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Green industry development and urban sustainability transitions in China's latecomer cities: A case of Dezhou

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Abstract: Under the discourse of sustainability transitions, cities that lag in industrialization and urbanization face the dual challenge of economic development and decarbonization. Developing green industries may offer a possible pathway for latecomer cities as it could bring both economic benefits and environmental wellbeing through local production and consumption of green innovations. The interest alignment between active green entrepreneurs and motivated local government has resulted in many successful green industry development stories in China's latecomer cities, accompanied by certain urban regime changes toward sustainability in many cases. However, to what extent and how green industry development can influence urban sustainability transitions remains an underexplored issue. Meanwhile, green industry development is subject to changes in the external landscape, entrepreneurs' strategies, and local supporting environments, which may lead to diverse transition outcomes. Investigating the rise and fall of the solar water heater industry in Dezhou as a case study, this chapter revisits the role of green entrepreneurs and local governments in green industry development and discusses the dynamic relationship between green industry development and urban sustainability transitions in Chinese context.

Keywords: green industry, urban sustainability transitions, latecomer cities, interest alignment

INTRODUCTION

It has been widely recognized that incremental innovations will be far from enough to address current global environmental challenges (Gates, 2021). Instead, we need more radical changes toward sustainability in major socio-technical systems such as energy, housing, and transportation, hence, sustainability transitions (Markard et al., 2012). Cities are the main battlefield of sustainability transitions as they consume more than 80 per cent of global energy and emit more than 60 per cent of global greenhouse gases but are also the centre of green innovation development and diffusion. Therefore, understanding urban sustainability transitions has gained increasing scholarly attention (e.g., Wolfram et al., 2017; Hölscher and Frantzeskaki, 2021). However, existing research tends to focus on Western developed cities, while the role of developing/less developed/latecomer cities is largely marginalized (Yu and Gibbs, 2018a). This is problematic as latecomer cities may host most of the growing urban population on the planet in the coming decades. Latecomer cities are in the process of urbanization and industrialization and are yet to be locked in by existing high-carbon development modes. If these cities can leapfrog to a sustainable mode of production and consumption from the very beginning, it would be of great significance to global sustainability transitions.

However, sustainable solutions usually have higher costs and the market usually lacks endogenous incentives to invest in sustainable solutions. It is a huge challenge for latecomer cities to sustain economic development while maintaining a low-carbon footprint. It is more reasonable for latecomer cities to develop green economies where decarbonization could be achieved without losing economic competitiveness (Gibbs and O'Neill, 2017). Therefore, developing green industries may offer a reasonable pathway for latecomer cities to engage in sustainability transitions. From the production side, green industries could bring GDP, tax income, and employment that latecomer cities mostly aspire to. From the consumption side, the application of green technologies at the local level could bring changes in urban infrastructure, user practices, policies, and institutions. Yet, existing research has not provided sufficient knowledge on the relationship between green industry development and urban sustainability transitions. Thus, a number of key research questions remain underexplored. How and to what extent can green industry development lead to urban sustainability transitions? What are the incentives and roles of heterogeneous actors (e.g., government, green firms, and citizens) engaged in green industry development and urban transitions? What happens to urban sustainability transitions if the green industry development fails?

Therefore, this chapter aims to offer some insights into these issues by investigating the dynamic relationship between green industry development and urban sustainability transitions in China, which has become the world's largest country in the production and consumption of many green innovations, particularly renewable energy technologies (RETs). It is interesting to see that most of these RET industries in China have emerged in non-core cities and regions. The opening of green windows of opportunity at the global and national level has given a strong push to the rise of these latecomer regions in green industries (Lema et al., 2021), which are also bringing urban regime changes toward sustainability to different extents. This chapter provides an in-depth case study on the development of the solar water heating (SWH) industry and its role in urban sustainability transitions of Dezhou, China's Solar City. The case is interesting because it allows us to see how the rise and fall of the green industry can affect urban regime changes toward sustainability, as well as the role of heterogeneous actors in such changes.

This chapter is organized as follows. Following this introduction, section 2 provides a literature review on green industry development and urban sustainability transitions. Section 3 describes the case study context and research methods. Section 4 elaborates on the dynamic relationship between green industry development and urban sustainability transitions in Dezhou from a temporal perspective. Finally, section 5 concludes.

GREEN INDUSTRY DEVELOPMENT AND URBAN SUSTAINABILITY TRANSITIONS

The concept of sustainability transitions stems from socio-technical transitions: the long-term and multi-dimension transformations of socio-technical systems. The key to socio-technical transitions is to transform the socio-technical regime, which is the embedded rules that orient the reproduction of existing socio-technical system elements and usually lead to lock-in or path dependence (Kemp et al., 1998). The multi-level perspective (MLP) proposed by Geels (2002) conceptualizes transitions as the interaction between three levels of stability, i.e. landscape, regime, and niche. The landscape is the external environment that may bring pressure on incumbent regimes and open windows of opportunity for innovations. Niche is the protected space where innovations are nurtured and even empowered to challenge existing regimes. Sustainability transitions research highlights the role of niche innovations (usually green innovations) in addressing big environmental challenges (van den Bergh, 2021). Green innovations can be categorized into four phases: process innovation, product innovation, product substitution, and system innovation. The former two innovations are usually incremental innovations that may bring a certain level of efficiency improvement; product substitution brings radical changes in product concepts and functions, providing different products or services for similar purposes (e.g., electric vehicle vs internal combustion engine fuel vehicles); system innovations focus on the change of the entire socio-technical system, including social structures and organizations (e.g., sharing economy). Sustainability transitions are not only about improving resource use efficiency, but more importantly promoting changes in social behaviour and institutional structures.

It is not surprising to see sustainability transitions at the city level increasingly gain scholarly attention due to cities' impact on global sustainability challenges. Conceptually, scholars differentiate sustainable urban transformations (SUT) from urban sustainability transitions (Wolfram et al., 2017; Hölscher and Frantzeskaki, 2021), though in many cases the terms are used rather interchangeably. While some scholars argue that SUT is a subset of urban sustainability transitions (Ernst et al., 2016), in this chapter we adopt Wolfram's et al., (2017) conceptualization that urban transformation is "the process and outcome of changing the systemic configuration of urban areas" (p.20) and thus a more encompassing concept containing changes in both socio-ecological systems (SES) and socio-technical systems (STS) （Hölscher and Frantzeskaki, 2021). In contrast, urban sustainability transitions mainly refer to the change process being confined to human-made socio-technical systems, with less attention paid to the natural ecological system. The underlying assumption here is that sustainability transitions at the urban level will eventually lead to improvement in the urban ecological system e.g., air quality and biodiversity.

Cities can be the place where sustainability transitions occur but also the seedbed for wider-scale transitions (Hodson and Marvin, 2012). A useful classification has been made by Hölscher and Frantzeskaki (2021) in understanding transformations in, of, and by cities. Transformation *in* cities focuses on the factors and processes that drive place-specific transformation within a city; transformation *of* cities focuses on the outcome of changes in urban (sub)systems or functions (e.g., energy, housing, transport, and food); transformation *by* cities views cities as change agents in the transformation of wider scales and distant territories. If following this conceptualization, developing green industries may be seen as a way to initiate sustainability transitions in cities, which may lead to transitions of cities and even promote transitions at a wider scale.

A green industry refers to the industries that "develop and sell products, solutions or technologies that reduce carbon emissions and pollution, enhance resource and energy efficiency, and prevent the loss of biodiversity and ecosystem services" (Grillitsch and Hansen, 2019: 2166). Green industry development can be an important pathway to realizing low-carbon city visions. A narrowly defined low-carbon city may only refer to cities with low levels of carbon emissions, but a more broadly defined low-carbon city may also include those cities developing green industries, albeit that the manufacturing process of these industries may not itself be low-carbon. Post-industrialized cities may face more environmental pressure but also have more capacities to initiate comprehensive transitions covering both production and consumption sides. For latecomer cities, the priority is usually promoting living standards, and the development and adoption of green innovations rarely follows a climate change mitigation rationale (Tirado-Herrero and Fuller, 2021). Therefore, green industry development may offer these cities a starting point to engage in long-term urban sustainability transitions.

Nevertheless, the process from green industry development to urban sustainability transitions is rarely linear and spontaneous. Instead, it needs the collective agency of place leadership, innovative entrepreneurs, and institutional entrepreneurs to promote the uptake of green innovations in local contexts and transformation of urban regimes. It is also the case that green industry development may fail due to environmental changes or lack of endogenous capacity. It is reasonable to expect that if a green industry plays a strong role in the local economy, it could bring a more profound effect on urban transition, but if the industry only has a small role in the local economy, it is less likely to bring systematic changes at the urban level.

Therefore, to explore pathways toward urban sustainability transitions in latecomer cities, it is of great significance to understand the relationships between green industry development and urban sustainability transitions, and the role of heterogeneous actors played in such relationships. The fast development of green industries in urban China offers many interesting cases to examine such relationships and may provide insights for urban sustainability transitions in other countries' contexts.

CONTEXTS AND METHODS

SWH Industry Development in China

Renewable energy technologies (RETs) are a typical type of product substitution green innovation. Since the Renewable Energy Law took effect in 2006, China's RET industry has grown dramatically to become the world leader in terms of both production and installed capacity (IEA, 2021). This has been greatly facilitated by the green institutional, market, and technology window of opportunity opened at the global and national levels (Lema et al. 2021; Binz et al., 2021). Many latecomer cities and regions took advantage of these windows and leapfrogged to the front in RET production and adoption. In RET development, while most attention is drawn to the eye-catching wind turbines and photovoltaics (PV), solar thermal energy technologies play a rather low-key but important role in green energy provision both in China and worldwide. In fact, the installed capacity and produced energy of solar thermal technologies are second only to wind power and much higher than that of PV (Mauthner and Weiss, 2014). China's position in solar thermal heating is even more striking, representing more than 80 per cent of the world's production and 70 per cent of consumption (Luo, Huo and Xie, 2013; Mauthner and Weiss, 2014). Though the GDP value and technology complexity of SWH is much lower than that of the wind industry and PV industry, it has played, and will continue to play, an important role in China's pathway to carbon neutrality.

Solar thermal energy is a form of technology for harnessing solar energy to generate heat or electricity. China's remarkable success in solar thermal energy lies primarily in low-temperature collectors (below 80 C) that are widely employed for hot water and heating. The most commonly used SWH collectors are evacuated tube collectors and flat-plate ones. The low-cost evacuated tube SWH has an overwhelming dominance in China's SWH market, especially in rural areas since 1994. At its peak, evacuated-tube SWH accounted for 95 per cent of China's SWH market. In the last decade, due to its advantages in being incorporated into high-rise buildings, the flat-plate collector is gaining popularity in China's cities. The vast utilisation of SWH has brought enormous energy and environmental benefits for China, as well as the world (Luo et al., 2013).

In response to the global oil crisis, China started its research in solar energy at the end of the 1970s. The commercialization of solar thermal technology grew slowly until 1994 when a technological breakthrough was achieved in the large-scale manufacturing of all-glass evacuated tubes by Tsinghua University, which led the industry into a new era. Private entrepreneurs began to 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. The following decade witnessed the rapid growth of China's SWH market, with an annual growth rate of 30 per cent in sales (Wang and Zhai, 2010). In 2006, the central government promulgated China's Renewable Energy Law, prioritizing renewable energy generation and utilisation in China's energy development. It stated 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. Real estate developers were encouraged to consider the requirements for using solar energy when designing and constructing buildings. In 2007, China's Medium and Long-Term Plan for Renewable Energy (2007-2020) set specific targets for SWH installation: a total heat collecting area of 150 million square meters to be installed by 2010 and 300 million square meters 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 utilization of solar thermal energy. In particular, many provinces and cities implemented a mandatory installation policy that requires new residential buildings to incorporate solar water systems into the design and construction process of new buildings.

Accelerated by the rapid growth of the real estate industry in China's urbanization, the SWH-incorporated building project market experienced a drastic increase, with its market share rising from 35 per cent in 2007 to 45 per cent in 2011. While the flat-plate SWH market witnessed a dramatic increase with an annual growth rate of over 50 per cent, the individual retail SWH market is shrinking, especially from 2010 onwards. By 2012, the industry consisted of approximately 3,000 enterprises, among which 1,800 were SWH manufacturers and the rest are component equipment producers (Hu *et al.*, 2012). However, many small evacuated-tube SWH firms died thereafter with the decline of the individual retail market. Geographically, most SWH firms were concentrated in a few regions, such as Zhejiang, Shandong, Jiangsu, Yunnan and Beijing. At the city level, 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. Small and medium-sized cities are the major markets for SWH. Dezhou is such a city with strong performances in both SWH production and adoption, earning the reputation as China's solar city.

Background of Dezhou

Dezhou is located in the northwest of Shandong Province and China's third-largest Economic Zone – Bohai Economic Rim. From an economic development perspective, Dezhou is a typical latecomer city in China. Historically, Dezhou was an important agricultural city in China and 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. It was not until 1995 that the dominant role of the agriculture sector in Dezhou's economy was replaced by secondary industry. In 2019, Dezhou's GDP per capita reached RMB 52.3 thousand (Dezhou Statistic Bureau, 2020), nearly 40 per cent below the provincial average.

When it comes to the 21st century, the solar energy industry emerged quickly and became the most frequently promoted city image of Dezhou. In 2010, the city was home to more than 120 enterprises engaging in solar-related industries, achieving more than RMB 50 billion in sales revenue and selling a total of 26 million square meters of SWH, which accounted for approximately 70 per cent of Shandong's and 16 per cent of China's capacity respectively. 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. In 2005, the city was awarded 'China's solar city' by China's Solar Association. Dezhou boosted its international reputation when it hosted the 4th World Solar City Congress in 2010. However, the harmonious relationship between SWH industry development and urban sustainability transitions began to destabilize after 2015 due to the decline of the industry and a change in government-business relations.

Therefore, Dezhou's story offers an insightful case to examine the dynamic relationship between green industry development and urban sustainability transitions. The primary data for this analysis is based on on-site observation and semi-structured interviews conducted in the authors' fieldwork in China, including 30 interviews in Dezhou and 10 interviews in Beijing, where most national-level industry associations and policy-makers were based. The first round of site observation and interviews (36) was conducted in 2014 and 2015. As the authors found new development in Dezhou's solar transition in recent years, 4 follow-up interviews were taken in May 2020. These first-hand qualitative data are complemented and triangulated by secondary materials such as policy documents, industry reports, and news media coverage.

SWH INDUSTRY DEVELOPMENT AND SUSTAINABILITY TRANSITIONS IN DEZHOU

Political-economy Contexts

Since the Reform and Opening Policy, China has witnessed a huge scale of economic liberalization, which, to a certain extent, has created a quasi-federal structure, providing local governments with incentives and a roadmap for change (Thun, 2004). One of the key reforms was the decentralization of political power from the central government to subnational provincial and city-level governments, which gained more administrative autonomy, but also the responsibility to govern the social-economic activities within their jurisdictions (Oi, 1992). In particular, China's fiscal contracting reform is believed to have a very profound effect on local governments' incentives (Zhou, 2004). The tax reform since 1994 devolved more administrative responsibility to local governments but largely reduced their share in national tax revenue distribution. Therefore, local governments strived to enlarge the local economic base to increase their fiscal revenues to address the rising administrative responsibilities e.g., healthcare, education, and infrastructure construction. In the meantime, the central government is able to exert a strong influence on local governments' governing practices through the cadre performance evaluation system (CPES), in which higher-level governments decide the appointment, promotion, and dismissal of local cadres (Tsui & Wang, 2008). For a long time, economic growth has been a dominant indicator in deciding local officials' political performance. This system has resulted in a 'political promotion tournament' among local governments (Zhou, 2004), and those who performed well in economic development are more likely to be promoted. This incentive scheme thus has greatly stimulated China's local economic development, but it provided few incentives for environmental improvement in the early days.

Under such a political-economic context, boosting economic development through industrialization was the key priority for Dezhou as one of the least developed agricultural cities in Shandong. As stated in Dezhou's 10th FYP (2001-2005): "being economically underdeveloped is the biggest reality of Dezhou; development is of overriding importance, and accelerating development is the biggest politics", and "as a traditional agricultural region, accelerating industrial development is the key to catch-up with the medium-developed cities in Shandong province". The local government thus wished to cultivate several leading industries as the engine of economic growth. By the mid-2000s, secondary industries had achieved a dominant position in Dezhou's GDP. The equipment manufacturing, food, chemical and textile industries became the four competitive industries in Dezhou. Among them, Dezhou's central air-conditioning industry was reported to account for 12 per cent of China's production capacity (Dezhou Government, 2006), but the industry was dominated by small enterprises and had a rather polluting image. Meanwhile, new energy, new materials, biomedicine, and culture and sports goods industries were emerging. In 2010, these eight leading industries' main business income accounted for 73.9 per cent of Dezhou's total industry income, of which, the four emerging industries accounted for 27.1 per cent. Dezhou's new energy industry mainly consists of solar energy, biomass energy, wind energy equipment, new energy automobiles and geothermal pumps. Among these, the solar industry gained the most attention and won Dezhou a green image as China's Solar City.

Emergence of SWH Industry in Dezhou

The emergence of Dezhou being a solar city is closely associated with the entrepreneurial story of Huang Ming, the founder of Himin. After graduating from the China University of Petroleum in 1982, Huang Ming worked in Dezhou for a state-owned oil drilling research institute, where he learned that oil was not a sustainable energy source and would be used up in decades. In 1987, a book, *Solar Engineering of Thermal Processes* by Duffie and Beckman, introduced Huang Ming to the field of solar thermal energy. 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 in public places or giving them to his acquaintances as gifts to see how they worked. In 1992, when China was experiencing deeper marketization reform after Deng Xiaoping's 'southern tour', Huang Ming joined the 'tide of going to business' by setting up Xinxing High-Tech company. It was a family workshop with a dozen workers engaging in 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 R&D teams and recruiting well-known solar thermal researchers. Himin set up China's first solar testing centre in 1997 and China's first private solar thermal research institute. Meanwhile, Himin started a 'Solar Science Popularization Tour' to promote the SWH market nationwide. These market promotion efforts are widely believed in the industry to have created the potential market for Dezhou and China's solar thermal industry. With the huge demand for cheap hot water from China's unprecedented urbanization, Himin grew to be the world's largest solar thermal collector supplier.

At its peak, Himin was called 'the kingdom of solar products'. Its main business included SWH (hot water solutions for households and business groups), solar thermal power generation, solar lighting systems, energy-saving glass screens, solar air-conditioning, and solar seawater desalination. By 2014, Himin had sold more than 10 million square meters of solar energy, saving a standard coal amount of 20 million tonnes and reducing pollution levels by 20 million tonnes. Benefiting from Himin's technology spillover and market expansion, a thriving solar industry emerged in Dezhou. The talent outflow from Himin increased spin-off activities and enhanced technology and tacit knowledge spillover to other firms. By 2010, Dezhou had more than 120 enterprises engaging in solar-related industries, which employed one-third of the city's workforce (Tyfield, Jin and Rooker, 2010). In 2005, due to Himin's wide influence and pervasive SWH adoption, Dezhou was awarded 'China's Solar City'. 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 the China-Switzerland low carbon city cooperation projects and hosted the 4th World Solar City Congress, when Himin and Dezhou's green reputation reached its summit.

The sustainable development model created by Himin developed a new pathway that saw commercial and environmental aims coexist harmoniously. Himin had not only become a well-known green enterprise in China but also had been widely cited by the international media as the marker post for the sustainable development of renewable energy. Due to Himin's contribution to the renewable energy industry, Huang Ming was elected as a delegate to the National People's Congress (NPC) in 2003, where he, together with other delegates, proposed to draft China's Renewable Energy Law. Huang Ming was China's first private entrepreneur who was invited to give speeches at the UN twice to introduce the Himin model to the world. In 2008, Huang Ming was elected as vice president of the International Solar Energy Society.

Influence on Dezhou's Sustainability Transitions

The rise of the SWH industry and Himin was well aligned with the then local government's development interests. Interviewees suggested that it is precisely because Dezhou is a small less developed city without other dominant industries that the SWH industry has played a pivotal role. As an entrepreneur illustrated: "Dezhou government wanted to promote Dezhou to the world, so they needed a recognised star enterprise. Eventually, they believed Himin could be the best city label of Dezhou" (Interview, SWH entrepreneur). The SWH industry successfully lobbied the Dezhou government to initiate the Solar City Strategy in 2005 as part of Dezhou's development vision and to implement favourable policies toward the industry, including the promotion of the solar industry as Dezhou's leading industry and positioning Dezhou as a leading solar city both within China and globally. During this process, Huang Ming's personal influence and his close connections with the local place leaders played a pivotal role.

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. Meanwhile, a solar city strategy committee was established to promote and implement the solar city strategy. The committee was led by the principal leaders of the municipal government and successively issued policy documents that encouraged and normalised the technology research, industry development, and application 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 World Solar City Congress in 2010. After the congress, the solar city office was kept to promote the application of solar energy in Dezhou and to help solar enterprises extend new technologies with demonstration projects. In 2009, Dezhou's *Low Carbon Dezhou Plan* incorporated low carbon economy aims into its urban economic development plan.

The most controversial move of the Dezhou government was to provide Himin with a large piece of land at a discount to the market price for building the Sun Valley in the eastern suburbs. Dezhou's government highly valued the World Solar City Congress as a historic event for Dezhou's development and supported Himin with RMB 60 million to build the Sun Valley as the Congress site as well as being an iconic landmark for Dezhou. The government also promised to solve the issue of relocation of residents on the land, but this did not go very smoothly. This valley was planned to be the centre of production, research, exhibition, and cultural communication of solar products, including SWH-building integration, solar thermal power generation, solar lighting system, solar air-conditioning, and solar seawater desalination. As a senior staff in Himin recalled: "Himin aimed to be the world's No.1 as the model of solar application…the Sun Valley is model of the future city using solar energy. Himin will not only be the champion in one field but an all-around champion and the model of comprehensive development and utilization of renewable energy. We wanted to be the evangelist and practitioner of renewable energy development" (Interview, Himin staff).

As the industry became more financially and politically powerful, it was able to ally with other actors to reconfigure regime institutions, norms, standards, and discourses within the city. While individual SWH installations had become an established social phenomenon in Dezhou in the early 2000s, the SWH industry began to explore the more challenging SWH-building integration 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 in 2001 and sought to cooperate with real estate developers to develop SWH-building projects but initially failed. In those early days, estate developers were reluctant to install SWH because of its unreliability and lack of know-how about incorporating SWH into buildings. The building design institutes were also ignorant about SWH-building integration. In 2004, together with Dezhou Architect Design Institute, Himin developed and promoted the first design standard for SWH-building integration projects in Dezhou and Shandong province. In 2006, together with Shandong's Department of Construction, Dezhou's SWH industry created China's first standard schematic handbook for the integration of building and solar energy. More boldly, Himin also decided to change 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 – 'Future City' – as a model project to show how solar energy could be integrated into residential buildings. This project became a model of green building and showed the possibility of solar-building integration. Though the estate project was deemed a high-end project and inspired other estate developers in Dezhou, the sale of its buildings was limited due to high cost.

Although several estate projects in Dezhou adopted SWH-building integration to promote sales, it did not become a common practice among estate developers until the government implemented a mandatory installation policy in 2005. The mandatory installation policy required new building projects to integrate SWH in design and construction. Many estate developers initially attempted to avoid the regulation, but the resultant loss of market competitiveness eventually forced them to incorporate SWH into building construction. Once SWH-building integration became a new practice, property buyers have preferred to purchase those estate projects that have incorporated SWHs. From this point, institutions and actors involved in the general building infrastructure were no longer hostile to SWH-building integration in Dezhou, and 95 per cent of new residential buildings in its central urban area had SWH systems incorporated by 2014 (Dezhou Government, 2014).

On the user side, this solar city vision was supported by residents, who were proud of the city's new identity as China's Solar City and were willing to accept solar thermal products. These attitudes have to a large extent been shaped by the SWH industry, which has exerted a strong discursive power in influencing the way how the issue should be discussed (Yu and Gibbs, 2020). For instance, while electrical water heaters (EWHs) are usually viewed as a safe and convenient product in developed cities in China, it is not considered as safe or convenient as SWHs in Dezhou. This attitude is largely attributed to the influential promotion by the local SWH industry, enabling the use of SWH as a taken-for-granted routine for local residents.

The diffusion of SWH in Dezhou thus became a self-sustaining process when a positive feedback loop was established among the SWH industry, local government, estate developers, and urban residents (Yu and Gibbs 2018a). The SWH industry is the key actor in allying with these actors to promote regime change in urban building infrastructure, policies, mindsets, and user practices. As the solar industry became an iconic industry in Dezhou, and with the growing political and discursive pressure for low-carbon development from the international and national landscape, Dezhou decided to build a solar economy through its 11th FYP (2005-2010) and 12th FYP (2011-

2015) and planned to develop a solar-related business with more than RMB 100 billion output by 2015. This plan, however, did not materialize.

The Decline of SWH Industry in Dezhou

The harmonious relationship between the SWH industry and the local government began to destabilize after the World Solar City Congress in 2010. Both the industry and the local government were too eager to promote Dezhou as the benchmark for green energy development, resulting in bold investments that were beyond the city's financial capacity and the industry's future revenue. When the political and economic environment for Dezhou's SWH industry changed after 2010, the hidden risks began to spring up and pull down the industry. While Himin diversified its businesses and earned the reputation of 'the kingdom of solar products', the crisis began to eat into its success. First of all, as the individual SWH market began to declined, Himin's revenue from its main business—evacuated-tube SWH—dropped sharply. Due to the quick rise of competitors and its low marketing flexibility, Himin's SWH market share reduced from more than 30 per cent to 10 per cent in China around 2010. Second, the 'Future City' project was too advanced and costly for Dezhou's real estate market at that time, resulting in a huge financial failure. After 2008, when many cities began to mandate estate developers to incorporate SWH into new buildings, China's urban market became more fragmented and not friendly to non-local firms without place-specific knowledge and connections. Himin was no longer competitive in the SWH-building integration market due to huge upfront investments and the fact that '*guanxi'* (interpersonal relationships) and low prices were instrumental in achieving successful bids (Yu and Gibbs, 2018b). Lastly, and most deadly, Himin invested RMB 3 billion to build the ‘Sun Valley’, but this investment did not bring enough revenue as expected. Because of this, Himin was in debt for more than RMB 2 billion after the World Solar City Congress. The huge fixed assets became a time bomb for Himin. Himin resorted to attempting a stock market listing three times in 2007, 2010, and 2012, but all failed. This was believed to have much to do with Himin’s unclear financial relationship with Huang Ming’s family businesses, a dishonest history of tax evasions, and close personal relations with a former place leader who was sentenced to jail for corruption in 2012. Subsequently, Himin has struggled to survive under this huge financial debt, and barely showed signs of recovery.

Things became worse sharply when the then vice governor of Shandong Province was arrested for corruption in 2012. The then vice governor was Dezhou’s top place leader between 2001 and 2007 when the Solar City Strategy was put forward and had strongly supported Dezhou’s solar economy with various favourable policies. Media coverage reported that Huang Ming had some unlawful personal connections with this place leader and that Himin illegally acquired the land for ‘Sun Valley’ from the government at a low price. These reports were not officially confirmed, but Himin did become a very sensitive topic for the Dezhou government after the then leader’s arrest. In the same year, Himin’s third endeavour to appear on the stock market failed. Overnight, the heavy debt load, bold diversification, slow market growth, family business management, and vague government relations all came together to pull down this solar giant. The then Dezhou government tried to help by providing some commercial loans for Himin, but this barely stopped the decline of Himin.

Meanwhile, China's political environment was changing. When Xi Jinping came to the power in 2013, he initiated a nationwide campaign ('Eight-point regulation' and 'fighting tigers and flies at the same time') to regulate the work behaviour of government officials and combat corruption. On the other side, the regulations have discouraged many local officials from taking bold investments or having close relations with private enterprises. As an interviewee observed: "Since the movement of fighting 'tigers and flies', many things happened, government officials no longer dare to provide direct support to enterprises. It seems now many things are slowing down because everybody is avoiding risks" (interview, SWH firm staff).

In 2015, a new place leader was deployed to Dezhou as the CPC secretary. This new administration decided to cut off relations with Himin and let the market determine its fate. In its 13^{th} FYP (2016-2020), Dezhou planned to adopt a comprehensive and steady approach to achieve coordinated economic development, but no longer invested in the solar city or solar economy. In 2017, the Solar City Committee was also abolished. As a government official commented: "We have basically abandoned this (solar city) brand now" (interview, government official). After years of struggling, Huang Ming released an open letter in 2018 to complain that the Dezhou government did not financially help Himin as promised before hosting the World Solar City Congress, which he believed was the main reason for Himin's decline. Since then, the solar industrial interests and Dezhou's government priorities have become disconnected. Though there are still dozens of SWH firms operating in Dezhou, the solar industry's influence on the local economy and society has declined rapidly. Nonetheless, the positive sign is that user practice of using SWH has been established in Dezhou. The Solar City Office has also been kept to promote the implementation of SWH-building integration. Dezhou therefore remains a city with a high adoption rate of SWH, even among the young generations.

DISCUSSION AND CONCLUSIONS

Urban sustainability transitions contain different levels of transitions, i.e. transitions *in/of/by* cities. It is reasonably easier for cities to incubate several green niche innovations and even lead to wide adoption in major sectors such as energy, transportation, and housing within their territories. However, it would be much more challenging to transform urban regimes that are embedded in existing infrastructures, industry structure, user practices, institutions, and cultural meanings. Previous research has not provided sufficient understanding of how change agents direct transitions from being *in* cities to being *of* cities (for an exception, see Huang et al., 2018). We have even less knowledge on the sustainability transitions *in/of* latecomer cities which usually lack endogenous incentives and capabilities to initiate sustainability transitions. The opening of green windows of opportunity and the rise of the green economy offers latecomer regions a new possibility to achieve both economic and environmental objectives. Latecomer cities can leverage their resource advantages (e.g. natural resources, land, and labour forces) to promote green industry development, but successful development usually entails active innovative entrepreneurs and institutional entrepreneurs to draw extra-regional knowledge and investment into the local innovation system and struggle for a favourable selection environment. Due to the absence of powerful incumbent industries, green industries are more likely to gain a key economic position in latecomer cities in terms of tax contribution and employment provisions. In such a way, industry interests may be well aligned with local development priorities and gain more legitimacy in the local context (Gibbs and Jensen, 2021).

With the support from global green economy discourses and local governments, green entrepreneurs may be empowered to stretch and transform regimes to facilitate their green businesses. This process will inherently struggle with urban regimes in infrastructures, user practices, cultural meanings etc. The relatively weaker regime in latecomer cities could provide a less harsh selection environment for green innovations and impose lower resistance to the change caused by green industry development. Dezhou's story illustrates such an interest alignment between the SWH industry and local development priorities, which enabled the industry to exert a powerful influence on urban sustainability transitions at its peak. However, the relationship between industry development and local priorities is not fixed, rather, it is subject to changes in the political-economy environment, industry development status, government-business relations etc. It is realistic to expect that an industry may lose its social-economic impact and influence if its economic prospects decline. This dynamic government-business relationship is not unique to Dezhou in China. Similar dynamics have been observed in e.g. LDK in Xinyu and Suntech in Wuxi (Zhang et al., 2021). Even so, the regime changes incurred during green industry development may remain friendly to green innovation applications, indicating a non-linear relationship between green industry development and urban sustainability transitions.

Also, an urban sustainability transition is a multi-scalar process. The interaction between green industry development and local development priorities is shaped by broader political-economy contexts. On the one hand, the urban development priorities are not only responding to local needs, but also reflecting the will of higher-level governments. In China, since the Opening and Reform Policy, economic development has been the most powerful discourse. Promoting economic development gains the most legitimacy for both central and local governments. In the last two decades, as China's economic development stepped up to a new level, local priorities have gradually shifted to focus more on local needs for better lives e.g., education, healthcare, and ecological environment, especially in more developed cities. Nonetheless, economic development is still the priority for many latecomer cities, though environmental improvement also gains more weight.

On the other hand, the international and national landscape changes towards legitimating a green economy offer latecomer cities opportunities to leapfrog to more sustainable modes of production and consumption. The central government is able to direct the local priorities towards a green economy through long-term planning, regulatory pressure, and cadre performance evaluation. In general, local governments want to reap both economic benefits and environmental benefits from green industries, but local governments put different weight on them depending on the focal industries' characteristics (e.g. the economic output) and the city's development level (Yu and Huang, 2020). In latecomer cities, local governments usually need to bind with certain green industries more deeply from an economic logic, with the 'green' element seen as a bonus. A relatively big green industry in a developing city could coordinate with multi-scalar interests and anchor external resources to promote city-level transitions (Yu and Gibbs, 2020). Therefore, the more fundamental difference between urban sustainability transitions lies in the power relations between industrial developments and urban regimes, which are not necessarily decided by the absolute size of the industries but by their relative importance within local development priorities.

For transition governance in latecomer cities, the lessons learned might be that it is important to maintain long-term resilience of interest alignment between green industries and local priorities. Despite that the green economy has become a popular discourse, the narratives could move between 'green' and 'economy' depending on circumstances (O'Neill and Gibbs, 2016). The green industry itself is still maturing in both a technological and a market sense. If only meeting the 'green' aspect, industrial experiments may not be able to scale up. In Dezhou's case, the early growth of the SWH industry was a spontaneous process following the law of the market, but it became politicized in the later phase as both the entrepreneurs and the municipal government were too eager to promote the industry to an unrealistic level with a huge investment that was way beyond the city's financial capacity and the industry's economic prospects. Therefore, it is challenging for public authorities to make smart decisions as to whether, when and how to intervene in transition governance. This entails an accurate and realistic grasp of the market trend on the one hand, and the adaptivity of governance approaches on the other. It is also important to ensure sectoral diversity of the local economy because over-reliance on one specific industry or firm would harm the industry-territory relationship in the long run. It would be of both theoretical and practical value for future research to pay more attention to the institutionalization of the enabling mechanisms of industry-territory relationship in urban sustainability transitions.

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