This is a repository copy of *Urban energy transitions : spatial organization, political contestations and urban governance*.

White Rose Research Online URL for this paper:
https://eprints.whiterose.ac.uk/178110/

Version: Submitted Version

Book Section:

Huang, P. orcid.org/0000-0002-7573-715X and Castán Broto, V. (2017) Urban energy transitions : spatial organization, political contestations and urban governance. In: Solomon, B.D. and Calvert, K.E., (eds.) Handbook on the Geographies of Energy. Edward Elgar Publishing , pp. 380-392. ISBN 9781785365614

https://doi.org/10.4337/9781785365621.00038

This is a draft chapter/article. The final version is available in Handbook on the Geographies of Energy edited by Barry D. Solomon and Kirby E. Calvert, published in 2017, Edward Elgar Publishing Ltd. https://doi.org/10.4337/9781785365621. The material cannot be used for any other purpose without further permission of the publisher, and is for private use only.

Reuse
Items deposited in White Rose Research Online are protected by copyright, with all rights reserved unless indicated otherwise. They may be downloaded and/or printed for private study, or other acts as permitted by national copyright laws. The publisher or other rights holders may allow further reproduction and re-use of the full text version. This is indicated by the licence information on the White Rose Research Online record for the item.

Takedown
If you consider content in White Rose Research Online to be in breach of UK law, please notify us by emailing eprints@whiterose.ac.uk including the URL of the record and the reason for the withdrawal request.

eprints@whiterose.ac.uk
https://eprints.whiterose.ac.uk/

29 Urban energy transitions: spatial organization, political contestations, and urban governance

Ping Huang and Vanesa Castán Broto

BACKGROUND

The current unprecedented rates of urbanisation have followed a seemingly unlimited and easily accessible supply of energy. Yet, energy is most often produced remotely and simply imported into cities through energy infrastructure systems. UN Habitat (2016) reported that "cities consume 78 percent of the world's energy and produce more than 60% of all carbon dioxide and significant amounts of other greenhouse gas (GHG) emissions". Cities are also the frontier battlefield for tackling the ongoing energy transitions towards a low-carbon society. Energy transitions refer to radical, large-scale and integrated socio-technical changes. Thus, the field of transitions aims to capture the co-dynamics of energy related technologies, institutions, social and economic sub-systems. Energy is intertwined with the whole urban economy (van den Bergh, et al., 2011).

Scholars in urban studies have argued that the urban is always central for energy transitions as much as energy transitions shape the urban fabric and the whole range of experiences that take place in the city (Rutherford and Coutard, 2014). Furthermore, cities are increasingly regarded as key local "managers" of energy transitions in a broad scheme of transformation. This is not only with regards to local governments' actions, but also, with regards to the actions of a wide range of public and private actors that are seeking to shape urban energy transition. There is thus an intensive interaction between energy transitions and urban change. The urban is constitutive of low-carbon transitions, both creating the possibilities for transition and bringing together a myriad of actors that can make it possible

(Bulkeley, et al., 2014).

In recent years, transition scholars have also developed a strong interest on the role of 'space' in transitions. They come associated with a growing interest on space as relational, this is, as emerging from social interaction, rather than as a mere container (Thrift, 2004, 2008). Equally, ideas of relational space have emerged in transitions research leading to discussions about how to define the distance between actors, and how to consider different relations of separation and proximity that shape transition processes (Coenen, et al., 2012). Truffer and Coenen (2012) propose an understanding of transition spaces looking both at the actual local contexts of innovation and the different relations that shape the innovation landscape.

Despite the theoretical recognition of space as relational, most of the empirical studies of energy innovation and transitions tend to emphasise historical and linear storylines of socio-technical transitions on a scalar space, mainly in a nation -state bounded space, which largely follow only one pathway that actually occurred, overlooking the possible infinite pathways in the future. Besides, the concrete spatial contexts within which transitions take place have been largely neglected (Suurs, et al., 2010; Negro, et al., 2012). This is particularly significant for urban areas because of their importance in mediating energy transitions. To bridge the gap, and following recent work by Rutherford and Coutard (2014), the aim of this chapter is to raise a discussion about the spatial heterogeneity, political contestation and urban governance of energy transitions. Taking spatial heterogeneity of energy transitions as constitutive, this chapter argues for a focus on the specificities of transitions to sustainability. The diverse spatial contexts of cities, alongside multiple political contestations and governance directions, may generate quite different tendencies towards a more sustainable urban energy system. Rutherford (2014) has further pointed out that the role of cities varies across world regions. In this chapter we focus on China, a country which offers examples of nationally-led energy transitions. Our objective here is to show how the focus on the urban forces an analytical change that enriches and develops the transition storyline.

The structure of the chapter is as follows: firstly, it reports recent scholarly developments to understand urban energy transitions, with particular emphasis on how the urban contexts of transition shape the possibilities of changes. Then the chapter illustrates the argument with examples of Solar Water Heating system (SWHs) and Solar Photovoltaic (solar PV) innovation and socio-technical transitions in two Chinese cities, and explains that space is not appropriately considered.

TRANSITION THEORY, SPACE AND THE RISE OF URBAN ANALYSIS

In the last two decades, energy innovation and transitions research has gained many insights into the innovation process of emerging energy technologies and the resulting socio-technical change. Two analytical approaches are particularly relevant: technological innovation systems (TIS) and the multilevel perspective (MLP). TIS scholars view innovation as a collective activity and, thus, they analyse how innovations are developed and deployed through the complex interactions among a multitude of different actors and organizations that are enabled and constrained by physical artefacts as well as by institutions that are regarded as ‘the rules of the game’. The TIS perspective is often applied to describe and analyse the emergence of radical innovations (Carlsson and Stankiewicz, 1991; Hekkert, et al., 2007; Bergek, et al., 2008). Rather than looking into the concrete activities of key actors and networks in technological innovation process, the MLP pays attention to the relative role of emerging technologies and related societal elements in the broader socio-technical systems. The MLP views transitions as emerging from a nested hierarchy of structuring processes, which consists of interactions between socio-technical niches, regimes, and landscapes. Furthermore, the MLP argues that transitions take place when changes from one socio-technical regime to another occur, which are triggered by radical novelties at the niche level and changes of exogenous environment at the landscape level. Socio-technical regime refers to the mainstream and highly institutionalised set of rules carried by different social groups, which stabilises existing technological trajectories. Niches act as 'incubation rooms' enabling the development of novelties to compete with the existing regime. Both niches and regimes are situated within a broader landscape, which is constituted by macro-economics, deep cultural patterns, and macro-political developments. Changes at the landscape level also create pressure on the mainstream regime, even though it usually takes place and develops slowly (Geels, 2002; Geels and Schot, 2007; Smith, et al., 2010).

As explained above, a body of critique has emerged which warns against simplifying and mechanizing the role of space in energy transitions process (Berkhout, et al., 2009; Coenen, et al., 2012; Truffer and Coenen, 2012; Bridge, et al., 2013; Bergek, et al., 2015; Hansen and Coenen, 2015). For instance, TIS functional analysis generally simplifies administrative power of government as selected policies that are primarily observed at the national level. In a case study of the development of carbon capture and storage technologies in the United States, national energy plans were simply used to represent governmental guidance on carbon capture and storage technologies without reflection on whether these are implemented in practice (van Alphen, et al., 2010). The coordinating and conflicting relations between official policymakers and other actors (e.g. energy companies or utilities), which may lead to the 'actual' guideline, have been largely neglected.

A lack of consideration of space in sustainability transitions research might be rooted in the origins of this field. A thorough review on the formation of this field conducted by Truffer and Coenen (2012) demonstrated that TIS and MLP research both drew on Innovation Studies and Technology Studies, but developed into two quite different scholarships. One of the main preferences, rooting in the two strands of literatures, refers to their primary concerns on socio-technical changes over time (the temporal concept of ‘transitions’) for a given geographical unit (e.g. a country), but frequently overlooking changes of the socio-spatial characteristics within or across places (the spatial perspective of ‘transitions’) (Bridge, et al., 2013). In this regard, the MLP approach built on insights from Technology Studies concerning the history of technology and sector formation processes, focusing on interrelation between socio-technical characteristics of technology development, rather than the dynamic spatial contexts within which transitions take place and evolve (Coenen, et al., 2012). For example, using the MLP framework, a case study of history of the British coal industry has described when transitions (events) from coal dominance to the four-fuel economy (1913-1967) occurred and for what reason, and the destabilisation of coal in the electricity sector (1967-1997). The analysis led to an insight that the privatisation of the electricity supply industry in 1990 was the major reason of socio-technical change of the British coal industry (Turnheim and Geels, 2012). However, a few questions remain unanswered: what caused the privatisation in the first place? And what local contexts and dynamics made it happen and spread? The MLP is limited to explain contextual factors which shape transitions but that are not the main focus interest.

Both the TIS framework and the MLP approach overemphasise when innovation activities occur. Specifically, the TIS framework, as part of a broader family of innovation systems approaches, has placed innovation at the centre of transitions, as the key success factor for competitiveness of firms, regions and entire nations. By doing so, transition studies often privilege successful innovations over the general, and often accidental, social processes that lead to a transition, while cases of failed innovation are rarely documented. This is something already broadly identified by transition scholars, who had questioned the field’s focus on actors and networks of influence. These perspectives have also led to a narrow technology supply-side focus, which largely neglects the feedbacks from end-users in specific places and, overall, the main socio-spatial institutional structure elements (Hansen and Coenen, 2015). In conclusion, the sustainability transitions approach (TIS and MLP) shows "the conceptual deficits and methodological weaknesses regarding spatial characteristics of transition processes" (Truffer and Coenen, 2012, p. 6).

These critiques have led to an increasing enthusiasm about a spatial turn in sustainability transitions research (Raven, et al., 2012; Rutherford and Coutard, 2014; Wieczorek, et al., 2015). Existing approaches applied to spatial analysis are primarily developed upon concepts and frameworks such as MLP and TIS yet adding spatial sensitivity (Binz, et al., 2012; De Laurentis, 2013; Gosens, et al., 2015). Going beyond the nation focus of socio-technical transitions studies, Binz et al. (2012) viewed TIS as a global socio-technical system which is constitutive of varied national subsystem of the TIS, the international TIS, and the coupling domains, and emphasized the strong interactions between different nation-bounded TISs through the practices of actors, networks and institutions. Yet, greater efforts are needed to address the space-specific aspects of energy transitions.

A key consequence, for example, is that lack of awareness of spatial aspect may lead to simplified ideas about the possibility to deliver best practice examples or to uncritically translate the socio-technical innovations that have worked in a particular context into another. Bridge et al. (2013) have provided a geographical alternative to the primary temporal concerns in conventional transitions theory. They argued that an "energy transition is fundamentally a geographical process that involves reconfiguring current spatial patterns of economic and social activity" (Bridge, et al., 2013, p. 331). The strong connection between energy systems and pre-existing geographical configurations, energy accessibility, and the transformation of spatial arrangement of the built environment demonstrates that their understanding of transitions requires situating them in spatial contexts, alongside material components of urban infrastructure regimes.

Zooming into the socio-spatial institutional contexts within which transitions take place and unfold, there has been a call to place transitions into particular places such as cities, and at the same time paying attention to the spatial relations within and across that place (Hansen and Coenen, 2015). Because of the growing interest on urban energy transitions (Droege, 2008), cities have become ideal settings for the experiment of transitions. Empirical case studies on cities adopting socio-technical perspectives such as TIS and MLP risk generalizing and simplifying the complex interactions between energy transitions and urban contexts, particularly when they use an 'average' viewpoint to observe the specific places with heterogeneous spatial contexts where transitions unfolded. As a response, scholarship on urban governance and energy transitions has produced some of the most interesting insights in relation to the spatial characteristics of transitions.

Putting Urban Areas at the Center of Energy Transitions Analysis

A group of scholars have recently argued for a sort of 'urban turn' in research about low carbon transitions in several special issues in major journals of urban and energy studies (e.g. Coenen and Truffer, 2012; McCormick, et al., 2013; Rutherford and Coutard, 2014; Rutherford and Jaglin, 2015; Truffer, et al., 2015). These papers cover a range of empirical case study and theoretical developments around the relations between cities and transitions. In addition to situating transitions within specific urban areas, these studies have looked at how cities act as 'transitions managers' of a broader socio-technical systems (socio-technical perspective), and explained how energy transitions give rise to deep urban changes, for instance, through changes of spatial organization (spatial perspective). A spatial perspective on transitions research that places cities at the center captures the dynamic interaction between energy transitions and urban change on a daily basis, which makes the energy transitions processes more visible and articulate with everyday urban politics, therefore leading to more practical political debates and practices (Rutherford and Coutard, 2014).

The energy system is conceived as a socio-technical system that is comprised of social and technical elements of energy related activities, rather than solely as an exclusively material system containing energy infrastructure and energy flows (Bulkeley, et al., 2010; Hodson and Marvin, 2014). Responding to conventional perspectives on transitions, studies of energy transitions have led to an explicit interrogation of the notion of city no longer confined to a contextual understanding that merely regards city as relatively inactive and passive local contexts for transitions. Conversely, these studies have used insights from transitions to also question institutional representations of cities focused on city leaders, or local governments. In doing so, urban-based research on transitions has looked into the whole dynamics of urban processes where urban processes and practices are viewed as both constituents and consequences of energy system change (Hodson and Marvin, 2010a, Nevens, et al., 2013; Rohracher and Späth, 2013; Hodson, et al., 2016).

Urban processes directly drive or hinder socio-technical transitions within cities, which conversely influence changes of urban energy systems and the built environment in a more sustainable direction. Rutherford and Coutard (2014) identified three strands of focus in urban energy transitions:

1) Materiality of energy flows and their socio-technical characteristics, linked to an interest on infrastructure that has permeated recent urban studies;
2) The location of the urban in broader institutional and economic networks that links near and far places, with an emphasis on its relational characteristic of transitions; and
3) The dialectical processes of contestation that configures transitions as being inherently political.

Urban energy transitions can thus be viewed in relation to the change of spatial organization, political contestations and urban governance.

Firstly, the change of spatial organization has been viewed as more constitutive of energy transitions in urban studies, rather than merely consequences of these socio-technical changes (Sengers and Raven, 2015; Hodson, et al., 2016). Varied energy technologies are embedded in urban energy infrastructures (e.g. the natural gas stations for vehicles) that have diverse spatial patterns in different urban contexts. For example, in the cases of Beijing or Shanghai (China), natural gas stations for vehicles are usually kept outside of residential areas, since the population density is extremely high in the downtowns (Wang, et al., 2015), while the distribution of stations in Urumqi (China) does not see this spatial pattern (Ma, et al., 2013). Thus, the radical innovation and diffusion of energy technologies imply the emergence of a coordinate transformation of urban energy infrastructures, which largely rests with the compatibility and flexibility of existing technostructure used in the production of infrastructure services.

To gain a deeper insight into the spatial nature of energy transitions and the internal connection of patterns of urban spatial organization and socio-technical energy systems, Monstadt (2009) has put forward the notion of `urban infrastructure regime' to describe the stable socio-technical configurations of urban infrastructure system, which includes institutions, techniques, and artifacts elements. This notion enables us to capture the spatial factors that shape and are shaped by space-specific socio-technical innovation activities (socio-technical niches) and the structure of socio-technical regimes both embedded in urban infrastructure regimes. One of the key spatial factors is the extant physical configuration of an urban area such as settlement location and structure. For instance, the urban and suburban differences in building structure frequently lead to different potentials of the adoption of distributed generation technologies like solar Photovoltaic systems (PVs). In rural areas, single housing units with individual large roof space allow the installation of PVs with lower costs, however urban multi-storey houses with smaller surface of shared rooftops constrains the PVs application (Balta-Ozkan, et al., 2015).

Secondly, the change of spatial organisation and social practices related to urban energy transitions are always shaped by, and even dependent on, dynamic and contested political discourses in cities. The strand of urban politics of energy transitions arises from these considerations, which views energy transitions as “inherently of a political nature, simultaneously reflecting, reinforcing and transforming existing institutional and governance arrangements, consensual or conflictual relationships between different actors and the unequal distribution of power within and among social groups and interests” (Rutherford and Coutard, 2014, p. 1369). On the one hand, the dynamics of local political discourse around energy, which frequently combine with diverging social interests, dramatically change the direction of transitions trajectory (McFarlane and Rutherford, 2008; Späth and Rohracher, 2010a; Hodson and Marvin, 2012; Castán Broto and Bulkeley, 2013a; Moss 2013). A good example is the changing discourses of energy security under different political regimes in Berlin and the impacts on the way energy focus was discussed and pursued. From 1920s to the West Berlin’s blockade of 1948/49, and till nowadays, the core issues of energy security shifted from lack of adequate generating capacity to incapability to be self-sufficient in electricity generation, and more recently to vulnerability of energy infrastructures from terrorist attacks (Moss, 2013).

On the other hand, the contesting and conflicting power relations across a city are identified in some cases as an indispensable factor of urban energy transitions (Jaglin, 2013; Verdeil 2013). Focusing on the divergence of interests between national and local governments in a case of Cape Town, Jaglin (2013) finds out that local and national energy priorities emerge in different ways, leading to explicit conflicts across different levels of government who strive to impose their vision for a dominant transition pathway. For example, encountering the electricity blackouts since 2005 in Cape Town, national electricity suppliers and regulator provided a solution of building up more coal and nuclear power stations, while local response strategy mainly relied on a package of demand-side management measures. This conflict has in a sense hindered the policy implementation: the Western Cape had not even met half of its target of improving energy efficiency in the following year.

Thirdly, the potentially significant and growing roles of urban actors in energy transition have been gradually recognized, since responses to energy issues have been allocated to urban authorities in many countries along with increasing responsibility and mandate, which are situated in the context of growing urban population and increasing heterogeneity of energy supply and consumption patterns at city level (Hodson and Marvin, 2010b; Rutherford and Jaglin, 2015). Against this background, there is a wide window of opportunity for local actions conducted by a broad range of actors within city (Späth and Rohracher, 2010b; Castán Broto and Bulkeley, 2013b; Rutherford and Coutard, 2014). Focusing on the role of urban authority in transitions from coal-fired to renewable energy generation in Los Angeles (L.A.), Monstadt and Wolff (2015) offer an in-depth case study showing how the efforts of local policymakers enabled a considerable success of incremental change of energy technologies through adjustments within the established patterns of the existing infrastructure regime, for example the ‘Million Trees L.A.’ program, rather than following California's aggressive climate mitigation agenda aiming at a fundamental transformation of energy systems. Moreover, new governance arrangements emerge in the context of urban low-carbon transitions, such as community energy planning. A good example is the community energy planning practice in Elmshorn (Germany), where building heating and electricity demand are entirely covered by local and renewable energy resources (Petersen, 2016), which implies that community energy planning might act as an important catalytic force to deliver sustainable energy transitions.

The following two brief case studies illustrate some of the implications of the focus on urban energy transitions: guidance and supports of local authorities have played an essential role in so-called successful cities of low-carbon energy transitions, while the impacts of other spatial factors like the change of spatial organization and underlying political contestations seem invisible in the mainstream of the political and social contestations.

ENERGY TRANSITIONS IN TWO CHINESE CITIES

China has undergone a tremendous process of urbanisation since the 1980s; by 2030 Chinese cities are expected to house about 1 billion people, which will inevitably lead to an increasingly high energy consumption and GHG emissions (Schroeder and Chapman, 2014). Moreover, as the largest GHG emitter in the world, China seems to play an irreplaceable role in the task of combating climate change. In June 30th 2015, China announced the 'Enhanced Actions and Measures on Climate Change (EAMCC)', in which it has set the goal of lowering carbon dioxide emissions per unit of GDP by 60% to 65% from the 2005 level. To achieve this goal, it necessitates fundamental changes in current energy systems: given the fast rates of urbanisation, Chinese authorities are looking at cities and urban areas as central spaces of intervention for a broader energy transition. This urgency has been further highlighted in governmental discourses. For instance, in EAMCC, it is stated that "the low-carbon development concept will be integrated into the entire process of urban planning, construction and management". More recently, in the 'Climate Summit for Local Leaders (04 Dec 2015)' in Paris, a parallel session entitled 'Cities of the Future: Innovation and Sustainable Urbanization in China' further discussed the issues of deploying new technologies to promote sustainable urbanization in China. Overall, urban energy innovation and transitions are vital for sustainable urbanization and a low-carbon urban future in China.

In 2010, China's National Development Reform Commission (NDRC) announced a programme of low-carbon pilot city, in which eight cities have been selected. And in 2012, the second round of low-carbon pilot city has extended to 29 cities. Moreover, more than 200 cities of China's 600 major cities have announced the goal of low-carbon development (Schroeder and Chapman, 2014). With ongoing efforts to pursue low-carbon energy transitions, a large number of Chinese cities are experiencing different volume of changes due to innovation and deployment of renewable energy technologies, which are increasingly embedded into urban infrastructure and built environment. In the following two brief case studies, we take a brief look into solar power innovation and transitions in two typical cities in China, to examine the interactions between urban change and energy transitions, and particularly to explain that space is not appropriately considered.

Solar Water Heating System (SWHs) in Dezhou City

Dezhou City, situated in Shandong Province, is referred to as the "Chinese solar valley". Dezhou City is a frequently cited example of successful practice of urban energy transitions in China. For instance, the development and application of solar water heating system in Dezhou is very advanced. Around 100 solar PV and SWHs companies have developed in Dezhou, among which there is the world's largest SWHs manufacturer, namely the Himin Solar Co. Ltd.. Moreover, SWHs have been installed in about 80 percent of all buildings in Dezhou. It seems fair to say that SWHs has become an essential part of Dezhou's energy systems (Schroeder and Chapman, 2014).

Li et al. (2011) conducted a thorough review of the popularization of SWHs in Dezhou, and argued that strong government guidance supports successful SWHs transitions. Since 2006, the Dezhou municipal government started to actively institute various policy instruments to stimulate SWHs adoptions in the city. For example, a subsidy of 1000-yuan was allocated to every rural household for purchasing SWHs in 2006. The subsidy lowers the high costs of SWHs by two-thirds, which has effectively enhanced the application of SWHs products in rural Dezhou. The emergence of local government's support was mainly triggered by the development of the local SWHs industry, which provided a large amount of job opportunities and increased local revenues. This was especially urgent in the context of growing pressure from central and province governments in pursuit of GDP. At that time, they argue, a tight private enterprise-local government coalition in Dezhou was gradually formed. The institutional coupling of local authority and the SWHs industry has gradually led to an emergence of a special socio-spatial institutional configuration, which have resulted in even stronger promotion of SWHs adoption by the Dezhou government. This is a common approach to understand low carbon innovations in China. While this analysis provides some sanitised explanation of how change occurs, it is limited however to explain the mechanisms whereby innovations are embedded in a particular material and political context. For example, the role of political contestations is minimised despite the evidence that local political discourses and the change of building configurations have played an essential role in facilitating the SWHs transition in Dezhou.

The mainstream local political discourses around SWHs in Dezhou have supported the SWHs transition since the solar industry became a major sector of Dezhou's economy. Nowadays, three out of every ten jobs in Dezhou are related to local solar industry. Local residents have a wide range of involvement with the SWHs industry, which inevitably improves households' perceptions of SWHs products and increases their willingness to purchase SWHs products, even though the costs are higher than other alternatives. Moreover, a strong network of maintenance services of SWHs products also improves consumers' confidence in investing high costs SWHs products. Simultaneously, inadequate roof space in high-rise building have been major challenges for SWHs popularization in China, which is also the case in Dezhou. In the year 2005, the local construction bureau of Dezhou enacted a building regulation 'Notice of Fully Popularizing Solar Water Heaters on Newly Constructed

Buildings', which requires SWHs in every new or renovated apartment buildings (Li, et al., 2011). This regulation has led to the incremental change of building structures that enables SWHs to obtain fully utilized solar radiation. The spatial configuration change of buildings in Dezhou inevitably stimulates the popularization of SWHs products.

Solar Photovoltaic (Solar PV) in Baoding City

As one of the eight low-carbon pilot cities, Baoding City, Hebei Province has placed a particular focus on the building and developing of manufacturing capability for the renewable energy sector. For example, in 2006, the Baoding government named their city as China's "Electricity Valley", simultaneously with the central government's designation of Baoding as the main industrial base for development of new energy sector in China (Schroeder and Chapman 2014). A series of policies for renewable energy manufacturers were enacted such as targeted tax benefits for renewable energy manufacturers. As a result, nearly 200 renewable energy companies emerged in Baoding, some of which are the biggest manufacturers in their fields in China and even in the world. For example, Yingli Solar is the world's largest solar panel manufacturer. Moreover, in the 12th Five Year Plan of Baoding for 2011–2015, there is an ambitious plan for the development of a world-leading manufacturing sector for new energy and energy equipment (Baoding Municipal Government, 2011). Schroeder and Chapman (2014) further argue that the strong support of Baoding government, for instance for investment in infrastructure and supporting institutions, played an essential role as the incubation bases for the development of new energy enterprise start-ups.

Baoding municipal government has made an enormous effort to catalyse the solar PV transformation of urban public infrastructure, which has resulted in large-scale changes of spatial configuration of public lighting infrastructure. Just within a few years, solar PV has become the major electricity source for public lighting services in Baoding, including all the lights of the main tourist sites, 100% of traffic lights, more than 90% of street lights on major roads, and 85% of lights in public parks (Xie, 2011). However, urban villages have been largely left out during the solar PV transition (Tian, 2014). Generally speaking, most of the local authorities in China frequently possess enormous power and financial capacity to conduct changes of public infrastructure within city, while the perceptions of local residents whose tax dollars finance the change have been largely neglected. In both an interview of Baoding's mayor in 2011 and a policy report from a local official, the major focus of attention is on the package of policy instruments that can make the development and application of renewable energy possible, while none of which has mentioned interests of local residents and underlying conflicts (Xie, 2011; Tian, 2014).

In these two there is emerging evidence that urban change and energy transitions have strong relationships with each other. Clearly, the cases support the notion that consistent and strong support of local governments are the key contributors of the so-called successful energy transitions in Dezhou and Baoding. However, this analysis overlooks other important processes which are also at work in transition, in terms of changes of spatial organisation, political contestations, and the multiple dimensions of local governance (Table 29.1).

<TABLE 29.1 ABOUT HERE>

CONCLUSIONS

The need to integrate spatial considerations of innovation in transition studies is now a recognised theoretical and empirical demand. Yet, despite numerous calls to do so, the empirical evidence has been slow to emerge. In some cases, studies that have put space and politics at the centre of analysis (e.g. Bulkeley, et al., 2014; Hodson and Marvin, 2014), however, have often been perceived as being peripheral to transition studies (e.g. Coenen and Truffer, 2012; Hansen and Coenen, 2015). Given the importance of transition studies to understand energy transitions, the task for energy geographies is two-fold: 1) to develop further empirical evidence and theoretical advancements in analysing the spatiality of transitions; and 2) to engage with mainstream transition studies to demonstrate the relevance of geographical analysis.

Following the synthesis made by Rutherford and Coutard (2014) we propose a three-dimensional framework to attend to the dimensions of energy and space in transitions looking at 1) changes of spatial organisation; 2) political contestations; and 3) urban governance. We have argued that these three dimensions should be approached from a relational perspective, as emerging from social interaction, and situating transitions within particular contingent moments in which numerous factors come together. The resulting perspective emphasises the coevolution of energy transitions and urban change, as the current embeddedness of energy systems in contemporary society cannot be understood without a parallel understanding of the dimensions of urbanisation and its drivers.

We offer two case studies of energy transitions in China as a means to provide a speculative analysis of the dimensions that are highlighted in this perspective. An explicit consideration of space in energy transitions challenges the notion that governments and businesses complexes can easily drive transitions if only they are given the right tools. Rather, these analyses in China have often obscured the complex nature of the interrelated and mutually dependent processes that constitute a transition. The case of Dezhou, for example, highlights how implementing SWHs required enrolling local users, through a process of subjectification whose politics are really not understood (because of the emphasis on government leadership and business models that dominates the analysis). In Baoding city, in contrast, the issue was one of ensuring metabolic circulation through embedding the technologies in the current infrastructure system. Read together, the cases point out that an explicit consideration of space in energy transitions turns focus to the everyday politics of technology and the vital materialities that shape their operation.

REFERENCES

Balta-Ozkan, N., T. Watson and E. Mocca (2015), 'Spatially uneven development and low carbon transitions: Insights from urban and regional planning', *Energy Policy*, **85**, 500-510.

Baoding Municipal Government (2011), 'The 12th five-year plan for economic and social development of Baoding (in Chinese)', http://www.bdrd.gov.cn/news/show.asp?id=767.

Bergek, A., M. Hekkert, S. Jacobsson, J. Markard, B. Sandén and B. Truffer (2015), 'Technological innovation systems in contexts: Conceptualizing contextual structures and interaction dynamics', *Environmental Innovation and Societal Transitions,* **16**, 51-64.

Bergek, A., S. Jacobsson, B. Carlsson, S. Lindmark and A. Rickne (2008), 'Analyzing the functional dynamics of technological innovation systems: A scheme of analysis', *Research Policy,* **37**, 407-429.

Berkhout, F., D. Angel and A. Wieczorek (2009), 'Sustainability transitions in developing Asia: Are alternative development pathways likely?', *Technological Forecasting and Social Change,* **76**, 215-217.

Binz, C., B. Truffer, L. Li, Y. Shi and Y. Lu (2012), 'Conceptualizing leapfrogging with spatially coupled innovation systems: The case of onsite wastewater treatment in China', *Technological Forecasting and Social Change,* **79**, 155-171.

Bridge, G., S. Bouzarovski, M. Bradshaw and N. Eyre (2013), 'Geographies of energy transition: Space, place and the low-carbon economy', *Energy Policy,* **53**, 331-340.

Bulkeley, H., V. Castán Broto, M. Hodson and S. Marvin (eds) (2010), *Cities and Low Carbon Transitions,* London: Routledge.

Bulkeley, H., V. Castán Broto and G.A.S. Edwards (2014), *An Urban Politics of Climate Change: Experimentation and the Governing of Socio-Technical Transitions,* London: Routledge.

Carlsson, B. and R. Stankiewicz (1991), 'On the nature, function and composition of technological systems', *Journal of Evolutionary Economics,* **1**, 93-118.

Castán Broto, V. and H. Bulkeley (2013a), 'Maintaining climate change experiments: Urban political ecology and the everyday reconfiguration of urban infrastructure', *International Journal of Urban and Regional Research,* **37**, 1934-1948.

Castán Broto, V. and H. Bulkeley (2013b), 'A survey of urban climate change experiments in 100 cities', *Global Environmental Change,* **23**, 92-102.

Coenen, L., P. Benneworth and B. Truffer (2012), 'Toward a spatial perspective on sustainability transitions', *Research Policy,* **41**, 968-979.

Coenen, L. and B. Truffer (2012), 'Places and spaces of sustainability transitions: Geographical contributions to an emerging research and policy field', *European Planning Studies,* **20**, 367-374.

De Laurentis, C. (2013), 'Innovation and policy for bioenergy in the UK: A co-evolutionary perspective', *Regional Studies,* **49**, 1111-1125.

Droege, P. (ed) (2008), *Urban Energy Transition: From Fossil Fuels to Renewable Power,* Oxford: Elsevier.

Geels, F. (2002), 'Technological transitions as evolutionary reconfiguration processes: A multi-level perspective and a case-study', *Research Policy,* **31**, 1257-1274.

Geels, F. and J. Schot (2007), 'Typology of sociotechnical transition pathways', *Research Policy,* **36**, 399-417.

Gosens, J., Y. Lu and L. Coenen (2015), 'The role of transnational dimensions in emerging economy 'Technological Innovation Systems' for clean-tech', *Journal of Cleaner*

Production, **86**, 378-388.

Hansen, T. and L. Coenen (2015), ‘The geography of sustainability transitions: Review, synthesis and reflections on an emergent research field’, *Environmental Innovation and Societal Transitions,* **17**, 92-109.

Hekkert, M.P., R.A.A. Suurs, S.O. Negro, S. Kuhlmann and R.E.H.M. Smits (2007), ‘Functions of innovation systems: A new approach for analysing technological change’, *Technological Forecasting and Social Change,* **74**, 413-432.

Hodson, M. and S. Marvin (2010a), ‘Can cities shape socio-technical transitions and how would we know if they were?’, *Research Policy,* **39**, 477-485.

Hodson, M. and S. Marvin (2010b), *World Cities and Climate Change: Producing Urban Ecological Security,* Maidenhead, UK: McGraw-Hill Education.

Hodson, M. and S. Marvin (2012), ‘Mediating low-carbon urban transitions? Forms of organization, knowledge and action’, *European Planning Studies,* **20**, 421-439.

Hodson, M. and S. Marvin (eds) (2014), *After Sustainable Cities?,* London: Routledge.

Hodson, M., E. Burrai and C. Barlow (2016), ‘Remaking the material fabric of the city: ‘Alternative’ low carbon spaces of transformation or continuity?’, *Environmental Innovation and Societal Transitions,* **18**, 128-146.

Jaglin, S. (2013), ‘Urban energy policies and the governance of multilevel issues in Cape Town’, *Urban Studies,* **51**, 1394-1414.

Li, W., G. Song, M. Beresford and B. Ma (2011), ‘China's transition to green energy systems: The economics of home solar water heaters and their popularization in Dezhou city’, *Energy Policy,* **39**, 5909-5919.

Ma, L., J. Geng, W. Li, P. Liu and Z. Li (2013), ‘The development of natural gas as an automotive fuel in China’, *Energy policy*, **62**, 531-539.

McCormick, K., S. Anderberg, L. Coenen and L. Neij (2013), ‘Advancing sustainable urban transformation', *Journal of Cleaner Production,* **50**, 1-11.

McFarlane, C. and J. Rutherford (2008), 'Political infrastructures: Governing and experiencing the fabric of the city', *International Journal of Urban and Regional Research,* **32**, 363-374.

Monstadt, J. (2009), 'Conceptualizing the political ecology of urban infrastructures: Insights from technology and urban studies', *Environment and Planning A,* **41**, 1924-1942.

Monstadt, J. and A. Wolff (2015), 'Energy transition or incremental change? Green policy agendas and the adaptability of the urban energy regime in Los Angeles', *Energy Policy,* **78**, 213-224.

Moss, T. (2013), 'Socio-technical change and the politics of urban infrastructure: Managing energy in Berlin between dictatorship and democracy', *Urban Studies,* **51**, 1432-1448.

Negro, S.O., V. Vasseur, W.G.J.H.M. van Sark and M.P. Hekkert (2012), "'Solar eclipse: The rise and 'dusk' of the Dutch PV innovation system', *International Journal of Technology, Policy and Management,* **12**, 135-157.

Nevens, F., N. Frantzeskaki, L. Gorissen and D. Loorbach (2013), 'Urban transition labs: Co-creating transformative action for sustainable cities', *Journal of Cleaner Production,* **50**, 111-122.

Petersen, J.P. (2016), 'Energy concepts for self-supplying communities based on local and renewable energy sources: A case study from northern Germany', *Sustainable Cities and Society*, **26**, 1-8.

Raven, R., J. Schot and F. Berkhout (2012), 'Space and scale in socio-technical transitions', *Environmental Innovation and Societal Transitions,* **4**, 63-78.

Rohracher, H. and P. Späth (2013), 'The interplay of urban energy policy and socio-technical transitions: The eco-cities of Graz and Freiburg in retrospect', *Urban Studies,* **51**, 1415-1431.

Rutherford, J. (2014), 'Urban energy Transitions', blog, http://urbanstudiesjnl.blogspot.co.uk/2014/05/urban-energy-transitions.html

Rutherford, J. and O. Coutard (2014), 'Urban energy transitions: Places, processes and politics of socio-technical change', *Urban Studies,* **51**, 1353-1377.

Rutherford, J. and S. Jaglin (2015), 'Introduction to the special issue – Urban energy governance: Local actions, capacities and politics', *Energy Policy,* **78**, 173-178.

Schroeder, P. and R. Chapman (2014), 'Renewable energy leapfrogging in China's urban development? Current status and outlook', *Sustainable Cities and Society,* **11**, 31-39.

Sengers, F. and R. Raven (2015), 'Toward a spatial perspective on niche development: The case of bus rapid transit', *Environmental Innovation and Societal Transitions,* **17**, 166-182.

Smith, A., J.P. Voß and J. Grin (2010), 'Innovation studies and sustainability transitions: The allure of the multi-level perspective and its challenges', *Research Policy,* **39**, 435-448.

Späth, P. and H. Rohracher (2010a), ' 'Energy regions': The transformative power of regional discourses on socio-technical futures', *Research Policy,* **39**, 449-458.

Späth, P. and H. Rohracher (2010b), 'The 'eco-cities' Freiburg and Graz: The social dynamics of pioneering urban energy & climate governance', in H. Bulkeley, V. Castán Broto, M. Hodson and S. Marvin (eds), *Cities and Low Carbon Transitions,* London: Routledge, pp. 88-106.

Suurs, R., M. Hekkert, S. Kieboom and R. Smits (2010), 'Understanding the formative stage of technological innovation system development: The case of natural gas as an automotive fuel', *Energy Policy,* **38**, 419-431.

Thrift, N. (2004), 'Summoning life', In P. Cloke, P. Crang and M. Goodwin (eds), *Envisioning Human Geographies,* London: Routledge, pp. 81-103.

Thrift, N. (2008), 'Re-animating the place of thought: Transformations of spatial and temporal description in the twenty-first century', in A. Amin and J. Roberts (eds), *Community, Economic Creativity, and Organization,* Oxford: Oxford University Press, pp. 90-119.

Tian, B. (2014), 'A discussion of the development of low-carbon city in Baoding (in Chinese)', *Statistics and Management,* **12**, 70-72.

Truffer, B. and L. Coenen (2012), 'Environmental innovation and sustainability transitions in regional studies', *Regional Studies,* **46**, 1-21.

Truffer, B., J.T. Murphy and R. Raven (2015), 'The geography of sustainability transitions: Contours of an emerging theme', *Environmental Innovation and Societal Transitions,* **17**, 63-72.

Turnheim, B. and F. Geels (2012), 'Regime destabilisation as the flipside of energy transitions: Lessons from the history of the British coal industry (1913–1997)', *Energy Policy,* **50**, 35-49.

UN Habitat (2016), 'Urban themes - Climate change', http://unhabitat.org/urban-themes/climate-change/

Van Alphen, K., P.M. Noothout, M.P. Hekkert and W.C. Turkenburg (2010), 'Evaluating the development of carbon capture and storage technologies in the United States', *Renewable and Sustainable Energy Reviews,* **14**, 971-986.

Van den Bergh, J., B. Truffer and G. Kallis (2011), 'Environmental innovation and societal transitions: Introduction and overview', *Environmental Innovation and Societal Transitions,* **1**, 1-23.

Verdeil, E. (2013), 'The contested energy future of Amman, Jordan: Between promises of alternative energies and a nuclear venture', *Urban Studies,* **51**, 1520-1536.

Wang, H., H. Fang, X. Yu and K. Wang (2015), 'Development of natural gas vehicles in China: An assessment of enabling factors and barriers'. *Energy Policy*, **85**, 80-93.

Wieczorek, A., R. Raven and F. Berkhout (2015), ‘Transnational linkages in sustainability experiments: A typology and the case of solar photovoltaic energy in India’, *Environmental Innovation and Societal Transitions,* **17**, 149-165.

Xie, HY. (2011), ‘Mayor of Baoding talking abour the roadmap to new energy’, *China Urban Economic,* 8, 13-15. (in Chinese) ✓