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Policies and Practices of Low Carbon City Development in China

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Summary

Globally as well as in China, cities have contributed to most of the economic output and have accordingly given rise to most CO_2 emissions. In particular, given unprecedented urbanization, cities will play an even greater role in shaping energy demand and CO_2 emissions. Therefore, cities are the key to meeting its proposed carbon intensity target in 2020 and whatever climate commitments beyond 2020 that China may take. Given the paramount importance of cities, China is practicing low carbon city (LCC) development. Against this background, this paper first summarizes the general situation and main characteristics of China's LCC development. The paper then identifies eight problems and challenges for China's LCC development including the absence of sound carbon accounting systems, lack of low-carbon specific evaluation system, rare use of market-based instruments, insufficient government-enterprise interactions, excessive budget dependence on land concession, increasing difficulty in further carbon mitigation, inevitable emissions growth due to rising living standards, and coal-dominant energy structure in the foreseeable future. Since these challenges are not applied to one or few cities, but are to all cities across the country, finally, the paper discusses how governments, in particular the central government, should address these problems and challenges. Given that China has faced great difficulty ensuring that local governments act in accordance with centrally-directed policies, the paper in particular discusses ways to incentivize local governments not to focus on economic growth alone and to move away from a heavy reliance on land concession. The paper ends with emphasizing on putting a price on carbon a crucial step for China's endeavor of harnessing the market forces to reduce its energy consumption and carbon emissions and genuinely transiting into a low-carbon economy.

Keywords: Policies, Practices, Low carbon city, Market-based instruments, Energy, Governments, China
JEL Classification: Q42, Q43, Q48, Q54, Q55, Q56, Q58, O13, O53, R52, R58

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Policies and Practices of Low Carbon City Development in China

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ABSTRACT

Globally as well as in China, cities have contributed to most of economic output and have accordingly given rise to most of CO_2 emissions. In particular, given unprecedented urbanization, cities will play an even greater role in shaping energy demand and CO_2 emissions. Therefore, cities are the key to meeting its proposed carbon intensity target in 2020 and whatever climate commitments beyond 2020 that China may take. Given the paramount importance of cities, China is practicing low carbon city (LCC) development. Against this background, this paper first summarizes the general situation and main characteristics of China's LCC development. The paper then indentifies eight problems and challenges for China's LCC development including the absence of sound carbon accounting systems, lack of low-carbon specific evaluation system, rare use of market-based instruments, insufficient government-enterprise interactions, excessive budget dependence on land concession, increasing difficulty in further carbon mitigation, inevitable emissions growth due to rising living standards, and coal-dominant energy structure in the foreseeable future. Since these challenges are not applied to one or few cities, but are to all cities across the country, finally, the paper discusses how governments, in particular the central government, should address these problems and challenges. Given that China has faced great difficulty ensuring that local governments act in accordance with centrally-directed policies, the paper in particular discusses ways to incentivize local governments not to focus on economic growth alone and to move away from a heavy reliance on land concession. The paper ends with emphasizing on putting a price on carbon a crucial step for China's endeavor of harnessing the market forces to reduce its energy consumption and carbon emissions and genuinely transiting into a low-carbon economy.

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1. INTRODUCTION

Low carbon development is one of the key models proposed and being practiced globally for combating climate change. Many cities including mega-cities like London, New York and Tokyo have taken actions and played leading roles in low-carbon city (LCC) development even without national policies or commitments(Liu et al., 2012). Cities are the key to meeting carbon reduction targets (Word Bank, 2011). First, cities are the main contributors of greenhouse gas (GHG) emissions. According to the International Energy Agency (IEA, 2008a), cities emitted 19.8 gigatonnes of CO_2e (GtCO_2e) from energy use, or 71% of global energy-related GHG emissions in 2006. By 2030, this number is expected to climb to 30.8 GtCO_2e, or 76% of global energy-related GHG emission. Moreover, 80% of this 11Gt CO_2e cumulative increase will come from cities in non-OECD countries, mainly from rapidly urbanizing countries such as China and India. Second, cities are uniquely important partners to address climate change because they are homes not only to large concentrations of people but also to an agglomeration of productivity (OECD, 2010). Last, local governments often have the authority to take prompt action that would influence GHG emissions (Word Bank, 2011; Tang, 2009; Lei et al., 2011).

In China, cities contribute to more than 75% of the national economy in 2009, and this number is expected to increase to 95% by 2025 (Dhakal, 2009). They are also responsible for more than 60% of national energy consumption (Chinese Academy of Sciences, 2009). In the future, Chinese cities will play a greater role in determining China's energy demand and CO_2 emissions given the fact that China is experiencing unprecedented urbanization. In 2011, China's urban population exceeded that of rural areas, and its urbanization rate is forecast to increase from the current 51% to 79% by 2050 (ERI, 2009; Zhou et al., 2011a). During this process Chinese cities will absorb about 400 million rural residents. As Dhakal (2009) shows, the ratio of urban to rural per capita commercial energy uses in Chinese cities is 6.8, and the ratio between urban to national average is 1.9.Those huge numbers of new migrants will demand greater energy use and emit more energy-related GHG than their rural settlements mainly due to income rise and lifestyle change. In this context, some positive steps have been taken to curb GHG emissions: many cities in China are developing LCC initiatives that are expected to be strengthened due to a mandatory target included in the "Twelfth Five-Year Plan (FYP) to reduce the carbon intensity by 17% by 2015, relative to the 2010 level." The imperative to transit to low-carbon pathway has been integrated into agendas for Chinese government officials.

These promising LCC activities inspire more and more scholars to carry out studies on LCC or the low-carbon society in China (Liu and Deng, 2011; Glaeser and Kahn, 2010; Cai et al., 2012). Most of these emerging studies, however, are broadly confined to theoretical and conceptual discussions and lack short-distance observations of the policies and practices of LCC in China (Li et al., 2010; Dai, 2009). In a practical way, Liu and Wang (2010) conclude that there are four kinds of development patterns in the practice of LCC in China. The World Bank (2012) provides LCC guidelines for actions that Chinese cities could take as well as many practical cases on low-carbon development inside and outside of China. A similar analytical framework can be found from Zhou et al. (2011b), Lei et al. (2011) and the Chinese Society for Urban Studies (2009). However, research that provides conclusions on the policies and practices of LCC development in China and identifies its existing problems through a well-grounded approach is scarce. Therefore, more research that seeks to fill this gap may help shift China's cities onto a low-carbon pathway.

The remainder of this paper is structured as follows. Section two describes the general situation of LCC development in China. Section three discusses its main characteristics, including geographical distribution, stage features, and China's own particularities. Section four analyses problems and challenges in the development of LCC, and Section five proposes countermeasures from the perspective of the government, in particular the central government.

2. GENERAL SITUATION OF CHINA'S LCC DEVELOPMENT

The usual routine to develop LCC in China begins with a top-level planning which includes targets for low-carbon development. Those quantitative targets help cities define, compare, and track progress toward low-carbon future. So far, nearly one hundred cities in China have established targets for LCC, with some listed in Table 1. Different from the absolute emission goals of most cities in developed countries, most cities in China (with the exception of Hong Kong) adopt intensity-based targets for LCC to allow for additional emissions growth due to expected urbanization and industrialization. Also, short-term (2015) and medium-term (2020) goals are common, while long-term (post 2020) goals are rare. This is consistent with the Chinese central government's commitment to voluntarily reduce carbon emissions per unit of its GDP (i.e., carbon intensity) by 40% to 45% by 2020 compared to 2005 level[1].

Table1 Targets for LCC set by several cities in China

City, Province	Planning Documents	Date of publication	Targets (aggregated and sectoral indicators)
Baoding, Hebei	Baoding government notice on LCC construction[a]	December 2008	By 2020, CO_2e per unit of GDP should be 35% lower than that of2010; CO_2e per capita should be controlled within 5.5 tonnes; value-added from new energy industry should account for 25% of industrial value-added
Chengdu, Sichuan	Chengdu work plan of LCC construction[b]	January 2010	By 2015, CO_2e per unit of GDP should decline to 1.15 tonnes; non-fossil energy consumption should be more than 30% of the total; forest coverage rate should increase to 38% or more
Wuxi, Jiangsu	Wuxi planning of low carbon economic development[c]	March 2010	By 2015, CO_2e per unit of GDP of industry should be 45% lower than that of 2005; renewable energy consumption rate should be 20%; share of urban public transportation should increase from 22% to 32%; energy consumption of buildings should be reduced by 45% relative to 2005 level
Xiamen, Fujian	Master planning for Xiamen as a low-carbon	March 2010	By 2020, CO_2e per unit of GDP should be 60% lower than that of 2005; total CO_2 emission should be controlled within 68.64 million tonnes; CO_2 emissions from transportation, residential buildings, public buildings, industry

[1] See Zhang (2011a,b) for detailed discussion on stringency and credibility issues related to China's carbon intensity commitment and their Implications.

	city[d]		should be curbed within 12.36, 6.53, 12.69 and 30.2 million tonnes, respectively
Tianjin	Tianjin planning to combat climate change[e]	March 2010	By 2015, CO_2e per unit of GDP should be 0.169 ton/1000CNY, or 15.5% lower than that of 2010; forest coverage rate should be more than 23%
Guiyang, Guizhou	Guiyang action plan of low carbon development[f]	July 2010	By 2020, energy consumption per unit of GDP should be 40% lower than that of 2005; CO_2e per unit of GDP should decrease from 3.77 in 2005 to 2.07-2.24 ton/1000CNY
HongKong	Public consultation on Hong Kong's climate change strategy and action[g]	September 2010	By 2020, GHG emission should decline from 42 million tonnes in 2005 to 28-34 million tonnes; CO_2e per capita will decrease from 6.2 tonnes in 2005 to 3.6-4.5 tonnes.
Nanchang, Jiangxi	Nanchang work plan for national LCC pilot program[h]	October 2010	By 2020, CO_2e per unit of GDP should be 45%-48% lower than that of 2005;non-fossil energy consumption rate should be 7%;the forest cover rate should be up to 28%
Beijing	Beijing 12[th] five-year plan for saving energy and addressing climate change[i]	August 2011	By 2015, CO_2e per unit of GDP should be 18% lower than that of 2010; CO_2 emissions in the industry sector should be kept at the level of 2010; the share of high-quality energy in total primary energy consumption reaches to 80% or above, with natural gas and new and renewable energy accounting for at least 20% and 6%, respectively; forest coverage rate in the built area increases to 40%.
Shanghai	Shanghai 12[th] five-year plan for saving energy and addressing climate change[j]	March 2012	By 2015, CO_2e per unit of GDP should be 35% lower than 2005; CO_2e per unit of value added in the industry sector should be 22% lower than that of 2010; the share of non-fossil energy in total primary energy consumption reaches to 12%; forest coverage rate in the built area increases to 38.5%

[a]http://news.bdall.com/epaper/bdrb/page/1/2008-12-24/01/46931230098875390.pdf, accessed 1June 2013.

[b]http://www.chengdu.gov.cn/wenjian/detail.jsp?id=rqCjb9nR4OFMn1EJZiIF, accessed 1June 2013.

[c] http://www.ssfcn.com/detailed_gh.asp?id=23408&sid=1573, accessed 1 June 2013.

[d] http://wenku.baidu.com/view/872f490c76c66137ee0619da.html, accessed 1 June 2013.

[e] http://www.tjzb.gov.cn/system/2010/05/05/000243884.shtml, accessed 1 June 2013.

[f] http://wenku.baidu.com/view/5f59031fa300a6c30c229f31.html, accessed 1 June 2013.

[g] http://www.epd.gov.hk/epd/tc_chi/climate_change/consult.html, accessed 1 June 2013.

[h] http://www.fsou.com/html/text/lar/173250/17325052.html, accessed 1 June 2013.

[i] http://www.bjpc.gov.cn/fzgh_1/guihua/12_5/12_5_zx/, accessed 23 August 2013.

[j] http://www.shdrc.gov.cn/main?main_colid=327&top_id=312&now_id=345&main_artid=22207, accessed 05 June 2013.

In addition to setting targets for LCC, these cities employ appropriate policy instruments to realize the LCC blueprints. Table 2 summarizes the common policies implemented by the aforementioned cities, principally targeting the energy, industry, transportation, commercial and residential sectors.

Table 2 Common policy objectives and contents for LCC in China

Policy Objectives	**Policy Contents**
Adjustment of industrial structure	Gradually shut down or upgrade highly-polluting but low-efficient enterprises in energy-intensive industries; Undertake an assessment of fixed asset investment projects for energy use and environmental impact; Promote high-tech, high value-added industries; develop an equipment manufacturing industry that supports low-carbon development; Increase the investment in infrastructure construction in tertiary industries to improve the service quality.
Upgrading of industrial technologies	Carry out an energy audit for key energy-consuming enterprises; impose responsibilities of saving energy on enterprises; supervise and evaluate energy conservation; Encourage clean production; implement mandatory clean production audits for large polluters; Establish entry requirements for projects in industries, i.e. new projects are required to reach the international or domestic advanced level of energy efficiency; Promote energy-saving technologies such as clean and efficient usage of coal, renewable energy, carbon capture and storage, etc.
Improvement of energy mix	Upgrade power plants with burning gas instead of coal; deploy new energy such as solar energy, wind, biomass, and shallow geothermal energy; Extend the use of solar energy in the production and use of fields; encourage powerful enterprises to construct small-scale PV power stations; Launch pilot programs of straw solidification and gasification development, as well as straw power generation projects.
Encouragement on public transportation	Combine public transportation planning with urban planning, such as retaining and widening sidewalks, opening up bus lanes, developing urban rails, bus rapid transit (BRT), regular buses, etc; Increase investment in public transportation, adopt economic instruments such as prices, fees, taxes aimed at encouraging residents to use public transportation; Build transition between non-motorized systems and public rail systems to facilitate the use of public transportation for residents.

Enhancement of building energy efficiency	Establish building energy-saving standards; set up an energy consumption statistical system and energy audit system; Integrate low-carbon concepts into building design and construction; give priority to green, energy-saving building materials and technologies, especially the BIPV (Building Integrated Photovoltaic) system; Carry out energy-saving retrofit on existing buildings, starting with government buildings.
Optimization of urban form	Develop a dense and compact spatial strategy by utilizing land conservatively and intensively; Classify land resources into 3 categories: prohibited exploitation zones, restricted exploitation zones, and optimized exploitation zones; Make full use of the underground space.

The six policy objectives and their contents can generally depict the overall situation of LCC in China. It is worthwhile noticing that those low-carbon means are not mutually independent, but rather synergic (De Macedo et al., 2006). The literature (OECD, 2010) discusses the synergy existing in low-carbon measures at the city level. Taking the relationship between urban form and transportation as an example, land-use zoning policies that allow for higher densities and greater mixing of residential and commercial use, helps reduce transportation distances and frequency, and therefore the energy required for urban travel. In turn, transportation infrastructure polices shape the demand for land (Wang et al., 2007). Complimentary policies between sectors is so crucial that most Chinese cities scarcely make one-sided low-carbon efforts, but take complementary and multifarious measures to build a comprehensive low-carbon society. Although LCC in China is still at its initial stage, with much planning but few solid results, potential synergy can be expected if those policy packages proposed in the planning are well carried out.

3. MAIN CHARACTERISTICS OF CHINA'S LCC DEVELOPMENT

3.1 Geographical distribution

The LCC under planning in China have formed into four regional clusters, namely the Circum-Bohai-Sea region, Pearl River Delta, Yangtze River Delta and the southwestern region (Fig. 1). The former three clusters are located in the developed eastern coastal regions, most of which are in the middle, later, or even post stages (like Beijing, Shanghai) of industrialization. With abundant sources of technology, capital, and manpower, these three regions have solid foundations and strong motivations to promote a low carbon transition of city development. The southwestern region is still in a relatively backward stage in terms of the economic development; thus it shows great willingness to house the shifted industries from the eastern China (Wei and Bi, 2011). Developing LCC will promote new technology and emerging industries, which will consequently enable it to synergize economic and environmental benefits.

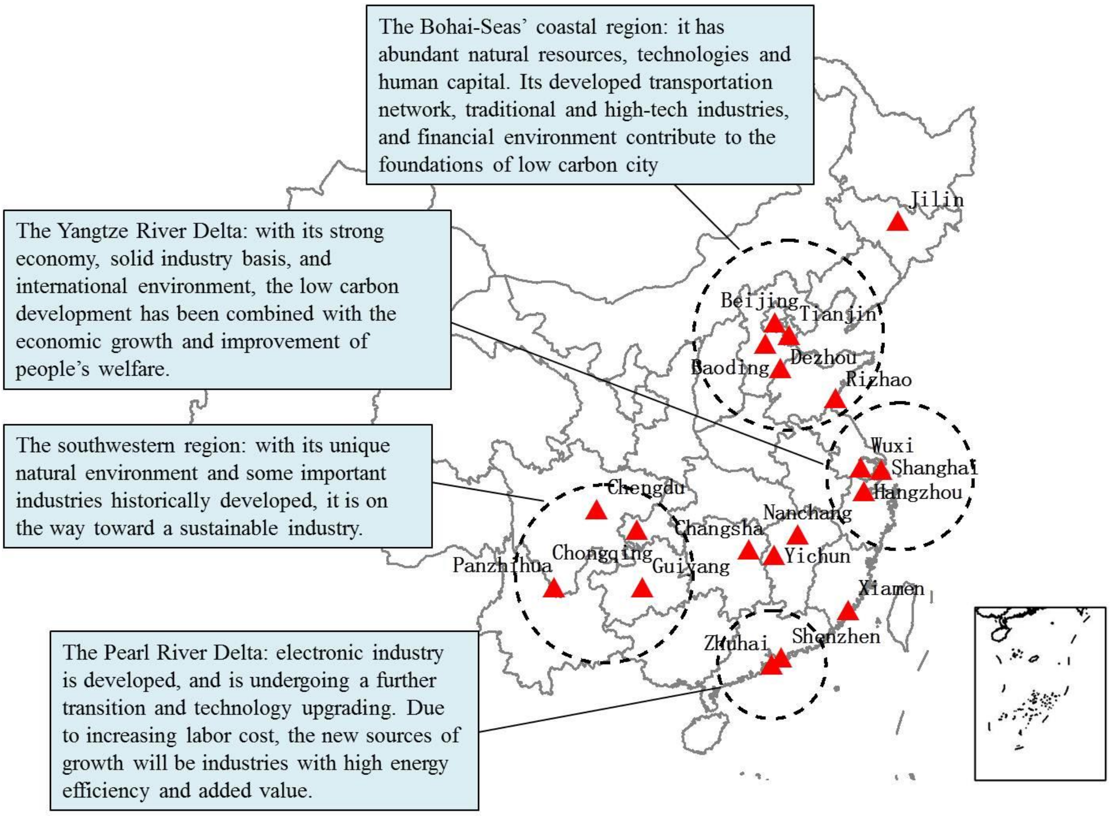

Figure 1 Geographic distribution and regional agglomeration of China's LCC
Source: China Center for Information Industry Development (2011).

3.2 Stage features of policies and practices development

Currently, LCC initiatives are implemented under the central government dominated, top-down administrative framework. During the past several years, national-level policies' progress in mitigating GHG emissions has propelled urban China to explore low carbon transition (Table 3). It can be concluded from Table 3 that the determination of the central government to curb its soaring GHG emissions and the guidance from National Development and Reform Commission (NDRC) are keys in the enhancement of China's LCC, which has become more comprehensive and systematic.

Table 3 National-level policies promote local-level actions on climate change

Time	National policies	Responsibility Transmission Mechanism	Regional Practices
Before 2005	No specific national goals aimed at low carbon development		Few cities paid attention to low carbon development

2005-2010	The 11th FYP set a mandatory goal of a 20% reduction in energy intensity	Central government signed agreements with local governments with the enforced goal of energy conservation included	Shutting down backward production capacity, improving energy efficiency and promoting renewable energy became the key issues of local governments
November 2009	Before Copenhagen Climate Conference, China announced the goal of a 40%~45% reduction in CO_2 intensity by 2020, compared to 2005 level	Cities started a low carbon campaign in order to get potential preferential policy	Many cities drew up plans for LCC; special concerns were given to new energy industry
July 2010	NDRC initiated the first batch of "5 provinces and 8 cities" LCC pilot program	NDRC directed the pilot regions to carry out LCC work in a systematic approach	Pilot regions submitted their work plans to the central government with explicit targets and concrete measures included
March 2011	The 12th FYP launched the mandatory goal of a cumulative 17% reduction in CO_2 intensity	Allocate the national goal to provinces and cities.	Low carbon development has substantially changed from voluntary action toward compulsory responsibility of each region
December 2012	NDRC launched the second batch of "1 provinces and 28 cities" LCC pilot program	NDRC required the pilot regions to establish GHG emission target responsibility system	The second batch proposed the targets of total emissions as well as the year to reach the emission peak

Specifically，the low carbon development of Chinese cities has evolved from focusing on low carbon industries toward a comprehensive transition, and from low carbon concept advocacy towards actual actions. Those changes took place around the year 2010. During the 11th FYP period, Chinese cities showed great enthusiasm for exploring low carbon development. Regardless of their own industrial foundation and ability of scientific research, many of them strived to develop a new energy industry with the belief that new energy was equal to "low carbon" (Bi et al., 2009). Around 2010, as the central government embarked on an explicit and ambitious attempt to reduce carbon intensity, and the NDRC initiated the first batch of the "5 provinces and 8 cities" low carbon pilot program, LCC in China began moving into an intensive phase of testing a comprehensive and systematic LCC framework. This framework included adjusting economic structure, optimizing energy structure, improving energy efficiency, increasing carbon sinks and advocating low-carbon lifestyle. Fundamental work like GHG emission accounting has also commenced. Furthermore, the mandatory national-level goal of carbon intensity reduction in the 12th FYP has been allocated to each province. Thus, low carbon development has substantially changed from voluntary action toward an enforced responsibility of each region. To further scale up the low-carbon development pilot program, the NDRC launched the second batch of low-carbon pilots in December, 2012. In August 2013, the NDRC approved the second batch of "one province and 28 cities" low carbon pilot program, covering Beijing, Shanghai, Wuhan and Qingdao. Combined with the first batch of low carbon pilot program, six provinces and 36 cities' low carbon pilot programs across China have gotten approved by the NDRC.

3.3 Intensity-based targets for LCC

Table 4 displays CO_2emission reduction targets of 10 typical cities worldwide, which range from 20% to 40% reduction in total emissions by the year 2020 or 2030, relative to the base year level. Compared with targets in Table 1, it is evident that all cities in mainland China adopt intensity-based targets while global developed cites take absolute emission cuts. This difference can be explained by rapid urbanization in China. Feng et al. (2012) pointed out that urbanization and its associated income rise and lifestyle changes are important driving forces for CO_2 emissions growth in most regions in China. Therefore the continuing urbanization, along with high economic growth, puts tremendous pressure on Chinese cities' energy consumption and CO_2 emissions. This includes large-scale urban infrastructure construction, and higher per capita carbon emissions brought by higher income and life quality enhancement. Such an unstoppable tendency makes an intensity-based target reasonable, as it allows for additional emission growth before the emissions reach the peak.

Table 4 Targets for LCC proposed by several developed cities worldwide

City	Baseline year	Reduction rate (%)			Absolute reduction volume (million tCO_2e/yr)
		2020	2030	2050	
BuenosAires	2008	-	30%	-	-
Chicago	1990	25%		80%	36
Hong Kong	2005	50%-60%	-	-	8-14
Los Angles	1990	-	35%	-	51.6
Madly	2004	20%	-	50%	-
New York	2007	-	30%	-	32
Seoul	2007	-	40%	-	-
Toronto	1990	30%	-	80%	22
Sydney	2006	30%	-	70%	-
Tokyo	2000	25%	-	-	-

Source: Climate Leadership Group (2009).

3.4 Exercising low-carbon concepts according to local conditions

As mentioned before, strengthening industrial restructuring and technological upgrading, improving energy mix and energy efficiency, prioritizing public transport and promoting efficient public transport systems, and optimizing urban form are promoted in a comprehensive way among low-carbon cities. Meanwhile, these cities have established their own development models according to the stage of economic development and the endowment of local resources. To illustrate, let us take several examples in China. Tianjin, a city dominated by heavy industries, emphasizes industrial structure adjustment and industrial technologies upgrading by propelling three batches of industrial self-innovation projects. Baoding, a city called the" Chinese Power Valley," established six industrial clusters including wind power, photovoltaic (PV) power, power storage, power-saving, power automation equipment manufacturing. Although the production of these devices is energy-intensive, they are required in order to popularize renewable energy. Dongtan, located in the China's most developed city--Shanghai, is expected to be the first carbon neutral district in the world, where heat and power is obtained from wind, biomass, waste and solar PV power generation. Guangzhou, a city equipped with the most advanced metro system in China, has invested RMB 9.1 billion in building five metro lines and purchasing 500 new buses including 30 BRT buses. Xiamen, famously rated the China's most livable city, is committed to being a compact city by scientifically planning urban land use, constructing public and non-motorized transport systems, and creating transport-oriented living and working facilities.

3.5 Heavy reliance on mitigation efforts from industries

Fig.2 illustrates the different mix of sector emission shares in one U.S. city (Portland, Oregon) and a typical Chinese city. In terms of its sector mix, though Portland may not be typical for developed countries, its GHG inventory exhibits a commonly high share of transportation emissions (38%), followed by the commercial (25%), residential (21%), and industry (15%) sectors. Thus low-carbon transport and low-carbon buildings are their main concerns. In contrast, GHG emissions of Chinese cities are dominated by industry (69%), with smaller shares of emissions from other sectors. A main reason for the high share of industry in Chinese cities is the strong presence of heavy industry in many local economies in China, entailing special efforts from these industries. For instance, experiences from the U.S. and Japan show that transport and building energy-saving issues are on top of the list of LCC scheme (Dai, 2009). However, in China, developing emerging low-carbon industries and popularizing advanced energy-saving technologies could be a pivot of LCC strategies (Wang et al., 2005; Liu, 2012).

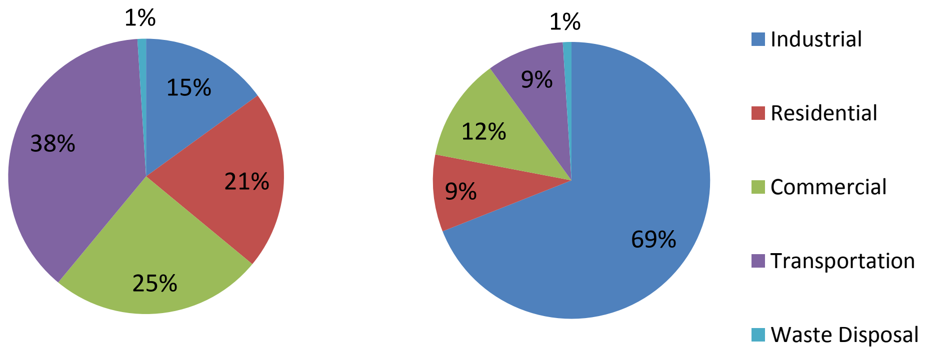

Figure 2 Comparison of GHG emissions inventory by sector between Portland, Oregon (left) and typical Chinese cities (right)

Source: Zhou et al. (2011).

4. PROBLEMS AND CHALLENGES FOR CHINA'S LCC DEVELOPMENT

It has been three years since the NDRC initiated low carbon pilot program. Is the performance of the first batch of pilots up to the expectation? Due to the absence of a low-carbon specific evaluation system, and also given the fact that these pilots are in the early stage of capacity building and tools design, it is difficult at this point to exactly answer whether the first batch of pilots are on the right track to reach low-carbon future. Though endeavors of those pilots are really noticeable, it is generally believed that these pilots have not met with the NDRC's expectation, i.e. playing an exemplary role and developing innovative low-carbon development way that would be of great value to other regions (Qi, 2013).

What explains such unsatisfactory results? First and the most important, many local governments in the pilots gain limited awareness of low-carbon development since they bear great burden of developing economy during the process of rapid industrialization and urbanization. In fact, their real motives for developing LCC are to get the preferential policies and financial support from the central government, which would help attract more investment and promote local economy. Aiming at sheer economic growth at the expense of environment had led China to miss its energy-saving goal in 2010, thereby having huge implications for meeting its LLC development goals. How to incentivize local governments not to focus on economic growth alone is beyond the scope of LCC development and it is actually a problem of political-economic institution. It is not only applying to low-carbon development in cities, but more general in nature as it involves cooperation between central and local governments in the context of government decentralization, and also the tax sharing system (Zhang, 2012a). To address this problem is challenging but crucial to achieve the desired goal, which can be found in the final discussion part. Second, developing LCC is completely new for pilots. They start from scratch and learn as they go. Fundamental work like establishing a carbon accounting system and performance evaluation system is under development. A variety of policy tools such as demand-and-control measures, financial stimulus and market-based instruments remain to be further improved, and in particular local governments' capacity for designing market-based tools needs to be strengthened. Third, generally speaking, due to rising living standards and coal-dominated energy mix, there will be inevitable emissions growth for most Chinese cities, implying challenges ahead to further mitigate GHG emissions. Those problems and challenges are not only applied to pilot cities, but are to all cities across the country.

4.1 Absence of sound carbon accounting systems

A well-designed carbon accounting system is the key to a low-carbon transition because of its numerous benefits: assisting policy makers in gaining an in-depth understanding of the real situation so as to explore specific ways to problems, helping quantify and evaluate the effects of policies, preparing the cities or sectors for emission trading, etc. Unfortunately, to date there is still no standardized or nationally recognized accounting system for Chinese cities. Many researchers suggest that establishing a sound accounting system for China should be a prerequisite to realize a low-carbon transition (China Center for Information Industry Development, 2011; Bi et al., 2009; Han et al., 2012; Guan et al. 2012; Cai et al. 2013; Wang et al., 2013). In fact, the accounting system has barely begun, not only on the local level, but also on the national level. The national GHG emissions database updated in October 2010 is the first publicly available database to include provincial level data since 1994. Nevertheless, there are shortcomings for this top-down accounting approach. First, it is too broad to be applied to organizations, firms or equipment, and thus fails to activate business and civil society to conduct emission reduction activities (Chen, 2011). Second, in China there is a risk of emission misrepresentation accompanied by poor quality of energy data due to the opacity of the statistical approach of data collection including reporting, validating, and other institutional factors (Guan et al., 2012). Hence, the irregularities and distortions of emission data create difficulties and challenges for target allocation and domestic trading at the nation level.

4.2 Lack of low-carbon specific evaluation system

A comprehensive and specific evaluation system will help cities tell right from wrong. For instance, improving the energy efficiency through adoption of efficient technologies is a good practice for LCC development, while it is bad to fulfill their target responsibility by hastily moving those energy-intensive industries out of jurisdictional boundaries. Unfortunately, to date LCC evaluation system only demonstrates the top-level indicators including energy efficiency, carbon intensity, percentage of non-fossil energy and forest cover, as Table 1 shows. Such a generalized evaluation system leaves rooms for carbon leakage in the context of differentiated climate abatement commitments among cities. Carbon leakage refers to the phenomenon that carbon-intensive firms transfer from policy-restricted regions to less regulated regions, resulting in the failure of controlling emissions[2]. In China, under the pressure derived from policies of energy conservation and emission reduction, many energy-consuming firms practice interregional transfer from the east to the west (Wei and Bi, 2011). For example, during 2008 and 2010, Inner Mongolia received 754 projects with a total production value of RMB 551 billion from eastern regions (Miao et al., 2012), and in 2009 Henan Province took over foreign and domestic investment of RMB 250 billion with petrochemical projects being the main contribution (Wu, 2010). What is worse is that when those shifted firms relocate factories they usually expand production capacity at the same time (Sun, 2010).

The theories of market failure and policy failure can be applied to explain carbon leakage. First, the cost of GHG effects is not integrated into the production cost of individual firms, and policies aimed to internalize this external cost will increase the overall cost for firms. Driven by profit maximization, firms will try hard to avoid the carbon cost by moving to the less policy-regulated regions. Second, local governments have significant autonomy to clear the energy-intensive but economy-inefficient firms out of jurisdictional boundaries with administrative power, so as to meet their energy-saving targets. Therefore, it is important to include comprehensive market mechanisms that eliminate externalities brought about by GHG emissions, as well as strengthen supervision from the supervising authority in order to make mitigation efforts that really matter.

4.3 Rare use of market-based instruments

As previously mentioned, China's approach to controlling GHG emissions has relied on a top-down, direct regulatory system, to a large extent through command-and-control measures.

[2] Zhang (2012b) provides a comprehensive review of carbon leakage and the effectiveness of anti-leakage policies associated with differentiated climate abatement commitments among countries.

Economic instruments such as carbon taxes, carbon trading, carbon offsets and energy performance contracting (EPC) have played a very limited role (Wu, 2011). For example, during the 11th FYP, the total CO_2 reduction volume reached 1.25 billion tCO_2e through mandatory regulations and auxiliary financial stimulus, while only 0.035 billion tCO_2e were reduced through market-based instruments (Qi, 2011). Another example is the low-carbon pilots. The command-and-control measure and financial stimulus are their main tools. Major command-and-control tools include phasing out obsolete production capacity, mandatory standards, mandatory tasks, and standards for industry admittance. Low-carbon development special fund is the most effective tool to provide financial support for the pilots (Qi, 2013). In contrast, markert-based instruments are still in the stage of exploration and localities' capacity for market-based instruments design seems weak. Actually, compared with mandatory regulations and financial funding, it needs greater institutional innovation to put a price on carbon emissions (externality) and bring the carbon market into operation, given the fact that the market mechanism in China is not sound and far from mature.

Objectively speaking, in the initial stage of low-carbon transition, mandatory policies are more suitable for China. For one reason, a top-down framework takes full advantage of fitting well with the Chinese administrative system. Another reason is that the current market in China lacks spontaneity in terms of GHG reduction. In this context, it is necessary for the government to establish regulations and provide economic incentives to drive the low-carbon transition. Nevertheless, by applying mandatory regulations, China has achieved a limited success in meeting the energy saving goal for the 11th FYP, and continues to face rising energy demand and increasing difficulty in further cutting energy and carbon intensities. Having recognized the limited efficacy of top-down approaches and the difficulties in sustaining their effects, China began to look at market-based instruments as potentially valuable alternatives when moving into the 12th FYP period (Han et al., 2012). With carbon trading still in its infancy, as a first step, the NDRC initiated carbon trading pilots in seven provinces and cities aiming to create a functional national system that would be in place by 2016 (NDRC, 2011).

4.4 Insufficient interaction between the governments and enterprises

As aforementioned, GHG emissions of Chinese cities are dominated by industry, and therefore energy-intensive industrial enterprises are the key players in urban transition towards low carbon development. Their involvement, however, is absent from the policy making process. This is mainly because of the Chinese top-down administrative approach as previously discussed. In fact, the enterprises implement the directives solely made by the governments, and often low-carbon transition is treated by the enterprises merely as a political task or an excessive burden. An analysis of the impact of policy at the company level is essential (Dieperink et al., 2004). A series of empirical studies have been conducted to analyze company-level issues in China such as major factors determining a company's energy saving efforts (Liu et al., 2012), awareness and acceptability of market-based instruments (Liu et al., 2013a), and affordability of energy-saving policy costs (Liu et al., 2013b).

According to a survey concerning energy-saving issues on energy-intensive enterprises in Shandong Province[3], several important findings are derived as follows: (1) Difficulties of external

[3] The survey was conducted by the School of Environment, Tsinghua University in 2011. There are 57 effective samples, including 21 chemical enterprises, 12 iron and steel enterprises, 12 pulp

financing, uncertainty of the quality of new technologies and high profitability expectation of energy-saving projects are major barriers to private investment in energy efficient technologies. Additionally, 82% of the surveyed companies could only accept energy saving projects with a payback period of less than 3 years. (2) Respondents indicate a limited knowledge of market-based tools for energy saving and carbon mitigation, and they think of those tools as a threat to the increase of energy cost. Actually they are more familiar with financial stimulus including subsidies, power price discrimination, and preferential taxation. (3) The responses of companies to increases in energy costs vary from such positive countermeasures as energy saving by managerial measures and investing in energy efficient technologies, to negative ones like moving the factories to less carbon-regulated regions and production expansion to cut down unit energy cost. As we can see, the bottom-up approach of policy analysis provides a unique perspective in which the policy makers learn about the policy performers, making it necessary for the Chinese government to interact more with the enterprises for the sake of more feasible and pertinent energy and climate policies.

4.5 Excessive budget dependence on land concession

A dense and compact spatial development strategy emerges as a crucial strategy to reduce GHG emissions (Yu, 2010). There have been growing numbers of empirical studies (Norman et al., 2006; Grazi et al., 2008; Brownand Logan, 2008; Kamal-Chaouland Robert, 2009) confirming that the spatial urban form has a critical impact on GHG emissions. A consensus of those studies is that cities with higher densities and greater mixing of various facilities can enhance climate goals while urban sprawl and groundless land-use zoning can lead to larger emissions through a variety of different mechanisms. Urban land expansion rates that are higher than or equal to urban population growth rates suggest that urban land is over expansive (Seto et al., 2011). It is found that most Chinese cities are spatially expanding in a haphazard, inefficient, and unsustainable way. According to the World Bank (2012), urban land has expanded faster than the urban population in China between 1995 and 2008. A case study (Tan et al., 2005) of the Beijing–Tianjin–Hebei region, whose urban system is the largest in China, also shows that the urban land expansion rate was evidently faster than the urban population increase rate in this area from 1990 to 2010.

One of the causes for blind expansion of urban land outstand the local governments' heavy reliance on off-budget funds from land concession (World Bank, 2012; Dhakal, 2009). In China, local governments are responsible for not only providing public services, but also for promoting their local economies. Given that the central government only accounted for less than 25% of the country's total government expenditure but received over 50% of the total government revenue in China (see Table 5)[4], local governments increasingly face the burden of rapidly growing

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and paper mills, 11 cement enterprises and 1 ferrous alloy processing enterprises.

[4] Since the tax-sharing system was adopted in China in 1994, taxes are grouped into taxes collected by the central government, taxes collected by local governments, and taxes shared between the central and local governments. All those taxes that have steady sources and broad bases and are easily collected, such as consumption tax, tariffs, vehicle purchase tax, are assigned to the central government. VAT and income tax are split between the central and local governments, with 75% of VAT and 60% of income tax going to the central government. As a result, the central government revenue increased by 200% in 1994 relative to its 1993 level. This

expenditures on financing urban infrastructure and urban development. This gap is generally filled by various off-budget funds mainly raised by converting rural land or rural-urban fringe land into urban use. Specifically, municipal governments acquire rural land at low prices set by the state, equip the land with urban infrastructures, and then sell or auction the serviced land to developers, thereby generating cash flow. This discrepancy between acquisition costs and sales revenues is sizable, creating a strong incentive for local governments to develop land that often far outpaces real demand. For example, the ratio of off-budget funds from land concession to local governments' total revenues in China rapidly increased from 36.2% in 2008 to 71.7% in 2010 (National Bureau of Statistics of China, 2009-2011). Another example is that the land area for industrial parks is commonly two or three times larger than actual needs (World Bank, 2009). The durability and almost irreversibility of buildings and infrastructures creates a lock-in effect on urban long-term GHG emissions, creating reasons for concern regarding China's urban sprawl which is motivated by municipal financial incentives.

Table 5 Shares of the central and local governments in the government revenue and expenditure in China, 1993-2009

Year	Government Revenue		Government Expenditure	
	Central Government (%)	Local Governments (%)	Central Government (%)	Local Governments (%)
1993	22.0	78.0	28.3	71.7
1994	55.7	44.3	30.3	69.7
1995	52.2	47.8	29.2	70.8
1996	49.4	50.6	27.1	72.9
1997	48.9	51.1	27.4	72.6
1998	49.5	50.5	28.9	71.1
1999	51.1	48.9	31.5	68.5
2000	52.2	47.8	34.7	65.3

led the share of the central government in the total government revenue to go up to 55.7% in 1994 from 22.0% in the previous year (see Table 5). In the meantime, the share of the central government in the total government expenditure just rose by 2%. By 2009, local governments only accounted for 47.6% of the total government revenue, but their expenditure accounted for 80.0% of the total government expenditure in China. On the one hand, to enable to pay their expenditure for culture and education, supporting agricultural production, social security subsidiary, etc, local governments have little choice but to focus on local development and GDP. That will in turn enable them to enlarge their tax revenue by collecting urban maintenance and development tax, contract tax, arable land occupation tax, urban land use tax, etc. On the other hand, local governments seek off-budget funds from land concession to cover a disproportional portion of the aforementioned government expenditure. Objectively speaking, this tax-sharing scheme in China plays a part in driving local governments to seek higher GDP growths and off-budget funds from land concession at the expense of the environment (Zhang, 2008, 2010 and 2011b).

2001	52.4	47.6	30.5	69.5
2002	55.0	45.0	30.7	69.3
2003	54.6	45.4	30.1	69.9
2004	54.9	45.1	27.7	72.3
2005	52.3	47.7	25.9	74.1
2006	52.8	47.2	24.7	75.3
2007	54.1	45.9	23.0	77.0
2008	53.3	46.7	21.3	78.7
2009	52.4	47.6	20.0	80.0

Source: National Bureau of Statistics of China (2010).

4.6 Increasing difficulty in further carbon mitigation

A number of studies have depicted the future carbon emission trajectory for China through scenario analysis. As exhibited in Fig.3, despite certain differences, scenario results of those studies all indicate a continuous decline in carbon intensity for China from 2005 to 2050, and also a decelerating rate of such a decline, implying that there will be more challenges over time posed to China in order to further mitigate GHG emissions. However, some exceptions to the decelerating rate of decline in carbon intensity exist, such as the descending trend in scenarios of ERI-ELC, UNDP-EA, IEA-Baseline which will be more notable after 2030. This presupposes that the electric automobile, the fourth generation of nuclear power, CCS, and renewable energies are deployed on a large scale, thus resulting in an enormous investment demand and an increasing marginal cost of mitigation. Therefore, without technological breakthroughs, it is hard to realize these ambitious goals, re-confirming the great difficulties in carbon mitigation for China. Take the power sector as an example. In 2007, the energy conversion efficiency of coal-fired generation units in China had already topped the world (IEA, 2008b; China Electricity Council, 2007). Considering the fact that the continuous progress in energy conservation and technology deployment in the 11th FYP, mitigation potential from technical progress has become very limited (Cai et al., 2008, 2010).

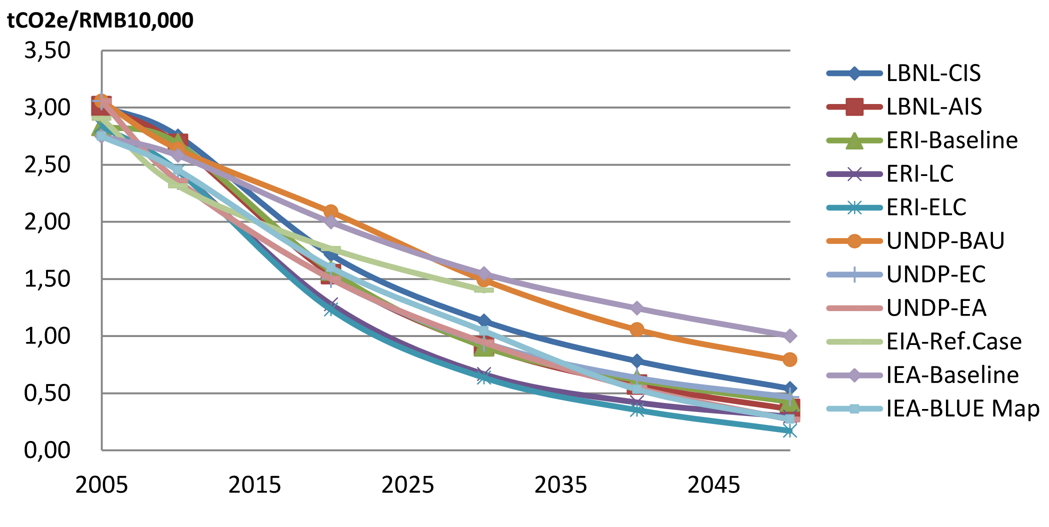

Figure 3 Scenario results of carbon intensity trajectory in China, 2005-2050

Sources: ERI, 2009; Zhou et al., 2011a; UNDP, 2010; EIA, 2008; IEA, 2010.

4.7 Inevitable emissions growth due to rising living standards

Life quality improvement is closely related to rising incomes. With higher disposable incomes, the lifestyles of urban dwellers become more energy intensive (Dhakal, 2009). Along with remarkable economic boom since the 1980s, China's CO_2 emissions per capita have grown rapidly from 2.1 tons in 1990 to 5.4 tons in 2008, surpassing the world average level of 4.5 tons in that year (CAIT, 2012). When compared to developed countries, however, the gap of per capita economic output and energy consumption is huge. For example, in 2008, GDP per capita in China was only 13% of that in the U.S., CO_2 emissions per capita were 17% of the U.S. value (CAIT, 2012). Thus, continuous growth in per capita output and CO_2 emissions is inevitable, considering the fact that China will continue in the course of urbanization and industrialization for a long time.

The Kaya Identity (Kaya, 1989) provides an intuitive approach to the interpretation of historical trends as well as future projections of energy-related CO_2 emissions. From a historical perspective, the energy intensity of economic output has dramatically decreased from 1990 to 2010 in four mega-cities of China, i.e. Beijing, Shanghai, Tianjin, and Chongqing. Nevertheless, economic output per capita has surged over the same period, resulting in a big increase in total energy-related CO_2 emissions (Dhakal, 2009). It is worthwhile noting that those four mega-cities are highly urbanized and economically important, whose per capita CO_2 emissions are well above the national average level. Therefore, promoting economic growth and improving life quality while curbing CO_2 emissions poses a big challenge to large amounts of boom towns in China.

Looking into the future, Fig.4 displays the predicted average rate of change of total CO_2 emissions and each individual Kaya component from 2008 to 2035 for China, OECD and non-OECD countries. Worldwide, the most significant decline in energy intensity of economic output is projected for China, at 2.6 percent per year. However, that decline is offset by the projected increase in China's economic output per capita, which grows by an average of 5.4% per year over the same period, emerging as the most significant driver of positive growth in energy-related CO_2 emissions.

Among the four Kaya components, policymakers generally focus on the energy intensity of economic output (E/GDP) and carbon intensity of the energy supply (CO_2/E). Reducing growth in per capita output may have a mitigating influence on emissions, but the government generally pursues policies to increase rather than decrease output per capita, in order to advance such objectives as life quality improvement. Combined with the results of Kaya decomposition, it is justifiable to come to the conclusion for China of inevitable growth of CO_2 emissions driven by economic development and improvement of residents' living standards.

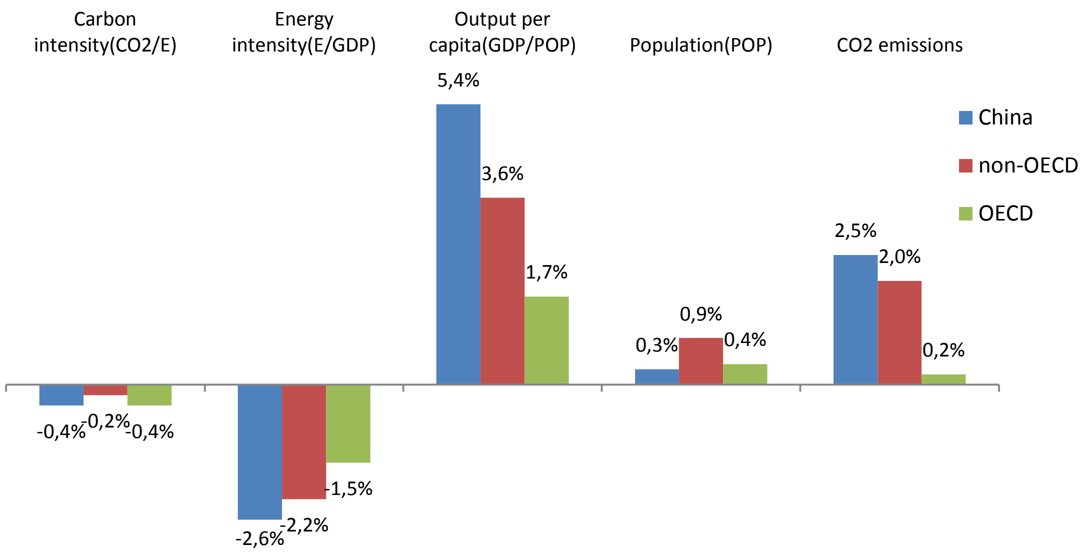

Figure 4 Average annual changes in Kaya decomposition components of CO_2 emissions growth for China, 2008-2035

Source: EIA (2011).

Note: Due to rounding, components will not sum exactly to total average annual growth rates

4.8 Long-term predominance of coal in energy mix

Coal overwhelmingly dominates China's energy mix, accounting for approximately 70% of China's total primary energy consumption (TPEC) in China in 2011, which is significantly higher than the world average level of 29.5% (BP, 2012). In industrial sectors, 58% of final energy consumption was supported by coal in 2007, while the corresponding world average is only 27% (IEA, 2009; IEA, 2011). As for cities, GHG emissions from many Chinese cities are dominated by direct coal use, as well as coal-fired electricity. In contrast, the inventory of a U.S. city is principally composed of emissions from electricity, natural gas, and gasoline, all of which are less carbon-intensive than coal (Fig. 5).

Unfortunately, China is expected to continue to be fueled primarily by coal use because of its abundant supply, low cost and easy access. Thus, it is likely that this will lead to an inertia effect of energy consumption. This viewpoint has been confirmed by many studies.Fig.6 summaries their projections of the proportion of coal in China's primary energy mix. Despite the continuous decline in the ratio of coal consumption to TPEC, the predominance of coal in China's energy mix will remain until 2050. In a UNDP-BAU scenario, nearly 60% of TPEC is projected to be met by coal in 2050, while only 32% is projected to be met by coal in the IEA-BLUE map scenario, the lowest value among various scenario results. The reason for this aggressiveness is that the IEA-BLUE Map scenario is uniquely target-oriented: it sets the ambitious goal of halving global energy-related CO_2 emissions by 2050, relative to the 2005 level. Therefore, it reflects that in order to achieve the two centigrade goal, China is facing formidable challenges in energy structure adjustment, particularly through the sizable reduction in coal use as suggested by the IEA-BLUE map scenario.

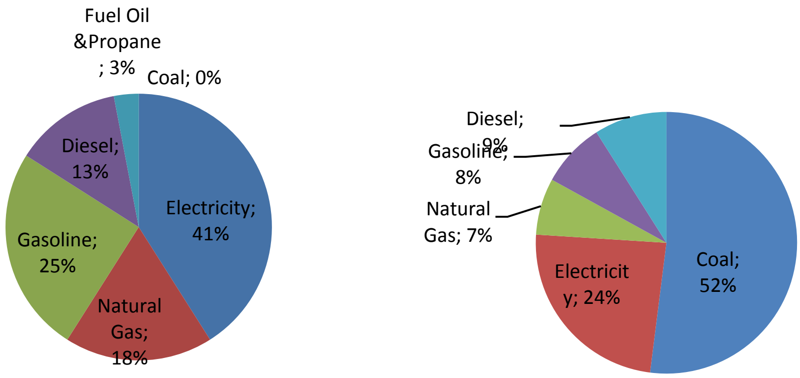

Figure 5 Comparison of U.S. (left) and Chinese (right) city-level carbon inventories by fuel
Source: Zhou et al. (2011b).

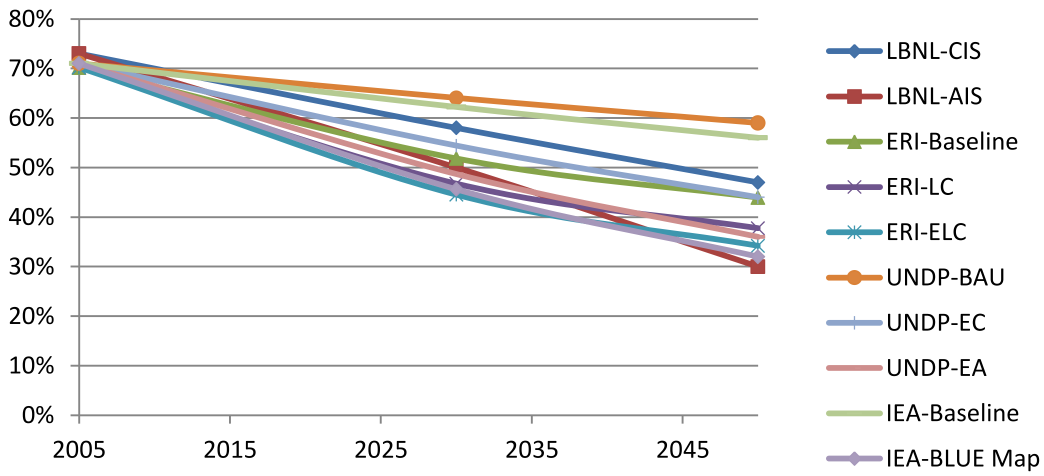

Figure 6 The proportion of coal in China's primary energy mix under different scenarios, 2005-2050
Sources: ERI (2009); Zhou et al. (2011a); UNDP (2010); IEA (2010).

5. CONCLUSIONS AND DISCUSSIONS

China has gradually recognized that the conventional path of encouraging economic growth at the expense of the environment cannot be sustained. It has to be changed. To that end, China has decided to cut its carbon emissions per unit of GDP by 40-45% by 2020 relative to its 2005 levels, and to drive its future energy use and carbon emissions below the projected baseline levels to the extent possible.

Globally as well as in China, cities have contributed to most of economic output and have accordingly given rise to most of CO_2 emissions. In particular, given unprecedented urbanization in China, cities will play an even greater role in shaping energy demand and CO_2 emissions. Therefore, cities are the key to meeting its proposed carbon intensity target in 2020 and whatever climate commitments beyond 2020 that China may take.

Given the paramount importance of cities, China is practicing low carbon city development. All these cities have set energy-saving and carbon-curbing targets. To accomplish these goals, they are making efforts towards strengthening industrial restructuring and technological upgrading, improving energy mix and energy efficiency, prioritizing public transport and promoting efficient public transport systems, and optimizing urban form. In this process, however, cities have confronted with a variety of problems and challenges. They include, but are not limited to, the absence of sound carbon accounting systems, lack of low-carbon specific evaluation system, rare use of market-based instruments, insufficient government-enterprise interactions, excessive budget dependence on land concession, increasing difficulty in further carbon mitigation, inevitable emissions growth due to rising living standards, and long-term coal-dominant energy structure. These challenges are not applied to one or few cities, but are to all cities across the country. Some challenges are related to LLC development, but some are more general in nature.

The government (mainly referring to the central government) should develop technical guidelines for LCC to solve the problems commonly existing in the local-level LLC development, especially designing a sound carbon accounting system that is nationally recognized and easy to apply; strengthen supervision on the localities from the central government by providing direction and rewarding good practice, etc.), and in relation to this, a benchmarking and evaluation system (e.g., a comprehensive set of performance indicators) for low-carbon urban development among cities should be established to monitor, track and evaluate how cities are performing in LCC development; and attach importance to interaction with the enterprises by constructing a feasible policy framework fully considering both administrators' feasibility and performers' acceptability. As for cities in less developed regions who are incapable of effectively implementing LLC due mainly to lack of financial support, the central government should establish a fund earmarked on LLC development, supplemented with contributions from provincial governments.

Moreover, China mostly relied on administrative means to achieve its energy-saving goal for 2010. The country has had a limited success in meeting that goal, and continues to face rising energy demand and increasing difficulty in further cutting energy and carbon intensities. It is becoming increasingly crucial for China to harness market forces to reduce its energy consumption and cut carbon and other conventional pollutants and genuinely transit into a low-carbon economy. To that end, China is experimenting with low-carbon provinces and cities in six provinces and thirty-six cities. Putting a price on carbon is considered a crucial step for such endeavor. A carbon tax or a domestic carbon trading scheme, if established, will serve as a cost-effective supplement to costly administrative means on which China has mainly relied to meet its current energy saving goal. In case of a domestic carbon trading scheme, the key issue is its scope and coverage. Given the fact that the costs of abating carbon emissions differ significantly among emissions sources cross provinces and sectors, having broad coverage of emissions sources from all industries nationwide creates a means of obtaining low-cost abatement options, thus minimizing the total cost of achieving the national energy-saving and emissions goals. This is an ideal option. In practice, however, a carbon trading in China would have to start from selected sectors or regions, although the limited scope and coverage will reduce its cost-effectiveness, because China needs a reasonable length of time to develop and operate a national carbon market. This explains why a carbon trading scheme in China is initially of limited scope and coverage, with 7 pilot carbon trading in two provinces and five cities currently under development and an aim to establish a national carbon trading scheme by 2016. However, in terms of timing, given that China has not levied environmental taxes yet, it is better to introduce environmental taxes first, followed by carbon taxes, not least because such a distinction will enable China to disentangle additional efforts towards carbon abatement from those broad energy-saving and pollution-cutting ones. To be effective, either of market-based instruments requires a sound carbon accounting system in place. For a carbon trading scheme, the cap on emissions is required. There is an encouraging sign that several cities in the second batch of LLC pilot program are proposing when their emissions reach the peak. Once these are decided, it will help to set a cap on emissions for these cities, and enable them to establish a carbon trading scheme.

The country has faced great difficulty ensuring that local governments act in accordance with centrally-directed policies, since the past three decades of economic reforms have witnessed a shift in the control over resources and decision making to local governments (Zhang, 2012a). This challenge is more general in nature, not only applying to LLC development in cities. Rather, it involves cooperation between central and local governments in the context of government decentralization. This not only had led China to miss its energy-saving goal in 2010, but also has huge implications for meeting its LLC development goals. Clearly, the central government needs to set appropriated incentives to get local governments' cooperation. One way to incentivize local governments not to focus on economic growth alone and ensure that local officials are held accountable for energy saving and pollution cutting in their cities is developing sustainable municipal finance mechanisms that move away from a reliance on land concession. The central government really needs to cultivate steady and sizeable sources of revenues for local governments. Enacting property taxes or real estate taxes for local governments is urgently needed. Broadening the current coverage of resource taxation and significantly increasing the levied level also helps to increase local government's revenues while conserving resources and preserving the environment. The resource tax levied on crude oil and natural gas by revenues rather than by existing extracted volume, which was applied nationwide since November 2011, is the first step in the right direction. However, the current coverage of resource taxes is too narrow, falling far short of the purposes of both preserving resources and protecting the environment. Thus, overhauling resource taxes includes broadening their coverage so that more resources will be subject to resource taxation.

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