Article:

Huang, P. orcid.org/0000-0002-7573-715X and Yu, Z. (2021) Aligning industry interests with urban priorities to foster energy transitions: insights from two Chinese cities. Cambridge Journal of Regions, Economy and Society, 14 (2). pp. 341-359. ISSN 1752-1378

https://doi.org/10.1093/cjres/rsab003

Aligning industry interests with urban priorities to foster energy transitions: Insights from two Chinese cities

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Abstract: This paper uses the Dimensions of Urban Energy Transitions (DUET) framework to analyze energy transitions in two Chinese cities at different development stages and provide insights into the mechanisms underlying decarbonized industrialization. The results show that a "green" coalition between industrial actors and local governments is critical to the initiation and scale-up of low-carbon innovations that provide strong endogenous incentives for proactive transitions. The study unveils the relevance of technology-specific characteristics and the potential countering effect of urban politics in shaping the outcomes of energy transitions, adding both nuance and depth to the DUET framework.

Keywords: energy transition; low-carbon economy; industry-territory alignment; China

JEL Classification：R58, O25, Q48

Introduction

Contemporary ecological crises cast serious doubts on the current mode of economic production and consumption (Jackson, 2009). Research on sustainability transitions raise questions such as will local economy be "sacrificed" in the pursuit of decarbonized production and consumption? Can cities simultaneously deliver industrial development and low-carbon transitions (Yu and Huang, 2020)? Such questions are particularly relevant for developing countries, where basic societal needs are yet to be fulfilled, and local priorities are attractive to industrial development targeting energy-intensive and carbon-generating industrial processes. Increasing scholarly and public interests have been paid to the development of low-carbon economy as a pathway toward sustainability transitions (Davies and Mullin, 2011). Nevertheless, how to develop a low-carbon economy in a systematic, institutionalized, and practical manner remains a largely unanswered question.

The body of literature on green entrepreneurship has highlighted the agency and impacts of entrepreneurs in green transitions, but it usually underplays the role of contextual factors (Gibbs and O'Neill, 2012). In concurrent with the 'spatial turn' in innovation and transition studies, there is a growing recognition that entrepreneurial activities need to be situated within and interpreted from broader socio-spatial contexts (Rutherford and Coutard, 2014; Yu and Gibbs, 2020). These contextual factors include, but are not limited to, natural endowments, industrial proximity, infrastructure, institutions, politico-geographical structures, and culture-rooted imaginaries (Jasanoff, 2015; Jasanoff and Kim, 2013; Huang and Castán Broto, 2017). Integrating geographical thinking in innovation and transition studies, Huang and Castán Broto (2018) developed an analytical framework-- Dimensions of Urban Energy Transitions (DUET)--to contextualize energy transitions within urban dynamics by bringing together the technological, social, spatial, and political facets of urban energy transitions. In particular, it captures the relational dynamics between industrial interests and urban priorities, and the formation of alignment between the two as a key driver for local energy transitions.

Applying the DUET framework, this research intends to answer the question of *how does the interplay between urban priorities and industrial interests shape energy transitions in different urban contexts*. The experiences and lessons from two Chinese cities, Shenzhen and Dezhou, provide insights into the trade-offs, opportunities, and challenges accompanying the path of decarbonized industrialization. The findings contribute to existing research by revealing how the dynamic interactions between urban priorities and industrial interests lead to distinct energy transition outcomes in different urban contexts. The findings also unveil important influencing factors in industry-territory interactions, adding analytical richness to the DUET framework.

The remainder of the article proceeds as follows. Section 2 reviews extant literature and delineates the theoretical framework. Section 3 introduces the study area, research method and data. Section 4 presents an empirical analysis of energy transitions in Shenzhen and Dezhou. Special focus is placed upon the dynamic evolution of the alignment/dis-alignment between industry interests and urban priorities. Conclusions are drawn in section 5.

Theoretical framework

Within both academia and policy circles of energy transitions, there have been debates about the legitimate degree of balance between economic growth and environmental sustainability (Newell et al., 2009; Smits, 2015). In the past decade, more radical discourses have emerged to fundamentally question the logic of capitalism. The degrowth movement, for instance, criticizes the capitalist system based on infinite growth and, instead, advocates for a paradigm that goes beyond 'growth as a sign of progress' (Fournier, 2008). From the demand side, the key idea is to move away from the quantity of consumption to the quality of consumption. However, for developing or under-developed countries, this radical degrowth model may deprive them of the opportunity for economic prosperity. Scholars, therefore, argue that for less developed countries, economic development, or more specifically industrialization, is still a vital pathway for addressing various societal challenges such as poverty alleviation, job creation and infrastructure improvement (Zhang, 2011). This line of thought highlights the positive role of industrialization in building a low-carbon future. On the one hand, industry *per se* possesses an inherent ability to decarbonize, enabled by continuous technological innovation (Gru¨bler, 1995). On the other hand, industrialization is an effective means of achieving economic growth, which helps increase a society's resilience (e.g., stronger economic, physical, and technological capabilities) towards the impacts of climate change (Wells and Thirlwall, 2003).

The strategy of low-carbon economy is hence increasingly endorsed in climate and energy policymaking (Davies and Mullin, 2011). Inherently, the idea of low-carbon economy seeks to strike a balance between (continued) economic growth and environmental sustainability (Bina, 2013). In practice, the meaning and approach of green economy vary according to differing interpretations

(Ferguson, 2015; O'Neill and Gibbs, 2016). From a more transformative perspective, the green economy represents an approach of selective growth that gradually phases out energy-intensive industries and instead embraces clean technologies, resource efficiency, and ecological modernization (Bina, 2013; Ferguson, 2015). Green entrepreneurs are usually assigned an important role in fostering low-carbon economies (Burch et al., 2016; Isaak, 2017), with their strong agency in developing and commercializing disruptive technological innovations (Gibbs and O'Neill, 2014; Willis et al., 2007). The emergence and diffusion of technological innovations have been extensively examined in the field of innovation studies and sustainability transitions, giving birth to salient frameworks such as the multilevel perspective (MLP), the technological innovation system (TIS), and the strategic niche management (SNM). A key concept in transition theories is the sociotechnical niche, defined as a protected space that facilitates experimentation and innovation (Kemp et al., 1998). Sociotechnical experimentation represents purposeful actions to introduce niche innovations into urban contexts. The nurturing of niche experiments entails the channeling of key resources, including specialized technological knowledge, financial investment, niche market, and technology legitimacy (Binz et al., 2016). In this process, green entrepreneurs play an important role in mobilizing system resources and scaling-up experiments. The mobilization of resources, therefore, constitutes the key industry interests of urban experimentation, especially for green start-ups.

In the past decade or so, conventional transition theories are being increasingly criticized for the stance of decontextualizing or spatially neutralizing transition processes (Truffer and Coenen, 2012; Bridge et al., 2013; Hansen and Coenen, 2015). Bridge et al. (2013) noted that the "energy transition is fundamentally a geographical process that involves reconfiguring current spatial patterns of economic and social activity" (p. 331). Gibbs and O'Neill (2012) also pointed out the messiness of the transition process and the non-negligible role of local economic, social, and political contexts. This line of thought is supported by a growing body of empirical evidence. For instance, O'Neill and Gibbs (2016) delineated how green entrepreneurs actively engage with broader discourses of green economy to frame their entrepreneurial practices and to create spaces for their businesses. Yu and Gibbs (2020) illustrated how multi-scalar institutional and social structures influenced the agency of green entrepreneurs in resource mobilization, network building, and institution transformation for urban sustainability transitions. This body of literature represents part of an intellectual trend to bring geographies into transition studies (Truffer and Coenen, 2012; Rutherford and Coutard, 2014). The key message is that the visions of energy transitions need to be embedded within contextualized territorial circumstances. The deployment of urban and regional policies, the operation of informal, localized institutions, the availability of natural resources endowments, the specialization of local industries and technologies, and the place-specific aspects of local market formation all exert significant influences on energy transitions (MacKinnon et al. 2019). To bring spatiality into sustainability transitions, it entails the contextualization of entrepreneurial experimentation, particularly in urban contexts. The DUET framework represents such a conceptual effort. Developed by Huang and Castán Broto (2018), the DUET framework is a spatially informed analytical approach for urban energy transitions. In addition to the dimension *sociotechnical experimentation* as specified above, the DUET framework conceptualizes two additional dimensions to represent and incorporate the spatiality of urban energy transitions, namely of *socio-spatial (re)configuration* and *urban politics* (figure 1).

(Figure 1 about here)

Socio-spatial configurations of cities represent both constituents and consequences of transitions of the energy system (Hodson and Marvin, 2010, Nevens et al., 2013; Rohracher and Späth, 2013; Hodson et al., 2016). The DUET framework theorizes two key elements of socio-spatial (re)configuration - territorial proximity and socio-spatial embeddedness. From the lens of relational geography, the urban is no longer a passive container of energy transitions but instead a relational 'transition space' (Coenen et al., 2012). Various relations of separation and proximity hence manifest as key factors shaping and reshaping transition processes (Coenen et al., 2012; Huang and Castán Broto, 2017). Building upon Boschma's (2005) relational reading of innovation activities, the DUET framework proposes three forms of territorial proximity that are of particular relevance for transition research, including geographical proximity, cognitive proximity, and institutional proximity (Huang and Castán Broto, 2018). Moreover, because every city is attached to or embedded in pre-existing spatial entanglements, socio-spatial embeddedness depicts the degree of path dependency of energy technologies. In particular, it deals with how deeply technology is embedded in urban socio-spatial structures (e.g., the infrastructure fabric and social practices) (Bridge et al., 2013).

Elements of local socio-spatial configurations such as natural endowments, manufacturing structures, and institutional infrastructure define territorial priorities, which may pose advantages or disadvantages for the development of sociotechnical experimentation (Castán Broto and Bulkeley, 2013). Huang et al. (2018), for instance, showed how pre-existing conditions of the built environment shaped the selection of solar thermal technologies in Chinese cities. Similarly, Ma et al. (2013) identified richness in natural gas resources as a key driving factor for the rapid development of natural gas vehicles in Chongqing, with strong government support. Urban priorities are not static, and their dynamics are subjected to place-specific transition politics (Grillitsch and Sotarauta, 2018; Hu and Hassink, 2017). In the DUET framework, the interplay between industry interests and territorial priorities constitutes a key part of the politics of urban energy transitions (figure 1). On the one hand, entrepreneurial experimentation operates within heterogeneous power relations of urban stakeholders, especially political actors; on the other hand, the local government often possesses significant political power to either support radical changes or prevent them (Rutherford and Jaglin, 2015). Aligning industry interests with urban priorities is hence critical to the survival and success of sociotechnical experimentation, especially at the early stage of experiments (Huang and Castán Broto, 2018). A few studies have shed some light on this issue. For instance, Carvalho et al. (2012) demonstrated how local governments provided supportive physical and institutional infrastructure to catalyze cleantech niches out of the coupling of urban governance priorities and the interests of cleantech firms. Normann (2015) showed how timing mattered in the matching of technological solutions with political agendas that shaped the rise and fall of offshore wind in Norway. This study extends these prior efforts by applying the DUET framework to investigate the dynamic interplay between green entrepreneurs who represent localized industrial interests and local governments who formulate urban political priorities (figure 1). Specifically, the study explores to what extent the alignment/dis-alignment between urban priorities and industry interests shapes the trajectory of urban energy transitions, which remains less understood in the literature.

Study area, methodology, and data

The empirical analysis focuses on two cases of energy transition in China, New Energy Vehicle (NEV) development in Shenzhen and the application of solar thermal technologies in Dezhou. For case selection, the study follows the strategy of theoretical sampling (Eisenhardt, 1989). That is, the cases are manifestations of a theoretical construct (the DUET framework) and are used to exemplify or enrich the theory (Eisenhardt, 1989; Patton, 1990). Guided by the DUET framework, the unit of analysis is a city that meets specific theoretical propositions (Yin, 1994): first, the case city exhibits a trend of energy transition around a particular low-carbon technology; second, there is a leading local enterprise representing the industrial interests of the focal technology. Moreover, as suggested by Eisenhardt (1989), the cases need to represent a certain level of diversity to enhance the generalization of theories. For this study, we intentionally selected two case cities with relatively dissimilar socioeconomic characteristics and different dominant low-carbon industries. This strategy can strengthen the analytical generalization of the DUET framework to account for the dynamics and effects of different urban contexts (developed cities vs. latecomer cities) and technology typologies (emergent, high-end technologies vs. conventional, low-end technologies). Lastly, we also consider data availability and accessibility in the selection of cases (Yin, 1994). Table 1 presents a summary of the key characteristics of the two case cities.

(Table 1 about here)

Shenzhen is a coastal city located in the south of China, known as the "Silicon Valley of China." NEV development in Shenzhen represents an energy transition in-the-making, with wide-spread NEV application in the public transport system (Huang and Li, 2019). This achievement is inseparable from the rise of a local NEV manufacturer, "Build Your Dreams" (BYD). Currently, BYD is the only electric car manufacturer that makes its own battery and is the largest rechargeable battery manufacturer in the world (Ogan and Chen, 2016). In 2016, BYD was among the top 20 enterprises that contributed most to Shenzhen's GDP. In Shenzhen's low-carbon transitions, BYD is an important player, and in turn, BYD makes use of favorable local policies and public resources to support its business and to explore the local market. A 'green' coalition has apparently been established between BYD and the Shenzhen municipal government.

Dezhou is located in the north-west of Shandong Province, a part of China's third-largest economic zone—Bohai Economic Rim. Dezhou is a typical developing city in China. Its GDP per capita in 2019 was only a quarter of the level of Shenzhen. Nonetheless, since the early 2000s, Dezhou has been widely recognized as a pioneering city in renewable energy development and earned the reputation of 'China's Solar City' (Yu and Gibbs, 2018a, 2020). Dezhou not only accommodates an important solar water heater (SWH) cluster in China but also has a high adoption rate of SWHs among residents. In this transition, the powerful SWH firm Himin, which used to be the largest SWH manufacturer in the world, had played a dominant role in promoting the development and diffusion of SWH technology in Dezhou. The industry also altered the local government's future vision to put the solar industry as a top priority for Dezhou with favorable policies. However, as the industry showed signs of decline in recent years, a dis-alignment was observed between urban priorities and solar experiments.

The primary data is based on semi-structured interviews conducted in the authors' fieldwork in China, including 17 interviews for Shenzhen and 30 interviews for Dezhou (table 2). For Dezhou's case, the first round of interviews (26) was conducted in 2014. As we found new development in Dezhou's solar transition in recent years, four follow-up interviews were taken in May 2020. Interview transcripts were reviewed and coded. The coding scheme was driven by the research question of this study, supported by researchers' interpretative activities. For each interview transcript, we sorted relevant content into key thematic domains of the study, including urban priorities, industry interests, and the interactions between the two, and a summary sheet was generated to draw comparisons of the two cases. First-hand interview data were complemented by secondary materials such as policy documents, industry reports, and news media coverage.

(Table 2 about here)

Empirical analysis of energy transitions in two Chinese cities

"Build Your Dreams" in Shenzhen

Evolution of Shenzhen's development priorities

After the reform and opening-up policy, Shenzhen was designated as a special economic zone (SEZ), with a series of preferential policies such as tax relief and free or low-rent industrial land. Ever since, Shenzhen witnessed a massive influx of foreign investment and quickly established a base of labor-intensive export-oriented processing manufacturing. Nevertheless, due to the rising costs of land and labor and the damage to the environment, it became increasingly difficult to sustain this mode of economic development (Ogan and Chen, 2016). Since the late 1980s, a wave of economic restructuring started to unfold in Shenzhen, moving from low-end processing manufacturing to more technology-intensive, higher-value-added industries. This priority was highlighted in both the 8th Five-Year-Planning (FYP) (1991-1995) and the 9th FYP (1996-2000) of Shenzhen. By 2000, high-tech industries accounted for almost 42.3% of the industrial output[i]. In Shenzhen's 10th FYP (2001-2005), the share of high-tech industries of the industrial output was set to reach 50% till 2005.

The 11th FYP period (2006-2010) was characterized by further industry restructuring. Because Shenzhen's economy was highly unbalanced, relying disproportionately on the electronic information industry, the government initiated a new round of industrial upgrading by developing technology- and capital-intensive equipment manufacturing industry and basic industries. "To promote moderate-heavy industrialization" was written in Shenzhen's 11th FYP, and more detailed plans were laid out for the strategy. The northern districts of Shenzhen, such as Baoan and Longgang, were oriented towards developing heavier industries. In Longgang district, for instance, the Baolong Industrial Park was aimed to form an automobile cluster.

Entering the 12th FYP period (2011-2015), the urban priorities of Shenzhen started to shift from economic-centered to more environmental-oriented. This shift was partially driven by the change in the national priorities. At the Copenhagen Climate Change Conference in 2009, the Chinese government set the goal of reducing 40–45% of the carbon emission intensity by 2020, compared with 2005 levels. The central government has since taken a series of low-carbon actions, including the Low-carbon City Strategy. Shenzhen was selected as one of the eight low carbon pilot cities. The new energy industry was listed as one of Shenzhen's strategic industries. In the 12th FYP published in 2011, a section was devoted to the implementation of low-carbon and green development and several projects of NEVs were listed as key projects during the 12th FYP period. In 2012, the "Shenzhen National New Energy Automobile Industry Base" was established, which was certified by the Ministry of Commerce and the Ministry of Science and Technology as the fourth batch of "National Strategic Emerging Industry Bases".

Entrepreneurial experiments of BYD in Shenzhen

Before founding BYD, Wang Chuanfu was a researcher in the General Research Institute for Nonferrous Metals located in Beijing, majoring in battery technology. In 1992, Deng Xiaoping's southern tour drove further opening-up of the Chinese economy and inspired the enthusiasm of the whole society for entrepreneurship (Guan et al., 2019). It was against this background that Wang quitted the job in a public research institute in 1995 and thereafter started his own battery business in Shenzhen. Wang's background as a battery researcher has proved to be an advantage for early-stage innovation. For instance, BYD re-designed the manufacturing process to convert it from capital-intensive to labor-intensive (Wang and Kimble, 2010). This process innovation not only coped with limited financial resources but also made use of abundant and cheap labor resources in Shenzhen then. In 2002, BYD became the world's second-largest battery manufacturer (Marinov and Marinova, 2012).

The year 2003 was a turning point. Through the acquisition of Tsinchuan Automobile Company in Xi'an, the battery producer founded the subsidiary BYD Auto and officially entered the automobile industry. Initially, the manufacturing plant was based in Xi'an. Nevertheless, with BYD's strategy of exploring the overseas market, Xi'an, in a geographical sense, was not suitable for the mass production of export cars. BYD hence sought to establish a new manufacturing base in the southeast coast of China. In 2004, the Longgang district of Shenzhen signed a framework agreement with BYD to build an auto manufacturing base in Pingshan new district. In 2007, the new production base was completed, which could create 30,000 to 40,000 jobs and the production capacity was 200,000 vehicles per year[ii].

In 2008, BYD started to produce hybrid electric cars and later pure electric cars (Marinov and Marinova, 2012). In the same year, a new research institute for automobile was opened in Shenzhen, and BYD launched the world's first mass-produced plug-in hybrid automobile. In 2010, BYD pioneered the idea of 'Electrified Public Transportation Solution'. In the same year, BYD launched its first battery EV for public transportation (Masiero et al., 2016). Since 2015, BYD's NEVs have ranked first in global sales for four consecutive years (Shang and Choi, 2020). The achievement is inseparable from BYD's consistent emphasis on and strong capacity in technological innovation. Till the end of 2016, BYD possessed more than 18,000 patent applications globally. Starting as a battery manufacturer with merely twenty employees, BYD has now grown to be the industry leader and a global brand in NEVs.

The evolution and consolidation of the interest alignment between Shenzhen and BYD

BYD was founded at a time when Shenzhen was trying to upgrade its industry from low-end processing manufacturing to high-tech, high-value-added industries. Therefore, BYD, registered as a battery company, obtained substantial key resources through the local government during the initial stage of corporate development. For instance, the municipal government established many surety companies to help channel capital to promising start-up enterprises in favorable sectors. The Shenzhen High-tech Investment (SZHTI) Group is one of them. Established in 1994, two of SZHTI Group's major shareholders were the State-owned Assets Supervision and Administration Commission of Shenzhen Municipality and the Finance Commission of Shenzhen Municipality. In 1996, BYD received an annual financial guarantee of 2 million RMB from the SZHTI Group. In 1998, SZHTI Group provided a financial guarantee of 9 million RMB for battery business expansion and R&D investment; and in 2000, SZHTI Group again provided a financial guarantee of 70 million RMB to BYD for the construction of an industrial park[iii]. These financial resources were critical for BYD's business expansion and R&D activities.

Entering the new millennium, when Shenzhen sought to develop its automobile industry, BYD established BYD Auto to enter the automobile market. BYD and the Shenzhen municipal government shared a common interest in constructing a new plant of BYD in Shenzhen for the manufacturing of vehicles, particularly NEVs. The municipal government, as revealed by one interviewee, had played a quite proactive role in making this happen:

> *"At that time, in terms of industry development, Shenzhen decided to promote the strategy of moderate-heavy industrialization. Considering that first there were no joint venture auto enterprises in Shenzhen, second China's fuel vehicle technology lags far behind the west, and third the electronic industry in Shenzhen is very developed, covering the whole industry chain, we chose to develop the new energy vehicle industry. The municipal government invited BYD to build a plant in Shenzhen."*

Commenced in 2006, the construction of the new manufacturing base was finished within merely 329 days. This is inseparable from strong support from local government, particularly the Longgang district government, with relevant departments opening the green passage for BYD to speed up the construction. Because of the agglomeration effect of BYD, Shenzhen has now successfully developed a cluster of NEV industry, with a total of 18 new energy enterprises. In 2017, the added value of the new energy industry in Shenzhen reached 67.64 billion yuan[iv]. A former mayor of Shenzhen described the interest alignment between Shenzhen and BYD:

> *"BYD's enterprise development strategy is in line with Shenzhen's urban development strategy, conforms to Shenzhen's current road of independent innovation and modern industrial system construction, meets the requirements of the Scientific Outlook on Development, and also conforms to the blueprint of creating a national innovative city."*[v]

In 2010, BYD put forward the 'Electrified Public Transportation Solution', which offered an action plan for Shenzhen to advance low-carbon strategies. Out of this interest alignment, both BYD and the Shenzhen municipal government took concrete actions to realize the vision of ''Electrified Public Transportation'. In 2010, BYD, together with the Shenzhen Bus Group, established the Peng Cheng E-taxi Company. The primary purpose was to experiment with the application of electric vehicles in public transportation. The purchase of electric vehicles was heavily subsidized by the government, as described by one interviewee:

"In the early days of demonstration application of electric taxis, the Shenzhen municipal government provided high subsidies to BYD, covering two-thirds of the price of electric cars (including both national subsidy and local subsidy). The subsidized price is comparable to the price of a standard gasoline car for taxis."

Initially, the E-taxi company encountered many difficulties such as the lack of charging infrastructure and low user acceptance, but gradually it managed to realize profits. The success of Peng Cheng E-taxi Company has encouraged more financial capital into the electric taxi market. Till 2019, E-taxies accounted for 99% of the total taxi market in Shenzhen. In 2017, Shenzhen became the world's first city to electrify 100% of its public buses (TCSM 2017).

Overall, the Shenzhen case exhibits a benign interaction between industrialization and decarbonization. The rise of BYD is closely intertwined with the growth of Shenzhen. As described by BYD's CEO Wang Chuanfu in a media interview:

"Without the reform and opening-up policy, there will be no Shenzhen; and without Shenzhen, there will be no BYD"[vi].

In turn, Shenzhen has also benefited much from hosting BYD and the NEV cluster, first in the rise of Shenzhen as an automobile manufacturing base and later as a role model in low-carbon urbanization, particularly in the development of electric public transportation. Shenzhen has gradually gained not only national but also international reputation in low-carbon energy transitions. Figure 2 summarizes the continuous interest alignment between Shenzhen and BYD.

(Figure 2 about here)

The sun rises and sets in Dezhou

Evolution of Dezhou's development priorities

Comparing to Shenzhen, Dezhou represents a more general story of Chinese cities' industrialization after the opening-up reform. Sitting on the fertile lower reaches of the Yellow River, Dezhou has long relied heavily on the agricultural sector, which accounted for 65.88% of Dezhou's GDP in 1984. Thereafter, the beginning of industrialization drove its rapid economic development. Nevertheless, Dezhou remains one of the least developed regions in Shandong in terms of both absolute GDP and GDP per capita.

Before the early 2000s, industrialization was a top priority of Dezhou. Under the political discourse of "*being economically underdeveloped is the biggest reality of Dezhou, and accelerating development is the biggest politics*" (Dezhou 10th FYP, 2000), transforming its economic structure from an agriculture-based one to a manufacture-based one was deemed the key engine of Dezhou's economic development. By the mid-2000s, the secondary industry had achieved a dominant position in Dezhou's GDP. Equipment manufacturing, food, chemical, and textile industries became the four competitive industries. There were also emerging industries such as new energy (solar energy in particular), new materials, biomedicine, and culture and sports goods industries. In 2010, the main business income of these eight leading industries accounted for 73.9% of Dezhou's total industry income.

After 2005, the Dezhou government shifted the local development strategy to make Dezhou's secondary industry bigger and stronger through fostering leading high-tech enterprises. In Dezhou's 12th Five-Year Industry Plan (2011-2015), the above four emerging industries were expected to represent 35% of Dezhou's industry income, and the high-tech industry's proportion was expected to reach 30% in 2015. In particular, the solar industry gradually became an icon industry in Dezhou. With the growing political and discursive pressure for low-carbon development from the international and national landscape, the solar industry was assigned greater importance in the city's economy. In its 11th FYP (2005-2010) and 12th FYP (2011-2015), Dezhou decided to build a solar economy and planned to develop a solar-related business with more than RMB 100 billion output by 2015. This plan, however, did not materialize.

When it comes to the 13th FYP (2016-2020) period, the Dezhou government embraced the idea of 'coordinated development', highlighting a sustainable relationship between economic, social, and ecological development. Although upgrading the economic structure is still of top priority, Dezhou has begun to adopt a more comprehensive and steadier pathway through new modes of industrialization, urbanization, agriculture modernization, and informatization.

Entrepreneurial experiments of Himin in Dezhou

The change of Dezhou's territorial priorities is closely intertwined with the development of the SWH industry, in which the leading firm Himin played a central role (Yu and Gibbs, 2020). Similar to Wang Chuangfu's story, Huang Ming, the founder of Himin, worked for a public research institute before joining the 'tide of going to the business'. Huang began to experiment with solar thermal technologies in the late 1980s and established a family workshop engaging simple SWH manufacturing in 1992, which paved the way for the establishment of Himin in 1995. In 1996, Himin initiated a 'Solar Science Popularization Tour' around China to advertise its brand and explore the national market. This endeavor is believed to have significantly facilitated China's SWH market formation. Meanwhile, Himin upgraded its technological capacity by collaborating with top universities and building its R&D teams with a leading returnee scientist from Australia. With the rapidly growing SWH market in China, Himin soon became the world's largest SWH manufacturer by the beginning of the 21st century.

Benefiting from Himin's technology spillover and market expansion, a thriving solar industry emerged in Dezhou. By 2010, Dezhou had more than 120 enterprises engaging in solar-related industries, producing 16% of China's SWH. Himin's practice was then internationally recognized as a marker post for sustainable development that realizes a win-win for the environment and the economy. Himin acquired more political impact after Huang Ming was selected as a delegate for China's National People Congress in 2003 and the vice president of the International Solar Energy Society in 2008. In the same year, Himin received a $ 1 billion investment from Goldman Sachs and Dinghui Investment.

Since 2001, Himin began to promote SWH-building integration projects in Dezhou and nationwide. After failing to collaborate with estate developers, Himin started to experiment with some small-scale demonstration solar buildings by itself and then developed a large-scale estate project 'Future

City' in 2006 as a model of SWH-building integration. At the same time, supported by the municipal government, Himin built a huge 'Sun Valley' of 3000 acres in Dezhou's eastern suburb. This valley was planned to be the center of production, research, exhibition, and cultural communication of solar products, including SWH-building integration, solar power generation, solar lighting system, solar air-conditioning, and solar seawater desalination. As a senior staff in Himin recalled:

> *"The Sun Valley is a 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".*

While Himin diversified its businesses and earned the reputation of 'the kingdom of solar products', risks awaited at the corner. First, the revenue from its main business—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% to 10% in China around 2010. Second, the "Future City" project was too advancing and costly for Dezhou's residents then, resulting in a great financial failure. After 2008, when many cities began to mandate estate developers to incorporate SWH into buildings, Himin grew slowly in the market due to huge upfront investment and the fact that 'guanxi' (interpersonal relationship) and low price earn bids (Yu and Gibbs, 2018b). Third, Himin invested RMB 3 billion to build the 'Sun Valley' but turned out to be a failure. Because of this, Himin was in debt of more than RMB 2 billion after the World Solar City Congress. Himin applied for listing on the stock market three times in 2007, 2010, and 2012, but all failed[vii]. The main reasons were believed to be its unclear financial relationship among Huang Ming's family businesses, history of tax evasions, and close personal relations with a former local political leader who was jailed for corruption in 2012[viii] (will be elaborated on this in the next section). Since then, Himin struggled to survive under this huge financial debt but barely showed signs of recovery.

Alignment and dis-alignment between industrial interests and urban priorities

At the first stage (1980-2004), the priority of Dezhou was industrialization. Back then, Dezhou's manufacturing sector was dominated by small, state-owned, and polluting enterprises. The spontaneous and fast growth of Himin since 1995 challenged this stereotype. Himin not only became an icon green enterprise but also promoted a booming solar industry in Dezhou, contributing to the city's tax revenue, employment, and branding (Yu and Gibbs, 2018a). This bottom-up success significantly influenced Dezhou's development strategy. As an entrepreneur illustrated:

> *"In the past, people knew Dezhou because of braised chicken, but this product was a low-end product…Dezhou government wanted to promote Dezhou to the world, so they needed a well-known star enterprise. Eventually, they believed Himin could be the best city brand of Dezhou… The government expected that the leading enterprise Himin, together with those supporting solar enterprises, would make a difference to Dezhou".*

At the second stage (2005-2015), the Dezhou government aimed to build a bigger and stronger manufacturing industry by fostering big brands and high-tech private enterprises. Particularly, the Dezhou government put forward the Solar City Strategy in its 11th and 12th FYP, aiming to build Dezhou as the solar city of China and the world. A solar city strategy committee led by the principal leader of the municipal government was established, who issued many policy documents to support the technology research, industry development, and application of solar energy. Since 2005, Dezhou had officially encouraged SWH-building integration and changed to mandatory policy in 2008. Also, a

Solar City Office was established specifically for organizing the World Solar City Congress 2010 and promoting solar building demonstration projects. The most controversial move, however, was to provide Himin a large piece of land at a discount to the market price for building the Sun Valley. Dezhou government highly valued the World Solar City Congress as a historic event for Dezhou's development and supported Himin with RMB 60 million subsidies to build the Sun Valley as the congress site as well as the landmark of Dezhou. The government also promised to compensate for the relocation of residents on the land, which did not go very smoothly. Nonetheless, the Solar City Congress was successfully held in 2010, and Dezhou and Himin won many national and international green awards and investments.

After the congress, however, the enormous fixed assets became a time bomb for Himin. Things went down sharply when the then vice governor of Shandong Province, Huang Sheng, was arrested for corruption in 2012. Huang Sheng was among Dezhou's top leadership during 2001 and 2007 when the Solar City Strategy was put forward, who strongly supported Dezhou's solar economy with various favorable policies. Media coverages reported that Huang Ming had close personal connections with Huang Sheng, and Himin illegally acquired a large area of land from the government at a low price[ix]. These reports were not officially confirmed, but Himin did become a sensitive issue to the Dezhou government after Huang Sheng's arrest. In the same year, Himin's third endeavor to list on the stock market failed. Overnight, the heavy debt load, bold diversification, slow market growth, family business management, and vague government-business relations all came together to pull down this solar giant. Dezhou government offered some help by providing some commercial loans for Himin, but this barely stopped the decline of Himin.

In 2015, a new leadership was formed in Dezhou as the secretary of Dezhou's CPC committee. This new administration decided to cut off the relations with Himin and let the market determine its fate. In the 13^{th} FYP (2016-2020), Dezhou planned to adopt a comprehensive and steady approach to achieve coordinated development and no longer invested in the solar city strategy or solar economy. In 2017, the Solar City Committee was also abolished. In 2018, Huang Ming released an open letter online to complain that the Dezhou government did not provide financial support to Himin as promised, which he believed was the main reason for Himin's decline[x]. The relation between Himin and the Dezhou government began to deteriorate. As an official commented:

> *"We have basically abandoned this (solar city) brand now".*

Nonetheless, the positive side is that the user practice of using SWH has been established in Dezhou. The Solar City Office is also kept to promote SWH-building integration. Dezhou maintains a high adoption rate of SWH, even among the young generations. Figure 3 summarizes the evolution of the alignment and dis-alignment between industrial interests and urban priorities in Dezhou.

(Figure 3 about here)

Result analysis

The two cases exemplify both similarities and differences in urban energy transitions. The application of the DUET framework reveals the operation of different dimensions of energy transition in the local contexts. Place-based socio-spatial dynamics shape the formation and evolution of territorial priorities. In Shenzhen, for instance, the geographical location, the political designation as a national SEZ, and the industrial basis of the electronic sector have shaped the urban development priorities at different stages. Entrepreneurial experimentation inevitably encounters a selection environment that is primarily defined by territory-based priorities. The alignment of the two is therefore critical for furthering energy transitions. Both cases demonstrate the facilitating role of industry-territory alignment in innovation initiation, diffusion, and application. In Shenzhen, BYD obtained critical financial resources during its business expansion because the company fitted well into the city's broader industry agenda. Similarly, when the solar industry was integrated into Dezhou's industry strategies, Himin managed to gain many key resources (e.g., land and institutional supports) from the local government.

The two cities exhibited substantial spatial heterogeneity in industry-territory interactions, with differing mechanisms of alignment formation between industry interests and urban priorities. In Shenzhen's case, the local government played a more proactive role in drafting the city's development strategies. The EV sector happened to fit into the mosaic of the city's blueprint of industry development, and BYD seized the window of opportunity that was opened by the local government. It was hence the shift of urban priorities that allowed for the growth of particular green niches. In contrast, the Dezhou municipal government played a more passive or reactive role. It was pioneer entrepreneurs who led the transitional process, while the municipal government's actions merely followed entrepreneurial initiatives and reoriented its urban priority to solar city building because of the rise of Himin. This indicates that place-particularities such as socioeconomic status matter in the approaches of transition governance. Shenzhen is a developed city in China and possesses more capacities in pursuing the city's own developmental agendas, while Dezhou has limited resources in formulating and enforcing ambitious development plans and is more likely to adapt to or take advantage of on-going bottom-up dynamics that align with the city's economic interests. This indicates that the outcomes of transition politics are contingent upon different socio-spatial contexts.

Lastly, the two cases also show the temporal dynamics of the institutional alignment between local government and industry actors, which is shaped by the intensive interactions between innovation, governance, and spatial factors. In Shenzhen, we observe a continuous consolidation of the alignment, with further integration of BYD into Shenzhen's low-carbon agendas, particularly in electrifying the public transport system. While in Dezhou, the formed industry-territory alignment is relatively fragile, and recent years have seen a significant trend of decoupling between Himin and the local government. In Dezhou's case, the early growth of the SWH industry is a spontaneous process following the law of the market, but in the later phase, both the entrepreneurs and the municipal government are too eager to promote the industry to an unrealistic level with a huge investment that is way beyond the city's financial capacity and the industry's economic prospects. The change of local leadership further led to fundamental shifts in the policy focuses, in which the SWH industry is no longer a development priority for Dezhou. In Dezhou, there is a weakening trend in the alignment between industrial actors and local government, portending the prospect of a reversal of solar energy transition. The spillover effects of industry-territory alignment required to enable a more comprehensive urban low-carbon transition are therefore fragile.

Conclusion and discussion

This study applies the DUET framework to analyze two cases of energy transitions in China. The findings reveal the critical importance of the industry-territory alignment in urban energy transitions. Despite the emergence of the green economy as a popular discourse, the narratives could move between 'green' and 'economy' depending on circumstances (O'Neill and Gibbs, 2016). If only meeting the 'green' aspect, industrial experiments may not be able to scale-up or be sustainable, especially in developing countries. In the two Chinese cities, we observe the formation of a so-called "green" coalition between industrial actors and local governments, which proved to be critical for the initiation and scale-up of low-carbon innovations and further proactive transitions. The formation of the industry-territory alignment is a dynamic rather than a static process, and the relationship between industry interests and territorial priorities is constantly shaped and reshaped by the changing power relations between transition actors. The results demonstrate the applicability of the DUET framework in diverse urban contexts with differing political and socioeconomic settings.

The study unveils two important influencing factors in industry-territory interactions, which might contribute to the theoretical construct of the DUET framework and add both nuance and depth to the understanding of the dynamics of urban energy transitions.

First, the study uncovers the relevance of technology-specific characteristics in the formation of the industry-territory alignment. Defined by inherent features such as technological complexity, costs, and productivity, low-carbon technologies differ substantially in terms of the economic benefits and potential (e.g., job creation and revenue generation) that they can bring to a region in transition. For local governments, there are always economic motivations underlying green industry development (Yu and Huang, 2020), which assigns a critical role to technology-specific attributes in shaping the dynamics between industries and urban priorities. As a potential extension to the DUET framework, future research might explore diverse patterns of industry-territory alignment in urban energy transitions in correspondence to different technology typologies. More structural insights can be generated through the temporal analysis of the degree of stability, strength, and continuity of industry-territory alignment.

Second, the study reveals the potential countering effect of urban politics in shaping the outcomes of energy transitions. In the DUET framework, urban politics is conceptualized as an integral dimension of urban energy transitions, and industry-territory alignment is considered an intended and desired outcome of urban political processes. Nevertheless, the Dezhou case has exposed the fragility of industry-territory alignment. Even when industry-territory alignment is reached and an energy transition initiated, a reversal of the transition might still occur with regime shifts in territorial priorities. This raises critical questions about the resilience of industrial experiments to institutional instability. As argued by Cohen and Naorb (2017), the political window of opportunity for green development is by nature limited in time and unstable. In some countries, the local priorities may shift because of the change of the governing party, and thus green agenda may easily go back to normal economic development or welfare state (ibid.). Even under a one-party regime like China, urban development strategies are still not stable due to the regular change of local leadership (Hu and Hassink, 2017). This highlights the importance of the institutionalization of the enabling mechanisms of industry-territory relationship in energy transitions, which could be a promising avenue for future research.

It is noteworthy that although this study has demonstrated the importance of industry-territory alignment in generating and strengthening momentum for urban energy transitions, the cases are limited in number and the empirical knowledge gained is largely confined to the Chinese context. Given the uniqueness of China's political system and the relatively authoritarian style of transition governance that assigns government a more prominent role in energy transitions, we caution against overgeneralization of the findings at this stage and call for more research on this topic in diverse political contexts.

The two cities exhibit different patterns of industry-territory interplay, which indicates a need to differentiate structurally weak regions and structurally strong ones in the approaches of transition governance. For less developed cities like Dezhou, echoing Zheng's (2016) observations, the highly personal and unstable official-merchant relations need to be replaced by more impersonalized and institutionalized government-business relations. Chinese society is a correlative society that builds upon interpersonal networks (guanxi) (Fei, 1985). This is particularly evident in small and less developed cities like Dezhou (Yu and Gibbs, 2018c, 2020). Although in some cases, guanxi can play a positive role in the formation of the industry-government coalition, it can also make the processes of urban energy transitions too politicized and highly unpredictable. An institutionalized government-business relation that is both stable and sustainable is hence imperative. For structurally strong cities like Shenzhen, because more resources and stronger governance capacities are in place, the transition could be initiated in a more planned, coordinated, and resilient manner, and the city is more likely to maintain long-term resilience of industry-territory alignment. However, the challenge lies in how to really materialize the institutionalized government-business relation to generate and maintain the innovation momentum of leading enterprises for radical/disruptive innovation that leads to the emergence and development of next-generation technologies.

Acknowledgments

This research is supported by China Postdoctoral Science Foundation Grant (NO.2019M650758) and Breakthrough Energy for a project on Chinese energy innovation policy.

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Endnotes

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[ii] http://www.lg.gov.cn/xxgk/xwzx/zwdt/content/post_2488471.html

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[vi] http://news.stcn.com/2019/0106/14780868.shtml

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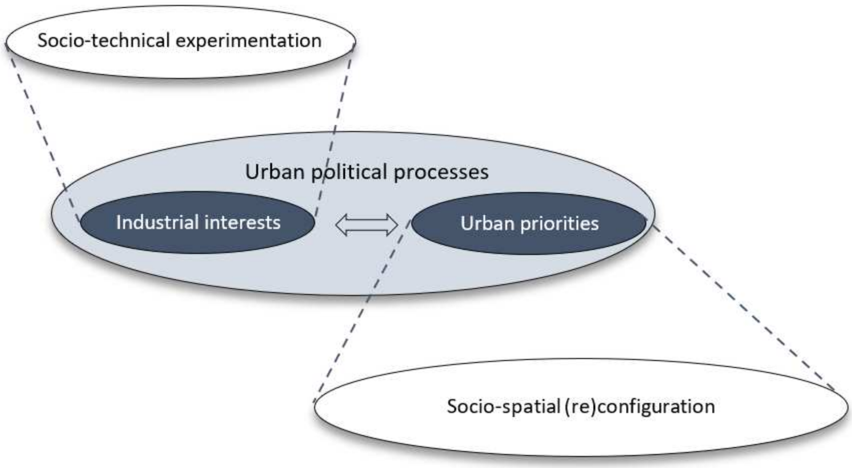

Figure 1. The Dimensions of Urban Energy Transitions (DUET) framework

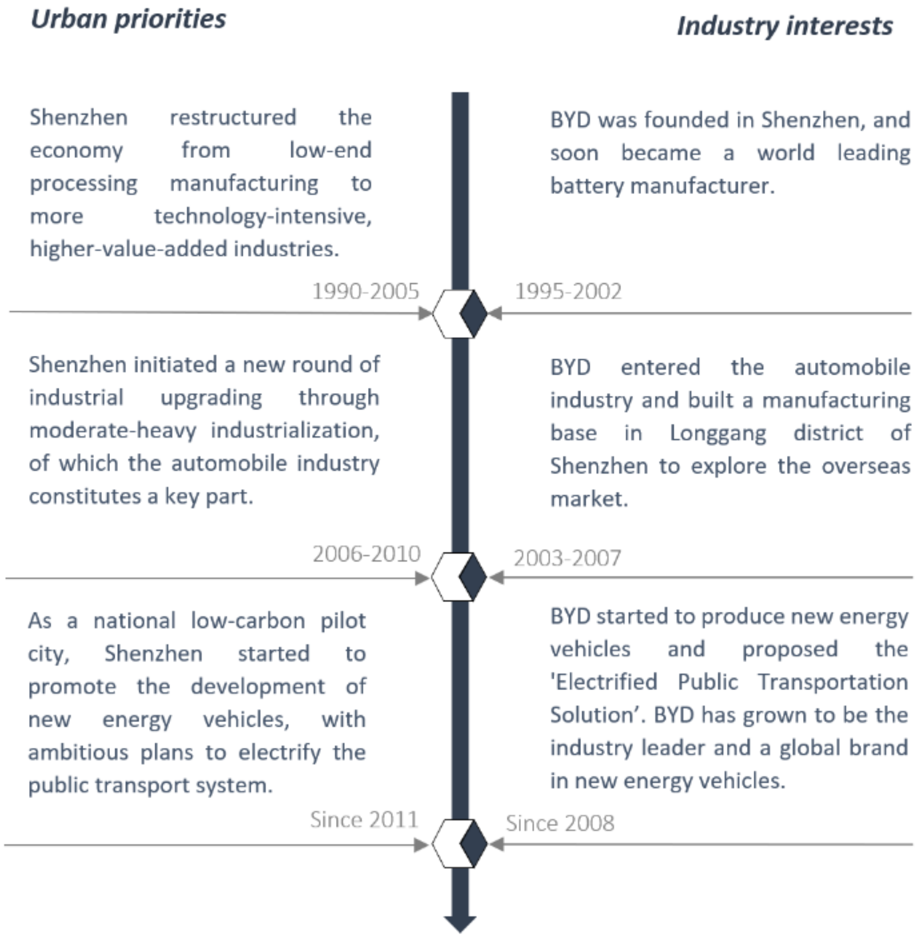

Figure 2. The evolution of interest alignment between Shenzhen and BYD

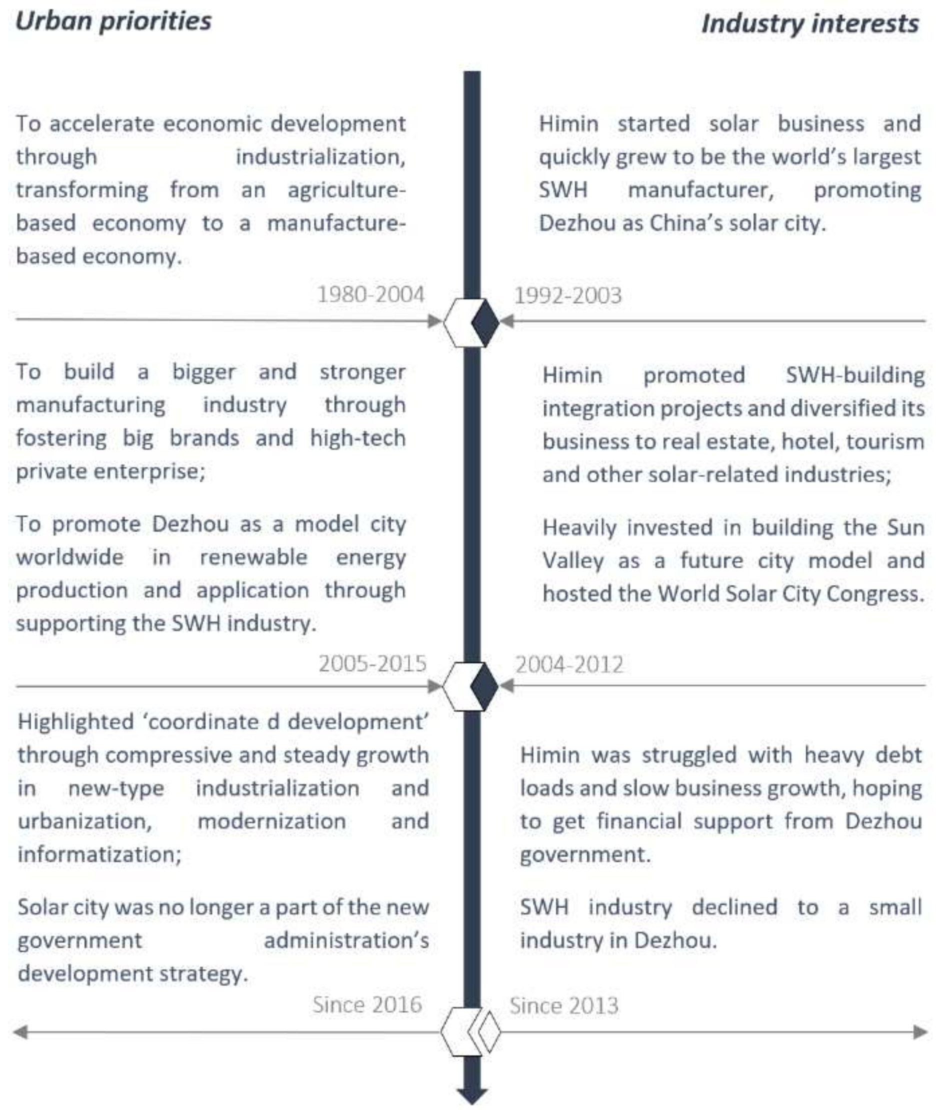

Figure 3. Evolution alignment and dis-alignment between industrial interests and urban priorities in Dezhou

Table 1. Key characteristics of the two case cities (2019)

Urban characteristics	Shenzhen	Dezhou
Population (million)	13.4	5.7
Urban built-up area (km^2)	960.5	165.0
Gross domestic production (GDP) per capita (thousand RMB)	203.5	52.3
Share of tertiary sector in GDP (%)	60.9	47.9
Focal technology	New energy vehicle	Solar water heater

Source: Shenzhen Statistics Bureau, 2020; Dezhou Statistics Bureau, 2020

Table 2. Interview information

Type of organization	Number of interviewees

	Shenzhen	Dezhou
Firm	6	20
Government	5	6
Academia	3	2
Industry association	3	2
Total	17	30