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LOW CARBON INNOVATION IN CHINA 中国低碳创新

Low-Carbon Innovation in China: Prospects, Politics and Practices

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Acronyms

CAE	Chinese Academy of Engineering
CAS	Chinese Academy of Sciences
CGTI	China Green Tech Initiative
EU	European Union
EV	Electric vehicle
E2W	Electric 2-wheeler
FYP	Five-Year Plan
GHG	Greenhouse Gas
ICE	Internal Combustion Engine
IEA	International Energy Agency
INGO	International Non-governmental Organisation
IP	Intellectual Property
IPCC	Intergovernmental Panel on Climate Change
MEP	Ministry of Environmental Protection
MIIT	Ministry of Industry and Information Technology
MOA	Ministry of Agriculture
MOF	Ministry of Finance
MOST	Ministry of Science and Technology
MOT	Ministry of Transport
NGO	Non-governmental Organisation
NDRC	National Development and Reform Commission
MLP	Multi-level perspective
PRC	People's Republic of China
PV	Photovoltaic
SOE	State-owned enterprises
UNFCCC	United Nations Framework Convention on Climate Change
US	United States
WRI	World Resources Institute

Summary

China's potential transition to a low-carbon, climate resilient or 'post-carbon' society is a key concern for the world. There is an urgent need for better understanding of this process, posing major challenges for social science given the complex, systemic and emergent nature of the multiple processes involved in such a possible transition. This Working Paper is the first of a series of four 'China Low Carbon Reports' outlining the STEPS-Centre affiliate project 'Low Carbon Innovation in China: Prospects, Politics and Practice', led from Lancaster University. The project is designed around problem-led social scientific research involving partners from leading UK and Chinese institutions. It aims to assess the status of, and opportunities for, low-carbon transitions in China by going beyond existing technology-focused approaches to innovation. In particular, this involves a re-insertion and reconceptualisation of power within the processes of low-carbon transitions, conceived as processes of socio-technical systems, and with greater attention paid to everyday social practices of both 'users' and producers. Through this distinct approach, the project offers empirical, methodological and theoretical contributions to the study of (low-carbon) socio-technical transitions both in China and more broadly. The paper outlines the background to this project, the urgency of deeper and more productive understanding of the prospects of low-carbon transition in China, and the theoretical and methodological approaches adopted to do this.

1. Overview

China's potential transition to a low-carbon, climate resilient or 'post-carbon' (Urry 2011) society is a key concern for the world. There is an urgent need for better understanding of this process, posing major challenges for social science given the complex, systemic and emergent nature of the multiple processes involved in such a possible transition. This Working Paper introduces an ESRC-funded project 'Low-carbon Innovation in China: Prospects, Politics and Practice', designed around problem-led social scientific research involving partners from leading UK and Chinese institutions.[1] This project aims to assess the status of, and opportunities for, low-carbon transitions in China by going beyond existing technology-focused approaches to innovation. In particular, this involves a re-insertion and reconceptualisation of power within the processes of low-carbon transitions, conceived as processes of socio-technical systems, and with greater attention paid to everyday social practices of both 'users' and producers. Through this distinct approach, the project offers empirical, methodological and theoretical contributions to the study of (low-carbon) socio-technical transitions both in China and more broadly.

First, we outline the importance of the People's Republic of China (PRC) within the global challenge of climate change mitigation, demonstrating the need for greater understanding of the processes through which China might transition towards lower carbon pathways of development. Second, we provide a brief overview of both the policies that have deployed, and literature that has investigated, 'innovation' – conceived at various levels – as a potential response to this challenge. Specifically we examine Chinese narratives, policies and targets that have linked the country's focus on technological innovation to its environmental objectives. Third, we identify and investigate two aspects of the Chinese story that have remained relatively neglected in previous analyses of low-carbon innovation (as opposed, say, to climate policy more generally (Heggelund *et al.* 2010; Hallding *et al.* 2011). These are, first, the importance of politics and power, conceived in terms of strategic and productive power relations, and of China's particular governance context in low-carbon transitions, and second, the significance of social practices where previously the demand side of innovations, their reception and consumption, have been largely neglected. From here, we outline the overall methodology of the project, including its design around three research packages, each of which studies two different 'pathways' of systemic change associated with specific low-carbon innovations (Leach *et al.* 2010). The final section describes the potential insights that the project design and methodology should deliver and especially its implications for low-carbon innovation practice and policy in the UK, China and elsewhere.

[1] The project's Chinese partners are Tsinghua University (Dr WANG Yu), Graduate School at Shenzhen, Tsinghua University (Dr LI Ping) and the Chinese Centre for Agricultural Policy of the Chinese Academy of Sciences (Dr SONG Yiching). We are grateful to all our Chinese partners for their discussion, which has fed into this Working Paper, and to ESRC for funding this work (project ES/K006002/1).

2. The Environment and Climate Change Challenge in China: a Global Issue

Scientific studies of climate change and other planetary boundaries (Rockström *et al.* 2009) suggest ecological limits to current forms of development, demanding systemic changes at a global level (Leach *et al.* 2012). Yet in 2014, we see little evidence of the systemic transformations needed to mitigate climate change and to deal with other environmental crises. Fossil energy use is associated with many negative environmental effects, including global climate change. Yet around 80 per cent of the global primary energy supply is still derived from burning fossil fuels, oil, gas and coal (Berners-Lee and Clark 2013; IEA 2014).

The Intergovernmental Panel on Climate Change (IPCC 2013:7) warned that:

> atmospheric concentrations of carbon dioxide, methane, and nitrous oxide have increased to levels unprecedented in at least the last 800,000 years. CO_2 concentrations have increased by 40 per cent since pre-industrial times, primarily from fossil fuel emissions and secondarily from net land use change emissions.

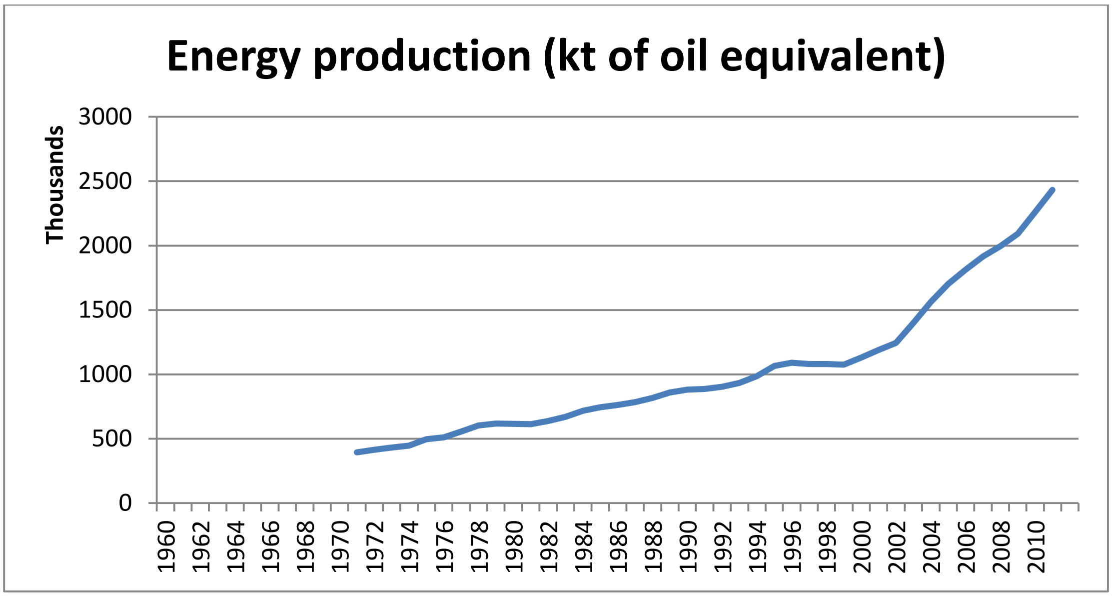
Energy use from burning fossil fuels contributes directly to greenhouse-gas (GHG) emissions which in turn seems to generate rising temperatures and other observed effects. According to the IPCC the global mean surface temperature rose by 0.85°C ± 0.2°C between 1880 and 2012 (IPCC 2013). This has been particularly significant over the last 50 years. The IPCC reports that on a global level they found high increases in heavy precipitation events, more frequent droughts (especially in the (sub)tropics), changes in the large-scale atmospheric circulation and increases in tropical cyclone activity since the 1970s (IPCC 2013; IPCC 2014). The IPCC's latest Fifth Assessment Report highlights the observed and partly irreversible changes to the earth's ecosystems, particularly the changes to the oceans, which absorb a large part of the CO_2 and thereby become acidified, and the cryosphere (IPCC 2013; IPCC 2014; Urban 2014).

Today, the majority of climate scientists agree that 'the possibility of staying below the 2^{o} Celsius threshold by 2100 between "acceptable" and "dangerous" climate change becomes less likely as no serious global action on climate change is taken' (Urban and Nordensvärd 2013:4; Tyndall Centre 2009; Richardson *et al*. 2009; Urban *et al*. 2009; Urry 2011; Urban *et al*. 2011.

Climate scientists estimate that for a 50 per cent chance of limiting temperature rises to this 2^{o}C target, a global atmospheric CO_2 equivalent concentration of 400 to 450 ppm must not be exceeded. And yet the 400 ppm target was recently exceeded and emissions are still rising (Richardson *et al*. 2009; Tans and Keeling 2013). Emissions must in fact be reduced very rapidly at a global level to have a reasonable chance of avoiding dangerous climate change (Urban 2014; Carrington 2013) and there has to be a rapid downturn of emissions across the globe (see calculations in Berners-Lee and Clark 2013). Most of the fossil fuels lying under the ground or the seas must be left there and not burnt. This has very major implications for corporations and states that believed that most of that fossil fuel energy would indeed get to be burnt and turned into profit (see Carbon Tracker 2013, on dire economic implications). Other major environmental (and societal) issues that are linked to high carbon development pathways are air pollution, resource depletion and peak oil.

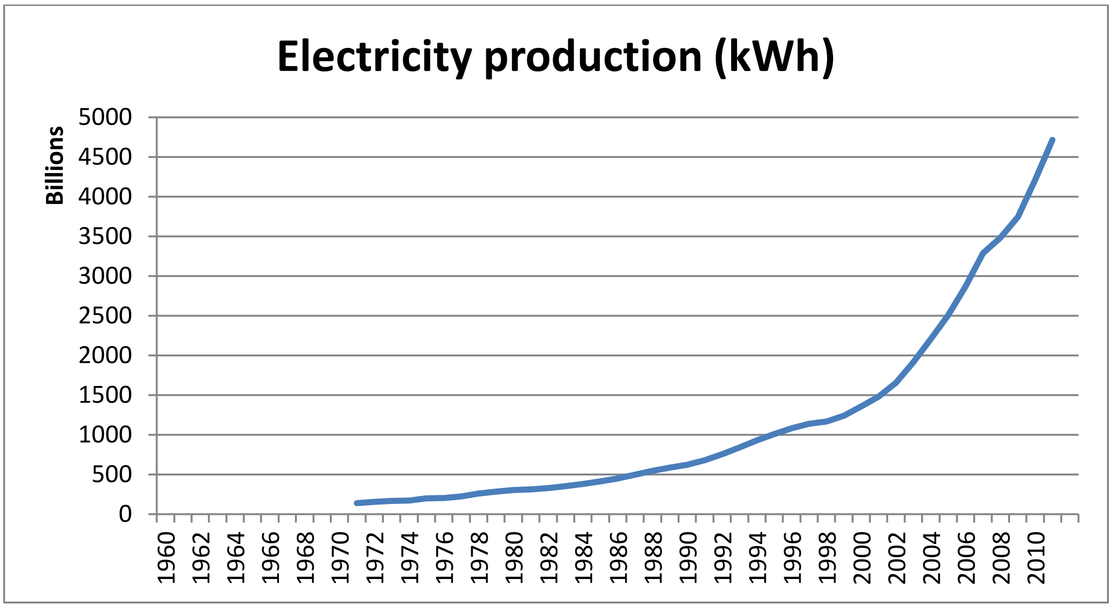
China is absolutely central to developing low-carbon transitions (Urban *et al.* 2009; Urban 2014; Wang and Watson 2009). Energy demand increased with the country's unprecedented economic growth, averaging 10 per cent p.a. for 30 years, so that with its high dependence on coal – China's coal-fired power sector is the world's largest single anthropogenic source of CO_2 emissions (Harris 2010) – China is now the world's largest energy user and absolute carbon dioxide emitter (IEA 2013). Energy use, production and CO_2 emissions have increased rapidly in China since its economic reforms. CO_2 emissions increased from 876,633kt in 1970 to 8,286,892kt in 2010, more than a nine-fold increase (World Bank 2014; IEA 2014). The rate of increase was particularly high between 2000 and 2010. Similar developments have been observed in total energy use, production has increased from 394,149kt of oil equivalent in 1970 to 2,262,039kt of oil equivalent in 2010, an almost six-fold increase (World Bank 2014; IEA 2014; see Urry 2013: Chapter 6 on the dramatic increases in oil consumption within contemporary China). Figures 2.1 to 2.4 show how dramatically China's energy production, electricity production and CO_2 emissions have increased in recent decades.

Figure 2.1: Energy production between 1970 and 2010 in China



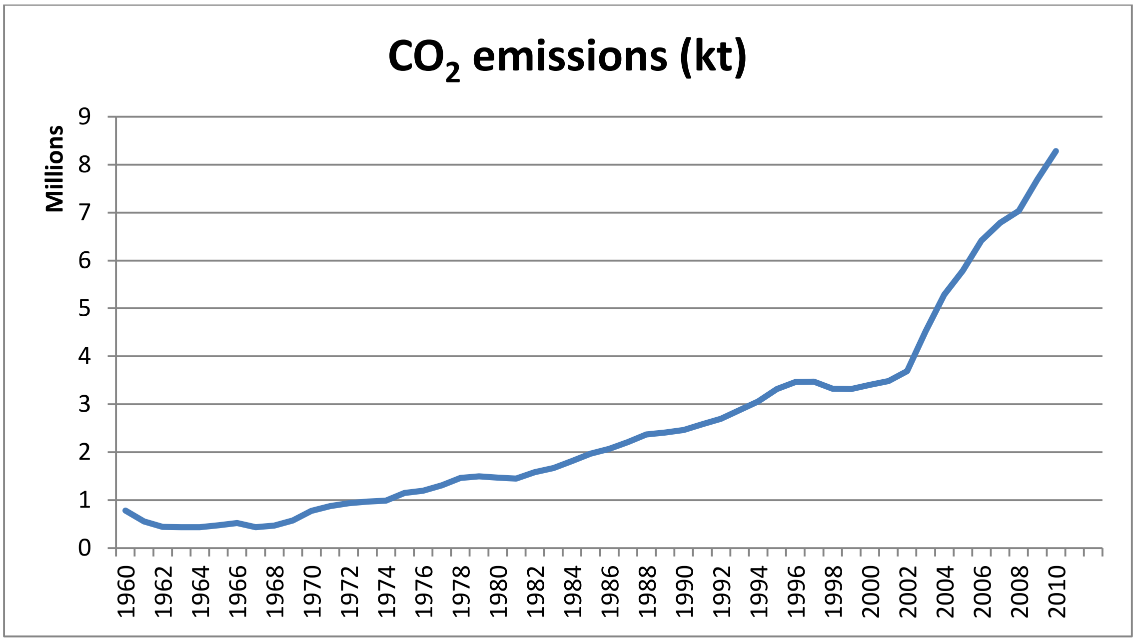
Sources: World Bank 2014 and IEA 2014

Figure 2.2: Electricity production between 1970 and 2010 in China



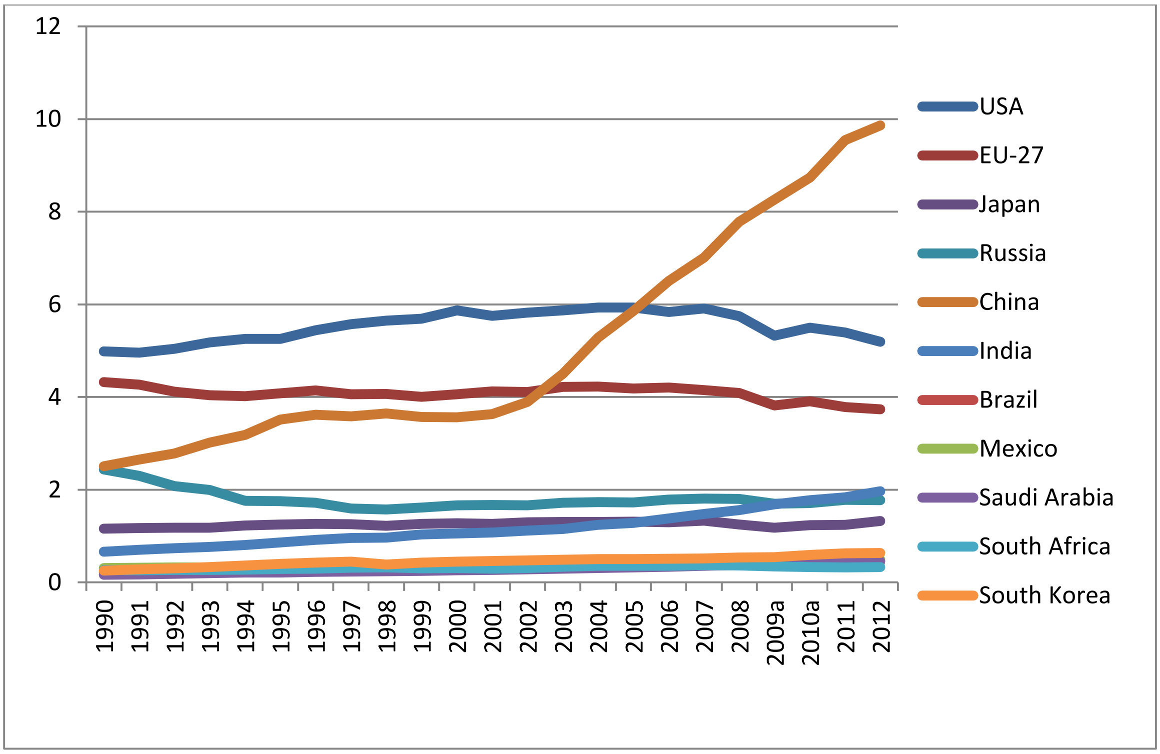
Sources: World Bank 2014 and IEA 2014

Figure 2.3: CO_2 emissions between 1970 and 2010 in China



Sources: World Bank 2014 and IEA 2014

Figure 2.4: Total volume of CO_2 emissions from fossil fuel use and cement production for selected countries, 1000 million tonnes of CO_2, 1990-2012



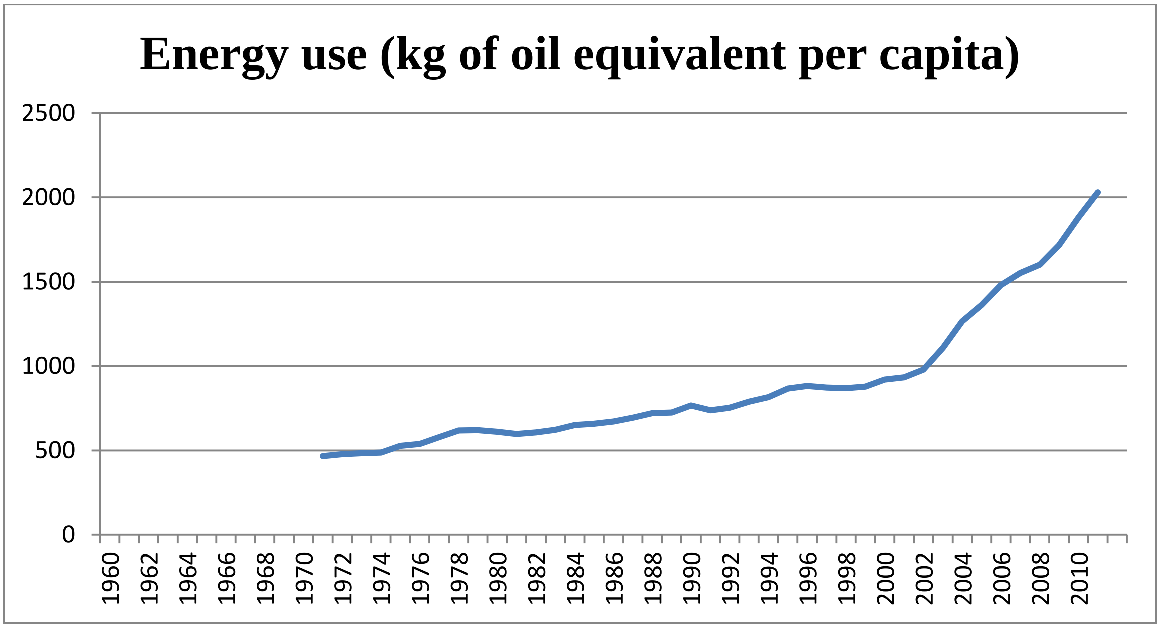
Source: Netherlands Environmental Assessment Agency

It is often suggested that *per capita* energy use and *per capita* CO_2 emissions are low in China compared with high-income countries. But while China had low *per capita* figures for energy use and emissions for a long period, it has been catching up more recently. China's *per capita* CO_2 emissions are increasingly comparable with those of the European Union (EU), while in Europe they have been somewhat declining since the mid-1990s and were 7.3 tonnes CO_2 per capita in 2010. In China, by contrast, they have steadily increased and risen to 6.2 tonnes by 2010 (World Bank 2014; IEA 2014).

Most recently, in September 2014 on the eve of the New York Climate Conference it was announced that China's *per capita* emissions exceeded the EU's for the first time in 2013 (Financial Times 2014).

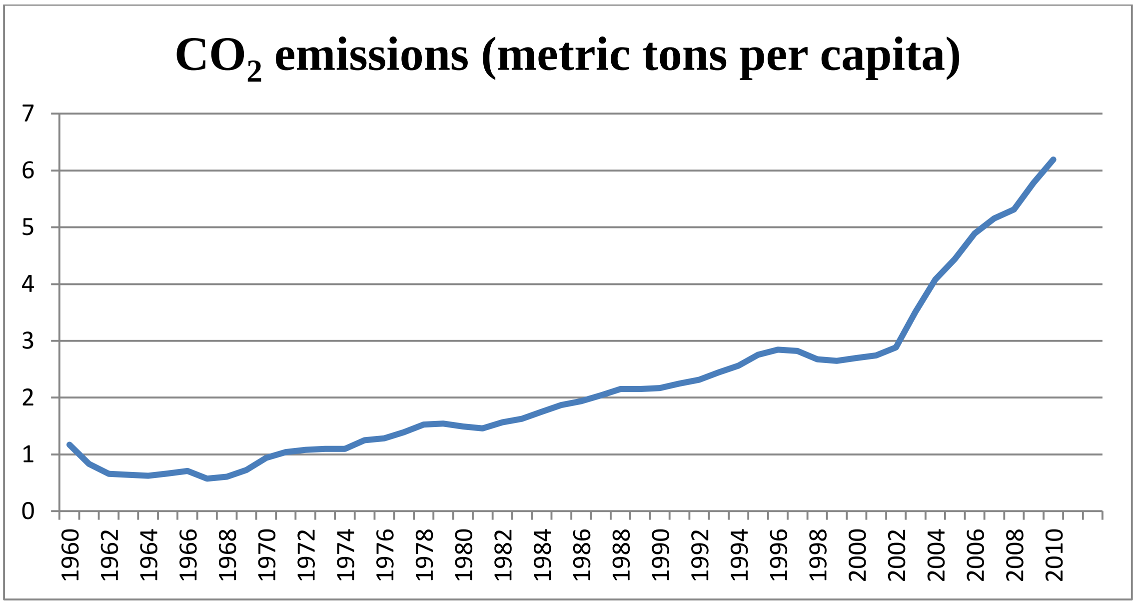
Figures 2.5 and 2.6 show how *per capita* energy use increased in China over the past few decades, particularly in the last few years. Figure 2.7 compares Chinese *per capita* emissions with those of industrialised societies, illustrating particularly clearly the convergence in China's and Europe's *per capita* CO_2 emissions.

Figure 2.5: Energy use per capita between 1970 and 2010 in China



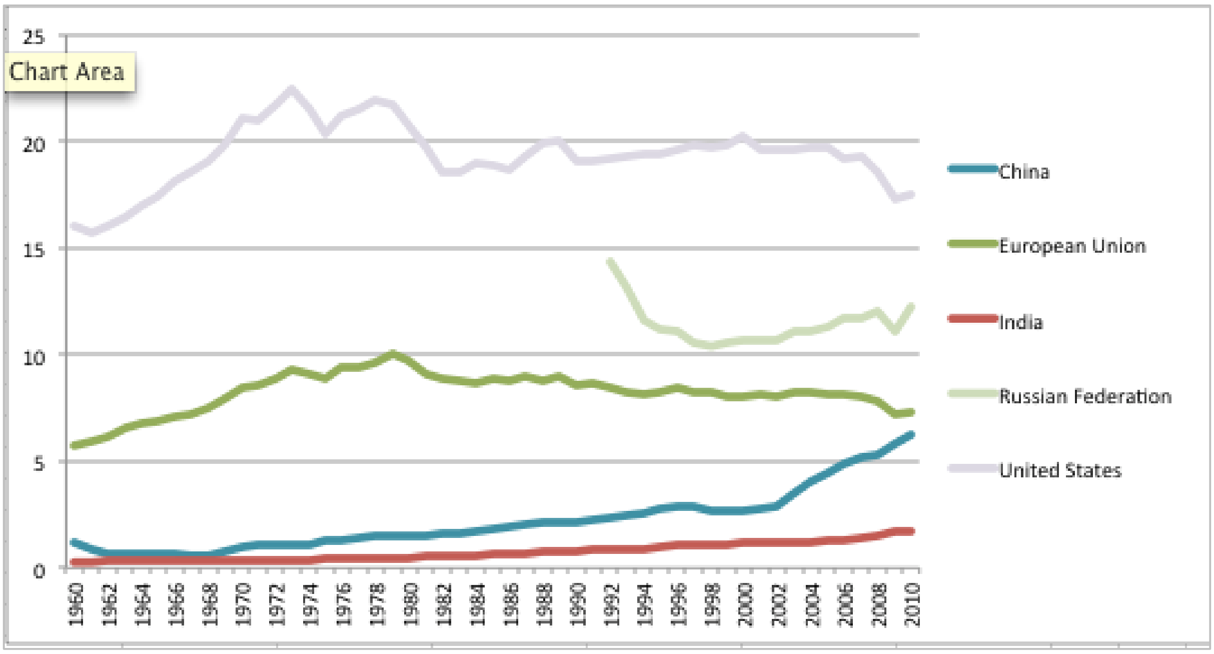
Sources: Data from World Bank 2014; IEA 2014

Figure 2.6: CO_2 emissions per capita between 1970 and 2010 in China



Sources: World Bank 2014; IEA 2014

Figure 2.7: CO_2 emissions per capita between 1970 and 2010 among selected emitters, tonnes CO2 *per capita*



Source: World Bank 2014

China's historic emissions are lower than many high-income countries, notably the States (US). The World Resources Institute (WRI) concluded in 2005 that about 75 per cent of global climate change was due to the historical contribution of developed countries (Baumart *et al.* 2005; Hansen 2011). But taking into account the rise in energy use and emissions in China over the past decade, this picture is changing fast, with some arguing that China's cumulative emissions will be the highest of any country within 10 to 20 years (Stavins 2014).

This debate is complicated, however, by the question of the proportion of China's CO_2 emissions that are in fact due to manufacturing goods not for Chinese consumption but for export to higher income societies, particularly the US and Europe. One study found that 25 per cent of China's emissions in fact resulted from the export of high amounts of manufactured goods moved in vast container ships to high-income countries (Wang and Watson 2007; Pan *et al.* 2009). There is thus an offshoring of emissions from advanced economies to China, an issue significant in negotiations at the 2009 United Nations Framework Convention on Climate Change (UNFCCC) Copenhagen Climate Change Conference. Some, though, further argue that decreasing or flatlining emissions and energy use within industrialised societies, especially after the financial crisis of 2007/8, may begin to change this pattern (see Figure 2.7, as well as Urry (2014) on the possibilities of 'reshoring' manufacturing through developing 3D printing). Whatever position one may take, therefore, regarding the contested distribution of responsibility and even 'blame' for growing global GHG emissions (Harris 2011), such is the size of China and the rate of its economic growth that all such debates are rapidly becoming moot, if still, understandably, heated on both sides, while a clear and undeniable conclusion emerges in their stead, that Chinese GHG emissions must be tackled (in *some* way and by *many* agencies) as a global matter of urgency.

3. Innovation as a Response

Globally, the discourse of innovation has been put forward as a major way of 'fixing' climate change alongside broader arguments for developing 'sustainability-oriented innovation systems' (Altenburg and Pegels 2012). Similar themes have been adopted in discussions of the 'entrepreneurial state' (Mazzucato 2013), which stress the vital role of governments, not only in driving R&D investment in strategic green sectors, but also in constructing a market for innovation and in building the skilled workforce required to serve emerging areas of eco-innovation. The rapid socio-economic development in China offers unparalleled opportunities for systems-changing low-carbon innovations (Berkhout *et al.* 2011), a possibility that dovetails with a drive for increased 'indigenous' or 'independent' innovation in order to build competitiveness and growth (Jakobson 2007; Schwaag-Serger and Breidne 2007; Wilsdon and Keeley 2007).

According to numerous metrics of science and innovation, China's innovation performance is growing at an extraordinary pace (Gao and Guan 2009; Royal Society 2011; Hu 2011). China has already overtaken the EU regarding the share of its economy devoted to R&D. According to the OECD, in 2012 China invested 1.98 per cent of its GDP in R&D, compared with 1.96 per cent for the 28 member states of the EU (Van Noorden 2014). While some argue such measures have limited impact on actual innovation performance and productivity growth (Comin 2004; Lane 2009; Ejermo *et al.* 2011), they still receive policy attention in the UK (Bound *et al*. 2013) and elsewhere, and are the result of intense policy efforts to build an 'innovation-based economy' in China. China's President Xi Jinping was reported by state news agency Xinhua in 2013 to have said, 'the fundamental approach to breaking up the bottleneck restriction on China's economic development was through innovation and technology' (Xinhua 2013). In 2014, in a speech to the Chinese Academy of Sciences (CAS) and Chinese Academy of Engineering (CAE), Xi stated that, 'the direction of China's science and technology development is "innovation, innovation and innovation"', and noted that, 'independent innovation [should be the] essence [of a strategy to] free up the huge potentials of science and technology' (Xinhua 2014). According to this strategy, globally competitive capacities for innovation should move the Chinese economy beyond its current role as the low-cost workshop of the world (OECD 2008; Schwaag-Serger and Breidne 2007) so that greater economic gains would accrue to Chinese companies.

There is also now a large and rapidly growing literature on low-carbon innovation in China that documents impressive developments regarding renewable technologies such as wind energy, solar photovoltaics, hydropower and electric vehicles (EVs). Much of the earlier literature was generated by International Non-governmental Organisations (INGOs), consultancies and intergovernmental organisations (Climate Group 2009; Pew Environment Group 2010; Boston Consulting Group 2011; McKinsey Global Institute 2008). It is characterised by a relatively narrow focus on the supply side of the innovation system and developing improvements in manufacturing individual technologies. Scholars have, more recently, begun to adopt an innovation systems perspective to investigate the role of policies, firm strategies and university led R&D in building China's eco-innovation capabilities. In some cases authors have questioned how quickly the country's firms can come to a position of dominance, describing the journey towards eco-innovation leadership as a 'hard slog' rather than a 'leapfrog' (Rock *et al.* 2009).

Lema and Lema (2012) as well as Lewis (2013) analysed the shift from conventional 'technology transfer' to joint ventures and technology acquisition by Chinese (and Indian) firms in the wind energy industry and, working with other colleagues, Lema analysed in detail how Chinese wind power firms impacted on global value chains by component suppliers (Lema *et al*. 2013). Drawing on technological innovation systems approaches Bergek and Gosens (Bergek *et al*. 2008; Gosens *et al*. 2013) investigated learning in clean-tech innovation and Quitzow (2013) compared the co-evolution of policy, market and the solar photovoltaic (PV) industry within Germany and China. Fischer (2012;

2014) has provided fascinating accounts of the technology, policy and political barriers and challenges that characterised the Chinese PV sector, while Dai (2014) conducted political analyses of wind energy policy at national and local levels of government.

These studies have significantly built upon earlier work and explain the processes behind China's increasing capabilities within some elements of low-carbon innovation. Whilst they provide insights into the politics of innovation policy, they still focus primarily on production and industry, or attend to consumption and reception of innovations from an economic perspective of market demand and/or market failure. As such, while they provide a good basis for understanding industrial development in these strategic sectors, with a few exceptions, they engage less with political and sociological questions of transition that are especially pertinent from a systems perspective (see below). Work in innovation studies points to the importance of these demand processes for understanding the character and potential development of low-carbon transition, where these are conceived not as shifts in markets for specific technologies but as *socio-technical systems*. This, in turn, opens up the need to consider how to develop, not just a low-carbon technology or economy, but a much broader low-carbon 'economy-and-society'.

Literature from science, technology and innovation studies has drawn upon historical case studies to describe and analyse previous socio-technical transitions (Schot *et al*. 1994; Geels 2002; Elzen *et al*. 2004; Smith *et al*. 2005; Dennis and Urry 2009). This has developed into an emerging field guiding much academic and policy thinking around the challenge of 'decarbonisation' (Van den Berg *et al*. 2011). Whilst recognising its limitations (Smith *et al*. 2010), the 'multi-level perspective' or MLP (Geels 2002), has become the most widely adopted version of this at least within European literature.

The MLP describes three levels: the incumbent socio-technical regime or system; a set of emergent 'niches' that are attempting to unsettle this system and perhaps even generate the discontinuity that leads to a broader system transition; and an exogenous level or 'landscape' of what may be taken as relatively stable background factors, such as the broader political economy, ecology and geopolitics. Under this framework, the assemblage of heterogeneous elements (science, culture, technology, policy, industry, markets, user preferences), each with its own specific history, constitutes a socio-technical regime characterising the dominant sectoral configuration at any time. These regimes can be self-reinforcing through processes of 'technological momentum' (Hughes 2000), 'entrapment' (Walker 2000) or 'lock-in' (Unruh 2000), so creating situations in which individual corporations or entrepreneurs are highly constrained in their potential to 'disrupt'.

The tendency for socio-technical and environmental systems to reinforce a given direction or directions of change is also articulated in the pathways approach of the STEPS Centre, which adds to the traditions above by highlighting the role of politics and power in projecting dominant framings onto narratives that enable, constrain or signpost specific directions of system change (Leach *et al.* 2010). This approach allows for analysis of multiple niche-level alternatives in contrast to the dominant pathway (which would be referred to in the MLP as the regime).

The multi-level perspective describes how, through processes of niche accumulation and regime destabilisation (Turnheim and Geels 2012) and pressure from a higher 'landscape' level, these different components of the socio-technical regime become reconfigured in a way that, in turn, affects the form and dynamic transformation of each element. From this perspective, then, it is immediately apparent that neither new technology (supply) nor market forces (demand) alone will affect the kinds of system innovation necessary for low-carbon transition. Central here is understanding the complex nature of the innovation processes. There are crucial 'instabilities' or 'ambivalences' of technologies, most of which do not have a single, pure and unambiguous effect. Technologies may move around and exert a range of intended and unintended consequences as they become lodged within one or another system that are themselves in process and not inevitable or pre-determined in their consequences.

Thus what is involved is not just specific isolated technologies (and their sources of consumer demand) but rather new socio-technical systems that incorporate multiple self-sustaining, stabilizing and interacting processes that may generate distinct pathways of change. For instance, Dennis and Urry (2009) examine the many contingencies in the late nineteenth century and early twentieth century that were implicated in developing what is now known as the car-system, even including how there were three potential energy sources for this possible system, based on coal, oil and battery-power.

Indeed innovations can emerge unexpectedly from the left-field, from experimenters, NGOs or alternative groups (as with the late nineteenth century car system). Also, what is important is not the individual innovation *per se*, but the processes which over time synchronise a range of, often diverse, innovations generated within different industries across societies. In system change new technologies get combined with new or reconfigured combinations of elements. New systems form, often deriving from apparently unconnected innovations initiated within diverse, geographically distant locations (this is elaborated in Urry 2011: Chapter 8).

Most significantly, innovations are part of, and transform, social practices and institutions, hence they are 'sociotechnical'. Innovations are social in three ways. First, the social ties or networked relations between multiple innovators are highly significant. Resulting innovations stem from networks which are often globalised and not from individual 'geniuses' (see Birtchnell *et al.* 2013 for a social network analysis of 3D printing). Second, innovations presuppose transformations in underlying social practices. Examples include daily showering, the weekly shop, the school run, the annual conference, the foreign holiday, buying and eating food without regard to the seasons and so on (Shove *et al.* 2012). Many innovations remain as specialist niches, with only a handful developing into wider system changes if they are taken up, synchronised and gain (possibly global) traction as new social practices are engendered and sedimented. Arthur (2009) argues that:

> A revolution does not arrive until we reorganize our activities […] around its technologies, and until those technologies adapt themselves to us. For this to happen, the new domain must gather adherents and prestige. It must find purposes and uses…This time is likely to be decades, not years. And during this time the old technology lives on.
> Arthur 2009: 157

See also Edgerton (2006) on this point.

Central considerations here are the mass/social media, changing patterns of global governance, the social science of fashion, and different forms of everyday life within which such innovations may contingently be enfolded.

Finally, system innovations must be driven by new social power relations, political identities and coalitions and associated social inclusions and exclusions. In this way, a transition may develop momentum that underpins further social change, innovation and new power relations in complex positive feedback loops. Key here is the issue of power, and in relation to developing low-carbonism, particularly the mobilising interests of 'carbon capital'. This power centre typically lobbies against regulation and intervention in energy markets and energy prospecting; bends foreign policies and military interventions to its interests; undermines some post-carbon innovation; funds various foundations and think-tanks to 'merchandise doubt'; denies the finite nature of carbon resources and the anthropogenic nature of global warming, and; undermines mass transit alternatives (Oreskes and Conway 2010; Urry 2011: Chapter 6). However, even these well-resourced efforts are not uniformly successful, and understanding how they succeed or fail is a crucial element of understanding the politics of low-carbon transition. Nonetheless, it is still the case that carbon capital is along, with finance, the world's most powerful interest and it will be hard for any new system to emerge without it either being somehow implicated or possibly side-lined through the development emerging left-field, such as in China.

Moreover, according to Arthur the process of 'combination' or assemblage of disparate elements that may lead to a new system typically takes three to four decades (Arthur 2009). Likewise Nye (2014) argues that previous regime changes usually took forty or more years and, very significantly, did not involve the direct substitution of one energy source for another. Observations from historic energy transitions have shown that most transitions were rather slow, lasting several decades or even more than a century (Smil 2010; Solomon and Krishna 2011). A new regime involves reorganising society over decades, including its transportation system, population distribution and the nature of work and especially of forms of social practice (Nye 2014).

This conception of system innovation and socio-technical transition thus strongly suggests that low-carbon transition will depend significantly on transition, not just in supply-side energy technologies, but also in the social forms that instantiate the reception and consumption of specific low-carbon innovations and are thereby co-produced with low-carbon technological trajectories. Moreover, in the case of a transformation of the fundamental systems of modern life of fossil fuel use (Tyfield and Urry 2014) and particularly locked-in systems such as internal combustion engine (ICE) based automobility (Geels *et al.* 2013: xiii), the imperviousness of such transition to understanding in terms of 'technology' and 'markets' is particularly striking.

This perspective also offers considerable resources for understanding low-carbon transition in China. Yet studying transitions in China requires analysis of two areas that have been absent from most (international) research in that country. These are the specific socio-political aspects of system innovation and, within that, the transformation of specific social practices, such as eating particular lower carbon foods, changed levels of comfort/energy use in the home and the emergence of lower carbon mobility-based social practices. In this project, therefore, we take into account China's distinctive political economic system, the diverse and distributed range of actors enabling low-carbon innovation to emerge and the political processes through which power relations are contingently co-produced with, creating and reinforcing, potential low-carbon innovation trajectories.

In relation to the above, we examine the changing nature of environmental politics in China and the governance shifts that afford an increasing role for Non-governmental Organisations (NGOs) within a traditionally authoritarian system. Turning away from the top-down perspective on development of low-carbon technologies and the obstacles to their widespread dispersion (e.g. World Bank/DRC 2012), we take seriously the non-technological elements of system change, including importantly lower carbon social practices. Thus we avoid simply accepting a definition of innovation that overwhelmingly informs low-carbon policy, focused exclusively on high-technology, intellectual property (IP)-intensive R&D led by major corporations and research institutes. Instead we expand our purview to include wider forms of innovation such as new business models in small firms and NGOs, as well as changes in social practices, and how these different models are articulated in specific domains. We explore these two research challenges in the next section.

4. 'Politics' and 'Practice': Neglected Areas in Chinese Low-Carbon Innovation

Under the headings 'politics and power' and 'practice', we illustrate the relevance and centrality of these two broad sets of issues that are relatively understudied in analyses of potential low-carbon transitions in China.

4.1. Politics and Power

It is first necessary to examine the crucial issue of China's particular socio-political context. The PRC's history of environmental problems and approaches varies widely, from the Maoist era, when numerous projects affecting the environment, such as hastily built dams and land reclamation schemes, were carried out with what Shapiro (2001) described as 'utopian urgency' and 'dogmatic uniformity', to China's eventual participation in the United Nations Conference on the Human Environment in Stockholm in 1972. This was a turning point that led to the establishment of the country's first national environment agency, which later became the Ministry of Environmental Protection.

Since then, China's centralised and integrated national Five-Year Plans (FYPs) have played a key role, not only in setting the country's key strategic, economic and innovation priorities, but also in environmental initiatives. In the first decades of the People's Republic, FYPs emphasised ever-higher production targets in industries such as coal and steel. However, by the Sixth FYP (1981–1985), at the start of China's Reform Era, FYPs would also include energy conservation efforts. Around the same time China passed the first of its environmental laws and regulations, including the Environmental Protection Law (1979) and the Water Pollution Law (1984). The Ninth Five-Year Plan (1996–2000) was the first to include the term 'sustainable development' (Geall and Pellisery 2012), and in 1997, the Fifteeenth Party Congress listed the, 'huge environmental and resource pressures caused by population growth and economic development', as major difficulties facing the Chinese population (Meng 2012).

China published the first national climate-change plan of any developing country in 2007. This formalised China's commitment to addressing climate-change mitigation and adaptation, while also upholding the principle of 'common but differentiated responsibilities' and integrating climate change into other policies for national and social economic development, thus establishing that climate policies do not take priority over other national objectives (Harris 2010). Climate change is also emphasised in the Twelth Five-Year Plan (for 2011–15) (NDRC 2011; Ng 2011), which lists seven strategic emerging industries for support, including environmental protection and energy efficiency, new energy, biotechnology and clean-energy vehicles (some of which will be investigated in this project), and pledges a reduction in energy consumption per unit of GDP (energy intensity) by 16 per cent, a carbon intensity reduction of 17 per cent and a target for non-fossil fuel to account for 11.4 per cent of primary energy consumption. It also established the Top-10,000 Energy-Consuming Enterprises Programme**,** which aims to save energy among enterprises that use more than 10,000 tonnes of coal equivalent per year and transportation companies, public buildings, hotels and commercial enterprises consuming more than 5,000 tonnes of coal equivalent per year.

Throughout, China remained a one-party (although supposedly multi-party), nominally Communist state. However, its economy has been transformed dramatically, and is today characterised as a variant of state capitalism (Breznitz and Murphree 2011; Huang 2008; Naughton 2011; Tsai 2007; Keith *et al.* 2013). Although privatisation of state-owned enterprises (SOEs) has proceeded apace since the 1990s (WB/DRC 2012), the political economic domination of major SOE national champions and the associated 'cadre-capitalist alliance' (So 2003) of top party-state leaders and SOE managers has ‘reached a new peak in recent years’ (Zhang 2011: 148). In 2009, the total profits of two giant SOEs (Sinopec and China Mobile) were larger than those of the largest 500 private companies (Li 2011:13). State-owned companies account for 80 per cent of the stock market, including the three largest companies by revenues (all in the Global Fortune top ten). Nominally ‘private’ companies, especially national champions, are closely connected with state institutions.

Key questions for China’s low-carbon transition are the strengths and weaknesses of this state capitalist approach and the extent to which it is capable of acting as an ‘entrepreneurial state’ (Mazzucato 2013). Since 2006, the Central Government, as buyer and seller in key industries, has introduced stringent, complex and fast-changing regulations on high-tech foreign enterprises mandating high local-content requirements and transfer of proprietary technologies (Hout and Ghemawat 2010). Through a suite of policies and investments that have created an ‘absorptive state’ (Bound *et al*. 2013), the country has managed to build (or acquire) world-leading firms in strategic green sectors such as manufacturing solar panels and wind turbines (Lema and Lema 2012; Schmitz 2013).

Beyond the production of such hi-tech products, however, the potential for nurturing low-carbon innovation in large firms to translate to wider low-carbon transitions is an open question, a distinction that again presupposes an understanding of innovation that goes beyond the techno-economic orthodoxy. For such innovation capacity requires attention beyond such firms to a wider range of actors, including so-called users. It also requires analysis of the implementation of such plans, policies and models, which should be understood in the context of the complex dynamics of China’s environmental governance and governmentality (Economy 2005; Edin 2003; Wang 2013).

Crucial here is that China’s structure of state power relations is, in fact, far from monolithic and ruthlessly efficient. The literature on China’s environmental governance notes, for example, the horizontal fragmentation created by the proliferation of competing and overlapping decision-making bodies at an elite level. While in theory, China’s Ministry of Environmental Protection (MEP) is the highest central government institution regulating the environment, other organisations often take the lead on particular environmental issues. Chinese environmental governance is thus characterised by ‘fragmented authoritarianism’ (Lieberthal 1992; Mertha 2009) with protracted bargaining between bureaucratic units, including ministries, advisory bodies and top-level ‘National Leading Groups’ specifically established to coordinate cross-jurisdictional issues. Other ministries beyond MEP that play a key role for low-carbon innovation include the Ministry of Science and Technology (MOST), Ministry of Finance (MOF), Ministry of Industry and Information Technology (MIIT), the Ministry of Commerce (MOFCOM), Ministry of Transport (MOT), the Ministry of Agriculture (MOA) as well as the powerful National Development and Reform Commission (NDRC) which decides for example about the medium- and long-term plans for renewable energy (Urban *et al*. 2012).

Furthermore, such horizontal fragmentation is also matched by vertical fragmentation. The considerable devolution of power to the provinces and localities, first introduced in the early Reform Era, has created a complex arrangement often described by the Chinese metaphor *tiao kuai* (‘branches and lumps’) where central government authorities lack the capacity to demand enforcement of environmental laws and policies at the local level. Under China’s relatively decentralised approach, local environmental bureaus, for example, are funded by local governments, rather than the MEP, meaning they tend to act in the interests of those very institutions they are tasked with regulating (see also Harrison and Kostka 2012; Teng 2012). This includes SOEs who may often be of higher rank in the complicated political hierarchy and/or have greater political resources at their disposal.

For instance, SOE reform has granted SOEs (especially major national SOEs) greater managerial autonomy from the party-state. However, this has to a great extent simply inverted the relations of influence, rather than created arm’s-length institutional relations (Jiang forthcoming; Zhao 2010).

With senior Party figures still passing through senior management positions on their rise through the ranks, and with great fortunes of personal wealth to be made, often through borderline or even outright corruption, the situation today can be one approximating 'state capture' by these SOEs, rather than 'corporate capture' by the party-state (Dickson 2008; Tsai 2007). The politics of EV transition are thus intimately related to the broader socio-political challenges of a powerful cadre-capitalist class (So 2003). Furthermore, and more prosaically, economic targets often mean that local officials are rewarded politically by central government for achieving GDP growth, even if it comes at the expense of the local environment.

Chinese observers of the effects of this decentralisation also note the extent to which a 'project system' (Tian 2014; Qu 2012) logic has been instituted across government at all levels, a 'governance model between the traditional system and market mechanisms' (Tian 2014: 1) where local governments compete for projects to attract special funding from central government (Qu 2012: 10). In the field of low-carbon innovation, one finds an illustration of these dynamics in central government plans around urbanisation, where cities dedicated to low-carbon development and electric mobility have been 'identified and encouraged to compete for solutions' (Fischer 2012: 5). While the 'ideological foundation' of such a system is technocratic (Tian 2014: 3), its 'expert rationality' often acts instead as 'cover for sectoral interests and interest groups'. 'In practice', writes Kelly (2014: 57) such an arrangement, 'produces governance that sits uncomfortably half-way between full-scale planning signed off by ministers and the flexibility and canny differentiation of the market.'

Furthermore, non-governmental actors, institutions and discourses have greater sway over decision-making around environment, climate change and innovation policies than in previous periods. Over the past 15 years, many influential officials and policymakers at the central level have supported citizen oversight, media coverage and other forms of public participation by civil society in order to improve local enforcement of environmental regulations in the context of waning 'legitimacy' (Wang 2013). Regime legitimacy and performance legitimacy are concepts widely discussed and understood in Chinese policymaking, and are significant in driving reforms towards new cadre evaluation systems, as well as the introduction of laws and regulations such as the Environmental Impact Assessment Law (EIA) (2002) and transparency initiatives on open environmental information and innovations such as Hotline 12369. The last of these is a phone tip-off line for citizens to report pollution incidents and environmental violations and is operated by the MEP (CCICED 2013).

While many institutional procedures for such public participation are vague and poorly enforced, and environmental advocacy is closely monitored and subject to periodic crackdowns (Geall and Hilton 2014), green NGOs have proliferated, and there are now 492,000 legally registered social organisations in China, according to a 2012 government report, of which many are green. Concerns about environmental issues have increased among China's newly empowered middle class(es) (e.g. Li 2010; Goodman 2014), with opinions expressed more freely and rapidly than ever before due to increasingly ubiquitous social media and messaging technologies. Urban protests increasingly focus around the lack of transparency and accountability concerning potentially polluting developments (Ansfield 2013; Tang 2013; CCICED 2013; Geall and Hilton 2014), and according to some in the Chinese Government, they represent the most common catalyst for 'mass incidents' or protests (Bloomberg 2013).

4.2. Bringing Power into Transition Studies

Beyond incorporating an understanding of the Country's environmental politics and governance into work on China's potential low-carbon transition, there is a need to attend to power itself, which has been overlooked in much prior work on socio-technical transitions, particularly the MLP (Meadowcroft 2009a; 2009b) and has only recently begun to receive attention in transitions studies in Europe (Kern 2011; Lockwood 2013). Power has re-emerged as a key concern across many of the social sciences, and especially those that are roughly problem-led and post-disciplinary, such as development studies (Gaventa 2006), political ecology (Wolf 1972; Greenberg and Park 1994; Bryant 1997) and innovation and/or science and technology studies (Stirling 2014). Yet turning to power is not a straightforward step, since the concept and its definition is arguably one of the most unsettled, if not contested, issues in the social sciences. Hindess (2006: 1) notes, ‘there is little of value to be said about the concept of power as such'. Yet, conversely, defining what we mean by ‘power’ is a gauntlet we cannot refuse to take up, for as Gaventa (2003:12) notes, perhaps the most common of ‘traps’ to fall into regarding such a move is simply to assume, and not to ‘define or address or use [it] in a coherent manner.’

Beyond power’s ‘neutral’ and scientific meanings as causal power or capacity (‘power to’), its popular meaning as domination of some over others (‘power over’), or even radical conceptions (such as Lukes (1974)) that include its invisible exercise – preventing the powerless from recognising their own condition – is the notion of power as a matter of the *constitution of social realities*. Following the later work of Foucault (2004; 2009; 2010), who has been its foremost exponent, this perspective is concerned primarily with *how* power is exercised and itself constructed, rather than using it to explain its effects. In this conception, society is constituted by power-laden social relations, that condition and enable or constrain specific forms of strategic agency. These power relations are themselves mediated by various technologies, including forms of knowledge, measurement, procedure and practice that act as potential points of strategic leverage (Hindess 1996) and which may be studied in concrete detail. Such analysis thus elicits an understanding not only of governance but also of governmentality (the ‘conduct of conduct’), a concept about which there has been considerable social scientific interest within the Chinese studies field (Dutton 1992; Rofel 1999; Yeh 2005; Jeffreys and Sigley 2009), but there has been little attention focusing upon socio-technical transition or low-carbon innovation in China. The aim of this project is thus to explore how forms of social rule and order are constructed out of diverse techniques and rationalities that manifest across whole social formations, and in forms of *self*-regulation and -construction, rather than through decisions located only in the citadels of states and corporations.

In contradistinction to the other, more familiar concepts, power here is thus not analysed in terms of a capacity and its legitimacy (Hindess 1996). Power in this view is not something that is seen as possessed in greater quantities by some than others. It is, ‘more appropriately seen as a kind of shorthand, a convenient (if not always helpful) way of invoking “the total structure of actions brought to bear” by some on the actions of others’ (Hindess 2006: 116, quoting Foucault 2001: 336). Nor is it *a priori* normatively bad until legitimated by consent, but rather productive and normatively ambivalent, assessable only in concrete instances. The reasons for preferring this conception to the others are manifold and the focus of a large literature that cannot be touched on here. However, for our purposes, the primary reason for such a shift in the conception of power is that it allows for a fuller understanding of the issues of system transition. In particular, this conception of power allows for existing (structures of) power relations, including situations of system lock-in, to be re-dynamized and so opened up in terms of exploring both how the existing system actively re-produces itself and thus, by contrast, potential strategic points for discontinuity and/or the emergence of new systems.

Comparison with the MLP is instructive in this regard (Tyfield 2014). While the MLP has been used successfully to analyse large-scale system innovations that have taken place in the past, it remains a persistent problem for MLP analyses to explain, or insightfully illuminate, prospective real-time transitions (Smith *et al.* 2010). This is especially the case regarding the difficulty of showing how specific successful niches may be scaled up to effect a regime level transition. For MLP, this is conceptualised in terms of the articulation or ‘alignment’ of the diverse social factors and forces, which the MLP rightly emphasises are involved, into seemingly coherent (and increasingly so) systems. In conceptualising these simply as factors, however, there is no account of how these somehow aggregate into new wholes. Moreover, the factors themselves must be treated as atoms, qualitatively unchanging, at least for the sake of the analysis. This problem is particularly clear when considering prospects for low-carbon transition in China, where the elements at play in constructing an emergent system change rapidly in a complex process of mutual adaptation and antagonism.

Conversely, a relational, dispersed, productive conception of power directly furnishes a concept on which to hang the explanation of how a system transition emerges and without ruling out qualitative change in these 'factors', i.e. as new forms of productive power emerge via new power-technologies and dynamic, strategic power relations, in turn driving the formation of both new socio-technological assemblages *and* the parallel transformations in political coalitions, governmental institutions, subjectivities etc. Both the potential ruptures and openings in the existing lock-in and a process of positive feedback loops in which peripheral niches may *become* powerful, ultimately challenging system lock-in, are thus presented. In short, socio-technical system transition is understood (and understandable) *as* a transition in systems of power-relations, *as a power transition*.

Moreover, innovation, itself conceived as a socio-technical system process of new-world-making, co-produced with the socially and culturally-conditioned reception and consumption of new offerings (not just their technical development), thereby becomes a key window into this recursive process. In adopting a dynamic conception of power in our study of prospective system innovations, we are therefore required to study what are (or are not) emerging as particular framings of 'the problem', here of low-carbon transition, and the 'governance processes and architectures [that are becoming] mutually supporting and interlocked' (Leach *et al.* 2010: 370).

Further, the role of the 'landscape' level in MLP theory (including structural and governance contexts within which the regime exists) and its interaction with regime and niches is under-developed in terms of power. Major changes in the 'landscape' may be conceptualised as leading to specific 'windows of opportunity' for system change, affecting a disruption that specific niches could take advantage of. Yet the causation in this case remains one way, from landscape to regime levels. In the case of China, particularly, it is an open question whether what is additionally in play is the opposite process, by which the accumulation of diverse niches, and shifts in socio-technical regimes may seed profound 'landscape'-level change, in particular, the relationships between various state and non-state actors, and the role of users of technologies within a rapidly-changing socio-technical and political context. While there has been little theorisation in this area (though see Perez 2002, *Cf.* Tyfield 2012: Chapter 15), we might speculate that such landscape level changes could potentially open local, regional or national systems up to more diverse pathways of change imagined. Not through the high-tech lens of 'indigenous innovation', but through an alternative view of China's low-carbon transition that encompasses shifts in socio-political structures.

This question in turn opens up the qualitative, normative dimensions of socio-technical transitions and pathways, overlooked in conventional MLP analysis. These include the '3Ds' (Stirling 2009): *direction* of innovation (or pathway) trajectories; the *distribution* of costs, benefits and risks associated with these pathways; and the *diversity* of pathways, including those that are locally appropriate and emergent, rather than nationally or globally imposed. Whether through high-tech, government-driven approaches or more bottom-up, emergent forms of innovation, China's particular trajectory may well have global consequences in the medium-term for the qualitative nature of low-carbon societies. Low-carbon innovation in China thus raises key issues for understanding the politics and sociology of moving to a post-carbon 'economy-and-society' (Giddens 2010; Urry 2011; Newell and Paterson 2011).

4.3. Practices

Second, it is necessary to recognise that supporting industrial innovation and introducing new technologies is one element in a broader socio-technical transition that must incorporate social practices, norms, infrastructures, techno-scientific knowledge, networks and symbolic meanings (e.g. Geels 2002; Geels 2005). Most analysis of low-carbon innovation in China focuses upon issues of production and the supply side (including analyses of data on patents, R&D expenditure etc.). The demand side, the reception and consumption of innovations (Bhidé 2009) including changes in associated social practices (Shove and Walker 2007; Büscher *et al.* 2011), is largely neglected (and not just in industries, such as solar PV, that were until recently overwhelmingly for export). This is true even of more rigorous scholarship that focuses on learning and innovation capabilities in specific sectors of low-carbon significance (Watson *et al.* 2011; Simon 2011; Segal 2010; Lema and Lema 2012; Jakobson 2007).

As outlined in some of the theories of socio-technical transition discussed above, changing markets, user preferences and practices are central in enabling transitions to more sustainable systems. Whilst governments have attempted to foster behavioural change through public information/education initiatives, research suggests that the link between attitudinal change and subsequent behaviours is subject to structural and institutional conditions (Ockwell *et al*. 2009). Social practice theorists also critique the notion that behaviour (and potential behaviour change) can be understood as rational, cognitive individual processes, highlighting how practices are social, habitual or routinised, systemically-situated and performative. These insights are vital in order to understand the complex ways that social practices develop or disappear, as in the growth of daily laundering (Shove and Walker 2010) or different forms of shopping and eating (Southerton *et al.* 2011). They also help to develop understanding of the culturally-embedded framings through which different socio-technical pathways are viewed and experienced by different users (Banister *et al.* 2012, on competing theories of how to reduce the impact of transport).

Such an approach sees social practices as not only mediating many of the relationships between the elements in socio-technical transitions, but as ordering and shaping the interactions between them. Thus reconfiguring practices around a particular technology can actually lead to changes in other interlocking habits, opening up opportunities for new innovations to emerge and play a reinforcing or steering role in niche or pathway development.

Shove and Walker (2010) note, for example, how the weekday congestion charge introduced in London in 2003 led to a shift in the timing of visits to friends and relatives to outside charging hours (such as weekends). And they point to the limitations of the MLP in how to 'govern practices'. With such routines changing rapidly alongside most other aspects of social life in China, adopting 'practices' as a specific lens becomes a promising way to understand the associated socio-technical change, especially insofar as this is analysed as a key element of contemporary and changing power relations (*cf.* Shove and Walker 2010).

Drawing attention away from the supply side also prevents a limited view of transitions centred around particular technologies (e.g. battery electric vehicles or solar water heaters) and creates space for more interconnected niches (e.g. networked, multimodal mobility systems including car sharing, bicycles; mini-grids based on solar PV, etc.) to be the focus of study. Recognising the multiple factors involved in transitions, and in particular how the reception of new innovations can influence social practices, also highlights the importance of less high-profile, more bottom-up innovations that may be disruptive, originating in China as low-cost, 'below-the-radar' innovation (Zeng and Williamson 2007 Breznitz and Murphree 2011; Kaplinsky 2011; Tyfield *et al.* 2010). The project will, through attending to user perspectives and practices, provide a more robust basis for understanding the potential of these disruptive innovations, the pathways through which they might emerge, and the role played by policy, politics and power in organising the 'demand side' of potential low-carbon transitions.

Considering 'politics' and 'practice' together brings out important links. Questions around the potential for China not only to drive low-carbon innovation but also to foster broader transitions warrant significant research effort. How does the central authority of the state extend to the diversity of actors involved in wider system change, brought about and enabled by multiple forms of innovation? Does the groundswell of bottom-up and disruptive innovation from diverse publics raise challenges that are particularly acute for a relatively hierarchical and fragmented authoritarian technocracy? How will shifts away from current governance conditions, potentially opened up by the increasing engagement of the world's largest online population (Yang 2011) especially in health, environment and sustainability issues (*cf.* Thøgersen and Zhou 2012; Pew Environment Group 2013), change the processes through which state-level policies, strategies and targets can be translated (or not) to transitions at the 'street level'?

5. Methodology and Case Studies

Given these questions and reconceptualisations, we are led to the following research questions regarding low-carbon innovation in China:

1. Are low-carbon transitions emerging in specific domains, where and why? Are they gaining significant traction?
2. With what effects do they relate to broader processes of decarbonisation of societies as a whole and especially to the development of lower carbon social practices?
3. What socio-political changes are emerging in China with implications for these socio-technical systems and social practices, and what are the implications?
4. What lessons does China's state capitalist approach to low-carbon innovation offer UK industrial policy for low-carbon transition and the generation of globally competitive low-carbon industries?

In both Figures 5.1 and 5.2, the model schematically describes the process of transition emergence as a strategic power relational process. Bold arrows denote the analytical focus of the step, while dotted lines denote processes understood to be happening but which are abstracted from for the purpose of this specific step in the analysis.

How can one conduct research to identify an emerging socio-technical system transition in which the future is not known in advance? Deploying concepts of socio-technical systems and a constitutive, productive, relational conception of power, the challenge becomes, on the one hand, the exploration of how narratives, rationalities, techniques and practices shaping power relations are mediating self-sustaining trajectories, with a growing 'power momentum', of low-carbon innovation in specific domains (Figure 5.1) and on the other, the potential impacts of these emergent innovations on the social elements constitutive of empowered strategic agency before and after possible transition (Figure 5.2).

Figure 5.1: Two step analysis of emergence of a power socio-technical transition - step 1

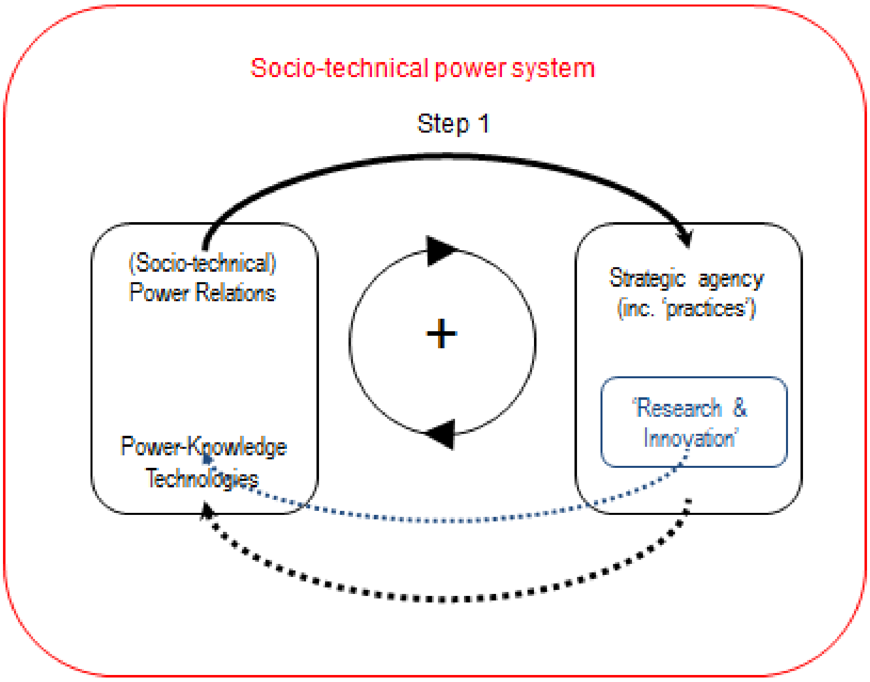
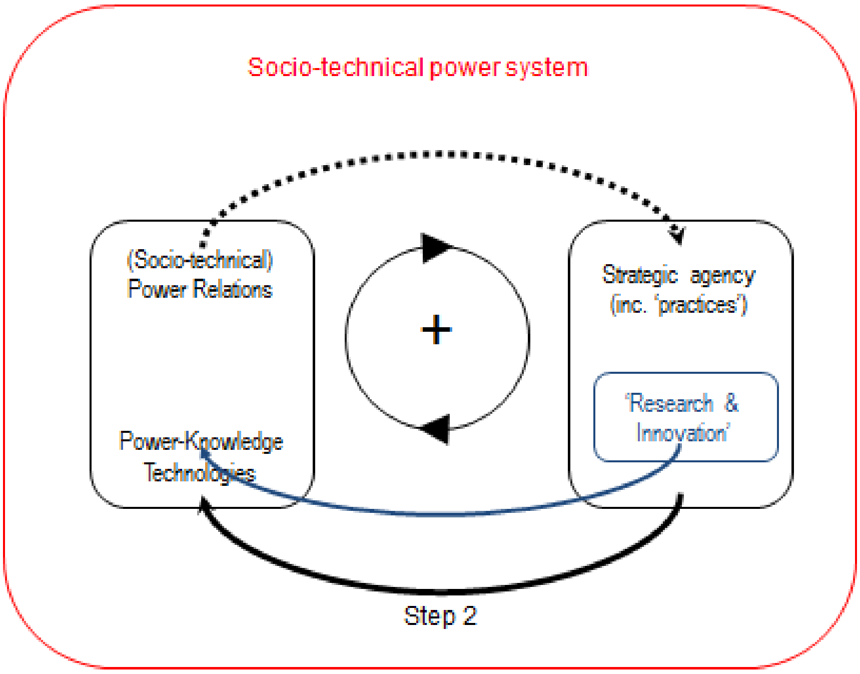


Figure 5.2: Two step analysis of emergence of a power socio-technical transition - step 2



These elements include political economy, consumer preferences and gendered social practices, cultural politics, and the evidence of new and changing power blocs, social identities and social classes. Put together one may assess the extent to which these elements may come to be assembled to form a new system and thus are enabling a self-sustaining and reinforcing dynamic not only in the context of but also actively responding to, incumbent structures, imaginaries and practices (Cohen 2010), hence generating a power momentum capable of, in time, challenging an incumbent system lock-in.

What would be the methodology of such a project? To be consistent with our deployment of the concept of power described above, the goals of research here are not epistemic alone but *political*-epistemic, in terms of trying to *transform* power relations. Moreover, this purpose is itself an epistemic imperative, for given the dynamic (Gaventa 2005: 19) of changing power relations, one comes to better understand it by *engaging* it, or its participants, at a practical level. Such research is also both analytical and normative (Leach *et al.* 2010: 376), concerned with both the complexity of the problems under consideration and objectives of environmental sustainability and social justice (Leach *et al.* 2010: 370), but without presuming to legislate on what these complex goals mean in concrete. Rather, as with other phronetic research (Flyvbjerg 2001) it is ultimately to cultivate the reflective understanding of the participants themselves (Flyvbjerg *et al.* 2012), specifically regarding the framings, truths, action and consciousness at work in, and formed by, current power configurations (Gaventa and Cornwall 2006: 125: 127), and hence *their own* strategic positioning and enablement/disablement, especially regarding dominant framings and pathways. The aim of phronetic research is thus not just to cultivate understanding of the research community (and the users of their research), but to contribute to the construction of such a reflexive, phronetic society.

As such, phronetic research is different to action or participatory research, while having some features in common in that:

> it is it does not privilege collaboration with the people being studied as much as some forms of participatory action research; instead, it privileges producing knowledge that improves the ability of those people to *make informed decisions about critical issues confronting them* (regardless of whether that research is done in collaboration with those people or not).

(Clegg and Pitsis 2012: 73, emphasis added)

Phronesis thus depends neither on a prima facie (and tacitly normative) privileging of distributed knowledge-making *nor* on a prior commitment to the normative project for/with which the action research is to be conducted.

With these considerations in mind, we turn to the specific methods relevant to this research project. In each sector of inquiry – the three different but overlapping domains of agriculture, energy and transport – the research project turns its attention to comparison of two pathways. One broadly characterised by high-tech, centrally-supported and IP-intensive models of innovation, the other by dispersed, emergent, often user-led and lower-tech, usually lower-cost approaches. Such comparison serves both methodological and theoretical purposes.

Theoretically, it opens up the possibility that the most promising avenues for low-carbon innovation in China, in terms of effecting system transition there and overseas, may not be in the high-tech, proprietary models of innovation that are the overwhelmingly recipients of government (and think-tank) attention. Instead, we will also investigate the extent to which the already-identified strengths of Chinese innovators in lower-tech disruptive or below-the-radar innovation (discussed above) offer a different and potentially more compelling substance to the official discourse of 'indigenous innovation' (*zizhu chuangxin*, 自主创新).

Secondly, methodologically, exploring transitions in systems of power relations and the diverse technologies, including practices, through which these are mediated potentially opens up an unlimited set of issues with which to grapple. To reduce this to a manageable research task, therefore, we deploy the comparison of the two innovation models, as these allow for the identification of pragmatically important differences between the two models that present a practicable set of aspects to investigate. This includes the identification of research participants, the range and number of which will be justified on the basis of concrete considerations regarding the social, cultural and political contexts and issues relevant to each of the three domains. Across all cases, however, qualitative evidence will be gathered both through interviews and focus groups with top-down producers and bottom-up users of various descriptions.

More specifically, then, in the case of solar energy (Urban and Geall 2014), the research project investigates:

1. the centrally supported development of solar photovoltaic modules, a largely-export oriented, IP-intensive industry, in which China is now the world's largest investor, producer and exporter; and,
2. the production and use of solar water heaters, low-cost standalone systems of which China has the world's largest installed capacity (REN21 2012).

These pathways are interesting to study in order to understand better the differentiated dynamics of innovation diffusion at the global level and indigenous innovation processes around the development and widespread deployment of locally produced solar water heaters. A low-carbon transition in China will necessarily involve a shift from high-carbon energy pathways, and coal combustion in particular, so renewable energy is crucially important, especially where it becomes an industry valued for its role as a driver of growth, beyond sustainability concerns.

China has become almost unquestionably the world leader in renewable energy, most notably in wind energy, solar energy (both solar PV and solar water heaters) and hydropower. China is leading the renewable energy field globally in terms of investments, production and installed capacity (IEA 2013). China spent US$67 billion alone in investments for renewable energy in 2012 (Frankfurt School-UNEP

Centre, 2013) and it is reported that it aims to spend 1.8 trillion RMB (£180 billion) in the five years between 2010 and 2015 for investments in renewable energy (Bloomberg 2013). While the initial development of the solar PV industry was mainly geared towards the export market, especially for Europe and the US – a situation that has changed since 2011, particularly in response to high US tariffs (Fischer 2014) – solar water heaters are predominantly used domestically with an estimated 30 million households as users (China Green Tech Initiative (CGTI) 2011). Chinese university-linked research institutes developed the unique Chinese 'evacuated tube design' in the 1990s and today it is estimated that 95 per cent of the patents for core technologies of solar water heaters world-wide are held by Chinese firms (CGTI 2011). Esposito *et al*. (2014) describe solar water heaters as the 'undiscussed protagonist' for a transition from fossil fuels to low-carbon energy. Solar water heaters may have the potential to become a disruptive, low-cost innovation that could redefine household energy access and energy supply by making it more decentralised, individualised, independent, cost-effective and sustainable.

Secondly, the project examines two potential pathways for <u>low-carbon urban mobility</u> (Tyfield *et al.* 2014):

1. the development of electric vehicles, specifically by Chinese-domiciled companies; and,
2. the emergence and development of electric 2-wheelers (E2Ws), again specifically produced by Chinese-domiciled companies.

The number of cars in China increased over 4-fold between 2004 and 2010 to 40.3 million (NBS 2011), with growth expected at seven to eight per cent annually (Sperling and Gordon 2009). This has consequences for climate change, pollution, congestion, high accident rates and rapidly rising oil consumption. American car intensity seems impossible in China as it would consume all of current world oil output (IEA 2011). The Chinese Government has identified EVs as a 'key strategic industry' with RMB100 billion (£10 billion) of support over the next 10 years, aiming to get five million on the road by 2020. Chinese car companies, more than those domiciled elsewhere, are focused on developing EVs. But EVs come with significant problems: they do nothing to solve traffic gridlock; they are only as 'low-carbon' as their electricity; innovation capacity for EVs in China remains heavily dependent upon foreign enterprise; and there is almost a complete lack of consumer demand for EVs, despite state subsidies.

This is in marked contrast with E2Ws. China is already the world leader with approximately 120 million on the road by 2009. Moreover, at much smaller weights and not facing the same constraints of sitting in congestion, they make much more efficient use of (even conventional high-carbon) electricity than do EVs, substantially increasing their low-carbon credentials. Finally, the market is dominated by small, start-up Chinese companies, some of which have grown to large enterprises, using their own technology. E2Ws are thus potentially a significant Chinese 'disruptive' low-carbon innovation that may even come to redefine given social understandings of technologies including the car itself (Tyfield and Urry 2012), what it looks like, what it can do, how it is used, owned, manufactured and paid for. For this to happen, though, E2Ws must become part of various new social practices that move beyond the conventional car, which is increasingly necessary for mobilised social practices within rapidly growing Chinese cities (Urry 2013: Chapter 6).

Finally, in the domain of <u>agri-food systems</u> (Ely *et al*. 2014), the project investigates two case studies:

1. the centrally-supported development of genetically modified phytase maize as a potential component of intensive agri-food (including livestock) systems, and;
2. the emergence of organic and agro-ecological approaches to the production and consumption of maize and associated agricultural products.

These two agri-food pathways are not only linked by maize, a key staple Chinese food and feed grain with a long and important history, but also by rapidly changing diets. This radically altered food system not only has climate impacts, but also requires innovation to address some of its key other environmental and social challenges, including food safety, food security and food sovereignty at varying levels.

From the perspective of policymakers and scientists, innovation in Chinese agriculture has principally occurred in seeds, fertilizer input and livestock technologies. However, a greater attention to social practice reveals that there are other forms of innovation in Chinese agri-food systems, many in response to consumers' changing practices: efforts such as green food labelling schemes, organic food delivery projects, community-supported farms, agricultural cooperatives or social movements around vegetarianism and other dietary practices. Therefore, the research considers innovation as it pertains to a low-carbon transition in Chinese agri-food systems, particularly in the context of a shift towards more meat-based diets.

Our methods then have been chosen in order to explore these four questions across these six case studies. Elmore described 'forward-mapping' as a strategy that,

> begins […] with as clear a statement as possible of the policymaker's intent, and proceeds through a sequence of increasingly more specific steps to define what is expected of implementors (sic) at each level. [It ends with a statement] again with as much precision as possible, what a satisfactory outcome would be, measured in terms of the original statement of intent.
> Elmore (1979: 602)

Traditional implementation studies thus focus on the extent to which policy framings of technology development and transition are successfully imposed on users.

By contrast we adopt a variant of a backward mapping methodology to compare and contrast differing framings/visions of system transition from innovators, consumers and users back to the visions elucidated in high-level regulatory/policy statements or company strategies. Backward-mapping adopts perspectives and practices of users/'street-level' regulators as a starting point, and maps backwards to understand the disjunctures with regulatory/industrial framings at progressively higher levels. Employed in this way, backward-mapping aims to unmask user framings of technologies, the contexts in which they are encountered and the socio-technical practices associated with their use. This allows the analyst to identify inconsistencies, bottlenecks and irreconcilable tensions between the regulatory/policy framings on the one hand and the user framings on the other. This can often help to explain how regulations/policies succeed or fail. Backward mapping has already been applied multiple regions and sectors in China by Adrian Ely, one of the project team, (Van Zwanenberg *et al*. 2011; Jin *et al.* 2011) and is well-suited to an in-depth analysis of system interactions, governmentality and practice theory.

Here, though, to manifest the central concern with productive power relations and practices, backward mapping is not employed to explain the success or failure of politicies/strategies by presenting (whether to the 'board' or the 'street' or both) the 'reality' of the street-level reception in contrast with the top-down 'image' (*Cf.* also the contrast to action research described by Clegg and Pitsis above). The goal is not to assist efficient, or even equitable, policy-making *specifically*. Rather we aim to produce credible maps of how these all fit together in the construction of a (possibly emerging) systems of power relations, and specific roles and placements in that system which can then be presented to one and all, in order to furnish a phronetic reflexivity regarding such changing power relations; i.e. showing *how* low-carbon transition is/is not happening, the qualitative social dimensions of the resulting society and the strategic positioning of different agents in that ongoing process.

Dai's (2014) work, whilst not adopting a backward-mapping approach, has attempted to identify differences between the interests of policy-makers and other actors at national and sub-national levels and offers lessons for our project. Beyond interests, however, we will aim to characterise broader framings of innovation and transition, in particular to compare dominant producer framings for each case study with the actual reception and use of the respective innovations and how these interrelate. The former will be analysed through semi-structured interviews as well as (for triangulation, given understanding of the primarily practical, lived and political-strategic nature of what is being explore) site visits, discourse analysis of major strategy documents and, where possible, some extended observation. Evidence on the latter will come from interviews, focus groups, and extended observations of social practices related to innovation and use (Clegg and Pitsis 2012: 73: 75).

The conclusions of the research using this set of methods, therefore, is what the *participants* themselves think should be done, thereby also creating impact in terms of leading them to think more reflexively on their own conceptions of their strategic agency and goals. Adopting a phronetic approach and in this way aiming to broaden out and open up social appraisal (Stirling 2008), we will present a set of transition pathways and the social and environmental futures to which they could potentially lead. These will have been shown to have both genuine purchase with significant constituencies involved, such as participants/informants, in the research process and to be analytically credible given the existing social power relations and their dynamics of change.

6. Conclusions: Tentative Findings and Implications for Policy

As explained above, this project aims to fill various gaps in knowledge by offering in-depth analysis of low-carbon innovation and transition in China. As well as advancing our knowledge and understanding of the Chinese case specifically, the project will offer insights into processes of socio-technical transition, and especially the roles played by politics, power and practice more generally. In addition, through adopting the backward-mapping approach outlined above with attention to user perspectives and social practices, it will progress attempts to research real-time prospective transitions and pathways of change. Thus it will contribute to addressing key theoretical and methodological challenges in innovation studies, as well as adding significantly to the currently limited literature on (low-carbon) socio-technical transitions in China.

Beyond this, the project aims to derive evidence that can inform policy and strategy in China, the UK and elsewhere. Data and analysis from the research packages discussed above will provide both general lessons and specific examples of policies that are – or are not – helping to build low-carbon innovation capabilities and the international competitiveness of associated Chinese firms, and to accelerate low-carbon transition. In particular, the project will seek to provide insights that can inform policymakers and stakeholders in their search for low-carbon transitions that deliver not only environmental benefits, but fulfil social objectives around employment and improved wellbeing. Adopting the phronetic approach to research discussed above, the project will engage these stakeholders as participants in the project rather than as just research subjects, and will dedicate significant resources to communication and dissemination activities, including events to be held in Beijing, Shenzhen and London in early 2016. These will create spaces for reflection, facilitate networks and learning between otherwise disparate stakeholders and contribute an evidence base for low-carbon innovation policies within the UK (beyond the 2015 general election), China (beyond the Thirteenth FYP) and globally (beyond UNFCCC COP21 in Paris).

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