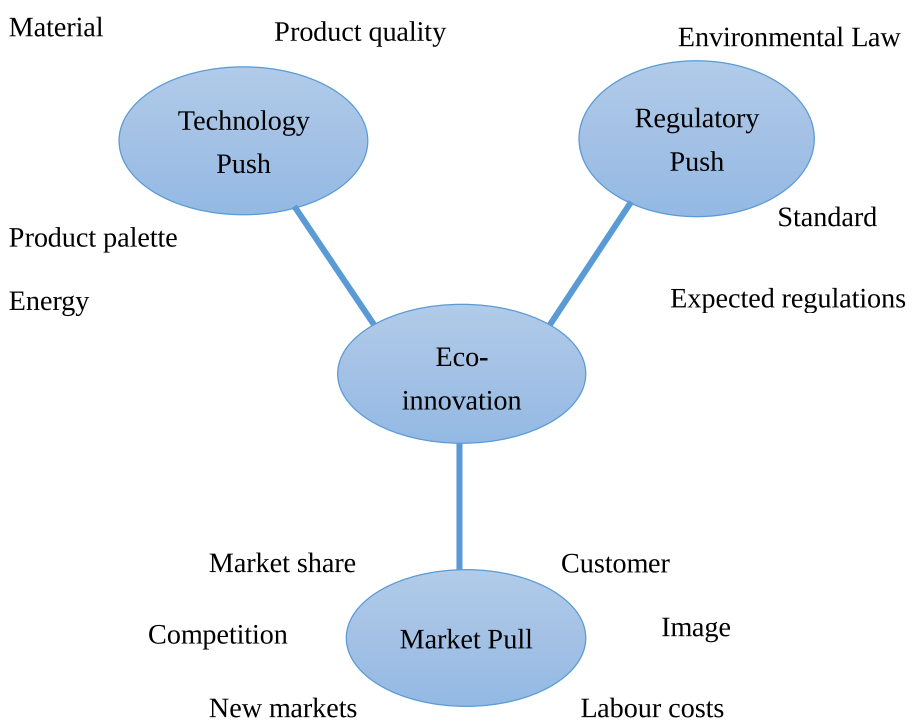

Figure 2.5 Drivers of eco-innovation

Source: adapted from Rennings (2000:326).

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Policies and regulations are the most frequently mentioned driver for eco-innovations (Beise and Rennings, 2005; del Río González, 2009; Horbach, Rammer and Rennings, 2012; Kesidou and Demirel, 2012). Discussions in traditional innovation economics mainly focus on the role of technology development and market factors, but due to the ‘double externalities problem’ of environmental innovations, as well as their technological and financial risks, policy intervention is believed to be essential for the realisation of environmental innovations (Rennings, 2000; Horbach, 2016). The distinction here is made between incentive-based instruments and regulatory approaches. Incentive-based instruments (e.g. subsidies and feed-in tariffs) play a critical role in creating and expanding market demand for environmental innovations, thus, firms are encouraged to invest in the focal environmental technologies. A classical case is the German feed-in tariff policy, which provides substantial market incentives to renewable energy manufactures and has enabled Germany to be the leading country in the utilisation of renewable energies, particularly wind and solar PV (Jacobsson and Lauber, 2006; Dewald and Truffer, 2012).

The regulations also drive environmental innovations but follow a different logic from incentive policies. In institution theory, regulation is one pillar of the institution and it provides explicit guidance to firms through rules, controls, rewards and sanctions (Scott, 2008). Regulatory pressures (e.g. environmental laws and standards) force firms to adopt environmentally benign technologies. Compliance with regulations not only allows firms to avoid the cost of violation but also brings competitive advantages. The so-called Porter's hypothesis describes a ‘win-win’ situation that could be achieved when proper environmental regulation pressures drive firms to boost environmental R&D and thus make high profits from green products (Porter, 1996). Regulatory pressure is typically related to pollution emissions. Through analysing the environment-related patents of 326 publicly traded firms from polluting industries in the United States, Berrone *et al.*, (2013) prove the hypothesis that environmental innovations increase as regulatory pressure rises.

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The key role is often assigned to the governments at various level. As the sustainability transition is for the public good, the government is supposed to be the leading actor in promoting environmental innovations (Smith, Stirling and Berkhout, 2005). For instance, Söderholm (2013) finds that the presence of government interventions, in terms of financial, legislative and consultative means, have significantly facilitated Swedish transitions in water and sewer systems, by moving the transition-related uncertainties and costs from the local level to regional and national level. At the city level, local government can practice four roles in driving renewable energies development (Bulkeley and Kern, 2006): a) governing by authority (regulator); b) governing by enabling (promoter), such as promoting certain policies towards relevant stakeholders; c) governing by provision (supporter), such as providing financial incentives to start-ups; and d) self-governing (role model), such as being a role model by installing solar technology on public buildings.

The role of culture has been neglected in transition literature (Tàbara and Ilhan, 2008; STRN, 2010). In transition studies, culture is often seen as a part of the exogenous landscape that cannot be altered by agents in regimes and niches. It is not clear how cultural artefacts such as worldview, values, and beliefs change in transitions. Among the few contributions in this field, Tàbara and Ilhan (2008:70) advocate understanding culture and particular cultural change "as part of the conscious production of agents resulting from the awareness of the limits and potentialities of their own culture in the processes of social change". In the case of sustainable transition in Spain's water policy, they argue that instead of biophysical pressure such as water scarcity, the collaborative culture among intellectuals and social groups is the primary trigger of societal transition towards a more adaptive pattern of organisation. However, cultural change alone cannot bring transitions. Some transition scholars emphasise the interplay of culture and other factors in transitions (Wirth *et al.*, 2013). More understandings are expected to be developed as to how culture facilitates or impedes transitions.

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Another strand of the transition literature has emphasised the role of landscape factors, such as globalisation and global financial crisis. Rock *et al.*, (2009) use historical and empirical evidence to illustrate how globalisation influences sustainability transitions in developing countries, concluding that transitions can be positively affected by globalisation, but it depends on how global forces interact with local socio-political landscape (e.g. the political-economic institutions, values, and regulations broadly guiding an economy and its relationship to the environment). Compared to neo-liberal states in South America, capitalist development states in East Asia have performed better in harnessing globalisation to promote sustainability transitions because of their broad openness to global investments and effective public-private institutions, which links green technologies and environmental standards to production activities at the firm level. As to global economic crisis, some scholars believe it will continue to accelerate destabilisation of existing regimes and thus inevitably lead to transitions (Loorbach and Huffenreuter, 2013), but Geels (2013a) contends that the impact of financial crisis on sustainability transition can be both positive and negative by creating a window of opportunities on the one hand, but weakening public, political and business attention from environmental problems on the other hand.

2.4 Criticisms and development

2.4.1 Power and agency

Conceptually, the lack of power and agency in transition frameworks, particularly in the MLP, has been frequently criticised (Smith, Stirling and Berkhout, 2005; Genus and Coles, 2008; Markard and Truffer, 2008; Lawhon and Murphy, 2012). Agency is the ability to bring about changes. In socio-technical transitions, the agency is the "ability to intervene and alter the balance of selection pressures or adaptive capacity" (Smith, Stirling and Berkhout, 2005:1503). It has been argued that the MLP is too functionalistic and structural in nature, leaving very little room for the analysis of agency. MLP is robust in explaining transition process as the result of an interplay between stable regime mechanisms,

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destabilising landscape pressures, and emerging niche innovations, but it is weak in revealing the role and strategies that different actors play in the process (Smith, Stirling and Berkhout, 2005). Regime transformation is more often treated as a monolithic process that is largely driven by rational actions, which is problematic. Lawhon and Murphy (2012) claim that the transition literature tends to be too techno-deterministic, that is, focusing on the replacement of particular technological artefacts as a means to achieve sustainability transitions. Neglected here though is "how, why, and through whose agency these changes come about" (p360). To make impacts, agency inherently requires exercising power in political, economic and institutional aspects. Resources available to actors are the main sources of power, but they are not evenly distributed among regime members. The transition process involves various kinds of actors with different expectations, interests, resources and capacities, causing winners and losers. Therefore, how transitions come out is largely affected by power differentials. The induced power asymmetric may impede transitions if the incumbents are dominant, or facilitate transitions if niche actors are more powerful.

Both MLP and TIS are suggested to incorporate the various type of agency, such as power and conflict, interpretation, entrepreneurship, and organisational resources and capabilities (STRN, 2010). As Smith *et al.,* (2005:1508) advocate, sustainable technology transition may be better understood as "change mediated by the resources, interest, and expectations of institutionally embedded networks of actors". There have been a few contributions addressing agency in transitions in terms of power relations (e.g. Avelino and Rotmans, 2009; Grin *et al.*, 2010; Avelino, 2011; Tyfield, 2014) and transition politics (Meadowcroft, 2009, 2011; Kern, 2011), but they tend to rely too much on the "simplistic dichotomy between proponents and opponents of transitions" (Bakker, 2014:62). Indeed, there is a variety of rationales in the transition process, and incumbent actors do not necessarily attempt to hinder niche innovations as many transition studies assume. Facing emerging innovations, actors' rationale as to whether to support them is not only motivated by their interests, but also affected by their capacities and expectations (Bakker,

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2014). Even if instant interests are not provided, regime actors may still choose to sustain niche innovations in order to learn about the benefits and threats of new pathways. As Bakker (2014) illustrates in the case of the Netherlands EV recharging system, some regime actors (e.g. grid actors) support niche innovations so that they can influence their development in line with their own interests. Some choose to be involved in the niche development because of collective expectations. Therefore, the rationale of actors in transitions needs more investigation, especially those core actors who have more influence on the speed and direction of transitions.

Transition theory could also benefit from in-depth studies on how power is generalised, mobilised, interacted with and exerted in achieving system shifts. Power is commonly defined as the capacity to act, to receive, to change and to resist. Owning resources and means does not necessarily mean being powerful, rather, it is the capacity to take advantage of them that matters in constituting power (Lukes, 2005). Power is relational that one cannot exercise power without a counterpart or a subject. The powerful are able to further their interests and affect (favour or disfavour) others' interests. The transition process is inherently political at various levels, involving power struggles among different actors to define the landscape, sustain or destabilise regimes, and protect or expose niches (Meadowcroft, 2011). No single actor has sufficient power to generate transitions, but in many real cases, there are usually certain influential actors dominant in directing the process, positively or negatively. Transition studies have emphasised resources as an important part of power, which is, however, not sufficient to understand what empowers certain actors to lead changes.

In response to this, Geels (2014) introduces four forms of power, namely, instrumental, discursive, material and institutional power into the MLP. Instrumental power refers to the resources (e.g. financial capital, authority and media access) that actors use to reach their interests. Discursive power is influential in shaping public discourses in terms of both what issues should be discussed and how they are framed. Material power defends

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regimes through improving the incumbent technologies towards a cleaner direction. Institutional power relates to the broad political culture, ideology and governance structure that champion the strategies of incumbent actors. However, these forms of power are stilled viewed purely negative and resistant that are only held by the powerful regime agents, which renders MLP "continues to find itself in the analytical stalemate of having to explain how currently 'powerful' can be unseated (by 'niches'), when they have all the power" (Tyfield, 2014:592). Inspired by Foucault, Tyfield (2014) instead advocates a relational, dispersed, and productive conceptualisation of power in understanding system transitions, in which new forms of productive power drive the formation of niche assemblages and transform the regime configurations, hence, " as a power transition, how the 'pieces come to fit together' is straightforward to understand"(p591). Nonetheless, under what geographical-historical contexts do these productive powers emerge? This question remains implicit in transition studies and this research tries to address it by drawing insights from relational economic geography, which is justified in section 2.5.

2.4.2 Operationalisation of MLP

Another conceptual gap lies in the operationalisation of the MLP framework, including ambiguous understandings of MLP levels and how they should be applied empirically. As the core concept of MLP, the regime is still not clearly defined and lacks consistency in empirical studies (Genus and Coles, 2008; Lachman, 2013). Due to its problem in operationalisation, "empirical applications tend to depict regimes as too 'monolithic' and 'homogenous', not adequately considering persistent institutional tensions and contradictions" (Fuenfschilling and Truffer, 2014:772). On the delineation of the regime concept, it is sometimes referred to as the rules, but is also used as a synonym for 'system' at other times (Markard and Truffer, 2008). The former interpretation emphasises that regime is the rule (or deep structure) embodied in artefacts and performed by actors that make up the regime (Kemp, Schot and Hoogma, 1998; Geels, 2002), while the system interpretation regards regime as a conceptual composition of artefacts, knowledge, practices, institutions and infrastructures etc. (Hoogma, 2002).

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Confusion is also found regarding how to apply the concepts of regime and niche in practice. First, the hierarchical ontology of MLP may make it difficult to distinguish the analytical levels empirically, especially when it comes to the role of actors, who act across several levels simultaneously (Jørgensen, 2012). For instance, the government in many cases is the green niche supporter on the one hand, but also a part of the established regime on the other hand. Some researchers have therefore looked for a flatter model of transition process (Shove and Walker, 2010), which is characterised by horizontal circulation of elements and multiple relations of reproduction across different scales. Jørgensen (2012) also develops a flat approach of 'arena of development', which is a space where socio-material activities are located, providing stages where actions and dynamics can be performed. This may be a fruitful alternative but seems less straightforward than MLP in explaining how transition occurs.

The second barrier to the operationalisation of MLP is how to draw the boundary of the regime or define it at specific levels empirically (Berkhout, Smith and Stirling, 2004). In sectoral terms, a regime can be identified either at the sector level (e.g. energy system) or sub-sector level (e.g. wind energy) or even the level of particular technology (Markard and Truffer, 2008). In terms of spatial scale, both the national level and sub-national level can be conceptualised as regimes or niches. The status of regime and niche are relative. Therefore, a regime shift in one level may merely be seen as a niche practice from the perspective of a higher level (Smith, Stirling and Berkhout, 2005). A city's practice in sustainability, for example, could be viewed as a niche experiment when looking at its contribution to national change, but it also could be regarded as a regime change when we focus how this practice comes out within the city. It is not so much problematic to apply the concept of regime at a specific level according to different focal problems, yet, needed is a more careful delineation of the concept in empirical terms by justifying why the notion is used in a certain sector or territory (Markard and Truffer, 2008).

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2.4.3 Multi-regime interaction

Multi-regime interaction or ‘boundary crossing innovation’ is a promising but still underdeveloped research topic in transition studies (Raven, 2007; Raven and Verbong, 2009). Existing transition literature has focused on the competition between the regime and the niche in a single focal system at the expense of co-evolution with other regimes, which may also complement or block the focal technology transition. Raven (2007) argues that multi-regime interaction could be an important mechanism for triggering changes in regimes. He and his colleagues have developed an multi-regime interaction typology of competition (when regimes fulfill similar functions), symbiosis (when regimes reap mutual benefits from cooperating), integration (when previously separated regimes become one, partly or completely), and spill-over (when rules are transferred from one regime to another) (Raven and Verbong, 2007, 2009). To give an example, Raven (2007) shows that the Dutch biomass regime is a result of long-term co-evolution between the waste regime and the electricity regime: a changing selection environment in the waste regime drove a process of variation, which then attracted attention from electricity regime actors, who were searching for alternative energy sources in response to rising oil prices and stricter environmental requirements. Similarly, Haley (2015) shows that the Québec hydroelectric regime has enabled EV development because they share overlapped system functions such as knowledge development and guide of the search. Multi-regime interaction moves beyond technology-specific analysis and benefits from considering broader sectoral contexts. In MLP analysis, regimes are usually seen as a constraining or competing factor for niches, but in a multi-regime perspective, incumbent regimes may also play an enabling role in niche developments in other systems. As Raven (2007) acknowledges, however, transition in a single regime is already very complex and thus broadening management for multi-regime transitions may be impossible in practice. Nonetheless, it is still worthwhile to study how different regimes relate to each other and how multi-regime contexts impact on niche development (Raven and Verbong, 2007).

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2.4.4 Methodology

There is also a continuous debate on the methodological issue of transition research. For one thing, many historical transition studies have been criticised for their uncritical use of historical secondary data sources. As Genus and Coles (2008: 1441) explain:

> [previous research] concerns the employment of an evolutionary historical case study method without acknowledging the debates surrounding the presentation, and use, of such data…..thus it is possible that the apparently arbitrary nature of transition characteristics might derive from the flawed use of secondary data sources.

The MLP analysis has already exhibited its strength in the interpretation of empirical transitions, but it could better benefit from more critical research methods in data collection and analysis. Moreover, the majority of empirical transition studies apply a single case study methodology. Sustainability transition is a multi-faceted and long-term process, which rarely happens. It is difficult to build a large database to statistically analyse the relationship between variables as in positivist research (Geels, 2011). The interpretation of cases involves the creativity of the researchers, which may compromise the rigour of the research. It is suggested to embrace more methods such as comparative case studies, network analysis, and agent-base modelling.

2.4.5 Limitations in empirical research

Despite a growing literature addressing sustainability transition in developing countries, transition research has mainly focused on post-industrialised countries, especially having a 'European bias' (Markard, Raven and Truffer, 2012). Transition studies and practices were primarily initiated by Dutch scholars, and the Netherlands remains the centre of sustainability transitions research, with leading transition scholars, research institutes and active transition practices in various sectoral domains such as energy, waste, and transport (Geels and Raven, 2006; Raven and Verbong, 2007; Verbong and Geels, 2007). Besides, the UK, Germany, Denmark, Switzerland, Austria and Scandinavian countries are the central focus of transitions research, in terms of both historical transitions and purposive transition experiments. This geographical bias may restrict the generalisation of transition

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experiences since European countries are unique in their political systems, economic structures, and civil cultures. It is, therefore, advocated to examine the sustainability transitions in industrialising countries, which may have exhibited different sustainable pathways (Berkhout, Angel and Wieczorek, 2009b). Other than differences in social, economic and political contexts, developing countries are different from post-industrialised countries in at least two aspects of sustainability transition: motivation (or interest) and capacity. First, while developed countries put more emphasis on environmental sustainability in terms of both political discourses and public environmental awareness, developing countries usually prioritise economic development over environmental issues (Iizuka, 2015). Even though climate change and environmental degradation have been globally acknowledged problems, they are not viewed as urgent as improving living standards in many developing countries. Generally, neither civic society nor governments in the developing world have as much interest in sustainability transitions as in their developed counterparts.

Another barrier for sustainability transitions in developing countries is the lack of sufficient capacity, e.g., financial resources and technology stocks. Developing countries, in most cases, are not able to develop radical technologies domestically, but rely on imports from developed countries. Developing countries may be an important market for these technologies, but the embedded knowledge usually stays in their place of origin (Lachman, 2013). From a TIS perspective, knowledge development in developing countries entails more external linkages when compared to developed countries. The leapfrogging research emphasises the latecomer advantages of developing countries and advocates that environmental problems in developing countries could be avoided or mitigated by skipping to more advanced and cleaner technologies from the beginning (Perkins, 2003). Recent transition literature has begun to investigate transitions in the developing Asian context (e.g. Bai, Roberts and Chen, 2010; Liu and Shiroyama, 2013; Hess and Mai, 2014; Pant, Adhikari and Bhattarai, 2015), but whether and how developing countries can take latecomer advantages to achieve sustainability transitions

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in the context of fast urbanisation and industrialisation are still less known.

Last but not least, transition analysis is also found to have a strong bias towards the production side, while demand-side factors are less concerned (Grin *et al.*, 2010; Lachman, 2013). In particular, though TIS is expected to address the development, diffusion and utilisation of new technologies, most TIS research only deals with how technology develops on the supply side, emphasising entrepreneurial activities, knowledge development, and guide of the search. Much attention has been drawn to actors such as entrepreneurs, scientists and state agents in promoting new technology development, with other relevant actors such as consumers being excluded (Lawhon and Murphy, 2012). Many transition studies presume that environmental innovations would not be valued by the market itself but rather mainly rely on the regulatory pull and industry efforts to get promoted. Indeed, individual consumers may not have much say about centralised projects such as offshore wind farms, but they usually have decisive roles in the diffusion of decentralised innovations such as EV and domestic PV, and environmental behaviours such as cycling. The diffusion of innovations is not solely determined by the desirability of the products but also affected by the diffusion channels and networks among consumers (Rogers, 2003). Consumers should not be merely considered as rational agents, rather, they are also governed by social structures, or " the patterned arrangements of the units in a system, which gives stability and regularity to individual behaviour in a system" (Rogers, 2003:37). Therefore, studying sustainability transitions from the demand side with a focus on social structures and networks could be a promising future research agenda.

2.5 Geography of transitions

This research is particularly concerned with the lack of a geographical dimension in transition research (Coenen, Benneworth and Truffer, 2012b; Truffer and Coenen, 2012). It has been argued that transition research has suffered from a missing or poor conceptualisation of space and scale, as a consequence, little understanding has been

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developed about where sustainability transitions take place and why transition happens in a certain place while not in others (Raven, Schot and Berkhout, 2012; Gibbs and O'Neill, 2014b). Though there has been increasing literature studying sustainability transitions in various geographical places, there is still a lack of generalised knowledge about the conditions whereby transition occurs in specific places or what kind of places are more likely for sustainability transitions to take place. Coenen, *et al.*, (2012) point out three shortcomings of the MLP regarding geographical space: the dominance of the national level in addressing regime-niche interaction; the poor conceptualisation of spatial variety in regime structure and landscape pressures; and the missing recognition of the interdependence between niche development and place-embedded institutional configurations. Without sufficient attention to the actual places and contexts in which transitions unfold, the MLP remains an 'abstracted model of transition' (McCauley and Stephens, 2012:217) and risks reaching oversimplified conclusions that cannot be extended to other places (Coenen, Benneworth and Truffer, 2012b). On the other hand, the effects of scale are often overlooked in transition research. The fact that local niche-regime interactions are subject to external relations could be downplayed if the scale is ignored in the analysis. Moreover, much transition research simply conflates the MLP levels with territorial scales (e.g. global, national and local), which is a straightforward but still superficial conceptualisation of scale in transition dynamics.

Therefore, recent years have witnessed a rapidly growing interest in the geography of sustainability transitions, in terms of both the conceptual frameworks and empirical studies (e.g. Coenen and Truffer, 2012; Raven, Schot and Berkhout, 2012; Binz, Truffer and Coenen, 2014; Faller, 2015; Hansen and Coenen, 2015; Murphy, 2015; Truffer, Murphy and Raven, 2015). This is particularly contributed by scholars from economic geography, which has been proved very fruitful in mapping and illustrating the uneven spatial process of innovations (Coenen, Benneworth and Truffer, 2012b). Within the field of economic geography, in spite of some sporadic efforts engaging with environmental economic geography (e.g. Gibbs, 2000, 2006; Bridge, 2008; Hayter, 2008; Patchell and

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Hayter, 2013), the environmental issues remain relatively under-addressed. Sustainability transition offers a suitable platform that economic geography can contribute to environmental agendas because they share similar roots in evolution theory and innovation theory. Furthermore, transition studies could help geographers to understand better the development trajectories of industries, production networks, cities, and economies, thus, a promising intersection could be achieved between geography and sustainability transitions (Murphy, 2015).

From the perspective of sustainability transitions, the incorporation of geographical insights can at least benefit transition studies in two ways: mapping the variances of transition activities across space and revealing the underlying processes that leads to the pattern, meanwhile, acknowledging the importance of spatial linkages between that space and other spaces (Bridge *et al.*, 2013; Hansen and Coenen, 2015). Coenen, *et al.*, (2012) argue that TIS and MLP could be complemented by more focus on territorial embeddedness and multi-scalarity. Different places have various institutional contingencies and particularities. By contextualising territorial specificities, such MLP analysis will help to address the questions why environmental innovations are performing differently in different geographical settings and, consequently, how to translate local practices into generalised experiences and upscale them into mainstream regime practice (Coenen, Raven and Verbong, 2010). Also, more emphasis on multi-scalarity will help to depict trans-local relations and illuminate how local niche and regime factors interact with their networks across a range of scales. As discussed, transition studies have not addressed the role of power and agency adequately. This challenge could also be met by drawing on insights from geography, which have paid great attention to the uneven power relations resulted from socio-economic development (Lawhon and Murphy, 2012).

The remainder of this section will respectively elaborate how the concept of space and scale in geography would add more value to transition research, and to the MLP in particular. At the same time, recent contributions in the geography of sustainability

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transitions will be reviewed. I concur with Hansen and Coenen (2015) that the geography of transitions literature has paid growing attention to the role of geographical contexts in the transition process, but the issue of multi-scalarity still expects more contributions. Methodologically, future research could reap much more benefit from comparative case studies and empirically, transitions in small and less developed cities could be a promising research field.

2.5.1 Space and scale in economic geography

There have been witnessed many 'turns' in geography, leading to an evolving understanding of space from absolute space to relational space. For a long period of time, positivist geographers, e.g., in regional science in the middle of 20^{th} century, viewed space as absolute space that is independent of any objects and relations, and working as empty containers that wait to be filled with information, entities, and activities (Jones, 2009). Absolute space is regarded as fixed pre-existing space in which things are passively embedded, regardless of how the activities within it proceed (Thrift, 2003). The activities in absolute space are very often understood as dominated by atomistic, rational, maximising economic actions.

The 'institutional turn' in economic geography, however, began to understand space as 'institutional settings' that shape the landscape of economic process (Martin, 2000) and highlight the importance of institutional variations in explaining spatial differences in economic activities and performances. Under this perspective, the institutional structure (including formal and informal institutions, and culture) occupies the main causal power in regarding the emergence and development of economic activities, but increasing attention is also being paid to the role of agency in the reproduction or evolution of these institutions. Firms in institutional economic geography are no longer viewed as completely rational. Instead, they are treated as agents with bounded rationality that are constrained by regulations, norms, and values, but meanwhile, contributes to the transformations of these institutions. Also, the state is expected to be the key agent in

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institutional changes, e.g., in legislative frameworks and policy programmes (Martin, 2000).

Evolutionary economic geography shares the assumption with the institutional approach that economic actions are subject to rules rather than simply driven by a rationale of maximisation (Boschma and Frenken, 2006). The difference lies in that while the institutional approach tends to relate agent behaviours to macro-institutions, the evolutionary approach primarily focuses on routines at the micro-organisation level (e.g. firms). Routines are the taken-for-granted ways of doing things. Due to the uncertainty of economic activities, firms rely on routines to make decisions so that the risks and costs of decisions could be reduced. Just like biological genes being inherited from generation to generation, the knowledge embedded in routines is reproduced and developed from time to time, conditioning firms' economic actions and eventually influencing sectoral and regional development (Boschma and Frenken, 2006; Martin and Sunley, 2006). Thus, the evolutionary perspective emphasises the role of path dependence in shaping current economic space. This path dependence results either from technological 'lock-in', dynamic increasing returns, or institutional hysteresis (Martin and Sunley, 2006). The process of path dependence is generated by the interaction between the micro-level (e.g. firms) and the macro-level institutions (e.g. state policies and regulatory arrangements) (Martin, 2012). During this process, space is transformed from a neutral space into real places by the spatial evolution of new sectors and networks (Boschma and Frenken, 2006). The trajectory of economic evolutions is also conditioned by spatial contexts, hence, place dependent (Martin and Sunley, 2006). Space is more than the passive outcome of evolutionary processes but also exerts influences on those processes. Evolutionary economic geography, therefore, aims to explore how spatial and historical contingency interact in leading to different economic processes in different places (Boschma and Martin, 2010).

The 'relational turn' of geography, in contrast to regional science and the institutional

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approach, places actors, actions, and the changes and developments resulting from their relations at the centre of its analysis (Boggs and Rantisi, 2003). It emphasises the role of economic actions in transforming localised material and institutional structures and conceptualises space as the product of social interrelations among actors (Bathelt and Glückler, 2003; Massey, 2005). As Yeung (2005:38) states: "dynamic and heterogeneous relations among actors and structures are conceptualised as causal mechanisms of socio-spatial change in economic landscapes[in relational turn]". Epistemologically, relational economic geographers doubt that space could be used as a causal factor for economic activities or regarded as an independent object without interaction with social structure and relations, thus, they do not believe in spatial laws but rather seek for explanations of economic processes and their consequence in places (Bathelt and Glückler, 2003). As human relations are contingent and contextual, they cannot be explained by universal laws. Bathelt and Glückler (2003) suggest understanding space as a perspective or, a geographical lens, through which the economic processes such as interaction, learning, and innovation are investigated as the core knowledge in analysis.

Ontologically, the relational approach puts greater emphasis on human agency over the structure, which could complement transition analysis in its lack of agency as discussed above. While structure-oriented interpretations, e.g., the institutional approach, do help to identify key socio-spatial patterns that explain the variance of economic performances, less known is how these patterns are produced and transformed (Boggs and Rantisi, 2003). The relational approach acknowledges that agents and economic actions are embedded in and subject to social structure and relations, hence, contextuality (Bathelt and Glückler, 2003), but it argues that they are not determined by the structures, rather, they are also shaping social relations and institutional structures for future economic actions (Murphy, 2003). Even if structural pressures were given, agents can interpret contexts differently and their strategies and actions may lead to new development pathways with new structures. Therefore, the economic process is contingent and open-ended. Methodologically, the relational turn implies the shift of focus from the macro-level (e.g.

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institutions and policies) to the agents and their relations at micro-level (Boggs and Rantisi, 2003), in which firms are usually the central object. Under a relational perspective, firms are not viewed as independent atomistic units but embedded in social relations where interest conflicts, resource flow, and learning take place.

Regarding scale, traditional economic geography pays considerable attention to the role of spatial proximity at the local and regional scale in industry and regional development. There has been a vast amount of literature proving that the co-location of economic activities brings agglomeration externality in terms of reducing transportation cost and sharing a bigger pool of workforce (e.g. Porter, 2000; Hanson, 2001). Organisations co-located within a small distance benefit substantially from learning from each other. The success of numerous industrial clusters all over the world has championed the value of geographical proximity. However, the time-space compression effect brought by modern communication and information technologies in recent decades has led to a widespread concern of 'the death of geography' (Morgan, 2004), or in other words, distance no longer matters. Indeed, many cooperations and learnings that used to only happen at short distances can now be achieved by distant interactions.

Whereas it seems that geography becomes less necessary in traded interdependencies (e.g. transportation cost and talent mobility), geographers still emphasise the role of physical proximity in untraded dependencies (e.g. culture, tacit knowledge and relations) that clusters need to grow (Coe, Kelly and Yeung, 2007). Particularly, in the age of 'knowledge economy', knowledge learning is of key importance for the development of firms, industries, and regions, and spatial proximity remains an irreplaceable factor that facilitates learning to take place. Unlike codified knowledge, which is standardised and can be transferred and accessed globally through information technologies, tacit knowledge is more geographically sticky. Tacit knowledge involves many non-verbal personally-embodied experiences that can only be learned from doing, and it can only be effectively shared among people who locate in a common social context (Gertler, 2003).

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Frequent face-to-face interactions between organisations with shared value, language, norms, and conventions are essential to trust building (Nonaka and Takeuchi, 1995) and, thus, effective transmission of tacit knowledge. In short, tacit knowledge is context-dependent and locationally sticky (Morgan, 2004). Though spatial proximity is not sufficient alone to enable learning to take place, it facilitates other types of proximity (e.g. institutional, organisational, social and cognitive proximity) that are also critical for learning and innovation (Boschma, 2005).

This focus on the local scale, however, may overlook the fact that processes constituted at other scales are also exerting great impacts on the formation of local socio-economic coordination (Boggs and Rantisi, 2003). There has also been much attention paid to the non-local scale in explaining regional development. For example, the work on global production networks (GPN) stresses the role of interconnections and links across national boundaries at the international level in transforming economic development in subnational territories (Coe, Dicken and Hess, 2008). Drawing on the GPN perspective, Coe *et al.*, (2004) conceptualise regional development as the consequence driven by the strategic coupling between globalising processes and regional assets and institutions. By this, they highlight that regional development is shaped by the forces and processes at various geographical scales. This resonates with the relational approach, which also advocates multi-scalarity and gives no privilege to any scale (Boggs and Rantisi, 2003). Space in relational geography is conceptualised as an open meeting place of interrelations that “run through differing spatial scales from the very local to the global and all points in between” (Massey, 2005:9). Space is no longer territorially bounded, but socially defined by interrelations, wherever they expand. In this approach, the presence of localised relational assets or institutional thickness in a region is no longer sufficient to explain its rises and falls. Instead, much causal weight is given to relations that cross territorial boundaries.

The buzz-and-pipeline model of cluster competitiveness developed by Bathelt, Malmberg

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and Maskell (2004) is a classical illustration of the advantages of a relational multi-scalarity approach. In this model, a local buzz refers to the multilayered information and communication ecology created by information flows, gossip and news within a cluster, while global pipelines refer to the channels accessing the extra-local source of knowledge. A local buzz facilitates the interactive learning within a cluster through encouraging the development of shared values, attitudes, and interpretive schemes, and thus, leads to a more dynamic cluster. On the other hand, with the existence of global pipelines connecting clusters to the rest of the world, not only individual firms can profit from the knowledge exchange relations with outside organisations, the clusters are also better off through the knowledge spillover from those firms acquiring information through their pipelines. However, too much inward-looking of a cluster may cause buzz congestion, that is, information overloaded within a cluster could disable actors to identify crucial knowledge, while too strong external links could result in hollowing out local buzz with less communication and information flow among the cluster. Therefore, an ideal cluster development would require a co-existence of the high level of local buzz and many global pipelines.

Surely, the relational approach is not without criticisms. One problem of relational thinking about the region is in putting too much weight on external flows and relations over internal territorial interests and constraints in influencing territorial politics (Jonas, 2012). Neither institutional structure (relational assets) nor actor networks alone could sufficiently explain spatial outcomes. The place-specific properties are undergoing continuously interactions with external flows and they are shaping each other. Yeung (2005) advocates to avoid the polarised explanation between institutional structure and actor network but pay more attention to what he terms ‘relational geometries’, which are “the spatial configurations of heterogeneous relations among actors and structures through which power and identities are played out and become efficacious” (p38). He believes that networks are mainly horizontal static ties among actors, who should not be viewed as fixed things in time and space. The so-called New Regional Geography also

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advocates that:

> places and regions as neither fixed territories nor a contingent 'coming together' of global flows and networks (which would imply that places and regions had little or no independent causal influence). Rather regions were to be examined as semi-coherent territories within which place-specific causal properties could shape–and in turn were shaped by–the wider dynamics of capital accumulation, state intervention (or withdrawal) and uneven development (Jonas, 2012:265).

In this sense, space is constantly under construction by the tensions between the flowing and the fixed.

2.5.2 Development in geography of transitions

The interest of incorporating a geographical dimension to transition studies began with Shove and Walker's (2007) critique of transition management, in which they stressed the relevance of social environment in shaping transition stakeholders' vision and participation methods. Truffer (2008) elaborated the trading zones between economic geography and social studies of technology (MLP in particular), e.g., the assumption of boundedly rational actors, the role of institutions, the co-evolution of technology and society, and multi-level analysis of socio-technical processes. Based on these complementaries, the combination of the two perspectives is expected to generate better understandings of the dynamic interactions between the socio-technical system and territorialised production systems. Furthermore, he proposed to specify socio-technical multi-levels concepts (landscape, regime, and niche) at global, national, and regional scale in the analysis. This, however, is subject to many debates in later literature (e.g. Raven, Schot and Berkhout, 2012; Späth and Rohracher, 2012; Affolderbach and Schulz, 2016). Since then, the field has witnessed a growing interest in addressing transitions in various geographical contexts, especially in emerging economies (e.g. Bai *et al.*, 2009; Berkhout, Angel and Wieczorek, 2009; Binz *et al.*, 2012), and at multiple spatial scales. Hence, the central contribution of economic geography to transition studies is believed to be the greater focus on territorial embeddedness and multi-scalarity (Coenen, Benneworth and Truffer, 2012b; Truffer and Coenen, 2012; Hansen and Coenen, 2015), which can

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respectively draw rich insights from institutional economic geography and relational economic geography. An additional bonus of adding geographic perspective is addressing the lack of power and politics in sustainability transitions (Lawhon and Murphy, 2012; Murphy, 2015).

2.5.2.1 Territorial contexts

> While space is no longer viewed as the container in which actions occur, it still plays a role in defining the field of opportunities and constraints.(Boggs and Rantisi, 2003:114)

While scholars use distinct terms describing spatial context, e.g., institutional embeddedness (Coenen, Benneworth and Truffer, 2012b), spatial embeddedness (Bridge *et al.*, 2013), place-specificity (Hansen and Coenen, 2015), and socio-spatial context (Murphy, 2015), they all emphasise the role of spatially embedded factors in conditioning transition processes. Territorialised institutions and endowments are indispensable factors that explain why niche development and regime transformation unfold unevenly across space. From an evolutionary perspective, innovation is highly dependent on the localised conditions, which:

> are not simply “accidental” or random but are often the product of, and reflect, the economic, social industrial and cultural, and institutional conditions inherited from the previous technological histories of a locality. (Martin, 2010:20)

As reviewed by Hansen and Coenen (2015), there has been an increasing amount of transition literature addressing different dimensions of place-specificity, including urban and regional policies, localised informal institutions, natural resource and endowments, local technological and industrial specialisation, consumers and local market formation. Though these localised factors can work alone to affect transition process, Gilbert and Campbell (2014) argue that it is the systemic combination and interconnected structure of regional factors (or regional configuration), rather than the simple collection of these factors, that gives rise to the radical technological paradigms. They also highlight four aspects of regional configuration: intellectual capacity (university and regional

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knowledge creation), industry concentration (technology related industries); social conditions (social demand) and political economy (institutions and policy supports).

Not surprisingly, territorial institutional settings (formal and informal) receive the most attention. The institutional structure matters because it provides contexts and frameworks in which environmental policies and regulations are produced (Horbach, 2008). At the national level, much interest is drawn to political factors that condition national environmental laws or subsidy schemes. Cooke (2011) compares the transition regions in three kinds of political models: a liberal market model (e.g. the USA and the UK), a co-ordinated market model (e.g. German and Sweden) and a hybrid model (i.e. the mix of liberal market and strong welfare states, such as Denmark and China), and finds that regions in liberal market economy have more autonomy to facilitate transition experiments, while those in hybrid models have relatively low autonomy but show more variety in innovation initiatives. Kern (2011) compares the Dutch Energy Transition project and UK's Carbon Trust initiative, which differ from each other in main activities, organisational form and role of the government, and attributes the differences partly to the institutional difference in the political system and civil society. He notes that the Dutch political system is characterised by close cooperation between political parties, trade unions, industry and environmental organisations to solve societal problems, while the UK is believed to be a more centralised and unitary state, which means the government can create new policies without too many checks and balances. These institutional differences, together with discourse and interest differences, result in two very divergent initiatives. Interestingly, Hess and Mai's (2014) qualitative comparison between 18 Asian countries finds that the level of renewable energy generation is inversely related to a country's democracy level. This may be what is happening in those countries, but does not necessarily mean a causal relationship between them.

At the urban and regional level, the role of local visions and policies in sustainability transitions is discussed in a large number of studies. While it is widely acknowledged that

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urban strategies and policies are often structured by higher level governance, e.g., interest from regional, national and global levels (Hodson and Marvin, 2012; Emelianoff, 2013; Haarstad, 2015), the localised dynamics of actors, networks and institutions also have a lot of say in shaping a city's future vision and specific policies. Because of the proximity between local actors and the better knowledge of place specificities, transitions at the local level are believed to be more manageable than at the national level (Hodson *et al.*, 2013). In their analysis of Austrian energy regions, Späth and Rohracher (2010) demonstrate that local visions not only translate abstract sustainable energy futures into concrete agendas according to the specific requirements and opportunities of regional context, but also develop the power to coordinate actors effectively within and across different scales. The local institutional structure also plays a crucial part in promoting green technologies (Dewald and Truffer, 2012). For instance, Carvalho, Mingardo and Van Haaren (2012) identify the role of Green Urban Transport Policies in catalysing local cleantech through three processes: a) levering technological exploration through knowledge learning, small scale entrepreneurship, and private-public research; b) providing room for experimentation and testing, which could be facilitated by frequent interaction and understanding between producer and users; and c) creating space for new technologies demonstration.

Of similar significance are the localised informal institutions, such as norms, values, and cooperative cultures. Place-specific norms and values not only matter in translating landscape pressures but also influence local visions and policies, because they, to a large extent, determine local actors' expectation about what are the priorities of the place. The close relationship between informal and formal institutions have been presented in several studies (Angel and Rock, 2009; Späth and Rohracher, 2012). To exemplify this, Wirth *et al.*, (2013) explain the regional differences of biogas technology in Austria as a result of the interplay between formal institutions and the professional culture of farming in each region. The local professional culture not only had much say on which technology to use but also had a modulating effect on policies. Informal institutions are also influential in

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facilitating niche network formation as shared values and tradition strengthen trust. In their analysis of three green grassroots initiatives in Austria, Denmark and Switzerland, Ornetzeder and Rohracher (2013) find that the tradition of cooperative culture is a salient spatial precondition before formal organisations are established to coordinate the grassroots development.

Perhaps the relationship between natural resources and environmental technologies is too self-evident that the role of the natural endowment is only occasionally mentioned in green transitions. The few contributions on this topic seem to have a particular interest in peripheral regions. Späth and Rohracher (2010, 2012) emphasise the role of the considerable stock of woody biomass in the energy transition in Murau, a remote small district in Austria. Likewise, Murphy and Smith (2013) illustrate how renewable energy technologies are integral to the sparsely populated Scottish Highlands and Islands mainly due to their abundance of renewable energy sources such as wind and tides. Patchell and Hayter (2013) argue that global environmental imperatives are redefining the role of peripheral regions in the global production network, as the availability of rich renewable energy sources is enhancing their competitive advantages under the new landscape pressure. On the other hand, an abundance of fossil energy sources may lead to regional lock-in to conventional technologies, while the scarcity of them could often force local actors to invest in renewable energies (Essletzbichler, 2012).

As advocated in evolutionary economic geography, regional industrial path renewal is much conditioned by existing industrial specialisations (Boschma and Martin, 2010). This is because regional knowledge stocks, resources, labour skills and even policies that favour existing industries and technologies often lead to a self-reinforcing industrial-technological path (Martin and Sunley, 2006). However, the geography of transition literature so far hasn't paid much attention to how the pre-existing local industries affect the emergence of new green innovations. Theoretically, the existence of competing industries could obstruct the development of a new industry, while technology-related or

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complementary industries may give a push to the new industry growth. The extent to which existing industries influence new industry development has much to do with the role they play in the local economy, technology innovations, and policy lobbying. Existing dominant industries could lead local development to pathways that may be hostile, indifferent, or friendly to the growth of eco-innovations. Though diversification to unrelated activities is more critical for the long-term regional development, regions tend to diversify into related industries due to path dependencies (Boschma *et al.*, 2017). Unfortunately, this topic has not been well discussed in the current geography of transitions literature.

Another shortcoming, as in the critique of general sustainability transitions, is the focus on the supply side while local consumers are neglected. With few exceptions (e.g. Dewald and Truffer, 2012), much attention is drawn to the supply side such as technology learning, entrepreneurship and resource mobilisation. Due to economic, social and cultural differences, consumers in different regions may have very diverse attitudes towards the same green innovations. Also, the local network of consumers and their relationships with producers could affect how niche innovations are diffused. As McLellan, Chapman and Aoki (2016) hypothesise, consumer preference may offer an indication of direction which, if given sufficient agency, may result in a transition from one type to another. Therefore, the role of local consumers and their networks should be given more attention in future research.

2.5.2.2 Scale and sustainability transitions

As noted above, the majority of sustainability transitions research does not explicitly deal with spatial scale, and empirical studies have disproportionately focused on the national level (Markard, Raven and Truffer, 2012). In contrast, the geography of transition literature pays more attention to the sub-national scale such as cities and regions (Hansen and Coenen, 2015). These studies usually appreciate the role of place-specificity and geographical proximity on the one hand, but also acknowledge or emphasise the effect of

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multi-scalar relations in shaping transitions in particular places on the other hand. A notable conceptual contribution in this regard is the multi-scalar MLP framework proposed by Raven, Schot and Berkhout (2012), which explicitly incorporates a spatial scale in addition to the time scale and structure scale in the original MLP. The scale is the analytical dimension to measure and study any phenomenon (Gibson, Ostrom and Ahn, 2000), and it has different ranges to express the differences. The multi-scalar MLP does not only mean the existence of different dimensions (time, structure and space), but also the different levels along each dimension (Table 2.3).

Table 2.4 Scales in a multi-scalar MLP

MLP level	**Time**	**Structure**	**Space**
Landscape	Long durée, sometimes rapid change caused by disruptive events	Exogenous environment	Typical landscape networks exhibit high degrees of proximity and power across incumbent socio-technical system
Regime	Decades	Endogenous structures enacted by extensive organisational networks and embedded in institutions and infrastructures	Typical regime networks exhibit high degrees of proximity and power within an incumbent socio-technical system
Niche	0–10 years	Protective space that enables development of alternative structures	Typical niche networks exhibit low degrees of proximity and power within an emerging socio-technical system

Sources: Raven, Schot and Berkhout (2012:72).

The spatial scale in this approach can be understood either absolutely or relatively. In the former, space refers to the bounded territory with place-specific institutions, resources, and relations that contribute to explaining why transitions or niche innovations are unevenly located. As to the relative aspect, spatial scale is understood as socially constructed by the interaction between actors, regardless of territorial boundaries. In this

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relational perspective, the focus of the analysis no longer rests on the contextual structure but the actor relations, through which information, resources, technologies and innovations flow across various spatial scales.

> As such, transitions do not simply occur within a certain territorially bounded space (e.g. a country) but emerge out of the tensions created in multi-scalar interactions between spatially distributed actors embedded in multi-level structures with different temporal dynamic. (Raven, Schot and Berkhout, 2012:70)

The early geography of transition studies proposed conflating MLP levels with specific territorial (or political) scales, e.g., the regime at the national level, niche at sub-national level and landscape at international level (Truffer, 2008; Furlong, 2011), and this is adopted in much subsequent empirical research. This view, however, is increasingly challenged by later contributions (Berkhout, Wieczorek and Raven, 2011; Essletzbichler, 2012; Späth and Rohracher, 2012). While positioning the slow-changing landscape at higher spatial level (national and global) seems widely accepted, there are many debates on where niche and regime locate in spatial scales. Nonetheless, a convincing argument is that niche needs not be exclusively local, and regimes can either have transnational features or remain subnational in their spatial reach, rather than merely sticking to the national scale (Raven, Schot and Berkhout, 2012). For instance, Essletzbichler (2012) contend that regions are different in infrastructure, natural resource endowments, and social and cultural capital and so on, therefore, they can represent their own regimes in complementing national regimes. Transitions at the regional scale are not only possible but desirable, because:

> regional and local policies can take advantage of locally specific regime configurations, benefit from localised spillovers, help maintain technological diversity and are more likely to enrol a large number of actors in the transition project, triggering the development of common regional visions that will be easier to implement than “distant” national guidelines. (Essletzbichler, 2012:812)

This is not to imply that the sub-national scale is more important than the national scale in transitions, rather they still need the support from national level (e.g. institutional

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framework and incentive policies) to function properly and to scale up to higher levels. Emphasised here also is a multi-scalar analysis that views local transition dynamics co-evolving with processes at higher scales. As in the TIS framework, Dewald and Fromhold-Eisebith (2015) propose a scale-transcending innovation systems approach that integrates the territorial innovation system (e.g. regional, national and international innovations system) concepts with TIS processes (R&D and knowledge, technology production, market formation and policy design), highlighting the dynamics at different scales that shape the interplay of actors in generating, applying and diffusing environmental innovations.

Empirically, there is a growing number of studies addressing multi-scalar interactions in transitions. The analytical focus is usually at the level of city and region, as local proximity facilitates network formation and learning (Dewald and Truffer, 2012), but meanwhile, more weight is put on extra-local relations with distant places and actors that contribute to local transition processes through the flow of knowledge, resources and technologies (Binz *et al.*, 2012; Binz, Truffer and Coenen, 2014, 2016). For example, Carvalho, Mingardo and Van Haaren (2012) illustrate that local clean-tech innovations are co-evolved with local innovation milieus of actors, networks, and institutions, and higher order structures such as national policies, as well as global knowledge mobility. While there is increasing interest in the ‘glocalisation’ process, that is, the direct relationship between the local and the global scale, Mans (2014) argues that national structure is still critical by providing different geographical settings that explain the differences in glocalisation process. In the case of renewable energy programmes in Cape Town and Casablanca, he finds the main aspects (plant size, local content and technology choices) that explain the varieties of glocalization between the two cities are the consequence of the national process. Hence, he advocates a global-national-local multi-scalar perspective in transition studies. Similarily, Sengers and Raven's (2015) bus rapid transit (BRT) case shows that international actors (e.g. NGOs and highly mobile experts) and urban actors are the key factors in the diffusion of BRT across national borders, but

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national actors also play an indispensable part, particularly in terms of providing financial resources and legitimacy.

Some studies focus on the role of transnational linkages in sustainability practices in developing countries. For instance, Binz *et al.*, (2012) reveal the importance of knowledge transfer from the international innovation system in the form of market interaction, project cooperation and professional overseas returnees for China's wastewater treatment innovation system, while Wieczorek, Raven and Berkhout (2015b) find that transnational linkages in terms of actors and knowledge flows are of particular significance in India's sustainability experimentation with solar PV projects. However, transnational linkages do not necessarily mean developing countries' one-way dependence on developing countries, rather there can be mutual interdependence between the industrialised countries and emerging countries, as shown in the case of the co-evolution of PV TIS in Germany and China (Quitzow, 2015).

2.5.3 Role of Cities

While the mainstream transitions literature has an obvious bias towards transitions at the national scale, the geography of transitions literature attends the role of cities and regions in sustainability transitions (Hodson and Marvin, 2012; Bulkeley *et al.*, 2013; Rohracher and Späth, 2013; Rutherford and Coutard, 2014). The MLP says little about cities and how cities fit in landscape-regime-niche hierarchies, and the relationship between national governments and urban actors has been underdeveloped (Hodson and Marvin, 2010). The conventional transition literature tends merely to regard cities as places for niche experiments for national transitions. For instance, Geels (2013b) suggests three roles of cities in national transitions; a) cities as primary actors; some national regimes operationalised in urban scales, such as district heating, water supply, and public transport, and thus national transition is the aggregate collection of urban transitions. In this scenario, cities and city government can play the critical role in initiating transitions. This is exemplified by the Netherlands' transition to piped water, which started in cities for

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various reasons (e.g. hygiene, comfort, convenience, social status and industrial use) and then national elements (e.g. technical standard and financial subsidies) stepped in to expand the transition to rural areas. b) cities as seedbeds for transition; that is, cities are the main location where niche innovations are created and entrepreneurial experiments are performed. Cities play a key role in the early phase of transitions but become less vital in the up-scaling phase because it requires more investment from the national level. c) cities can play only a limited role in those transitions that are characterised by limited infrastructure change, strong market interactions, and involving national-level system transformation with powerful incumbent actors.

However, recent contributions contend that cities are able to shape their own socio-technical transitions, particularly in global cities which have their own political aspirations, social interests, and capacity to coordinate urban sustainability transitions (Hodson and Marvin, 2010, 2012). There has been a trend in which cities are taking increasing responsibility for technology, innovation and competitive policies that used to only be national concerns. Indeed, cities are subject to national level governance, and, in many cases, transition efforts in cities are mainly in response to national priorities rather than local social interest. Yet, there exist various types of relationship between cities and national transitions, as cities have diverse capacities to either be 'shaping of' or 'shaped by' national transitions (Hodson and Marvin, 2010:481). Cities' responses to national pressure differ not only in how they interpret and translate these challenges but also in their capacities to act, which have been constrained by each city's own current and historic organisation of infrastructure (Hodson and Marvin, 2010). Some cities can only implement national transitions in their local contexts; some are able to mediate national transitions; some can develop the further capacity to enact their own purposive local transitions, and some urban transition practices are even scaled up to the national level and then top-down to other cities (Hodson and Marvin, 2009). Cities could be part of national transitions, but also can be the autonomous actors in pursuing their own transitions. More attentions have been paid to the role of local actors, especially policy

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and institutional entrepreneurs (e.g.mayors) (Block and Paredis, 2013), in urban sustainability transitions.

Drawing on multi-level governance thinking (Brenner, 2004), Hodson and Marvin (2010) argue that agency at the city level is not simply about the coalitions of local actors, rather, it involves the influence of both intentional and unintended actions by actors across regional, national, and supranational scales. That said, there are various power relations between different scales in different cities. Haarstad (2015) argues that urban transition governance involves a complex assemblage of institutions, networks, and localised sociotechnical artefacts, and he proposes to understand urban transition governance from three perspectives: vertical perspective, horizontal perspective, and infrastructure perspective. The vertical perspective is in line with multi-level governance thinking, emphasising that the urban governance process is structured by higher level formal institutions. The horizontal perspective stresses the relational features of cities that they are not bounded by any scale but are "intensive nodes that gather connections from more widely distributed spaces" (Rodgers, Barnett and Cochrane, 2014:1553). This perspective highlights the inter-city networks through which knowledge, discourses, and experiences circulate to enable learning to take place. What matters here is not only the local institutional legacies and path dependence in urban policy makings but also their relations with city-to-city networks. For instance, Emelianoff (2013) finds that local sustainability actions are legitimised or reinforced by the transnational municipal networks. In his case of Hanover, he shows that the ICLEI[2] alliance legitimates the local leadership when Germany did not have federal actions on climate change. Finally, the infrastructure perspective advocates that urban low carbon efforts are highly related to their physical forms, such as transport system, population densities, and the built environment. Urban infrastructure matters because it constitutes a part of the stable regime that restricts a city's options of available technologies or solutions for sustainability.

[2] International Council for Local Environmental Initiatives, founded in 1990 in New York, is an international association of local governments and national and regional local government organizations that have made a commitment to sustainable development.

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The work of Späth and Rohracher (2010, 2012, 2014) particularly contributes to the debate regarding the position of cities in MLP, or the role of cities in regime transformation (Hodson and Marvin, 2010). They abandon the idea that cities are simply sites of niche development in response to national regimes, and advocate that cities can be viewed as occupying an intermediate level between niche and regime. Though the notion of regime conveys high homogeneity, there can be significant variations of regime structure between cities, just as those between nations. Cities are parts of the wider national regime, and thus, can at least represent partial national transitions. Depending on the analytical focus, the role of cities in regime change varies. If the focus is on broader national regime change, cities are usually the places for niche experiments, which challenge existing national regimes by e.g., becoming a desirable showcase of sustainable solutions, aligning higher level actors, and facilitating institutional changes. On the other hand, if the focus is on the system changes at urban scale, such as the urban system of energy production and consumption, the rules or the assemblage of institutions, artifacts, norms, and user practices etc. in the cities can be regarded as meso-level regimes, because they have localised stabilities but also are embedded in wider regimes. In this case, local sustainable initiatives such as policy innovations and green projects constitute the niche experiments, expecting to alter urban regimes with the empowerment from national and global landscape discourses. As Hodson and Marvin (2012:423) put it:

> reorganising energy systems or effecting a transition at the city scale, therefore, necessitates a transition from a largely regionally nationally organised energy regime in a wider national system but also requires the constitution of a city-scale regime with variable levels of discretion afforded by national government.

Much empirical focus has been upon sustainability transitions in large world cities or developed western cities, such as London, Manchester, New York, San Francisco, Boston and Stockholm (Hodson and Marvin, 2010; Hodson, Marvin and Bulkeley, 2013; Gibbs and O'Neill, 2014b; Nykvist and Nilsson, 2015), while the role of smaller cities and less developed cities has been neglected. Since less developed cities lack political, economic

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and technological resources as in large global cities, it is of great theoretical and practical significance to explore how sustainability transitions could be realised in small less developed cities. Particularly, less developed cities of the global south are yet to experience industrialisation and urbanisation, and their transitions to more sustainable modes of production and consumption from the outset could have a very significant impact on mitigating global climate change. Under the new global landscape, the peripheral cities in economic terms may be better positioned in sustainability transitions as they are less locked-in by incumbent unsustainable regimes in post-industrialised cities. They may also provide favourable niche spaces for the experiments of sustainable technologies and governances. Nonetheless, they are expected to encounter many difficulties in sustainability transitions due to the shortage of endowments and capacities, and thus, powerful agents and trans-local relations may carry more weight in such places. Future research should engage more with transitions in cities outside of premium world cities and examine what transitions look like in ordinary cities and cities of the global south (Hodson and Marvin, 2010).

2.6 Leapfrogging

If following the same path of energy development as has happened in developed countries, developing countries are very likely to be locked into an environmental degenerating technology path, which is increasingly costly and difficult to break. The present thesis believes that addressing sustainability transitions in less developed cities could profit much from incorporating insights from the so-called leapfrogging literature, which is particularly interested in radical innovations in latecomer regions. Existing literature has reached a fruitful understanding of leapfrogging, though it still has yet to be well defined and theorised (Binz *et al.*, 2012). A clarification should be made between the technological leapfrogging and environmental leapfrogging. The former refers the skipping of stages of technology generation, indicated by the radical improvement of technology innovation and manufacture capacities (Lee and Lim, 2001; Schroeder, 2010). Lee and Lim (2001) identify three catching-up patterns of latecomers in terms of both

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technology capacity and market share: a) path-following, latecomers follow the same path as that taken by forerunner countries, but in a shorter period of time; b) path-skipping, latecomers follow the same trajectory but skip some stages in technology development, thus, saving time; c) path-creating; latecomers create their own development paths and lead the market. The latter two patterns can be viewed as leapfrogging. Latecomers tend to follow the path of product life circle in technology development (path-following), but they may also jump over some stages in technology development (path-skipping) and even create their own individual paths (path-creating) (Lee and Lim, 2001).

Environmental leapfrogging means that the adverse environmental impacts compared to business-as-usual development are avoided through the use of environmental technologies from the outset (Goldemberg, 1998; Perkins, 2003). Technology leapfrogging in renewable energies is not necessarily followed by environmental leapfrogging, which requires system changes not only in the energy sector, but also in main aspects of socio-economic activities (Schroeder, 2010). Binz *et al.*, (2012:157) define leapfrogging as:

> a situation in which a NIC [newly industrialising countries] learns from the mistakes of developed countries and directly implements more sustainable systems of production and consumption, based on innovative and ecologically more efficient technology.

Empirical evidence from first-tier industrialising countries (e.g. South Korea and Singapore) have proved this observation, while later industrialising countries may not leapfrog as easily as before since international rules have changed, but it remains a worthy and achievable policy goal (Perkins, 2003).

Sounding attractive, leapfrogging does not take place readily. Due to weak indigenous innovation capacity, developing countries often require technology transfer from developed countries in various forms, such as foreign direct investment (FDI), international trade, and joint ventures with transnational companies (TNCs) (Goldemberg,

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1998; Gallagher, 2006; Collier and Venables, 2012). Lema and Lema (2012) conceptualise two mechanisms of technology transfer: conventional and unconventional ones. The former refers to low level of cross-border interaction and less recipient effort (e.g. FDI, licencing and trade), and it is critical in the take-off phase; the latter has higher interactive requirements and depends on substantial investments (e.g. acquisition of foreign firms and overseas R&D), and it plays crucial role in the catch-up phases. However, technology transfer is by no means straightforward or easy. On the one hand, developed countries and TNCs are always less actively willing to transfer their advanced technologies in order to profit fully from existing technologies in developing countries. On the other hand, even if given unhindered knowledge diffusion from the international level, developing countries' capacity in knowledge absorption remains central to the learning process (Blum, Bening and Schmidt, 2015). Enough financial and technological capacity should have been developed in recipient countries in order to capture the spillover from the transferred technologies. This also requires huge long-term investment in personnel training and infrastructure construction. Furthermore, transferred technologies are often not well suited to developing countries' local requirements and the tacit knowledge encompassed in the technologies is difficult to absorb without enough knowledge base (Perkins, 2003). In short, three preconditions should be met if a latecomer wants to achieve leapfrogging (Perkins, 2003): a minimal endowment with basic infrastructure, as well as technological and organisational absorptive capacity; government interventions that strengthen incentives for the uptake of innovative technologies; and technology transfer and financial assistance from developed economies. Successful leapfrogging needs not only sufficient domestic capacity but also continuous interactions and connection with developed regions (Binz *et al.*, 2012).

For instance, Gallagher (2006) reveals the barriers of technology leapfrogging in China's automobile industry towards environmental technology. From the TNCs side, they are, understandably, reluctant to transfer their environmental technologies to reduce cost and in the fear of breeding future competitors in China's auto market. From China's side, there

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is a lack of stringent incentives from government to force automobile manufacturers to meet higher emission standards. This is contributed by the fact that, as a technology recipient country, China's domestic automobile industry is unable to meet higher emission standards due to weak technology capacity. This vicious circle is aggregated by China's poor fuel quality standard, which provides TNCs with excuses that the effectiveness of environmental technologies would be minimised without improving fuel quality. Leapfrogging thus requires recipient countries to enhance their technology capacities and to provide a friendly institutional environment, such as incentive policies and intellectual property legislations. On the other hand, though it seems that many advanced environmental technologies are available, developing countries are often restricted in options because of financial shortages.

Nonetheless, developing countries possess huge potential for environmental leapfrogging because they have the so-called latecomer advantages (Perkins and Neumayer, 2005). Being latecomers in technology development may allow developing countries to adopt cleaner technologies from the beginning since they are less locked-in by incumbent technologies as in developed countries. Binz and Truffer (2009:2) argue:

> As infrastructure sectors are not yet fully established in these [newly industrialised] countries, path dependencies that would strongly favour specific socio-technical configurations in OECD countries are not existing or much weaker in NICs.

Due to the lock-in of existing technologies and infrastructure, other socio-technical elements such as institutions, values, and user practices are also difficult to change in developed economies, constituting a hostile regime to new environmental technologies. In contrast, regimes tend to be less ordered and stable in developing countries, because:

> they are emerging in the context of higher rates of growth and compounded social, demographic and industrial transformations, but also because the institutional and governance capacities in these countries are less settled and remain contested. (Berkhout, Wieczorek and Raven, 2011:378)

Developing countries thus have more flexibility or manoeuvring space for new green

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technologies. For example, developing countries, especially those with large dense cities, could be the ideal places for EV adoption because their transport infrastructure is still in the construction phase and thus can be easily adjusted for EV technologies (Goldemberg, 1998). It is also possible that the developing cities have not developed the automobile culture of convenience, comfort and social status as in Western developed cities, and this may form fewer barriers to the diffusion of EVs. Furthermore, the latecomers could also benefit from the so-called learning investment. Developing countries can learn the experiences and lessons from the forerunners so as to diffuse environmental innovations faster and at less cost (Iwami, 2005). These latecomer advantages may enable developing countries to bypass the 'dirty' stage of economic growth through the use of a cleaner production paradigm (Perkins, 2003).

However, leapfrogging research has been so far dominantly focusing on the technology transfer at the national level and the firm level, paying little attention to the role of sub-national cities and regions in indigenous innovation. It places too much weight on unilateral technology transfer, ignoring that globalisation also exerts influence on reshaping the expectations and interests of actors and creating legitimacy at the local level (Binz, Truffer and Coenen, 2014). External learning is not necessarily international, instead, interactive learning within the national boundary is also critical for national innovation system (Lundvall, 1992). Sub-national cities and regions exhibit heterogeneous innovation capacities with a huge variance of local innovation milieus of actors, networks and institutions for the development of environmental technologies, and they enjoy geographical and social proximity that facilitates network formation and knowledge learning (Boschma, 2005; Dewald and Truffer, 2012). As local innovation is becoming increasingly essential for latecomers leapfrogging (Lema and Lema, 2012; Lundvall, 2007), the focus should be shifted towards more indigenous innovation on the local level where innovations actually occur. Advocated here is to look at the role of agency and power struggle at the local level, and explore how global megatrends redefine the power structure between local green proponents and incumbent actors (Lema, Iizuka

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and Walz, 2015). A central focus could be given to the role of green entrepreneurs in promoting institution changes and knowledge diffusion (Gibbs and O'Neill, 2014a; Furtado and Perrot, 2015). In addition, technology transfer research mainly deals with the codified knowledge, while the tacit knowledge, which is more place-sticky, is overlooked. It is of great value to examine not only the international knowledge relations (global pipelines) of champion firms but also how their learned knowledge spillover to local innovation networks (local buzz) (Bathelt, Malmberg and Maskell, 2004).

The second gap lies in the bias towards high-tech and high-investment industries, PV and wind energy in particular. This is perhaps due to their large capacity in generating renewable electricity, as well as the fact that they are regarded as the strategic industries in bringing GDP and employments (Schroeder, 2010). However, the focus on such high-tech industries is too narrow at the expense of ongoing innovation in the low-tech industries (Lundvall, 2007), which also have a profound influence on global low-carbon transitions. Due to the high-cost and R&D-intensive nature of PV and wind turbine, it may not be suitable to develop massively in many small developing countries. Since developing countries are rich in labour and natural endowment but short of capital, the proper technologies for them to leapfrog tend to be labour-intensive or resource-intensive ones (Goldemberg, 1998).

Particularly, latecomer countries may have a bigger role to play in the so-called 'disruptive innovations', which:

> Generally… were technologically straightforward, consisting of off-the-shelf components put together in a product architecture that was often simpler than prior approaches. They offered less of what customers in established markets wanted and so could rarely be initially employed there. They offered a different package of attributes valued only in emerging markets remote from, and unimportant to, the mainstream. (Christensen, 1997:28)

These innovations are usually low-cost and low-tech products targeting previously

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excluded markets, and they are often produced by non-incumbent players in novel contexts (Tyfield and Jin, 2010). Nonetheless, they possess a huge potential to move up markets and eventually emerge as dominant. Disruptive low-carbon innovations can also contribute significantly to global carbon mitigation, and they are of much greater and more direct relevance to low-carbon transitions in latecomer countries such as China (Tyfield, Jin and Rooker, 2010; Tyfield and Urry, 2012). Spatially, latecomer regions may have higher prospects in achieving such innovations.

2.7 Sustainability transitions and leapfrogging in less developed cities

I concur with Hansen and Coenen (2015) that the current geography of transition literature, as well as the general sustainability transitions research field, primarily focuses on the niche processes in various spatial contexts while less attention is paid to how regimes respond and how the variance of regimes across space contributes to the differences between niche development. As a result, niche-regime relations are neglected, as too much emphasis has been given to bottom-up niche processes. This is problematic because the growth of niches alone cannot bring about transition without interacting with the regimes. Regimes are generally viewed as obstructing forces to niche development, but it is still likely that some regimes or at least some elements of a regime may be supportive for particular kinds of niche innovations. At least theoretically, a niche innovation is more likely to grow in a favourable selection environment with fewer regime resistance. The concept of regime has long been depicted as ‘monolithic’ and ‘homogenous’, yet, there exists much variance in the strength of regime. As Fuenfschilling and Truffer (2014:776) argue:

> If the field is mainly dominated by one established field logic, the regime is likely to be highly coherent, stable and thus exert a strong power over an actor’s behaviour and cognition and, along with that, determine the course of development of the socio-technical system. As a result, the system is very stable and unlikely to change. On the other end of the scale, a weak regime would be described as rather incoherent and unstable with different field logics competing for legitimacy and therefore diminishing the overall structuration of the field.

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The geography of transitions literature has contributed substantially in explaining why niche innovations take place in various places, yet, it lacks a generalised theory about why sustainability transitions unevenly occur across space (Hansen and Coenen, 2015).

Drawing on the MLP, this thesis proposes that local sustainability transitions result from power struggles between niche development and regime resistance. Though MLP emphasises the role of landscape, I contend that the direct force bringing transition comes from the interaction or struggle between niche development and regime resistance, while the landscape works more in an indirect way as contextual factors that help to destabilise (or sometimes reinforce) regime resistance and empower (or discourage) local niche development. Theoretically, transitions are more likely to happen in those places that are characterised by weaker regime resistance and strong niche development. The relationship between niche development and regime resistance is reciprocal, with one falling and the other rising. In a latest contribution to the geography of transition literature, Boschma *et al.*, (2017) argue that there exists variance in the extent to which a regime is regionally institutionalised, and transitions or regional diversification are less likely to occur in the regions where a regime is strongly aligned with local institutions, knowledge base, and vest interests, but we can expect " windows of opportunity to exist in regions where the regime is less dominant and only weakly institutionalised or hybridised" (p8). In initiating transitions, developed economies may have been blocked by strong regime resistances in terms of investment, value, institutions and infrastructures and so on that have been shaped by established technologies and actors, even though they may have strong niche innovation capacities. By contrast, the regimes tend to be less stabilised in developing economies but their transitions may be mainly obstructed by the weak niche developments, since they only have limited technological and financial capacities.

As Bridge *et al.*, (2013) point out with regard to energy transition, spatial locked-in capital investment and consumption cultural norms constitute the major challenges for the substitution of fossil fuels, but the developing countries usually have not been locked-in

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in the same way and this can provide opportunities for the rapid uptake for renewables. It is also reasonable to assume that these latecomer advantages and the potential of leapfrogging could be possessed by less developed cities within a nation. Sustainability transition in a city can be viewed as a struggle between regime resistance (incumbent) and niche development (challengers). Sustainability transition is more likely to happen in cities with weak regime resistance and strong niche development, thus a less developed but growing city might be the desirable place for environmental leapfrogging. In applying new green innovations, regime resistance could be more persistent in developed cities. For example, Nykvist and Nilsson's (2015) research shows that the relatively slow development of EV in Stockholm is the result of strong regime resistance, poor niche development, and weak landscape incentives. Developed cities may have been locked-in to existing unsustainable technologies in terms of knowledge, scale economy, institutions and consumer preferences. The cost of switching to alternative green technologies could be much higher in developed cities. On the other hand, new green innovations are often not advanced enough to meet the diversified demands of developed cities. Green innovations often have some disadvantages in function, such as the unreliability of EV and solar energy. Developed cities could be a much more harsh selection environment for such new green innovations.

By contrast, less developed or latecomer cities are less locked-in by existing technologies, as infrastructures and rules yet have to be established. Besides, under the new global environmental discourse, green niche innovations may be further encouraged in non-core regions as a way of regional path creation, because they may coincide with local development in terms of national competitiveness and economic benefits (Essletzbichler, 2012). Green industry development could not only benefit a local economy in terms of revenue and employment but also earn green images that are rewarding for long-term regional development. Compared to developed regions, which very often have been dominated by conventional industries, developing regions may have more opportunities to develop green industries to be their leading industries, since they rarely have other

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dominant competitive industries. Given the limited amount of economic activities in small or less developed cities, it is likely that a large firm or a leading industry will play very crucial role in the local economy and even altering the local development path. Therefore, the local political and economic actors in latecomer cities may have stronger incentives to champion green niche innovations, and thus, green entrepreneurs could be more powerful if they align with other actors and upscale to challenge and even replace existing weak regimes.

From the demand side, less developed cities could be more friendly to certain green innovations as long as they fulfil some practical functions, e.g., reducing cost, because consumers in less developed cities tend to be less demanding than their counterparts in developed regions. Due to technological immaturity, decentralised green innovations are difficult to step over the threshold of the developed urban market, which has higher demands such as comfort, convenience, aesthetic and social status. Consumers in less developed regions tend to care more about cost and practical functions, if these can be met, the innovations are very likely to be well popularised in the regions. On the other hand, interpersonal networks also have much influence in the diffusion of innovations (Rogers, 2003). Less developed regions usually have closer interpersonal networks than the developed ones, and this could facilitate social learning about the given innovations and thus diffusion.

Admittedly, latecomer cities are limited in endogenous capacities to develop successful niche innovations, but the multi-scalar interactions with extra-local factors could enable them to overcome this obstacle and take advantage of latecomer advantages to achieve leapfrogging. As discussed, both regime and niche are multi-scalar in nature from a relational perspective (Raven, Schot and Berkhout, 2012). Niche innovations can involve actors and relations across various spatial scales, instead of being bounded exclusively locally. These multi-scalar relations could play an essential role in empowering local green niche development through mobilising the resources, knowledge, and technology, as well as legitimacy to the less developed cities. This is not to imply that less developed cities have advantages in diffusing every green technology, rather, their comparative advantages in the labour force and natural endowment imply that they may be more competitive in those technologies characterised by less capital-intensive and less R&D-intensive.

2.8 Summary

Sustainability transition has been an emerging research field in last two decades due to its focus on the fundamental transformation of existing main human sectors. The strength of the sustainability transition approach rests in analysing the co-evolution of socio-technical factors such as institutions, markets, user practices, policies, and cultures, in a systemic perspective. So far, two conceptual frameworks, MLP and TIS, have been developed to analyse sustainability transitions, and two policy-oriented approaches, SNM and TM, aim to purposely promote sustainability transitions in practice. The contributions and limitations of these approaches have been reviewed in this chapter. The present thesis predominantly draws upon the MLP because it provides a powerful framework in delineating sustainability transitions through its ability to order and simplify the analysis of complex and large-scale system transformations. Nonetheless, there remain some research gaps in this approach, such as too much focus on niche innovations, lack of power and agency, issues of operationalisation, single regime analysis, and less convincing methods. In empirical research, much interest is drawn to exploring the factors that drive or hinder sustainability transitions. It is acknowledged that sustainability transitions require systematic efforts and no one kind of factor alone can explain transitions, but there are some major factors influencing transition processes albeit their roles vary a lot according to the characteristics of sectors, geographical areas, and time periods. These factors include institutions (formal and informal), government regulations and policies, culture, social demand and infrastructure. Two main biases (towards developed countries and supply side of technology development) in existing empirical domains were identified. It remains unclear how sustainability transitions theory could

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apply to the fast industrialising and urbanising developing countries' contexts. Also, most research simply assumes that consumers act rationally economically, which is problematic and neglects the role of interpersonal networks in affecting consumer behaviours.

There is a growing body of the geography of transition literature addressing the lack of space and scale in sustainability transitions research. The main contributions in this field have drawn insights from economic geography. The institutional, evolutional and relational turns in economic geography have provided rich understandings about space and scale. This thesis believes that the relational understanding of space and scale from relational economic geography is of particular value to sustainability transitions research, because it reveals the importance of multi-scalar relations rather than territorially bounded factors that shape local contexts and it gives more credit to the role of power and agency that has been ignored in transitions research. So far, the geography of transition literature has paid much attention to the role of geographical contexts in the transition process, but the issue of multi-scalar still needs more contributions. Furthermore, while the focus tends to be drawn to the niche processes in various geographical areas, little work has been done on how regimes respond and how the variance in regimes accounts for different transition dynamics. Therefore, more careful elaboration on niche-regime relations is needed for future research agendas.

Compared to the general sustainability transitions research, the geography of transitions literature gives much more emphasis to the urban and regional level. Instead of viewing cities as only seedbeds for transitions, recent contributions have contended that cities can represent their own regimes and the proximity of local actors and better knowledge of place-specificity make cities a more manageable scale for sustainability transitions to take place. There exist different types of relationship between cities and national transitions as cities have different capacities to either be 'shaping of' or 'shaped by' national transitions. Nonetheless, agency at the city level is not simply about the coalitions of local actors and

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institutions, rather, it involves the influence of both intentional and unintended actions by actors across regional, national, and supranational scales. The national contexts still matter in addition to direct linkages between global and local scale in explaining the differences in the urban level transition processes.

This chapter argues that methodologically, future research could reap much more benefit from comparative case studies and empirically, transitions in small and less developed cities need more attention since they usually do not have the capacities that big developed cities have to mobilise for transitions, but they possess huge potential to achieve environmental transitions because of so-called latecomer advantages. The leapfrogging literature has argued that regime factors may not have been well established in developing countries, and thus environmental leapfrogging could be realised if they are able to take advantage of knowledge transfer and financial investment from the developed regions. Latecomers can even create their own paths that are more sustainable than the existing paths in the developed world. I believe this principle can also apply to the urban scale and propose to understand sustainability transitions at the urban level as power struggles between niche development and regime resistance. These factors are not bounded locally, rather, they are embedded in multi-scalar networks, whereby niche factors are empowered (or hindered) and regime factors are destabilised (or strengthened).

Sustainability transitions have more potential to be realised in cities that are characterised by weak regime resistance but strong niche development and thus, a growing latecomer city might be the ideal place for environmental transitions to take place. On the one hand, the established unsustainable regimes are less stable or absent in these cities, and on the other hand, under the new global landscape of environmental imperatives, green niche innovations could be more empowered as they may strengthen the cities' national competitiveness and bring economic benefits. Furthermore, large green firms or industries may have more power in shaping local development paths in such latecomer cities.

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As Raven, Schot and Berkhout (2012:76) suggest, a striking contribution to the existing transition literature would be "the focus on regional differentiation within national boundaries in combination with the role of transnational networks and institutions as important explanations." This thesis seeks to explore the above ideas on the sustainability transitions in two cities of China through examining both the place-specific niche-regime interactions and multi-scalar relations with extra-local actors and resources.

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Chapter 3 Methodology

3.1 Introduction

The principal research objective of this research is to reveal the role of latecomer cities and how geography matters in sustainability transitions. Therefore, it is necessary to understand the contexts that these cities are located in and investigate how actors, artefacts, institutions and other spatial-embedded elements in the cities interact to facilitate or obstruct sustainability transitions. This chapter provides the rationale and detailed descriptions for the methods I used to achieve the research objectives. I demonstrate how my methodological approaches relate to my theoretical questions. Before describing specific research methods, I start with framing the ontology and epistemology behind qualitative research and justifying the use of a case study method as a scientific, practical and useful approach to investigating my research questions (Figure 3.1). Then the choice of Dezhou and Beijing as case study cities of this research is explained in section 3. Section 4 breaks down the specific methods (interview, observation and document analysis) and describes the data collection process in the two cities. Section 5 illustrates how these data were analysed. Finally, I reflect on the ethics, power and subjectivity issues of my methodology.

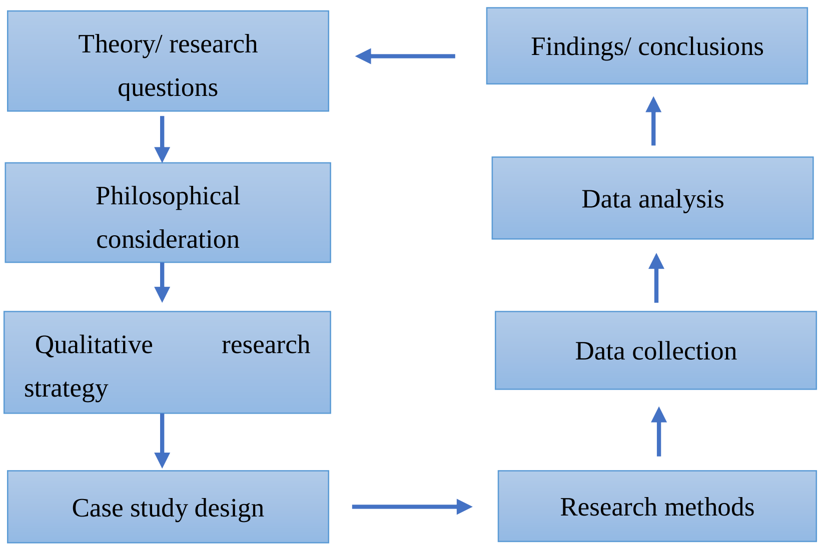

Figure 3.1 The methodology logic of this research

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3.2 Ontology and epistemology

> Just as we cannot speak a language successfully without following certain grammatical rules, so we cannot conduct a successful piece of research without making certain philosophical choices. Philosophy, like grammar, is always there. *(Graham, 2005:10)*

This section discusses the philosophical considerations that underlie my research strategy and design, as they deeply affect research methods in reaching theoretical results. ‘Fundamentalism’ asserts that true knowledge must be based on a set of solid truths, so that our logical deduction may be legitimated (Hughes and Sharrock, 1997). Scientists claiming new knowledge from their research have to justify their philosophical foundations about ‘what kinds of thing really exist in the world’ and ‘whether can we truly know anything about the real, external world’, which are often termed as ontology and epistemology respectively.

Social research, such as human geography, notably differs from the natural sciences in that it involves human actions with intentionality, rationality and reflexivity, whereas natural science only deals with the force of nature (Graham, 2005). Therefore, the core question of social ontology is whether social world should be considered as objective entities external to social actors, or as entities constructed by the perceptions and actions of social actors, leading to the epistemological concern as to whether the social world could and should be studied by following the principles and procedures in natural sciences (Bryman, 2012). According to the different combinations of ontologies and epistemologies, there have developed many philosophical paradigms debating with each other in social research, as well as in human geography. Here, I briefly introduce the three most influential strands of philosophical thinking that are related to this research: positivism, critical realism and constructivism.

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3.2.1 Positivism

It is acknowledged that it is difficult to define the doctrine of positivism in a precise manner as it is used by researchers in very different settings. Nonetheless, it is widely believed to be founded on five philosophical beliefs: a) only knowledge that is grounded in direct and empirical sensory experience can genuinely be warranted; b) valid knowledge is gained through gathering of facts and logical induction; c) statements or hypothesis based on empirical observations can be tested and accessed, and if verified, would assume the status of laws; d) scientists must be independent from the objects (value free); e) scientific laws should be clearly distinguished from normative statements (Bryman, 2012). The scientific methods based on positivism usually consist of both inductive and deductive processes: observation of facts; ordering and classifying of facts; making generalisations; hypothesis making; hypothesis testing; verification of hypothesis; and reaching knowledge in the forms of theories, laws and explanations (Haines-Young and Petch, 1986). Logical positivism, or critical rationalism, shares the ontology and faith in reason with positivism, but argues that scientific statements should rest upon falsification of hypotheses rather than verification, just as the well-known metaphor by Popper (1965) illustrates: the prior observation that swans are white cannot lead to the scientific statement that all swans are white.

Positivism dominates philosophical thinking in the natural sciences but also influences social research to a very great extent. For example, the revolution of regional geography in the middle 20th century tried to build scientific laws to predict geographical locations as natural science. However, positivism is criticised for the failure to acknowledge the role of observers in the constitution of social reality and that the social system is subjected to constant changes. In terms of representation, positivism views observational language as a direct and transparent representation of the phenomena it records, which has been challenged by a variety of hermeneutic and postmodern theories (Hoggart, Lees and Davies, 2002).

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3.2.2 Critical realism

Critical realism shares the ontology with positivism that there is 'reality' out there, independent from conscious human actions and, epistemologically, believes in the role of empirical observations in providing foundations for scientific statements, but rejects positivism's value-neutral principle or theory-free observation (Hoggart, Lees and Davies, 2002). As Sayer (1992) argues, evaluating and criticising researchers' own self-understanding cannot be avoided in the process of studying social phenomena. In the realists' view, empirical observations are necessarily dependent on theoretical prejudices. For instance, observing the same object under a microscope, a biologist's interpretation will considerably differ from a layman's, because what the biologist has learnt and the extent to which he takes knowledge for granted will have strongly influenced his perceptions (Sayer, 1992). In reaching scientific statements, realists doubt that empirical regularity leads to scientific laws. Instead, they emphasise a 'depth ontology' that encompasses "ontologically necessary structures of causation lying beneath the surface appearance of things" (Hoggart, Lees and Davies, 2002:19).

3.2.3 Constructivism

Constructivism takes the opposite ontological position to positivism and realism, by asserting that social phenomena and their meanings are continuously being constructed by social actors. The categories (e.g. organisation and culture) that positivists or realists take for granted to study the social world is challenged by constructivists. On the contrary, they contend that social phenomena and categories are constructed in and through social interactions (Bryman, 2012). From a constructivist view, meanings are not objectively lying in research objects, but in the relationship between researchers and the researched (Guba and Lincoln, 1994). Constructivists believe social reality is pluralistic, varying according to history, places, contexts and a researcher's own account (Chen, 2000). Therefore, researchers always represent a specific vision of social reality (Bryman, 2012). As Goodman (1978) says, the way humans observe things decides the nature of what they saw. The researchers' personal ways of thinking, use of language and interpretive

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principles must accord with their basic life norms, or they will not be able to explain the meanings of what they observed and cannot communicate with others (Chen, 2000). Methodologically, its interpretation of social phenomena requires totally different research strategies to those employed by positivists. Constructive research is conducted through gathering rich data from which ideas are induced, and generalisations are made through theoretical abstraction, rather than statistical probability.

3.2.4 The philosophical stand of this research

This research takes more a philosophical standpoint of critical realism, which ontologically acknowledges the existence of social reality, but epistemologically emphasises the role of researchers' interpretations. This helps to avoid the deductive determinism in positivism and relativism in postmodern constructivist approaches. Many social researchers share this philosophical standpoint, such as Weber's (1978) interpretive sociology (Verstehen), which focuses on the meanings that people associate with their social world. On the one hand, they agree that, like natural science, there are laws of social behaviour, which can be discovered through certain research methods. On the other hand, they recognise the fundamental differences between natural phenomena and social phenomena, which involves social actors' subjective understandings of the behaviour of both themselves and others (Chen, 2000). Social phenomena can be studied as intelligible realities, and researchers should observe the social behaviour objectively, but can interpret their meanings from researchers own accounts. Thus, "the relation between reality and human knowledge about it is, however, asymmetrical" (Bathelt and Glückler, 2003:126).

Both critical realism and positivism look for causal explanations for generalisation, but critical realism believes in contingent relations rather than necessary relations that happen regardless of contexts. Contingent relations advocates that two events are related to one another only under specific socio-spatial contexts. Socio-economic outcomes are contingent because they not only result from unpredictable human actions but also are influenced by the differences in local material and institutional structures (Bathelt and

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Glückler, 2003). Therefore, this research is not to pursue a universal mechanism that applies to all regions, but a context-specific analysis that may offer insights to places with similar socio-economic preconditions. The core of such analysis is the particular structure-agency dynamic, which is well elaborated by Bathelt and Glückler (2003:128):

> The application of this concept does not mean, however, that research ends with a contextual explanation of singular events in particular locations and circumstances at a given time. Instead, another important step of realist analysis is to go beyond individual events and their specific contexts in order to identify common aspects of the causal mechanisms that affect economic action. This involves the identification of the causal mechanisms which are at the heart of localised economic action and interaction as opposed to the formulation of spatial laws. This methodology aims to uncover basic conditions of specific contexts and relate them to others. In this way, de-contextualization provides a methodology to identify trans-contextual, more-or-less necessary circumstances and structures from contextualised events.

3.3 Research Strategy: qualitative research

3.3.1 Intensive vs extensive research

The aim of this research is to seek the underlying structure of causation in the case cities' sustainability transition. Therefore, I adopted an intensive research strategy. Intensive and extensive research are the two most basic but contrasting approaches in research methodology. Philosophically, intensive research is more related to realism, and extensive research to positivism (Clifford and Valentine, 2003). These two approaches ask different sort of questions, use different methods and apply different logics in generalisations, leading to the differences in depth and representativeness (Sayer, 1992). Intensive research is concerned with how some causal process proceeds in a single or a small number of cases, seeking to disclose the underlying links among events, mechanisms and structure, through thoroughly investigating the operation of one social system. Extensive research emphasises the discovering of common properties and general patterns through large numbers of observations. Sayer (1992) summarises more distinctions between intensive and extensive research design (Table 3.1). Intensive research is limited in

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representativeness but shows great strength in depicting the deep structure of a social system, which is exactly what this research aims for. Practically, intensive research tends to use qualitative research methods.

Table 3.1 Differences between intensive and extensive design

	Intensive	Extensive
Research question	How does a process work in a particular case or a small number of cases? What produces a certain Change? What did the agents actually do?	What are the regularities, common patterns, distinguishing features of a population? How widely are certain characteristics or processes distributed or represented?
Relations	Substantial relations of connection	Formal relations of similarity
Type of groups studied	Causal groups	Taxonomic groups
Type of account produces	Causal explanation of the production of certain objects or events, though not necessarily representative ones	Descriptive, representative generalisation, lacking in explanatory penetration
Typical methods	Study of individual agents in their causal contexts, interactive interviews, ethnography, qualitative analysis	Large-scale survey of population or representative sample, formal questionnaires, standardised interviews statistical analysis
Limitations	Actual concrete patterns and contingent relations are unlikely to be representative, average or generalizable; Necessary relations discovered will exist wherever their relation are present, e.g. causal powers of objects are generalizable to other contexts as they are necessary features of these objects	Although representative of a whole population, they are unlikely to be generalizable to other populations at different time and places; Problem of ecological fallacy in making inferences about individuals; Limited explanatory power
Appropriate tests	Corroboration	Replication

Source:Sayer (1992:243).

3.3.2 Qualitative research

Qualitative research is an inquiry method that focuses on the quality, process and meaning of entities, rather than quantity, intensity or frequency that can be experimentally

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examined or measured (Denzin and Lincoln, 2011). Whereas quantitative research addresses the general relationship between phenomena, qualitative research is more concerned with individual experiences and the underlying social structure. The qualitative research contains an array of attitudes and strategies for conducting an inquiry, aiming to discover "how human beings understand, experience, interpret, and produce the social world" (Sandelowski, 2004:893). Winchester and Rofe (2010:5-7) phrase the two fundamental questions of qualitative research:

> Question one: what is the shape of societal structures, and by what processes are they constructed, maintained, legitimised, and resisted?
>
> Question two: what are individual's experiences of place and events?

Qualitative research is used in many different disciplines and a clear definition of it has not been established in social science. Yet, some principal features of qualitative research have been well recognised (e.g. Chen, 2000; Hammersley and Atkinson, 2007; Denzin and Lincoln, 2011). a) Emphasis on a natural setting; researchers should conduct their research in real natural settings, which are believed to be the indispensable contexts of individual behaviours and social organisations; researchers themselves are viewed as research tools to explore the totality of the situation. b) Search for meanings; the aim of qualitative research is to reach interpretive understandings of social realities through researchers' personal experiences and interpretations of the world. Therefore, it is imperative for qualitative researchers to reflect their own intellectual, cultural or political positions in the research. c) Inductive approaches; theoretical categories and hypotheses come from the data and then test them through further comparison in the data to build theories. Especially, the grounded theory (Strauss and Corbin, 1994) calls for an open mind to analyse the data from the real world, regardless of researchers' pre-conceived worldviews, so that the reality in participant society could be seen. d) The intimate relationship between researchers and participants; it is impossible for qualitative researchers to study the participants without establishing interpersonal relationships since it is exactly through the interactions between the two that researchers explore the world (Owens, 1982). Therefore, the ethical issues and power relations between researchers and their participants should be critically reflected upon by researchers in collecting and interpreting the data (Dowling, 2010).

Though quantitative methods are usually considered more objective and rigorous in establishing general relationships, they have limited capacity in capturing the relevance of the institutional and socio-economic context (del Río González, 2009). While aggregate quantitative analysis tends to adopt a top-down perspective, qualitative methods investigate the why and how of decision making, allowing researchers to have in-depth understandings of cultural and social phenomena and the mechanisms that lead to such phenomenon. After a long emphasis on quantitative research methods, the latter part of the 20th century witnessed a dominance of qualitative research methods in Human Geography (Winchester and Rofe, 2010b). For this research, as Geels (2011) argues, sustainability transitions are long-term changes and do not frequently happen, hence, it is less likely that researchers can build a large database to statistically analyse relationships between variables. I adopted a qualitative research strategy because its strength in understanding individual behaviours and the social structures governing these behaviours. Therefore, this strategy is ideally placed to investigate the actors, institutions and other social factors that facilitate or hinder sustainability transitions in particular socio-spatial contexts.

3.4 Research design: case study

Qualitative research is more concerned with specifics than representations of general circumstance. I have adopted a case study approach as my research design to address my research questions. A case study is, as Thomas (2011:511) defines:

> a descriptive, exploratory or explanatory analysis of persons, events, decisions, periods, projects, policies, institutions, or other systems that are studied holistically by one or more methods. The selected case will be an instance of a class of phenomenon which provides an analytical frame, within which the study is conducted and which the case illuminates and explicates.

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Stake (1978:7) advocates that a case can be whatever 'bounded system' is of interest, be it a programme, an institution, a responsibility or a happening. The boundary is kept in focus to distinguish what is and what is not 'the case'. Stake (1978) argues, unlike other kinds of studies, where researchers' hypothesises or previously targeted issues determine what the study is about, it is usually what is found vital within the bounded system that determines the content of the study in case study research.

A case study is closely related to two dimensions: the number of cases and the amount of detailed information gathered in each case (Hammersley and Gomm, 2000). Usually, the fewer cases investigated, the more in-depth information can be collected from each of them. Thus, a case study usually refers to a few cases (often just one), in order to keep the depth of information. As a contrast to experiment, which also involves investigating a small number of cases, a case study does not have direct control of variables, but "construct cases out of naturally occurring social situations" (Gomm, Hammersley and Foster, 2000:3).

The case study approach is prevailing in qualitative research because it is powerful in inspecting a social or spatial phenomenon with more concrete and practical information, as well as in developing theory through testing, falsifying, expanding or generating explanatory theoretical concepts (Baxter, 2010). The concrete analysis in a case study is particularly useful to test whether and why (and why not) existing theoretical concepts or explanations apply to the context of the case. Stake (1978) believes that the allure of case studies is that they provide 'full and thorough knowledge of particular' situations. Case studies question the common belief that concrete, practical and context-dependent knowledge is less valuable than general, theoretical knowledge (Flyvbjerg, 2006). The strength of an explanatory case study lies in its deep and comprehensive exploration of causation and underlying principles (Yin, 2009). In the study of environmental technologies, case studies at the local level are able to reveal not only the details of technologies but also factors internal and external to the enterprises, as well as economic

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and social relationships which contribute to environmental technological change (del Río González, 2009).

One frequently mentioned critique of the case study approach is that it may lack generalisability or external validity, which concerns the degree to which its findings apply to other cases or phenomena. Much research, either in natural or social sciences, aims to predict and intervene practices on the basis of scientific laws or generalisations that have been reached. This point of view is more from a statistical generalisation, which is achieved through large samples. However, this positivist orthodoxy of generalisation is increasingly challenged by researchers, who either doubt the necessary of generalisation in social research or defend other kinds of generalisation other than statistical generalisation (e.g. Stake, 1978; Donmoyer, 2000; Lincoln and Guba, 2000; Schofield, 2000). Stake (1978) admits that a case study is not a suitable basis for statistical induction, but it provides an epistemological advantage to what he terms 'naturalistic generalisation', which is "arrived at by recognising the similarities of objects and issues in and out of context and by sensing the natural covariations of happenings"(p6). This indicates that the superior way for readers to understand is to provide information in the forms that are close to their personal natural experience. Lincoln and Guba (2000) challenge the conventional view of generalisation as universal laws unrestricted to time and space, and they propose an intermediate position between nomic generalisation and particularised knowledge, by "accepting generalisations (to whatever extent they may be possible) as indeterminate, relative and time- and context-bound, while not a wholly satisfying solutions, is at least a feasible one"(p32). Therefore, it is suggested not to either give up generalisation efforts on the one hand or emphasise generalisation too much on the other hand in case studies.

Gerring (2004:342) defines a case study as "an intensive study of a single unit for the purpose of understanding a large class of (similar) units". He argues that it is wrong to equate case study as 'N=1' research design. For one thing, case studies not necessarily

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employ just one case; for another, this equation conflates sample size with the quality of case study research (Baxter, 2010). It is problematic to impose statistical sampling principles on case studies, which seeks to acquire analytical generalisation instead of statistical generalisation (Yin, 2009). In analytical generalisation, existing theories play an essential role as templates, based on which the cases are compared and new theories are developed. Analytical or theoretical generalisation starts with existing theories, employs them to case studies and goes back to the revised, tested or newly developed theories. The generalisation of case studies is achieved through the extrapolation of logical relevance and theoretical meanings. Therefore, its effectiveness is dependent not on how representative the case is, but on the strength of theoretical reasoning. A case study approach emphasises the credibility of the explanations of phenomena and analytical generalisation, which can be accomplished by carefully selecting cases and generating theories that are neither too abstract nor too case-specific (Yin, 2009). Therefore, the generalisability concern may not be a problem if the case study is appropriately designed and the analysis is able to distinguish the tension between concrete and abstract concepts (Baxter, 2010).

3.5 Case study areas

This research involves a contrasting case study in the development of solar thermal energy between two Chinese cities, Dezhou and Beijing. Dezhou was chosen as a case city to investigate the role of latecomer cities in sustainability transitions. Located in north-west of Shandong Province (Figure 3.2), Dezhou was traditionally an agricultural city in China. After three decades' of fast industrialisation and urbanisation since China's reform and opening, Dezhou has grown to be an industrial city, but its industrial structure and urbanisation rate remains at a lower level compared to the national average. Nonetheless, Dezhou has become one of the leading cities in the development of solar thermal energy, with an SWH cluster of national importance and an SWH installation rate of 75.4% among its residents (Li *et al.*, 2011). These achievements led to Dezhou being designated as China's Solar City and wider international environmental recognition. Therefore,

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examining Dezhou's development pathway to solar thermal energy could shine a light on the role of latecomer cities in sustainability transitions.

Figure 3.2 Map of Dezhou in China

This research believes that the generalisation could be more valid by providing a contrasting case about why solar thermal energy is not well popularised in developed cities. Beijing is one of the most developed cities in China (Figure 3.3). It also has an important solar thermal industry cluster and is the technology centre of China's solar thermal industry. Both China's flat-plate and evacuated tube solar thermal collectors originated in Beijing. Dezhou's SWH cluster benefited substantially from Beijing's technology spillover. However, the market penetration of solar thermal energy in Beijing is much lower. In its urban area, the SWH installation rate was less than 7% in 2009. As a developed city confronted with serious environmental problems, Beijing is supposed to have the stronger capacity and motivation to apply renewable energy solutions such as solar thermal energy. The city has also implemented regulations to promote SWH installation but has achieved a limited outcome.

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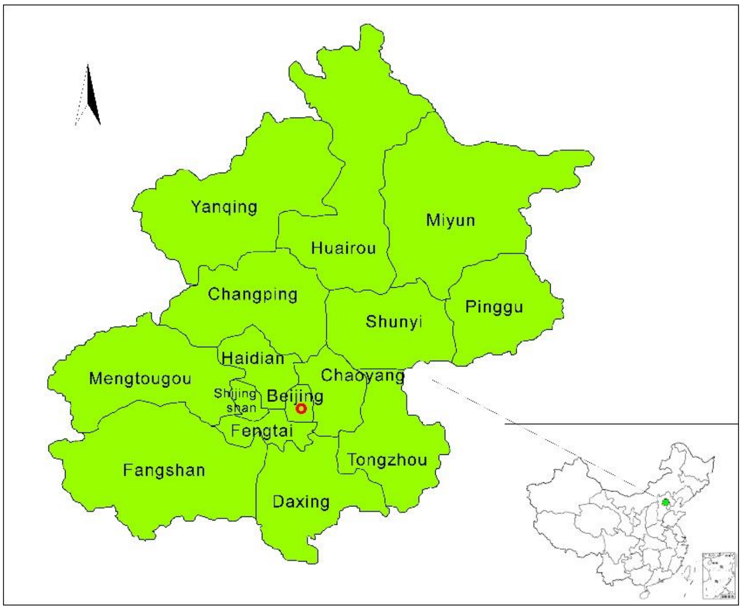

Figure 3.3 Map of Beijing in China

Table 3.2 Comparison of Beijing and Dezhou (2012)

	Beijing	**Dezhou**
Type	Municipality direct-controlled by central government	Prefecture-level city[3]
Area (sq. km)	16410	10356
Population (Million)	20.69	5.63
GDP per capita ($)	13863	6293
Share of tertiary industry in GDP	76.5%	33.6%
Urbanization rate	86.2%	46.2%

Source: China's City Statistics Yearbook, 2013.

Compared to Beijing, Dezhou is a latecomer in industrialisation and urbanisation (Table 3.2), but it has become the pioneer in solar thermal energy. A contrasting study of these two cities would help to reveal how geographical context and spatial linkages matter in

[3] China consists of 23 provinces, 5 ethnic minority autonomous regions, 2 special administrative region (Hong Kong and Macao), and 4 municipalities directly under the central government (Beijing, Tianjin, Shanghai and Chongqing). Prefecture-level cities are under the provincial governments and above county-level governments. In Shandong, there are 17 prefecture-level cities.

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the development of solar thermal energy in each city and illustrates the latecomer advantages of less developed cities in sustainability transitions.

A clarification should be made to warrant this contrasting case study rather than a comparative case study. At first sight, the lower popularity of SWH in Beijing could simply be attributed to the fact that it doesn't fit into Beijing's building infrastructure and market. It may also raise doubt regarding whether it is appropriate to compare cities belonging to different development levels. I would like to respond to this in following three aspects. First of all, what I am intending to do is a contrast between the two cities rather than a straightforward comparison. This is not simply a matter of differences between the terms 'contrast' and 'comparison', but also involves the different methodological thinking behind them. A comparison is more concerned with comparing the similarities and differences of the cases, with each case equally addressed, while a contrast aims for greater explanation of one case through using other cases as a reference point. Admittedly, with such a huge social-economic gap between Dezhou and Beijing, a direct comparison between them regarding particular social phenomenon might be inappropriate. But if researchers wish to understand the socio-technical factors in latecomer cities in more depth, a contrasting knowledge of a more developed counterpart is not only helpful but necessary. Without understanding what is going on in the more developed cities, the factors that matter in latecomer cities' context would not be interpreted being as significant as it should have been. In this research, the main inquiry focus is on the diffusion of SWH in Dezhou, but Beijing's story is also narrated here to illustrate the significance of the factors in latecomer cities' context.

Secondly, both the comparison and the contrast need to be based on certain similarities. Despite the vast socio-economic differences, the contrast between Dezhou and Beijing regarding SWH diffusion is warranted because both of them are the main SWH manufacturing clusters in China and both municipal governments encourage and mandate SWH installation in their urban areas, though at a different time. Nonetheless, there is a

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huge adoption gap of this technology between the two cities due to place-specific socio-technical factors. It is interesting itself to investigate why this gap has come into being and it could be very productive to illuminate how spatial context matters.

Thirdly, it seems reasonable at first glance that some audiences may argue the low installation rate of SWH in Beijing is simply because the technology doesn't suit its market, but they actually take the status quo for granted without asking why and how this status quo comes to exist. If it is the building infrastructure blocking the SWH diffusion, then why is the building infrastructure in Beijing different from Dezhou? If it is the market demand obstructing the diffusion, then what shapes the demand into its existing form? Again, these questions are related to each city's historical socio-economic contexts and the answers are crucial for understanding the advantages of latecomer cities against developed regions regarding environmental technology diffusions.

Last but not the least, the story of Dezhou's SWH diffusion would not be completed without Beijing's participation. This research tries not to over-emphasise the place-specific factors at the cost of missing important two-way linkages between the two cities, for instance, the SWH technology spillover from Beijing played a critical part in Dezhou's SWH industry development, while Dezhou's SWH mandatory policies also inspired Beijing's practices. As I shall demonstrate, the less developed cities enjoy several latecomer advantages but they still need continuous interactions with the developed regions in many ways to facilitate their sustainability transitions and leapfrogging.

3.6 Research methods and process

3.6.1 Research methods

I adopted a mixed-methods approach, including semi-structured interviews, document analysis and site observation for this case study. A multi-methods approach allows the researcher to undertake 'triangulation', that is, employing various data sources and

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collection procedures to study the same phenomena (Denzin, 1970; Hoggart, Lees and Davies, 2002). Every single method has its strength and weakness, whereas the advantage of triangulation is to use complementary methods to gain deeper insights on a research issue. It also enhances researchers' confidence in interpreting social meaning and behaviour with evidence from different sources. With multiple techniques used for collecting and cross-examining data, a mixed-methods approach ensures the rigour of qualitative research (Bradshaw and Stratford, 2010).

This sounds good, however, it is also possible that contradictory information is obtained from different data sets. For instance, in my data collection, I found many inconsistencies between interview responses and documentary sources. In this case, it is the researcher's responsibility to check with further information and decide which source is of more credibility. Inconsistency can also be a good thing in some way by leading researchers to inspect why the difference occurs and may thus gain deeper and more convincing understandings of the phenomena. Therefore, applying different research methods can reinforce or challenge data acquired from different sources and reduce the impact of potential biases that exist in a single method study, thus, giving credibility to qualitative research (Bowen, 2009; Winchester and Rofe, 2010a).

Regarding the specific research methods, document analysis, in-depth interviews and site observations were employed in this case study (Figure 3.4). Interviews formed the primary data source of this research. During my fieldwork in China from November 2014 to March 2015, 36 semi-structured interviews were conducted with solar enterprises, governmental officials, research institutes and estate developers. The interviews focused on the facilitating and obstructing factors of the diffusion of solar thermal energy in Dezhou and Beijing. The interviews also explored respondents' experiences and opinions on the development of solar thermal energy in the two cities, as well as how decisions were made and how these decisions influenced their development. In addition, document analysis, site observations, and attending industrial conferences were applied as ways of

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data collection.

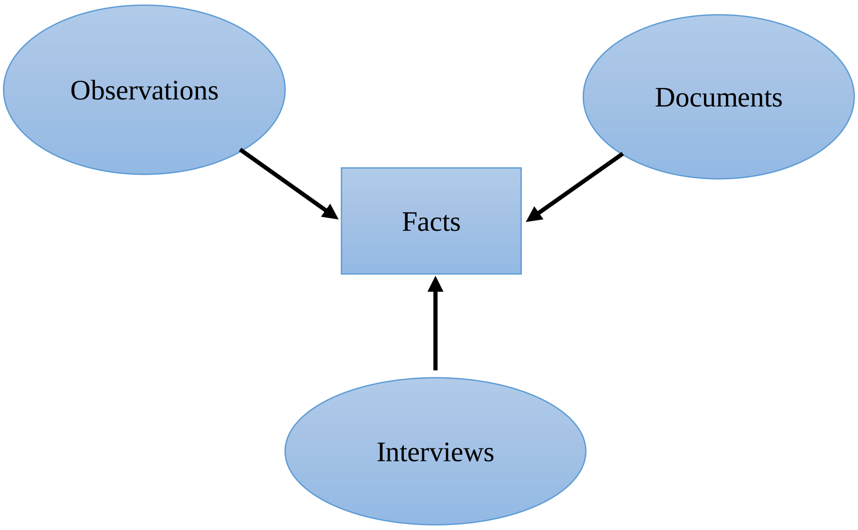

Figure 3.4 Data sources of this research

3.6.1.1 Interviews

Energy transition is a complex process, and thus, plentiful variables and factors underlying it can be expected. A qualitative interview method is believed to be the most appropriate method to capture the complexity (Mattes, Huber and Koehrsen, 2015). In order to have an in-depth understanding of the development of SWH industry in case cities, face-to-face interviews were conducted with municipal government officials, solar industry entrepreneurs, industry associations and research institutions, as well as entrepreneurs in related businesses, such as real estate companies. An interview is a data-gathering method through spoken exchange of information, aiming to find out what participants feel and think. Interviews used to be defined as a "face to face verbal interchange in which one person, the interviewer, attempts to elicit information or expression of opinion or belief from another person" (Maccoby and Maccoby, 1954:499). But now interviews have expanded to include new channels, such as telephone interviews and computer-mediated communications interviewing. An interview usually involves introducing a topic for discussion, listening to the answers and then probing with follow-up questions (Silverman, 2011). Compared to a standardised questionnaire, interviews are

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generally unstructured or semi-structured, allowing changes according to the interests, experiences and views of the interviewees in each interview (Valentine, 2005). This enables interviewees to describe and explain their lives or works in their own words and thus construct their own account of their experience, resulting in rich, detailed and multi-layered data (Burgess, 2002).

Interviews have often been criticised by positivists, who claim that interviewers could bias respondents' answers and thus are not able to be objective. The underlying assumption of this claim is that objective realities exist and the aim of interviewers is to discover the reality by asking questions. However, as discussed in the philosophy section, the so-called objective reality in social research is very different from positivism in natural sciences, because it also involves experience, aims and interpretations of researchers (Valentine, 2005). The participants of interviews should not merely be treated as objects to be exploited for information. Instead, they are humans with consciousness, which is always the 'medium' through which research occurs (Stanley and Wise, 2002). As Davidson and Layder (1994:125) argue:

> interviewers are not losing their 'objectivity', becoming partial or imposing a particular worldview on the respondent, rather they are using the interview as an opportunity to explore the subjective value, beliefs and thoughts of individual respondent.

Some researchers believe that the interview itself is a form of reality. It is a speech event and reflects particular social reality (Briggs, 1986). An interview is not a process in which respondents provide objective information to interviewers, but a process in which 'reality' and 'behaviour' are mutually interacted and co-constructed by each side of the interview.

This research adopted the semi-structured interview method. Whereas structured interviews have a rigorous set of questions, semi-structured interviews are more open to new ideas to be brought up during the interviews. It contains a number of predetermined questions or topics but adopts a flexible approach for discussion within the interview.

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This flexibility allows respondents to raise issues that the interviewer may not have anticipated, helping researchers to explore new directions and themes that may not have been learned from other sources (Silverman, 2011). In this way, the data is co-produced by the researcher and the researched (Legard, Keegan and Ward, 2003).

Interviews were applied in this research mainly to answer the research question: Why and how does (or does not) the transition to solar thermal energy take place in the two case study cities? The development of the SWH industry involves the efforts mainly from SWH enterprises and local governments. By interviewing entrepreneurs in the solar industry and relevant government officials, this research expects to reveal their experiences and opinions on the transition process. It is also expected to answer how their decisions were made and how these decisions influenced the development of solar thermal energy in Dezhou and Beijing. Furthermore, this research also interviewed people outside the industry and government agencies. These interviewees cover people from research institutes, universities and experts in related research fields, who are expected to provide neutral perspectives, and individual opinions towards the research phenomenon. These interviews provided not only the detailed experiences, views, and decisions from key individuals or agencies in the industry but also macro social factors that cannot be observed by individual insiders.

Questions in the interviews varied according to participants' working organisations, but most of them covered the themes on the organisations' profile, interviewee's personal experience, products (or services), markets, opinions about the driving and obstructing force of SWH industry in the case study areas, and their future visions. For example, the interview questions with SWH enterprises mainly consisted of the following aspects: a) Interviewees' information, personal experience, job descriptions and duties. b) Firm profile, such as the date of establishment, main products, the number of employees and information about the firm's establishers (if not the interviewees), why and how they entered the SWH industry. c) Technology development, e.g., technology learning, R&D

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activity, talent flow, cooperation. d) Market development, market areas, retail market and projects market, differences between different levels of cities. e) Driving and obstructing force of SWH diffusion in case study cities, such as consumer attitudes, government supports, policies, infrastructure and culture. f) The firm’s role in policy making and its future vision about the industry in case cities. Regarding local authorities, the questions focus on their policies towards SWH industry, such as how the policies were made; how were they implemented, and how they support the industry. An example of interview questions for solar firms is given in Appendix 1.

3.6.1.2 Document analysis

Document analysis was applied throughout this research, but especially in relation to the textual analysis of policy documents and industry history. Document analysis is believed to be particularly applicable to qualitative case studies (Yin, 2009). Documents are the written materials which relate to certain aspects of the social world. Documents are produced and used in socially organised ways, and thus can be referred to as ‘social facts’ (Atkinson and Coffey, 2004). Document analysis is a systematic procedure in which documents are reviewed and interpreted by the researcher to elicit meaning around a particular topic (Corbin and Strauss, 2008). It helps researchers to have an overview of the institutional, cultural and historical context in which the research phenomena locate.

In this research, document analysis is adopted not only for providing contextual information but also as a means of tracking changes and development in the case study cities. The historical data, reports and government policies enabled me to have a general picture of how the solar thermal energy industry has developed over time. Besides, information contained in documents can often suggest new questions that need to be asked and situations that need to be observed as part of the research (Bowen, 2009). Furthermore, document analysis provides supplementary data and helps to verify findings or corroborate evidence from other sources. In some cases, documents may be the only effective way to collect data when phenomena can no longer be observed or when

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participants cannot recall the details (Bowen, 2009), which often happens in interviews. The major limitation of document analysis is that documents are produced for different purposes than research. Consequently, a huge quantity of documents may only provide little useful details to answer the specific research questions.

The documentary materials in this research include laws, governmental policies, statistical data, newspapers (both printed and electronic ones), magazines, local history, industrial and scientific studies and market reports. These document materials were either gathered from the internet, or by physically visiting relevant organisations to ask for permission.

3.6.1.3 Participant observation

Participant observation is a research method where researchers spend a period of time being, working or living in a community in order to discover the functioning of the system (Laurier, 2003). It might also entail researchers establishing a social role within the community, rather than just being present at the site (Kitchin and Tate, 2013). It allows researchers to get as close to the research site as possible and thus gain first-hand knowledge of what actually happens in the system to enhance the understandings learned from documents or interviews. Interviews are interviewees' self-report of feelings, experiences and opinions, which may be different from what they really do, and observation helps to 'triangulate' through researchers' own ability to interpret (Kitchin and Tate, 2013).

The use of observation in this research fits the three 'c' purposes: counting, complementing and contextualising (Kearns, 2010). Counting means to enumerate what actually happens in the case area to add to (or contradict) understandings. For instance, in my fieldwork in Dezhou, I was able physically to observe and compare the percentage of evacuated tube SWHs installed on low-rise buildings and high-rise buildings, which helps to illustrate how building structures affect the diffusion of SWH. Complementing

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refers to providing complementary evidence by gathering additional descriptive information before, during or after other data collection methods (e.g. interviews). This gives 'added value' to the information collected from other sources. It also helps in raising practical questions when interviewing participants. The third purpose is to gain contextual understandings through observation. Researchers' direct experience in the socio-temporal context enables them to reach an in-depth understanding of the particular place. The field notes from observation not only provide a valid source of data, but also involves researchers' interpretation of the context, and thus it is an important personal text that researchers have to refer to when analysing data (Kearns, 2010).

16/11
皇明曝光行业潜规则也是挑战现有恶劣机制，推动强制安装标准 这也是niche的挑战成长行为。
在小城市，企业更有power and agency 去做各种各样的实验，比如未来城。

中午坐车随便看看这城市，从西到东半个多小时，道路宽敞，南北向街道多有太阳能路灯等。到德州汽车站就能看到太阳谷，于是就一个人先过去看看，把找房子的事都给忘了。穿插过几个道路，好不容易找到太阳谷的入口，太阳谷理想之门确实挺宏伟的。沿着太阳谷大道，走到微排国际酒店，在门口有皇明的产品展示与销售之处，除了显眼巨大的太阳能热水器，还有各种太阳能光伏发电利用的产品，如太阳能移动电源，太阳能手电筒，太阳能玩具等，太阳能微厨是现在皇明大力倡导的一个产品，在国内部受欢迎，在国外却挺受欢迎的。在展示处认识了新事业发展部的实习生赵梦佳，聊了聊皇明的产品，她说皇明的产品输在太贵，但真正能保证25年的使用年限，其他厂家也宣传25年的使用寿命，但实际做不到。皇明产品价格比较高，是他的劣势。（思考，在信息不对称的市场里，总是劣币驱逐良币，厂家与消费者信息不对称对技术创新的影响可见一斑，所以皇明大力揭示行业潜规则，也是还市场一个透明，力争提高消费者的辨别能力。这也是挑战市场体制，推动强制安装标准实行的niche挑战行为，可以多考察皇明为强制安装标准所做的努力）。经过赵梦佳的介绍，我还联系到了付俊卿老先生，70多岁了还在为太阳能事业做贡献，很了不起，很期待明天与付老的面谈，虽然我对自己的研究问题还不够熟悉，先了解了解吧。此事说明，多与守门者沟通聊天是很有用处的。在参观了皇明的微排酒店，别墅和科技产品展示后，确实为皇明的成就而感到了不起，黄鸣是个敢于做梦，并勇于实践梦想的人，这是个很了不起的事，虽然许多名字，概念听来十分随意，理想化，但他就是把它们都在自己的实验天地里都实现了：未来城，未来屋，太阳能商城，太阳谷，太阳能大学。。。等等。也正是因为在德州这样的小城市里，这种大企业才有足够的power and agency 去把城市当做实验场，践行着自己的梦想。太阳能事业是了不起的事业，这个研究是十分值得去做的，它定是未来重要的方向。回城就一直打电话询问租房子的事了，随便走走，很轻松的跟对方聊聊，买卖不成，也是朋友。北方冬天租房最棘手的就是暖气的问题了，租个称心的房子不容易 。
今日思考总结：
1）厂家与消费者信息不对称对新技术扩散的不利影响
2）皇明极力推动太阳能强制安装时挑战市场体制行为，它是如何组织其他参与者实现该挑战的
3)大企业在小城市有着更大的power and agency, 实验的效果更佳显著。 可以起个有趣的题目了： big firm, small city: Himin's solar experiment in China's solar city.

Figure 3.5 An example of my field notes

I kept field notes every day when I was in the fieldwork (to give an example, see Figure 3.5). I recorded my observation of case study cities' physical appearance, such as city landscape, building infrastructure, house structure and SWH installation; I recorded the process whereby I got in touch with my potential interviewees, including those cases where I was rejected; I recorded my random conversations with local residents regarding SWH industry, such as taxi drivers, house letting agents, university students, journalists and more often, house owners; I recorded my instant feeling and thinking after each

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formal interviews; I also recorded my experience in many events, such as the solar thermal energy industry conference. Finally, my own feeling, emotion and reflection of being a researcher in the case cities were recorded. Though it was written in a very informal way, it does provide very rich and validated resources to my data analysis.

3.6.1.4 Summary

The purpose of this research is to understand sustainability transitions in latecomer cities by using a contrasting case study of the popularisation of solar thermal energy in Dezhou and Beijing. A mixed-method approach was adopted in this case study, including interviews, document analysis and observations. These methods are not exclusive to each other but serve for investigating different dimensions of the research phenomenon. The interviews provide insights from entrepreneurs, government officials and experts; the documentary analysis and observation enhance my understandings by providing social and historical context to the development of the industry. Each method has its strengths and limitations. The data gathered from these different sources will verify and corroborate the findings, ensuring the credibility of this research.

3.6.2 Fieldwork process

It was easy to reach the case cities, but it was not easy to get access to potential interviewees. Before data collection, I had produced a list of possible people (organisations) to interview through document analysis and internet searching, but there remained many uncertainties about whether and how I could persuade them to participate in my research. It has been acknowledged by many scholars that doing fieldwork in China can be difficult due to political constraints and cultural challenges (Heimer and Thøgersen, 2006; Schroeder, 2010; Wang, 2014). While this seems to only apply to foreign researchers, native Chinese researchers would be also confronted with these problems, especially when no personal or official 'guanxi' networks had been established (Hu, 2015). Guanxi describes the relationships that may bring favours for the parties involved, and is one of the central ideas of Chinese society. Good guanxi, in many cases, is the key needed

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to opening doors otherwise closed. The biggest challenge, in my case, was to gain some key ‘mediators’ in the case study cities to facilitate my fieldwork.

3.6.2.1 Dezhou research phase

Before going to Dezhou, I had confirmed only two informants through the internet. It was interesting that hardly any institutions (enterprises or government departments) responded to my formal invitation emails, in which I introduced myself, my research objectives and how they could specifically contribute to the research (an English version is attached in Appendix 2). Unfortunately, only a university researcher responded to my email. As I had expected, email is not regarded as an important channel for formal communication in China’s small cities like Dezhou. Institutions which received the formal interview invitation either ignored it because they did not want to bother with it or may have found it difficult to find the best person to take the interview. It is especially the case in government agencies because the administration of SWH industry is dispersed amongst different departments. Some institutions might be less confident about their organisations, thus unwilling to accept interviews, especially small SWH enterprises, whose main business derive from imitation and low-price selling. I think another reason that they didn’t respond my email was the lack of trust on the internet. In particular, I introduced myself as a research student from a foreign university, so they felt no obligation to join the interview.

Therefore, I changed to telephoning and physical visiting to get access to the potential interviewees while in Dezhou. By telephoning, I was able to deliver more clearly my motivation, my sincere attitude and how they could specifically contribute to my research. This was very helpful to build trust with potential interviewees. Very often some institutions or individuals doubted how they could contribute, I emphasised that they were the important part of Dezhou being China’s solar city and their experiences were of great value. I could feel many times that the receptionists were very sceptical at first and then changed attitudes as I delivered my messages. By telephoning, it was also less likely for

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them to ignore researchers as they did with the emails.

Nonetheless, only a small portion of the respondents finally came to face to face with me. Normally, large enterprises were very welcome to my visiting, but small enterprises tended to reject it. The possible guess is that small enterprises were not confident to expose themselves. Some said they would call me back when available, but never called back; some said they had very busy schedules at the end of the year; some directly hung up when I introduced myself. As for government departments, the problem was that they could not find a suitable person to receive my interview because they were concerned that they may not know the answers to the questions I asked because of department division. Therefore, I insisted that my questions would be specific to their departments.

From 17th November 2014 to 9th January 2015 in Shandong, I conducted 26 face-to-face interviews in total (detail of the interview list is attached in Appendix 3). Among them, 16 were contacted through telephoning, 5 through physical visiting, and 5 through interviewees' recommendation (snowball sampling). Some researchers suggest that it is better to adopt a top-down sampling strategy to investigate local industries in China (e.g. Hu, 2015), that is, to gain official support from local governments, who have much power to facilitate approaching potential interviewees as researchers wish. But what I did is a bottom-up approach. For one thing, I failed to achieve high-level official support from local government, though I did benefit from Dezhou Solar City Office's help by recommending some interviewees. For another, I doubted how open interviewees would be to interviewers through a top-down approach since they are kind of forced to join the interview and may be cautious about what they say, especially those concerning local governments and policies. In my approach, I was in a more humble (or less empowered) position as a learner, and I did find the advantage that many interviewees were very open and willing to share their observations about the city, the industry and policies.

While in Dezhou, I could tell that the majority of the interviewees cherished Dezhou's

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designation as China’s Solar City and they were eager to advertise Dezhou to have more international influence. Being a doctoral researcher from an overseas university constitutes an advantage for me because they felt being valued by a remote international community and I was, to some extent, expected to contribute to their city promotion. In general, I also felt respected and valued as a PhD researcher from an oversea university. When I did the physical visiting in some enterprises, I talked to some staff first and introduced myself, and they were interested as to why I came from far away to visit their companies. Very often the staff were happy to introduce me to their superiors at the manager level, then I got access to the potential interviewees that I had expected. A representative of Dezhou’s solar industry media reported my visit in Dezhou, which also helped me to get more contacts. Some interviewees agreed to accept my interview because they had seen the report on the media.

For the first three weeks in Dezhou, my focus was on SWH enterprises, which can be divided into two types: evacuated tube SWH producers and flat panel SWH producers. The evacuated tube SWH has more than 20 years history and has been developed very well in Dezhou. The flat-plate SWH started to grow quickly since 2008, as it enjoys many advantages over evacuated tube SWH in integrating with high residential buildings, which became prevalent in Dezhou due to fast urbanisation and the consideration of land saving in urban planning. My main interview questions for these enterprises were related to their development history, technology learning, market expanding and their opinions about why Dezhou became the Solar City of China. In the fourth week, I interviewed Dezhou Solar City office, a unique government department in charge of promoting the use of solar products in Dezhou. Another interview was with a solar industry media company (Solar Vision), which reported my fieldwork in Dezhou on its media and facilitated my fieldwork in the following month.

In the fifth week, I went to Linyi, another city in Shandong province, for the Annual Conference of China’s Solar Thermal Industry. By attending the conference, I had a more

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broad and deep overview of China's solar thermal industry. During the conference, not only did I record many speeches from pioneering entrepreneurs, government officials and researchers, but also got many connections for my next fieldwork in Beijing. After the conference, I also conducted some interviews in Linyi and Jinan, as they are also important SWH industry bases in China. I also would like to hear what experts outside Dezhou could say about Dezhou's being China's solar city. In the sixth week, I interviewed another two government departments[4] in Dezhou, aiming to find what they have done to promote Dezhou's solar industry and how the policies were initiated and implemented.

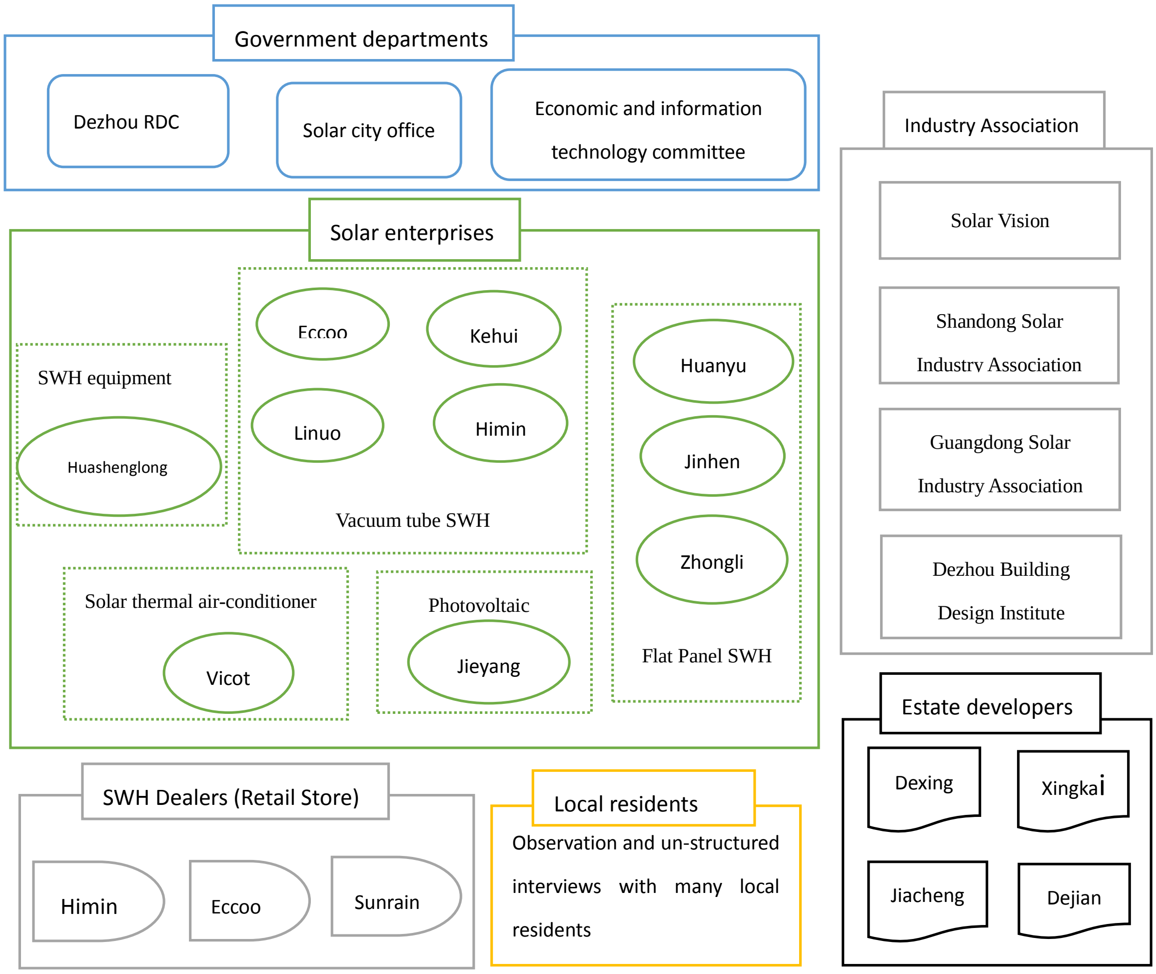

Figure 3.6 Dezhou Interviews summary

[4] The two departments are Dezhou Economic and Information Technology Committee and Dezhou Development and Reform Commission. The former is in charge of guiding and supervising local industry, and the latter in charge of industrial planning.

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In the last week, I shifted my focus to real estate developers and SWH dealers, as they have a closer relationship with the users of SWH. In 2008, the Dezhou government enacted a mandatory policy, requiring that all new residential buildings should install solar water systems. Therefore, the estate developers became the primary procurers of SWH and their experiences and opinions on integrating SWH into buildings deserve investigation. The interviews with SWH dealers were aiming to understand consumers' attitude towards SWH. In addition, during my fieldwork in Dezhou, I conducted observation and unstructured interviews with many local residents, who also provided much valuable information (Figure 3.6).

3.6.2.2 Beijing Research phase

From 10th January to 10th February 2015, I investigated Beijing's SWH industry as a contrast to Dezhou. Beijing is one of the five SWH manufacturing bases in China, with approximately 150 SWH enterprises in 2011. But in 2014 I could only find 22 Beijing's solar companies listed by the industry association. Unlike in Dezhou, where I could make interview appointments through unscheduled physical visits, Beijing's institutions normally have very formal visiting procedures. It was unlikely to get access to their working places without appointments. Though I did send emails as a complementary contacting method, telephoning seems the only effective way. At that time, the month was very close to the Chinese Spring Festival and most enterprises were very busy with their business before Chinese lunar new year. I did not pick the best time, so the process of getting connections was not easy as in Shandong.

Most enterprises I contacted in Beijing showed their interest in my research and were willing to accept my interviews, but they had problems in scheduling interviews. Much of my time in Beijing was spent contacting and negotiating with these enterprises. I also contacted some estate developers, but they showed no interest in the research because most estate developers did not care about SWH installation. For those estate developers that had installed SWH system, they thought it was only a small part of their business and

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did not want to talk much about it. I also contacted several government departments, e.g., Beijing's Housing and Urban-rural Construction Bureau and Development and Reform Commission, but I was rejected because they could not find a right person to answer my questions relating to SWH-building integration. Besides, it was very difficult for an individual researcher without official consent letters to get access to Beijing's government agencies.

Nonetheless, I managed to conduct 10 interviews in Beijing, including 7 interviews with solar enterprises and 3 with research institutes and associations (Figure 3.7) (a detailed list is attached in Appendix 3). The 7 enterprises I managed to interview are very typical ones in Beijing and three of them[5] are the largest solar enterprises in Beijing. They began doing solar thermal business in the 1980s and thus had much to say about China's solar thermal industry. Besides, Beijing is the home of many national research institutes and associations, who play important roles in policy making and offer professional views towards China's solar thermal industry.

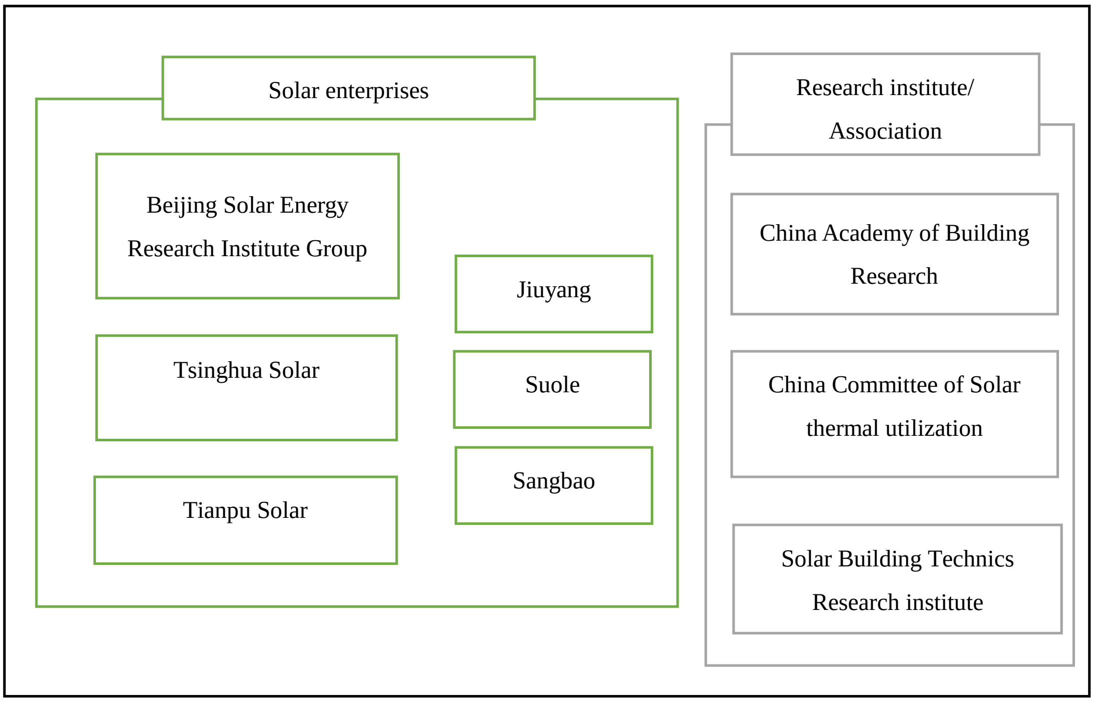

Figure 3.7 Beijing Interviews summary

[5] The three large firms are: Beijing Solar Research Institute Group; Tsinghua Solar and Tianpu Solar.

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3.6.2.3 Summary

This section describes the detailed process of collecting data in Dezhou and Beijing, through interviewing, documents and observations. During the process, I adopted different approaches to reach potential informants because of the distinct differences in many aspects between Dezhou and Beijing. This fieldwork process also has revealed some contextual differences between the two cities, such as the attitude of local government and estate developers towards SWH industry. Therefore, this process itself could be viewed as a valid data of my analysis.

Table 3.3 Shandong and Beijing Interviews summary

Type	Shandong	Beijing	Total
Solar industry	14	7	21
Governmental officials	4	0	4
Research institutes	2	2	4
Industry Associations	2[6]	1	3
Estate developers	4	0	4
Total	26	10	36

In terms of the number of interviews (Table 3.3), I was not very concerned about how many interviews I achieved, but more about how rich and effective was the information in each interview. As Bradshaw and Stratford (2010) explains with regard to the rigour of qualitative research:

> the number of people we interview, communities we observe, or text we read is an important consideration but secondary to the quality of who or what we involve in our research and secondary also to how we conduct that research. (p69)

I resorted to the sequential interview logic by Yin (2009). Case studies do not follow the sampling logic in quantitative research, which seeks for representativeness. Rather, it

[6] One of the solar thermal industry association was from Guangdong, interviewed in the annual solar thermal conference in Linyi, Shandong.

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believes that each informant helps us gradually to reach a comprehensive understanding of the research problem. Under this logic, the number of interviews is not pre-decided but is dependent on whether we have reached the state of information saturation during fieldwork. Previous interviews lead to new questions that need to be answered in the next set of interviews until researchers are confident that they have acquired enough information. I am confident that the data I collected has provided sufficient basis for further analysis.

For example, I conducted 4 interviews in Himin, the largest and most influential SWH enterprise in Dezhou. The number was not pre-decided, but I found the need to learn more about the company's history, market development, technology development and customer attitudes during the fieldwork. Therefore, I interviewed a senior staff, a marketing manager, an R&D manager and a store manager accordingly. This allowed me to have a comprehensive and deeper understanding of Himin's history and current situation. Similarly, the interviews with other SWH enterprises, government departments, estate developers, and industry associations, as well as the site observations, enable me to have a confident analysis of Dezhou's diffusion of SWH.

3.7 Data analysis

The document materials, interview transcriptions, field notes and pictures taken in the field constitute all the data for this research. The data were imported to, and analysed in, a qualitative analysis tool—Nvivo. Nvivo is a computer software package for qualitative data analysis. It allows users to classify, sort and arrange non-numerical information and unstructured data, including textual material, pictures and multi-media materials. It is very useful in coding by just assigning relevant textual sources (words, phrases or paragraphs) to according codes, rather than the traditional way of cutting and pasting physical papers. It is also very useful in examining relationships between data and making connections, through its search engine and query functions. Nonetheless, it is merely an assistant tool and cannot replace the researchers' analysis process.

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Data analysis is a detective process to make sense of the raw data. There are many approaches to analysing qualitative data, but a common guideline is through data description, classification and connection (Dey, 2003; Kitchin and Tate, 2013). The description provides thorough and comprehensive information about the research subjects, including situational contexts (e.g. spatial and social context of the research phenomenon), actors' actions and intentions and the consequences. Situational context is important because it provides the spatial-temporal conditions of the analysis and allows comparison with data from different contexts. Classification is the process to break up data and categorise them into different themes. This is the key process in coding. Connections are made in the process in which relationships among different themes are identified, including similarities, differences, and, more importantly, interactions. These three processes guided my data analysis (Figure 3.8)

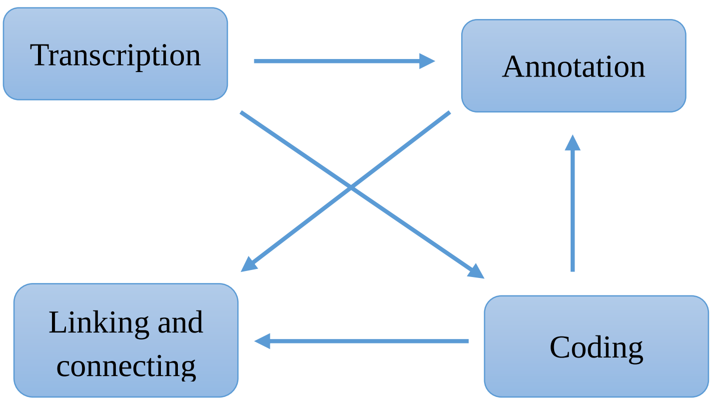

Figure 3.8 Data analysis procedures of this research

3.7.1 Transcribing and annotation

Among the 36 interviews conducted in fieldwork, 30 of them were audio recorded and 6 recorded with notes (see Appendix 3). The first step is to transcribe them into textual data. While transcribing, I made notes about my ideas, annotations and memos on the interviews. Especially when listening to the audios, the real sense of interaction makes the data more understandable and meaningful to some extent than simply reading textual

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materials. For instance, the tone of interviewees when they were making statements, helped me to judge how credible the statements are. It was also helpful to identify important messages that are different from others and trigger comparisons with other data and concepts from literature. I kept notes of these memos and annotations, or highlighted the phrases and paragraphs I viewed important during transcribing as the memory was fresh. These annotations provided my first impression of the data and facilitated the subsequent coding.

3.7.2 Coding and annotation

Coding is the process identifying and organising themes among a large amount of data. The purpose of coding is to reduce masses of complex data into smaller categories (data reduction), to create an organised structure and to aid searching the data, and analysis (Cope, 2010). The coding process is actually an analysing process, as Cope (2010: 285) illustrates:

> *coding is in many ways a recursive juggling act of starting with initial codes that come from the research questions, background literature, and categories inherent in the project and progressing through codes that are more interpretive as patterns, relationships, and differences arise.*

Rather than simply relying on either a theoretical proposition or grounded theory, my coding strategy incorporates both deductive and inductive approaches, so that I am able to link data with concepts from the literature and answer preconceived research questions, meanwhile, remaining open to unexpected concepts, ideas and patterns coming out from the data. At the same time when generating codes, I made annotations about the codes, such as why the codes were identified, what the meanings were, as well as how they connected to other codes or theories. This benefited the subsequent linking and connecting process.

3.7.3 Linking and connecting

After the coding process, I grouped codes together according to their relationships to develop a coding structure with several layers of sub-codes. This process is not just

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concerned with identifying similarities and differences but more importantly aiming to find how things associated and interacted. At this point, I started to organise the data into more integrated and coherent categories to answer my research questions. The annotations help to interpret the results by explaining their meanings, significance and relationships with relevant literature and theories.

3.8 Reflection: ethics, power and subjectivity

Before going to China for data collection, my research ethics statement had been approved by the research ethics committee in Department of Geography, Environment and Earth Sciences, University of Hull (Appendix 4). As a native Chinese, I had no cultural conflicts in the case areas. This research did not intrude into any participants' physical or mental well-being, privacy and confidentiality. I did realise there might be power asymmetries during the interactions with participants. In the interviews, my interviewees were mainly firm executives or government officials. It is more often that I was in a less empowered position as a student to learn about the participant's organisations and local phenomena that they were familiar with. The interview questions were not related to participants' personal issues, but their expert views on the social phenomena about the diffusion of solar thermal energy, so they felt confident and comfortable to share. Especially in Dezhou, participants were proud of Dezhou being China's solar city and thus were happy to share their experiences.

In none of the interviews were participants forced to join the interviews. I did inform the participants about my research purposes, methods and use of the research (including the contexts in which the results will be disseminated) when contacting them. I repeated this and asked permission for audio recording at the beginning of every interview. It has to be noted that, I chose to use the oral informed consent from interviewees, rather than the formal consent forms, which is not a common research practice in China (Schroeder, 2010). Formally signed consent forms may pose a barrier for interviewees to truly reveal what they think. As most interviewees are only representatives of their organisations in

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interviews, signing formal consents forms may make them unsettled about what could be done with the resulting data and worry about any possible responsibility in future. Regarding observation, I conducted overt observation, that is, I revealed myself as a researcher when observing or having conversations with informants. Therefore, I feel confident in the ethical part of this research.

I am also aware that I am more powerful when representing and interpreting participants' ideas. Particularly, the interviews were all conducted in Mandarin, so language also matters to representativeness. I translated them[7] carefully into English and paid much attention to the context of the conversations to represent their original meanings as possible as I could. Nonetheless, value-neutrality seemed impossible and subjectivities are unavoidable in qualitative research interpretation (Dowling, 2010; Bryman, 2012), because it involves social interactions and researchers' personal histories and perspectives. The way I perceived interviewees and their information has been conditioned by social norms and my own knowledge and worldview, which cannot be denied, but only acknowledged. The way to reduce subjectivity is to have critical reflexivity (England, 1994), that is, constantly to scrutinise the role of researchers themselves in the research process, be aware of how the social roles of researchers affect data collection and analysis.

[7] Due to the huge amount of data, I only translated those phrases and paragraphs that I quoted in the result as supporting evidence.

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Chapter 4 Development of China's solar thermal energy

4.1 Introduction

Before presenting the two patterns of SWH diffusion in Dezhou and Beijing (chapter 5), this chapter explores the general systematic barriers to the diffusion of SWH in China's urban market. Existing research has contributed a fruitful understanding of the diffusion of SWH in various countries, such as Greece, the UK and Germany (Sidiras and Koukios, 2004; Faiers and Neame, 2006; Mills and Schleich, 2009). These works have largely been concerned with the drivers and barriers from a user perspective, finding that economic saving is the central driving force and financial cost is the primary barrier. In addition, peer behaviour and environmental awareness also matter in the diffusion, although they are not as significant as economic factors (Woersdorfer and Kaus, 2011). In the case of China, researchers have examined the facilitating factors of SWH diffusion at not only the national level (Hu *et al.*, 2012), but also provincial level (Han, Mol and Lu, 2010; Goess, de Jong and Ravesteijn, 2015) and city level (Bai *et al.*, 2009; Li *et al.*, 2011). One feature of China's SWH popularisation is that its driving force is mainly attributed to the marked demand for economical hot water in its early phase, especially from the rural areas and small cities (Hu *et al.*, 2012). Among users, economic saving and convenience are the overarching considerations in adopting SWH, and environmental concern is not viewed as critical (Yuan, Zuo and Ma, 2011). Compared to Israel and Australia, the SWH industry in China is seen more as a business opportunity by local governments, rather than a response to energy security or environmental responsibility (Li, Rubin and Onyina, 2013). While there has been an absence of national incentive policies, local governments have the economic motivations (e.g. employment and fiscal revenue) to support local SWH industries through regulations and incentive policies (Han, Mol and Lu, 2010; Li *et al.*, 2011; Goess, de Jong and Ravesteijn, 2015). These policies are not without problems. For instance, Li *et al.*, (2007) argue that the bottleneck of SWH-building integration lies not in the technology development, but in the lack of an incentive mechanism to motivate

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relevant actors, especially the estate developers. The existing literature on SWH diffusion focuses on either user preference on the demand side or government policies, which is not sufficient to depict China's development of SWH. Other factors such as infrastructure, institutions, culture, and actor networks are overlooked. It is doubtful that financial barriers constitute the chief obstacle for SWH diffusion. Since rural markets can afford the technology, it is less convincing to conclude that financial cost is the main obstructing force in entering China's urban market.

Following this introduction, the next section introduces the socio-economic background regarding China's renewable energy development and a more specific account of the development of solar thermal energy is present in section 4.3. Section 4.4 summarises the policies in promoting the solar thermal energy industry and section 4.5 displays the spatial difference of solar thermal energy industry in China. Section 4.6 analyses the problems and barriers of SWH in entering China's urban market, and the future vision of the industry is discussed in the last section.

4.2 Background

4.2.1 Urban-industrial China

The past few decades have witnessed China's economic take-off since the reforming and opening at the end of the 1970s. This not only greatly improves the living standards of 1.3 billion Chinese, with GDP per capita rising from RMB 381 in 1978 to RMB 41907 in 2013, but also significantly changes the global economic landscape by becoming the second largest economy and 'world factory' in the world. This economic success is accompanied by an unprecedented industrialisation and urbanisation that the western countries had taken centuries to accomplish. This fast industrialisation is reflected in the transition of China's economic structure, in which secondary industry and tertiary industry accounted for 46% and 44% respectively in 2013. The output of secondary industry grew at the speed of 15% per year. Along with this, more than 500 million of the

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Chinese population have migrated to modern urban cities from rural areas, as the urbanisation rate[8] rose from less than 18% in 1978 to 53.73% in 2013, which deeply changes China's social and economic structure[9]. It's predicted that in the next two decades more than 300 million population will migrate to China's cities and the urbanisation rate will reach 70% in 2030 (World Bank, 2014).

However, the dramatic industrialisation and urbanisation have also placed a huge burden on China's natural environment and energy supply. Though China had promulgated the Environmental Protection Law of China in 1989, environmental supervision and legal implementation were poorly conducted by local governments, whose priorities were invariably economic growth. Environmental deterioration thus has swept across China in various forms: water contamination, deforestation and desertification, soil erosion, loss of biodiversity and air pollution. Non-government forces in pushing for environmental protection has long been weak in China. Nonetheless, environmental protection has been an increasingly wide concern among China's civil society, especially in the well-developed east of China. Environmental protests also have been increasingly frequently reported in the media (Reuters, 2015).

The huge scale of the industrialisation and urbanisation only partly explains these enormous challenges. Another part of the story lies in their "high input, high consumption and high emission" pathway (Zhang, 2005:4), which is characterised by extensive use of natural resources and uncontrolled greenhouse gas emissions. As a consequence, China has been the world's largest consumer of most natural resources such as land, water, mineral materials and fossil fuels. Research has found a linear relationship between urbanisation and energy consumption growth in China (Dhakal, 2009; Liu, 2009; Zhang and Lin, 2012; Xu and Lin, 2015) (Figure 4.1). As income rises, the growing urban population have changed their lifestyle to a more energy-intensive one (Hubacek *et al.*,

[8] Urbanization rate= urban population/ total population. In China's case, urban population refers to the population that stay in the urban areas more than six months a year.
[9] Data in this paragraph is from China social economic statistics database.

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2009). For example, the energy used in buildings currently accounts for one-fourth of China's overall energy consumption. This is not only because of the rapid development of real estate in cities but also the widespread use of energy-intensive household appliances, especially air-conditioning (Wang and Zhai, 2010). According to Dhakal's research (2009), urban areas are responsible for 84% of China's commercial energy consumption, mainly contributed by manufacturing, transportation and housing.

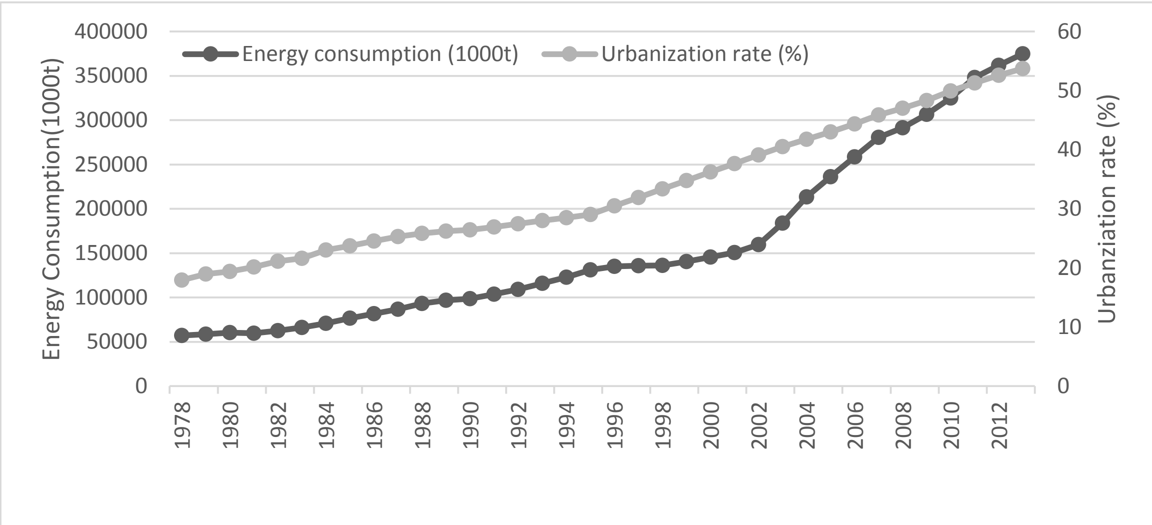

Figure 4.1 The change of urbanisation rate and total energy consumption in China (1978-2013)

Source：China social economic statistics database.

Although China has been the largest energy producer, it is still unable to meet its huge demand as the world's largest energy consumer (Birol, 2010). China has become a net importer of coal, and more than 50% of oil and 30% of gas consumption are relying on the foreign market. Furthermore, according to BP (2009), China's proved reserve of oil is only enough to meet its future need for 11.3 years if the current exploitation rate remains. The preserved reserve of gas and coal will only sustain for 32.3 years and 41 years respectively. Energy shortage and energy security have been a wide political concern across China.

On the other hand, though with a relatively low per capita emission, China had surpassed

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the United States as the world's largest carbon emitter by 2008 (World Climate Report, 2008), representing 23.33% of the global carbon emission. Apart from the abovementioned unsustainable industrialisation and urbanisation, China's coal-dominated energy mix is another root of this status. Compared to the world's 30% dependence on coal (BP, 2013), 70% of China's energy consumption is from coal (Shi and Zhang, 2012), which is the principal contributor to carbon emissions and other environmental problems such as air pollution. Consequently, China is facing increasingly imperative domestic pressure to deal with environmental pollution and energy security, as well as international pressure to mitigate carbon emissions (Liu and Shiroyama, 2013).

4.2.2 China's political discourse on renewable energy

In response to these challenges, China has been committed to the development of renewable energy since the beginning of the 21st century. This commitment has been followed by different levels of policies in various forms across the country. China's Five-Year Plan (FYP) has played a crucial role in guiding its economic and social reform by setting strategic priorities in the relative time frame. The 10th FYP (2001-2005) was China's first FYP that was dedicated to renewable energy development, setting a specific target for the annual utilisation of renewable energy [10] (Yuan and Zuo, 2011).

In 2005, China's National People's Congress (NPC) passed the Renewable Energy Law of People's Republic of China (hereafter, Renewable Energy Law), which took effect in 2006 and was amended in 2009. The Renewable Energy Law is China's first law concerning renewable energy. It highlights the strategic significance of renewable energy in meeting China's sustainable development target and energy demand. The law establishes several fundamental mechanisms for renewable energy development: renewable energy targets and planning, mandatory connection and purchase policy,; feed-in system; cost-sharing mechanisms; and a special renewable energy development fund (Schuman and Lin, 2012). Hence, this law provides the basic legal system and policy

[10] Hydro and biomass not included.

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framework for China's renewable energy policies (Zeng, Li and Zhou, 2013).

Based on the Renewable Energy Law, subsequent plannings, policies and regulations at both the national level and local level were issued to encourage renewable energy development, including administrative measures, price policies, tax and subsidies, technology standards etc. In 2007, China's State Council promulgated the *Middle and Long-term Plan for Renewable Energy Development (2007-2020)*, which for the first time explicitly set the target that non-fossil energy should account for 15% of China's primary energy consumption by 2020， while the figure in 2009 was 9%. In 2008, the 11th FYP for Renewable Energy Development issued by the National Development and Reform Commission (NDRC) set concrete targets for renewable energy development. At the Copenhagen Climate Change Conference in 2009, China's then-Premier Wen Jiabao pledged to reduce carbon intensity by 40-45% by 2020 based on the level of 2005 and to increase the share of non-fossil sources of energy to 15% of the primary energy consumption by 2020. The latest 12th FYP (2011-2015) is the first green development themed FYP, pledging a reduction in energy intensity and carbon intensity by 16% and 17% respectively, and to increase the share of non-fossil fuels to 11.4% by 2015. Following these national plans, relevant ministries and local governments have issued corresponding practical and specific incentives and managerial guidelines to support the renewable energy industry and its ultimate utilisation. Through these efforts, energy saving and emission reduction ('*jie neng jian pai*') has been a widely accepted political discourse across different levels of governments. Renewable energy is expected to play a vital role in achieving this ambition.

To date, China has been the leading country in renewable energy development in the last decade. According to BP (2015), China's renewable energy's share of the global total rapidly grew from 1.2% in 2005 to 16.7% in 2014. China has the largest installed capacity in hydropower, wind, and solar heating in the world (REN21, 2015). The emergence of China's renewable energy industry, especially wind energy and PV, has contributed

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significantly to reducing production cost and thus facilitates the installation of renewable energy worldwide. At present, renewable energy in total accounts for 20% of China's electricity production. Besides the largest contribution from hydropower, electricity from wind energy has taken the place of nuclear power, ranking second in non-fossil energies. PV, biomass and geothermal have also shown an increasing contribution to China's energy production. By contrast, the role of coal, though still dominant, has decreased, and its production began to fall for the first time since 1998, by 2.6% in 2014 (BP, 2015).

4.3 The development of China's solar thermal energy

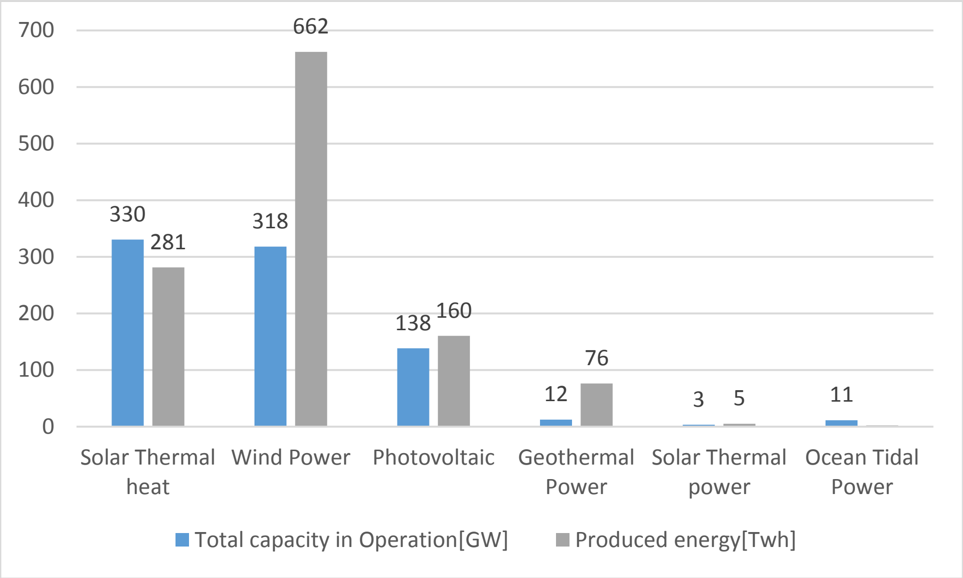

Figure 4.2 Total capacity in operation and annual energy generated, 2013

Source: Mauthner and Weiss (2014:7).

Solar energy is regarded one of the key renewable energy sources in many countries' green visions, for its unlimited reserves and easy transformation into other forms of energy without carbon emissions and pollution (Scheer, 2013). Solar thermal energy is a form of technology for harnessing solar energy to generate thermal energy or electrical energy. Currently, the most common use of solar thermal energy is SWHs for domestic use. According to IEA (2014), the global installed capacity of solar thermal heat had reached 330 GWth in 2013. Besides conventional renewable energies like hydropower and biomass, the contribution of solar thermal heating in generating green energy is

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second only to wind power and much higher than PV (Figure 4.2), but this fact is underestimated in many countries' energy policies (Mauthner and Weiss, 2014).

China is abundant in solar energy resources, with more than two-thirds of its territory receiving more than 2,000 hours of sunshine and 5000MJ / m^2 of solar radiation per year (Figure 4.3). The total amount of solar radiation received by China's land area each year is 3.3 $\times 10^3$~ 8.4 $\times 10^3$ MJ /m^2, which is equivalent to 2400 million tonnes of coal reserves. This provides a favourable geographical condition for China's solar energy development. To date, China's installed capacity of both PV and solar thermal heat have been the leading one in the world. Since 2006, China's PV installation capacity has witnessed an exponential growth, reaching 28.2 GW in 2014, second only to Germany. The rapid growth owed much to the government's incentive policies, notably after 2008, when the PV industry was heavily subsidised as part of China's Four Trillion Yuan investment to recover from the global financial crisis. However, the PV industry has been characterised by the so-called 'two outside' (Liu and Shiroyama, 2013), that is, both its core technology of raw materials and end market are heavily dependent on markets outside China. By contrast, the development of China's solar thermal energy has shown a very different but successful pathway. China not only possesses the world-leading indigenous technologies in solar thermal energy, but also has been the world's largest country in solar thermal utilization, accounting for two-third of the world (Mauthner and Weiss, 2014). But its role in China's renewable energy has long been overlooked due to the wide preference of energy that produces electricity rather than heat ('*zhong dian qing re*').

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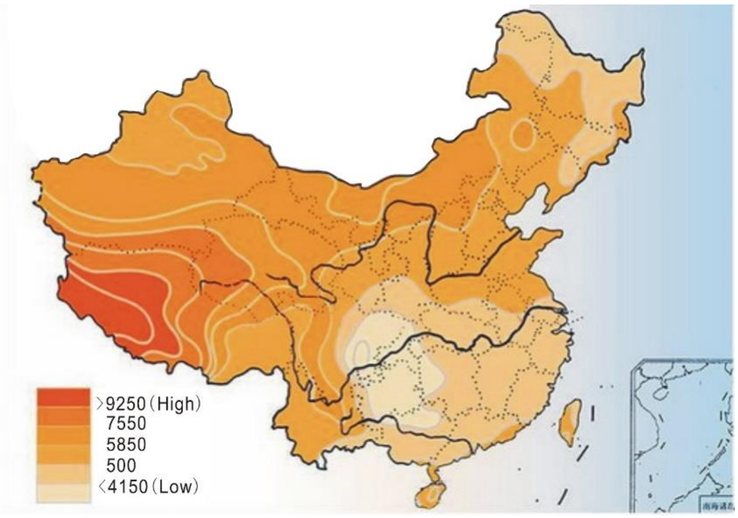

Figure 4.3 Distribution of China's solar energy resources (MJ/m^2.year)

Source: China Meteorological Administration (CMA).

4.3.1 Development history

One distinct feature distinguishing China's solar thermal energy from other renewable energy sources is that market forces, rather than policy push, were the principal driver of its popularisation. Government support did play a role in the early and recent years, but it had been missing for a long period of time in between. The development history is here divided into three phases:

Start-up phase: 1978-1994. In response to the global oil crisis, China started its research in solar energy by establishing solar energy research institutions and supporting solar research in top universities at the end of the 1970s. In 1980, Zhejiang University developed the 'honeycomb flat plate' SWH (Lu, 1999). In 1984, Tsinghua University invented the 'Magnetron sputtering graded aluminium - N / Al solar selective absorbing coating' technology, which greatly improved the solar absorption ratio to 85%, marking a significant breakthrough in solar thermal technology. This technology, however, remained in the research laboratory due to the lack of large-scale manufacturing equipment. In 1986, Beijing Solar Energy Research Institutes imported the Canadian flat-plate copper aluminium composite production line, which is believed to be the start of China's SWH industry. With the core technology solved, private entrepreneurs began to

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enter the SWH sector as they realised the potential market demand for hygienic lifestyles and hot water during China's fast economic and social development. As one entrepreneur explained his motivation, in the 1980s, doing farming was very dirty and tiring then, farmers had a huge demand for hot water bathing (interview 30). Previous to any kinds of water heaters, there had been some folk indigenous methods to use solar energy to produce hot water in China. The typical one was using black-painted gas cans under the sun to heat the water inside, which was very ineffective and unreliable (interview 1). With the improvement of people's living conditions, market demand for hot water increased. The improvement of flat-plate SWH technology met this demand and dominated China's SWH market in this phase. However, due to flat-plate SWH's high cost and disability in winter, as well as the low consumption power of Chinese consumers at that time, the industry grew very slowly (Hu *et al.*, 2012).

The rapid growth of evacuated tube SWH: 1994-2005. In 1994, a technology breakthrough in all-glass evacuated tubes by Tsinghua University, which also developed corresponding large-scale manufacturing equipment, led the industry to a new era (interview 32,35). The indigenous technology enabled the mass production of SWH and significantly reduced its cost (Luo, Huo and Xie, 2013). Some leading SWH enterprises initiated massive popularisation of solar energy knowledge around the country. These marketing efforts have been widely believed to have encouraged China's SWH market. The evacuated tube SWHs were first accepted by a number of urban residents with advanced environmental awareness. Then the market extended to rural areas, facilitated by the rising consumer power of rural residents. Although the initial cost of SWH was higher than electric water heaters (EWH) and gas water heaters (GWH), savings on energy bills and higher price/performance ratio were the primary reasons that it was widely accepted. The following decade witnessed the rapid growth of China's SWH market, with an annual growth rate of 30% (Wang and Zhai, 2010). At this phase, the evacuated-tube SWH grew to be the dominant SWH, with its market share more than 90%.

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Fast development of SWH-incorporated building project: since 2006. Since the Renewable Energy Law took effect in 2006, many provinces and cities have implemented a mandatory installation policy that requires new residential buildings (mostly under 12 stories) to incorporate solar water systems into new buildings' design and construction process. Accelerated by the rapid growth of the building industry in China's urbanisation, the SWH-incorporated building project market (hereafter, project market) had experienced a drastic increase, with its market share rising from 35% in 2007 to 45% in 2011. The project market is not confined to residential buildings, but also rapidly expanding to public buildings such as schools, hotels and hospitals, and factories. By contrast, the individual retail SWH market is shrinking, especially after 2010. As flat-plate SWHs enjoy advantages in incorporating into high-rise buildings more conveniently and are more aesthetically attractive, plus the reduction of cost and improved performance in winters, it witnessed a dramatic increase with an annual growth rate of over 50%.

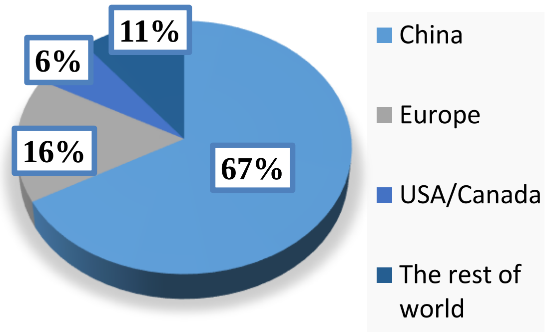

Figure 4.4 Share of the total installed capacity of solar thermal heat in operation

Source: Mauthner and Weiss (2014:16).

To date, China has been the world's leading country in solar thermal utilisation (Li *et al.*, 2011; Goess, de Jong and Ravesteijn, 2015). By the end of 2012, China accounted for 67% of total installed capacity worldwide (Figure 4.4). SWH in China is primarily for domestic use, especially hot water for domestic bathing. Since 2008, SWH has taken the place of EWH and GWH, dominating China's water heater market (Table 4.1). In terms of installed capacity, the share of SWH in China is 24%, second only to GWH (Cheng, 2013). Meanwhile, as a result of the fast growth of the project market, SWH spread from rural to urban areas, with the one-fourth of urban households using SWH (Wang and Zhai, 2010). The installation rates of SWH are more than 90% in some cities, for example, Rizhao, which was awarded a United Nations Habitat Award for its high installation rate of SWH(Bai, 2007). In addition to the application for domestic hot water, the technology has been applied in solar thermal heating, air-conditioning and industrial processes such as drying and sea water desalination. In terms of technology and production, China owns the most advanced technology in evacuated tubes. In 2012, China produced 639 million m^2 of solar thermal collectors, accounting for approximately 80% of the world production (Luo, Huo and Xie, 2013). The industry consists of approximately 3000 enterprises, among which 1800 are SWH manufacturers and the rest are component equipment producers (Hu *et al.*, 2012).

Table 4.1 Market share of different water heaters in China (2001-2012)

<table>
<tr><th>Year</th><th>Electric Water Heater</th><th>Gas Water Heater</th><th>Solar Water Heater</th></tr>
<tr><td>2001</td><td>30%</td><td>54.8%</td><td>15.2%</td></tr>
<tr><td>2003</td><td>44.23%</td><td>37.57%</td><td>22%</td></tr>
<tr><td>2005</td><td>45.2%</td><td>26.57%</td><td>28.23%</td></tr>
<tr><td>2007</td><td>42.3%</td><td>19.2%</td><td>38.5%</td></tr>
<tr><td>2008</td><td colspan="2">49.2%</td><td>50.8%</td></tr>
<tr><td>2009</td><td colspan="2">43.3%</td><td>56.7%</td></tr>
<tr><td>2010</td><td colspan="2">42.8%</td><td>57.2%</td></tr>
<tr><td>2011</td><td colspan="2">42.3%</td><td>57.7%</td></tr>
<tr><td>2012</td><td colspan="2">42%</td><td>58%</td></tr>
</table>

Source: Adapted from Luo, Huo and Xie (2013:11).

4.3.3 Technology specifics

The solar thermal collector is the key technology in utilising solar thermal energy. According to its application temperature, solar thermal collectors are divided into three categories: low-, medium-, and high-temperature collectors. High-temperature collectors (above 250 degrees) mainly use parabolic mirrors or lenses in large power plants to

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concentrate solar radiation on a heating medium, producing steam to generate electricity. Several high-temperature solar thermal power plants have been built in China, but its application remains in small-scale demonstrations and needs further research and development. Medium-temperature collectors (between 80-250 degrees) are used in industrial processes, such as cooling, drying, steaming and sea water desalination, but have not been applied extensively, either. China's outstanding success in solar thermal energy is primarily from low-temperature collectors (below 80 degrees), which are widely employed for hot water and heating. The most common used SWH collectors are the evacuated tube collectors and flat-plat ones.

Figure 4.5 Evacuated tube SWH on building rooftops

Source: (NetEase, 2009).

Evacuated tube or vacuum tube collectors consist of multiple evacuated glass tubes that respectively contain inner glass tubes covered by a selective coating (Figure 4.5). The heat absorbed from solar radiation is transferred to the heat-transporting medium, usually water, which circulates to a heat storage container through thermal convection. As the tubes are evacuated, the heat absorbed is not able to escape. Therefore, evacuated-tube collectors have higher thermal efficiency and better performance in winter than flat-plate collectors. Consequently, the low-cost evacuated tube SWH has an overwhelming dominance in China's SWH market, especially in rural areas since 1994. At its peak,

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evacuated-tube SWH accounted for 95% of China's SWH market. However, as glass tubes are easily broken, safety and maintenance are the chief deficiencies of evacuated-tube collectors. After 2010, the market share of evacuated-tube collectors began to fall due to problems in incorporating them into high-rise buildings. On the one hand, most evacuated-tube SWH can only be installed on the rooftop of buildings, but high-rise buildings do not have enough rooftop space to install evacuated-tube SWH for all the residents in the building. On the other hand, residents in the lower part of the building have to waste a lot of water before the hot water from the rooftop is transported to their apartments. The long water pipe also causes a lot of heat lost. In addition, as water flows through tubes, limescale will be generated after long use, not only reducing the thermal efficiency but also contaminating water quality.

Figure 4.6 Flat-plate SWHs on high-rise buildings' balcony

Source: author's fieldwork.

A flat-plate collector consists of an absorber plate, a transparent cover, a heat-transporting medium (e.g. water and air) and a heat insulating layer. The heat-collecting coating absorbs solar radiation and turns it into heat, which is transferred by heat-conducting medium to heat storage in an insulated water tank. Flat-plate collectors enjoy advantages such as simple structure, long service life, larger heat collecting area and water confined

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system. Flat-plate collectors can be installed both on rooftop and balconies of buildings, enabling SWH incorporation into high-rise buildings (Figure 4.6). On the negative side, the flat-plate collector has long been criticised for poor performance or disability in winters. In Europe, the flat-plate collector is the dominant SWH, accounting for more than 90% of its market. In recent years, due to its advantages in incorporating into high-rise buildings, the flat-plate collector is gaining popularity in China's cities. Nonetheless, China's flat-plate collector producers do not possess the core technology in the heat-collecting coating and thus, have to import from Europe, Germany in particular.

4.3.3 Environmental contribution

Table 4.2 The environmental benefits of solar thermal utilisation in China (2001-2012)

	Accumulated Installation	Standard coal saving	Electricity saving	SO_2 reduction	NO_2 reduction	CO_2 reduction	Smoke dust reduction
	million square meters	million tons	GWh	thousand tons	thousand tons	million tons	thousand tons
2001	32	4.8	133.44	155.2	70.4	10.3	120
2007	108	16.2	450.36	523.8	237.6	34.77	405
2012	255.77	38.02	1074	1240	568	83.16	968
Total	--	211.32	5892.02	6840	3096	455.18	5300.8

Source: Adapted from Luo, Huo and Xie (2013:13).

The vast utilisation of solar thermal energy has brought enormous energy and environmental benefits for China, as well as the world. From 2001 to 2012, the accumulated installation of solar thermal energy grew from 32 million m^2 to 255.77 million m^2, with a dramatic annual growth rate of 20.8%. The total saving of standard coal is 211.32 million tonnes, and electricity 5892 GWh. Each square meter of SWH collector can reduce the annual emission of SO_2, NO_2, Smoke dust and CO_2 by 4.85kg, 2.2kg, 3.75kg and 322kg respectively. From Table 4.2, readers can see the significant

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reduction of harmful gas emissions by SWH utilisation in China. In its future vision, China's accumulated installation will be 800 m^2 in 2020, saving standard coal amounts of 120 million tonnes.

4.4 China's policies on promoting solar thermal utilisation

China's central government played the key role in developing the SWH technology before its commercialization in the 1990s (Urban and Geall, 2014). The research on solar thermal technology was continuously supported by the national project of science and technology such as Project 863[11] (interview 28). After entering the civil market, SWH has been developed mainly at the local level without much support from central government. The SWH industry was not listed in the national financial support catalogue. Consequently, the industry had to grow by itself without national incentive policies such as subsidies or tax preferential treatment (Hu and Li, 2007; Li *et al.*, 2011). Instead, its industrialisation was largely attributed to the efforts of private entrepreneurs and household consumers (Luo, 2012). Only at the local level, are some SWH enterprises listed in the high-tech enterprise's catalogue by local government, and thus enjoy some favourable policies for high-tech enterprises (Hu *et al.*, 2012). But there were also many cities prohibiting SWH installations for safety and aesthetic reasons.

In 2005, China's NPC promulgated the Renewable Energy Law, prioritising renewable energy generation and utilisation in China's energy development. Regarding solar thermal energy, it states that the government shall encourage the installation of solar water systems and solar heating, and formulate technical and economic policies and technical criteria for the incorporation of solar systems into building construction (Article 17, 2005). Real estate developers are encouraged to take into account the requirements for using solar energy when designing and constructing buildings. In 2007, the NDRC's Medium and

[11] Project 863 or China's State High-Tech Research Development Plan was initiated in March, 1986. It aims to develop advanced technologies in a wide range of fields for the purpose of reducing technology dependence on western countries.

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Long-Term Plan for Renewable Energy (2007-2020) set specific targets for SWH: a total heat collecting area of 150 million square meters to be installed by 2010 and 300 million m^2 by 2020, replacing 30 million tonnes of coal equivalent (TCE) and 60 million TCE respectively. Driven by the Renewable Energy Law, a series of subsequent national and local policies and regulations have been enacted to promote the utilisation of solar thermal energy (Table 4.3). These policies and regulations have given a powerful push to the development of solar thermal utilisation.

Table 4.3 Policy environment of China's solar thermal industry since 2006

Law	*China's Renewable Energy Law (2006)*
Plan	*China's medium and long-term renewable energy development plan (2007)*
National policy documents	*Implementation plan to promote the solar thermal utilisation (2007)*
	Notice to accelerate the popularisation and application of solar water heating systems (2007)
	Energy saving regulations for civil constructions (2008)
	Notice to further promote renewable energy construction application (2011)
Support measures	*Special funds* *Subsidy* *Industry standards* *Demonstration projects*
Local incentive policies	*Mandatory installation policy* *Subsidies* *High-tech enterprise*

4.4.1 Mandatory installation policy

Since 2007, 20 provinces and 80 municipal governments have issued the mandatory install policy (Huo and Luo, 2012), requiring new residential buildings to integrate SWHs. As solar resources and building infrastructure vary significantly across China, national policies only encourage, rather than mandate, the incorporation of SWH into buildings. At the local level, the policy was tailored to local conditions. The policy is issued as either administration documents in most provinces, or as technology standards for construction projects in some provinces (Hu *et al.*, 2012). Most local governments require that buildings of, or less than, 12 stories should install SWHs, while some local governments set the standard even higher at 33 stories, or 100m (interview 16). Under this policy, the

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integration of solar water systems is a precondition for the approval of building new residential estates. The projects that are not in accordance with the requirement shall not be given permission for construction or completion inspection, while those projects complying with the policy will enjoy some privileges, such as priority in land use, simplified approval process and mitigation in building urban supporting facilities. This policy has to a great extent boosted the SWH industry and promotes SWH installation rate, especially in the urban project market.

4.4.2 Household appliance going to countryside

After the global financial crisis in 2008, China's household appliance industry suffered a serious overproduction due to the sharp export decrease. In response, the Ministry of Finance and Ministry of Commercial promulgated the *Detailed Regulations on Household Appliance Going to Countryside* in 2009. It provided subsidies, 13% of the product price, for rural residents to purchase new home appliances or to trade old appliances for new ones. SWH is listed in the subsidy catalogue, with a ceiling of RMB 5000 per SWH. Some local governments provide extra subsidies for purchasing SWH, reducing its initial capital cost by at most two-thirds of the price (Li *et al.*, 2011). In 2010, 9 million m^2 of collector area were installed under this policy (Huo and Luo, 2012). This subsidy policy ended in 2013.

4.4.3 Demonstration cities

In 2009, the Ministry of Finance and Ministry of Housing and Urban-rural Construction (MHURC) launched the *Renewable energy construction application city demonstration and implementation plan*. It encourages the integration of solar energy into buildings in demonstration cities. The state finance provides special subsidies to the selected demonstration cities, in which newly added solar energy application constructions should not be less than 2 million m^2 in the previous two years. Each province can have three prefecture-level cities and four county-level cities to bid for the demonstration project. From 2009 to 2011, a total of 72 cities and 146 counties passed the national selection and

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became demonstration cities, whereby each of them can receive RMB 50 million to 80 million subsidies. The central government plans to select 20 demonstration cities annually, aiming to motivate more cities to apply solar thermal energy into buildings.

4.5 Spatial differences

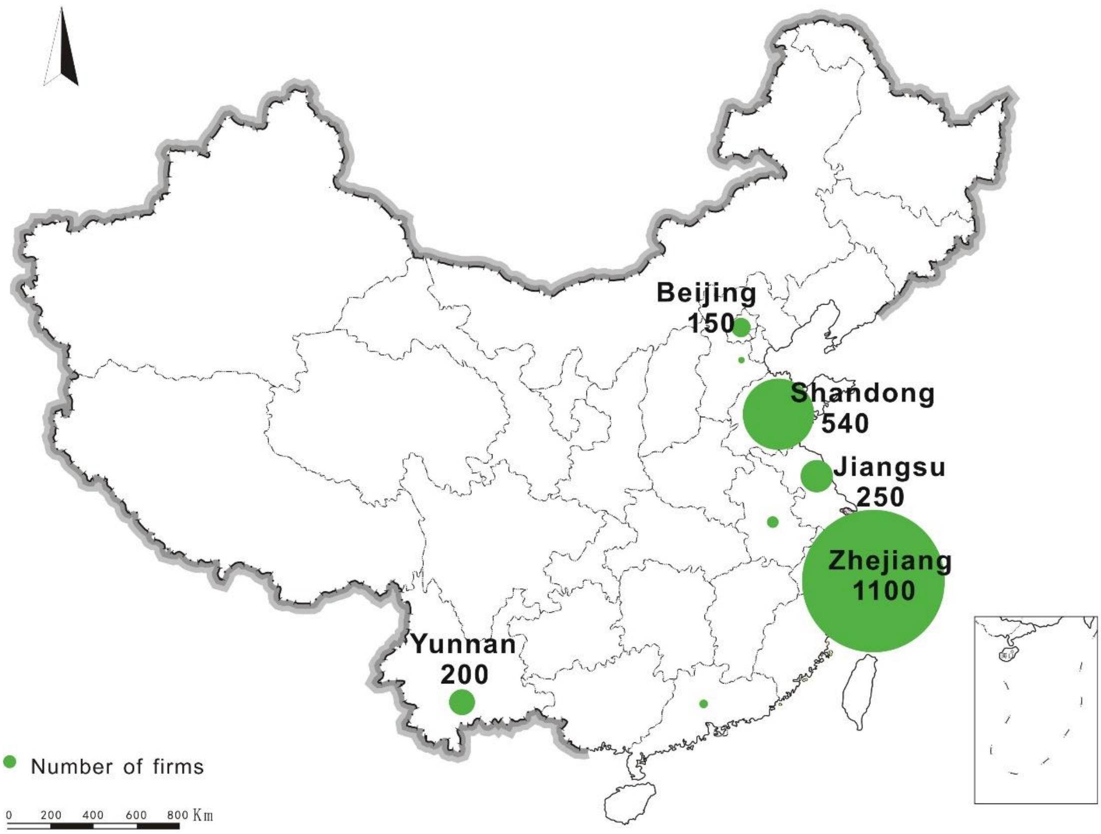

Figure 4.7 The spatial distribution of China's SWH enterprises in 2011
Source: Redrawn form Luo, Huo and Xie (2013:12).

Spatially, the manufacturing and utilisation of solar thermal energy are unevenly distributed in China. SWH manufacturing is concentrated in a few regions, such as Zhejiang (39.3%), Shandong (19.3%), Jiangsu (8.9%), Yunnan (7.1%) and Beijing (5.4%) (Figure 4.6), constituting the largest five SWH clusters in China. At the city level, the SWH manufacturing is mainly located in Jiaxing (in Zhejiang), Dezhou and Jinan (in Shandong), Nantong (in Jiangsu) and Kunming (in Yunnan). In terms of adoption, the installation rate of SWH varies widely at the sub-national level. The installation rate ranges from 4% in Guangdong province to 20% in Shandong province (Song, Ma and Li,

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2010). There is also an apparent divergence between large and small cities. Small and medium-sized cities are the main market of SWH. Many smaller cities have a very high installation rate of SWH. For instance, Haining, a county-level city, had an installation rate of 94.3% in urban areas and 65.8% in rural areas by 2007 (Han, Mol and Lu, 2010). Though Beijing is also one of the largest SWH manufacturing bases in China, its adoption rate of SWH is much lower when compared to smaller cities.

China's SWH Market Report 2006-2008 illustrates three barriers that explain the low market penetration of SWH in large cities. First, SWH is deemed as a grass-root, low-cost technology and most residents in large cities do not have much knowledge about SWH due to a lack of interest. Second, many city management departments restricted the installation of SWHs for safety and aesthetic reasons. Installing the SWH on the roof of a building may cause damage to the building and spoil the city's appearance. The third cause was the lack of attention from urban planning and building departments, who did not realise the significance of SWH in saving energy and improving the environment. In recent years, most of the restrictions on SWH installation have been cancelled and integration of SWH into buildings is widely encouraged, but the timing is not good for SWH installation in large cities. On the one hand, the substitutes for SWH, such as EWH and GWH have developed significantly, rendering SWH little space to penetrate. On the other hand, existing high-rise buildings with a high density of dwellings are not suitable for the installation of solar water systems.

4.5.1 Beijing

Beijing is the birthplace of China's solar thermal industry. Beijing's solar thermal cluster is not the biggest in terms of firm numbers (150 in 2010), but it is characterised by strong capacity in research and development, which is attributed to the high concentration of national research institutes and top universities in the city. Beijing Solar Energy Research Institute and Tsinghua University play the most crucial part in the development of China's flat-plate and evacuated tube collector technology, which spillovers to other regions

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through training workshops, talent mobility, property right trade, technology cooperation and imitations. Beijing's SWH industry grows with increasing number of SWH firms being established due to this technology advantage, but there are also many firms established in Beijing only to enjoy Beijing's city brand to promote marketing (interview 33, 34). Despite the long history and technology advantage, the application of SWH in Beijing has lagged behind. In its urban area, the installation rate of SWH was less than 7% in 2009. However, in suburban towns, the installation rate of SWH was about 30%, while in rural areas, the figure reached 85% in 2009. Beijing's Pinggu district has the highest installation rate of solar heating in China after its '*new socialist countryside building*' project. Most of the SWH enterprises in Beijing are located in suburban areas, such as Daxing, Miyun, Huairou and Mentougou.

4.5.2 Shandong

Shandong's SWH cluster is leading in China in terms of manufacturing and application (Goess, de Jong and Ravesteijn, 2015). It began in the late 1980s and grew quickly to be largest SWH producer in China, producing more than 10 million m^2 of solar thermal collectors annually. The cluster also has the most complete industrial chain in China's SWH industry, from raw materials to end products. It hosts 540 SWH manufacturers, most of which are concentrated in Jinan and Dezhou. Shandong also has the largest number of leading SWH firms in China, such as Himin, Linuo Paradigma, Sangle and Haier. In 2010, its top ten SWH firms produced 72% of Shandong's SWH, indicating a high level of market concentration (Cheng, 2011). Shandong's SWH industry is the pioneer in pushing the SWH-building integration. For instance, Himin has sought to cooperate with estate developers to integrate SWH into buildings since 2001, albeit not successfully at that time (interview 1). It then developed many demonstration building projects by itself to demonstrate how SWH can be incorporated into buildings. In 2005, Linuo Paradigma was the first firm in the industry that actually realised solar-building integration and it was the only firm that was awarded the National Housing Industrialisation Base by China's MHURC.

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In terms of application, Shandong has a remarkable installation rate of SWH. This is much attributed to the fast growing demand for economic hot water from residents and continuous popularisation efforts from the industry and local governments (Goess, de Jong and Ravesteijn, 2015). In the 1990s, the leading enterprises Sanle and Himin made huge efforts to popularise the knowledge of solar thermal energy, which met the growing demand of residents with rising incomes for a hygienic, but low-cost, lifestyle. Since 2006, Shandong's provincial and municipal governments have issued a series of policies to encourage the application of solar thermal energy. In 2007, Shandong provincial government implemented the *Shandong Intermit Management Method for Fiscal Subsidy Funding of Solar Heating System*, which provided 30% subsidies to public universities and hotels above three-star to install solar water systems. This policy was revised in 2009 and 2010, expanding the subsidy receiver to all schools and hotels, and raising the ratio of subsidy to 50% of the initial investment. Shandong was among the first group of provinces that actively promoted the integration of SWH into buildings. In 2009, the provincial government issued the *Implementation Opinion on Speeding up the Popularisation of Solar Thermal System*, which planned to increase the urban SWH installation rate from 20% to 40% and the rural from 5% to 10% by 2012. It mandated that all new residential buildings lower than 12 stories should incorporate solar thermal systems in the process of designing and construction. Residential buildings higher than 12 stories and public buildings were also encouraged to install SWH. By 2012, the accumulated installation of SWH in Shandong had exceeded 27 million m^2, benefiting 6 million households (Cheng, 2011).

4.5.3 Zhejiang

Zhejiang is among the first group of provinces that started developing SWH technology since the 1970s. In 1980， Zhejiang University invented the 'honeycomb flat plate' SWH, which significantly improved solar thermal efficiency (Lu, 1999). Parallel to this technological innovation, the first SWH manufacture was established in 1982 and

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demonstration projects were initiated (Han, Mol and Lu, 2010). But not until the introduction of the all-glass evacuated tube in 1992 did the industrialisation of SWH begin in Zhejiang, particularly in Jiaxing, in which the annual revenue from solar thermal collectors accounted for 13% of China in 2008. Zhejiang has been home to the largest SWH cluster in China, with 1100 enterprises, or one-third of China's total in 2011. However, Zhejiang's SWH cluster is characterised by small private business and family workshops. Only a few SWH enterprises in Zhejiang have mechanised assembly lines. The SWH industry's production capacity of Zhejiang is much less than Shandong, which only has half the number of SWH enterprises as in Zhenjiang. Nonetheless, Zhejiang's SWH cluster has China's most complete division of labour in the SWH industry.

On the application side, Zhejiang's penetration rate of SWH is the highest in China. Though it is not located in the solar-abundant region of China, the low-temperature SWH is still favourable in this area. According to Zhejiang Solar Energy Industry Association, the estimated installation rate of SWH in Zhenjiang was 30% by 2006, while the national average was 8%. The support from governments to this industry started in the early 1980s, primarily by introducing demonstration projects in the early phase and then subsidies, technical standards and mandatory installation policy in recent years (Han, Mol and Lu, 2010).

4.5.4 Jiangsu

Jiangsu's SWH industry began in the early 1990s. In 2011, there were approximately 200 SWH enterprises located in Jiangsu. Most of its SWH manufacturers concentrate in Nantong, Yangzhou and Lianyungang. Compared to Zhejiang, Jiangsu's SWH cluster also has a distinct grass-roots character, but it overall attaches more importance to brand building and quality management. Of China's Top 20 SWH enterprises, Jiangsu owns six of them. Solar Rain, established in Lianyungang in 1999, has surpassed Himin as the top seller of SWH in China in recent years. Though starting comparatively late, Jiangsu's SWH industry developed quickly primarily due to its favourable market environment.

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The popularisation of SWH in Jiangsu also began in small and medium cities. Recently, the project market and rural market are growing rapidly. Since 2006, Jiangsu's Building Design Standard has encouraged the integration of SWH in new buildings. In 2008, Jiangsu issued a mandatory policy to require all new public buildings to install solar water systems. There is no official statistics of the installation rate of SWH in Jiangsu, but it is estimated to be among the highest in China (Appliance, 2009).

4.5.5 Yunnan

Yunnan represents 10 percent of China's SWH production and 12 percent market share (MIIT, 2013), with approximate 200 SWH firms in 2011. Locating on a plateau in south-west China, the majority of Yunnan's territory enjoys a favourable geographical condition for utilising solar thermal energy. Especially in Kunming, the capital city, the household installation rate of SWH reached 60% in 2013. By 2013, the accumulated installation of SWH had risen to 17 million m^2, including 5 million m^2 in rural areas. Since 2007, Yunnan provincial government has started to support the SWH industry with specially allocated funding. It also enacted a mandatory building construction standard in 2008, requiring the incorporation of SWH into buildings. In its 12th FYP, Kunming planned to promote the SWH industry as one of the key projects in its new industrialisation phase.

4.6 Problems and obstructing factors in entering urban market

As discussed above, the fast growth of China's SWH industry is mainly attributed to market forces in its early phase. However, the SWH market itself does not fulfil its positive environmental externalities (Li, Rubin and Onyina, 2013), which are neither easily perceived by users, nor reflected in existing fossil fuel dominated energy markets (Neuhoff, 2005). The SWH industry in China is regarded more for business opportunities, rather than responding to concerns over energy security or environmental responsibilities (Li, Rubin and Onyina, 2013). After the Renewable Energy Law was promulgated in 2005, the incentive policies at national and local level began to play a dominant role in promoting solar thermal energy as a way to address environmental problems and energy

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security. The positive externality of SWH became more evident through government intervention. China has been the largest manufacture and installation market for solar thermal energy and, more importantly, enormous environmental and energy benefits have been achieved by the extensive utilisation of SWH. In this respect, China's SWH policies have been successful (Han, Mol and Lu, 2010).

Nevertheless, China's policies on promoting solar thermal energy still face problems in both technology innovation and market development. On the supply side, China's SWH industry has been criticised for its weak technological innovation (GTMS, 2012). After the breakthrough of evacuated tube technology, the subsequent two decades have not seen any radical innovations in the industry. The technology has been improved with incremental innovations, but the basic technology configuration remains unchanged. Many industrial interviewees believe that the heating efficiency of the evacuated tube has come to its limitation, therefore, there is no point to further invest in research and development (interview 4,12). Instead, they pay more attention to marketing. In addition, the evacuated tube SWHs in China have problems in fully integrating with buildings. Evacuated tube SWHs are currently popular in the rural area and small and medium-sized cities, but are unable to cater to the high-end demand in large cities (Hu et al., 2012), which require not only the high quality of SWH but also aesthetic and safe integration into buildings. As for flat-plate collectors, China's SWH enterprises have made several improvements such as solving the problem of freezing in winter. However, the core technology in solar thermal absorption film is still beyond China's SWH enterprises capacity (interview 2,12). The cost of flat-plate collectors remains high because Chinese enterprises have to pay a large amount of money to import the core technology from foreign countries. In fact, among the 3000 SWH enterprises in China, only around 20 of them have large-scale production and R&D capacities (GTMS, 2012). The products on the market are small in the product category and severely homogenised (Hu *et al.*, 2012).

Weak innovation leads to a vicious market competition. As the SWH products are

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severely homogenised, most enterprises choose to differentiate their products from others by lowering prices. Consequently, the product quality is not guaranteed. Many enterprises sell poor quality SWH at low prices, which not only drives out good quality SWH enterprises but also renders a bad reputation of China's SWH industry to consumers, who find it difficult to differentiate the good SWH products from the inferior ones due to information asymmetry. In 2010 to 2012, the percentage of qualified SWH products was only 86.7%、87.6% and 91.7% respectively. In the project market, estate developers in many cities have to install SWH under the mandatory requirement, but they do not trust the performance of SWH. As a result, they tend to install inferior SWH systems to minimise the cost for what they believe are unreliable systems. The fact that low price wins projects further aggravates the vicious competition of SWH enterprises and distracts the SWH industry from technological innovation. The following sections present and discuss the systematic barriers to the diffusion of SWHs in China's urban market with more details.

4.6.1. SWH industry and technological imperfection

4.6.1.1 Talent shortage

Lack of human resources is one of the barriers obstructing the industry's development (Goess, de Jong and Ravesteijn, 2015). Before 2005, SWH industry had been known as a 'peasant' industry. Except for a few entrepreneurs of large enterprises such as Tsinghua Solar and Himin, many entrepreneurs in the industry were previously farmers without a higher education background. Most entrepreneurs were previously sales agents of SWH firms (interview 12,33). They entered SWH manufacturing because they found the industry highly profitable and SWH technology was not difficult to imitate. Due to low prices and information asymmetry, more than 60% of the SWH market is dominated by small firms, among which are many in the form of family workshops (interview 2,5). Most of the small firms are speculative and sell SWH locally. These entrepreneurs barely invest in technology development. Large enterprises are the main actors in promoting the innovation and development of the industry, but only around 20 of them have large-scale

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production and R&D capacities (GTMS, 2012).

The shortage of skilled talent is attributed to following facts. First, the industry is deemed as a low-tech industry and top specialised talented people are not willing to enter the SWH industry. The industry itself has been too focused on market creation, while neglecting technology development. As a consequence, few enterprises have large investment in R&D talent. Second, SWH is a comprehensive technology involving a synergy of many different disciplines. The talent that is specialised in these fields would rather work for corresponding industries than SWH industry. As one interviewee put it:

> SWH looks simple, but if you want to innovate, you have to know water system, materials, heating, running, control and electric circuit, you name it. Only if you know all these things then you can create something good. The products were not expensive, but they involved many technology fields. As a result, the industry is short of specialised talents [interviewee 35].

Third, in China's higher education system, there is no specific academic major on solar water systems. Especially, the incorporation of SWH into buildings is facing a talent dilemma. The incorporation involves building design institutes, estate developers and SWH suppliers. The architects do not have much knowledge about solar water systems, while the SWH suppliers lack knowledge of building design. Although there have been cooperative efforts between SWH enterprises and universities to train talent for SWH-building incorporation, numbers are still in short supply (interview 16). As an entrepreneur commented:

> From my years of experience in this industry, the specialised talents in SWH-building integration would not exceed 200, they are very rare. Moreover, many firms just seek instant benefits by headhunting talents from their rivals, instead of building its own management system [interviewee 12].

An architect also commented:

> Architects do not pay much attention to SWH. They only care about building structure, space and appearance, while SWH suppliers focus on

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> efficiency and cost. In practice, architects may find the SWH ugly and thus refuse to use them. In SWH industry, there are hardly any architects. They have deviations in understating architects. So, there are very few specialised talents [Interviewee 36].

4.6.1.2 Weak system design

When it comes to SWH-building integration projects, the performance of solar water systems depends much more on the quality of system design, rather than single SWH products. The efficiency of solar collectors is only a part of the system performance, while thermal energy storage and transportation to end users are also critical to the eventual performance. Even if given an efficient solar collector, poor storage and transportation design will still result in a lot of energy loss. In addition, due to the unreliability of solar energy, many SWH-building integration projects choose to add a supplementary energy supply system, usually using more reliable electricity or gas. The supplementary system works when the solar thermal system ceases working in the night or in unfavourable weather. However, in practice, the two systems not only increase users' initial cost of installation but also represent a huge challenge for system design. Poor system design only causes more energy waste and thus a higher energy bill. For instance, a lot of electricity or gas may be consumed to boil the large volume of water in a water tank repeatedly in order to keep its working temperature if the solar system ceases working for a long time (interview 30). Therefore, system design of SWH integrated building projects is the key to system performance.

However, as discussed, specialised talents in the SWH-building integration sector is in short supply. Neither architects from building design institutions nor technicians from the SWH industry can maximise the system efficiency by themselves. Sometimes, in order to keep the aesthetic appearance of buildings, architects would rather sacrifice the efficiency of the solar system (interview 33,36). As every building differs from each other, the system design of every SWH-building integration also varies. So far, a standard system performance has not been guaranteed due to the weak system design of SWH-

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building projects.

> …some solar water projects invested by the national government, I don't say their names, turned out to cost dozens RMB to heat a tonne of water, while it's normally just more than RMB 10 for electricity to do so. Their cost is higher than using electricity, even as high as RMB 50, 60 or 70 for a tonne of water! Why? Unreasonable system design. The solar collector is ok, but the system design is unreasonable, the transportation pipes are too long to keep the heat. You heat it again and again, and you lose more energy [interviewee 30].

4.6.1.3 Policy reliance

After 2012, China's SWH retail market experienced a sharp decrease. The *Household Appliance Going to Countryside Policy* is widely believed among SWH industry to be responsible for the downturn. Though the industry witnessed the fastest growth during the application of the policy between 2009 and 2012, it has been criticised for affecting future markets. As one interviewee said:

> …the policy stimulates the market suddenly, meeting its long-term demand in short period of time. It's like the sales promotion in the supermarket, the first three days is ok, but the fourth day will see a steep decrease in the sale when the promotion cease [interviewee 35].

The reliance on incentive policies is also responsible for the undesirable technology innovation by distracting firms from technology innovation (Goess, de Jong and Ravesteijn, 2015), as one entrepreneur criticised:

> The majority of SWH firms merely took advantage of the incentive policies … they did not invest in R&D talents and technology innovation for urban project markets, not even management equipment [interviewee 12]

At the peak of the industry, there were around 5000 SWH enterprises in the market when the policy was operational. As the policy ceased, a large number of small local SWH enterprises died sharply. Many enterprises grew rapidly in terms of sale due to the policy, but they have not shown much improvement in product quality or technology research. The policy is also responsible for poor SWH-building integration after 2012. Too much

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focus was drawn to competing in the rural retail market and very few enterprises committed to upgrading technologies for urban project markets. When the policy ended and urban project markets began to grow, most of the SWH enterprises lacked the talents and technology capacity to complete the SWH-building integration well, which in turn, damaged the technology's profile.

4.6.1.4 Restrained large SWH enterprises

Though a number of large SWH enterprises do develop the technology capacity in SWH-building integration, they are restrained in competing in the project market. One characteristic differentiates the project market from the retail market is that 'guanxi' or personal relationship is a crucial consideration determining whether an SWH firm can win the project bids. In the retail market, the individual consumer chooses SWH products based on prices, quality and reputation, which the large SWH enterprises have much more influence. While in the project market, local SWH enterprises normally have a closer interpersonal relationship with local estate developers and government projects, which make it difficult for large non-local SWH enterprises to enter the market. Though many large estate developers focus more on SWH quality, guanxi is still an underlying consideration in decision making (interview 1,4,5,12,14,30). When asked what his enterprise mostly needed, one interviewee answered:

> Guanxi or connections, that's how the projects market runs. Be it estate developers or government projects, it is difficult to win the bids without interpersonal connections. Given the similar products and prices, surely they will give the offers to someone they have already known [interviewee 2]

Another barrier that restrains large SWH enterprises in the project market is the financial capacity. The SWH project market is highly dependent on real estate markets, while estate developers, in most of the cases, only see SWH integration as a mandatory burden. Consequently, the SWH industry lacks negotiating power with the estate industry. Most estate projects require SWH enterprises to cover the upfront investment of SWH-building integration first and get payment after completion, which is often not guaranteed. SWH

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enterprises face financial strain due to the long pay-back time of project fund, and thus are not able to construct many SWH-building projects at the same time. Even worse, some estate developers refuse to pay back the upfront cost. As one interviewee put it:

> even if you have the guanxi, you may not able to afford the upfront investment…how many connections can you have around the country? It is difficult for an SWH enterprise to become bigger in project market. It requires a lot of financial investment. Many estate developers break their faith with SWH enterprises and you don't get your money back [interviewee 30].

4.6.2 Market demand

4.6.2.1 High-end consumer demand

In the rural market, SWH consumers tend to care more about the cost rather than the quality. Under the Household Appliance Going to Countryside policy, the rural markets were filled with inferior products by small SWH enterprises due to the low industry standard (interview 1,4,12, 18). This had a severely negative impact on the growth of SWH industry in urban market as the consumers no longer trust SWH performance. Even though SWH provides relative advantages in economic saving, the comparatively wealthy urban consumers do not really appreciate it but care more about the negative side of the technology. Compared to its rural counterparts, urban consumers generally have more diversified demand for convenience, safety, beauty and even social status, which make it very challenging for grass-root SWH technology to meet. Instead, the EWH and GWH has gained much more popularity in the urban market which also poses a hard challenge for SWH to replace them. Higher income in urban areas also makes residents less concern on the energy bills, which renders renewable energy options less attractive (interview 32). Not only individual consumers but also estate developers and public or private organisations have higher demand standards which are still difficult for the new innovation to meet.

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4.6.2.2 Distorted project markets

For SWH-building integration project markets, estate developers have a different rationale. Reducing building cost is the priority for most estate developers. Under the mandatory installation policy, estate developers are forced to incorporate solar water systems into buildings, but they strive to decrease the SWH installation cost as much as possible. As a consequence, except for a few large estate developers, the majority of estate developers choose to install low price solar water systems, regardless of the quality (interview 1, 28). The mandatory installation policy only requires new buildings to install SWH systems, but with no specific requirements on eventual system performance. Therefore, the inspection of mandatory installation merely checks whether estate developers have installed a solar water system but not much attention was paid to how well the system works. Some estate developers even remove the solar water system from buildings after the inspections (interview 12, 28). In response, SWH suppliers are forced to reduce the cost of their products in order to win the bids from estate developers. Without enough quality control, the price battle only leads to inferior products, which in turn destroys the reputation of the whole industry, forming a vicious circle. For instance, Shenzhen was the first city in China that promulgated mandatory installation policy in 2005, but it was also the first city that cancelled the policy due to the poor inspection and quality control. As one SWH manufacture criticised:

> Some estate developers accept our products, but most estate developers regarded it as a burden. It doesn’t earn them any profit. Estate developers only view it as a mandatory quota to comply with the policy, if you don’t install SWH, you can’t get through inspection. They are not doing this seriously, all they want is to deal with the inspection [interviewee 33].

4.6. 3 Policies

4.6.3.1 Policy bias

The general landscape of low-carbon development, especially after the Renewable Energy Law was enacted, has given a strong push to the development of China’s SWH

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popularisation with a hierarchical policy support from the national level to local level. However, this green discourse landscape at the national level is not interpreted as imperative at the local level. After the support in the initial research stage, China's policies on solar thermal energy have been too focused on market creation, while ignoring the supply side to promote technological innovation. Compared to PV, solar thermal energy received much less policy support from both national and local governments. On the one hand, it might be due to the assumption that solar thermal technology is already advanced enough and the technology has been widely commercialised (Urban and Geall, 2014). On the other hand, as mentioned by many interviewees, there is a strong preference among governments for those renewable energies that generate electricity rather than that producing heat (interview 10, 11, 32). Electricity is regarded as an indispensable part of a society as it underpins many aspects of economic and social activities, while heat is only used in particular sectors at particular times, despite its higher energy efficiency and environmental contribution. At the local level, the preference for PV or wind energy has much to do with China's cadre performance evaluation system (CPES). The decentralisation and marketization since China's Reforming and Opening are believed to have weakened the authority of central state versus local governments, and CPES is the key mechanism for the party-state to control and monitor lower-level agents (Edin, 2003). Those government officers performing better in economic development terms have more chances to get promotions, and research has found that this political incentive for government officials has positively promoted China's local economic growth (Li and Zhou, 2005). Although the CPES has been reformed towards more social and environmental criteria to some extent in recent years, it remains a GDP-orientated system in many places at the local level. Apparently, the PV and wind industry bring more investment and thus GDP. In 2014, China's overall output of SWH industry was less than RMB 100 billion, while the annual output of PV has exceeded RMB 500 billion. Logically, local governments have more motivation in supporting the PV industry.

> The real energy conservation is reflected in energy replacement rate. They [governments] know PV has a low energy replacement rate, but why are

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> they still so enthusiastic with PV? Why? GDP! What they want is GDP. One PV project brings about billions RMB investment…They know the PV manufacturing is very polluting and energy consuming, but the GDP is rising [because of it], so they prefer PV [interviewee 33].

Besides, solar thermal energy is generally deemed as a low-end technology, which is not consistent with many local governments' visions to pursue high-end and high-tech industry. As an interviewee commented:

> The output of PV industry is much bigger than solar thermal, one PV firms' output may be comparable to the whole solar thermal industry. The government's rationality is nothing wrong by supporting the competitive industries, every government does that...PV is also regarded as the high-tech industry, its technology advance is much beyond solar thermal … [interviewee 12].

This political landscape weakens the government support for SWH industry, which generally has a limited role to play in local economies. In most cases, SWH industry has difficulty in lobbying for favourable policy supports from local governments. Except for the mandatory installation policy, solar thermal energy seems merely a free rider of other renewable energy policies or even policies for other industries and seldom has been the chief object of them. Take the *Household Appliance Going to Countryside Policy* as an example, it is not designed for promoting utilisation of renewable energies, but for expanding domestic markets for the household appliance industry, which suffered from a huge shrinking export market caused by the global financial crisis in 2008. SWH was just one of the products listed in the appliance catalogue going to the countryside, which also includes conventional water heaters. Though the SWH industry does benefit from this policy, it does not gain any favourable advantages over conventional water heaters.

4.6.3.2 Low industry standards

Ineffective innovations might be diffused through a decentralised system because of a lack of quality control (Rogers, 2003). China has around 30 relevant industry standard policies on SWH, but most of them are local level policies and are not strictly implemented. As a consequence, firms do not necessarily abide by the standards. The

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industry entry barrier is low due to the poor implementation of industry standard, and the majority of the SWH manufacturers in China have very limited capacity in production and quality control. In order to survive in the competitive market, they sell their poor quality SWH at low prices. Another cause of poor implementation of industry standards is that it is difficult to inspect the performance of SWH projects. So far, there are only three quality test centres of SWH in China. Especially for SWH-building integration projects, the performance of solar thermal systems relies on system design. It is easy to test the efficiency of the single solar thermal product, but it is difficult and costly to test the performance of the entire system, which performs differently according to weather conditions and building conditions. A professional quality inspection system of solar water projects has not been established.

4.6.3.3 Poor policy implementation

Most interviewees from the SWH industry admit the positive effect that the mandatory installation policy brings about, but they also complain about its poor implementation (interview 1, 2, 5, 12, 29, 31). The mandatory installation policy is issued by many local governments in the form of implementation opinions or administrative measures, which only have limited legal force, and thus the violation of this policy is not necessarily punished. During China's urbanisation, the real estate industry has played an increasingly pivotal role in the local economy and municipal finance revenues. Many cities' finance systems are characterised by land finance, that is, a large share of the municipal finance revenue comes from land development (Lin and Yi, 2013). By contrast, the role of SWH industry in the local economy is so small that it could be ignored in many cities. Many cities do not implement the mandatory installation policy stringently in order to protect the revenue from estate industry. As one interviewee illustrated:

> The [mandatory installation] policy is fine, but there are some deviations in implementation. Government supervision is not in place. Some estate developers don't install SWH, but they still get through inspections. The policy is not strictly implemented…Why? a lot of municipal fiscal revenues are from real estate industry [interviewee 12].

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Local protectionism was also believed to be responsible for the poor implementation of the industry standard (Luo, Huo and Xie, 2013). The SWH industry is identified more as a business opportunity by China's local governments, for its positive effects on job creation and fiscal revenue (Li, Rubin and Onyina, 2013). Especially, in those cities where the SWH industry plays a bigger role in the local economy, inspection of SWH products and projects is often not strictly implemented, in order to protect the local SWH industry. The rationale here is that if the standards are strictly implemented, not many local SWH enterprises could survive in the competition with large enterprises from other regions.

Inspections after project completion are vital to guarantee the quality of SWH-building integration. However, so far, there has only been three specialised national SWH testing centres and no independent third-party institutions are in charge of SWH-building integration inspections. Specialised inspection teams have not been established and performance standard of SWH-building integration that should have been complied with is missing. An informant from China's solar thermal industry committee said:

> Estate developers do not ask these test centres to inspect their projects. Instead, they hire inspection teams themselves. You don't even know whether these teams have the qualification of inspection. There has been no liability system in inspection so far. If there is any quality problem afterwards with the projects, the inspection team should be responsible for, but so far, not [interviewee 32].

The institutional cause of the poor implementation owns much to the governments' conflicting role between marketization and regulation (interview 30, 32). Failing to strike a balance between regulation and marketization, the government is believed to have functioned offside. In China's current market environment where trust is not well in place, fake and inferior products would destroy market order without quality control regulation, thus, complete marketisation is deemed impossible. Market failure and concerns to maximise SWH's positive environmental externalities calls for proper government intervention. On the government side, it is difficult to decide the proper extent and ways of intervention. The government is concerned if it intervenes too much by strictly

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implementing high standards, market competition may be hindered and may lead to monopoly and corruption, as only a few SWH enterprises can reach the standards. What's worse, the government does not have enough capacity and resources to supervise properly. Therefore, the industry is appealing for independent third-party institutions to conduct the SWH-building integration inspections. The current third-party institution is China's Solar Thermal Industry Association (CSTIA), which is actually a quasi-government institution. It is China's character that industry associations should be affiliated to corresponding government departments and CSTIA is under the Ministry of Agriculture. Both the president and secretary general of the association are former government officials. This government background makes the CSTIA less independent and unable to monitor the industry with unbiased standpoint. CSTIA is criticised for failing in quality inspection of SWH industry (interview 30). Currently, China is determined to detach industry associations from government departments.

4.6.4 A trilemma among actors

The system design problem of SWH-building integration is much attributed to the trilemma among architecture design institutes, SWH enterprises, real estate developers and governments. Architecture design institutes are generally not interested in SWH integration, nor do they have much knowledge about solar water systems. Some architects design institutes even delegate their design responsibility to SWH firms. In short, they are reluctant and unable to design SWH-building incorporation well. A senior architect explains a part of the story:

> The building design fee divide has not changed since 1949. Building equipment design only accounts for one-third of the fee, but its difficulty and contents have been increased a lot. Architects already have a lot of things to do, thus they do not want to spend more energy on new things like SWH. Instead, they pass the design responsibility to SWH enterprises and approve their design. This is not legally permitted, but this is what is happening there. SWH enterprises also lack the design ability, that's why many SWH-building projects are poorly constructed [interviewee 28].

SWH enterprises have long been competing in the retail market and lack the knowledge

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about building design for the collective installation project market, thus most of their SWH-building integration designs are not reliable. In addition, their main focus is to maximise profit by reducing cost, which leads to the use of inferior SWH on buildings as the eventual performance inspections are seldom strictly implemented. These inferior SWH systems undermine users' and estate developers' trust in SWH technology. In order to comply with the mandatory requirements, estate developers tend to install low-cost SWH systems, which are often inferior. The rationale behind this is that they can get through the inspection anyway as long as they have installed SWH systems, regardless of their performance.

On the local government side, the supervision of mandatory SWH installation is not strictly carried out. For one thing, real estate industry is the most important source of local fiscal revenue. The governments do not want to sacrifice fiscal revenue by offending estate developers (interview 12). For another, the lower industry standard is viewed as a way to protect local SWH industry as discussed above. Another problem is that many bureaus are involved in the inspection, making it unclear what their respective responsibility is, not to mention the conflicts of their own interests. The implementation of SWH popularisation policy calls for simultaneous collaboration among multiple bureaus.

As illustrated in Table 4.4, there are many interest conflicts among governments, SWH suppliers, architect design institutes and estate developers. Though the national discourse advocated by the central government is to develop a green economy and reduce carbon emissions, the priority for local governments is still economic development in most cases. Moreover, for design institutes, estate developers and SWH enterprises, reducing cost is an inherent part of their decision-making process, as profit-making organisations. In spite of many local governments issuing mandatory installation policies to meet the green economy discourse, the capacity failure in implementing and supervision provides room for business actors to escape the regulations. The weak system design capacity of business

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actors further leads to their actions that are against the initial objective of the policy. Hence, the primary bottleneck of SWH-building integration lies not in the technology development, but in the lack of an incentive mechanism to motivate relevant actors, especially the estate developers (Li *et al.*, 2007).

Table 4.4 Trilemma among actors

Actors	**Interests**	**Capacity**	**Actions**
Central government	Green economy, carbon mitigation, environment improvement	Lack of supervision capacity on local level	Renewable Energy Law Encouraging SWH installation policies
Local governments	Meeting Central government green targets, GDP, tax revenue and employment	Lack of inspection resources and capacity	Mandatory installation; But loose implementation and inspection of industry standard
Architect design institutions	Design revenue, not interested in SWH-building design, reducing design duties	Lack of SWH-building design capacity	Poor system design; Pass the design to SWH firms
SWH enterprises	Winning project bids, reducing product cost	Weak system design capacity	Dependent on low price and guanxi rather than technology capacity to win bids. 2) providing inferiors products
Estate developers	Getting through mandatory inspection; reducing installation cost	Unable to implement SWH-building design	Using inferiors SWH; Removing SWH after inspections

4.7 Summary and future visions

The same innovation can have very different purchase in different places, depending on how the local selection environment reacts to it. It is logical that a new innovation could face more obstacles in those places with a more demanding environment because their immature nature could often be amplified. This chapter challenges the orthodox claim that financial cost is the primary barrier to the popularisation of renewable energy technologies and contends a more systemic approach to understand the phenomenon from both the supply and demand side.

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The general landscape of green development has formed a favourable context for China's SWH diffusion in terms of legal institutional changes and renewable energy discourses, but it is still not forceful enough to exert more pressure on urban regimes. Since the industry is mainly driven by an economic rationale, environmental discourse is hardly imperative to push its further diffusion in the urban market. The technology is still not advanced enough to meet the high-end demand of the urban market. Neither economic savings nor environmental awareness provides enough incentive for urban consumers to adopt SWH. The shortage of skilled talent, weak system design, and price-oriented demand undermine the industry's innovation capacity. As the industry has only a small role in economic development, it is less likely to lobby for strong policy support. In entering the urban market, high-end market demand, the missing role of government, and interest conflicts among actors, constitute a very selective environment for the SWH to penetrate. Lack of high industry standards and poor quality inspection further aggregates the market environment, making it difficult for the technology to breakthrough.

In 2014, the SWH market experienced a sharp decrease due to the downturn of China's real estate industry. However, most of the interviewees believed that the decline was only temporary. As both climate change and environmental problems become increasingly imperative in China's policy agenda, government officials, researchers and SWH enterprises still have an optimistic vision of China's solar thermal energy industry. Nonetheless, the policy efforts are still relying on the local level, thus, more national level support are expected to genuinely appreciate the role of solar thermal energy in meeting China's GHG mitigation and renewable energy target.

Technology development is the key to realising this vision. The policy efforts are expected to encourage the industry's technology innovation rather than simply expanding the market by regulations and incentive subsidies. Many large enterprises have been committed to expanding solar thermal applications other than SWH. The focus is being shifted from low-temperature utilisation to medium-temperature utilisation in industrial

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processes and high-temperature utilisation for electricity generation. These technologies have been applied at a small scale, but the high cost remains a critical barrier for large-scale application. Another direction mentioned by many interviewees is that solar thermal energy should integrate with other energies, especially air-source heat, to compensate for its unreliability. Future decentralised energy supply for residential and industrial use will not be dominated by one particular energy, rather, it will be comprised of comprehensive systems combining different energy sources. Solar thermal energy is believed to be an important part of the system. The key problem is how to integrate different energy sources and maximise system efficiency.

Institutional reform is also required for healthy market development. Since the low industry standard is a chief bottleneck for widespread diffusion, implementing a higher industry standard is necessary to correct the distorted market. Nonetheless, this should be complemented by a stricter quality inspection institution. The government is expected to improve its supervision of solar thermal industry standards. Specialised inspection schemes should be formed to evaluate the system performance of SWH-building projects. Some SWH enterprises have begun to initiate a commercialised quality assurance system, calling for independent third-party institutions to conduct quality inspections. Moreover, the CPES should be oriented towards more of a focus on environmental sustainability, so that local governments have a more genuine interest in promoting renewable use seriously. Last but not least, a more comprehensive and benefit-based incentive policy at the local level is needed. Especially for the mandatory installation policy, estate developers could be better motivated to adopt SWH-building integrations if they are also offered with more ‘carrots’ than just ‘sticks’.

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Chapter 5 Diffusion of SWH in Dezhou and Beijing

5.1 Introduction

Having given the background of solar thermal energy development in China in the last chapter, this chapter goes down to the local level and contrasts the development of the solar thermal industry in the two case cities: Dezhou and Beijing. This will be helpful to explain why the manufacture and utilisation of solar thermal energy have unfolded unevenly across China. As mentioned, small and medium cities dominated China's SWH market. It is of value to investigate why the transition to SWH happens in some less developed cities rather than the developed cities, which are often believed to be the centre of technological innovation and with residents having more consumption power and an open attitude towards new innovations. Compared to Beijing, Dezhou is a latecomer in industrialisation and urbanisation, but it has been the leading city in manufacturing and utilisation of solar thermal energy. The variance in the popularisation level of SWH has much to do with both cities' contexts and locally embedded socio-technical factors. The focus of this chapter is on Dezhou, but the story of Beijing's solar thermal industry is also elaborated as a contrast. This, on the one hand, helps to make more sense of the influencing factors in Dezhou's context through contrasting; on the other hand, it avoids missing the linkages and connections between the two cities, which are also of much significance to Dezhou's SWH transition.

To this end, the factors influencing the SWH transition in Dezhou and Beijing are presented separately. Each section starts with introducing the geographical, social and economic contexts of the case city, as they are the important backgrounds where the transition happens or not. Among these, rapid industrialisation and urbanisation are believed to be the most prominent socio-economic phenomena. The Dezhou section demonstrates its facilitating factors from an actor perspective: i.e. how the main actors interact and push the diffusion of SWH in Dezhou. By contrast, the Beijing section

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illustrates the reasons why SWH has not been popularised in Beijing. The final section reveals the asymmetric relations between Dezhou and Beijing in both technological and political aspects.

5.2 The popularisation of SWH in Dezhou

5.2.1 Geographical context

Dezhou is located in the north-west of Shandong Province and at the north side of the lower reaches of the Yellow River, between 115°45′—117°36′E and 36°24′25″—38°0′32″N. It is in the warm temperate continental monsoon climate zone, with four distinctive seasons. The annual average temperature is 12.9℃ and the rainfall is 547.5mm on average. The city’s annual average sunshine is 2592 hours, with the sunshine rate at 60% and the total solar radiation of 124.8kcal/cm^2; both are higher than the national average (Dezhou Government, 2016).

Dezhou is located in China’s third largest Economic Zone---Bohai Economic Rim. It is 120km north to Jinan, the provincial capital of Shandong province, and 320km south to Beijing. Historically, Dezhou is an important node on the Beijing-Hangzhou Canal (or the Grand Canal) and the Beijing-Shanghai Railway, connecting east China and north China. At present, Dezhou remains an influential node in China’s national highway system. In 2006, the city was recognised as one of the main national transportation hubs. This role was further strengthened when Beijing-Shanghai High-Speed Railway started running in 2011. The time-space compression effect brought by transportation development enables Dezhou to maintain a close connection with developed regions.

Spanning 200 km from east to west and 175 km from north to south, Dezhou has an administrative area of 10356 km^2. Its territory includes one district, Decheng, where the municipal government is located, two county-level cities, Yucheng and Laoling, and eight counties. Its urban built-up area is $134km^2$, accounting for 1.29% of its administrative

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area. Currently, Dezhou is home to a population of 5.76 million, of which 0.6 million live in Decheng district. In 2012, the urban population in Dezhou reached 2.6 million, with an urbanization rate of 46.24%. Still, according to Dezhou's census system, 4 million of the population belongs to agricultural population and only 1.77 million are non-agricultural population (Dezhou Statistics Bureau, 2015). The city is experiencing a transition from being an agricultural city to an industrial city.

5.2.2 Economic and social development

Dezhou used to be one of the least developed regions in Shandong. Since China's Reform and Opening, Dezhou has experienced rapid economic development with an annual average growth rate at 17.9%. Its GDP dramatically grew from RMB 0.82 billion to RMB 260 billion in 2014 (Dezhou Statistic Bureau, 2015). Despite its fast growth, Dezhou remains a less developed region in Shandong in terms of both absolute GDP and GDP per capital (Figure 5.1). In 2014, Dezhou's GDP per capital reached RMB 45.6 thousand, just below the national average, but 30% less than the provincial average and only a half of the level of Beijing, one of the richest cities in China. In this respect, Dezhou is a typical developing city in China.

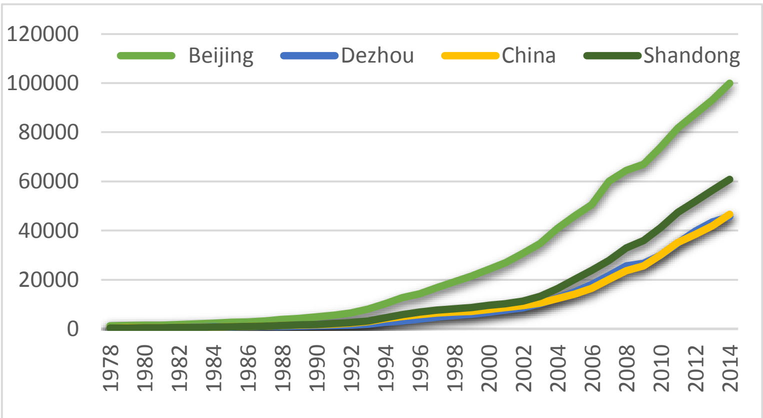

Figure 5.1 GDP per capital growth of Dezhou, Beijing, Shandong and China (RMB)

Source: Edited from Dezhou Statistics Yearbook 2015 and China Statistics Yearbook, 2015.

5.2.2.1 Industrialisation

Located on the fertile Yellow River Delta and endowed with desirable climate conditions,

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Dezhou was traditionally an important agricultural city in China. Up to now, Dezhou remains an influential production base for grains, cotton and oil crops. Dezhou's most well-known agricultural product used to be the Dezhou Braised Chicken, which had enjoyed a national reputation for more than 300 years. In 1978, the agriculture sector accounted for 57.18% of Dezhou's GDP, with secondary industry and tertiary industry 16.9% and 25.9% respectively (Figure 5.2). The proportion of the agricultural sector kept growing to a historically high level at 65.88% in 1984, and then decreased dramatically to less than 50% in 1988, as a result of the beginning of industrialisation. While tertiary industry grew gradually, secondary industry has experienced a fast growth since 1984. It was not until 1995 that the dominant role of agriculture sector in Dezhou's economy was replaced by secondary industry, which grew to represent half of Dezhou's GDP in 2003. In 2014, the three industries' share of GDP was 11.1%, 51.6%, and 37.3% respectively. Compared with developed cities such as Beijing, Dezhou's economy heavily relies on secondary industry and its tertiary industry performance is poorer than the national level (Figure 5.3). Dezhou is still in the early phase of industrialisation, whose dominance may still last for a long period of time in the coming decades.

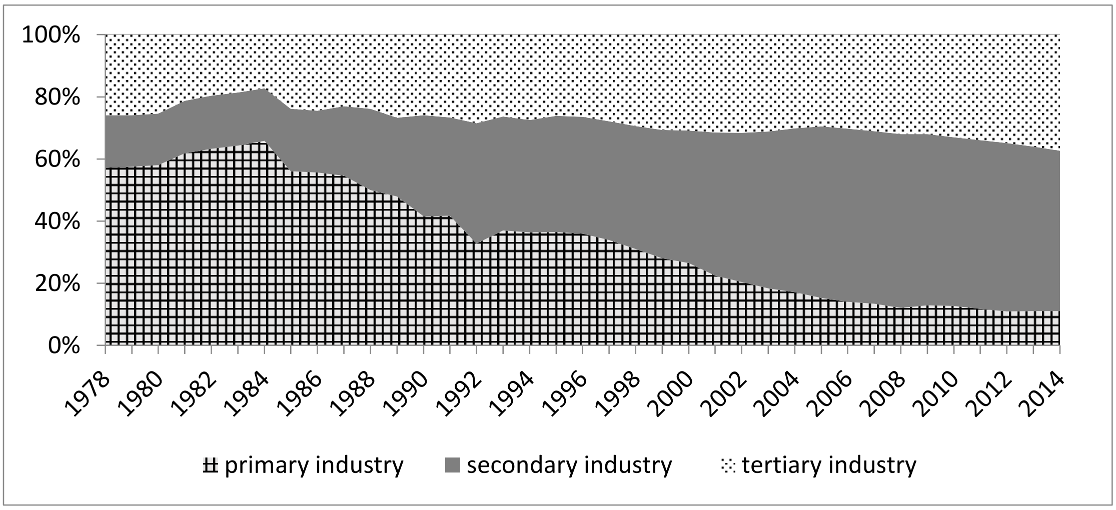

Figure 5.2 Dezhou's Industry Structure (1978-2014)

Source: Dezhou Statistics Yearbook, 2015.

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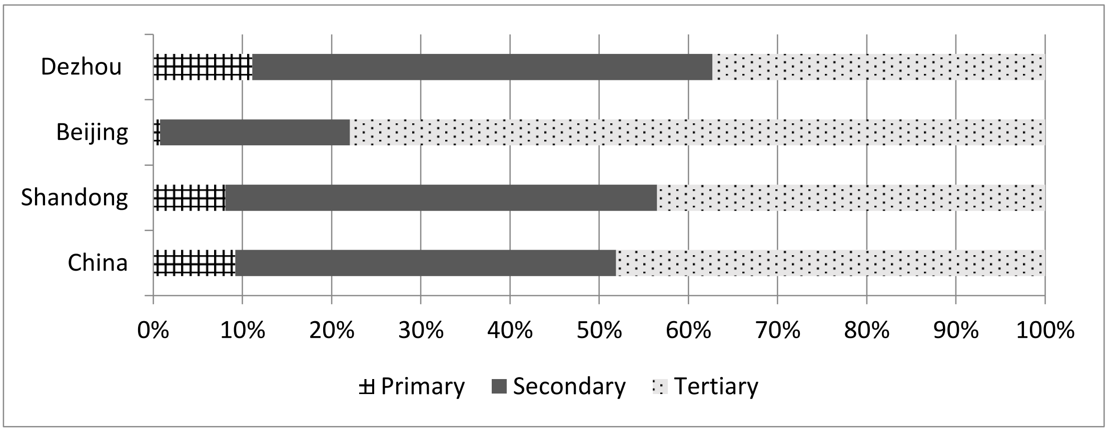

Figure 5.3 Industry structure of Dezhou, Beijing, Shandong and national average in 2014

Source: Edited from Dezhou Statistics Yearbook 2015 and China Statistics Yearbook 2015.

Looking into its secondary industry, the equipment manufacturing, food, chemical and textile industries are the four competitive industries in Dezhou. In particular, Dezhou's central air-conditioning industry is of national importance. The city was reported to account for 12% of China's central air-conditioning market (Dezhou Government, 2006). Though Dezhou also promoted itself as China's Central Air-conditioning City, the industry was dominated by small enterprises without many well-known brands. Meanwhile, new energy, new materials, biomedicine, and culture and sports goods industries are emerging. In 2010, these eight leading industries' main business income reached RMB 350 billion, or 73.9% of Dezhou's total industry income, of which, the four emerging industries accounted for 27.1%. In 2012, there were 3228 industrial enterprises above designated size in Dezhou[12], and 63 of them achieved more than RMB 1 billion income. High-tech industry's output value was RMB 153 billion, representing 24% of the output value of all industrial enterprises above designated size (Dezhou Statistics Bureau, 2012). According to Dezhou's 12th Five-Year Industry Plan, the four emerging industries would represent 35% of its industry income and High-tech industry's proportion would surpass 30% in 2015.

[12] Industrial Enterprises above Designated Size refers to enterprises whose main business incomes are no less than RMB 20 million.

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5.2.2.2 Urbanisation

Accompanied by the fast industrialisation, urbanisation is another prominent socio-economic phenomenon occurring in Dezhou. In 2012, the urban population in Dezhou reached 2.6 million, raising the urbanisation level from 30.5% in 2000 to 46.24% in 2012, with an annual growth rate of 1.31%, slightly above the provincial level (1.07%). Its urbanisation speeded up especially from 2009 at the rate of 2.54%, which attributed much to the growth of its county-level cities and towns (CCUD, 2015). Differing from the stereotype of urbanisation in China's large cities, Dezhou's urbanisation process is characterised by its focus on the modernisation of rural areas. In 2008, Dezhou initiated a plan of *Building rural communities and industries parks simultaneously*, which intended to merge 8319 administrative villages into 710 rural communities, and meanwhile build 1538 rural industrial parks so as to provide employment for the newly urbanised population. By 2013, 378 rural communities had been built or were under construction, housing 200,000 families; 876 rural industrial parks had been built, providing employment for 300,000 farmers.

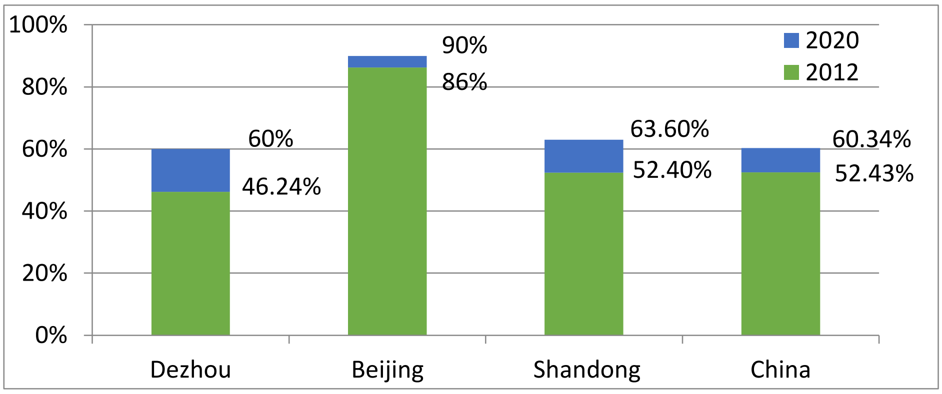

Figure 5.4 Dezhou, Beijing, Shandong and China's urbanisation rate in 2012 and 2020 vision

Source: Edited from Dezhou Urban Master Planning 2011-2020, Beijing Urban Master Planning 2004-2020, Shandong Urbanization Development Outline 2012-2020 and China Small and Medium City Green Book, 2013.

In spite of the fast growth and great efforts, Dezhou's urbanisation rate is still 6.16% less than the provincial level and 6.19% less than the national average level in 2012. The gap

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is much bigger when compared to the more urbanised Beijing (Figure 5.4). Dezhou's urbanisation will continue at a fast rate for decades. According to its future vision, Dezhou's urbanisation rate will rise to 60% in 2020, but may still be below the national and provincial level.

5.2.3 An emerging solar city

Dezhou's new energy industry mainly consists of solar energy, biomass energy, wind energy equipment, new energy automobiles and geothermal pumps. Among them, the solar energy industry is the most eye-catching one and has become the most frequently promoted city image of Dezhou. Dezhou's solar industry dates back to 1995 when Himin Group was set up, dedicated to SWH manufacturing. Initially, it was a small family workshop without much capacity for technology innovation. After a short cooperation with Tsinghua Solar as its regional manufacturing branch in Shandong province, the turn of the century witnessed the fast development of Himin. Not only did Himin become the largest SWH manufacturer in the world, but also grew to be one of the leading SWH enterprises in technology innovation. The market developed by, and technology spillovers from, Himin stimulated further local entrepreneurship in Dezhou's solar industry. In 2005, Dezhou government officially carried out the *Solar City Strategy* and a series of preferential policies and plans were implemented to provide comprehensive technological and financial support to the solar industry. Currently, apart from the dominant SWH manufacture, Dezhou has built a fairly complete solar industry chain, which is still fast extending to other related products, such as solar modules, PV systems, solar lighting systems, solar traffic lights and solar integrated buildings. In 2010, the city was home to more than 120 enterprises engaging in solar-related industries, achieving more than RMB 50 billion sales revenue and selling a total of 26 million square meters of SWH, which accounted for approximately 70% of Shandong's and 16% of China's capacity respectively. It is reported that around 800 thousand people in Dezhou are employed in the solar industry, representing one-third of the city's workforce (Tyfield, Jin and Rooker,

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2010).

Besides the huge scale of manufacture, Dezhou has shown a strong capacity for technology innovation in solar energy, though most of them were achieved by Himin. Dezhou owns 620 patents in solar technology and some of them have been leading global technologies. Dezhou also hosts more than 20 national scientific projects in solar energy, such as National High Technology Research and Development Program of China (or 863 plan). Dezhou is also the home to the leading research institute in the solar energy industry: The International Solar Energy Technology Academy of Sciences. A new industrial zone hailed as the Sun Valley has been built for experimenting with clean-energy urban projects and massive use of household utilities. With RMB 5 billion investment and 3000 acres of land, Dezhou Sun Valley is the largest solar energy production base in the world. The Sun Valley brings together the world's leading technologies in solar heat utilisation and building energy conservation. More than 500 new technologies are turned into products every year. The Sun Valley is planned to be the centre of renewable energy manufacturing, logistics, R&D, testing, science education, and tourism. In 2011, the world's climate forum in Thun, Switzerland, named Dezhou's Sun Valley as the 'Benchmark of contribution to addressing global climate change'.

The industry brings with it a wide application of solar energy in Dezhou. The installation rate of SWH in Dezhou is among the highest in China. Local residents view SWHs as economical and practical products. The municipal government has also made great efforts to demonstrate the use of solar energy, such as installing solar lighting along urban roads and building solar theme parks. Since 2008, the government started the Photovoltaic Demonstration Project in the old town areas, installing solar lighting in the city's main roads, attractions, residential and office areas. This saves annual 952 tonnes of coal and reduces 2372 tonnes of carbon dioxide emissions. Besides, the government provides an extra subsidy to extend the solar energy to rural areas. More than 20% of its villages have built solar powered bathrooms. The solar enterprises are also committed to demonstrating

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the application of solar energy. To give an example, Himin's headquarter building, Weipai Building, is the world's largest 'zero emissions' office building. It uses solar energy to provide hot water, refrigeration, heating, and lighting, reaching an energy-saving efficiency of 88%. This building has been widely recognised as the landmark of Dezhou.

In 2005, the city was awarded 'China's solar city' by China's Solar Association. Greenpeace China cited Dezhou as an example of how renewable energy can become a more common reality throughout the world. In 2009, Dezhou was designated as one of China's first Renewable Energy Demonstration Cities by the Department of Housing and Urban-Rural Development. In 2010, Dezhou was selected as one of the first pilot cities of China-Switzerland low carbon city cooperation projects. Dezhou boosted its international reputation when it beat the cities of Oxford and Adelaide to host the International Solar City Congress in 2010. Dezhou has been China's leading city in solar energy utilisation and it is now believed to be a new centre of renewable technologies.

5.2.4 Facilitating factors

This section presents the results why solar thermal energy has become popularised in Dezhou drawing on interviews and documentary data sources. Instead of focusing on the economic rationale of residents (e.g. Li *et al.*, 2011), this research found a positive feedback loop among four main actors: the SWH industry (Himin in particular), local government, urban residents, and estate developers. This enables us to understand the role of both supply side and demand side, as well as intermediary organisations in facilitating SWH diffusion in Dezhou. Particularly, the role of estate developers has long been ignored in similar research, but, in fact, they have much to say in relation to whether to install SWH on their buildings.

5.2.4.1 Himin: a powerful large enterprise

The emergence of Dezhou being a solar city is tightly interwoven with the growth of Himin, which has been widely believed to have played a dominant role in the

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development of Dezhou's solar industry. Dezhou's solar industry began with the entrepreneurial story of Huang Ming, the founder of Himin. After graduating from the China University of Petroleum in 1982[13], Huang Ming worked in Dezhou for a state-owned oil drilling research institutes under the Minister of Mineral Resources, studying oil drilling equipment. During his time working in the petroleum industry, Huang Ming learned that oil was not a sustainable energy source and would run out in decades. In 1987, a book, 'Solar engineering of thermal processes' by Duffie and Beckman (1980), introduced Huang Ming to the field of solar energy. He found the mechanism of solar thermal was easier than that of oil drilling and began to make SWH according to the book in his spare time. In 1988, Huang Ming made his first flat-plate SWH and improved it with more experiments. At that time, solar energy was hardly known to mass consumers. Huang Ming started exploring the potential markets by presenting SWH to his friends and relatives as gifts to see how they worked. As he expressed his entrepreneurial motivation in a television interview (Alibaba video, 2008):

> An impressive experience was when I sent my SWH to a relative as a wedding gift. My SWH was displayed on the wedding ceremony. I had not thought that it was popular at the ceremony. People found this 'monster', which did not use electricity or gas, and just turned on the machine then came hot water. People surrounded me and asked me a lot about the machine. From people's cheering faces, I saw the future of solar energy.

In 1992, when China was experiencing deeper marketization reform after Deng Xiaoping's 'southern tour', Huang Ming joined the 'tide of going to business' ('*xia hai chao*') by setting up Xinxing High-Tech company. It was more like a family workshop with a dozen of workers engaging simple manufacturing, but it paved the way for the establishment of Himin in 1995. In 1997, Himin cooperated with Tsinghua University as a regional manufacturing branch of Tsinghua Solar, which possessed the most advanced evacuated tube SWH technology at that time. Subsequently, Himin started to develop its own innovations by setting up its own international R&D teams. Not only did it quickly grow to be the world's largest solar thermal energy supplier, but also became one of the

[13] In 1982, the university's name was East China Petroleum Institute. It is located in Dongying, Shandong.

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leading technology enterprises in China's SWH industry. At present, Himin has participated in 22 national projects and possesses world-class core technologies such as interference coating, solar thermal power generation, and sea water desalination. Himin set up China's first solar testing centre in 1997 and China's first private solar thermal research institute: The International Solar Energy Technology Academy of Sciences. Now, Himin owns 20 laboratories and more than 1000 testing items from raw material to the whole unit.

Himin is called 'the kingdom of solar products'. Its main business includes SWH (hot water solutions for households and for business groups), solar thermal power generation, solar lighting system, energy-saving glass screen, solar air-conditioning, and solar sea water desalination. So far, Himin has extended more than 10 million m^2 of solar energy, saving standard coal 20 million tonnes and reducing pollution levels by 20 million tonnes. The sustainable development model created by Himin (or the Himin model) developed a new pathway that saw commercial and environmental aims coexist harmoniously. It realises the tripartite win-win of the environment, marketing, and industry. Himin has not only become a well-known green enterprise in China, but also has been widely cited by the international media as the marker post for sustainable development of renewable energy. Huang Ming was China's first private entrepreneur who was invited to give speeches in the UN (twice) to introduce the Himin model to the world. As the Himin model was seen to provide the world with a remarkable example and rich experiences in renewable energy development, Huang Ming was elected as vice president of International Solar Energy Society (ISES) in 2008.

Specifically, the role of Himin in Dezhou's and China's solar thermal industry has been illustrated in market promotion, value chain building, technology innovation, knowledge spillover, policy lobbying and city brand building.

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(1) Market promotion

In the 1990s, when solar products were rarely known by Chinese consumers, Himin made great endeavours to popularise solar energy knowledge in China. In Dezhou, Himin's early market promotion was confined to physical demonstrations in public areas and advertising in local newspapers. It was the first time that Dezhou's residents learned the idea of solar water heaters by Himin's local marketing efforts.

> At that time, nobody knew this product. He [Huang Ming] demonstrated his SWH on the public squares. Dezhou's residents were very surprised, what on earth these monsters are? He then explained about SWH…The first big business came from Dazhong Daily (a local newspaper). Himin used SWH to trade for advertisement, that is, we provided them SWH to cover our advertisement fees [interviewee 1].

Himin then tried to integrate SWH into residents' living habits. Another interviewee illustrated why SWH is popular in Dezhou:

> This has something to do with the living habit here, but it also attributes to Himin, which did a lot to popularise solar energy, guiding residents towards the living habit with solar energy. The earliest product of Himin was something like a black water bag. Put it on the rooftop and add water, then the black material absorbs solar thermal to heat the water. People needed hot water and they found this a good idea. As the technology improves, solar industry also grows. Residents think SWH is good for their life and it is economical, so they accepted it [interviewee 22].

Since 1996, Himin started to promote the SWH market nationwide. The most well-known endeavour by Himin is the 'Solar Science Popularization Tour' ('*ke pu wang li xing*') around the country. To date, Himin has published more than 300 million copies of its self-published *Solar Energy Science Report* and held activities such as *Solar Science Tour*, *City Environment Protection Tour* and *Green Storm* in thousands of cities, towns and villages around China, in order to popularise solar energy knowledge and to expand its market. It did not merely demonstrate to citizens what solar energy is, but strengthened consumers' trust in solar products. Himin's market promotion efforts are widely believed in the industry to have created the potential market for Dezhou and China's solar thermal industry (interview 1,4, 7,11,12,32). As Huang Ming stated in a television interview

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(Alibaba video, 2008):

> [In the 1990s], 99% of Chinese consumer had no idea about what solar energy is, not to mention what benefit could it bring to their family. When I started the business, the first thing was to develop the market. We did not think the conventional advertisements would be effective enough, so our first priority was to popularise the knowledge of solar energy. Our strategy then was to expand market through the popularisation of science and to build the firm brand through culture transmission. We popularised solar knowledge in Shandong, Jiangsu, Zhejiang, Fujian and Guangdong and so on. These efforts did promote China's solar energy market.

Himin is also one of the initiators of collectively installing SWH in China's urban project market. In 2000, Himin set up the first SWH collective installation project department in the industry, aiming to sell large-scale SWH to building projects such as hotels, hospitals, and schools. Himin started to explore SWH-building integration from 2001. It sought to cooperate with real estate developers to develop SWH-building projects but failed (interview 1,3). The chief reason was that estate developers had strict quality standards for SWH and they did not want to bear the risk of immature SWH products. In those days, estate developers were reluctant to install SWHs and lacked know-how about incorporating SWH into buildings. The building design institutes were also ignorant about SWH-building integration. Himin then decided to change the strategy by becoming an estate developer itself to build solar buildings. By this means, Himin changed itself from being solely the manufacturer of solar products to a solar building solution provider, aiming to promote the large-scale collective application of solar products. Therefore, Himin built some small-scale demonstration solar buildings and developed an estate project 'Weilai City' (literally means *future city*) as a model project to show how solar energy could be well integrated with residential buildings. This project became a model of green building and showed the possibility of solar-building integration. These endeavours propelled the Chinese urban SWH project market. The motivation for this initiative was well illustrated by an entrepreneur who formerly worked in Himin:

> When we communicated with building design institutes or estate developers, they knew very little about solar energy. Himin then decided to

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> demonstrate it itself by building some model projects. With the technology improvement, Himin believed the model projects were too small and there were many areas in buildings could be powered by solar energy. Huang Ming started to communicate with estate developers, but they thought SWH installation would spoiled building appearance and were reluctant to incorporate it. Here is why Huang Ming developed Weilai City project. For one thing, real estate was a high-profit market at the time. For another, he wanted to demonstrate the integration of solar energy and buildings [interviewee 12].

In addition, supported by Dezhou government, Himin built a huge 'Sun Valley' in the eastern suburb of the city, in order to experiment with clean-energy in household use and urban projects. Sun Valley brings together the world's leading technologies in solar heat utilisation and building energy conservation. Sun Valley attracts business and tourism from all over the world, demonstrating how the modern and future world can profit from solar energy.

(2) Technology spillover

The cooperation with Tsinghua University and the introduction of the Australian solar expert, Dr Qichu Zhang, played the critical role in Himin's technology development. External technology learning and substantial R&D investments made Himin one of the technology leaders in SWH industry. Many other solar firms started to emerge in Dezhou because of Himin, constituting a complete solar product value chain. Together with Himin's fast growth came an expanding market for related solar products and equipment. This created many opportunities for Dezhou's local entrepreneurs. A number of small firms were established as equipment providers for Himin in the early stage, but many of them became SWH producers as well because they have benefited from technology spillover from Himin. As one entrepreneur illustrated:

> Q (Question): Why did you enter this industry?
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> A (Answer): I entered this industry because of my family. They were making castings for Himin. At that time, Himin just started developing, we provided parts for it and grew stably.
>
> Q: What parts did you make?

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A: Water tank bracket, it is round and needs casting, cast iron, cast aluminium. This was what we did in my hometown, doing casting for Himin.

Q: Why Himin?

A: Because Himin was then the largest solar enterprise in China, it advertised a lot and the whole country was watching it. Though it was not as huge as today, it had already been the largest SWH firm in the country. As Himin grew, people all over the country came to Dezhou to learn from Himin. The market increased, but there were not many parts suppliers. We were geographically close to Himin, it was no surprise that customers came to us.

Q: From parts supplier to complete SWH manufacture, how did you step over the SWH technology threshold?

A: Learning.

Q: From whom?

A: From the industry leader, Himin. We were both in Dezhou, so close to each other. At the very start, we just imitated, copying Himin's design mechanically. Because SWH was a product of speciality, it didn't exist before. Under the circumstances, we could only imitate. We copied it and then we developed our own products [interviewee 4].

The technology spillover of SWH was much facilitated by the talent flow from Himin. In Dezhou, many solar firms' founders and employees, not only technical researchers but also managers and salespersons, had working experiences in Himin. This talent outflow from Himin increased the spin-off activities and enhanced technology and tacit knowledge spillover to other firms. The talent outflow from Himin was not only benefiting Dezhou but also China' SWH industry. Many large SWH firms' employees had worked in Himin before. It was more typical that many Himin's sales agents become SWH producers as well. As one interviewee in Beijing said:

I entered solar industry since 2000, but was not this company then, it was a sale agent of Himin. We sold SWH for Himin in Tianjin at that time. So did our company founder. She was working for Himin in 1999, then became an independent sale agent for Himin. Until 2005, she found this company in Beijing [interviewee 33].

Himin committed to moving up the value chain and providing high-end SWHs, which

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left much market room for small SWH firms in Dezhou (Li *et al.*, 2011). At the peak of Dezhou's SWH industry, there were more than 20 SWH manufacturers, all of which had some connections with Himin (interview 12). Many PV firms were also established with Himin's technology spillover, mainly through talent flow (interview 7). By this means, the solar industry grew quickly and played an increasingly significant role in Dezhou's economy. In 2010, the city was home to more than 120 enterprises engaging in solar-related industries, achieving more than RMB 50 billion sales revenue.

(3) Policy lobbying

As the industry expanded, its role in Dezhou's economy became increasingly pivotal. Being the leading firm in the industry, Himin exerted its policy influences at not only the local level, but also the provincial and national levels. Himin successfully lobbied the Dezhou government to integrate building the solar city as part of Dezhou's development vision and to implement favourable policies towards the industry, including the mandatory installation policy in 2008. In 2004, together with Dezhou Architect Design Institute, Himin developed and pushed the first design standard of SWH-building integration projects in Dezhou and Shandong province. Himin has also influenced landscape factors at the national level. In 2003, Huang Ming was elected a delegate to the NPC for its huge contribution to renewable energy. He was the main proposer of China's Renewable Energy Law, which came into force in 2006. Since then, China's solar thermal industry has enjoyed a favourable legal environment. In 2006, Huang Ming also promoted a '*new energy, new countryside*' proposal to suggest government push the application of renewable energies in rural areas. Himin also played an influential role in pushing for higher industry standards. Himin has more than 350 SWH standards, which is 7 times that of international standard. As the SWH market is seriously disturbed due to the lack of higher industry standards, Himin had held many press conferences to expose the 'hidden rule' of the industry, appealing to setting strict industry standards for the solar thermal industry.

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(4) City brand building

Though Himin is leading in China's solar thermal industry, the city it is based in was not well known nationally. For centuries, Dezhou has been only known for its braised chicken. With industrialisation, some industries grew prominently, such as sugar, central air-conditioning and traditional grain and oil. Respectively, the city was named China's Function Sugar City, China's Central Air-conditioner City and China's Grain and Oil City, but none of these had much national influence. The central air-conditioning industry, for example, was said to account for 80% of China's production (interview 5), but it was characterised by original equipment manufacturer (OEM) and small enterprises. It is also a heavy polluting industry. Indeed, some solar thermal firms, such as Zhongli and Vicot, were previously central air-conditioning manufacturers. They changed or expanded to solar business because they realised the unsustainability of the heavy polluting industry under a social discourse of green development on the one hand, and took advantage of Dezhou's new momentum as a solar city on the other hand (interview 5,8). Besides, there is much technology relatedness between air-conditioning industry and the solar thermal industry, making it easy for the air-conditioning manufacturers to cross the industry threshold.

Dezhou was a small city without much national renown. Himin's strategy was to build Dezhou as China's Solar City, driving Himin's development with Dezhou city brand. To build the solar city brand, Himin successfully lobbied the Dezhou government to make Solar City part of Dezhou's future development strategy and to implement favourable policies towards the solar industry. Building China's solar city then became a central part of the government agenda and was scheduled in the city's long-term planning. In 2005, Dezhou was designated as China's Solar City by three national industry associations, making it the only officially recognised solar city in China.

The Himin model developed a new path that achieves both economic and environmental aims simultaneously. It is based on Himin's influence that Dezhou won the reputation of

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China's solar city and hosted the International Solar City Congress in 2010, which greatly boosted Dezhou's city image to the world. Consequently, the local government had more enthusiasm to propagandise Dezhou's solar industry. As one interviewee said:

> In the past, people knew Dezhou because of braised chicken, but this product was a low-end product. There are many well-known chicken brands around the country, Dezhou braised chicken is not necessarily the best… Dezhou government want to promote Dezhou to the word, so they needed a recognised star enterprise. Eventually, they believed Himin could be the best city label of Dezhou because when many people came to visit Himin, they were surprised by Himin's solar demonstrations, like the solar hotel and green buildings. No other enterprises have invested that much as Himin in the solar demonstration. There are also many PV enterprises in the city, Dezhou government wanted to develop solar industry a leading industry, including solar thermal and PV. The government's expectation was that the leading enterprises Himin, together with those supporting solar enterprises, would make a difference to Dezhou [interviewee 12].

The green city image forms a positive feedback loop within the city, but at the core of this loop is Himin. As one interviewee from solar thermal industry put it:

> Visitors from all around the world come to Dezhou mainly for Himin, but when they are here, they find there are many more solar enterprises other than Himin providing different advanced technology and products. When the visitors saw our firm's products, they were surprised...Himin did play an important role [in building the city brand], it attracts a lot of attentions to Dezhou, and we benefit from this [interviewee 8].

5.2.4.2 Supportive government

An obvious attitude change toward the SWH industry was observed in Dezhou municipal government from the mid-1990s. As mentioned, market demand was the main driving force of China's SWH industry in its early stage and Dezhou was no exception. At the beginning, the industry was so small that not much attention was paid to it. As the industry grew, it brought Dezhou not only growing GDP and employment, but also both a national and international green reputation because it caters to global concern over climate change. At this point, the municipal government decided to develop the industry into a key sector for local development.

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Dezhou government promoted the solar industrial cluster through supporting leading enterprises and extending solar industrial value chains. In the 1990s, Himin was the only solar enterprise in Dezhou and its products were merely confined to vacuum tubes and SWH. The municipal government assigned a large expanse of land to Himin and provided considerable policy and financial support. Meanwhile, Dezhou highlighted the role of enterprises in independent innovation and facilitated their cooperation with universities and research institutes.

Based on the fast-growing solar industry, Dezhou municipal government put forward the *Solar City Strategy* in 2005, deciding to promote solar energy as Dezhou's leading new industry and to build Dezhou as the solar city of China and even the world. To build a solar city, the municipal government and county-level governments together provided more than RMB 80 million for the demonstration projects of solar energy every year. By 2012, Dezhou's investment in solar projects had reached RMB 14.85 billion (Cheng, 2013). Meanwhile, a solar city strategy committee was established to promote and implement the solar city strategy. The committee is led by the principal leaders of the municipal government and consists of a number of functional departments. Experts from universities and industries formed an advisory committee, offering consultancy services to the development of Dezhou's solar industry and are responsible for the research and proof of large construction projects. The solar city strategy committee successively issued policy documents which encouraged and normalised the technology research, industry development, and application of solar energy. Although the Solar City Strategy Committee was rather an empty body in its early years, it has gained more influence in recent years as the industry plays a more significant role in the government's agenda. Dezhou is the only city in China that has such a specialised institution to promote the development of solar energy. In 2008, Dezhou's Solar City Office was established in the Dezhou's Bureau of Housing and Urban, specifically for organising the International Solar City Congress in 2010 (interview 6,11). After the congress, the solar city office

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remained to promote the application of solar energy in Dezhou and to help solar enterprises extend new technologies with demonstration projects. In 2009, Dezhou was awarded the National New Energy Demonstration City and received RMB 60 million to subsidise more than 60 demonstration projects. In 2009, Dezhou's *Low Carbon Dezhou Plan* incorporated low carbon economy aims into its urban economic development plan. Further policy packages, such as technology innovation and land use privileges, were developed to encourage the solar sector. As a government official put it:

> …enterprises need land for further development, but the municipal government was strict in approving the land use. The government supports solar industry, so when they apply for new projects in new development zones, their projects were regarded as key projects, and their demand for land use was prioritised. For example, the land we assigned to Himin is quite large and those for Vicot, Zhongli, and Hangneng, are not small either [interviewee 17].

On the utilisation side, lots of endeavours have been made by Dezhou government to promote the popularisation and application of solar thermal energy. Dezhou is among the first group of cities that officially encourage SWH-building integration by issuing the *Notice on the comprehensive application of SWH in construction projects* in 2005. In 2006, together with Shandong's Department of Construction, Dezhou created China's first standard schematic handbook of the integration of building and solar energy (interview 11). In 2008, the municipal government enacted the *Notice on speeding up the application of solar energy* (or mandatory installation policy), explicitly requiring new construction projects to integrate SWH in design and construction. The integration of solar energy became a precondition for the approval of building new residential estates. The projects that do not comply with the requirement will not be given permission for construction or completion inspection. Conversely, those projects that are in accordance with the requirement will enjoy some privileges, such as priority in land use, a simplified approval process and mitigation in building urban supporting facilities. In 2009, Dezhou government authorised the China Academy of Building Research to develop the *Dezhou Renewable Energy Application in Construction Special Planning*, which clearly stated

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the long-term objectives of the application of renewable energy in construction.

In addition, in order to encourage dispersed rural residents to install SWH, Dezhou government subsidised every SWH purchased by rural residents. In the early stage, when public bathrooms were the main place where rural residents bathe, the government financially helped rural residents build public solar bathrooms. The government also hosts many solar cultural events, such as International Solar Expo and Solar Thanksgiving Day, to enhance communication with other countries and mobilise citizen's enthusiasm in solar energy. In particular, the International Solar City Congress in 2010 was deemed a key event in Dezhou's development, and it successfully boosts Dezhou's international recognition.

5.2.4.3 Networked residents

The story would not have been complete without the driving force from the demand side. There was a wide acceptance of SWH among local residents in Dezhou. Before the popularisation of home-use water heaters, residents in northern China generally bathed less often than in southern China due to geographical conditions (dry climate and water scarce) and cultural traditions (interview 1,4,6,10). In those days, the majority of people in northern China, especially in less developed regions, only occasionally bathed in public bathrooms, which they had to pay to go in. The situation was no difference in Dezhou, as a typical northern city. Though EWH and GWH came before SWH, they were not well popularised because they were deemed as a kind of luxury lifestyle which most residents were not able to afford. Nonetheless, the presence of home-use water heaters introduced residents to a more modernised bathing fashion. This demand was met by the less costly SWH. Though the initial cost of SWH is generally higher than EWH or GWH, it hardly involves any further energy cost in use. In the early 1990s, the earliest adopters of Himin's SWH were the relatives of the entrepreneurs and residents with higher education levels, such as teachers and doctors, which led to a demonstration effect for other residents. As SWH technology matured, an increasing number of residents chose to install SWH on

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their roofs because it saves on their energy bill. According to the survey by Li *et al.*, (2011) in Dezhou, the average payback period of an SWH for a typical three-person household is 8.3 years, allowing for 4 years free use of its designed life expectancy. Indeed, there were many people who chose to install SWH out of environmental awareness, but the majority of people accepted SWH because of the high price-performance ratio of SWH. As an entrepreneur put it:

> Ordinary people do not have much environmental concern though the central government is advertising hard in energy saving and emission mitigation. Ordinary people do not care about this, they think it is far away from their life and it is government's responsibility to address it. What they care is that SWH can guarantee their bathing needs and save on energy bill…Ordinary people just need tangible benefits, rather than high-profile slogan [interviewee 4].

Although compared to EWH and GWH, most SWH were not able to work effectively in winter, local residents view SWH as convenient, economical and safe products. As people bathe much less often in winter, the ineffectiveness of SWH in winter is acceptable, considering its economical merits. This bathing habit is being changed by SWH as it popularises and it improves residents living condition in many ways. As an interviewee said:

> In the past, in order to save coal or gas in winter, people use cold water to wash face. Children cried when they had to wash their face because the water was so freezing. Now, there are not many public bathing rooms, because every family has their own SWH. When they do laundry or wash dishes, they can also use the hot water from SWH, at least, it cost almost nothing to use. SWH does improve people's living quality [interviewee 1].

Besides the economic rationale of individual households, the close interpersonal networks among local residents in Dezhou are also an indispensable part of the diffusion. Interpersonal networks are able effectively to form and change attitudes towards new innovations and thus influence an individual's decision to adopt or reject the innovation (Rogers, 2003). Verbal communication and social learning by observation frequently happen in strong interpersonal networks, especially where models of positive outcome encourage adoption by recipients and observers. Fei (1992) argued that close

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interpersonal network or ‘guanxi’ is a distinct characteristic of China’s rural society. This characteristic may decrease but is still evident in small transition cities when compared to large developed cities in China. Dezhou has transitioned from being a small agricultural city in which close kinship and neighbourhood relations remain an obvious characteristic, thus the verbal communication and social learning of SWH acceptance diffuse quickly among acquaintances. As mentioned, the first group of SWH consumers in Dezhou were Huang Ming’s relatives, who bought SWH just to do Huang Ming a favour, but turned out to find the products useful and convenient, and the merits of SWH were proliferated among neighbourhoods (interviewee 3). After being known as China’s solar city, local residents are proud of being designated as a solar city and are more willing to accept solar products.

Peer comparisons often happen in acquaintance neighbourhoods and thus also contribute to the SWH diffusion. The culture of ‘face’ is not unique in Dezhou, rather, it is common in China’s acquaintance society, especially in rural areas. The desire of not lagging behind acquaintances is believed to be an important factor that drove the diffusion of many household appliances in China, such as TVs, refrigerators and telephones. The same social psychology applies to the diffusion of SWH in Dezhou and in many less developed regions of China. As an entrepreneur said:

> To be honest, many people choose to buy SWH because of comparison and following. For example, in a village with one or two hundred households, as long as one of them installs SWH, the rest of the community will follow. It just likes a single spark starting a prairie fire. As a result, whoever hasn’t had SWH on his rooftop feels losing face to the neighbourhood. The effectiveness of SWH is merely one side, the other side is whether this product satisfies people’s social vanity… [interviewee 4].

In such an acquaintance society, the interpersonal network exists not only within consumers but also between consumers and producers, as well as within producers. As many acquaintances worked in the SWH industry, mutual trust between producers and consumers has been enhanced for the products to facilitate diffusion. Furthermore, many

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of Dezhou's SWH firms were established or spun-off with help from relatives and friends who were already operating businesses in the industry. The personal network had played an important role in the diffusion of the market and the formation of Dezhou's solar industry cluster.

5.2.4.4 Forced installation by estate developers

New residential buildings are springing up as a consequence of Dezhou's rapid urbanisation, and real estate developers gain considerable power to decide whether to install SWH on their buildings. At the early stage of SWH development in Dezhou, individual households made decisions to adopt SWH or not, and estate developers did not pay much attention to this. The SWH retail market developed rapidly, with an increasing number of SWH installed on Dezhou's residential buildings. But due to the lack of installation standards, individual SWH installations often damaged building structures and appearances, and thus, some real estate developers began to take measures out of concern for building safety by installing SWH collectively to standardise SWH installations.

The collective installation of SWH was first adopted by some public institutions that built accommodation for their own employees. The first SWH-building integration project in Dezhou was a housing estate for civil servants. It was an experimental project, led by municipal government and designed by Dezhou Architect Design and Planning Institution (interview 22). This SWH-building integration design then spread to estate developers, who began to see the growing SWH market as a business opportunity and after 2003, began to install SWH collectively as a sales strategy to attract consumers to buy their developments. Some developers gave installed SWH to their customers as a privilege, others sold SWH collectively together with their developments at a discounted price.

Many developers, however, viewed SWH installation as a burden because it increased their building costs. The complexity of SWH installation and the unreliability of early

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SWH also added to their concerns. After the implementation of the mandatory installation policy, although real estate developers were forced to install SWH by government regulations, their SWH installation was also a response to growing market demand. At first, when the supervision of the mandatory policy was not in place, some estate developers did not install SWH as required, but this was gradually changed by market forces as not having installed SWH was seen as reducing their competitive advantage. As one interviewee stated:

> For estate developers, installing SWH not only comply with government's regulation, but also respond to market demand as a selling point to attract consumers to buy their developments. If you don't have installed SWH, but other developers have, you may lose the competition. That's the market force. Some developers may concern about the increase of cost from SWH installing, but actually, the cost will be transferred to customers who finally purchase the houses [interviewee 22].

In the early years, Dezhou government merely encouraged SWH-building integration in low-rise buildings under 12 stories. After 2008, the government required all new residential buildings to incorporate solar water systems in design and construction. The supervision of SWH-building integration was becoming stricter as well. Both design institutions and construction enterprises have to deal with specialised inspection for SWH incorporation (interviewee 22). By the end of 2014, the SWH-building integration projects represented 95% of Decheng's new buildings, and 50% of Dezhou's urban residential estates (Dezhou Government, 2014). The installed capacity of SWH in Decheng has reached 0.6 million m^2, saving standard coal amounts of 100,000 tonnes.

Furthermore, some SWH firms were founded by estate developers who saw the SWH-building integration as a potential business (interview 12). Though to some extent forced to do so, the growing real estate industry has been an indispensable part of Dezhou's SWH diffusion (Figure 5.5).

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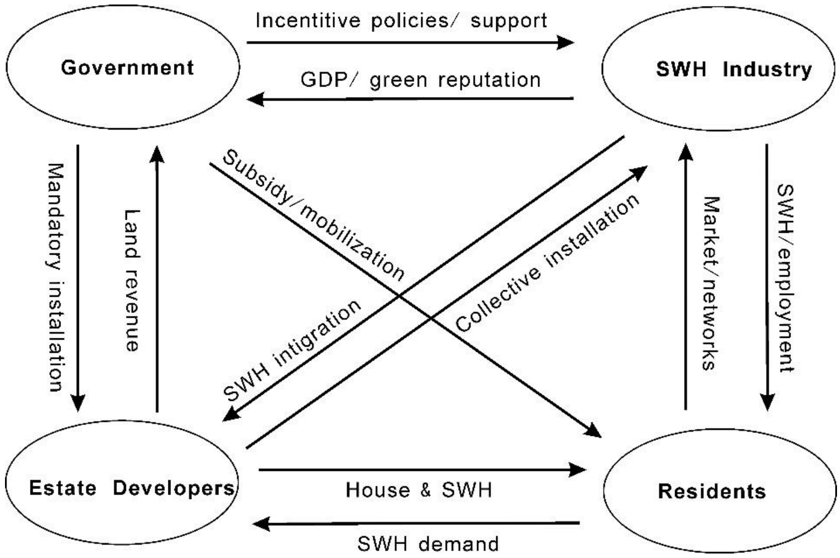

Figure 5.5 Main actors in Dezhou's SWH diffusion

5.2.4.5 Summary

Indeed, Dezhou's SWH industry is also confronted with the similar problems illustrated in Chapter 4. With a few exceptions (e.g. Himin and Vicot), the majority of the SWH firms are weak in technology innovation. In addition, there are also many real estate developers who tend to install low-quality SWH systems, which damages the image of the SWH industry. As residents become richer, their choice in favour of SWH is also challenged by its alternatives. Nonetheless, what makes Dezhou a leading city in SWH diffusion so far is the unique positive feedback loop among main actors covering both the supply side and demand side, as well as the supportive government. This positive feedback loop started with Himin's entrepreneurial role. It encouraged Dezhou and China's SWH market by popularising solar energy knowledge. Together with the economic savings for consumers, this provided a rapidly growing market for Dezhou's SWH industry. The close interpersonal networks within the city also contributed to the emergence of the industry and SWH diffusion. Through Himin's leading role and technology spillover in many ways, Dezhou's SWH industry started to emerge and grew to be a critical part of Dezhou's economic development and employment. Moreover, Dezhou was nationally and internationally recognised because the green industry catered to global concerns about climate change and green economy. Dezhou's government

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decided to support SWH industry as the city's leading industry by providing subsidies, tax preferences and a mandatory installation policy, requiring estate developers to incorporate SWH into new buildings. Estate developers have installed SWH partly in response to government regulations, but more importantly to remain competitive as SWH has been regarded as an indispensable part of houses by most local residents. The large scale SWH-building integration further enhanced Dezhou's international reputation as a solar city.

5.3 Beijing-- a less successful story

5.3.1 Context

Beijing is one of the most developed cities in China. In 2013, Beijing's GDP per capita had reached $ 15051. The Engel Coefficient of urban and rural residents have declined to 30.8% and 34.7% respectively (Beijing Statistics Bureau, 2014). According to World Bank standards, Beijing is recognised as a middle-income city. If measured by the UN Food and Agriculture Organization's standard, Beijing has become a wealthy city. Moreover, Beijing is the science, education, transportation and political centre of China. Beijing is home to the largest number (89) of higher education institutes in China, among which are many top universities, such as Peking University and Tsinghua University. The city also has a very high density of research institutes (380 in 2013). The concentration of universities and research institutes enables Beijing to be one of the most innovative cities in China, with the highest quantity of granted patents (74661 in 2014). The employed population engaged in scientific and technological activities is more than 720 thousand. In 2011, the output of high-tech industry accounted for 18% of Beijing's GDP.

5.3.1.1 Industrialisation

Since China's Reforming and Opening, Beijing's industry structure has experienced three phases of change (Beijing Statistics Bureau, 2015) (Figure 5.6). Before the middle 1990s, Beijing's economy was dominated by heavy industry, including steel, petrochemical and

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automobile industries etc. In 1983, '*Beijing Urban Construction Planning*' stated that Beijing's industry strategy was to develop the high-tech and technology-intensive industry. Though the plan also suggested not developing any more heavy industry, it still witnessed fast growth and dominated Beijing's economy. In 1993, China's state council approved *Beijing Master Planning (1991-2010),* which aimed to build Beijing into a service sector-oriented city. By 1995, the tertiary industry had reached 50% of Beijing's economy, rising from 23.7% in 1978. The next phase witnessed the further upgrading of Beijing's industry structure. In 1997, Beijing's municipal government carried out the *Capital Economy* strategy to transform from a manufacturing economy to a service economy. The subsequent Beijing's 10^{th} FYP and 11^{th} FYP further proposed to develop a 'scientific, service, cultural and open' capital economy with high-end and high value-added industries. By 2006, Beijing's service sector had accounted for 70% of Beijing's economy. With many state-owned financial enterprises located in the city, the financial industry grew to be the largest service industry in Beijing, followed by information services, real estate, wholesale and retail, and the transportation industry. Meanwhile, the share of the manufacturing sector had declined to less than 30%, but it had upgraded to modern manufacturing. Electronics became the largest manufacturing industry and the automobile industry grew quickly. After 2008, confronted with increasingly severe environmental problems and the global financial crisis, Beijing's priority was to improve the quality and efficiency of industrialisation by gradually transforming each industry towards high-end ones. Commercial service and science-technology service industries became a major part of Beijing's service sector, besides finance, retail, information service and real estate industries. In the manufacturing sector, the biomedical industry developed rapidly. In 2012, biomedical, electricity, automobile, electronics and equipment industries together accounted for 60% of Beijing's manufacturing output. Recently, the cultural and creative industry has grown quickly to be a major industry in Beijing's economy.

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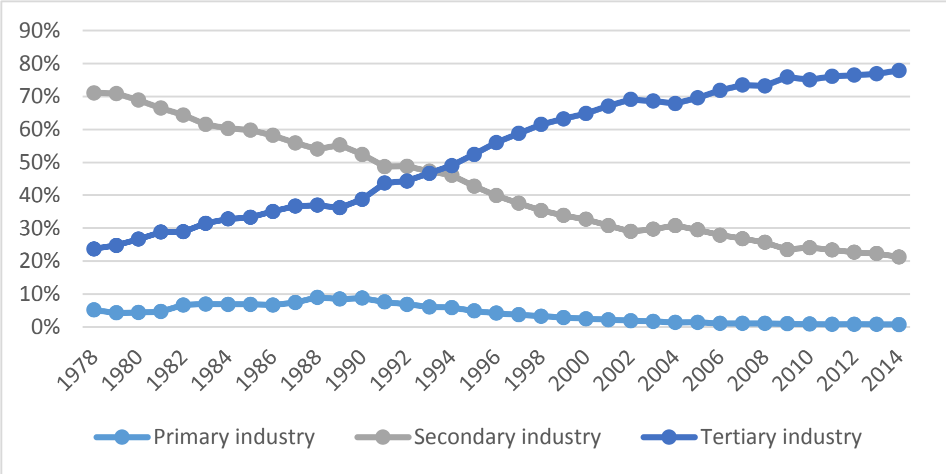

Figure 5.6 Changes in Beijing's industry structure (1978-2014)

Source: Beijing Statistics Bureau, 2015.

5.3.1.2 Urbanisation

Beijing is one of the most urbanised cities in China. In 1978, the population of Beijing was 8.72 million, and its urbanisation had reached 55%, higher than the current level of Dezhou in 2014. Since then, the city's population has grown significantly at an average rate of 2.5%, reaching 21.5 million in 2014 and 86.3% of the population live in its urban areas (Figure 5.7). Spatially, the population is highly concentrated in central Beijing, especially within its Sixth Ring Road[14]. Accompanying this population booming is the fast expansion of urban built areas. From 2000 to 2010, Beijing's urban built area sprawled at the rate of 109 km^2 per year, reaching 2348 km^2 in 2010 (Figure 5.8) (Xie *et al.*, 2015). This is contributed by both the expansion of the central city and satellite towns such as Changping, Shunyi, Fangshan, and Daxing. This process is a typical process of China's land urbanisation, in which vast amounts of farm land are converted to urban built land for housing, transportation, and factories.

[14] Beijing is a city of multiple ring roads, from 1st ring road to 6th ring road, and the 7th ring road is under planning. The 6th Ring Road was built in the 2000s and at present is the most remote ring road from central Beijing (around 15–20 km).

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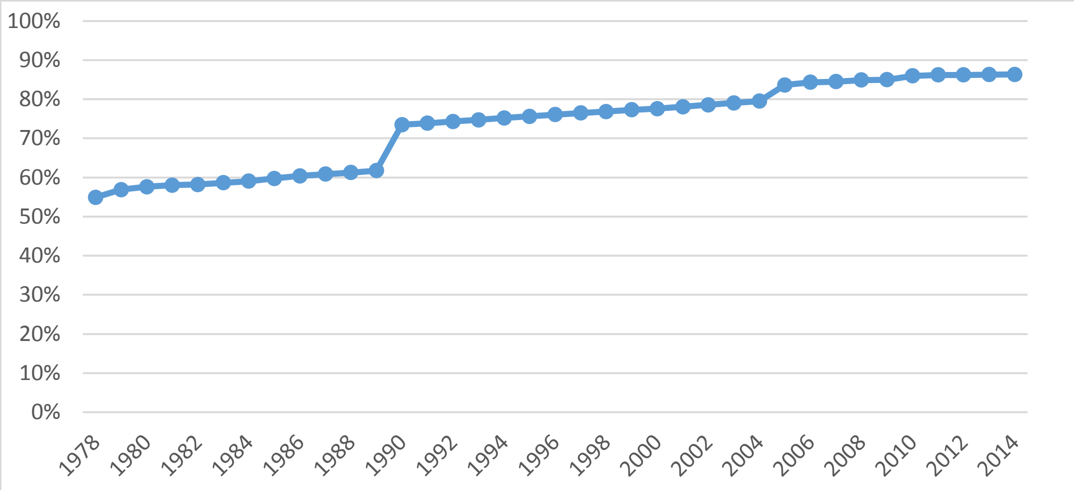

Figure 5.7 Urbanisation rate of Beijing (1978-2014)

Source: Beijing Statistics Bureau, 2015.

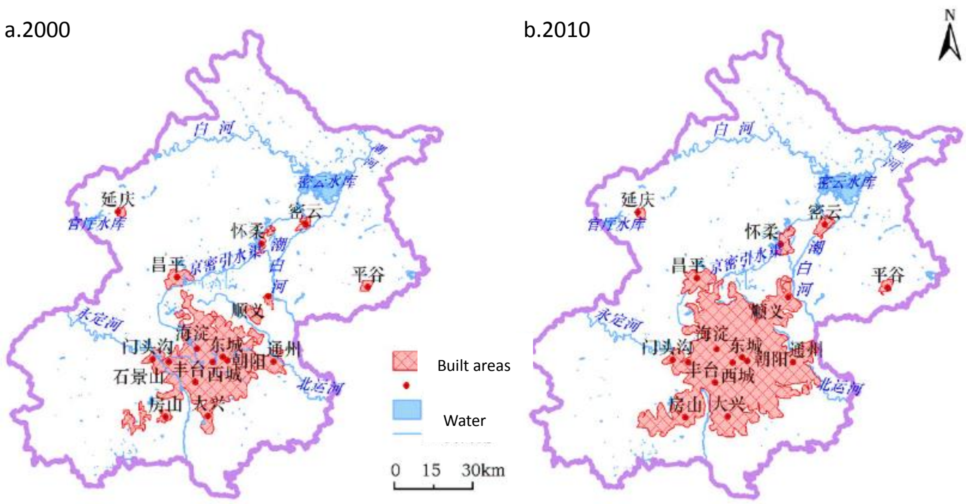

Figure 5.8 Morphological changes of urban space in Beijing (2000-2010)

Source: adapted from Xie et al.,(2015).

5.3.1.3 Environmental problems

Accompanied by fast urbanisation, Beijing is confronted with serious environmental problems and resource challenges. Like other big cities in China, Beijing has the common urban problems such as traffic congestion, water contamination, air pollution and waste pollution, but the biggest environmental problem in recent years is air pollution. Beijing

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was once listed as one of the top ten polluted cities in the world. It has been recognised that Beijing's air pollution is not simply contributed by the city itself, but is rather a regional problem in Bohai Rim, which includes Beijing, Tianjin and most of the territory of Hebei, Shandong, and Liaoning province. A high proportion of China's heavy industry is concentrated in this region. The geographical conditions of the region further aggravate the pollution by preventing winds from blowing away haze in winter.

In order to solve air pollution in Beijing, the region is required by central government to improve its industrial structure. For instance, a large number of steel factories and coal-fired power plants have been shut down in Hebei province. Regarding Beijing itself, it has taken many measures to tackle these problems, such as upgrading its industrial structure and relocating heavy industries. One typical example is the relocation of Capital Steel in 2005, which directly contributed to a huge decrease in carbon emissions in Beijing that year. In particular, the 2008 Beijing Olympic Games was a strong push for the city to improve its environment as well as residents' environmental awareness. Nonetheless, air pollution remains a huge problem and even becomes worse, especially in the winters.

Besides industrial emissions, coal consumption for heating in suburban Beijing and nearby Hebei province also causes substantial amounts of toxic gases. After the 2008 Beijing Olympics, pollution from manufacturing industry has been controlled and the major toxic gas emissions then come from the transportation sector and residents' heating, both of which have been largely driven by the booming population and fast urbanisation. In the 1990s and early 2000s, Beijing's municipal heating infrastructure construction failed to keep pace with the population flooding into the city. The heating infrastructure was not able to expand as fast as residential areas, and a huge number of migrants poured into the city's poor built areas, 'urban villages' for instance. Consequently, they did not have access to the municipal heating network and, instead, a vast number of dispersed small coal furnaces were used for heating in winter. This not only brought with it many

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gas poisoning accidents, but also became one of the primary sources of Beijing's air pollution. According to Zhang *et al.*, (2006), Beijing's SO_2 emissions in the heating season (from November to March) was 5.66 times as much as in non-heating seasons. It's reported that heating from unclean energy sources represented 64% of Beijing's heating in 2000 (Caixinenergy, 2015). Until 2010, there were still 3843 small coal-fired boilers.

5.3.1.4 Renewable energy development

In 1990, the share of coal in Beijing's energy consumption was about 65%. After years' efforts of reducing coal consumption, coal remained around 20% of Beijing's energy mix in 2013(Beijing Statistics Bureau, 2014). In 2013, Beijing's municipal government enacted the '*Beijing Clean Air Action Plan (2013-2017)*' to further transform its energy mix. According to the plan, coal-fired power generation will step out of Beijing's history by 2017, and many state-owned coal plants are being shut down. On the contrary, the use of cleaner energy such as gas, electricity, and renewable energies have seen an impressive increase.

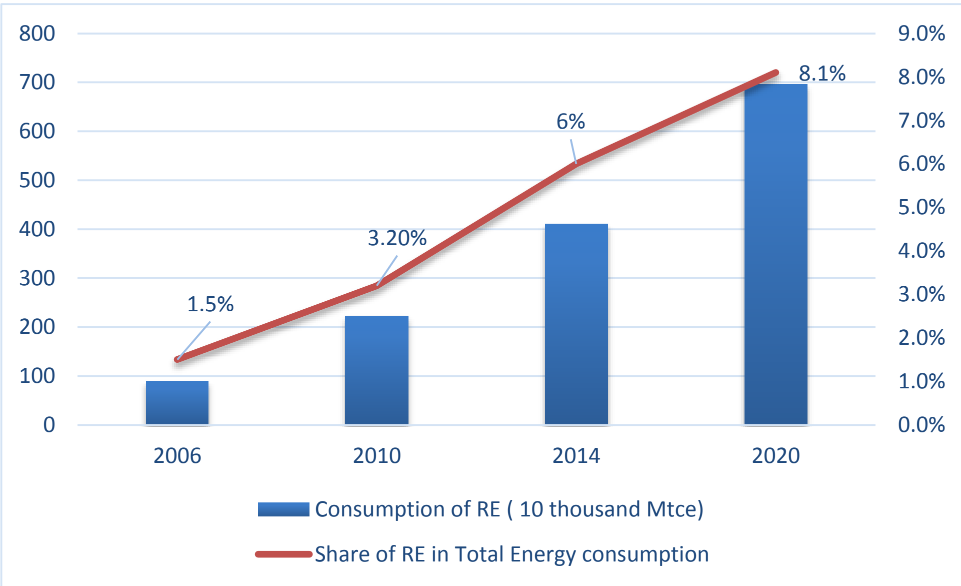

Figure 5.9 The development of Beijing's renewable energy (2006-2014) and target in 2020

Source: Beijing's Statistical Bureau and Beijing's 13 FYP of renewable energy development.

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Taking advantage of the 2008 Beijing Olympics, the 11th FYP period (2006-2010) witnessed the emergence of renewable energy applications in Beijing. The total application grew at an average rate of 30.1% from 2005 to 2010, increasing the share of renewable energy in total energy consumption to 3.2% (Figure 5.9). Meanwhile, the GDP output of Beijing's renewable industry reached RMB 40 billion in 2010. The fast growth was contributed by many newly built renewable energy demonstration projects in solar, geothermal, biomass, wind and hydro power. Beijing enjoys abundant resources in solar and geothermal energy, and the substantial amount of urban waste generated can be turned into biomass energy. These three constitutes the largest part of Beijing's renewable energy application, in which solar energy plays a dominant role (Table 5.1), accounting for more than 60%. In terms of utilisation form, the share of renewable energies for electricity generation and thermal use was 17.8% and 73.4% respectively in 2011. Thermal use, including solar thermal and geothermal, is the primary form of renewable energy utilisation in Beijing. Particularly, solar thermal (including SWH and solar greenhouse) represented 62.4% of Beijing's renewable energy use in utilisation. From a spatial perspective, the application of renewable energies is primarily concentrated in Beijing's suburban and rural areas. In 2011, suburban areas accounted for 80% of renewable energy use in Beijing. Though it grew quickly, the use of renewable energy in the urban area[15] was only around 20%.

Table 5.1 Use of Renewable energy in Beijing (10 thousand Mtce)

Year	2010		2011	
	Energy use	Share	Energy use	Share
Solar	145.8	62.4%	158.4	61.6%
Biomass	43	18.4%	45.7	17.8%
Geothermal	23.6	10.1%	30.9	12.0%
Wind	8.3	3.6%	8.8	3.4%
Hydro	13.1	5.6%	13.3	5.2%
Total	232.6	100.0%	257.1	100.0%

Source: Beijing Statistics Bureau, 2012.

15 Beijing's urban area contains 6 districts and development zones: Dongcheng, Xicheng, Chaoyang, Fengtai, Shijingshan, Haidian; the suburban area refer to 10 districts and counties: Mengtougou, Fangshan, Tongzhou, Shunyi, Changping, Daxing, Huairou, Pinggu, Miyun and Yanqing.

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Heating and air-conditioning consume two-thirds of China's building energy consumption. Beijing's early built buildings lack energy saving standards, resulting in high energy consumption. Renewable energies are expected to contribute to new buildings' energy saving. As mentioned, solar energy is the major part of Beijing's renewable energy consumption. Beijing's geographical location is rich in solar radiation, with sunshine hours between 2600 and 3000 per year, and 5400～6700 MJ / m^2 of solar radiation per year. Beijing's 11th FYP of Energy Development (2006-2010) had begun to push the application of solar buildings and SWH. It aimed to use renewable energies to cover 6% of the city's heating area. Beijing's 12th FYP of Renewable Energy Development aimed to increase the share of renewable energy in total energy consumption to 6%, which was realised in 2014 (Century New Energy, 2015). This was largely attributed to incentive policies for both PV and solar thermal industry. Since 2009, Beijing has enacted the '*Beijing's guiding opinions on speeding up the application of solar energy and industry development*' to provide subsidies of RMB 1 per Kw/h to the on-grid PV projects. Meanwhile, projects like '*Golden Solar*' and '*Solar campus*' were initiated to extend PV installation. Haidian and Shunyi were planned to be national PV demonstration districts. These efforts greatly increased the PV installed capacity, from less than 3 MW in 2010 to 160 MW in 2014. As to solar thermal utilisation, Beijing's Urban and Rural Housing committee implemented '*Beijing's regulations on the application of solar water system in urban and rural buildings*' (2012) and '*Beijing's regulation on civil energy efficient buildings*', both requiring installation of SWH in new residential buildings. By 2014, the application of solar energy has come to 1833 thousand tce.

5.3.2 Development in solar thermal energy

Beijing is the birthplace of China's solar thermal industry. Beijing's solar thermal cluster is not large in terms of firm numbers (150 in 2010), but it is characterised by strong capacity in research and development. In particular, Beijing Solar Energy Research Institute and Tsinghua University have played the critical role in the development of

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China’s flat-plate and evacuated tube collector technology. Beijing’s SWH industry grew with an increasing number of SWH firms being established due to this technology advantage, but there are also many firms established in Beijing to utilise Beijing’s ‘city brand’ to promote marketing (interview 33,34). Regarding application, most of the solar thermal energy application only occurs in Beijing’s suburban area, while the much more populated urban area is a harsh environment for SWH diffusion.

5.3.2.1 Technology centre of China’s SWH industry

Beijing’s SWH industry shows a distinct orientation in technology innovation. The beginning of Beijing’s solar thermal research was in response to the global energy crisis in the 1970s. Research in solar thermal energy was initiated on the grounds of perceived energy security aims instead of market demand. The high concentration of national research institutes and universities, as well as national support, enabled Beijing to be the centre of China’s solar thermal technology. As mentioned, Beijing Solar Energy Research Institute and Tsinghua University had become the technology leaders respectively in the flat-plate and evacuated tube collectors. Other research institutes have also contributed much to technology development. For example, China’s first solar thermal air-conditioning project was conducted by China’s Academy of Architects in 1970s (interviewee 28). Solar thermal technology remained in laboratories until 1985, when Beijing’s first private SWH firm, Jiuyang, was established. Though the technology of Jiuyang was rather primitive then, it indicated the beginning of knowledge spillovers from public research institutes into private sectors. As the founder of Jiuyang illustrated his entrepreneurship:

> At that time, I was very close to Beijing Solar Energy Research Institute, it was not far from my place, I went there to visit… I just used two combined flat plate collectors and one gasoline can, then it worked. It was convenient, my neighbours all came to my house for bathing. I thought this was a good thing, it helped solve the hygienic problem in rural areas. Then, I started the business in solar bathing [interviewee 30].

A similar entrepreneurial process happened to Tianpu, which was built in 1989 and then

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became Beijing's largest SWH firm for a long period of time. Its founder was previously a worker in Shandong province, where he found market demand for economic hot water bathing. He then resorted to Beijing Solar Energy Research Institute and created his business in Beijing, because of Beijing's technology and talent advantage (interviewee 31). Some spin-off SWH firms from Tianpu had developed a small cluster in south-west Beijing. Many other private SWH firms emerged in Beijing thanks to this knowledge spillover.

After evacuated tube solar collector technology matured in the 1990s, Tsinghua University and its spin-off firm, Tsinghua Solar, became the primary contributors of SWH technology spillovers not only to Beijing, but also other regions around the country. Particularly, the training workshop held by Tsinghua University in 1991 was said to be the 'Huangpu Military Academy'[16] of China's SWH industry, because it cultivated many influential entrepreneurs in China's SWH industry, such as the establisher of Himin, Huayang, and Linuo.

> After the products came out, we had a frustrating problem, that is, not many people knew our products. Why should they buy evacuated tubes, and for what use? It's seldom known to the market. After 1989, there was an open political environment and people were encouraged to go into businesses. We then initiated the training workshop… we trained them how to use evacuated tubes to make SWHs, and how to make water tanks and supporting frames. We provided the technology and evacuated tubes and encouraged them to mobilise resources to manufacture SWH… These 18 entrepreneurs [trained in the workshop] made great efforts in market promotion, enlightening China's solar energy market [interviewee 35].

At the beginning, many evacuated tube SWH manufacturers only were only expected to produce supporting equipment for SWH, and the core technology of evacuated tubes was monopolised by a few enterprises. But this monopoly was soon broken as other SWH

[16] Huangpu Military Academy, was one of most famous military academies in China's modern history. It was built by Kuomintang (KMT) in 1924, in Huangpu district of Guagnzhou, aiming to cultivate military officers for national revolution. A lot of famous military commanders during the Anti-Japanese War (1937-1945) and the Civil war (1945-1949) were trained in this academy. Today, it is a common metaphor to those institutes that have cultivated many influential persons in an area.

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firms caught up with the core technology. This catching up was attributed to the technology spillovers from leading firms, through talent mobility, property right trading, technology cooperation, and imitations. Though unintentionally, weak patent protection at that time is believed to have facilitated the technology learning. As an informant from Tsinghua Solar said:

> The key equipment in producing the absorption films was a combined effort from several institutes. The equipment was therefore not owned by one particular institute but was shared by several institutes. Some of them sold the equipment to others…since others were selling it, so were we. We did not have much idea about patent protection in those days. We had patents, but no idea about protection. People came to buy it, we just sold it…[interviewee 35]

After the initial development of evacuated tubes technology, there have not been many radical innovations in SWH industry, but incremental improvements in efficiency. As SWH firms in other regions (e.g. Shandong and Jiangsu) catch up, Beijing's SWH industry no longer seems to have absolute technology advantages over them. Nonetheless, Beijing remains the most crucial technology centre of China's solar thermal industry, due to its dominant position in aggregating top talents and leading information. As one interviewee put it:

> Beijing is an international city, the technology information here is always the first hand, you could easily have access to large amounts of first-hand information, such as large exhibitions and exchange forums, which are very helpful to your product promotion and technology innovation [interviewee 33].

At the same time, many Beijing SWH firms have relocated their manufacturing factories to other regions, especially the neighbouring Hebei province, where the cost of land and labour is much lower than Beijing. OEM is also increasingly adopted by Beijing's SWH firms to lower manufacturing costs. Indeed, there are many SWH firms that are registered in Beijing, but manufacture in another place, so that they could enjoy Beijing's city brand to promote their marketing, meanwhile, keeping the manufacturing cost lower (interviewee 34). To a similar end, most of the SWH manufacturing in Beijing locate in

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suburban areas, such as Daxing, Miyun, Huairou, and Mentougou.

5.3.2.2 Solar thermal application

Much of the application occurs in Beijing's suburban areas. In suburban towns, the installation rate of SWH was about 30%, while in rural areas, the figure reached 85% in 2009. For instance, Beijing's Pinggu District has the highest installation rate of solar thermal heating in China after its '*Building New Socialist Countryside*' project. Pinggu is located in northeast Beijing, with a population of 0.42 million. About half of the population lives in rural areas. It is an agricultural district with abundant ecological resources. Pinggu was most famous for its peach production and was awarded the Guinness Record as the world's largest peach production area. In 2004, the newly appointed CPC Secretary of Pinggu District initiated the new rural construction pilot projects in Pinggu. Four villages were chosen as pilot villages to develop rural folk tourism. That is, attracting urban residents to these villages to experience rural life and sightseeing. In order to achieve this, Pinggu government provided loans for rural residents to build new houses under collective planning. Renewable energies were applied in this process to realise the ecological theme of new rural construction. The newly built two-floor houses incorporated solar heating/ water systems in their construction. The installation of solar heating/ water systems was supported by the district government with RMB 15,000 of subsidy for each installation. By 2011, 305 households in the four pilot villages had installed more than 6000 m^2 of solar collectors. The systems provide not only hot water in warm seasons, but also heating in winter with the aid of other energy sources. Compared to conventional energy sources, solar heating/ water systems save 85% of energy for hot water and 65% in heating (Pinggu Government, 2011).

These, however, at their best, only cover a very small portion of Beijing's population, since the majority of the population is concentrated in the urban areas. Despite the long history and technology advantage, the overall application of SWH in Beijing's urban area has much lagged behind. In its urban area, the installation rate of SWH was less than 7%

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in 2009, compared to its counterpart in Dezhou with more than 75%. By contrast, EWHs and GWHs are more popular in Beijing's urban areas. Beijing is one of the most urbanised and developed cities in China, but it has been a harsh selection environment for SWH diffusion. The following section summarises the factors that obstruct the diffusion of solar thermal energy in Beijing.

5.3.3 Obstructing factors of SWH diffusion

5.3.3.1 Building infrastructure

> … Beijing is full of high-rise buildings. As the population grows quickly, high buildings spring up. The higher a building is then the less space on the roof for SWH installation…Many people now know SWH and are able to appreciate its economic rationality, but whether they finally purchase one depends on the suitability of their house structures. They cannot install SWH if the building structure is not suitable [interviewee 35].

By the time the SWH industry started growing in China, Beijing's urban built area had been largely covered with dense high-rise buildings. Due to the booming population and increasingly scarce land resource, residential buildings in Beijing are not only densely built but also make full use of their vertical aspect, resulting in a high plot ratio across the city. Plot ratio refers to the intensity of land use[17]. The higher the plot ratio is, the higher the land use intensity. This is a combined consequence of market forces and urban planning. A typical type of building in Beijing's urban area is the so-called tower building. As its name suggests, a residential tower building is a high-rise tower with apartments facing each direction on each floor. Tower building was originally popularised in Hong Kong. Since the 1980s, China's big cities learned from Hong Kong and started building tower buildings massively, because they save land use and are able to provide more housing apartments for residents. Beijing's tower buildings usually have 8 to 12 apartments on each floor and their heights are usually above 20 floors (see Figure 5.10).

[17] Plot ratio= the total aboveground building area on a land plot/ the land area of the plot.

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Figure 5.10 A typical residential community with high tower buildings in Beijing

This building infrastructure impedes the installation of SWH. For evacuated tube SWHs, there is not sufficient space on the rooftop of high-rise buildings for solar collectors. Even if there is enough space, the long transportation of hot water to lower floors would induce huge energy loss. Flat-plate SWHs are believed to have more advantages being incorporating into high-rise buildings because they can be installed on the external wall of each floor. But many apartments in tower buildings are not facing the sunny side and thus, could not enjoy the sunshine. This renders the use of flat-plate SWHs hardly effective.

Indeed, tower buildings only represent a certain proportion of Beijing's building types. There are also many low-rise buildings under 12 floors in Beijing, but their installation rate of SWH is also low due to consumer attitudes and institutional restrictions, which are discussed in the following sections. Low-rise buildings were initially built without consideration of SWH being incorporated. Low-rise buildings are not being built currently, as high-rise buildings dominate the real estate market. Although the city has continued to sprawl with new residential buildings being constructed, they were not designed to integrate with SWH. From 2012, Beijing implemented an SWH mandatory installation policy, and new buildings built were designed with SWH incorporation, but mostly in suburban areas. The majority of Beijing's building infrastructure has been

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locked-in by its fast urbanisation and it is hardly possible to redesign them in favour of SWH installation.

5.3.3.2 Substitute technologies

Existing substitute technologies tend to obstruct the diffusion of new innovations, especially when new technologies are not mature enough to compete with them on performance. EWH and GWH and other heating energies have been popularised much earlier than SWH. Moreover, the cost of coal, gas and electricity is very low for Beijing's residents when compared to their income. Beijing is China's first city having natural gas in residential buildings, and individual natural gas boilers have developed significantly. By the time the government started to encourage SWH installation, the market was dominated by EWH and GWH, making it difficult for SWH to replace these.

Conversely, when SWH started growing in Dezhou, EWH and GWH had not been well popularised, leaving much room for SWH diffusion. In Dezhou's rural areas, SWH even diffused earlier than EWH, and residents viewed EWH as a latecomer. As a rural teacher said:

> The old people all used the SWH, because it's safe, convenient and cheap, everyone knows how to use it, but EWH is complex, the old and children may not know how to use it. Only the young generation is open to new things. When they marry, they tend to buy EWH because they think it is more advanced than SWH.

The environmental merits of SWHs were both acknowledged in Dezhou and Beijing. But it is interesting that Dezhou's informants, be it industry experts, government officials or residents, often mentioned that SWH is superior to EWH in terms of safety, while this was seldom heard from Beijing's interviewees. There is no absolute standard stating that SWH is safer than EWH, but the popular impression of EWH among Dezhou is that EWH not only brings energy waste, but also involves safety risks, especially electric leakages. This might be the result of promotional efforts by the local SWH industry, which inherently emphasises the advantages of SWH and the disadvantages of its alternatives.

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For instance, Himin has launched several press conferences to expose the 'hidden rules' of China's EWH and GWH industry. They stressed the poor quality, electric leakage, short-life, and high energy consumption characteristics of low standard EWH and GWHs.

5.3.3.3 Market demand

Low energy costs and higher income levels together make renewable energy less attractive for individual residents in Beijing. It seems that the more wealthy a region is, the less incentive for its residents in energy savings. While saving on energy bills is viewed as the biggest merit of SWH by most residents in Dezhou, it is not the main concern for Beijing residents. Beijing residents tend to not care much about how much they spent on energy bills, as compared to Dezhou. Instead, comfort, safety, aesthetics and status symbols are the priorities when purchasing household appliances. As discussed in Chapter 4, SWH has long been viewed as a low-end product due to technology weakness. This is more evident in big developed cities like Beijing because it was unable to satisfy wealthy urban residents' high-end demand. Even though SWH industry has made great improvements in technology innovation, the vicious competition between SWH enterprises results in a poor reputation for SWH. Consequently, few urban residents have much knowledge of SWH. Instead, they tend to purchase EWH and GWHs which they believe to provide a better performance than SWH for reasons of convenience, safety and aesthetics.

> The cost of primary energy is too low. Beijing's residents are getting rich, coal and electricity could be easily afforded. SWH, at its best, is not as reliable as primary energy, right? It depends on weather and thus is not stable. But EWH is much more convenient, you can use it as soon as you turn it on. People in rich areas could be driven by environmental awareness while those in poor regions focus on economic savings…[interviewee 32].

This is agreed by another interviewee:

> Since residents have higher income, they really don't care the cost of energy use and see no need to install SWH. The downturn of SWH market in these two years also indicates that residents are careless on energy cost, some more consumption on electricity or gas makes no differences to their

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> life [interviewee 28].

As many interviewees suggested, residents in wealthy regions are more likely to be driven by environmental awareness rather than economic savings in using decentralised environmental technologies. Beijing's residents are generally believed to have a high level of environmental awareness. In particular, the Beijing Olympic Games has been a strong push factor in improving residents' attitudes towards environmental protection. In recent years, air pollution has been one of the top concerns in residents' daily life. Indeed, besides government's environmental measures, many civil environmental movements have been initiated. However, when it comes to small technologies like SWH, people tend to not pay enough attention to its role in reducing pollution. As one interviewee put it:

> It is very unlikely that people would notice that this single product could make a difference, at least, not in a direct way. When mentioning haze, they think of manufacturing factories or automobiles, the two largest pollution sources. How could they relate using EWH or GWH at home with air pollution? They are sure not to think so [interviewee 28].

In fact, solar thermal energy is playing a significant role in reducing emissions (Chapter 4), but this is not well known to citizens. Some interviewees believed that citizens still haven't taken many individual efforts to counter environmental problems, even if they understand the role of daily life change in improving the environment. Between a tiny improvement to the future public environment and an instantly comfortable lifestyle, most of the people would lean towards the latter.

> Most wealthy people using SWH are out of environmental awareness, which is common among Beijing residents due to the severe air pollution, but few people would take real individual measures to counter pollution as they think it is government's responsibility to make the sky blue [interviewee 32].

In short, neither economic savings nor environmental awareness provides sufficient motivation for Beijing's individual residents to use SWH. In Dezhou, the economic saving of SWH drives the growth of the retail market, which results in estate developers being encouraged to install SWH collectively to attract consumers. Estate developers in Beijing, however, do not find such a market demand for SWH installation, and thus, they

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do not have the incentives to integrate SWH into buildings. Though there are some large estate enterprises who actively incorporate SWH into their building to establish green images and to differentiate them from their competitors, the majority of estate developers do not bother with SWH (interview 27, 30, 32). Due to lack of trust in the quality of SWH, estate developers tend to regard SWH incorporation as a burden rather than a market opportunity (Chapter 4).

> One barrier is that estate developers still do not have the right knowledge about SWH. Their understanding of SWH remains in the early phase of SWH. Another barrier is the SWH itself, there is still much room to improve the integration of SWH in different types of building. On the one hand, estate developers do not know SWH well; on the other hand, SWH technology is not advanced enough [interviewee 35].

Even when residents had the desire to install SWH, many property managements did not allow the installation. Though there were no official documents to forbid the installation of SWH, most property managements in Beijing did not allow the individual installation of SWH on aesthetic and safety grounds. Some residents may have installed SWHs secretly, but estate management would take them down eventually (interviewee 28). As another interviewee put it, urban residents do not have much discursive power over estate developers (interviewee 27). Especially before 2008, while Dezhou's estate developers generally facilitated SWH diffusion, their counterparts in Beijing seemed to have played an adverse role.

> it's an unwritten rule, estate managements restrict the individual installation of SWH…Sometimes, it just likes cat-mouse game between residents and estate managements. Even if residents really wish to use SWH, estate managements just stand in the way [interviewee 33].

5.3.3.4 Institutional support

Beijing's solar thermal energy industry did receive government support in technology development in the early phases, but this support mainly went to universities and research institutes. Since the 1980s, the central government and local government have granted many key research projects in solar thermal technologies, such as at Tsinghua University,

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Beijing Solar Institute and China's Academy of Architect. Moreover, the municipal government also helped mobilise financial resources to state-owned SWH enterprises. An interviewee illustrated:

> In 2002, when Beijing started to promote green development and Capital Steel was about to move out Beijing, the then Secretary of Beijing CPC, Liu Qi, built a bridge between Capital Steel and green energies. One of the actions was that Capital Steel invested RMB 100 million to Tsinghua Solar. The current ownership structure of Tsinghua Solar is, Tsinghua University 31%, Capital Steel 28%...[interviewee 35]

Nonetheless, the majority of the SWH industry, private enterprises, had not received effective favourable incentives from government support. SWH industry's output is so small in Beijing's economy that not much attention has been paid to it (interview 32). Though solar thermal energy was also encouraged by the government, it did not gain many subsidies as in the PV industry. Many interviewees suggested that this is because the PV industry brings more GDP and is a more versatile electricity source. Thermal energy is not viewed as essential as other electricity sources (Chapter 4). In addition, although there were no official documents to prohibit SWH installation, the municipal management departments had to some extent played an obstructing role in urban SWH installation, for safety and aesthetics ground.

Since 2005, Beijing's SWH industry has started lobbying the government for a mandatory installation policy, but only when air pollution became so serious that the government decided to require new buildings to incorporate SWH systems from 2012; before then Beijing's SWH enterprises did not benefit from official encouragement. While many cities had implemented mandatory policies earlier, Beijing was much more cautious in carrying out mandatory policies. This has much to do with Beijing's national influence as China's capital. As an SWH entrepreneur explained:

> SWH is not well popularised in Beijing because Beijing's policies are very prudent…and conservative. It seldom promotes encouraging or mandatory policies, because it has a very big influence on the country… I have been discussing with Beijing government about mandatory policies since 2005.

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> The topic was there every year, but not once had results. Then there was a joke, the government once asked me to give a speech at a conference, I joked that my presentation draft was still the one in 2005… but we did understand, because of its position in the country. Beijing is very influential and thus, dare not to carry out policies easily [interviewee 30]

The mandatory installation policy finally came out in Beijing in 2012. Though being rather late in pushing this policy, Beijing was able to learn from policy practices in other cities and adapted them to Beijing's situation. For instance, unlike other cities, Beijing requires that the complementary energy for solar water systems should be gas, rather than electricity. This is believed to have better performance in energy saving. Besides, Beijing does not restrict buildings incorporating SWH to those less than 12 stories because it is hard to see new buildings under 12 stories in Beijing now (interviewee 28). As for high-rise buildings, it is not required to use a solar water system to cover all the households in the building, but at least, a certain portion of the building should have access to solar water. This policy was expected to give a strong push to the diffusion of solar thermal energy in Beijing.

However, the policy was not well implemented. The SWH building integration projects did witness an obvious increase since 2012, but the majority of the installation was achieved in government-led projects, such as public rental housing. Most estate developers do not abide by the regulations. "They [estate developers] evade installation, and the popularisation rate of SWH in the urban area is still very low" (interviewee 32). The core problem is that estate developers only seek low-cost SWH to cope with the regulation, plus the inspections of SWH incorporation are not well in place (Chapter 4). This, in turn, led to a lack of trust in the quality of SWH products. Therefore, estate developers tried many ways to avoid the installation. The mandatory policy is now in an embarrassing position:

> Due to the quality problems, the policy [in Beijing] is nearly paused, many divergences appeared, many projects stopped. It is being turned from side to side. A lot of arguments… [interviewee 30]

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5.3.3.5 Summary

As a much wealthier city, Beijing's development of the solar thermal industry was more out of concerns over energy security and the environment, rather than economic development. Its high density of research institutes and top universities makes Beijing the technology centre of China's SWH industry. But the actors in this technology innovation system, it seems, only remain on the supply side while market formation is largely absent. With some exceptions (e.g. solar heating in Pinggu district), solar thermal energy is not well popularised in Beijing. Being a first mover of urbanisation in China, Beijing's dense building infrastructure and well-popularized SWH-substitutes shape a hostile environment for SWH diffusion. Neither economic savings nor environmental concern provides enough incentives for individual residents to install SWH because their demand for hot water has changed towards high end as income rises. This, in turn, provides estate developers with little rationale to support SWH incorporation, which they do not trust. Considering its national policy influence, Beijing's government was very late in introducing an SWH mandatory installation policy. Although it is adapted to Beijing's situation, the policy is confronted with many problems in implementation. As a primary actor in installing SWH in Beijing, the estate developers barely see profits from conforming with the regulation. Therefore, further institutional changes are appealed to solve the trilemma among the industry, the users, and the government.

5.4 Beijing and Dezhou linkages

The above sections seem have described two contrasting but independent stories of solar thermal development in Dezhou and Beijing. The linkages between them, however, were also found to be essential to Dezhou's SWH industry development. This is particularly true in terms of technology learning, where Dezhou owns much to the geographical proximity to, and close connections with, Beijing. As mentioned, Himin benefited substantially from Tsinghua Solar's technology spillovers in its early stage of development. Huang Ming was the most famous entrepreneur in Tsinghua's 'Huangpu

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Military Academic' training workshops. There once was a short cooperation between Himin and Tsinghua Solar. In 1997, Tsinghua Solar purchased 20% of Himin's ownership, and Himin operated as a regional manufacturing branch of Tsinghua Solar in Shandong. Tsinghua Solar provided evacuated tubes while Himin focused on producing supporting equipment and assembling. As an entrepreneur who previously worked in Himin explained it:

> Himin was very small at the beginning, so it needed strength-borrowing. Tsinghua Solar belongs to Tsinghua University, Himin could benefit from association with this well-known brand …this drove Himin's market growth [interviewee 12].

The cooperation soon ended because both Tsinghua Solar and Himin wanted to expand to the whole SWH industry chain, including evacuated tubes and end product SWH. Himin then resorted to international experts, Australia in particular, to develop its indigenous evacuated tube technology. So far, Himin has become one of leading firms in SWH technology innovation, but it retains intensive connections with Beijing's research institutes. For instance, Himin established joint labs in Beijing with the Chinese Academy of Science to track world cutting-edge technologies in solar energy. In most cases, Himin provides research fundings to the joint research labs and owns the eventual patents. The R&D director of Himin explained the rationale:

> If we recruit 5 talents with doctoral degrees, each cost 1 million Yuan per year, then the five of them is 5 million Yuan per year. But the newcomers are often not guaranteed in reaching expected results. But if I fund 200 thousand Yuan to research institutes or a university, they can provide a dozen of doctors to work on the project. 200 thousand Yuan can bring the same result as 1 million Yuan does [interviewee 9].

Like Himin, most of the large SWH firms in Dezhou choose to cooperate with Beijing's universities and research institutes, because Dezhou lacks universities and R&D talent. There is only one undergraduate university in the city and it does not have much research capacity. Therefore, Dezhou's SWH firms are forced to seek R&D resources in Beijing. They take advantage of Beijing's talent resources to promote technology development through outsourcing, technical cooperation, training and inviting experts for short periods

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of time to guide their research. As a government official commented on Dezhou's talent resources:

> We don't necessarily seek to possess those talents in Dezhou, rather, we try to exploit their intelligence for Dezhou. It cost a lot to have them work in Dezhou and they may not be satisfied with Dezhou's living and working environment…nowadays, we have convenient transportation and communication, we can simply strengthen the cooperation with them and invite them to guide us regularly [interviewee 17].

The asymmetric relations between the two cities are presented not merely in technology learning, but also in political pressures. As discussed, in order to solve the air pollution in Beijing, most parts of Hebei, Shandong and Liaoning are required to improve their industrial structures and reduce emissions. Being only 300 km south to Beijing, Dezhou is facing the same political pressure to transition towards a green economy. As one official from Dezhou's Development and Reform Committee put it:

> We have paid attention to renewable energies since early because this transition is an intrinsic requirement. Dezhou is geographically very close to Beijing. Beijing's requirement of Dezhou in emission reduction is no less than Hebei province. The demand for transition is stronger, especially in recent years, as the haze is very serious [interviewee 19]

This political pressure from Beijing, as the capital of China, is also believed to have pushed the Dezhou government to sustain the renewable energy industry.

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Chapter 6 Discussion

6.1 Introduction

The previous two chapters presented the national context of China's SWH industry development and the two contrasting SWH diffusion stories in Dezhou and Beijing. The facilitating and obstructing factors of SWH diffusion in each city have been illustrated. This chapter further discusses how these factors work and why they matter in China's context. The difference between the two SWH development paths is a combined consequence of place-specific niche-regime interactions and multi-scalar relations that destabilise or empower local factors. For instance, I shall explain why certain local governments have higher incentive to support particular industries in relation to China's political system. The rationality and actions of local actors can be better understood by linking them to China's broad social, economic, cultural and political contexts. Furthermore, I shall highlight the role of power and agency that have been neglected in MLP approaches. As shown in Dezhou's case, the largest SWH firm Himin plays a singularly important part in influencing changes of local and even national institutional structure. It seems that the smaller a city is (in economic terms), the bigger role large firms (industries) can play in creating local development paths. Nonetheless, the exertion of power by local agents often requires supports from extra-local relations. I also attempt to contribute by discussing the role of less developed cities in sustainability transitions. Obviously, not all less developed cities are able to achieve sustainability transitions because most of them lack the necessary technological and financial capacities. However, due to their latecomer advantages, they possess the high potential to leapfrog to sustainability if they are able to take advantage of multi-scalar interactions with developed regions and choose the appropriate development paths.

This chapter is organised as follows. Section 6.2 focuses on the place-specific niche-regime interactions that explain the two different stories in Dezhou and Beijing. Section

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6.3 elaborates on the role of multi-scalar relations and power in Dezhou's sustainability transitions, and Section 6.4 summarises the chapter and provides a general discussion on sustainability transitions in latecomer cities.

6.2 Place-specific niche-regime interactions

Table 6.1 MLP factors in Dezhou and Beijing

		Dezhou	**Beijing**
Landscape		Climate change, energy security, green economy	Climate change, energy security, green economy
Regime resistance	Building Infrastructure	Low-rise building/ later developed solar-integration buildings	Early built dense tower buildings, not suitable for SWH installation
	Policy environment	Supportive	No incentive policies, even adverse before 2012.
	Substitute products	EWH, not popular before SWH	EWH, GWH, low-cost traditional energy
	Market demand	Low-end, economical hot water	High-end, diversified, safety, aesthetic, convenient, stable, status symbol
Niche development	SWH technology	Advantages valued	Not valued
	SWH Industry	Crucial role in economy and city brand building	Not important
	Actors	Powerful large firm, supportive government, motivated residents and estate developers	Universities, research institutes, private enterprises
	Network	Acquaintance society, positive feedback loop among actors	Thin, technology links among supply side

Against a background of fast industrialisation and urbanisation in China, both Dezhou and Beijing face landscape pressures from the global and national level to develop a green economy. This landscape legitimises local green niches and champions their momentum and growth to challenge existing regimes. However, whereas Dezhou has been a supportive niche for SWH adoption, the application of SWH in Beijing has lagged behind, despite its being an influential manufacturing and technology development base. Beijing is one of the most urbanised and developed cities in China but has been a harsh selection environment for SWH diffusion. Applying the MLP concepts,

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the factors influencing SWH diffusion in Dezhou and Beijing are presented in Table 6.1.

6.2.1 Regime resistance

As discussed in the literature review (Chapter 2), the concept of the regime can be understood either as the underlying rules guiding the reproduction of social-economic practices or the systematic configurations of socio-technical factors such as institutions, norms, user practices, and technical artefacts. In both interpretations, the concept does not stick to any particular spatial scale, though the majority of transitions research tends to view regime factors at the national level. The core of this concept lies in its relative stability when compared to the highly dynamic niche concept and highly stable landscape concept. The regimes are the rather stable rules or configurations of socio-technical factors but are still likely to be transformed in the short-run by the pressures from both niche and landscape. Therefore, the notion of the regime is not necessarily bound to the national level. Many rules or configurations of socio-technical factors at the urban and regional level also show high stability, or at least are laborious to be altered in short term, and thus impose certain logics on the self-reproduction of socio-technical factors. Therefore, cities can also have rather stable regimes in particular socio-technical systems. The regime variances in different cities exert a different level of resistance to niche development. Regarding this case of SWH diffusion, while Beijing has constituted a strong regime resistance, Dezhou has not yet established a hostile regime to the SWH niche development, and some regime factors are even friendly to this environmental technology. The following sections compare and discuss how the main regime factors, including building infrastructures, institutions, substitute technologies, and social demand, work in the two places that belong to different development phases in industrialisation and urbanisation.

6.2.2.1 Building infrastructure

The physical infrastructure of a place is often taken for granted in the transition literature, and little attention thus has been paid to how it comes into its existing form and to what

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extent it facilitates or hinders particular sustainability transitions. Many transition researchers have focused on the social structure such as human institutions and rules, as well as the interplay of actors within spatial contexts (e.g. Mattes, Huber and Koehrsen, 2015). However, this is not enough to map the whole story. The physical infrastructure also significantly matters, though may not be as evident as other factors. Just as natural conditions influenced, and even determined, the human agricultural production in early human history (Diamond, 1997), the physical infrastructure in contemporary cities also conditioned human choices, though to a lesser extent due to human agency.

Beijing's case demonstrates the role of urban building infrastructure in affecting the adoption rate of SWH. Its form of building infrastructure is highly related to China's unique urbanisation. The unprecedented urbanisation in China is not only about hundreds of millions of the population moving to cities, but also means enormous urban physical landscape changes in the transport system, energy supply, and building infrastructure etc. to accommodate its growing population and economic activities. Urban physical landscape transformation is especially prominent in China's large developed cities like Beijing and Shanghai because they are China's 'economic magnets' pulling in most of the migrating population. During this process, cities horizontally sprawl out at an unprecedented rate, eating into a massive amount of agricultural land. In response, China's central government put forward a very strict regime to protect agricultural land from becoming urban construction land. Since 2006, the 'red line of 1.8 billion acres of agriculture land' has been an unbreakable legal configuration in China to preserve agriculture land for national security. Down to the city level, each city is planned with limited land use for urban construction. As land has become increasingly scarce, more focus has been turned inward in cities by renewing urban land and vertically growing with dense high-rise buildings springing up for commercial and residential uses. Large cities have started this vertical growth much earlier as a consequence of the high cost of land use. Since the 1980s, China's big cities learned from Hong Kong and started building tower buildings in large numbers, because they save land use and are able to provide more

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housing apartments for residents, resulting in the high intensity of land use. This process is a combined consequence of market forces and urban planning. For estate developers, higher plot ratio means a lower cost of land use in their developments. For consumers, a high plot ratio reduces their living comfort, but it also lowers the purchase cost of houses. For urban planners, higher plot ratio helps to solve the scarcity of urban land and saves it for future development. China's many large cities no longer approve low-rise residential buildings in their urban areas, while latecomer cities generally have more options in building types. Therefore, urbanisation, in the physical term, is a 'locked-in' process, narrowing the options that could be achieved otherwise on the land.

The urban physical infrastructure is not neutral, rather, it favours some technology innovations and against others. Usually, it is integrated with the conventional fossil-fuel regime and thus, very difficult to be transformed for renewable solutions such as EV and decentralised solar technologies. Based on established infrastructure, existing technological systems could exploit the economy of scale and thus leave little room for the competing innovations (Unruh and Einstein, 2000). A rigid urban infrastructure not only imposes an immediate obstacle for new innovations to integrate but more importantly, it is usually the logical base for many social practices, mindsets and policy making. In other words, it conditions urban actors' behaviour and the possible options to change the practices (Haarstad, 2015). As Furlong (2011) argues, it is problematic to view infrastructure simply as a 'black-box' with little interaction from users, although invisibility is one of its main features as infrastructure matures. As urban physical infrastructure is increasingly taken for granted, the established rules, behaviours, cognitions, and artefacts attached to it also gain more legitimacy, forming further obstacles for new innovations.

Mills and Schleich (2009) investigate the effects of geographic, residence and household characteristics on Germany's adoption of the SWH system and find that residential characteristics, including the age of the residence and layout (e.g. multistory or detached

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house), affect its adoption rate. Generally, the older and the higher a residential house is, the less likely it would be to install a solar system, which coincides with my observations in Beijing. In Beijing's case, its high-rise tower buildings basically rule out the possibility for SWH installation but give more legitimacy to conventional water heaters. After the implementation of a mandatory installation policy, new residential buildings are suitable for SWH incorporation, but consumer preferences have been locked-in to the conventional ones, making the policy less successful. By contrast, as a latecomer in urbanisation, Dezhou's residential buildings are principally low-rise ones, providing considerable available space for SWH installation. This market inertia continues in the high-rise buildings market because the government's mandatory installation policy was implemented at the same time as the emergence of high-rise buildings in Dezhou. Therefore, urban infrastructure matters because it constitutes a part of the stable regime that constrains a city's options of available technologies or solutions for sustainability (Haarstad, 2015).

This observation is not confined to SWHs. For instance, Tyfield *et al.*, (2014) find that the tightly packed building infrastructure in China's populated megacities represent a barrier to EV adoption, as few residents have private garages for charging, whereas certain rural areas (particularly in Shandong) have demonstrated a promising niche market for cheaper and low standard EVs. The latecomers in urbanisation generally have not been dominated by particular physical forms and this leaves room for the uptake of new environmental innovations. To give an another example, Späth and Rohracher (2014a) show that the transition to biomass energy in Murua, Austria, is much related to its small and dispersed population and limited industry, which makes the region 'off the radar' of the national gas grid, therefore, help to form a discursive niche due to less resistance from incumbent energy infrastructure.

6.2.2.2 Estate developers

Li *et al.*, (2011) has also explored the diffusion of SWH in Dezhou, but they mainly

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focused on the financial rationalities of residents in adopting SWH and completely ignored the role of estate developers in the diffusion system. This is probably because SWH-building integration had not been so widespread then as today. Nonetheless, Dezhou's estate industry had begun incorporating SWH into buildings since the early 2000s as a consequence of market competition and government regulations, and it is, therefore, problematic not to include them in an adequate account. On the contrary, as the SWH market is increasingly shifting from the individual market to the project market, collective installation in residential buildings become the major application area of SWH technologies and thus estate developers have much power to decide whether to adopt them. From their perspective, the starting point of adopting SWH is not to champion the green technology, but primarily to maintain and enhance their competence in the housing market by either building green images or complying with regulations. From a multi-regime perspective (Raven and Verbong, 2007), the building regime itself is subject to changes due to the environmental landscape pressure. As residential buildings are one of the major energy consumption sources in China, new buildings are subject to an increasingly higher standard of energy efficiency. Some regime actors respond by looking into green technologies. The rationalities, or business logics, have slightly changed from mere cost-profit focus to involving green image or social responsibility. As discussed, the major part of energy efficiency targets is realised by passive building structure and materials, and added-on green technologies can only play a small part in energy reduction. Nonetheless, it still opens the opportunity window for SWH installations. This demonstrates how multi-regime interaction could bring about changes in the focal regime. The relationship between building regime and water heater regime can be described as, in Raven and Verbong's (2007) conceptualization, symbiosis (i.e. both regimes gain mutual benefits through cooperating) and integration (i.e. water heater regime partly becomes part of the building regime). Obviously, the two regimes do not enjoy the same social-economic status, as the real estate industry plays a much more crucial role in the local economy and tax revenue than the water heater industry. The water heater regime is rather dependent on the building regime, within which a small change could trigger much

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deeper influence on water heater regime. Therefore, the multi-regime interaction typology should consider more relations between regimes with asymmetric social-economic importance and how the interactions work differently in both directions.

In Dezhou's case, estate developers in general have a comparatively open attitude toward SWH installation. Some of the estate developers are involved in this technology diffusion because their voluntary choices as business strategies, more of them, however, are involved due to regulative authority. As SWH-building integration gradually becomes a standard practice, violating the regulations could not only be punished by authority forces but also suffer from losing competitiveness in the estate market. Some estate developers have even set up their own SWH firms to join the market. Still, many estate developers do not think the lack of SWH installation would affect their businesses, and they do not bother with SWH integration when the inspection system is not effectively in place (in Beijing's case) or just cope with the regulations by taking down SWHs after inspection (in Dezhou's case). On the other hand, the Dezhou government's vision of building a solar city is also creating a positive expectation on solar technologies among many estate developers. Dezhou's estate developers are much less hostile to SWH adoption than their Beijing counterparts. This difference reveals the importance of aligning key regime actors into the niche development process (Hörisch, 2015). If so, although they do not help to sustain niche growth, there is, at least, less regime resistance than there would have been.

6.2.2.3 Market environment

Market demand is perhaps the most challenging selection environment for new innovations. The preference for existing technologies has been the consequence of the co-evolution of supply side, demand side, relevant institutions, infrastructures, as well as cultural factors. From a purely economic perspective, a product's cost and performance (utility) are the most critical determinants of its diffusion. The criteria to adopt certain innovations have been shaped by the existing products in the market, and the established use habits constitute an immediate obstacle for new technologies to overcome. As a

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forerunner in economic development, Beijing's GWH and EWH systems had developed significantly by the time when SWH began to be promoted by policymakers. The popularisation of GWH and EWH is related to the development level of the local economy since residents in wealthier regions are more likely to afford the initial cost and subsequent fuel cost of GWH and EWH.

According to Rogers' (2003) innovation-decision process, the adoption of a new innovation starts from individual knowledge about the new innovation, including awareness-knowledge (i.e. just being aware of the existence of the innovation), how-to knowledge, and principle-knowledge (i.e. the underlying principles of how it works). Based on this knowledge, other innovation-decision processes, e.g. persuasion, decision, implementation and confirmation, then proceed. The early dominance of GWH and EWH in Beijing renders few of its urban residents having awareness-knowledge of SWH, not to mention the how-to knowledge and its relative advantages. As advocated in Faiers and Neame's (2006) investigation of the UK's solar power diffusion, if the relative advantages of new innovations have not been identified by consumers, it is unlikely that they will be adopted.

Even when SWH's relative advantages in energy saving and their environmentally benign outcomes are recognised, they are not so attractive to Beijing's urban residents whose purchasing criteria have been biased towards convenience, safety, aesthetics and comfort, and since their domestic energy bill only accounts for a small portion of their incomes, they do not have much incentive in saving energy bills. As some interviewees suggested, consumers in less developed regions are more sensitive to economic savings, while those in developed regions have higher requirements on product functions and effectiveness. This forms a hard selection environment for new innovations which usually cannot compete with established technologies in overall performance. Indeed, residents in developed regions are more able to afford the higher cost of new innovations, but more capacity does not guarantee more willingness. Moreover, consumption practices of

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oneself have been an increasingly significant indication of individual freedom and social status of China's rising middle class, hence, "consumerism is of heightened social and political significance" (Tyfield *et al.*, 2014:29). The pursue of this social identity through individual consumption usually leads to the aspiration of expensive and advanced products, which further marginalises low-end innovations such as SWHs.

Environmental awareness has been a critical driver of the diffusion of many renewable energy technologies (RETs), but it has different purchase in different places. For instance, though both geographically belonging to the wealthy Europe, Mid-and Northern Europe (e.g. Germany, Austria, and Denmark) are primarily motivated by environmental consciousness in the diffusion of SWH systems, while Southern Europe (e.g. Spain and Italy) does not show such a pattern (Tsoutsos and Stamboulis, 2005). Environmental pressures have driven many local authorities to popularise RETs because the criteria of governing performance have been altered towards the environmental ones, but they seem not having been taken seriously enough by individual social members to take environmental actions in developing China, even in its first-tier cities. On the one hand, due to the lack of knowledge about the SWH, residents doubt how such a small domestic appliance could make a difference to environmental improvement. On the other hand, even if they realise the significance of this environmental technology in achieving a greener environment, and have a concern for environmental issues, their awareness is still not imperative enough to drive them to sacrifice their individual comfortable lifestyle for collective environmental benefits. There is still a gap between environmental consciousness and genuine actions. As a consequence of this lack of an individual market, estate developers see no incentives for installing SWH collectively. Only a few large estate developers see adding this green technology as a way to build green images and thus are willing to accept SWH-building integration.

In contrast, as a latecomer city, Dezhou's resident income level is much lower than Beijing's. When GWH and EWH were popularised in Beijing, most Dezhou residents

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viewed them as a rather luxury lifestyle item. Because of lower income, they were very concerned about their energy bills, which made EWH and GWH not widespread in Dezhou before SWH emerged. The emergence of SWH happened to occur at the same time when Dezhou residents' living standards began to rise and catered to their demand for economical hot water use. Unlike in Beijing, the market selection criteria in Dezhou has always been about economic savings, which is the primary relative advantage that an SWH can provide over its substitutes. Compared to economic savings, other criteria such as convenience, comfort and aesthetics are not that prioritised, leaving much room for SWH growing at the initial stage. Given the growing individual market, Dezhou's estate developers also changed their attitudes from hostility to embracing the technology. In addition, the government's subsidy and incentive policies make the SWHs even more attractive to the local market. Overall, the regime in user practices in Dezhou are much weaker and even welcomes the new technology. This aspect of regime resistance is highly related to the development level of a region. Similarly, Tyfield *et al.*, (2014) find that the low-tech electric two-wheels (E2W) is currently restricted in China's advanced cities but has a prospective niche market in areas with a relatively lower level of urbanisation, income and automotive industry support. Being a latecomer in economic development means having different selection criteria from developed regions, and if the new green technology is able to meet its principal criteria (e.g. economic saving), it is very likely that a wide adoption will follow.

6.2.2.4 Institutional changes

Institutions, including formal and informal ones, are also the stable component of an established regime. As advocated in the transitions literature (Hodson and Marvin, 2010; Carvalho, Mingardo and Van Haaren, 2012), formal policies and regulations play a substantial role in driving or obstructing local sustainability transitions. However, their focus seems merely limited to how particular institutional arrangements affect transition practices, while little attention has been paid to how these particular institutional arrangements have evolved or why they maintain their legitimacy in certain places. The

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results of this research imply that the institutional changes towards new innovations may more readily happen in small latecomer cities (if they wish to) than in big developed cities. It is rational that new experiments mainly take place in small places so that the cost would not be too high in case the experiments fail. For instance, China's Reforming and Opening policy started with establishing special economic zones in Shenzhen, Zhuhai, Xiamen and Shantou, which were all small cities in the late 1970s, rather than in big cities like Shanghai. The rationale behind this was that, on the one hand, it was extremely difficult to transform the socialist institutions that had been developed for decades in China's big cities overnight to new economic forms, while small cities had yet to develop with their own institutions. In addition, considering the unpredictable risks, these new economic experiments were likely to fail, and the failure in big cities may cause undesirable national impacts as they had a much more critical position in the national economy. However, experimental failures in small cities usually only impact locally and the cost of failure could be acceptable from the national perspective. The special economic zone turned out to be a very successful experiment and big cities like Shanghai were then listed as new special economic zones in the 1990s to further exploit the profit of reforming nation-wide. The architect of China's reform, Deng Xiaoping, described this reforming philosophy as like a person crossing a river by feeling his way over the stones. In other words, it is safer to start institutional experiments in places with fewer obstacles and cost and then fine tune them for wider applications. This experimental wisdom is widely applied in China's political practices to initiate new policies and regulations nationally.

While the above political process seems more from a national strategic perspective, acknowledged here is the principle that institutional regime resistance is generally weaker in small less developed cities than in big developed cities for new economic practices. Latecomer cities are usually small in economic scale, less dominated by established industries, and less locked-in by existing institutional arrangements because they are yet to be developed. Furthermore, as the Chinese proverb '*it is easier to turn around a small ship*' suggests, smaller cities could enjoy more institutional manoeuvrability in facing

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landscape changes, while a '*Titanic*' is more difficult to change routes to escape icebergs in time due to its huge inertia. It is also reasonable to expect that institutional changes in small places may exert bigger influences.

Regarding the two cases in this research, apparently, the policy changes favouring SWH diffusion are much more smooth in Dezhou than in Beijing. The incentive and mandatory policies for SWH have gained much market ground in Dezhou, but it is not the case in Beijing. A common resistance force of institutional changes comes from vested interests who strive to sustain existing institutions so that their interests would be maintained. In both case study cities, the real estate industry plays a crucial role in their local economy (chapter 4), and they have much to say on whether to refuse or embrace SWH-building integration. The difference lies in that many of Dezhou's estate developers see SWH-building integration as a business opportunity, while Beijing's estate developers tend to view installing SWH as merely a financial burden and many are concerned about the performance of SWH. Hence, the real estate industry in the two cities have very different attitudes towards SWH-integration, and these attitudes are exerting influence on the policy-making process. As mentioned in Chapter 4, the process of making local industry policy goes through several rounds of survey, drafting, feedback and revision. During this process, the voices of relevant players are heard and represented. Although the SWH industry advocates SWH-integration, the policy could not be passed without compromise from the real estate industry. Even though the mandatory policy eventually was put forward, estate developers could still stand in the way of its implementation to maintain their interests. This largely explains why the mandatory policy fails in Beijing.

Besides, as local governments are the main drivers and promoters of policy changes, their attitudes and motivations matter profoundly. The SWH industry provides many economic benefits in Dezhou in terms of tax revenue, investment and employment, and the absence of other dominant industries drives the local government to promote the SWH industry as a leading industry. The mandatory installation regulations thus were early put forward to support the industry without much resistance. In Beijing, however, the role of SWH industry in the local economy is so small that not much attention is paid to it. The government began to take initiatives in SWH installation at the time of Beijing Olympic Games, mainly through several demonstration projects in Olympic sports facilities. The predominant motivation of SWH installation in Beijing is for the environmental good, but it seems that this motivation alone is not forceful enough to bring policy changes. Before Beijing's mandatory installation policy in 2012, though there were no official policy documents to forbid SWH installation, it faced many obstacles in practice because neither residential managers nor municipal administration departments welcomed the installation of SWH on buildings because they thought SWH installation might cause safety problems and spoil the urban appearance.

The other concern of Beijing, as a city of national influence, is that its policy changes might lead to a wider demonstration effect on other cities across the country. It has to make sure that the effect of the new policies is positive before it diffuses to other places. Within the city itself, a policy change will also bring great influence on local development due to its large scale of population and socioeconomic activities. Once a new policy is implemented, broader changes in relevant infrastructure, investment, institutions and norms are expected to follow. The cost of institutional experiments in such a big city would be very high if they turn out to be undesirable. Therefore, these concerns render Beijing very cautious about enacting new policies readily. Only after obvious benefits of the new policy have been found in other cities did Beijing follow with its own version that is adapted to local conditions.

As a prefecture-level city, Dezhou has lesser governing autonomy than Beijing, but it enjoys more freedom to exercise new institutional experiments as it won't bring much potential undesirable influence to the national level. Dezhou's institutional change towards the SWH industry needs only to take into account its local consequence, making the policy-making process much more straightforward. This analysis reveals the multi-

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scalar features of local institutional resistance. The institutional changes in a city are not only about the interaction between local promoters and vested interest but also have been conditioned by its extra-local relations with other spatial scales. The more influential is a city in the national network, the more weight is expected to be put on it in its decision makings. This makes the institutional changes in such cities even more difficult and complex as there are too many interests to be coordinated. A small less developed city, in contrast, is usually limited in its national influence and thus, local interests are the primary decisive consideration in policy makings. Since the potential cost of the experiments is limited both within and outside smaller cities, there are fewer resistances to promote institutional changes.

6.2.2 Niche development

6.2.2.1 Technological niche

The technological characteristics of the innovation itself are important determinants of its diffusion. Rogers (2003) classifies five attributes of innovations that affect their rates of adoption, a) relative advantages in economic, social status and functions; b) compatibility with culture and values, previous ideas and clients' need; c) complexity; d) triability (i.e. whether can be tried with least cost) and e) observability (i.e. whether the use of the innovation can be observed by others easily). Among these attributes, the first two are considered the most essential in deciding whether an innovation could be widely diffused. The adoption of an innovation is not simply because of its relative advantages in various forms, but also depends on how these relative advantages are perceived by potential adopters and whether they fit their needs, which inherently involves considerable differences among different demographic groups.

After three decades of development, China's solar thermal technology has made many significant breakthroughs in reducing cost and improving performance, such as the indigenous innovation of evacuated tube technology, the anti-frozen technology of flat-plate collectors, and the system incorporation with buildings. Moreover, China's solar

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thermal technology has been applied in industrial use, such as heating and air-conditioning, and its use in generating electricity has shown signs of large-scale application. Nonetheless, the technology, as a ‘hopeful monstrosity’ (Mokyr, 1990), is still confronted with many problems in performance such as unreliability, safety, aesthetic and system design (chapter 4). After all, unlike other domestic appliances, the major components of SWH works in the outdoor environment, exposed to changing weather conditions, and thus it requires a higher standard of quality. Even worse is the information asymmetry between users and producers facilitating a vicious competition among producers by lowering product quality, rendering a poor image of SWH among consumers. In spite of these problems, its relative advantages in economic saving and carbon emissions are highly valued in some places because they are compatible with the local specific needs. The attribute of economic saving is more attractive in less wealthy regions than in rich ones. Dezhou was such a city in which residents had a lower income level, therefore, they had more interest in economic saving technologies. Compared to their economic benefits, the other attributes in reliability, safety and aesthetics were of much less concern. These negative features are important considerations to consumers in rich cities because they have greater financial ability to afford more technology options, while in latecomer cities and rural areas, they are considered not essential as long as it achieves its chief function in providing free hot water. Therefore, this technological niche has much purchase in latecomer regions.

In contrast, the SWH technology niche began in Beijing because of long-term energy security concerns and then the potential environmental benefits. The primary drivers of this technology development are the government, state-owned university, research institutes, and some private SWH manufacturers on the supply side. On the demand side, even though SWH provides certain relative advantages, the relatively wealthy consumers do not really appreciate it but care more about the negative side of the technology. Not only individual consumers but also estate developers and public or private organisations have higher demand standards which are still difficult for the new innovation to meet.

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Hence, the same innovation can have very different purchase in different places, depending on how the local selection environment reacts to it. It is logical that a new innovation could be more welcomed in those places with a less demanding environment because their immature nature could possibly be ignored, as long as it provides practical advantages. For environmental technologies, while environmental motives may not be imperative enough to drive their adoption in currently developing China, economic interests usually have more persuasive power, especially in less developed areas.

6.2.2.2 Actors and networks

The two contrasting cases reveal the underestimated significance of human agency in sustainability transitions. Given the regime structure, Dezhou's SWH actors, especially the SWH industry and the government, have more incentive and power to direct changes in institutions, infrastructure and user practice etc, so that the transition is greatly facilitated. The following section explains where these powers come from and how they exert an impact on regime changes.

(1) Role of large green firms: '*a big fish in a small pond*'

Evidently, the large firm Himin is the pivotal player in Dezhou's transition to SWH. Its powerful role in local transition can be understood from two aspects. On the one hand, the firm itself has developed the absolute instrumental power to lead the socio-technical changes. Within two decades, Himin quickly developed to be one of the world's largest SWH manufacturers. Its financial size has grown fast and kept attracting investment from domestic and international investors, such as Goldman Sachs and CDH, who together invested US100 million dollars in Himin for its green business in 2009. Furthermore, it has developed a strong innovative capacity by drawing talent internationally and taking advantage of cooperation with top universities in China. As a profit-seeking business unit, Himin is a very active change agent which purposively direct changes in its favour (Rogers, 2003). Himin made huge endeavours to popularise solar knowledge around the country, changing consumers' attitudes towards the innovation when it was hardly known

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by Chinese consumers, which greatly facilitated China's SWH market expansion. Due to the global landscape imperative on climate change, Himin's contributions in popularising this green technology has not only been recognised at the national level but also at the international level. Its founder Huang Ming became a nationally-known green entrepreneur and was elected as the delegate to the NPC on behalf of the renewable energy industry. At the international level, his achievements were also highly appreciated. He was elected as the vice-president of ISES. Himin's green model has been a typical successful case of China's business story and its founder has become a star entrepreneur of national influence through the media. It can be seen that the firm has accumulated much strength in finance, innovation, reputation and politics.

On the other hand, the comparatively small economy of Dezhou makes the role of Himin even more vital in the city. Interviewees suggested that it is precisely because Dezhou is a small less developed city without other dominant industries that the SWH industry has a significant role to play in Dezhou. By contrast, there are also several nationally-known SWH firms like Himin in Beijing, such as Tsinghua Solar and Tianpu Solar, but they have not exerted much influence in Beijing because the city's economy and branding would not be much different without them. However, the SWH industry is of singular significance to Dezhou's local economy and city branding, because the economic size of Dezhou was comparatively small and other well-known leading industries for city promotion were absent. The growth of the SWH industry contributed significantly to the local economy in terms of tax revenue, investment and employment. At its peak, the industry is reported to account for one-third of the city's workforce (Tyfield, Jin and Rooker, 2010). Furthermore, it is only because of this green industry that Dezhou has gained international recognition. This key role in the local economic development and city branding enable the industry to have 'structural power' (Newell and Paterson, 1998) in directing local dynamics.

Geels (2014) argue that incumbent big businesses are able to influence policy-making in

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many ways due to the local economic dependency on them. Big businesses usually have close relational networks and frequent contacts with policymakers, which may result in the latter internalising the former's ideas and interest in a subtle way. Moreover, big firms can deliberately use corporate strategies to influence policymakers through, e.g. providing information, exerting pressure, offering incentives, and directing lobbying in the favour of their interests. This role of big business is not necessarily related to incumbent regime actors, rather, emerging green businesses may also fulfil such a role in influencing local policy-making as long as they are 'big' enough in the local context. Himin and the SWH industry successfully lobbied the local government to establish the vision of building Dezhou as China's solar city. This vision then was widely accepted within the city and subsequent incentive policies were implemented to pursue this vision. As the SNM literature argues, a shared vision is critical in strengthening the commitment of local actors (van der Schoor and Scholtens, 2015). While the industrial actors share the solar city vision mainly for economic benefits, the local government sees the industry as a strategic new industry that will bring Dezhou an international green city image as well as GDP growth.

It seems that Dezhou's solar city vision is not that clear to its urban residents in terms of specific targets or concrete contents, but they are proud of being part of China's Solar City and thus are willing to accept solar thermal products. This willingness is also to a large extent shaped by the SWH industry, Himin in particular, which not only popularises the knowledge of solar energy consistently but also actively promotes the advantages of solar products over their substitutes. What matters here is that these efforts not only raise the awareness of SWH among residents but more importantly, shape local consumers' positive attitude towards SWH and negative attitude to its substitutes. While EWH is viewed as a safe and convenient product in Beijing, it is not considered as safe or convenient as SWH in Dezhou. This attitude is largely attributed to the influential promotion by the local SWH industry. This is a typical exertion of discursive power in influencing the way how an issue should be discussed. When a technology is deemed a

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necessity of daily life, it is not strange that it becomes widely adopted. Due to its local influence, the industry is able to make the use of SWH a new routine for the urban residents. This routine renders consumers taking SWH use for granted, meanwhile, keeping other options out of decision-making process. It becomes a self-sustaining process when the new innovations have been integrated into the social practice.

Himin (and the industry) is able to ally regime actors to push changes in building infrastructure to favour SWH installation. When the individual SWH installation had become an established social phenomenon in the early 2000s in Dezhou, the existing building infrastructure still lay in the way of collective installation of SWH. System SWH-building integration requires know-how from both SWH and architecture and such a learning process is costly and takes time before performance improvement occurs (Tsoutsos and Stamboulis, 2005). Himin then resorted to the Dezhou Architecture Design Institute for cooperation. Combining the knowledge of both building structure and solar products, they developed the first design standard for SWH-building integration, which was then adopted by the provincial level of Shandong. Though a number of estate projects adopted SWH-building integration for promoting sales, it was not a common practice among estate developers until the government implemented the mandatory installation policy, in which the industry played a very active role in lobbying (Goess, de Jong and Ravesteijn, 2015). Since then, though there remained many technical problems in SWH-building integration, the general building infrastructure was no longer hostile to SWH installation in Dezhou. During this process, the previous regime actors in building sectors such as estate developers and architectural design institutes were allied to push the infrastructural change. This reveals how influential Himin and the industry are in Dezhou's institutional change. By contrast, Beijing's SWH industry has also lobbied hard for a mandatory policy, but only received a very late response. Beijing's SWH industry is bigger than Dezhou's in terms of firm numbers and economic output, but its relative importance in the local economy is much less than its counterpart in Dezhou. That explains the power differences of the SWH industry between the two cities. Power is not

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something held by actors but is more about the relations between actors and the structure (Yeung, 2005; Tyfield, Ely and Geall, 2015).

The role of Himin in Dezhou is like a big fish in a small pond, and the waves it creates go beyond the pond to a wider space. The success of Himin in the emerging renewable energy industry enabled it to exert political influence at the provincial (Goess, de Jong and Ravesteijn, 2015) and national level. This was achieved when Huang Ming was elected as the only representative from the renewable energy industry in China's NPC in 2003. Huang Ming, as the main proposer, allied with many other representatives to put forward the proposal to establish China's Renewable Energy Law. The success of this legislation was due to China's urgent need for green development on the one hand, but on the other hand, the human agency in promoting the change should not be underestimated. The consequent new legislation and the subsequent policies towards the renewable energy industry formed a new and more compulsory landscape, which imposes direct pressures on regime actors at the both national and local level to champion the production and consumption of renewable energy. Huang Ming, as an icon of the renewable energy industry then, played a crucial role in this legislative landscape change.

The role of Himin in the diffusion of SWH can be well illustrated by Jacobsson and Johnson's (2000) notion of prime mover, which is defined as "actors who are technically, financially and/or politically so powerful that they can initiate or strongly contribute to the development and diffusion of new technology" (p630). Prime movers perform four roles in promoting the new technology: raising awareness, undertaking investments, providing legitimacy, and diffusing new technology. Facing the obstructing forces from the existing system, powerful actors are expected to emerge and lead the change. Prime movers fulfil such a role and they are the key actors in creating new technological systems. In Dezhou's case, Himin not only diffuses SWH widely but also builds a new technological system, which encompasses many networked actors and favourable institutions to make the diffusion a self-sustaining process.

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Research on green or sustainable entrepreneurship has suggested that green entrepreneurs can challenge existing regimes not only through their green business but, more importantly, through networking with other mesolevel actors (Hörisch, 2015). Gibbs and O'Neill (2014a) also argue that green entrepreneurs can contribute to sustainability transitions by acting as 'system builders' to advocate for wider system changes in such as regulations, standards and norms. However, it is not clear that under what conditions green entrepreneurs can fulfil such a role as system builders. In their investigation into the UK's green building sector, Gibbs and O'Neill (2014a) find that green business influencing government policies actually rarely happens, because small and medium-sized enterprises have limited resources to engage in lobbying activities. This may be the case at the national level, but there could be more diverse relationships between green entrepreneurship and government policies at the urban and regional level. The contrasting roles of SWH industry in Dezhou and Beijing implies that green entrepreneurs in latecomer economies have more potential to act as prime movers or system builders than in large economies because of their comparatively critical role in local economic development, and hence, political and discursive influence in local contexts.

(2) Role of local government

The existing transition literature has not reached a consensus on locating local authority in the MLP. Very often, the municipal government is viewed as a part of the urban regime that is hostile to niche activities (Bulkeley *et al.*, 2011). For instance, Bolton and Foxon (2013) shows that the local government as regulator is more interested in promoting short-term economic efficiency in the incumbent infrastructure sector, which counterposes the development of district energy systems at the urban scale. Some scholars argue that a local authority works more as an intermediary agent (e.g. Hodson and Marvin, 2010) or a third party facilitator (e.g. Mans and Meerow, 2012b) in urban sustainability transitions. In fact, the local authorities are often a mix of niche and regime characteristics (Mans and

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Meerow, 2012b). On the one hand, they are usually characterised by incremental change, risk-aversion and less dynamism, and their changes are usually driven by institutions rather than agencies. On the other hand, some parts of the local government often seek to bring radical changes. For example, mayors, as a powerful political leadership, can exert crucial influence in directing urban transitions as demonstrated in Mans and Meerow's (2012a) case of Baoding, in which the mayor actively promoted the city’s national profile as a green power valley in China. Fudge, Peters and Woodman (2016), however, suggest that local authorities can be active and powerful niche actors in enabling institutional changes by taking advantage of the window of opportunity from landscape pressure, engaging the local community and sustaining appropriate technology innovations. Some local authorities tend to view energy and environmental issues as more of an extension to existing energy service provision, whereas others are more willing to act as niche actors.

Therefore, the role of local government in energy transitions cannot simply be assigned to regime actor or niche actor. Instead, the state itself is harbouring both regime elements and niche elements (Avelino and Wittmayer, 2016). Its role in regime changes can vary from time to time, as well as from place to place. From a temporal perspective, though local government has long been an incumbent in the existing system, its interest is subject to constant changes due to the dynamic from within, and the pressure from the external environment. Within the government itself, the political leadership changes every few years and their interests and attitudes towards new industry may differ significantly. In some political contexts, the local political leadership, such as mayors, are very influential in directing the cities’ future visions and development pathways, thus, their personal interests matter significantly. These changes in interests may be the consequence of landscape pressure, industry lobbying, personal learning, or the pursuit of political achievements. Unlike Western political systems, the local leadership in China’s context usually have more power in influencing local social-economic development (Hu and Hassink, 2015). For example, Bai (2007) attributed much of the high installation rate of SWH in Rizhao to the active promotional efforts by the then mayor, who was a young

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doctorate officer enthusiastic about ecology and environment. Before becoming the mayor, he was a professor at the Shandong University of Technology and helped improve the production technology of the solar industry when serving in the Economic and Trade Commission of Shandong Province. Under his strong leadership, Rizhao became a nationally-known green city from being a small less developed city. He was then promoted as the vice governor of Shandong province to extend the experience of Rizhao. Similarly, Aristova (2016) compared the development of geothermal heat pumps in Beijing and Shenyang, concluding that the fast installation of this technology in Shenyang is, to a large extent, due to the mayor's personal preference, which has much to do with the mayor's educational background in engineering. In this research, as shown in chapter 5, the CPC secretary of Beijing's Pinggu District played the leading role in applying solar thermal heating in its area of jurisdiction.

It is not unusual that the political leaderships have the motivation to develop certain green projects, but how much influence they can bring with this depends on the struggle between their agency and the government structure. Political entrepreneurship may play an active role in leading or sustaining niche development, but the running of government routine often stands in the way of the transitions. This can be exemplified by the case that in many of China's big cities, though local authorities officially encourage the use of SWH, some administration departments still prohibit SWH installation because of concerns over safety and urban appearance. Furthermore, many interests of local government, such as tax revenue and employment provision, are still related to incumbent industries. Therefore, a local government may support both the incumbent actors for economic interest and niche actors for environmental benefits at the same time. When it comes to specific cities, the proportion of niche force and regime resistance in local government can vary significantly.

In Dezhou's case, the local government has displayed significant characteristics as an active and powerful niche actor in SWH diffusion. This can be observed from both its

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interest and actual governance. As discussed in Chapter 4, local GDP growth was the decisive criteria of local officials' working performance in China's CPES. Recently, the environmental criteria are also gaining more weight in the evaluation system, but they are still much less important than GDP. The local government thus has the inherent interests to support the industries that will bring the region more economic competency and green images as a bonus. The renewable energy industry receives unprecedented government support because it brings economic benefits and caters to global environmental landscape pressure. However, to what extent the industry receives official support has much to do with its role in the local economy. For instance, Zhu and He (2015) compare two development paths of the apparel industry cluster in Ningbo and Yongkang and find the different cluster pathways in the two cities is mainly as a result of their diverse local governance. The apparel industry in Ningbo is characterised by grass-roots development and is export-oriented. It only accounts for small part of Ningbo's economy, and thus it does not receive much support from local government. The industry upgrading is mainly as a result of global competition and in response to the rise in labour costs. By contrast, Yongkang is a county-level city, and the apparel industry plays a critical role in the local economy. The cluster's upgrading and learning are achieved mainly through local government support. Though not dealing with the renewable energy industry, this example reveals the rationale of China's local governments in supporting particular industries. Thanks to its relatively crucial role in the small local economy, the SWH industry meets both the economic and environmental interest of the local government in Dezhou. Therefore, from the motivation perspective, the local government has every reason to champion the SWH industry growth. Its governance practice further empowers the niche development.

Regarding the specific role of local government in the transition, I believe the multiple modes of local governing on environmental protection developed by Bulkeley and Kern (2006) is very helpful to frame the discussion. They identify four types of governing capacity, namely, self-governing, governing by authority, governing by provision, and

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governing through enabling. Self-governing refers to the capacity that the local government governs its own activities such as procurement of green technologies and demonstration of sustainable lifestyles like cycling. The local government can use its own resources to invest in sustainable technologies and apply them in public facilities so that a demonstration effect could be induced. The municipality in this mode works more as a risk-taking consumer and role-model of green technology use. It is accomplished through the process of organisational management. Governing by authority, or governing by regulation (Kern and Smith, 2008), means the local government using its authority over other actors to promote green standards through, e.g. planning and regulations. It relies on the use of sanctions. Governing by provision means providing particular forms of services and resources such as financial subsidy so that green investment could be encouraged. It is achieved mainly through material and infrastructural means. As to governing through enabling, the local government acts as the core actor in facilitating and coordinating the private-public partnership and community engagement to take green actions. In this scenario, persuasion, argument and incentives are the primary means to work. These modes are not exclusive to each other, and in many cases, they are used together to deal with specific issues. The difference is that these modes of governing often have different purchases in different places. For instance, Bulkeley and Kern (2006) find that the local governing related to climate protection in the UK and in Germany is mainly through self-governing and enabling, such as reducing energy consumption in municipal buildings and promoting awareness about the energy use and its impacts. Mans and Meerow (2012a) compare five cities' (Baoding, Calgary, Hamburg, Piracicaba, San Diego) governance of renewable energy clusters and find that governing through enabling is the most commonly used mode. While this mode has more weight in the three western cities, governing by authority is the most prominent in Baoding's practice.

The differences in governing the SWH industry are also found between Dezhou and Beijing (Table 6.2). Whereas Dezhou practices all four modes of governance, Beijing mainly shows capacity in self-governing and governing by authority. Even so, there is

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also a different level of governing capacity in the two modes between the two cities. In terms of self-governing, Dezhou municipal government has been an active role-model of SWH use since the early 2000s. Dezhou first experimented with SWH-building integration in its employees' residential community before it officially encouraged this practice. After being awarded the status of China's Solar City, the municipal government deployed many demonstration projects in municipal buildings and urban public facilities such as museums, stadiums, hospitals and schools. The projects are not merely limited to solar thermal technologies, but also photovoltaic products for traffic lighting and public parks. The demonstration is effective because it increases the observability of an innovation (Rogers, 2003). The government demonstration projects not only evaluate the effectiveness of the innovation (experimental) for knowledge learning and further improvement but also displays the desirability of the innovation (exemplary). In a social system, the local governments can play the role of opinion leadership in the diffusion of innovation (Rogers, 2003), because their evaluations and adoptions of innovations are often respected and followed by other social members. Thus, the demonstration of local government informally influences the attitudes and behaviour of others in a desired way. Through these efforts, the image of the solar city is further strengthened and citizens' awareness of solar energy is improved. Beijing municipal government also shows activities of self-governing in relation to SWH use. However, these demonstrations were rather constrained to several specific sites, such as installing SWH on public sports facilities for the Olympic Games. Apparently, Dezhou's self-governing is more continuous and covers bigger municipal areas than Beijing's. Therefore, the self-governing of Dezhou achieved more positive demonstration effects within its relatively small urban areas.

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Table 6.2 Modes of SWH governance in Dezhou and Beijing

	Dezhou government	**Beijing government**
Self-governing	Installing solar products in municipal facilities; Starting SWH-building integration in government employees' residential communities.	Installing SWH on a few public facilities, e.g. Olympic stadiums.
Governing by authority	Standard for SWH-building integration; Mandatory SWH installation;	Standard for energy-efficient buildings; Mandatory SWH-building integration, but mainly implemented in government-led projects, e.g., public rental housings.
Governing by provision	Grants for demonstration projects; Preferential land use; Solar city offices;	Research funds;
Governing through enabling	Solar City Vision; FYP; Consumption subsidies; Hosting World Solar City Congress; Solar Expo and cultural event; Official Propaganda of solar city	FYP; Bridging investment between conventional industry and solar industry;

In both cases, governing by authority seems to have played the key role, particularly in Beijing's case when compared to other modes. Building standard and mandatory SWH installation regulations are the most prominent approaches in this mode of governance, but there exist several differences between the two cities. In Dezhou, the government pushes more specific building standards so that they should be designed with space for SWH installation at an early stage. In contrast, Beijing' building standard places more emphasis on reaching a certain level of energy efficiency, which is among the highest in China, regardless of what technologies achieve this requirement. This energy efficiency standard can be achieved mainly through insulation technologies, and the use of renewable energy only plays a very limited role. This standard, to a certain extent, promoted the SWH installation, but it is not as specific and clear as Dezhou's building standard requiring space for SWH use. As to the mandatory policy, it exerts a more

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regulatory force on estate developers to incorporate SWH in building designing and constructing. Dezhou's mandatory policy is not only implemented much earlier than Beijing's but also offers 'carrots' other than 'sticks' of violation. The developers complying with the regulation will be given priority in land use and mitigating responsibility for public infrastructure. In terms of implementation, Dezhou's mandatory policy is well carried out in various types of buildings, while Beijing's requirement is mainly achieved in government-led projects, such as public renting houses. As discussed in Chapter 5, due to cost-saving concern and the lack of trust in SWH products, many estate developers in Beijing try many ways to bypass the regulation, leaving the regulation under a lot of debates and on the edge of suspension. Obviously, governing by authority has more purchase in Dezhou and it suggests that the practising of authority could be better complemented with more specific technology options and more systematic supportive measures such as quality inspection. Also, if incentives for abiding with regulation could be provided other than sanctions for violation, the regulation outcome would be more desirable.

Compared to their Western counterparts, China's municipal governments may have a bigger role to play in terms of governing by provision, because the urban infrastructure of transport, energy and waste are usually run by state-own enterprises (SOEs), and local governments have much influence on the decision-making of these enterprises. Furthermore, the key production factor of land in China's urban area is also state-owned and local government is the sole agent of its urban land. Before the current prevailing bidding system, allocating land-use right at a preferential price to specific industries or enterprises is a common approach for local governments to attract investment and encourage entrepreneurship (Zhou, 2013). In order to compete with other cities, other than providing preferential land use, many local governments offer more services such as shortening the administration process for enterprise registration and tax reductions. Many economists have believed that this competition among local governments is a strong driving force of China's economy during last few decades (Cai and Treisman, 2006; Lu

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et al., 2013). In order to sustain the SWH industry, Dezhou municipal government has allocated large scale preferential land areas to solar enterprises in its new development zone. Financially, Dezhou municipal government has allocated numerous grants for SWH demonstration projects (Li *et al.*, 2011). Furthermore, Dezhou established the specialised solar city office to help solar enterprises search for demonstration grants and popularise their products. Dezhou's provision thus covers land, finance, and services. By contrast, the provision of Beijing's government to local SWH industry is limited to research funding to universities and research institutes. It should be noted that as the capital of China, Beijing's substantial research funding was actually assigned from the national government, rather than Beijing municipal government. Considering this, Beijing municipal government's role in governing provision to SWH industry is even smaller, and this is reflected from the Beijing's SWH industry interviewees.

More distinct differences were found between the two municipalities regarding governing through enabling. Whereas Beijing seems merely to give the signal to encourage the use of solar thermal energy through its FYP, Dezhou's promotional efforts are more comprehensive. Indeed, Beijing also helped motivate investment into SWH enterprises, such as brokering the cooperation between Capital Steel and Tsinghua Solar (Chapter 5), but this is not a common practice but limited to a few state-own enterprises. In Dezhou's case, solar thermal energy is not only encouraged in local industry policy, but also integrated into its local strategic vision to build China's solar city. This strategic vision is more than giving a clear signal to the local community, but being realised with more concrete measures, including hosting the World Solar City Congress and promoting and marketing Dezhou as a solar city nationally and internationally. Other events such Solar Expo and Solar Thanksgiving Day are held annually to enhance the communication between Dezhou and other countries and inspire residents' enthusiasm for solar energy. Furthermore, financial subsidies are provided to encourage SWH installation. The local government also played a crucial role in enhancing the cooperation between building design institutes and SWH enterprises in SWH-building integration. Through these

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enabling efforts, Dezhou gains increasing recognition and reputation as an emerging solar city nationally and internationally (Wei, 2012).

Therefore, judging from both its interest and actual governance, Dezhou's local government has been a powerful niche actor in regard to SWH diffusion, while Beijing's is an intermediary actor, if not a regime actor. In China's political system, local governments usually have more resources and authority, and their governing by authority, provision, and through enabling can exert a bigger impact if they have more interest in particular transitions. However, given that the government is an organisation comprising different agencies and interests, the role of policy entrepreneurship needs more exploration.

(3) Role of users

Users have usually been seen as the end point of a diffusion process and their role is mainly reflected in their purchasing power. This, however, largely overlooks many important processes of diffusion other than purchasing. How do users get awareness of a new innovation? Where do users learn the know-how and principal knowledge about the innovation? How do social structures exert an impact on their decision-making? Do users play any other role other than consumers in the diffusion process? These questions have not been explicitly answered in transitions research. The diffusion of SWH in Dezhou provides some insights to these questions and reveals the relevance of social structures and user-producer relationships in transitions (Dewald and Truffer, 2012).

Like other decentralised technologies, financial rationalities of users have been the primary determine factor that SWH is widely accepted (Sidiras and Koukios, 2004, 2005; Li *et al.*, 2011). Admittedly, users' need for high performance /price ratio water heaters since the 1990s provides a huge market niche for SWH development in Dezhou as well as in many other parts of China (Hu *et al.*, 2012). With rising living standards, a more

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hygienic but affordable lifestyle become prevalent and SWH meets this trend. Li *et al.*, (2011) place much emphasis on the economic benefits of SWH such as a short payback time in Dezhou's diffusion, but it is worth questioning to what extent consumers actually do the math in reality. The results from my interviews and observations in Dezhou also acknowledge the importance of individual economic rationality, which might be the most decisive factor in the diffusion, but it is far from enough to explain the diffusion in the difference between Dezhou and Beijing since the product offers similar economic benefits in both cities. Instead, what matters to the difference is the place-specific social structure and interpersonal networks. The hypothesis of the rational actor in orthodox economic tradition has long been challenged by the more practical notion of bounded rationality (Simon, 1982; Kahneman, 2003). Actors' economic behaviour is not necessarily merely guided by the efficiency criteria, but rather structured and shaped by actors' institutional contexts, hence, they are institutionally embedded actors (Funfschilling, 2014).

Rogers (2003) distinguishes three types of decisions regarding innovation adopting. Optional innovation-decisions are made by individuals independent from the decisions of other members in a system; collective innovation-decisions are made by the consensus among the members of a system; and authority innovation-decisions are made by relatively few individuals in a system who possess power, higher status or technical expertise. Apparently, all of these three types of innovation-decisions are found in Dezhou's case and correspond to the individual users, estate developers and municipal government respectively. The collective decision by estate developers and authority decisions by the local government have been discussed above, so I shall elaborate more on the optional decisions by individual users here. Rogers' innovation diffusion theory argues that users adopting an innovation is not simply due to impulse decisions, but as a result of a sequential stages of actions, including knowledge (i.e. be aware of the existence of an innovation), persuasion (i.e. forming attitude toward the innovation), decision (i.e. deciding to adopt or reject an innovation), implementation (i.e. putting the innovation into use) and confirmation (i.e. seeking reinforcement of the already made innovation-

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decisions). First of all, how do potential users learn the knowledge of a particular innovation? Are users only being passively exposed to the knowledge of an innovation or, on the contrary, actively seeking the knowledge out of their needs? These then are related to information channels or communication networks through which social learning of an innovation occurs.

Depending on how relatively early an individual is in adopting new innovations than the other members of a social system, innovation adopters are categorised into five types, innovators, early adopters, early majority, late majority, and laggards (Rogers, 2003). Innovators are those who venturesomely accept and introduce new ideas from a cosmopolitan level to local circle of peer networks. They are the gatekeepers in the flow of new ideas into the local diffusion system. The early adopters usually play the role of opinion leaders in a local diffusion system. They usually enjoy the higher social-economic status and serve as a role model for the rest of a social system. Through their adoptions and evaluations, the uncertainty of the innovation is reduced for potential adopters. The early majorities are those who adopt an innovation just before the average number of a system, while the late majorities adopt just after the average number. The laggards are the last group in a social system to adopt an innovation. There have been found many differences among these categories in terms of factors such as socioeconomic status, personality characteristics, and communication behaviour. Generally, earlier adopters are financially better off, have more education and higher social status; they are more open-minded and have a more favourable attitude toward changes; they are more actively engaged with their information channels and more influential in their interpersonal networks. Evidently, these adopter groups follow different logics that can not be simply assigned to economic rationalities. While some groups are more motivated by efficiency criteria, others, usually the later adopters, might just follow pioneers due to the bandwagon effect to maintain social desirability (Woersdorfer and Kaus, 2011). When there are enough individuals adopting an innovation, it comes to the point of critical mass, where the further diffusion of the innovation become self-sustaining.

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The diffusion of SWH in Dezhou also shows these adopter categories. In this case, Huang Ming is a typical innovator. He learned the idea of solar thermal energy from his personal working experience and interest and brought the knowledge from cosmopolitan level to the local. Through his entrepreneurship, the ideas were transformed to a concrete technology that offers many economic and environmental benefits. The major early adopters of the technology were those with higher socio-economic status in Dezhou such as teachers and doctors. They were respected and trusted in local society and their adoptions led to a role model effect. In terms of the collective SWH-building integration, the local government, building design institutes and some estate developers were the early adopters. However, there was also a portion of early adopters who were the relatives and friends of the SWH entrepreneurs. They did not necessarily play the role of opinion leadership, but were able to facilitate the diffusion through their own interpersonal networks. The subsequent diffusion of SWH had much to do with its economic benefits, but the close interpersonal networks of local society also played a critical role. If merely judging from financial capacity and environmental attitude, which have been regarded as the primary determinants of the diffusion of many environmental technologies, SWH should have been more popularised in Beijing rather than Dezhou. On the contrary, the key factor, in this case, is the place-specific communication networks. This also has been revealed by Woersdorfer and Kaus (2011), who found that peer group behaviour was the main trigger for solar thermal system adoption in Germany.

How local communication networks work in the diffusion of innovations relates two concepts, homophily and heterophily (Rogers, 2003). Homophily refers to the similarity between individuals in certain attributes, such as occupation, education and beliefs. A generalisation proposed by Rogers (2003:305) is that "exchange of ideas occurs most frequently among the individuals who are alike, or homophilous". This is because communication between those who are alike is usually more effective as they share common meanings and mutual understandings. On the contrary, communication between people with marked differences could be less effective due to the knowledge, cognitive and even psychological distance. Therefore, interpersonal communication networks are mostly homophilous. Homophily could act as a barrier for diffusion from a vertical perspective as elite groups seldom interact with the non-elites, but once an innovation is adopted by members in a homophilous social system, it is very likely to diffuse fast horizontally as a consequence of effective social learning. The notion of homophily and heterophily provide useful insights to understand the difference of SWH diffusion between Dezhou and Beijing. It seems that a city's social variety (heterophily) grows with its economic development. Generally speaking, the more economically advanced a city is, the higher social variety it has (Thomas and Darnton, 2006). As a modernised international city pulling in millions of immigrants annually, Beijing is a city of social varieties in occupations, educations, incomes, beliefs and other socioeconomic characteristics, and the gap between the social members could be extremely large. High variety is believed to be beneficial to the generation of innovations (Florida, 2002, 2005), but it could also pose a barrier to diffusing an innovation widely among various social groups. In contrast, less developed cities are quite often constrained to limited industries, their social systems are more characterised as homophily in socioeconomic status and cognitive attitude. Being a latecomer to industrialisation and urbanisation, Dezhou was such a city with a rather homophilous social system. Therefore, the social learning of SWH installation through observation and communication happens more frequently and effectively due to social members' similar socioeconomic conditions. Also, social learning, in turn, enhances homophily. As Woersdorfer and Kaus (2011:2283) state, "Social learning thus produces a homogenization of consumption patterns in intensively interacting consumer groups".

Nonetheless, the notion of homophily only describes the similarity within an interpersonal network, not the strength. Homophily increases the probability of communication, but not necessarily the trust between social members, which may be more critical in social learning. Peer behaviour is an important trigger of diffusion, but peer behaviour from

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strangers may not bring as much influence as that from acquaintances who know and trust each other. Like heterophily, weak social ties are believed to help individuals being exposed to more opportunities (Granovetter, 1973, 1983), and thus, facilitate diffusion of an innovation to different social systems and distantly located places. However, within a specific social system, strong social ties could be more helpful in diffusing an innovation to a larger number of social members. Strong ties not only enhance the trust among social members on the pull side but also increase the peer pressure on members who do not adopt the innovation on the push side. As demonstrated in Chapter 4, the afraid of 'losing face' to peer communities has been an indispensable driver of SWH diffusion in China's rural society. The social structure of China's traditional rural society is based on kinship relations or guanxi networks, in which individuals build social networks along their own kinship ties with themselves locating the centre, resembling "the cycles that appear on the surface of a lake when a rock is thrown into it" (Fei, 1992:60). As society modernised, kinship relation is increasingly challenged by friendship relations and business relations. The more modern a society is the fewer kinship relations in place (Inkeles and Smith, 1974; cited in Al-Haj, 1995). Dezhou is transitioning from being an agricultural society to an industrial society. The kinship relations within its social structure have declined but still remains a distinct characteristic when compared to the modernised cities. Furthermore, unlike Beijing and other big cities, where urbanisation is primarily contributed by immigrants from various regions of the country, Dezhou's urbanisation is mainly a consequence of the transformation of local rural residents into urban residents. Therefore, their kinships, friendships and neighbourhood relations remain in Dezhou's urban society, and these strong ties facilitate the diffusion of SWH through effective observation and word-of-mouth communication, as well as peer pressure among acquaintances.

The strong social ties not only work among consumers but also enhances user-producer relationships. The close interpersonal networks at the regional level play an indispensable role in the diffusion of market and technology information, which are essential to the

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formation of industry clusters (Li, Bathelt and Wang, 2011). Researchers emphasise the co-location of users and suppliers in local market formation, especially in the early phases because spatial proximity enhances interaction and mutual learning (Dewald and Truffer, 2012). However, judging from my observations in Dezhou and Beijing, the co-location of producers and potential users does not necessarily lead to close interaction between them. Beijing is the birthplace of China's SWH technology and owns one of the largest SWH clusters in China, but the cluster's market is primarily outside of its own administrative territory. What makes a difference in Dezhou's case, however, is the close social ties between producers and local residents in the early development stage. In Dezhou's case, many pioneering adopters of SWH were the entrepreneurs' relatives and friends, who adopted the innovation because of trust and kinship relations rather than being financially better off and more open-minded to innovations. As the industry grew in the local economy, a big portion of the local residents was involved with the supply side both directly and indirectly as employees, sale agents and the like. With many acquaintances working in the SWH industry, the local residents were even motivated to adopt the innovation through frequent trust-based communication. As I have presented in Chapter 4, interpersonal networks or guanxi also matter significantly in the growth of SWH-building integration market. Many interviewees have suggested that guanxi plays the key role in winning collective installation projects from estate developers and governments. In project markets, local SWH enterprises normally have a close interpersonal relationship with local estate developers and government projects, which makes it difficult for non-local SWH enterprises to enter the market. Though many large estate developers focus more on SWH quality, guanxi is still an underlying consideration in decision-making.

While the guanxi network still prevails in transitioning cities such as Dezhou, it is much less dominant in post-industrialized modern cities where traditional informal social rules have increasingly been replaced by formal market rules and legal configurations (Guthrie, 1998; Hsu and Saxenian, 2000). Since SWH technology is not mature enough from a

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purely technological perspective, relying merely on market rules to diffuse the environmental technology may not be sufficient, especially in modernised urban areas. Traditional social relations have often been viewed as a barrier for the modern market system, but in this case, they demonstrate several advantageous aspects in popularising the decentralised technologies for public well-being.

Therefore, the role of users in sustainability transitions lies in not only their rational preferences that offer an indication directing transition from one type to another (McLellan, Chapman and Aoki, 2016), but equally and maybe more importantly, their place-based social relations and trust relationships that help to form a close niche network containing both the demand and supply side to facilitate the transitions. Therefore, some scholars have advocated focusing on the community level rather than the individual level in sustainability transitions so that the social capital and trust in the community could be taken advantage of (Aylett, 2013). Moreover, when a transition discourse becomes dominant in the community, a sense of place identity is enhanced, which in turn reinforces the mobilisation of more resources and participations (Späth and Rohracher, 2014a). As Aylett (2013:869) shows the example of Solarize Portland:

> By changing the scale of action from the individual to the community, Solarize accomplished two things: it was able to use social ties to build demand for technological change, and simultaneously to use technological change to reinforce and expand those ties through a shared sense of accomplishment that community members could point to with pride.

Likewise, the reputation of being China's Solar City increases Dezhou residence's sense of community identity, and thus, reinforces their faith in the transition to solar energies. Again, kinship-based social relations are more easily found in less developed regions (Späth and Rohracher, 2014a), and latecomer cities in modernisation could still make use of it to promote certain environmentally-benign innovations, on the precondition of formal legal rules.

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6.3 Multi-scalar interactions and power

> While the sub-national scale is important to speed up RET deployment and niche development and garner local support for RETs, they cannot function independently from strong incentive policies at the national scale. While it is important to consider the sub-national scale in transition research and policy, an exclusive focus on the sub-national scale and neglect of national and supra-scale processes will result in an incomplete understanding of those processes. (Essletzbichler, 2012:813)

The previous section only discusses the place-specific factors that facilitate or hinder sustainability transitions at the local level. However, it is problematic to isolate contextual factors from non-local relations in understanding where transitions take place. Jessop, Brenner and Jones (2008) argue that socio-spatial theory needs to contain a multi-dimension of territory, place, scale and network (TPSN), and single dimension could lead to:

> the trap of conflating a part (territory, place, scale, or networks) with the whole (the totality of socio-spatial organisation), whether due to conceptual imprecision, an overly narrow analytical focus, or the embrace of an untenable ontological (quasi-)reductionism. (p391)

The mere focus on place overlooks the process in which place productions are interrelated with the territory, scale and network. The dynamic of the place-specific factors is never self-sustaining in closed territorial containers. Instead, it is intertwined with networks that cross multiple spatial scales. A multi-scalar understanding of regional development would help to reveal why certain place-specific factors gain impetus in particular contexts and how local transition practices can exert influence on higher scales.

This research understands the different SWH adoption level in the two cities as a consequence of not only place-specific factors, but also multi-scalar interactions (Figure 6.1). This includes not only vertical relations (e.g. local-regional-national-international) but also horizontal relations among places. While the international consensus on climate change have legitimised and encouraged the development of the SWH industry in both Beijing and Dezhou, this had greater purchase in Dezhou where a configuration of a

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dominant local firm, supportive local government and engaged consumers came together to form a protective niche. Dezhou's local practices were not only scaled up to the national level, but also influenced China's institutional landscape by promoting the making of the Renewable Energy Law, after which the industry enjoyed a favourable policy environment. Urban practices can thus influence policy at higher levels reflecting the two-way relationship between policy levels (Hansen and Coenen, 2015). In China's transition to solar thermal energy, Beijing plays a role as a technological niche, while Dezhou is both a technology and a market niche. Horizontal links between the two cities are also pivotal as flows of technological know-how and talent are of particular importance to the development of Dezhou's SWH industry. As Carvalho, Mingardo and Van Haaren (2012) illustrate, local clean-tech innovations are co-evolved with local innovation milieus of actors, networks, and institutions, and higher order structures (e.g. national policies), as well as global knowledge mobility. These horizontal and vertical linkages and interactions between multiple scales can help to destabilise incumbent regimes and opens a window of opportunity for the growth of the niche (Murphy, 2015).

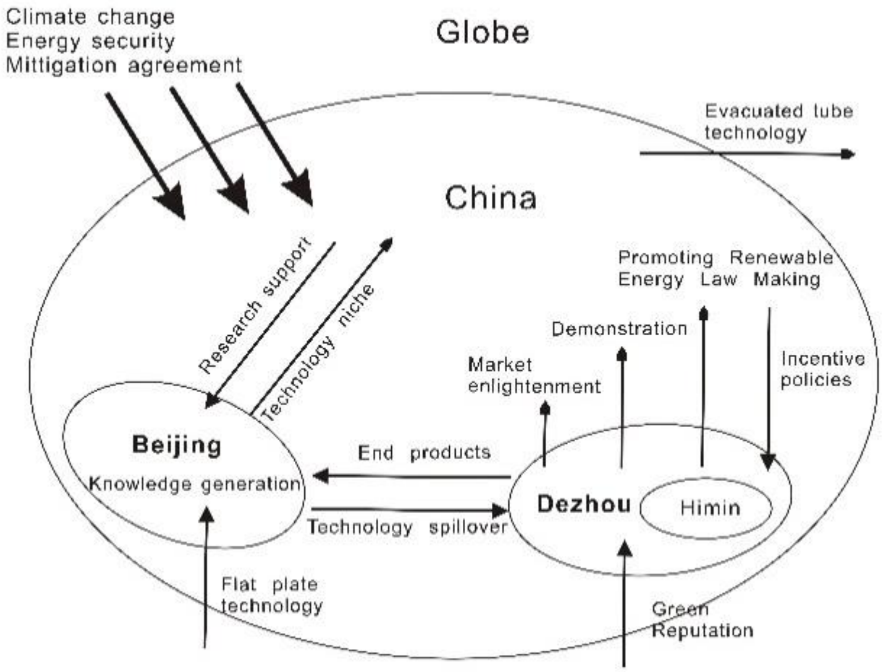

Figure 6.1 Multi-scalar interactions of the SWH industry in China

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Nonetheless, it remains unclear exactly how, and to what extent, non-territorial relations impact upon territorial features (e.g. resources, actors, interests and institutions). This raises a number of questions - what kind of multi-scalar interactions facilitate the local niche development? How are the interests of different governance levels coordinated to sustain the transitions? In what way do multi-scalar relations empower local actors to challenge incumbents? The following section will discuss three crucial dimensions in sustainability transitions: knowledge, interests, and power from a multi-scalar perspective.

6.3.1 Knowledge flow

Knowledge generation and diffusion is one of the critical functions in a technological innovation system (Hekkert *et al.*, 2007; Bergek *et al.*, 2008). The development of Dezhou SWH industry exhibits the key role of extra-regional knowledge relations in sustainability transitions (Binz, Truffer and Coenen, 2014). Less developed regions are generally wanting in endogenous financial and technological resources for knowledge creation, which has been a crucial restraining factor of regional development. Thus, knowledge learning from developed regions, to a large extent, is indispensable to their leapfrogging. Universities and research institutes are the key players in scientific knowledge generation, but these players are generally absent in less developed cities like Dezhou. As the home to many top universities and national research centres, Beijing naturally became the central city in receiving national R&D investment in solar thermal technology in response to the global energy crisis in the 1970s. While China still relies on foreign technology for flat-plate solar thermal collectors, it has become the world's leading country in vacuum-tube technology, which was one of the few examples of China's indigenous innovation. Possessing the two key solar thermal technology players, Tsinghua University and Beijing Solar Research Institute, Beijing grew to be China's knowledge centre for solar thermal technology. The knowledge generation of this technology is thus attributed substantially to national behaviour out of energy security concerns.

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The technology was not widely applied until it entered the business field for civil use. The knowledge diffusion of solar thermal technology had initially occurred within Beijing, giving birth to several private SWH firms and then one of China's largest SWH clusters. Responding to the call for industry-research cooperation, Tsinghua University also established its own SWH firm, Tsinghua Solar. The knowledge began to diffuse nationwide when Tsinghua University hosted two solar thermal technology workshops in 1991 to encourage its commercial applications. These workshops played a critical role in the early diffusion of solar thermal technology knowledge and had greatly driven the entrepreneurship of SWH business by cultivating many technological entrepreneurs, including Huang Ming. This process symbolised the beginning of knowledge transfer from the national level to local level, from public to private, and from centre to peripheries.

Before attending the Tsinghua technological training workshops, Huang Ming had already begun his own research on SWH technology through his personal learning in the late 1980s. However, his technology was not mature until receiving the technology spillover from Tsinghua Solar. At the beginning, Himin was established as a regional manufacturing branch of Tsinghua Solar in Shandong Province. The core technology of evacuated tubes was possessed by Tsinghua Solar, and Himin was restricted to assembly. The cooperation was suspended two years later because both firms decided to expand their businesses to the whole industry chain as the SWH market grew quickly. Nonetheless, the initial cooperation was vital to Himin's technology learning in evacuated tube technology. Himin began to catch up with this core technology after it brought in an international leading vacuum-tube technology, the Three High Vacuum Tube, from Sydney University, Australia. The leading scientist of this technology, Dr Zhan Qichu, a Chinese-Australian, became the chief scientist of Himin's R&D team. Despite locating in a talent-absent city, Himin was able to keep its technological advance through its national and international knowledge learning network. For instance, Himin set up a joint research laboratory with China's Academy of Science in Beijing, and it designed China's first solar

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thermal electricity generator in 2004. Its cooperation with Shandong University (in Jinan) also gave birth to the Balcony-SWH for high-rise buildings. The same strategy was applied by other big solar thermal firms in Dezhou, such as Vicot and Zhongli, whose cooperation with Beijing's universities and research institutes was very crucial to their technology advance. It could be fair to say that these relations with knowledge abundant places are indispensable for latecomers to catch up.

Down to the local scale, these big firms, especially Himin, play the role of global pipelines in importing advanced knowledge through their own networks and diffuse them to the local cluster through local buzz. Small firms find it difficult to establish wider learning networks, but their geographical and social proximity to local large firms greatly lowers their obstacles for knowledge learning. As many interviewees suggested, SWH technology involves many experience and learning-by-doing, hence, tacit knowledge. Talent mobility is the key mechanism by which the technology diffuses in Dezhou's local milieu. As I have discussed above, the local interpersonal network encourages SWH entrepreneurship in Dezhou. Many small firms do not invest in R&D activities, but simply imitate others. As one entrepreneur put it:

> We now have nearly 70 people in our firm, but none of us engages in R&D. To be honest, what we do is simply imitation. Because small firms like us do not need R&D. The technology has been very mature, and the efficiency of the absorbing film has reached 95%, there is very little room for improvement. It has come to its limit, and only large firms are trying to find alternative solutions, such as ceramic materials or plastics materials [Interviewee 12]

Interestingly, the weak implementation of intellectual property protection (IPP) seems to have facilitated knowledge diffusion because imitation is not seriously punished. As an R&D manager of a large firm said:

> We put like RMB 5 million annually in IPP, but this only works with other large firms. Small firms can not even afford the lawsuit. We did go to court sometimes and we won, of course. I don't think any problem with the IPP law, but the implementation. We pay the money for IPP, but it doesn't work

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> properly. The key problem is implementation...it is not strict enough, the violation is only punished with some fine [interviewee 9].

Due to Himin's national influence, the spin-offs from Himin spread around the country, carrying the knowledge nationwide. In addition, Vicot's solar thermal air-condition technology also came to dominate the industry. To some extent, due to these large firms, Dezhou is not simply a knowledge receiver, but has also become a knowledge generator that contributes to the further diffusion of solar thermal knowledge nationwide. This is not only confined to technology information, but also the experience in SWH-building integration and mandatory installation policies. Nonetheless, its technology improvement still requires continuous non-local relations with knowledge-abundant places. The shortcoming in knowledge generation is a key barrier in latecomer cities, and it cannot be overcome in short run. But this doesn't necessarily impede their learning from developed regions, especially when a few energetic actors are able to draw the knowledge from wider levels into local milieu through their multi-scalar networks.

6.3.2 Interest coordination

The popularisation of solar thermal energy in Dezhou displays the significance of interest coordination among different governance levels because it is the key mechanism whereby local niches gain legitimacy or are empowered (Hodson, Marvin and Späth, 2016). Needless to say, global climate change has exerted unprecedented landscape pressures at the international level. Green development, reducing carbon emissions, and the like, have been the imperative discourses around the world. However, these pressures are not equally assigned to, and perceived by, every country. Apparently, small economies are not expected to contribute as much emission mitigation as large economies such as OECD countries. Confronting the same global environmental challenge, large economies are exposed to more international political pressure to make changes. As the world's second largest economy, 'world factory' and largest carbon emitter, China shoulders much more responsibility in carbon mitigation than most of the other countries. These landscape pressures resonate China's endogenous challenges in energy security and environmental

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improvement. China's framing of sustainable development problem has gradually shifted from focusing energy security in the early stages to more concern about global climate change and domestic environment pollution due to the rising demand for clean air from civil society. This problem framing reflects China's national interests and motivations in low carbon development.

In response, China was among the first group of countries signing the Kyoto Protocol in 1998. More importantly, many institutions have been changed at the national level to facilitate low carbon development. Not only were the national FYPs prioritising renewable energy development, but also the Renewable Energy Law was enacted to provide a supporting institutional framework. Also, China is making efforts to shift its GDP-oriented CPES towards more weighting on the environment, though this change has different levels of purchase in sub-national governance. The global financial crisis in 2008 also stimulated China's large-scale investment in the green energy sector in order to both maintain economic growth and cater to global green visions. Since 2009, China's political leadership has made several solemn promises to the international community regarding China's target for carbon mitigation. '*Jie neng jian pai*' (energy saving and carbon mitigation) has become a new prevailing discourse in China's media, government running and business field. These problem framings and institutional changes at the national level are essential because they transform the economic, ecological and political landscape that favour certain types of green development at the subnational level through economic priorities, standards and regulations (Hodson, Marvin and Späth, 2016). National institutions thus contextualise the interaction between regimes and niches at the lower scales. It is particularly important that parameters and priorities have been altered in the economic realm. Those economic activities that are in accordance with national priorities in green development will normally be supported by policies and resources such as financial funding.

Though interests at the national level in many cases shape priorities at the lower spatial

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level, they might not be realised without satisfying various interests across scales. Accompanying the marketization of China's economy since the Reform and Opening is the decentralisation of political power from the central government to subnational governments. Provincial and urban level governments gradually gain more administrative autonomy and responsibility to govern the social-economic activities within their territories. Since 1994, China's tax-sharing reform has caused a great transformation in the relationship between the central government and local governments. The tax reform devolves more administrative responsibility to local governments, but largely decreases their proportion in national tax revenue distribution. For instance, the central government retains 75% of the added value tax, and local governments only have the remaining 25%. The fiscal revenues of local government are restricted to fewer categories such as business tax, income tax of local corporates, and income from transferring state-owned land use. With the rise of administrative responsibility and the decrease in tax revenue from national distribution, local governments have an inherent interest in increasing their fiscal revenue by enlarging the local economy base. This reform has been widely believed to have stimulated economic competition among local governments and thus singularly drives China's economic growth. The devolution of power from the national to the local level has caused a profound effect (Tyfield, Ely and Geall, 2015). Additionally, the overwhelming weight placed on GDP in the CPES further motivated local governments to support local large industries. The recent adjustment towards environmental performance has led to many champions of local green industries.

For many centralised energy systems (e.g. geothermal heating and wind energy), local governments are the main adopters due to the huge threshold of infrastructure investment. When it comes to decentralised energy systems such as PV and SWH, it has to be asked whether the national and local priorities are compatible with wider public and householders' interests in comfort, convenience and reducing bills (Hodson, Marvin and Späth, 2016). The development of the SWH industry in Dezhou displays an important coordination of interests between governance levels. As discussed above, municipal

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governments have an inherent motivation to support green industries because of both economic and environmental benefits. At the individual level, SWHs meet individual citizens' interest for hygiene and bill saving. These interest congruences are reinforced as positive outcomes enhance the confidence at each scale.

6.3.3 Agency and Power

Dezhou's transition to solar thermal energy is not simply a passive response to national priorities, rather, it also contributes to shaping national institutions from the bottom-up. Not only were Dezhou's practices, such as SWH-building integration and mandatory installation policy, followed by many other cities around the country, but equally important, its powerful industrial actor promoted China's Renewable Energy Law legislation. This might be incidental more or less to a less developed region, but in fact, it helps to understand the paradox of embedded agency, that is, how an agency that is constituted by institutions could develop against and shape the institutions (Funfschilling, 2014). The previous section offered an account as to why particular actors (e.g. SWH entrepreneurs and local government) can have agency in challenging the regime in the place-bound circumstance, but what is missing here is how they gain power through multi-scalar actor relations.

An important fact is that Huang Ming worked for a state-owned research institute in Dezhou before turning to SWH business. Huang Ming was among the first group of university graduates after China resumed the college entrance examination system in 1977. At that time, university graduates were very highly valued and respected in the society, because very few people could have access to higher education. They were deemed as social elites, or '*Tian zhi jiao zi*' (the ones blessed by God), especially in the less developed areas. During 1978-1988, graduates from China's public universities were not allowed to choose jobs by their own wishes, instead, it was the state at the different levels that uniformly allocated jobs according to the demand in SOEs and institutions. After graduation in 1982, Huang Ming was assigned to a state-owned oil drilling research

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institute, which was located in Dezhou but administrated by China's Ministry of Geology and Mineral Resources[18] of the central government. Huang Ming worked as an oil drilling equipment expert in the research institute for 12 years before he started his own SWH business. It was during this working experience that Huang Ming learned that oil drilling is not sustainable and developed the idea to develop renewable energy. This professional experience not only allowed Huang Ming to have access to knowledge from wider networks, but also facilitated his SWH business because local consumers have more trust in entrepreneurs from an SOE background. This career path enables Huang Ming to have a more favoured position in entrepreneurship than many other local farmer entrepreneurs, in terms of technology and marketing. Assigned organisations or elites to less developed regions from the higher governance levels usually have more influence at the local place. Due to their limited stock of both knowledge and capital, less developed regions are generally difficult locations to cultivate their own local elite actors and large scale-transcending enterprises in the first place. The location of assigned SOEs and actors from higher levels can thus exert more influence if they are able to interact closely with local networks.

By drawing upon knowledge spillover from technology leaders at the national and international level, Himin quickly developed into the world's largest solar thermal energy manufacturer mainly due to China's fast-growing SWH market. Its environmental achievement was well recognised at the international level and national level, which in turn facilitated further financial and technology investment from international players. Huang Ming himself was a national political actor when he was elected the delegate of NPC. The industry is able to bring such a substantial impact to the local development pathway, not only because of its crucial role in the local economy but also its multi-scalar relations. The industry and the niche practice gain the power to challenge the local regime because of its coincidence with higher level interests and through establishing technological, financial and political relations. Such scale-transcending actors thus have

[18] It was incorporated to the Ministry of Land and Resources in 1998.

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a very pivotal role to play in the transitions of latecomer areas.

Similar observations may also apply to the political actors. Unlike in many Western political systems, where local leaderships are elected locally, the leadership in China's local government is usually appointed by the higher-level government. While most of the local leadership are promoted from the local government system, there are many local leaders appointed from both the vertical level (e.g. leadership from other administration regions) and horizontal level (e.g. leadership from SOEs and state-owned Universities). They can move between governments in different places, SOEs and ministries. This enables the assigned leadership to carry their governing experience from one place or one field into another one. The appointed leadership in Rizhao is a typical case, in which the Mayor brought his own expertise in solar energy and network from previous leadership experience in Shandong Technology University to popularise solar energy in Rizhao (Bai, 2007). Local political leaders can exert their power by exercising interpretive, formal and network leaderships (Hu and Hassink, 2015). This is not suggesting that such appointed local leaderships from higher-level are indispensable to the sustainability transitions in latecomer regions, but highlighting their external relations could be beneficial to local transitions.

Latecomer regions are capable of fostering elites, but less likely those actors with multi-scalar networks that empower them in local contexts. Therefore, the assigned political leadership, local branches of SOEs or TNCs may play an effective role in establishing trans-local relations in local places. Transition initiatives led by these elite actors may not only alter the local socio-technical configuration, but also can exert influence on the broader transition at the higher level. This view is well expressed by Späth and Rohracher (2014a:118):

> local actors aiming to bring about fundamental change to a local energy system are, in many cases, dependent upon the support of non-local institutions, policies and actor constellations (particularly at the provincial, national and EU levels). However, such local initiatives are also important

> for broader transition dynamics, not only due to the nurturing of socio-technical niches, but, more importantly, because they can establish and align supportive institutions, visions and actor networks and facilitate changes also beyond the locality (advanced standards, model for other cities, etc.) and, consequently, can expect some support from 'higher' governance levels, given their successful networking.

This analysis displays the key role of agency and power in the sustainability transition in latecomer regions. The ability to act against institutional structures or regime is not simply by virtue of possessing resources. Rather, as Smith and Raven (2012:1031) see it, "agency as the result of a collective and embedded capacity and hence developed and reproduced through actor networks". Nonetheless, neither actor networks that are too inward-looking, nor those that are too outward-looking could bring sufficient power in driving changes. As Bathelt, Malmberg and Maskell (2004) have argued, too strong a reliance on external relations could hollow out local clusters due to less communication among local networks. Therefore, certain key actors are expected to link local networks with trans-local networks, through which knowledge, resources, reputation and legitimacy are gained to empower local initiatives. The Dezhou case shows an explicit local network of SWH industry, local government, estate developers and civil society, with the large enterprise Himin at the centre interacting with trans-local networks, drawing knowledge from its global pipelines, receiving international financial investments, influencing the national institutional structure and earning a pioneering green image. Based on this, three national associations awarded Dezhou as China's solar city, which further enhanced the city's vision in solar energy. These key actors thus play the role of intermediary between the local node and global network (Späth and Rohracher, 2014a).

A similar observation was found in the energy transition of Murua, a small peripheral region in Upper Styria, Austria (Späth and Rohracher, 2010, 2012, 2014a). Its transition to biomass energy was attributed to several territory-bounded features, such as a large stock of wood biomass, not being connected to the gas supply network due to a small and dispersed population, and a relatively close-knit community which enhances trust.

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Nonetheless, Späth and Rohracher (2014a) stressed the critical role played by the head of the regional energy agency, who together with a small circle of professional energy activists developed the ‘Energy Vision’ of Murau, combining both the environmental discourse of de-carbonisation and the economic development discourse. The initiative was recognised as a guideline at various spatial reaches from local to EU level. This is substantially attributed to the fact that the regional energy agency director was also an official manager of the regional EU-LEADER programme and participated in development planning at the Upper Styria level. The competencies and reputation of this single expert facilitated the up-scaling of Murua’s transition vision. As Späth and Rohracher (2014a:113) describe his role,

> he was involved not only in most of the debates concerning the economic development of the regions but also in the discussions with experts and funding agencies about the design and management principles of funds for regional development at the national and European level. Hence, he formed an important link between the local network and networks in command of the required resources at the national and international levels, including the national and European communities of experts on regional development, the European network of energy agencies and various EU research projects.

Dezhou’s case differentiates from Murua in that it is the star entrepreneur rather than political actors that fulfilled the intermediary role in linking local and trans-local networks. However, we should not overestimate the role of elite actors at the expense of missing institutional structures in latecomer regions’ sustainability transitions. Elite actors and their trans-scaling networks do not come out from nowhere. They are not in free rein but, on the contrary, are still “operating within a context of institutions, norms and rules which condition their choices and relations, i.e. within a broader system which is constituted by both structures and agents” (Boggs and Rantisi, 2003:111). Elite actors may have more agency against the institutional structure, but, in fact, the resources and relations that empower them are usually acquired from the very multi-scalar institutional structure. As the Dezhou case exemplifies, it is through meeting the institutional expectations at the different levels (e.g. economic saving at the individual level; GDP growth at the local level, and environment targets at national and international level) that the SWH industry

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is empowered to make a difference in Dezhou.

This analysis resonates with Yeung's (2005) advocacy to avoid polarised explanations between institutional structure and actor network, and to pay more attention to the 'relational geometries'. Relational geometries connect actors and structures through horizontal and vertical power relations, thus, actors are dynamic and evolving in such relations that they practice various forms of power through social actions and according to their positions in relational geometries. Relational geometries may be too complex to depict because they comprise "local and non-local actors, tangible and intangible assets, formal and informal institutional structures, and their interactive power relations" (p48), but they do suggest a middle way to link the two polarised frameworks in contemporary economic geography – actor networks and institutional structures. As such, regional development or transition is no longer simply explained by the presence of advantageous assets or institutions in 'lucky' regions (Storper, 1997:44), but also through the "relational complementarity and specificity of these actors, assets and structures" (Yeung, 2005:48).

6.4 Sustainability transitions in latecomer cities

Although not explicitly expressed, there is a general assumption in transition research that landscape changes impose undifferentiated pressures to regimes at lower spatial scales. However, it is often the case that the extent that landscape changes affect the preference and awareness of local actors are different (McLellan, Chapman and Aoki, 2016). Apparently, China's political system exerts different landscape pressures on the two case study cities. The general landscape discourses may have been adjusted towards the green economy, but they have been interpreted differently at the local level. For forerunners of economic development, they suffer more pressure on the transformation of economic structure and have a higher imperative to green the economy, while latecomers still view economic development as the first priority. Therefore, the landscape of the green economy has a very different purchase between developed and less developed cities. In the former, they pay more attentions to the 'green', but for the later developers, the

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'economy' is of more concern. Even so, 'green' activities would still be supported in latecomer areas if they are incorporated into local economic development strategies. If the green industries bring sufficient economic benefits, they would be valued and even more favoured as it also brings green images, which may provide another incentive for local government. The landscape discourse of the green economy thus exerts a top-down impetus for changes in existing regimes by altering the performance criteria and the expectation of policy makers and industries, limiting the potential improvement of established technologies, and opening the window of opportunity for new actors (Tsoutsos and Stamboulis, 2005). Scholars have also argued that green niche development could be combined with local economic development in non-core regions (e.g. Scott, 1988; Storper and Walker, 1989; Boschma and Van der Knaap, 1997; Essletzbichler, 2012). Linking environmental sustainability to regional path creation not only strengthens local industry's competitiveness but also delivers the economic benefits that less developed regions most long for, and thus, ally more strategic actors to empower niche development (Essletzbichler, 2012).

Applying the MLP framework from a geographical lens, this chapter analyses the underlying factors that facilitated Dezhou's transition to solar thermal energy and discusses the general advantageous conditions for sustainability transitions in latecomer cities and regions. Through the contrast with Beijing's case, this research argues the transition in Dezhou is mainly explained by its place-specific niche-regime interactions, which are shaped by both place-bound assets and institutional structures, as well as multi-scalar relations. Other than identifying the uniqueness and specifics of Dezhou's sustainability transition, this discussion also attempts to illustrate the general niche-regime interaction in latecomer regions. Section 6.2 presented the regime resistance and niche development separately, however, it has to be noted that the two levels are not independent of each other, rather there is a trade-off relationship between them. The regime and niche are involved in an on-going interaction and their status depends on the strength of the other. A weak regime gives more space for niche development, which

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further weakens the regime. Therefore, the above presentation of regime resistance involves niche development and vice versa, in order to avoid a static description of their interactions. Moreover, the boundaries between regime and niche in practice are not that clear-cut as suggested in the MLP (Hörisch, 2015). It is more complex when it comes to specific actors, who can cross niche-regime boundaries and possess both characteristics simultaneously. As argued, there are many struggles between changing force and structure within local government, rendering a dynamic role of local government in specific transitions. Similarly, green entrepreneurs are not necessarily being niche actors all the time because they may "move between 'green' and 'conventional' business, evolving over time, such that this is a fluid and blurred, rather than static, state" (Gibbs and O'Neill, 2014a:1102).

Although the boundaries are not straightforward, it is still able to see distinct niche-regime interactions between places at different development phases. This thesis proposes that sustainability transitions are more likely to occur in latecomer cities with less regime resistance but powerful niche development. Spatially locked-in capital investment and consumption norms constitute the major challenges for the substitution of fossil fuels, but developing world locations usually have not been locked-in in the same way and this can provide opportunities for the rapid uptake of renewables (Bridge *et al.*, 2013). Such cities overall face less regime resistance for new technologies, leaving space for niche growth and ultimately regime changes if the niche actors are able to take full advantage of latecomer advantages. Actors and institutions at the local scale, therefore, play a key role in shaping niche development (Dewald and Truffer, 2012).

I have demonstrated that the transition to solar thermal energy in Dezhou is the result of the struggle between weak regime resistance and strong niche development. Suitable building infrastructure, less demanding but networked consumers and supportive local government policies formed a favourable selection environment for the SWH industry to grow and to align with other actors, gaining momentum to up-scale and replace the

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existing weak regime. In line with Dewald and Truffer's (2012) research into the German PV industry, locally bound market processes have provided a basis on which Himin's promotional strategies could build, while trust between pioneering and other users has facilitated diffusion. Conversely, Beijing, in spite of its core position in SWH technology development, has failed to diffuse SWH widely because it has been locked-in by building infrastructure, consumer preferences and institutions that are hostile to SWH adoption. Different institutional logics in specific cities may, therefore, encourage or hinder transition processes (Hansen and Coenen, 2015). As Fuenfschilling and Truffer (2014) argue, niche growth needs not only an internal niche formation process, but also to coincide with specific regime institutional logics so that increasing support could be gained. In applying new green innovations, developed cities may be locked-in to existing unsustainable technologies in terms of knowledge, scale economies, institutions and consumer preferences. On the other hand, new green innovations often have some disadvantages in function (Kemp, 1994), making it difficult to meet the diversified demands of developed cities. Smaller, less developed cities are less locked-in by existing technologies, as infrastructure and rules have yet to be established.

There is also a thick network of SWH actors in Dezhou because each of them benefits from positive feedback loops. The powerful firm Himin successfully lobbied local government to support the development of the SWH industry and influenced national renewables policy. The local government then became an active driver of SWH diffusion. As Murphy (2015:79) argues "niche innovators who are also well connected to and/or legitimated in the eyes of actors in an incumbent regime can play a particularly important role in facilitating regime transitions". Local residents were motivated and real estate developers installed SWH to comply with government regulation, as well as in response to market demand. Interpersonal networks were also crucial in Dezhou - these not only facilitated social learning about SWH among consumers, but also enhanced mutual trust between consumers and producers, and promoted diffusion. Thus engaged end-users and regulatory institutional arrangements supplement formal government support

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programmes in Dezhou (Dewald and Truffer, 2012). In Beijing's SWH industry, the main actors are those concentrated in technology development, such as universities, research institutes and private SWH firms. The legitimacy of new industries or products rely on their alliance with relevant institutions of a given place, or they will suffer from high scepticism and lack user acceptance (Aldrich and Fiol, 1994). Without sufficient participation and support from local government, real estate developers and residents, the network is merely confined to technological exchange on the supply side. These results thus reveal the importance of consumer and local market formation in sustainability transitions, which so far have been only sporadically addressed in the geography of transitions literature (Hansen and Coenen, 2015).

Moreover, a strong government-industry relationship seems more likely to take place in smaller cities, since the industry has a bigger role in the local economy and city branding. Thus, green entrepreneurs may gain more power to promote the penetration of green technologies, reflecting the importance of actors and their relations in shaping institutional structures (Murphy, 2003; Yeung, 2005). Applying Smith and Raven's (2012) conceptualisation of niche protection, the economic latecomers actually provide a passive space where regime selection pressures are held off (shielding) and sustain the development of niche innovations (nurturing). The success of shielding and nurturing gives more promise to the niche innovations, empowering niche actors to gain more protective supports, which in turn "assist in further nurturing, greater empowering, and eventually the institutionalisation of the innovation within a transformed selection environment" (p1034). The process involves not merely niche innovations gaining competitiveness in established regimes (fit and conform), but more importantly, undermining and restructuring incumbent regimes to facilitate niche growths (stretch and transform), in which niche advocates such as green entrepreneurs and local authorities have a critical role to play, as shown in Dezhou's case.

Other than the presence of these advantageous conditions, equally important are the multi-

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scalar actor relations for sustainability transitions in latecomer cities. As advocated in leapfrogging research, the lack of technological and financial capacity are the key obstacles for latecomer regions and thus, the knowledge and resources that flow from developed regions is indispensable to their leapfrogging. Dezhou's case shows the possibility that less developed cities and regions can leapfrog to sustainability. In an age of globalisation and informatization, traditional disadvantages in talent and information in these cities can be compensated by the frequent flow of knowledge and talent from extra-local regions. If such cities are able to absorb technology spillover from developed cities, their latecomer advantages could help them to achieve leapfrogging. While it is difficult for latecomer cities to establish wide-scale non-local relations, a few elite actors are expected to bridge the local networks with trans-local networks. They can play the role of global pipelines in terms of knowledge learning, and as powerful promoters of local initiatives to higher governance levels through their personal economic and political relations. Therefore, it is reasonable for latecomer regions to make great efforts in recruiting global high-end talents, not simply because of their professional skills, but more importantly, their multi-scalar networks with the external world.

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Chapter 7 Conclusions

7.1 Thesis summary

Global environmental change has imposed an unprecedented challenge to modern human society. Considering its huge scale and high complexity, addressing climate change inherently calls for systemic and radical transformations at the global, national, and local level. Sustainability transitions research has become an emerging research field since the 1990s due to its focus on fundamental transformations towards more sustainable production and consumption. While the research field has achieved many theoretical contributions and practical implications, it is still suffering from many shortcomings that impede its full potential. In particular, this thesis has identified a number of research gaps in the existing sustainability transitions literature. Empirically, research into sustainability transitions in developing countries remains a marginalised position and it is still not clear whether or how the 'Euro biased' transition theories can be applied in the developing country contexts since their political, economic and ecological landscapes are very different. In addition, the national level appears to be dominant in transition research, while many scholars have argued that cities and regions may have a bigger role to play in addressing global sustainability issues due to the social proximities of their niche actors and the potential to upscale local initiatives to higher levels. The key empirical gap this research has focused on is the neglect of the role of less developed cities and regions in sustainability transitions. Inspired by the leapfrogging literature, this thesis believes that less developed cities and regions enjoy many latecomer advantages in sustainability transitions, and if these advantages are well utilised, it is very likely that environmental impacts would be avoided or minimised during their periods of urbanisation and industrialisation. Therefore, less developed cities and regions have high potential to achieve environmental leapfrogging from the outset and this could have great significance for both the current and future development of human society given their likely future growth.

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Theoretically, the role of space and scale in sustainability transitions is still underdeveloped. Though there are many contributions in addressing niche innovations in various geographical contexts, less known is how the regime varies across space and how the niche and regime interact in place-specific and multi-scalar contexts. Furthermore, sustainability transitions theories, especially the MLP, are accused of placing too much account on the structure at the expense of human agency and power. The MLP puts much weight on the evolution of technological artefacts driven by rational actions, which is problematic. This thesis believes that agencies have different power relations in different geographical contexts and they are embedded in, and reproduced through, actor networks that cross scales. The thesis argues that niche actors in latecomer regions may have more power to drive sustainability transitions if they are connected to multi-scalar supporting networks. Drawing insights from the literature of sustainability transitions (MLP in particular), geography (relational geography in particular) and leapfrogging, this thesis has proposed understanding sustainability transitions as power struggles between regime resistance and niche development, and thus, latecomer regions could have higher potential for sustainability transitions as they are less locked-in by existing regimes and niche actors could be more powerful to direct desired changes. An analysis framework has also been developed to explore the latecomer advantages in sustainability transitions from the perspective of place-specific niche-regime interactions and multi-scalar interrelations. The landscape is not overlooked, rather, this research sees it working in a less direct way in transition dynamics, but playing the critical role in undermining existing regimes and empowering niche actors.

While China's achievements in PV and wind energies in recent years have been well studied, its most successful story in popularising solar thermal energy is less researched, especially at the city and regional level. China's solar thermal technology started with national investment out of energy security concerns and then became popularised mainly due to market forces at the early stage by meeting the rising demand for a bill-saving,

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hygienic lifestyle from China’s rural areas. When this technology was encouraged within cities in response to the increasing pressure of environmental discourses, it confronted many obstacles in entering the urban market, such as low technology profile, high-end consumer demand, and conflict of interests among main actors. However, these factors of resistance have different purchase in cities at different development stages. Through the elaboration of two contrasting SWH diffusion stories in Dezhou and Beijing, this research has found that the wide diffusion of SWH in Dezhou is a combined result of weak regime resistance and strong niche development, which is conditioned and shaped by the place-specific contexts and multi-scalar interrelations. The results of this research highlight the latecomer advantages of less developed cities and regions in sustainability transitions and contribute to the theoretical development of sustainability transitions through a geographical lens.

The conclusion of this research summarises the main findings in section 7.2 by answering the research questions raised in Chapter 1. Section 7.3 discusses this thesis’s theoretical contributions to the existing literature and the policy implications for sustainability transitions in latecomer cities and regions. The last section discusses the limitations of this research and suggests several avenues for future research to improve the understanding of sustainability transitions in less developed areas.

7.2 Answering the research questions

7.2.1 What is the institutional context of China’s sustainability transitions?

Though this research has focused on sustainability transitions at the subnational level, the national context is an indispensable part of the story. The national context conditions the institutions, behavioural logics, and interests at the city and regional level. In spite of its fast economic growth, China is still the world’s largest developing country, and economic development has always been the first priority of government at the different governance levels since the late 1970s. The decentralisation or power devolution to the local level

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enables local governments to play the leading role in regional development. China's tax sharing system and GDP-centred CPES together drive local governments to develop the local economy as the top priority, especially in less developed regions. The economic benefit, in most cases, is the primary rationale that green industries are supported by the governments. Meanwhile, China's framing of sustainable development problems is shifting from resource scarcity and regional ecological destruction to global climate change and cross-regional pollution, with subsequent corresponding institutional changes, such as FYP, Renewable Energy Law, and greener CPES, which have been made to encourage low-carbon industries. These national institutional contexts contextualise local interests and institutions. National green discourses destabilise the existing unsustainable regimes and legitimise local green niches. Therefore, though there has been increasing advocates for the direct interactions between the global and local scale, the national contexts still matter significantly in conditioning their relations.

7.2.2 Why and how do sustainability transitions occur in certain cities?

Due to its technological imperfection and the 'hard selection' urban environment, SWH confronts many obstacles in entering the urban market, but it has become well popularised in certain cities such as Dezhou. This research finds that the transition to solar thermal energy in Dezhou is the consequence of a place-specific power struggle between strong niche development and weak regime resistance. Compared to the developed regions, the resistance within the regime, including those related to building infrastructure, market demand and institution changes are less hostile to, and even, welcoming for, SWH diffusion in Dezhou. On the other hand, these weak regimes provide a wider space for niche development. Not only are the technological flaws accepted compared to its economic benefits, but more importantly, a positive feedback loop is developed between the powerful SWH firms, dedicated local government, motivated estate developers, and networked users. The results highlight the role of agency and actor networks. It is through a few powerful actors' multi-scalar relations that the niche actors can have access to global

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knowledge, direct market demand, lobby for policy changes and integrate with city development visions. In addition, the kinship-based interpersonal networks facilitate the diffusion of SWH. The niche development is vigorous because it caters to national and international green landscape discourses and meanwhile meets the economic interests of local governments and urban residents. Being recognised as an international green example also strengthens actors' sense of local identity and thus, they are more willing to be involved in the SWH development.

7.2.3 What is the role of latecomer cities in sustainability transitions?

The research has argued that latecomer cities have not been dominated by incumbent unsustainable regimes, in terms of infrastructure, market demand, and institutions, and this could constitute a desirable passive space for shielding, nurturing and empowering green niche development. Apparently, not all the less developed regions are able to make full use of these latecomer advantages due to the lack of capacity in generating knowledge and attracting financial investment. However, given the weaker regime resistance, niche development could be more influential as long as niche actors are able to develop multi-scalar relations that bring in knowledge, financial capital, legitimacy and reputation. Also, closer interpersonal networks can be an asset of latecomer cities in not only facilitating the diffusion of green innovations on the consumption side, but also to encourage green entrepreneurship on the production side. A few key elite actors such as large firms and political entrepreneurs could have a critical role to play in bridging local networks and extra-local networks. The new prevailing global landscape of the green economy is redefining the role of peripheral regions in the global production network, and this could, in turn, improve their 'economy' part, which is the main rationale why the 'green' part is championed in less developed regions. The latecomer cities not only have a better chance to restructure their own incumbent regimes, but also may contribute to the regime changes at the higher governance level, through being green models, altering standards, and even influencing national institutional landscape changes through the actions of the powerful

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actors present in such places.

7.2.4 How do space and scale matter in sustainability transitions?

Overall, incorporating geographical insights helps to map and understand the variance of sustainability transitions across space through the focus on territorial embeddedness and multi-scalar interactions. Though space is no longer simply viewed as the passive container of human activities, it still conditions the opportunities and constraints for sustainability transitions to take place in certain locations. Place-specific factors, such as institutions (formal and informal), future visions, industrial bases, natural endowments and interpersonal networks play various roles in destabilising (or strengthening) local regime resistances, empowering (or weakening) niche development, hence, resulting in different patterns of niche-regime interactions and thus, different transition outcomes. However, these place-specific factors are not locally bounded, rather, they are reproduced and gain significance through multi-scalar interactions. Scale matters because transition practices have different purchases at the different scales. The local scale is usually where niche innovations occur due to the proximity of actors and territorial assets, and the variance of resistance within the regime provides various growing spaces for them. The national scale plays an important role in contextualising niche-regime interactions because national interests and institutions assign different power to local niche actors and incumbent regimes. The landscape pressures at the global and national level are not equally perceived at the lower scales due to spatial differences in interests and institutions, which can also lead to different patterns of niche-regime interactions. Moreover, the relational understanding of space and scale helps to understand how local agency and power is gained through scale-transcending actor networks and how they exert influence on sustainability transitions at the different governance levels.

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7.3 Contributions of this thesis

7.3.1 Contributions to sustainability transitions theories

Responding to the calls for a geographical perspective in sustainability transitions research, this thesis has contributed to the debate about where sustainability transitions take place by focusing on the role of less developed cities, which has so far rarely been addressed. It also responds to calls to investigate the socio-spatial embedding of transitions and those locations which are amenable (or not) for transitions and technologies (Truffer, Murphy and Raven, 2015). By drawing insights from economic geography and the leapfrogging literature, this research has developed a unique framework (i.e. place-specific power struggle between niche development and regime resistance) to analyse the transition mechanisms in less developed regions and revealed their latecomer advantages in shifting to sustainability under the global landscape of green development. While sustainability transitions in large world cities may be more crucial for global sustainability targets, sustainability transitions in less developed cities and regions could be more cost-effective due to the fact that they are less locked-in to the incumbent regimes (e.g. infrastructure, social demand, institutions and interests). To fulfil less developed cities' potential in sustainability transitions, it is essential that local niche development coincides with the interests at various governance levels and that certain economic or political actors can develop multi-scalar relations through which knowledge, resources and legitimacy flow in. It is less likely for less developed regions to establish wide-scale non-local relations, but it is very likely for certain key elite actors to bridge local and non-local networks through their own relations. These actors are able to act their agency in local transitions because of their relative importance in the local economy and city branding activities, as well as their multiple relations with higher scales. These relations can be built through meeting the interests of multiple scales. This analysis thus challenges the emphasis on the technological rationale in the MLP and demonstrates how agency and power matter significantly in directing transitions. This analysis is not advocating that agency and power are always critical in sustainability transitions

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regardless of spatial and temporal contexts. On the contrary, their role is contingent. For less developed cities, where the development conditions are much less favourable, the agency is expected to play a more crucial role in sustainability transitions.

This thesis also contributes to the debate on the confusing role of the urban scale in MLP research. It is superficial simply to presume that niches, regimes and landscape represent the local, national and global level respectively. In line with Späth and Rohracher's (2010) argument that cities are located at an intermediate level between niche and regime, this research shows that cities can be the analytic level to incorporate both regimes and niches, but can also be a niche when considering their role in the broader national transition. In analysing the diffusion of SWH in Dezhou and Beijing, cities are a scale where both regime and niche locate and interact. When looking at the transition from the national level, both cities play the role of a niche. These roles of cities in the MLP are not contradictory, but complementary. Cities can be large enough to incorporate system properties, but meanwhile, they are small enough to take the advantage of proximity for niche innovations and actor network building (Späth and Rohracher, 2012). The urban scale, therefore, offers a very useful analytical arena for sustainability transitions and a multi-scalar perspective enhances the understanding of the role of cities in sustainability transitions.

Some scholars have argued that the landscape is a residual level in the MLP as it provides less explanatory power in transitions (Funfschilling, 2014). This research also does not see the landscape factors as a direct force in influencing sustainability transitions, but they are the key elements in shifting the balance between niche development and regime resistance at the local level. This thesis challenges the assumption that landscape forces exert undifferentiated pressure on regimes at the lower spatial levels. Rather, it contends that global landscape pressure is interpreted and responded to differently at the local level due to place-specific interests, resulting in different power struggles between niche-regime interactions in different places. Whereas developed regions may develop the

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pressures and interests of replacing existing unsustainable regimes mainly due to their indigenous social demand, environmental pressures and interests in less developed cities and regions are usually driven by external landscape forces. The global discourses on sustainability and national institutional changes provide a new criteria system for the latecomer regions to compete with the developed regions other than on economic criteria. Therefore, this thesis contributes to developing a more critical understanding of landscape force and its place-contingent relationship with niche-regime interactions at the lower spatial scales.

Another contribution of this research is the analysis containing both supply side and demand side, as well as the intermediate role of local governments. While the majority of transitions research only focuses on the production side, such as entrepreneurial activities and knowledge development, the role of users is usually neglected or they are simply viewed as rational individuals who make decisions according to efficiency criteria. This research has displayed the importance of territorially embedded social structures and interpersonal networks in not only affecting consumer attitudes towards niche innovations on the consumption side, but also influencing entrepreneurship and knowledge spillovers on the supply side. The role of users in sustainability transitions is not merely realised by accepting green innovations, but more importantly, by engaging in local niche actor networks and supporting local sustainability visions. This thesis argues that since the kinship-based social structure is more prevalent in less developed regions, it could be taken advantage of to facilitate the diffusion of decentralised green innovations.

In addition, the thesis has argued that the role of local government in sustainability transitions cannot simply be assigned to being the regime actor or the niche actor. Rather, their role in regime changes can vary from time-to-time, as well as from place-to-place. This research has evaluated local governments' role in transitions through their institutional interests and actual governance. Local governments can play a leading role in promoting transitions through self-governing, governing by authority, governing by

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provision and governing through enabling. It seems that while governing through enabling is more preferred in Western political systems, governing by authority and by provision have more purchase in China's context as the authority and many resources are mainly allocated by local governments.

7.3.2 Contributions to leapfrogging literature

The leapfrogging literature has been dominated by research at the national level and firm level, while there is less knowledge on how leapfrogging take place at the city and regional level. The research in this thesis also highlights the latecomer advantages as advocated in leapfrogging research, but further conceptualises the latecomer advantages in terms of both niche development and regime resistance at the urban level under global and national landscape. Much leapfrogging literature primarily focuses on latecomer advantages in terms of infrastructure, institutions and the learning investment on the supply side, while this research contributes by revealing more comprehensive and specific latecomer advantages in less developed regions through a contrast with more developed regions. It is through the contrast that the latecomer advantages in terms of less hostile market demand, greater acceptance of institutional change, close government-industry relationships and interpersonal networks in both the supply and demand side are demonstrated. These findings significantly promote the understanding of latecomer advantages and help to suggest sounder practical implications to make leapfrogging happen. Due to the proximity of relevant actors, the city and regional level may have a higher potential to leapfrog than at the national level.

The leapfrogging literature highlights the significance of technology transfer from developed regions for less developed regions. However, it has not been well addressed as to how, and through whom, the knowledge from developed regions is learned and diffused. This research stresses the critical role of large firms in fulfilling such a role. While it is laborious for less developed regions to establish broad non-local relations to facilitate the flow of knowledge and resources, it is possible and realistic that a few powerful actors

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such as big firms and the political leadership can establish such non-local relations and link them with local learning networks. Due to their key position in these multi-scalar relations, these key elite actors gain more power to direct local development pathways toward the desired direction. The research, thus, contributes in adding the role of agency and power to leapfrogging research. The role of these key actors is not only in facilitating technology transfer and resource mobilisation but also in gaining more legitimacy, building local images and upscaling local initiative to the higher levels through their economic, political and discursive influences.

Lastly, the leapfrogging literature has been too focused on the economic and technological realm, while this research has shown that global environmental discourse has provided a new pathway for less developed regions' leapfrogging. Less developed regions remain peripheral in terms of economic development, but they could have a better chance to leapfrog in terms of environment and sustainability. The global environmental imperatives are repositioning the role of less developed regions in global production networks (Patchell and Hayter, 2013). They challenge the economic criteria that used to be viewed as the key to regional development and offer another pathway that latecomers may have a better chance to lead due to less regime resistance in adopting green solutions and their place-specific endowments in, for example, renewable energy resources. The success in the environmental realm does not merely place them in the forefront of ecological sustainability, but in turn, helps to promote local economic development through building a green image and attracting green investment. Green entrepreneurs thus may have a bigger role to play in leading the local economy in such places as other sectors may not have been well developed.

7.3.3 Contributions to economic geography

The key contribution of this research to economic geography is having developed an analysis framework that avoids the polarised explanation between institutional contexts and actor networks, advocated in institutional economic geography and relational

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economic geography respectively. Ontologically, concurring with Raven *et al.*, (2012), the thesis contends that space should be understood both absolutely and relationally. Space is neither merely a passive container where things happen, nor a rational unit in a universal spatial law. Rather, space is constantly in the making by both territory-bounded factors and scalar-transcending relations, which have different explanatory power in different spatial outcomes. Space is not only imposing a structural force on the things within but meanwhile, is being shaped by the agency and actor relations that cross scales. Epistemologically, the thesis doubts the universal spatial laws in positivism or the subjective reality in constructivism, but advocates a contextual causal relation, that is, the spatial law is contingent to the particular time and places. The thesis has shown that regional development advantages and disadvantages are not fixed, instead, they gain or lose purchase under different landscape conditions and depend on how the agency makes use of them. The spatial outcome is contingent because it is a combined consequence of the fixed and the flowing. Both institutional structure and actor relations are of important causal power in producing spatial results, but they have different weights in different contexts. Methodologically, the thesis contributes by applying a contrasting case study method other than the most often used single case study and the comparative case study in geographical research. This method uses one case as an analytical focus and meanwhile uses another contrasting case as a reference to better illustrate why certain factors (e.g.institutional assets and actor relations) make more sense in particular contexts. It is through the contrasting analysis that the thesis reveals the general latecomer advantages of less developed cities and regions in sustainability transitions. Meanwhile, it also illustrates the shortcomings of latecomer regions and thus, their necessity to establish close linkages with forerunners so that knowledge, resources and legitimacy can flow in.

7.3.4 Practical implications for sustainability transitions in latecomer cities

The global landscape change towards green development has offered the economic latecomers a new opportunity to leapfrog in both economic and environmental realms. The landscape change is critical because it provides a new set of system criteria other

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than economic performance for regional competition. Due to their lagging behind in urbanisation and industrialisation, economic latecomers may have a better chance to outperform their developed counterparts in environmental leapfrogging, as their institutions, infrastructure, market demand and user practice have not been highly locked-in by incumbent regimes. Given these weaker regime resistances, the key challenge for less developed regions is whether they are able to develop powerful green niches to overthrow the established regimes. To this end, this thesis suggests three main practical implications for sustainability transitions and leapfrogging in latecomer regions.

First of all, it is essential that the green niche developments are incorporated with local economic development. Economic growth is still the primary interest in many less developed regions. Meeting this interest, green niche activities could be more likely to involve and mobilise more local actors, e.g. the authorities, entrepreneurs, and civil residents. It is recommended that less developed regions develop green industries that can bring local employment, tax revenue, and economic savings for civil residents. Under the global and national discourse of green development, local green achievements could be highly praised by higher governance levels, which in turn supports local green niches with more economic investment, political legitimacy, and green reputations. Building a green image can further enhance economic development through, e.g. attracting green investment, ecological tourism, and preferential policies, and this, in turn, strengthens the local actor networks of green niches.

Secondly, to exploit and make full use of the local place-specific assets. These regional assets could be natural endowments in particular resources, local formal and informal institutions, a homophilous social structure and close interpersonal networks. Abundance in renewable energy sources, for example, may help latecomer regions reposition their role in global production networks. Since the opportunity cost of radical institutional changes is generally smaller than that in developed regions, less developed regions could enjoy more space or flexibility in institutional changes if they wish. Furthermore, close

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interpersonal networks could be exploited to facilitate the diffusion of green innovations to the wider population. Considering their relative backwardness in technological and financial capacities, latecomer regions may be more advised to develop less R&D- and capital-intensive green industries in the first place, so that they can get the utmost out of their latecomer advantages.

Of similar importance is to develop multiple relations (e.g. political, economic and cultural relations) with the external world so that knowledge, resources and legitimacy for green development could be drawn into latecomer regions. While improving the overall learning capacity of a region should always be a long-term target in latecomer regions, it may take generations of efforts in education and knowledge investment. A more cost-effective way could be cultivating or bringing in a number of scale-transcending actors, who are able to bridge the local learning networks and the external ones through their personal multi-scalar relations. The key role here is assigned to those political leaderships, green entrepreneurs, and professional experts who can exert influence beyond their local boundaries. Through these relations, not only knowledge, resources and legitimacy could be brought in to sustain local transition activities, also, these actors could be empowered as system builders to direct desired system changes. It is thus advised for less developed regions to pursue those top-level talents who have not only advanced professional skills but more importantly their multi-scalar networks.

7.4 Limitations and future research agenda

It has to be noted though that this study is based on a less capital-intensive technology, SWH. Unlike wind turbines or PV, which are characterised by high R&D intensity, large investments and government-led activity, SWH is a low cost, less R&D intensive and market-driven green technology. This enables less developed cities like Dezhou to compete with developed cities in the innovation and application of the technology. Future research could benefit from more cross-case comparisons between different green sectors, such as geothermal, biomass, and wind energy. In latecomer regions, while internal assets

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and relations may play a bigger role in developing low-tech green sectors, external knowledge and financial resources could be more critical for the development of high-tech green sectors. This research may have contributed with a more bottom-up transition story, but more could be done from the top-down perspective and on the interaction between these two forces, so that a more comprehensive understanding of transition practices in various latecomer cities could be achieved.

Secondly, the terminology of less developed cities or latecomer cities (regions) is not sufficiently conceptualised. In this research, the term less developed cities or latecomer cities is used to have a direct contrast with their developed counterparts in the same national boundary. The terms here are applied to those cities and regions that comparatively lag behind in a nation in terms of economic development, rather than those categorised by absolute criteria such as GDP per capita. The less developed cities identified from a gradient perspective may not be compatible with the later ones. Clearly, within the term of less developed cities and regions, there exist cities at different levels of economic development. In this research, most residents in Dezhou are able to afford the initial cost of the green technology, but how about those regions in extreme poverty? How 'less developed enough' could the latecomer advantages discussed in this research be exploited to promote sustainability transitions? The thesis hypothesises that sustainability transitions have more potential to be realised in the less developed but growing cities. This is a general observation, and future research can contribute with a more specific categorisation of less developed cities and their various roles in sustainability transitions.

Finally, this thesis proposes to understand sustainability transitions as a direct power struggle between niche development and regime resistance. Dezhou's transition to SWH results from the dynamic interaction between strong niche development and weak regime resistance, while Beijing exhibits contrary characteristics. The status of 'weak' and 'strong' is relative, with one rising and the other falling. However, without a more

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generalised measuring system, the judgement of ‘weak’ or ‘strong’ could be arbitrary. How strong is a niche development? One possible and promising way, as already advocated by some scholars, is to incorporate insights from TIS functions. The cases in this research have also demonstrated several TIS functions in transition, such as market formation, resource mobilisation, entrepreneurial experiments and legitimation. These TIS functions could be useful tools to evaluate the performance of niche development. Also, the structural failures framework in TIS could be beneficial to examine the strength of regime resistance. An MLP-TIS combined framework may offer not only an understanding of the dynamic interaction between niche development and regime resistance, but also a more generalised and comparable assessment system of their strength in different cases. However, since these concepts in MLP and TIS have different ontological settings, future research should proceed with the integration with more careful elaborations.

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Appendix

Appendix 1

An example of my interview questions (with solar enterprises)

1) Background information:

- Please could you introduce yourself and your company—When was it established? What are your main products? Number of employees?

2) The development of solar thermal industry

- Please tell me a bit about the development history of your company.
- Where did your technology learn from? Do you have your own R&D?
- Where is your main market of your products? How is the market developed?
- What is the role of solar thermal industry in Dezhou's economic, social and environmental development?

3) The facilitating and obstructing factors

- What do you think are the facilitating factors for the development of your company and the industry?
- What government efforts have been taken to support this industry? Have any particular policies helped you in your business? How much do you benefit from these efforts?
- How do you view urbanization in Dezhou's transition to solar energy?
- What are the obstructing factors or barriers?—Institutions/ Policies/Infrastructure/ Technology/ Market/ Social awareness? Other industries?

4) The role of cities

- Why did you choose to start your business in Dezhou? What are the advantages and particularities of Dezhou, comparing to other cities?
- To what extent the industry has engaged in policy making in Dezhou? How?
- Do Dezhou's efforts have influences on the national level? How?

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Appendix 2

Inviting letters to potenial interviewees

Zhen Yu
PhD Candidate
Department of Geography, Environment and Earth Sciences
University of Hull
Hull
HU6 7RX
Telephone: +44 07459008629
Email: Z.Yu@2013.hull.ac.uk

Dear XXX,

My name is Zhen and I am an economic geography PhD candidate in the Department of Geography, Environment and Earth Sciences at the University of Hull, UK. I am currently conducting research on sustainability transitions in Chinese cities and Dezhou is one of my case studies as it has a world-renowned reputation for the popularization of solar energy. My research objective is to gain a better understanding of how and why solar thermal technology diffuses in Dezhou. I will be visiting Dezhou for two months from mid-November 2014. As you are an expert and participant in the development of Dezhou's solar energy, I am interested in interviewing you to learn from your vast experience and valuable insights. The interview would last for roughly one hour and would be arranged at your convenience. The interview would be audio-recorded (with permission) and anonymised. It would also only be used for research purposes. The research is sponsored by Chinese Scholarship Council (CSC) and University of Hull. Results from the research will be published in English peer-reviewed journals and presented at international conferences, such as the Association of American Geographers (AAG) and the International Sustainability Transition Network (STRN). I hope this will help to raise Dezhou's international profile.

Reproduced below are some sample questions I hope to cover in the interview:

- What is the role of solar industry in Dezhou's social and economic development?
- What do you think are the facilitating factors for the development of the industry?
- What are the obstructing factors or barriers?
- What are the advantages and specificities of Dezhou, comparing to other cities?
- To what extent the industry and civil society have engaged in policy making in Dezhou?
- What is the relationship between Dezhou's transition efforts and policies at the national level?

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I do hope that you will agree to participate in this research. If you feel that you are not the right person within your organization, or if you do not want to be interviewed, please feel free to pass this request to someone else. If you have any questions please do not hesitate to contact me.

I look forward to hearing back from you.

Sincerely yours,

Yu Zhen

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Appendix 3

List of interviews

	Date	Organization	Interviewee	Duration	Type	Location	Audio Record
1	17/12/14	Himin Solar	Business Center	118’	Solar Enterprise	Dezhou	Yes
2	21/12/14	Jinghen New Energy	Production/Market Department	20+26’	Solar Enterprise	Dezhou	Yes
3	23/12/14	Himin Solar	Director of Business Center	130’	Solar Enterprise	Dezhou	Yes
4	01/12/14	Kehui Solar	General Manager	65’	Solar Enterprise	Dezhou	Yes
5	04/12/14	Zhongli Solar	General manager office	75’	Solar Enterprise	Dezhou	Yes
6	05/12/14	Dezhou Solar City Office	Section Chief	35’	Government department	Dezhou	No
7	08/12/14	Jieyang Solar	General Manager	60’	Solar Enterprise	Dezhou	Yes
8	09/12/14	Vicot New Energy	General manager office	96’	Solar Enterprise	Dezhou	Yes
9	10/12/14	Himin Solar	Director of R&D	57’	Solar Enterprise	Dezhou	Yes
10	13/12/14	Solar Think Tank	General Manager	55’	Consultant Institute	Dezhou	Yes/ half no due to technology issue
11	15/12/14	Dezhou Solar City Office	Director	41’	Government department	Dezhou	Yes
12	16/12/14	Huangyu Solar	General Manager	90’	Solar Enterprise	Dezhou	Yes
13	19/12/14	Guangdong Solar industry Association	Secretary general	30’	Industry Association	Linyi	No
14	20/12/14	Huasolar Solar Tech	General manager office	50’	Solar Enterprise	Linyi	No
15	23/12/14	Shandong Solar industry	Secretary General	40’	Industry Association	Jinan	No

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		Association					
16	25/12/14	Linuo Paradigma Solar	General Manager office	97’	Solar Enterprise	Jinan	Yes
17	31/12/14	Dezhou Economic and Information Technology Committee	Deputy Director	63’	Government department	Dezhou	Yes
18	03/01/15	Eccoo Solar	Store Manager	40’	Retailer	Dezhou	Yes
19	04/01/15	Dezhou Development and Reform Commission	Section Chief	44’	Government department	Dezhou	Yes
20	05/01/15	Jiacheng Estate	Chief inspector of Design Department	35’	Real estate developer	Dezhou	Yes
21	06/01/15	Dexing Group	Director of engineering department	47’	Real estate developer	Dezhou	Yes
22	07/01/15	Dezhou Building and Planning Design Research Institute	Director of Technology Department	50’	Research Institute	Dezhou	Yes
23	07/01/15	Himin	Store Manager	35’	Retailer	Dezhou	No
24	07/01/15	Xingkai Real Estate	Director of Design Department	40’	Real estate developer	Dezhou	NO
25	08/01/15	Dejian Group	Deputy Director of Design Department	36’	Real estate developer	Dezhou	Yes
26	08/01/15	Sunrain Solar	Store Manager	28’	Retailer	Dezhou	Yes
27	16/01/15	Hailin Energy Tech	Director of Marketing	57’	Solar enterprise	Beijing	Yes
28	19/01/15	China Academy of Building Research	Director of Solar thermal conversion committee	55’	Research institute	Beijing	Yes

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29	21/01/15	Sanpu Solar	Director of R&D Dvision	50’	Solar enterprise	Beijing	Yes
30	22/01/15	Beijing Jiuyang Industry Co,.Ltd	Chief executive	66’	Solar enterprise	Beijing	Yes
31	23/01/15	Tianpu Group	Director of Brand Center	60’	Solar enterprise	Beijing	Yes
32	30/01/15	Committee of China’s Solar Thermal Utilization	Sectory General	64’	Association	Beijing	Yes
33	30/01/15	Sola Solar Energy Tech	Director of technology	50’	Solar enterprise	Beijing	Yes
34	02/02/15	Golden Sunbo Solar	Director of Marketing	60’	Solar enterprise	Hebei/ Beijing suburban	Yes
35	02/02/15	Tsinghua Solar	Director of international business	50’	Solar enterprise	Beijing	Yes
36	06/02/15	Solar Building Technics Research institute	Deputy Director	51’	Research institute	Beijing	Yes

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Appendix 4

Research ethics statement

A PROFORMA FOR

STAFF AND POSTGRADUATE RESEARCH STUDENTS BEGINNING A RESEARCH PROJECT

Department of Geography

Research Proposer(s):…Zhen Yu…………………………………………………………....................

Programme of Study (postgraduate students)…………PhD in Human Geography…………………

Research Title:

Sustainability transition in urban-industrial China: a case study in China's solar city

Research (brief):

Sustainability transition, a fundamental transformation towards more sustainable modes of production and consumption, has become an emerging topic of research and political arena since the end of 1990s. However, it has been recently criticized for its missing or naive conceptualizations of space and scale. We have relatively little understanding about where transitions take place and why transitions occur in one place and not in another. Besides, the majority of transition research has unconsciously been dealt with at a national level, while the role of cities and regions is largely marginalized. Sustainability transition theory development has been deeply influenced by its European origin. It remains a question whether this theory can maintain its theoretical purchase when apply to practice in developing countries.

Taking Dezhou, China's solar city, as a case study, my research aims to explore what factors facilitate or obstruct China's urban sustainability transition and how can less developed cities create new path towards sustainability. During my fieldwork, documentary analysis, semi-structured interviews and focus group interviews will be employed to understand how the transition towards renewable energy takes place in the city. Hopefully, with a much different institutional and political contexts from post-industrial European countries, China's transition process toward sustainability may expand current theory boundary and provide heuristics to not only the global south, but also the global north.

Source of Research Funding (where appropriate) …China Scholarship Council …

Proforma Completion Date: …10/10/2014…………

This proforma should be read in conjunction with the ethical principles. It should be completed by the researcher. It should be sent on completion, together with a brief (maximum one page) summary of ethical issues raised by the proposed research, for approval to the Geography Ethics Officer prior to the beginning of any research.

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Part A

1. Will your research involve animal experimentation? No

If the answer is 'YES' then the research/teaching proposal should be sent direct to the University Ethics Committee to be assessed.

2. Will your research involve human participants? YES

If the answer to both questions is 'NO', there is no need to proceed further with this proforma, and research may proceed (however, please send a copy of the form to the Ethics Officer). If the answer is 'YES' please answer all further relevant questions in part B.

Part B

3. Will the research involve people under 18 years of age? No

If yes, have you taken the following or similar measures to deal with this issue?

(i) Informed the participants of the nature of the research? Y / N

(ii) Ensured their understanding? Y / N

(iii) Gained the non-coerced consent of their parents/guardians? Y / N

4. Will you obtain written informed consent from the participants? YES

If yes, please include a copy of the information letter requesting consent

If no, what measures will you take to deal with obtaining consent?

I will provide all participants with clear written and/or oral information on the purpose, methods and use of the research (including the contexts in which the results will be disseminated), and give them opportunity to ask further questions. Participants will not be put under pressure to participate, and will be able to withdraw from all or part of the research at any time. I will seek informed consent from participants, and where appropriate ask participants to sign an agreement confirming they are willing to participate and understand the nature of the project.

It should be noted that such signed consent will not be sought in the case of interviewees in China. Researching in China, formal consent forms pose a significant barrier as they act to unsettle rather than reassure respondents about the research and what will be done with the resulting data. Nevertheless, all Chinese participants will receive information equivalent to a consent form and records of their consent will be kept. For interviewees, this process will be part of the email exchange that is the basis of their recruitment, with the consent information sent as attachments in the guise of

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background about the project. Such participants will want to know what the project is about and so will read these and only accept an interview when they consent to the description of their role in the research – so their emails will be a record of such consent. All participants will also receive in this information contact details for the research team and for a significant person not involved in the research.

5. Issues for participants. *Please answer the following and where you respond YES in any case, state how you will manage perceived risks:*

a) Do any aspects of the study pose a possible risk to participants' physical well-being? NO

b) Will any important information about the research be deliberately withheld from the participants? NO

c) Are there any aspects of the study that participants might find humiliating, embarrassing, ego-threatening, in conflict with their values, or be otherwise emotionally upsetting?* NO

d) Are there any aspects of the study that might threaten participants' privacy (e.g. questions of a very personal nature; observation of individuals in situations which are not obviously 'public')?* NO

e) Does the study require access to confidential sources of information (e.g. medical records)? NO

f) Could the intended participants for the study be expected to be more than usually emotionally vulnerable (e.g. medical patients, bereaved individuals)? NO

*Note: if the intended participants are of a different social, racial, cultural, age or sex group to the researcher(s) and there is **any** doubt about the possible impact of the planned procedures, then opinion should be sought from members of the relevant group.

6. Might conducting the study expose the researcher to any risks (e.g. collecting data in potentially dangerous environments)? NO

7. Is the research being conducted on a group culturally different from the researcher?

NO

If yes, are sensitivities and problems likely to arise?

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If yes, please *describe how you have addressed/will address them.*

8. Does the research conflict with any of the Department's research principles? (please see attached list, page 7). NO

If yes, describe what action you will take to address any conflicts?

9. Will the research require the consent of any outside organisation?

YES

If yes, describe how you will obtain consent.

In order to conduct focus group with local residents, I will seek permission from the relevant local government department.

Name of Researcher ………Zhen Yu……………………………………………………………

Signature …………… Yu Zhen………………… Date ………10/10/2014……………

This research proposed in this proforma must gain recommendation for approval from the Geography Ethics Officer. Once this is gained, formal approval will be given by the Geography Ethics Committee.

It is recommended that the research referred to in this proforma is given approval by the Geography Ethics Committee. Y / N

Name of Ethics Officer ……………………………………………………………………….

Signature ……………………………………………… Date…………………………………