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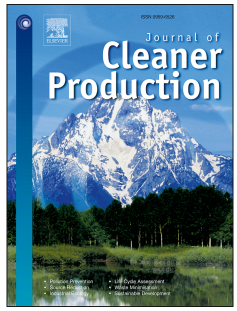

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Yuan Peng, Xuemei Bai

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Experimenting towards A Low-carbon City: Policy Evolution and Nested Structure of Innovation

Yuan Peng, Xuemei Bai*

The Fenner School of Environment & Society, Australian National University, Linnaeus Way, Acton ACT 2601, Australia

* Corresponding Author. Email: xuemei.bai@anu.edu.au

Abstract

Cities can play a key role in the low-carbon transition, with an increasing number of cities engaging in carbon mitigation actions. The literature on urban low-carbon transition shows that low-carbon urban development is an inevitable trend of urban sustainable future; there is a great potential albeit with some limitations for cities to reduce its carbon footprints, and there are diverse pathways for cities to achieve low-carbon development. There is, however, a limited understanding in terms of the internal mechanism of urban low-carbon transition, especially in rapidly developing economies. This paper attempts to address this gap. We examine how low-carbon policies emerge and evolve, and what are the enabling mechanisms, taking Shanghai as a case study. We developed an analytical framework drawing on system innovation theory and sustainability experiments for this purpose. A total of 186 relevant policies were selected and analyzed, which is supplemented by the interviews with stakeholders in the government to gain a deeper insight into the policy contexts in Shanghai. We found that the city's low-carbon initiatives are embedded and integrated into its existing policy frameworks. A strong vertical linkage between the central and the local governments, and more importantly, a nested structure for innovative policy practices were identified, where a top-down design is met with bottom-up innovation and proactive adoption of enabling mechanism. The structure includes two layers of experiments that facilitate learning through policy experiments across scales. The uniqueness, effectiveness, applicability and limitations of these efforts are discussed. The findings provide new theoretical and empirical insights into the multilevel governance of low-carbon transition in cities.

Key words: Cities and climate change; Low-carbon city; Low-carbon policy; Sustainability experiment; Enabling mechanisms; Nested structure of innovation.

1. Introduction

Cities can play a key role in climate change mitigation, not only because they are the major carbon emitter accounting for up to 75% CO2 emissions (IPCC, 2014), which is expected to grow with increasing urbanization (UN, 2014), but also because of their capacity, flexibility, and willingness to actively engage in climate change debate and action as demonstrated by many front-runners among them (Allman et al., 2004; Granberg and Elander, 2007; Rosenzweig et al., 2010; Zimmerman and Faris, 2011). Many cities have either committed or already made substantial efforts to reduce their carbon emissions, with various levels of ambitions and capacities (Broto and Bulkeley, 2013; Bulkeley et al., 2010). More recently, numerous cities have declared to aim for 100% renewable energy or zero carbon emission in the following decade or so (ACT, 2016; Melbourne, 2014). Collectively, such city level initiatives and efforts may have the potentials to shift the carbon trajectories towards a more sustainable end.

There is a substantial body of literature on urban low-carbon transition, with various focuses such as the overall trend, challenges and features of urban response to climate change at international scale (Betsill and Bulkeley, 2006; Bulkeley et al., 2012; Corfee-Morlot et al., 2009; McCormick et al., 2013); various case studies of local government practices for low-carbon transition, focusing on local climate change policy, financial programs, investment benefit for low-carbon development, low-carbon transition in sectors (Bulkeley and Kern, 2006; Fuller et al., 2009; Gouldson et al., 2014; Newman, 2004); scenario modelling and carbon emissions calculation to inform urban policy making (Fong et al., 2009; Gomi et al., 2010; Li et al., 2010; Phdungsilp, 2010); and the effectiveness of urban level low-carbon practices (Allman et al., 2004; Nakamura and Hayashi, 2013; Van der Heijden, 2016). Collectively, these research show that the concept of low-carbon urban development has been increasingly adopted in cities worldwide; cities have a great potential for global Greenhouse Gas (GHG) reduction by reshaping their carbon trajectories; and there may be diverse pathways and degree of success in achieving this target (Bai et al., 2010; Coenen et al., 2010; Newton and Bai, 2008). However, there is limited understanding in terms of the internal mechanism of urban low-carbon transition, with some critical questions left to be further explored, e.g. how low-carbon policies emerge and evolve in the local and national policy context, how innovative policies emerge and play a part in urban low-carbon transition, and what institutional setting and mechanisms are needed to support policy implementation and novelty practices. Such knowledge gaps are more significant in rapidly developing cities, where a more rapid increase in carbon emission is projected (Ru et al., 2010; U.S.EIA, 2013), and where integrating global concerns into local management can be more challenging compared to cities in developed countries (Bai 2007).

We aim to address some of these knowledge gaps taking Shanghai as a case study. Shanghai is a city that has been undergoing rapid economic growth and transition, initiated many innovative practices towards low-carbon transition, and is a designated Pilot Low-Carbon City in China. To better understand the internal mechanisms of a major metropolitan government in a transition economy in tackling low-carbon development, we ask two questions: a) How low-carbon policies emerge and evolve within the local and national policy context; b) What are the supporting structure and enabling mechanisms of innovative policy practices, both in terms of institutional and financial, for implementing the urban low-carbon policies.

We employ the concepts of system innovation and sustainability experiment for analysis. Sustainability experiment is defined as planned initiatives that embody a highly novel socio-technical configuration likely to lead to substantial (environmental) sustainability gains

(Berkhout et al., 2010). The experiments are designed to be the practicing ground for innovations in terms of building actor-network, stimulating learning processes, and promoting them to develop into a stable social-technical configuration (Bai et al., 2010; Kemp et al., 1998; Loorbach, 2010; Loorbach and Rotmans, 2010). The “innovations” can be ‘‘knowledge-based innovations’’, e.g., technical innovations – relying on knowledge and expertise; or ‘‘relations-based innovations’’, e.g. governance innovations that aim to alter the relationships between people in an organization; and ‘‘mixed innovations’’ that include attributes and aims of both types (David cited in Daniell et al., 2014)[1]. In addition to these typologies, there are different ways of doing things, which we define as the “process-based innovations”. Much of the novelties discussed in this paper will be about “relations-based”, “mixed” or “process-based” innovations, as will be detailed in later sections. To enable a fine-tuned analysis of the role of main actors, various vertical and horizontal linkages, and the enabling mechanism supporting the experiments at different levels, the concept of experiment is used at two different layers—on the one hand, the city as a whole can be considered as sustainability experiment when examining its role in informing national low-carbon policy-making. On the other hand, the city can be seen as a locus for numerous sustainability experiments (e.g. policy practices and pilot projects) implemented by the city. The structural relationship between these two layers is discussed.

Hooking low-carbon issues to existing local policy scheme has proven to be effective in addressing climate change related issues at city level (Bai, 2007; Betsill, 2001). In this regard, a better understanding of the structure and trajectory of existing policy framework of a city, in particular, those with low-carbon implications is important. A set of criteria is developed for the selection of relevant local policies with low-carbon implication. A total of 186 policies are selected, categorized, put in time sequence and analyzed in relation to development stages of the city. Further, based on a thorough analysis of governmental documents and interviews with government officials, the institutional setup to facilitate cooperation between government sectors, and financial mechanism for policy implementation are discussed. To evaluate the effectiveness of these policies and governance, we discussed trends in energy consumption, air quality and CO_2 emission in Shanghai from 1998 to 2015. Finally, the limitations and broader applicability of Shanghai case are discussed.

There are six sections in this paper. The following section presents a brief review of current understanding of low-carbon city initiatives, as a context for examining Shanghai’s low-carbon transition. In section 3, we present the analytical framework of this paper and the methodology of data collection and analysis. Section 4 presents the relative positioning of low-carbon policies in the existing broader policy framework and its evolution; Section 5 presents enabling mechanisms for policy implementation, where we present a nested structure for innovative policy practices. Section 6 discusses the characteristics of low-carbon governance, evaluates their effectiveness using quantitative data, and discusses the applicability and limitation of Shanghai experience in a broader context. Section 7 presents the conclusion.

2. Understanding low-carbon city initiatives

Low-carbon cities can be interpreted from different perspectives and analytical lenses, e.g. emphasis on controlling GHG emissions without compromising city' economic development and livability by World Bank (Baeumler et al., 2012) and World Wildlife Fund (WWF, 2008), emphasis on renewable energy substitution and decoupling economic growth from fossil energy by The Climate Group (Stephens, 2010), emphasis on setting a quantitative CO2 emissions reduction target and a concrete low-carbon developing plan by Asia-Pacific Economic Cooperation (Rufo et al., 2012). Cities worldwide may be at different economic development stages, varying in carbon endowments and local government capacity. Especially for rapidly developing cities, they are confronted with more challenges of balancing the economic development and carbon emission control.

The low-carbon city concepts have been discussed in China as well. Many Chinese scholars argue that low-carbon cities will be an inevitable developing choice and essential approach for cities in China to achieve urban sustainability in the future, with an increasing focus on decoupling economic development from GHG emissions (Chen and Zhu, 2009, 2013), or developing low-carbon industries (Gu et al., 2009; Liu and Wang, 2010; Yang and Li, 2013); while others highlight a societal transition approach beyond the economic sector, including low-carbon infrastructure, culture, lifestyle, consumption behavior and so on, aiming at achieving synergies between low-carbon transition and the quality of life transition (Dai, 2009; Liu et al., 2009; Yuan and Zhong, 2010).

The literature on low-carbon cities in China largely falls into the following three categories:

1) Quantitative modelling to identify emission sources, baselines as well as future emission scenarios at city and national level, aiming at identifying priority action areas and inform policy development (Chen et al., 2009; Li et al., 2010; Lin et al., 2013; Wang et al., 2011; Xu Guoquan, 2006; Zhang et al., 2011), or identifying co-benefit between different GHG emission reduction strategies and local environmental protection measures (Dolf and Chen, 2001; Lin et al., 2010; Yang et al., 2013). Findings from these research show that GHG emissions can be controlled if appropriate policies are in place, and integrated solutions may be needed.

2) Developing indicator systems for measuring "low-carbon city" (Price et al., 2013; Shao and Ju, 2010); and evaluating existing policies, programs, and instruments (Lo, 2014; Price et al., 2011; Wang and Chang, 2014). These studies indicate that an appropriate evaluation system should fit in China's economic and social context, also have identified challenges in implementation.

3) The growing body of literature on Emission Trading Scheme (ETS) in China and its pilot program shows that the implementation of ETS in China faces many problems (Zhang et al., 2014), such as a national emissions intensity target creates difficulties for making a cap, and ETS implementation interacting with regulation in the energy sector (Jotzo and Löschel, 2014). In practice, ETS programs in pilot cities and provinces differ from one another in many aspects, e.g., sectoral coverage, cap setting, allowance allocation (Jiang et al., 2014; Qi et al., 2014; Wu et al., 2014).

While providing valuable insights regarding low-carbon initiatives and their performance, there is a gap in above literature- a lack of systematic research on internal mechanisms of urban low-carbon transition, especially from the perspective of local governments' proactive role and its institutional setup.

In practice, a national policy scheme of pilot low-carbon cities/provinces was launched in 2010 in China. The central government aims to stimulate policy learning from this program to inform national-level policymaking. As a new policy in implementation only for a few years, there are a limited number of papers on it. These papers mainly discuss barriers in implementation, for example, the lack of clear definition or specific guidance and methods on how to make a low-carbon initiatives for pilot cities (Khanna et al., 2014); the lack of more ambitious mitigation targets set by local authorities than the allocated ones from the up-level (Khanna et al., 2014; Zhang, 2015); less involvements from the public and other stakeholders (Khanna et al., 2014; Zhang, 2015); the need for a managerial system for exchanging experience, evaluating performance, etc. (Wang et al., 2015). However, there is an absence of empirical evidence regarding how these pilot cities formulated low-carbon initiatives within their existing policy frameworks and institutional settings, and how these policies have been operationalized in practices across various urban areas.

3. Analytical approach and data

3.1 Theoretical perspective and analytical framework

The analytical framework of this study encompasses three elements: the system innovation and sustainability experiments concepts, the context and evolutionary process of relevant policies, and key implementation mechanisms.

Experimentation and Transition

Experiment is an important concept and analytical element in system innovation theory (Elzen et al., 2004). Experiments represent small initiatives in which the earliest stages of a process of socio-technical learning takes place. Experiments typically bring together new networks of actors with knowledge, capabilities, and resources, cooperating in the process of learning (Berkhout et al., 2010). In the early stage of innovation study, the experiment is always technical-central (Geels, 2005a, b; Twomey and Gaziulusoy, 2014), however, in fact, many experiments are in the field of policy and institutional reform and implementation processes (Bai et al., 2009).

The concept of experiment in system innovation theory emerges from the concept of niche, in multilevel perspectives (MLP) (Geels, 2005a). Niche is "protected spaces", which shields them from a mainstream market selection. Niches are important because they provide locations for learning processes (Geels, 2005a). Regimes are the meso-level concept, and usually, are characterized by a stable set of institutions that govern the behavior of actors; by contrast, in niches, rules are more fluid and emergent (Berkhout et al., 2010). The macro-level is landscape, which refers to aspects of the wider exogenous environment. It contains a set of heterogeneous, slow-changing factors, but it also contains shocks and surprises, such as wars, rapidly rising oil prices, which are beyond the direct influence of actors and cannot be changed at will (Elzen et al., 2004; Geels, 2005a). System innovations come about through the interplay and alignments between dynamics at multiple levels (Geels, 2005a): (1) niche innovations build up internal momentum, (2) exogenous developments create pressure on the regime and (3) tensions in the regime create windows of opportunity for the expansion of niche innovations (Geels, 2002; Geels et al., 2016; Smith et al., 2010).

The role of experiment in the system innovation theory shows that experimentation is an essential learning process. No matter what results the experiment ends with, it may offer feedbacks or accumulate experiences, which may contribute to positive change. Focusing in the urban context, Bai et al. (2010) note that individual innovative practices can be considered ‘‘experiments’’ when they harbor the potential to bring about regime change towards a sustainable end. Also, experimenting can be an essential process in transition management that has the potential to overcome the tension between the open-ended and uncertain process of sustainability transitions and the ambition for governing such a process (Frantzeskaki et al., 2012). Laakso et al. (2017) identify four key functions of experimentation, i.e. testing, creating profound influence, multiplying influence, and promoting systemic change. This categorization clarifies what can be expected from an experiment, thus may help actors to evaluate and adopt experimental approaches in practice.

Two layers of experiments are identified in this study. The national government can designate larger scale experiments at city level, with the aim to inform, test, and modify a particular policy before a broader introduction of it. Also, within city, a low-carbon policy experiment/project implemented can be seen as an experiment if the project contains highly novel components, designed to test out first with the plan to be introduced in other parts of the city if successful.

Low-carbon policy evolution process

The nature of curbing CO2 emission lies in reducing fossil energy consumption. By recognizing this, the city managers may re-think the global concerns of tackling climate change. That is, it may not be a remote concern, but can be associated with some existing policy schemes. The CCP[2] experience in US cities suggests that climate change is most likely to be reframed as a local issue when the preferred policy response (controlling GHG emissions) can be linked to issues (e.g., air quality) already on the local agenda (Betsill, 2001). Bai (2007) argued that linking up with local issues (e.g., environment protection, energy security) can be even more important for cities in developing countries, where more severe local issues often top the policy agenda. . Likewise, a similar conclusion has been found in research in post-industrial countries,

In China, even though urban low-carbon schemes have only emerged in recent years; existing studies show that policies for energy efficiency improvement, environmental protection have been in place for a long time (Andrews-Speed, 2012; Price et al., 2011). We assume that new emerging urban low-carbon initiatives may be rooted in existing policy framework, rather than a completely new thing. To verify this hypothesis, low-carbon policy evolution process is inspected, with the purpose of understanding the trajectory of policy development in the past and at present.

Enabling mechanisms for implementing urban low-carbon initiatives

Cities are complex systems, and many urban challenges require a systems approach to tackle (Bai et al., 2016). Climate protection is a complicated challenge and only can be achieved if there is inter-departmental cooperation (Allman et al., 2004). Institutional mechanisms can either facilitate policy execution, if the mechanisms and the specific requirements for policy implementation match one another, or set the scene for implementing a policy. Generally, the scope of institution needs to be defined for a specific context (Connor and Dovers, 2004). In this research, we refer institution to government structures and how government units cooperate.

In addition, efficient financing is a core requirement for empowered governance. Climate change creates new challenges for urban finance: it necessitates a greening of existing financial instruments and put additional pressure on city budgets, which creates the need for additional resources (Kamal-Chaoui and Robert, 2009). In practice, deficient financing tools and budget constraints at local levels of government appear to hamper the success with efforts to confront climate change challenges in cities in many places of the world (Collier, 1997; Kamal-Chaoui and Robert, 2009). In this research, we examine the existing financial supports for low-carbon policies implementation in Shanghai and how these funds operate.

Analytical framework

As shown in Fig.1, Shanghai case study will be examined from three analytical perspectives: 1) low-carbon experiments in two layers to understand how vertical linkage enables policy experiments; 2) low-carbon policy evolution process to examine how urban low-carbon initiatives rooted in the city existing policy framework; 3) enabling mechanisms to analyze how urban low-carbon initiatives are implemented. This framework is supposed to address the research questions raised in Section 1, and it is designed for a combined analysis of policy evolution from time sequence, and an enabling institutional structure based on vertical linkage and horizontal linkage.

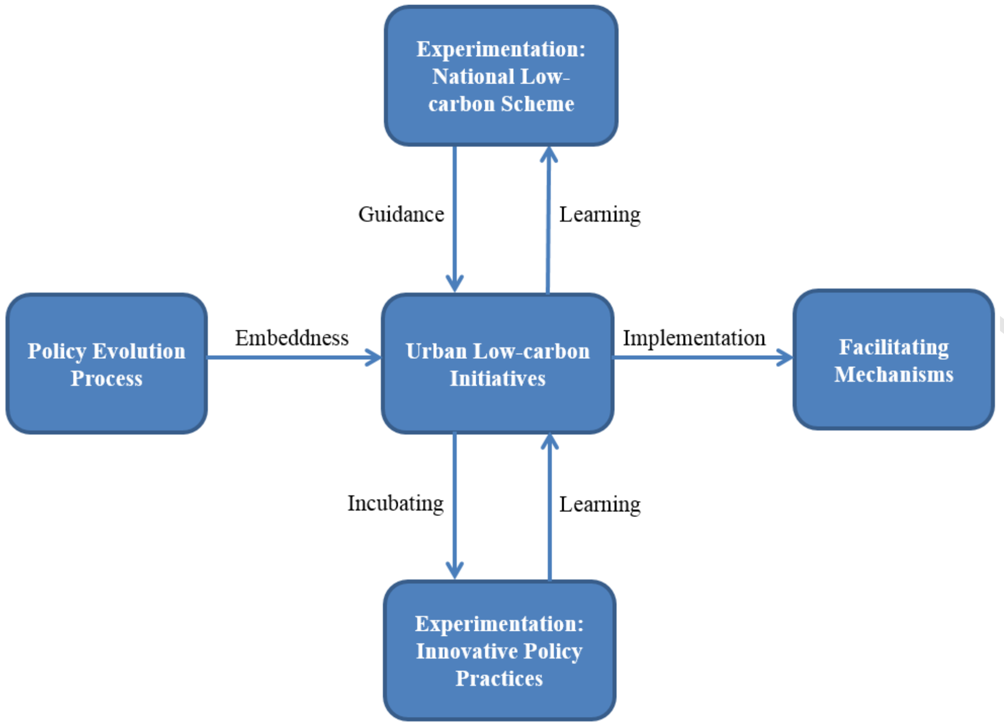


Fig. 1. Analytical framework integrating policy evolution process and linkages between different governmental units

3.2 Data collection and analysis

Data on a total of 186 policies are collected and analyzed. They are mainly collected from websites of Shanghai governments, public reports, and codes of policies, as well as internal government reports. These desktop sources are complemented by interviews with former and current government officials.

Some policies, e.g., environmental policies, energy policies, have co-benefits of controlling GHG, even though they are originally formulated to tackle environmental or energy issues (Dolf and Chen, 2001; He et al., 2010). Thus, the low-carbon policy scope we define in this paper includes energy saving, environmental protection, and low-carbon. The policies selected in this study are those issued after 1998 because the Chinese government began to make more substantial efforts into energy conservation and emissions reductions since 10^{th} five year plan period (i.e. after 2000). In order to identify specific policy measures and instruments, these policies are further divided into 13 subcategories. The number of the policy within each sub-category is calculated and put into the chronological order of introduction. The detailed criteria for policy selection and classification are clarified in supplementary materials.

In order to examine the effectiveness of policies, we examined several indicators including: annual energy consumption, energy intensity and energy consumption per capita, air quality indicators of SO_2, NO_2 and inhalable particulate, and annual CO_2 emission, CO_2 emission intensity and CO_2 emission per capita. The primary data are collected from Shanghai Statistical Yearbook. The CO2 emission in Shanghai is calculated based on city's energy consumptions from 1998 to 2015. The total emission includes the annual CO_2 emission calculated from local fossil energy combustion, as well as from imported electricity that is generated in other areas but consumed in Shanghai. The accounting method is stated in supplementary materials in details.

4. The evolution and drivers of low-carbon policies in Shanghai

4.1 Low-carbon policies evolution process

Selected policies are further sorted into 13 sub-categories (see supplementary materials) according to their purposes or policy measures, e.g., air pollution reduction, building energy saving, etc. The policy number of a sub-category and its emergence time can reflect local governmental efforts into areas of energy, environment, and low-carbon management (detailed explanation in supplementary materials). The numbers of policy measures introduced over time within these 13 sub-categories are shown in Fig.2.

Three insights can be drawn from Fig.2: 1) Most of the policy measures are continuous, which means once a policy measure has been adopted, it will be further supported by follow-up or relevant policies in following years until the initial target is achieved. 2) The policy focuses seem to vary in different years. This is because some policies are task-oriented. Once a policy program (with a specific task) is accomplished, the local government will move on to another task; then policy focuses change. 3) Both the number of policies and the number of sub-categories are growing over time, which shows an increasing and substantial endeavor undertook by Shanghai government.

A milestone during this evolution process is the introduction of city's low-carbon initiatives in 2012, i.e., *Shanghai 12th five-year plan for energy conservation and addressing climate change*. GHG management, environmental emissions control, and energy conservation are supposed to be synergistically addressed in this scheme. Before that, no explicit objective for GHG control was officially announced. Moreover, it is also the first time that Shanghai government incorporated climate protection target into city's five-year plan policy system, which is the most important policy scheme in China. In general, if clear targets and detailed policy measures are proposed in the five-year plan, local government will achieve the objectives in the following five years.

Base on above analysis, we conclude that Shanghai's low-carbon initiatives have been rooted to city's existing policy framework. *Shanghai 12th five-year plan for energy conservation and addressing climate change* covers a broad range of policy areas, including energy conservation and environmental protection, both of which had been introduced and implemented before city's low-carbon initiatives launching (shown in fig.2). In other words, although explicit low-carbon policies are new, relevant policies with low-carbon implications have been in place before it. Thus the whole evolution process can be divided into two distinctive stages: implicit stage (GHG control embedded in energy policies and environmental protection policies) and explicit stage (low-carbon initiatives and explicit low-carbon policies being introduced).

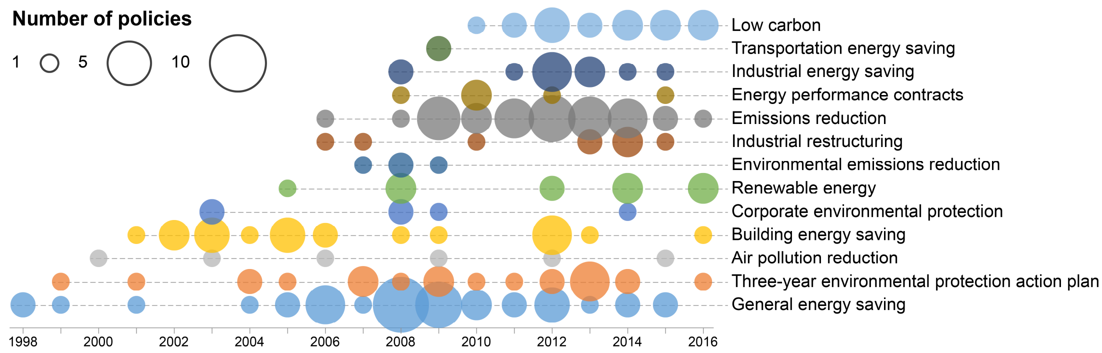


Fig.2. The evolution of low-carbon related policies

4.2 The drivers of low-carbon policies evolution

The economic development of Shanghai, especially the growth of GDP and the industrial restructuring, has a significant impact on local energy consumption and GHG emissions. Shanghai was a traditional heavy industrial city since New China establishment (Tu and Shi, 2006) with a high rate of fossil energy consumption in the industry sector. Then, after the reform and opening-up in China, city's industrial structure began to change, due to a new economic strategy to encourage service sector development. Although the proportion of service sector in Shanghai is increasing (accounting for 64.8% of Shanghai's GDP in 2014)[3], the secondary industry is still the largest consumer of end-use energy (55.2% in 2014)[3]. Also, total energy consumption of Shanghai is continuously growing because of rapid development and living standard improvement. To control the energy use, on the national scale, the central government regularly designated energy controlling targets to Shanghai according to national energy policy schemes. The growth of energy use and requirements from the central government are drivers for Shanghai government to enact a serial of energy policies as shown in Fig.2.

Addressing air pollution is another major driving factor. Heavy industries have caused serious environmental problems in Shanghai because of coal combustion. Meanwhile, air pollution from transportation became severe as well, due to a growing number of motor vehicles. A senior official from Shanghai government said that "The truth is, battling against air pollution has become the most primary task in Shanghai nowadays".

Thus, there were three main policy measures with low-carbon implication: 1) industrial restructuring driven by economic development; 2) energy saving target set by the central government; 3) local environmental pollution and resource constraints.

In 2009, the Chinese government committed controlling China's carbon emissions to the international world. To fulfill this promise, a national carbon-control target had been made, and translated down to local governments, which became a local performance indicator for evaluating local government officials' works. The external pressure from the international society on GHG mitigation had converted to internal pressures for local authorities, and marked the beginning of the explicit stage for urban low-carbon transition. During this stage, greater efforts were made by the Shanghai Government than before by enacting several explicit low-carbon policies, such as designating the pilot low-carbon areas at district level, introducing local standards of carbon labeling, and setting up a special fund for energy conservation and emissions reduction.

5. Innovative policy practices and enabling structures

5.1 Policy experimentation and innovative elements in policy practices in Shanghai

In Shanghai case, innovative elements can be observed in low-carbon policy experiments. This fact can be explained as a result of the relation between the central and the city governments. New national policy is often introduced without detailed guidance, thus leaving plenty of rooms for local governments to explore and experiment with innovative policy approaches. Below are several of such examples in relation to low carbon policy.

Going beyond top-down target

Shanghai government has set more ambitious targets than national targets, with actions going beyond what is required by the central government. Two examples illustrate this well. Although the central government requires local authorities to make a local GHG inventory every five years, Shanghai government updates their inventory every year in order to accurately monitor the city's GHG emissions. The government believes this is necessary because Shanghai is experiencing ongoing rapid economic development. Another is the example of carbon labeling. The central government has issued policies and standards on carbon labeling at the national level since 2010. To support these policies, Shanghai government developed and issued two local standards of carbon labelling since 2013, which are the first local policies of this kind in China.

Pilot programs at sub-city level

Shanghai government carries out pilot programs at the sub-city level based on, or in a similar way to, national programs to stimulate policy learning and gain local experience. A case in point is a pilot program for encouraging sub-city areas to transition to low-carbon districts. Shanghai is a megacity with various industries and businesses, e.g., a harbor area, a central business district, an export processing zone, etc. Diverse pathways are needed to assist these various areas and industries with low-carbon transition. In 2011, eight areas at the sub-city level were designated as pilots to explore innovative policy practices and administrative mechanisms, as well as to trial advanced technological applications.

Introducing regular planning cycle at local level

Local plans are regularly updated to achieve local policy targets, e.g., *three-year environmental protection action plan* is an innovative policy mechanism to address local environmental problems, which has been implemented in Shanghai since 2000. The target and countermeasures for controlling air pollution are included. By now, six rounds of plans have been enacted, which demonstrates that constant efforts are being undertaken for environmental protection.

Innovative institutional arrangements

Shanghai government introduced a new way of allocating duties to government units to supervise energy consumers in the city. Under this new arrangement, the municipal-level departments are responsible for large state-owned companies, while district-level governments are in charge of the others within their jurisdiction. This mechanism assures that supervisor can have real authority to manage corresponding energy users. This institutional arrangement was initiated in Shanghai as an innovative practice to achieve the energy conservation target.

5.2 Enabling mechanisms

Two major enabling mechanisms are identified in Shanghai case, i.e. an institutional mechanism that fosters inter-departmental coordination, and a financial mechanism consists of the special fund program.

The coordination mechanism

Shanghai Municipal Commission of Economic and Information (SHEIC) was the main authority for the city's energy control because SHEIC is in charge of the secondary industry that is the largest energy consumer. With rapid urban and economic development, the energy consumption in transportation and building sectors have grown substantially, which is out of SHEIC's administrative scope. This resulted in a scattered energy consumption management function across several departments. In addition, tackling issues like air pollution requires cooperation between energy management sectors and the environmental protection bureau (SHEPB). A coordination mechanism across government sectors was called for.

In 2008, a leadership team for energy conservation and emissions reduction was set up, members of which are key city leaders and department heads. The executive office was established in Shanghai Municipal Development & Reform Commission (SHDRC). In 2009, *Shanghai energy saving regulation* was revised. In the newly revised regulation, SHDRC was appointed to coordinate city's overall energy management. "SHDRC is responsible for overall coordination, supervision, and administration of Shanghai's energy conservation. More specifically, SHDRC is supposed to draw up the city's integrated energy saving plans and policy measures, and is responsible for coordinating policies implementation". This newly revised regulation officially confirms SHDRC's coordination duty across different government sectors, thus ensure a more effective policy implementation.

The financial mechanism

In order to finance the variety of innovative practices outlined above, Shanghai government established a special fund for energy conservation and emissions reduction. The guiding policy includes the funding sources, supporting scope, responsible departments, assessment procedure, etc. Policy areas listed in city's low-carbon initiatives are included in fund supporting scope.

The leadership team and Shanghai Finance Bureau (SHFB) are jointly responsible for the fund's management. In practice, it is the execution office set up in SHDRC who coordinates the fund's operation. Therefore, SHDRC is not only a sector coordinator but also a fund manager; the special role of SHDRC connects the coordination mechanism and the financial mechanism working together.

The fund allocation is task/project-oriented, and requires a well-planned specific project before the application. A detailed implementation policy also needs to be formulated. Table 1 presents some examples of the projects supported by the special fund. The implementation policy can be jointly or separately issued by government sectors, including subsidy range, selection criteria, subsidy standards, etc.

This financial mechanism has three features: 1) it financially supports policy implementation of city's low-carbon initiatives; 2) SHDRC has overarching authority of making the overall plan, coordinating government sectors, and managing the special fund, which ensures the financial resource to support city's key projects and the low-carbon strategy; and 3) all implementation details have been elaborated before a policy project is approved, which could guarantee the execution efficiency in practice.

Table1. Examples of policy projects supported by the special fund

Time	Policy project	Policy number	Project partners
2008	Special subsidies to promote distributed energy supply systems and gas air-conditioners	[2008] No. 48	SHDRC, SHCTC, SHEIC, SHSTC, SHFB
2008	Special subsidies to develop renewable energy	[2008] No. 96	SHDRC, SHFB
2009	Subsidies as incentive to eliminate and renew old or used vehicles	[2009] No. 17	SHCC, SHDRC, SHEPB, SHPSB, SHFB
2009	Special subsidies for projects of building energy conservation	[2009] No. 816	SHCTC, SHDRC, SHFB
2009	Special subsidies for energy saving and emission reduction in transportation	[2009] No. 1640	SHCTC, SHDRC, SHFB
2011	Special subsidies for ground works and capacity building regarding energy saving and climate change	[2011] No.073	SHDRC
2012	Special subsidies for clean energy substitution of coal/mahout consumption	[2012] No.36	SHDRC, SHEIC, SHEPB, SHFB

	boiler		SHCTC, SHQTSB
2014	Encouraging purchase and use of new energy vehicles[2]	[2014] No.21	SHDRC, SHEIC, SHSTC, SHCTC, SHPSB

Note: 1. Abbreviations for Shanghai government sectors

Shanghai Municipal Urban Construction and transportation Commission (SHCTC)

Shanghai Municipal Commission of Science and Technology (SHSTC)

Shanghai Environmental protection Bureau (SHEPB)

Shanghai Public Security Bureau (SHPSB)

Shanghai Municipal Commission of Commerce (SHCC)

Shanghai Municipal Bureau of Quality and Technical Supervision (SHQTSB)

2. “New energy vehicles” refers to electric vehicles, hybrid vehicles and fuel cell vehicles in the policy.

5.3 Nested structure of innovative policy practices

The vertical linkages between the central and the city governments encourage low-carbon policy experiments. Shanghai is designated to be a low-carbon pilot city by the central government, with the aim of gaining hands-on experience to inform future policy-making nationwide. The central government plays a role as a target setter and performance evaluator; while the Shanghai government plays a role as a local entity who has much leeway to innovative trial approaches to achieve upper-set targets. The extent to which local governments respond to the central government depends on their motivations, capacity, and constraints (Qi et al., 2008).

As discussed above, the Shanghai government established two enabling mechanisms for implementing city’s low-carbon initiatives. The coordination mechanism joins policy fragments from various government sectors in charge of economy, energy, and environment. Financial mechanism ensures resources are available to sponsor low-carbon policy projects. With these two enabling mechanisms, various policy experiments are emerging, to the benefit of policy learning.

Through in-depth analysis of Shanghai case, we identify an emergence of a nested structure, which encourages innovative policy practices for urban low-carbon transition (Fig.3). The structure encompasses two layers of experiments, one instigated by the national government through the low carbon pilot cities and provinces program where each city or province is an experiment, and the other instigated by individual cities where various experiments on policy measures, financial mechanism, and institutional design are conducted within the city. This is similar to the multilevel perspectives presented in system innovation literature (see for example Geels, 2002), but with a different role of the upper level government where it is actively involved in designing and enabling the experiments with a clear goal to achieve policy learning.

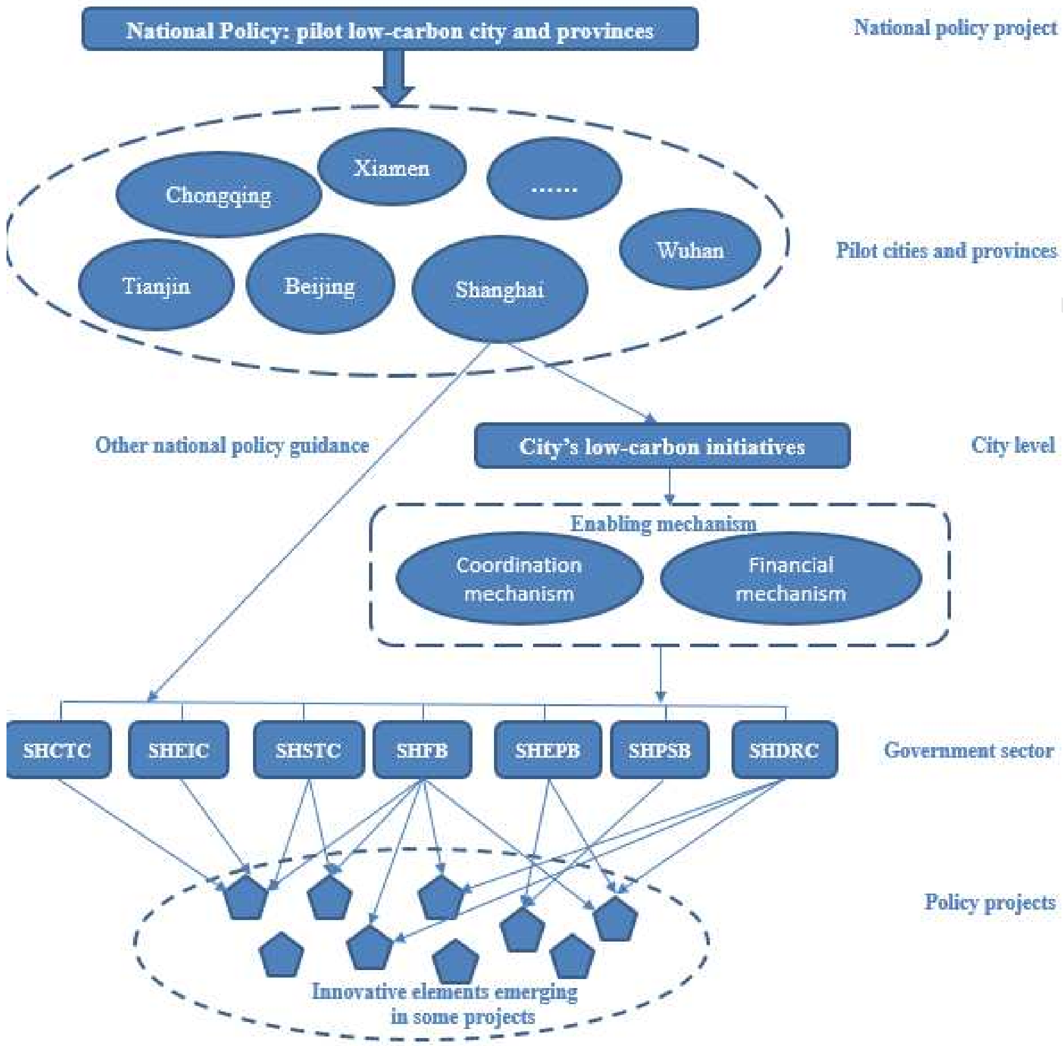


Fig.3. Nested structure of innovative policy practices

6. Discussion

6.1 A Shanghai Model

There are several characteristics of Shanghai's low carbon approach, as summarized below. City's low-carbon initiatives are embedded and integrated into existing policy framework, instead of a completely new strategy. Low-carbon policies evolution process in Shanghai can be divided into two stages: implicit stage and explicit stage. Before 2009, which is implicit stage, Shanghai has been on its way of adjusting industrial structure, improving energy efficiency and controlling air pollution, etc., the co-benefits of which contribute to GHG control. In explicit stage, Shanghai low-carbon initiatives were introduced, which is an integrated policy strategy tackling multiple challenges. The low-carbon initiatives are rooted in the city's existing policy framework. The strategy of hooking "low-carbon" onto other local policies schemes is common and not necessarily initiated in Shanghai. But, Shanghai's low-carbon initiatives are more than re-interpreting traditional policy schemes with low-carbon implication, with new low-carbon policy measures such as local pilot low-carbon developing districts, carbon labeling also emerged and been practiced.

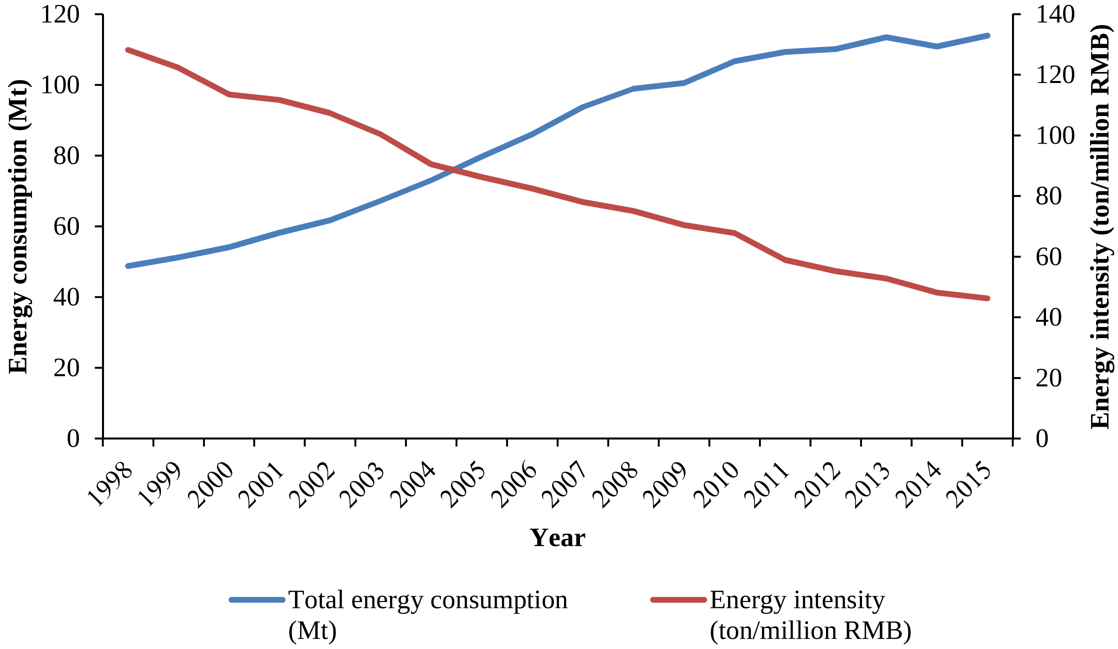
The strong vertical linkage between central government and local government provides favorable institutional setting for low-carbon policy experiments. In China, municipal authorities are required to achieve targets set by the central government, although the actual efforts may vary greatly depending on their level of motivation and capacity. Such an institutional setting leaves much room for local governments to conduct policy experiments aiming at policy learning while fulfilling the task. Shanghai is designated as a Pilot Low-carbon City, which opened opportunities for various policy experiments to incubate innovations. With the city's efforts, a number of creative policy practices emerged in Shanghai, e.g., introducing regular planning cycle at a local level, and going beyond the top-down target. In this sense, the vertical cooperation of governments across levels presented in Shanghai case is facilitated by the institutional setting in China.

Coordination mechanism and financial mechanism enable low-carbon initiatives implementation, and also are innovative practices initiated by the local government. SHDRC is responsible for both coordinating sectors and managing fund. Its role avoids overlapping or shifting duties between government departments, and also ensures the financial supports in synergy with policy implementation. This institutional setting and funding mechanism are instrumental in local low-carbon actions.

A nested structure for innovative policy practices can be identified through Shanghai case study. This nested structure consists of the institutional arrangement between different levels of government (vertical linkages), coordination across government sectors (horizontal linkage) and a financial mechanism. It presents a favorable setting for low-carbon policy experiments aiming at policy learning, developed under a clear leadership role of central government and giving more governing leeway for local authorities. Importantly, this policy framework reveals the importance of local capability in urban low-carbon transition in terms of institutional arrangements and financial resources.

6.2 The effectiveness of Shanghai Model

Demonstrating the effectiveness of Shanghai's various initiatives quantitatively is challenging, because the low carbon policies has been in place relatively short time ago and some of the effects need more time to appear, and more importantly, the city is under a rapid development. Nevertheless, here we examine the energy consumption, and CO2 emission in Shanghai over a period from 1998 to 2015 as shown in Fig.4, Fig.5, and Fig.6, to see whether the effectiveness is manifested by these trends.



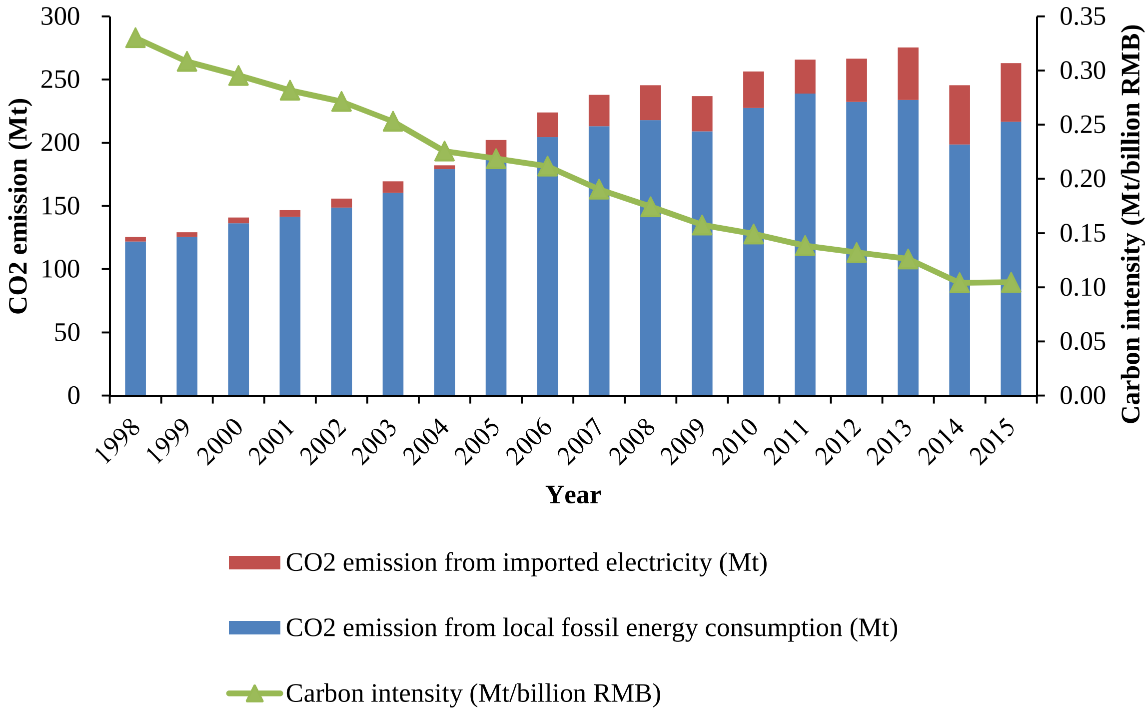
Data source: Shanghai statistical yearbook

Fig.4. The trends of total energy consumption and energy intensity in Shanghai from 1998 to 2015

The total energy consumption (Fig. 4) kept increasing due to the fact that Shanghai has experienced a rapid economic growth. This increasing trend slowed down during 2010-2015, which overlaps with the period where more explicit low-carbon and other policies were implemented (see Fig.2. on the policy evolution process). The energy intensity kept decreasing, showing a decoupling of economic growth from energy consumption. The energy consumption per capita grew from 1998 to 2008, and, after 2008, fluctuates within a narrow range (Fig.6). These trends may present positive outcomes of the various policies discussed above. Several issues remain, e.g. the fossil energy use still accounts for a large part of total energy consumption, while the proportion of local non-fossil fuels in primary energy consumption is low (0.7% in 2015) (according to *Shanghai 13th five-year plan for energy development*). This fact may imply a structure challenge of primary energy use in Shanghai.

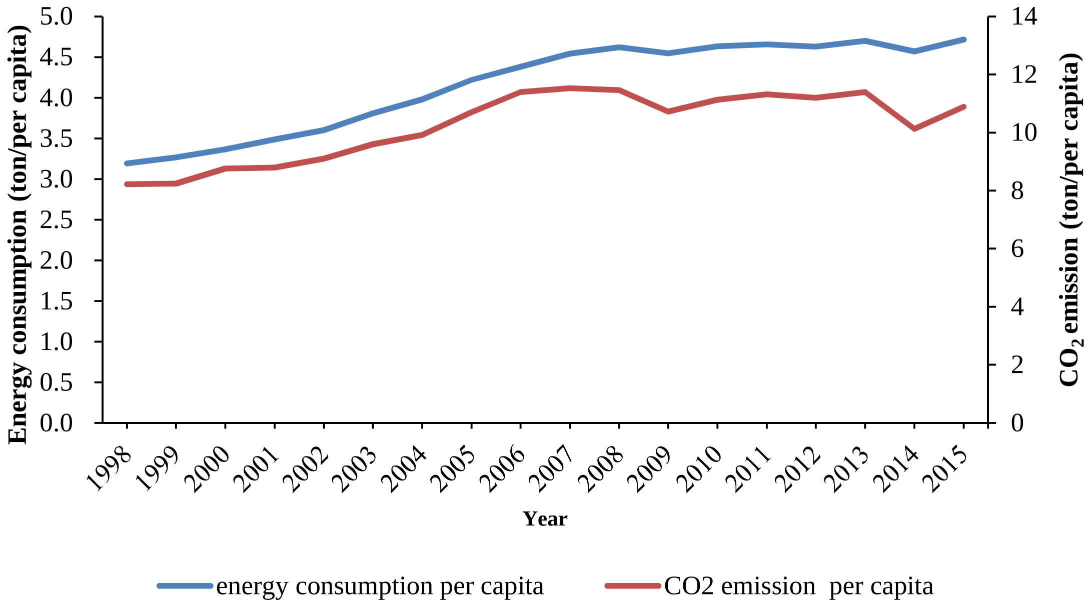
We estimate annual CO_2 emission of Shanghai based on fossil energy consumption and imported electricity from State Grid (which means this part of CO2 emitted outside of the city). Fig. 5 shows the trends of CO2 emission and carbon intensity, and Fig. 6 shows the trends of CO2 emission per capita from 1998 to 2015 in Shanghai. It can be seen that the total emission is growing over time, but since 2010, the growth seems to slow down and fluctuates. The peak emission appears in 2013. According to *Shanghai 13th five-year plan for energy conservation and addressing climate change*, the annual CO_2 emission is targeted to be less than 250 Mt by 2020, which is less than in 2013. The carbon intensity has been following a decreasing trend, showing a reduction of 67.9% in 2015 compared to 1998. The trend of per capita CO_2 emission increases until 2006, followed by a period of fluctuation; and then it starts to decrease after 2013 (Fig.7). The share of CO_2 emission from imported electricity is growing. This tendency is more prominent during 12th five-year plan period, accompanied by a decreasing trend in the share of the direct emission from fossil fuel use within Shanghai administrative boundary.

While it is not possible to accurately attribute these trends to specific policies, it is reasonable to assume that these are positive outcomes of the various efforts made by Shanghai city in reducing energy consumption and CO_2 emission. In particular, a possible inflection point implies that the policy framework and nested structure of low-carbon governance identified in this study may enable a sustainability transition in Shanghai. However, this transition has only just begun. The increasing share of the CO_2 from transboundary electricity suggests the need to pay closer attention to the externality in achieving Shanghai's low-carbon target.



Data source: calculated by the authors

Fig.5. The trends of CO_2 emission and carbon intensity from 1998 to 2015 in Shanghai



Data source: calculated by the authors

Fig.6. The trends of energy consumption and CO_2 emission per capita from 1998 to 2015 in Shanghai

6.3 The applicability and limitation of Shanghai Model

The strong vertical linkages and the nested structure identified in Shanghai case study may be enabled by the institutional environment in China where a central government always plays a powerful role. Thus, the application of Shanghai Mode might be confronted by the fact that institutional settings could be different in other municipality contexts worldwide. However, we argue that the governance model demonstrated by Shanghai case may not be limited to China's context due to the nature of climate governance. Previous research on multi-level governance found that the relations between local, regional, and national state authorities have been critical in local response and competence to climate actions (Bai et al., 2009; Bulkeley, 2010; Corfee-Morlot et al., 2009; Deangelo and Harvey, 1998).A study in several OECD countries argues that local action and experience can inform national policy; national governments can work hand-in-hand with local governments to require and encourage the development of locally tailored policy and voluntary action (Corfee-Morlot et al., 2009). However, in reality, the role of municipalities in key sectors related to GHG emissions is usually defined by central or regional governments and is delegated to local authorities, so local governments may have limited powers and resources to achieve a transition (Bulkeley, 2010; Corfee-Morlot et al., 2009; Jones, 2012). Moreover, active supports from upper-level government vary from case to case: some supports are based on specific programs (Corfee-Morlot et al., 2009), or there is an absence of national leadership on the issue of climate change (Gore et al., 2009). In this sense, we could understand that the nature of cities' climate strategies and actions requires integrated efforts that involve multiple levels, and there is no reason why a stronger and more enabling vertical linkages, or a similar nested structure of innovation cannot be formed in other institutional settings.

The Shanghai case demonstrates a rather successful approach of the multi-level governance, which may be needed as a possible sustainable solution to drive a profound societal transformation towards a sustainable and low-carbon future (McCormick et al., 2016). From theoretical perspective, Shanghai case provides important addition to multilevel governance, where the current regime is actively involved in and enabling the niche experiments with the purpose to extract learning. In practice, the Shanghai case demonstrates the combination of an active and enabling role of the national government with the capacity and vision of the local governments is essential for low carbon initiatives to be successful.

There are several important limitations and remaining tasks in Shanghai's low carbon initiatives. Even though the nested structure is well designed and engenders positive results at implementation stage as quantitatively proved in Section 6.2, the full impacts and effectiveness are still to be seen as the transition has just started and the total CO_2 emission is still large. Moreover, while the focuses of this paper are policy experiments, policy innovations, competence of municipality, and relations between government units/levels, there is a broader structural context such as the high dependency on fossil fuel and relatively low renewable energy share. Improving energy efficiency is important but with limitations. Furthermore, the growth of imported electricity may signify a growing externality during Shanghai's low carbon transition. Last but not the least, these policies are mainly targeted at big firms. As a government officer admitted during an interview, the financial and policy supports, and monitoring for small firms are inefficient. Future study may need to include the roles of non-government stakeholders, as well as the pathways of upscaling the successful experiments.

7. Conclusion

This research investigates the internal mechanisms of urban low-carbon transition in rapidly developing economies, taking Shanghai as a case study city, with a particular focus on low-carbon policies evolution process and enabling mechanisms for policy experiments. The findings show that Shanghai's low-carbon initiatives are rooted in its existing policy framework, which is complemented by new policy instruments with explicit target at carbon emissions reduction Shanghai's low-carbon initiatives demonstrate a strong vertical linkage between central and local governments. We identified a nested structure for innovative policy practices, which is a combination of top-down design and bottom-up, proactive adoption of enabling mechanism, and multiple layers of experiments. Such a structure provides a favorable institutional setting for capturing learning from policy practices and experiments at different levels. The effectiveness of low-carbon initiatives in Shanghai is demonstrated by energy consumption and carbon emissions trends. The Shanghai case may offer new insights to study the multi-level governance of low-carbon cities, where the current regime is actively involved in and enabling the niche experiments with the purpose to extract learning. In practice, Shanghai case may demonstrates the importance of combining an active and enabling role of the national government with the capacity and vision of the local governments for a successful low carbon transition in cities.

Footnotes:

1. David, A., 1996. Structure et dynamique des innovations managériales, Cinquième conférence de l'AIMS, Lille. (In French).
2. CCP: Cities for Climate Protection (CCP) campaign sponsored by the International Council for Local Environmental Initiatives.
3. Data from the Shanghai Statistics Bureau.

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Highlights:

Shanghai’s low carbon initiatives integrate existing frameworks with new policies.

New institutional set-up and financial mechanism are essential for experimentation.

A nested structure of policy innovation may facilitate transfer of learnings.

Effectiveness of such initiatives is demonstrated by CO_2 emissions and other trends.