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A Different Explanation on How a Less Developed City Struggled out of Its CO2 Emission Dilemma: Main Drivers and Determinants[1]

Abstract: Facing up to the global warming, China has addressed great efforts on low carbon development. Since the year 2010, it has issued two batches of low carbon pilots. However, not all the pilots produced satisfactory outcomes as expected, while a less developed pilot city, Guangyuan got a reassuring result which was considered as a surprise. How do we explain this surprise? How a less developed city struggled out of its CO2 emission dilemma while pursuing the industrialization and urbanization? Using sequential game and multi-case comparison, this paper tries to examine the main drivers of Guangyuan's low carbon initiative and the determinants of its achievement. The analysis shows that Guangyuan had no advantages in low carbon potential compared with its reference cities, while the low carbon surprise was due to its strong political willingness and leadership, an effective multi-level governance network and a

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low carbon oriented evaluation system for local officials. It demonstrates that a less developed city could solve the CO2 emission dilemma while seeking its economic growth; Technical level, fund and human resources are important but not dominant; to ensure the implementation of low carbon policies, meeting low carbon objectives should be taken full consideration into the evaluation system for local officials.

Keywords: Low carbon pilots; Multi-level governance; Sequential city game, China.

1. Introduction

China has addressed great efforts on low carbon development. Since the year 2010, it has issued two batches of low carbon pilots. The first batch of pilots included five provinces as Guangdong, Liaoning, Hubei, Shanxi, Yunnan, two municipalities as Tianjin, Chongqing, and six cities as Shenzhen, Xiamen, Hangzhou, Nanchang, Guiyang, Baoding. The second batch included Hainan province and 28 cities. In order to make possible experiences of the pilots applicable to their similar areas respectively, all the pilots were selected based on the local consent and also to be geographically and economically diverse.

Regarding the progress of the low carbon pilots, people hold different views. Song et al. (2015) reviewed the CO2 emission status of 36 pilot cities according to their CO2 emissions during the 11th Five-Year Plan period and their CO2 reduction targets for the 12th Five-Year Plan. They indicated that comparing with other non-pilot cities and provinces, these pilots did more effective work in low carbon development, and had more aggressive CO2 emission reduction targets. Xie (2014) stated that the low carbon pilot program had made a significant achievement, as the average decrease of carbon intensity of all the ten pilot provinces and districts of the first batch in 2012 was 9.2% by the year 2010, which was faster than the national average level of 6.6%[1].However the average decreasing rate couldn't represent for all the pilots' achievement due to the

[1] On the forum of "Low Carbon Pilots Experience Exchange" December 2013, XIE Zhenhua, the deputy director of China's NDRC announced that China's low carbon pilots had made a manifest outcome.

diversity of the pilots. Climate Change Department of National Development and Reform Commission (NDRC, 2014) made an exhibition of low carbon pilot city program and claimed that low carbon pilots had made a satisfactory contribution to industrial structure upgrading, life style and production mode transformation, but it didn't check the situation of emission reduction. Ding and Yang (2013) examined the progress of low carbon pilot provinces and cities mainly from the perspective of planning and strategies. They stated that the pilots had made a progress in low carbon development strategies and planning design. Different pilots were seeking suitable development modes in line with their characteristics. Meanwhile they also pointed out that the low carbon implementation was not so good, and the short term and mid-long term targets of the first batch were not aggressive enough, as some were only a little bit higher than the national target. Liu et al. (2011) made an analysis on the relationship between economic growth and CO2 emissions for low carbon provinces based on the data of 1995-2008, which showed that the pilot provinces was only in a weak decoupling status. Some local officials in low carbon pilot cities expressed their pessimistic views that some pilots even showed no difference comparing with non-pilot cities[1].

The arguments above, whether optimistic or pessimistic, were not based on a unified comprehensive evaluation system. The optimistic focused on the planning design and strategies making, while the pessimistic concerned more about the implementation. If we adapt the low carbon city assessment index framework[2] of Chinese Academy of Social Sciences (CASS) to look at the pilots (Zhuang et al., 2011), not a few cities would counter the unsatisfactory results. According to China Financial Daily, in 2013, for more than 50% of the pilots, energy use per unit of GDP exceeded the national average and remained at a high level, such as Shanxi, Yunnan, Liaoning and Baoding (Xv, 2014). As to the growth rate of total energy consumption, Guangdong, Shanxi, Liaoning and Chongqing were all above the national average rate at the

[1] The author made interviews with four researchers, 10 officials in charge at local level and 3at central level.
[2] It includes low carbon output, low carbon consumption, low carbon resources and low carbon policies.

corresponding period[1]. In Shanxi, the total energy use in 2011 and 2012 were 98 hundred million tce and 106 hundred million tce, with a growth rate of 9.9% and 8.9% respectively. While the national average rate in the same period were 7% and 3.9% respectively[2]. Till now, a satisfactory progress was made on low carbon institution construction and policy making, as most pilots had accomplished low carbon development planning, formed their leaderships and set up the regulations and policies to match their targets, while not all pilots had produced manifest results yet.

There was an argument that cities with higher economic growth level are more likely to reach better reduction results as they usually have more funds, technical support and other resources, so less developed cities are not encouraged to deploy the low carbon pilot city program[3]. However, this was not the case. Guangyuan, a pilot city whose GDP per capita was at the lowest level among all the pilot cities and far below the national average level (see Fig.1), unexpectedly got its reassuring result.

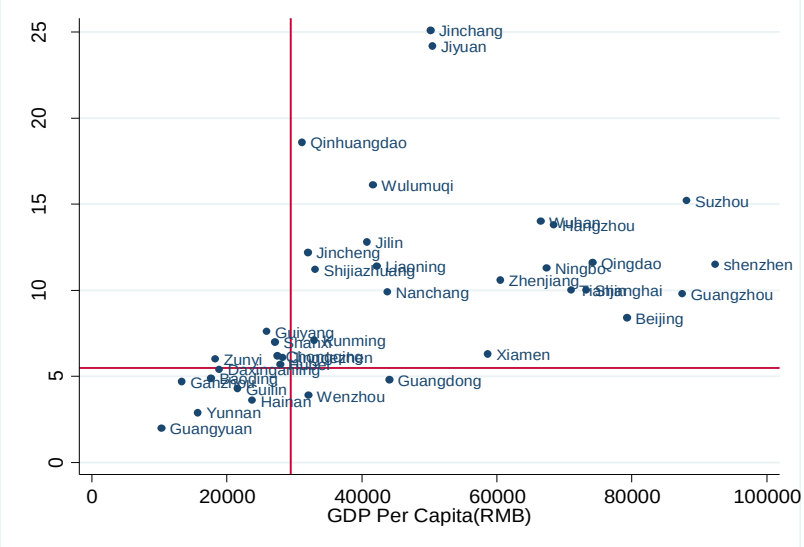

Fig.1. The GDP and CO_2 emission per capita of low carbon pilot provinces and cities

Note: The national average level of GDP per capita and CO2 emission per capita were set as the origin of the coordinate system.

Source: the CO2 emission information of pilots is from China NDRC, the national CO2 emission per capita is calculated based on the data from China Statistical Yearbook 2011, the population and GDP data at national, province and district levels are from China Statistical Yearbook 2011, at city level are from their statistical yearbooks respectively.

[1] The other 9 pilots (the first batch) haven't released their data till now.
[2] National Statistics Bureau, as of 2013, http://www.stats.gov.cn/tjsj/ndsj/2013/indexch.htm.
[3] According to our investigation, DRC of Sichuan province preferred to promote its well-developed city to be low carbon pilots because of this consideration. And so did some other local DRC officials.

From the perspectives of low carbon output[1]and low carbon consumption, we can see a stable trend of low carbon development. As Fig.2 shows, during the year 2007~2012, Guangyuan's carbon productivity experienced a manifest increase, from 0.44, 0.39, 0.49, 0.59, 0.67 and till to 0.69 in the year 2012 (10,000 yuan/tons CO2). The CO2 emission per unit energy consumed was declined gradually. CO2 emissions per tons of standard criteria coal (SCC) went down from 1.796 in 2007 to 1.63 in 2012 at a decreasing rate of 8.9%, much faster than the national average of 3.7%.

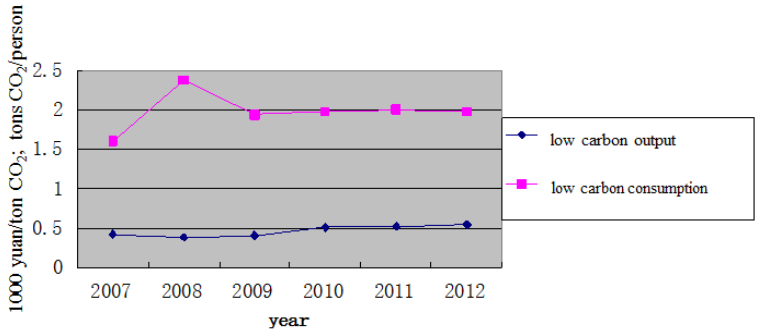

Fig.2. Guangyuan's carbon output and consumption (2007-2012).

Source: data were from Guangyuan Development and Reform Committee (DRC).

It was a surprise that manifest achievements were made in a far less developed city with unfavorable position. What impelled Guangyuan to take the lead in this low carbon initiative? How could a less developed city solve its CO2 emission dilemma? It's worthwhile to find out a reasonable answer to this puzzle.

2. Guangyuan's CO2 Emission Dilemma and Its Low Carbon Initiative

Guangyuan, a victim city of China's Wenchuan earthquake in 2008, is located in the northern mountainous area of the Sichuan Basin It covers an area of 16,300 square kilometers and has a population of 2.48 million (2010)[2]. As one of the least developed cities in Sichuan province, Guangyuan is economically far less developed. In 2013, its

[1] Another expression of energy efficiency, it equals GDP output / carbon emission (ten thousand yuan/ton).
[2] Date from Guangyuan Statistics Beurau, 2011.

GDP per capita was about 16.7 thousand yuan[1]. The Wenchuan earthquake once hit a great shock in its development process. Nearly five thousand people died and more than thirty thousand people injured in Guangyuan. It caused a direct economic loss of over 120 billion yuan[2]. The whole infrastructures for electricity, communication, water supply and transportation were severely damaged, which left Guangyuan a tremendous pressure of three joint tasks as reconstruction, industrialization and urbanization.

Considering these tasks and citizens' livelihood, Guangyuan quickly developed its reconstruction plan to address post-earthquake recovery. However, the plan was lack of integration and coordination between economic development and environmental protection. For example, "Guangyuan Urban and Rural Post-earthquake Rebuilding Plan" emphasized the supply of new buildings as fast as possible, while neglecting building energy efficiency and renewable energy utilization (Sichuan DRC, 2008). Originally Guangyuan just intended to take advantage of the rebuilding opportunities and pursue economic development via industrialization, constructing the city as a comprehensive regional transportation hub, a metal smelting base, a coal power generation and hydro power generation base, and a natural gas chemical processing base through developing several polar industries, such as metal smelting, energy and chemical industry and building materials manufactory. In order to expand its industrial development, the local government even established an "express path" for industrial reconstruction projects to get faster administrative approvals via much simpler procedures and less strict requirements (especially waived some of the environmental requirements). As such, energy intensive and highly polluting industries were planted into its territory by taking the opportunities of reconstruction and counterpart assistance[3].

As a result, Guangyuan was apparently at a high risk of falling in the lock-in effect of carbon-intensive investment. It was facing up to a severe CO2 emission dilemma.

[1] Date from Guangyuan DRC, 2014.
[2] Date from Guangyuan DRC, 2008.
[3] After Wenchuan earthquake, China's central government assigned counterpart assistance project immediately, as a part of this project, Zhejiang, Marco and Heilongjiang were responsible for Guangyuan.

According to the three scenarios of Guangyuan's carbon emissions[1] from 2005 to 2020, if it keeps business as usual, its CO2 emission by 2015 and 2020 will reach 13.68 million tons and 19.29 million tons respectively. However, in a low carbon scenario, its CO2 emissions will be 10.95 million tons and 16.08 million tons respectively (see Fig.3). It means that if Guangyuan integrates low carbon strategy into its reconstruction planning, it could avoid the lock-in effect of carbon-intensive investment.

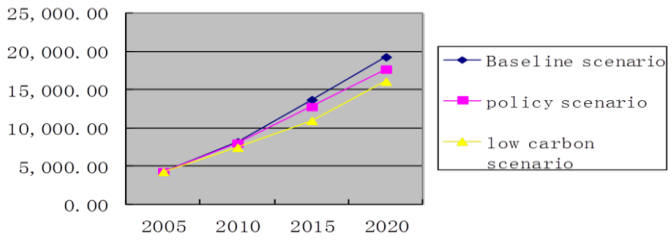

Fig.3. Guangyuan's carbon emission scenarios (2005-2020).

Source: calculated according to the data from Guangyuan DRC, 2010.

The turning point was in December 2008 when Guangyuan government approved the low carbon strategy after continuous debates among the officials within Guangyuan city and tough discussion between Guangyuan government and its upper level. It seized the post-earthquake recovery opportunities to shift the carbon intensive mode to its own way of low carbon rebuilding and development. Guangyuan announced its ambitious low carbon target2and launched ten policy actions, composed of technological aspect and non-technological aspect (see Table 1). The former were known as low carbon industrial cluster, energy saving and energy structure optimization by enhancing clean energy supply, green building pilot, household bio-gas promotion, forest carbon sink, green transportation (including urban bicycle system and using gas instead of patro[l]); the latter provided the core factors for a multi-level governance network, such as low carbon communities, low carbon oriented official evaluation system[3], public education for all citizens, the special low carbon agency and leadership to push forward the low carbon development.

[1] "Guangyuan's Low Carbon Rebuilding and Development: Challenges, Roadmap and Recommendations" of Guangyuan Municipal Government, July 2010.
[2] It promised 15% lower carbon intensity of local GDP comparing with other reconstruction cities and to apply for China's second batch of low carbon pilot city.
[3] It means that low carbon contribution is take into consideration in the evaluation system for local official performance.

Table 1. Guangyuan's main low carbon policy actions.

Technological	Low carbon industrial cluster	Energy saving & structure optimizing	Green building pilot	Household bio-gas promotion	Forest carbon sink	Green transportation pilot
Non-technological	Low carbon communities	Low carbon oriented official evaluation system	Public education	Special agency for low carbon development	/	/

Source: from investigation.

Using CASS' low-carbon city evaluation system (Pan et al., 2009) to examine Guangyuan's low carbon development, we can get the result as Table 2 shows[1].

The "status" is a relative judgment comparing to the standards or national average level. If Guangyuan reached or exceeded the standards, noted as "yes", otherwise "no". Since Guangyuan government adopted low carbon approach, it immediately took measures to crack down the coal power plants and to develop its renewable and clean energy reserves at the same time. The share of non-fossil energy went up steadily from 27.7%, 28.3%, 28.4%, 28.6%, 35% and till to 36.1% respectively during the period 2007-2012. In 2011, as most of the clean energy plants began to run, there was a leap from 28.6% to 35%. Likewise, the CO2 emission per unit energy consumed was declined gradually. Guangyuan's carbon productivity increased from 0.44 in 2007 to 0.69 in 2012 (10,000 yuan/tons CO2)[2]. Guangyuan showed a stable improvement according to the main low carbon variables, see Fig. 4.

[1] The data used in the evaluation are from Guangyuan municipality, Sichuan province and national statistics, or from field investigation, interviews.

[2] There was a turning point around 2008 and 2009. Guangyuan's aim at the first beginning was to recovery and speed up GDP growth rather than environmental concerning. It changed its strategy in the late 2008, which led to the increase of carbon productivity, although it was still at a low level of 0.49 in 2009.

Table 2. The main indicators of Guangyuan's low carbon development (2007-2012).

Indicators	Secondary indicators	Unit	Standard	National average	Guangyuan	Status
Carbon output	Carbon productivity[1]	10,000 yuan/ton CO2	Higher than national average	0.40	0.41(2007)	No
				0.47	0.39(2008)	No
				0.47	0.49(2009)	No
				0.51	0.59(2010)	No
				0.55	0.67(2011)	Yes
				0.56	0.69(2012)	Yes
Carbon consumption	Per capita carbon emission[2]	Tons CO_2 /person	Either both GDP per capita and carbon emission per capita < national average; or carbon emission per capita 0.5X% > national average if GDP per capita is X% > national average	4.97	1.61(2007)	Yes
				5.11	2.39（2008）	
				5.40	1.95（2009）	
				5.92	1.99（2010）	
				6.43	2.01 (2011)	
				6.80	2.35 (2012)	
Low carbon resource	Carbon emission per unit energy consumed	Tons CO_2 /tons standard criteria coal	Lower than national average, and a gradually decline	2.40	1.79(2007)	Yes
				2.38	1.78(2008)	
				2.38	1.78(2009)	
				2.34	1.77(2010)	
				2.35	1.71 (2011)	
				2.31	1.63(2012)	
	% of non-fossil energy in primary energy[3]	%	> national average	6.8	27.7(2007)	Yes
				7.7	28.3(2008)	Yes
				7.8	28.4(2009)	Yes
				8.6	28.6(2010)	Yes
				8.0	35.1 (2011)	Yes
				9.4	36.1 (2012)	Yes
	Forest coverage rate	%	>national standards	45	47.2(2007)	Yes
					52.6(2010)	
					52.8(2011)	
					54.0 (2012)	
Low carbon policy and public support	Low carbon policy	/	Having made low carbon policies and planning	/	Began in 2008, and promoted later on	Yes
	Public awareness of low-carbon city building	%	>80%	/[4]	3.1%(2008)	No
					95%(2010)	Yes
					97%(2011) 98%(2012)	Yes

Source: The values were calculated from the data provided by Guangyuan DRC and from author's annual investigation and interviews since 2008.

[1] National average level is calculated according to the data from China's National Statistics Bureau.
[2] National average level is calculated according to the data from China's National Statistics Bureau
[3] National average level is calculated according to the data from China's National Statistics Bureau
[4] Data not available.

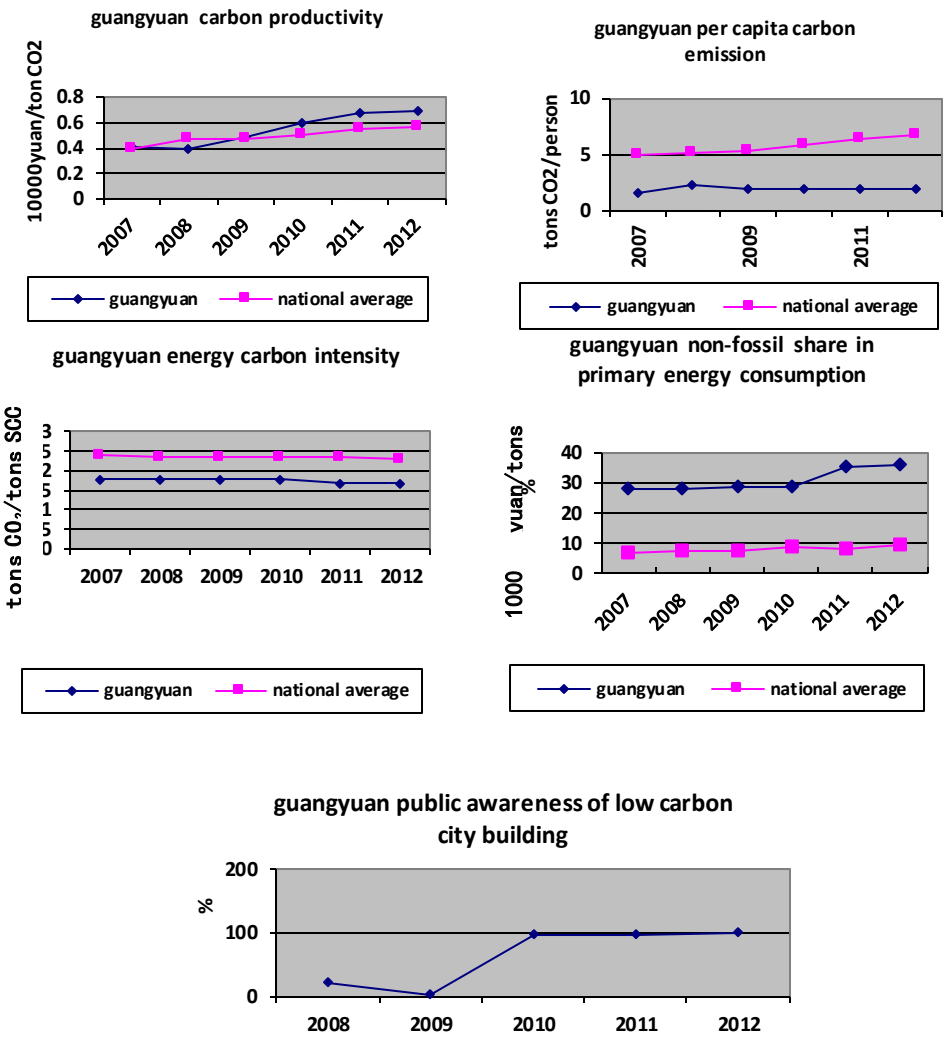

Fig.4. The main indicators of Guangyuan low carbon development

However, Guangyuan's per capita carbon emission is inevitably undergoing a gradual increase due to the promotion of citizens' living standards from a very low level. As in some remote village in Guangyuan, there was still no electricity supply. With the progress of industrialization, electricity was provided and rapidly followed by the use of electrical appliances. Therefore there would be an increasing demand of energy consumption with carbon emission. The public awareness of low carbon development in Guangyuan city was also reassuring. According to the annual observations on local residents, the result of 2008 was only 3.1%, but it went up to 95% in the year 2010 and 97% in 2011, 100% in 2013 respectively. Guangyuan is heading its way to low carbon development. As a result, Guangyuan was awarded China's Ten Outstanding Low Carbon Cities in 2011 and China's Leading Low Carbon City in 2013. Guangyuan

citizens felt proud of their low carbon initiative and good air quality "There are 365 days of good air quality in one year. We can enjoy the fresh air and then the life"[1].

3. What Made Guangyuan's Low Carbon Surprise?

It was a puzzle why Guangyuan took the low carbon initiative and what led to its satisfactory result. The prevailing answer was that Guangyuan gained enough assistance and fund during its post-earthquake reconstruction period[2]. However, this answer was proved incomplete: first, many neighbor cities (hit by earthquake) gained assistance and fund as well as or even more than Guangyuan, but they didn't adopt low carbon approach at that time. And some pilots had more low carbon resources than Guangyuan but without manifest corresponding outcomes. Considering that Guangyuan represents the less developed cities in western China, it's necessary to seek the answer in order to gain possible experiences for other cities.

3.1 Methodology and case selection

We introduced the multi-case comparison and sequential game to examine Guangyuan's low carbon potential and political willingness. We chose Deyang and Hanzhong as the reference set of comparison due to three considerations: first, they hold the similar natural low carbon endowment. Guangyuan, Deyang and Hanzhong are neighbor cities with similar natural resources; second, they are all Wenchuan earthquake victim cities who gained similar counterpart assistance and funds supports; third, the two reference cities are of different kinds, as Hanzhong which is in Shanxi province (the first batch low carbon pilot province) represents the majority of low carbon pilots, while Deyang represents the well-developed cities. The first step is to compare the low carbon development potential between the cities on technological and natural endowments according to Kaya equation, then to explore Guangyuan's motivation of low carbon initiative; the second step is to look at the strengths, weaknesses, opportunities and

[1] Interview with Ms Sun, a 59-year old lady in Shanghejie low carbon community, Lizhou district, Guangyuan, April, 2013.
[2] According to the interviews and the media reports, such as Huaxi Metropolis Daily and Sichuan Daily. http://www.sc.gov.cn/hdjl/xwfbh/zzqhfcj/bqbd/201007/t20100707_985835.shtml.

threats of Guangyuan's low carbon development compared with the two reference cities; the third step is to introducing the sequential game to discuss the main drivers of Guangyuan's low carbon initiative and achievements based on the investigation and in-depth interview.

3.2 What impelled Guangyuan to take the lead in low carbon initiative?

Comparing with its neighbor cities, from the low carbon potential perspective, Guangyuan was not a gifted city.

According to Kaya equation[1], the CO2 emissions will be impacted by energy mix, energy intensity, income level and population. Among these factors, energy intensity improvement plays the most important role in reducing CO2 emissions in a short term (Tatsuya et al., 2009). It is expressed as the equation below:

CO2 emission=population* (gross world production/population)* (gross energy consumption/gross world production)* (CO2 emission/gross energy consumption)…(1)

"Gross energy consumption/regional GDP" reflects energy efficiency, while "CO2 emission/energy consumption" reflects energy structure. While the carbon sink is not taken into consideration in the equations above. However, forest and reforestation are looked as an important measure in many pilot cities and also a part of China's climate policy actions. If take forest carbon sink into account, (1) can be converted into regional level as:

Regional CO2 emission=regional population* (regional GDP/regional population)* (gross energy consumption/regional GDP)* (CO2 emission/energy consumption)－(forest + reforestation) * (CO2 sink/forest stock)……(2)

Therefore, according to the equation above, given a certain period of time (2012), we can look into a city's low carbon potential based on the following factors:

A, potential of energy efficiency upgrading (lowering the energy intensity of the economy), which is measured by energy use per unit of GDP, its potential could be

[1] Kaya, Yoichi. "Impacts of carbon dioxide emission control on GDP growth: Interpretation of proposed scenarios," paper presented at IPCC Energy and Industry Subgroup Response Strategies Working Group, Paris, France, 1990

examined by the access to the low carbon technologies which is determined by local technological level (A0), the number of patented technology applications (A1) and human resources (education level, A2) and willingness to pay (R&D investment, A3);

B, potential of energy structure optimization (lowering the carbon intensity of the energy use), measured by CO2 emission per unit of energy use, depended on the proportion of the clean energy (B1) and access to the clean energy (B2);

C, carbon sink, measured by forest rate (C1) and reforestation effort (C2);

D, economic level, measured by regional GDP per capita

Table 3 shows the main indicators of low carbon development potential of the three cities. The comprehensive index of technological progress is considered as the most important factor to measure the technological level. As only Deyang and Guangyuan had issued their data of 60.96 and 40.4 respectively in 2012, so here the amount of patented technology applications and college-level population are used as supplementary. And the proportion of R&D expenditure in GDP is used as index of local willingness of paying for technology, while GDP per capita can be considered as an indicator of capacity to pay for the technology. As Table 3 shows, Guangyuan lags behind its reference cities according to the most indicators of low carbon potential.

Table 3. The main indicators of city low carbon potential

(Guangyuan, Deyang and Hanzhong, 2012).

	A				B		C (%)		D
	A0 (%)	A1	A2 (‰)	A3 (%)	B1	B1	C1	C2	D(￥) Thousand
GY	40.4	548	49.97[1]	1.3	36.1	45	54	57	18.67
HZ	/	769	62.79[2]	1.4	/	/	58.18	65+[3]	22.61
DY	60.96	2108	62.34[4]	2.91	/	/	38.5	50+[5]	35.94

Source: calculated according to the original data from the city government portal website, unless noted.

[1] The main data bulletin for the sixth nationwide population census (Guangyaun), 2013.
[2] The main data bulletin for the sixth nationwide population census (Hazhong), 2013.
[3] Hanzhong Ecological Building Outlines, Hanzhong Municipal Government, January, 2013.
[4] The main data bulletin for the sixth nationwide population census (Deyang), 2013.
[5] The General Planning for Deyang Urban Development 2008-2020, as of March 2011, from http://wk.baidu.com/view/a79a28bc960590c69ec376bc?pcf=2#page/1/1392053290922.

As Fig.5 shows, Deyang, ranks the leading position of comprehensive level of technological progress, 18% much higher than the provincial average level. Its number of patented technology applications was 2108 in the year of 2012, and Hanzhong and Guangyuan were 769 and 548 respectively. Considering the population difference, the patented technology applications per million residents of Deyang, Hanzhong and Guangyuan in 2012 were 587.19, 225.51 and 220.08 respectively. The college education level in Guangyuan was also much lower than the other two. Their R&D expenditure intensity accounted 1.3 (Guangyuan), 1.4 (Hanzhong) and 2.91 (Deyang).

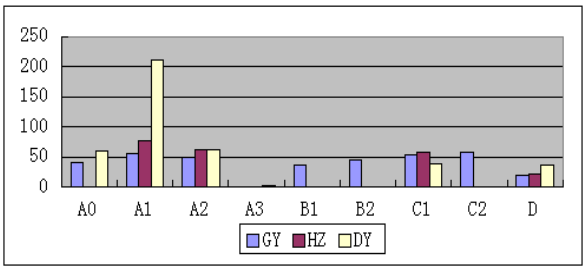

Fig.5. A brief comparison of low carbon potential between GY, DY and HZ

Before its low carbon initiative, Guangyuan's energy efficiency was relatively low compared to the national and provincial average level. A large part of industries in Guangyuan were energy intensive and with high growth rate of pollution and carbon emission, especially its seven key industries (energy, non-ferrous metal smelting, mechanics and electronics, building materials, medicine chemistry, textile, food and beverage processing) which contributed 93.2% of the total industrial added value in 2008. As Table 4 shows, in 2008 Guangyuan's unit GDP energy consumption was 1.186 tce/10,000yuan, higher than the national average level of 1.102 tce/10,000yuan, but lower than Sichuan provincial average level of 1.381 tce/10,000yuan. Guangyuan's energy consumption per unit industrial added value in 2008 was 3.54 tce/10,000yuan, much higher than the national average level of 2.189 tce/10,000yuan and provincial average of 2.477 tce/10,000yuan.

Table 4. Guangyuan's energy consumption indicators compared to national level and neighbor cities in the same province (2005-2008).

	Unit GDP energy consumption (tce/10,000yuan)				Energy consumption per unit industrial added value (tce/10,000yuan)			
	2005	2006	2007	2008	2005	2006	2007	2008
Guangyuan	1.29	1.263	1.207	1.186	4.11	3.93	3.64	3.54
National average	1.22	1.2	1.16	1.102	2.59	-	-	2.189
Sichuan provincial average	1.53	1.498	1.432	1.381	2.94	2.82	2.62	2.477
Ya'an City	1.2	1.178	1.128	1.097	2.69	2.54	2.37	2.29
Bazhong City	0.91	0.886	0.85	0.822	3.22	3.09	2.89	2.62
Ziyang City	1.13	1.121	1.074	1.016	1.7	1.65	1.53	1.37

Source: data from Sichuan's unit GDP energy consumption of all cities (2005-2008).

Even compared with its three neighbor cities with similar economic situations (Ya'an, Bazhong and Ziyang), as Fig.6 shows, till the year 2008, Guangyuan's unit GDP energy consumption was still much higher, and so was the energy consumption per unit industrial added value.

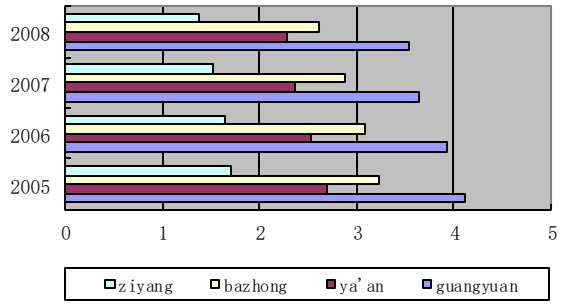

Fig. 6. Guangyuan's energy consumption per unit industrial added value compared with its neighbors in the same province.

Source: data from Sichuan's Unit GDP energy consumption of all cities (2005-2008).

While when the natural low carbon endowments are involved, Guangyuan shows good potential as its large forest stock was of 54% in 2012 and it has an ambitious reforestation planning of 57% by the year 2020. Hanzhong held the highest forest rate in 2012 of 58.18% with an eight-year plan of more than 65% by the year of 2020, Deyang was 38.5 with a plan of more than 50%, and Guangyuan was in between. Guangyuan is rich in clean energy, such as resident biomass, natural gas, hydro-power, resident solar system, wind-solar combined system appliance and geothermal energy in

practice. However, Hanzhong and Deyang are also abundant in clean energy resource as the three cities were all in the same geologic plate with similar geothermal energy stock, as well as the same latitude and climate zone with solar energy resource.

As analyzed above, although Guangyuan is rich in low carbon natural endowments, it has no comparative advantages compared to Hanzhong, its neighbor low carbon pilot city; on the contrary, Guangyuan was at a disadvantage status of low carbon potential with regard to the technology, human resource and economic capacity. It means that the technological, economical and natural endowments could not give the right explanation for Guangyuan's low carbon initiative and sound result. Comparing with Deyang and Hanzhong, Guangyuan lagged behind in technologies, human resources and funds. As an undeveloped and remote area, there was inertia of the old development mode which was somehow hard to be got rid of in a short time. Although the post-earthquake assistance was an important factor, it's not a determinant, since the other low carbon pilot as Hanzhong, and the neighbor city Deyang were also the receiver of the post-earthquake assistance, but they haven't made the sound result of low carbon development.

Being located far away from the provincial center (Chengdu city), Guangyuan was historically marginalized in Sichuan province in terms of policy support and incentives, and Guangyuan was not included in "Chengdu-Chongqing Economic Zone"[1]. Therefore neither its economical nor geological conditions could provide Guangyuan favorable incentives for investors as other neighbor cities did[2].

So what drove Guangyuan to take the lead in low carbon initiative despite of its backward situation and relatively weaker low carbon potential comparing with its reference cities? The sequential game provided us a reasonable explanation. The main driver originated from Guangyuan's possible payoff in the sequential city game[3] if it

[1] Consequently, with the marginalized and backward situation, in order to attract more investment and industries to emigrate in from developed areas, Guangyuan government used to provide preferential policies, including preferential land use policy and preferential tax policy as main incentives for the investors, but neglect the potential carbon emission and other pollution. As a result, 44 large (with investment larger than 100 million yuan) industrial companies moving in Guangyuan at the early stage of post-earthquake recovery were with higher energy consumption than the local existing industries. To ban them was a difficult trade-off between the economic growth and emission reduction.

[2] According to the interviews with cadres in Guangyuan Merchants promotion Bureau, 2009.

[3] The cities in the same province usually are in a fierce competitive relationship, including GDP.

took measures on low carbon issue. Guangyuan had no any opportunities to win the city game due to its disadvantages since it lagged far behind other cities in Sichuan province with regard to technological, financial and human resources. However, if Guangyuan took the lead in low carbon rebuilding but other cities not, it might have 50%+ possibility of win (this generally implies support from upper level and upgrading its city reputation[1]). And Guangyuan knew well that the other cities would not (because low carbon was not the favorable policy at Sichuan provincial level during that period)! In fact, before Guangyuan made its choice, the other earthquake-damaged cities had already taken their decision of business-as-usual[2]. Therefore, it was a sequential game.

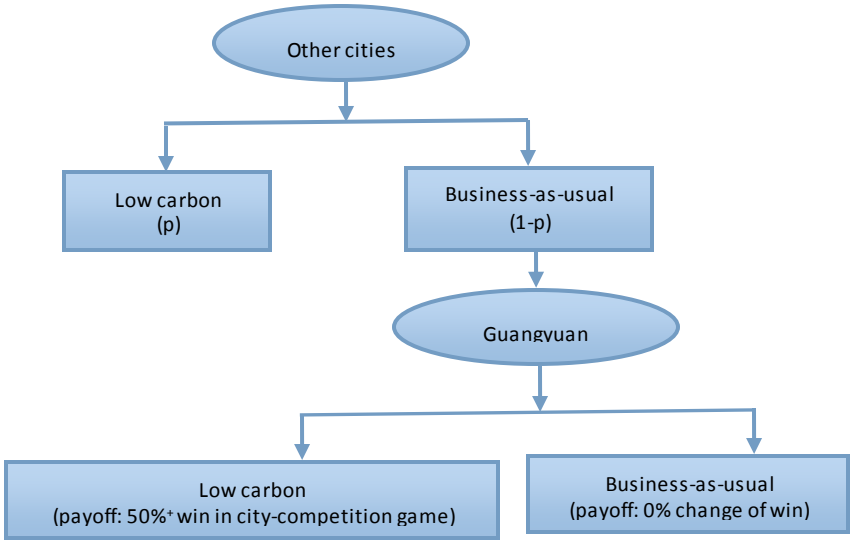

Fig. 7. Game tree of Guangyuan's response in sequential city-competition strategy.

See Fig.7. As the other cities had already continued their rebuilding in a mode of business-as-usual, the possibility of their low carbon choice (p) was 0%, while the possibility of business-as-usual was 100% *(1-p). So, obviously, this left Guangyuan two choices: business-as-usual or low carbon initiative. Low carbon was a double-faced sword, if succeed, it would bring Guangyuan reputation, fund and policy support, while if failed, Guangyuan would be more awkward. Given the global low carbon development trend, we could roughly give the 50% + possibility on its success.

[1] Before 2008, Guangyuan was a remote poor place almost unknown to outside world.
[2] It means that economic recovery and GDP growth are the overwhelming targets but other than low carbon development.

However if Guangyuan chose business-as-usual, it would certainly be a loser in city-competition game as it always did (0% possibility of win)! No doubt, for Guangyuan, a poor city without any advantages in GDP race, low carbon approach was its dominant strategy! This provided Guangyuan a great impetus to take the lead in low carbon initiative.

Mainly driven by the city game, Guangyuan policy maker decided to set up a low carbon industrial cluster. Consequently, Guangyuan cracked down 97 above-scaled carbon intensive factories till late 2009, and refused almost all the carbon intensive aid projects[1]. To deploy the low carbon policy action, Guangyuan government urged all the existing industries to upgrade their energy system, such as using natural gas instead of coal which required quite a lot financial support from Guangyuan governmenta[1] side. Guangyuan local government ever set up a low carbon fund in 2009 to provide subsidy or bonus to the enterprises that completed the energy transformation from coal to natural gas. In order to form a low carbon energy supply system, Guangyuan cut off 59 existing coal power plants. It tried to promote household natural gas, household solar system, biogas, wind-solar combined system and other renewable energies with governmental funds.

3.3 How did Guangyuan make its low carbon surprise?

The sequential city game provided us the main impetus for Guangyuan's strong political willingness to take the lead in low carbon initiative, but it could not give us a reasonable explanation for Guangyuan's low carbon achievement. In order to find out its main determinants, we made a SWOT analysis on Guangyuan's low carbon rebuilding and development based on the on-the-spot investigation, and did a questionnaire survey along with the in-depth interview with local officials, cadres and citizens in Guangyuan and its reference cities.

By SWOT matrix, we can take a close look at its strengths, opportunities, weaknesses and treats as regard to the low carbon development. As shown in Table 5, we can find five main features which made up for Guangyuan's weaknesses and threats

[1] Guangyuan DRC, 2009.

which retarded its low carbon process. On the other side, six internal strengths and external opportunities were the main contributors to low carbon prospect, known as strong political willingness, effective governance network, low carbon embodied official evaluation system, and feasible policy actions, which pushed forward Guangyuan's low carbon development as internal drivers. At the same time, technical spillover effect, multi-faceted support, national climate protection initiative and market preference to low-carbon products provided a strong external support.

Table 5. SWOT matrix of Guangyuan low carbon rebuilding and development.

	Strength（S）	Weakness（W）
Core factors：	S1. political willingness S2.low carbon embodied evaluation system S3. effective governance network S4.workable policy actions S5.citizens' acceptance S6.low carbon natural endowments	W1. multiple-task stage, specially the urgent demands of rapid economic growth for recovery would cause the emission surge; W2. backward in technology and human resource W3. inertia of the old development approach W4. lack of fund; W5. carbon intensive industries as economic mainstay
	Opportunity（O）	Threat（T）
Derived factors：	O1. technical spillover effect O2. multi-faceted support and cooperation after earthquake O3. national climate and environmental protection initiative O4. Market preference to low-carbon products	T1. GDP oriented evaluation system for official performance (municipal level); T2. competition of GDP growth and investment attracting with other cities T3. marginalized regional status; T4. without the acknowledgement nor support from its provincial level

Source: from the survey by on- the-spot investigation.

This was confirmed by our further in-depth interview and questionnaire survey. According to the 90 valid questionnaires[1], to the question "What do you think are the most important contributors to Guangyuan's low carbon rebuilding and development? (multiple choices)", there were twenty-four different answers, among which seven options repeated above 30 times (see Fig. 8), as follows[2]:

Leaders group's strong willingness of low carbon development;

[1] It was made in April 2013, most questionnaires were delivered within Guangyuan, the other few were in Bazhong, Hanzhong and Deyang

[2] It's interesting that, most officials were indifferent with low carbon endowments, while citizens preferred low carbon endowments as the second choice. However both officials and citizens took strong willingness as their most frequent answer.

Low carbon embodied evaluation system;

An effective multi-level governance network;

Post-earthquake assistance;

Feasible policy actions;

Citizen's increasing acceptance;

Low carbon endowments.

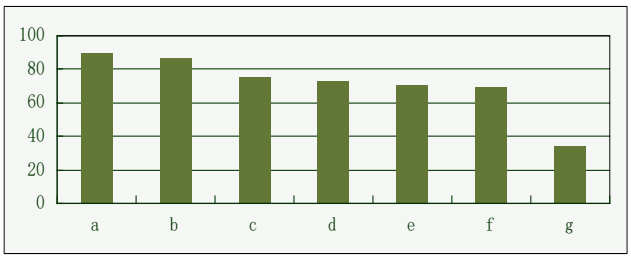

Fig. 8. The most important advantages/support for Guangyuan's low carbon development.

Source: drawn from the survey made in April 2013.

Among the questionnaire respondents, 93% of the citizen selected natural endowments as a dominant factor of Guangyuan's low carbon surprise, while none of the officials did that. Instead, the official respondents only listed it as an ordinary factor. That's because officials had more knowledge about the fact that natural endowments were not Guangyuan's comparative advantage, although Guangyuan was abundant in a variety of clean energy resources such as natural gas, hydro, solar and geothermal, etc.[1] In the same way, the post-earthquake assistance and citizen's increasing acceptance were essential, but not the overwhelming factors. On-the-spot investigation based on SWOT analysis, depth-interview and questionnaire survey proved political willingness,

[1] According to Guangyuan Statistics Bureau, it held a potential hydro power of 290MW, and a natural gas reserve estimated to be 5 trillion m^3 in 2009. Currently installed capacity for hydro power and thermal power totals 900MW, and the capacity predicted to exceed 3000MW by 2015。Guangyuan has a large reserve of natural gas as confirmed by China Petroleum and Sino PEC. Furthermore, the fluent biomass resources also provide Guangyuan a potential for biogas development. Moreover, Guangyuan has a remarkable carbon sink. Its forest coverage rate in 2007 was 47.2%, 2.2% higher than that specified in the national eco-city standard. According to "Guangyuan Forest-city Plan", Guangyuan's forest coverage rate will reach 57% by 2020. Given the fact of culture and historical heritages, and natural resorts, Guangyuan was provided a rich resource to form a clean energy supply system and establish a low carbon industrial cluster, such as gardening, tourism and cultural business.

effective governance network and low carbon embodied official evaluation system as three dominant factors.

All the interviewees looked political willingness as a key factor of Guangyuan's low carbon surprise. Due to China's administration feature, most of the policy decisions were made by a top-down approach. That is to say, only if the leaders group holds the willingness, could the low carbon policy come into being and be put into practice. With the strong political will of leaders group, Guangyuan became more strategic and forward-thinking to pursue its low carbon development after the earthquake. In late 2008, Guangyuan municipal government confirmed low carbon development as its overwhelming strategy and embarked on its ambitious plan and specified goal to achieve its low carbon recovery and development. At that time, an effective multi-level governance network was formed to ensure the implementation of the low carbon policy actions.

As regard to the implementation of the policy actions, the in-depth interview (with the local officials and cadres who were in charge of the low carbon deployment) showed, 100% of the interviewee confirmed the evaluation system considered as the "work bible". At that time, within Sichuan province, only Guangyuan city combined its evaluation system for official performances with the low carbon index which was used to make assessment for the officials from county level till to the town and village levels.

This low carbon embodied evaluation system was matched closely to its multi-level governance network. As shown in Fig. 9, adjunct to this network, the low carbon tasks assigned by municipal level with a certain value were allocated to different districts or counties, then the same way from the district or county level to the town level and then till to the community or village level. The sub-level was responsible for the deployment according to the assigned plan, while the upper level made assessment for the lower level according to their work performance. If it's fulfilled, the cadres in charge would win the official competition through the evaluation system and have opportunity to be promoted, or vice versa[1]. Through this network and evaluation system,

[1] Interview with Zhang Deqiang, Guangyuan municipal organization department, April, 2012.

the low carbon preference at Guangyuan city level was definitely passed on level by level till to the lowest one. This domino effect of low carbon preference drove all the cadres in Guangyuan city to attach the priority to low carbon actions.

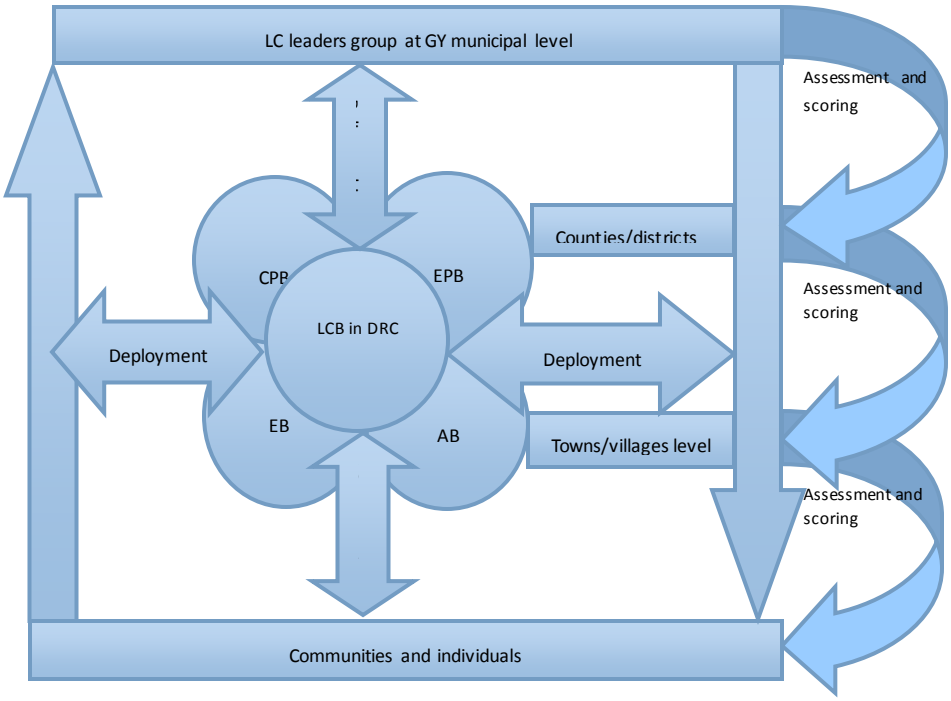

Fig. 9. Multi-level governance network for low carbon development.

CPB: construction and planning bureau, EPB: environmental protection bureau, AB: agriculture bureau, EB: economic bureau, LCB: low carbon bureau.

The low carbon leading group with a special agency (low carbon bureau, LCB) acted an important role in the governance network. It was adjunct to the development and reform committee (DRC). In order to ensure the full deployment of low carbon actions citywide, both the secretary of Guangyuan municipal committee of the CPC and the mayor joined the leaders group and took the charge, working together with the directors in different departments related. LCB had the authority to recommend the other agencies if concerning low carbon issues, moreover, it can coordinate with the organization department, involving the official evaluation process in order to inspect the implementation of low carbon policy.

As Fig.9 shows, at the horizontal dimension, the special agency LCB acted as a hub which coordinated the different agencies and stakeholders to address the low carbon issues. Five main functions should be emphasized in this network, known as

government-guided regulation and principle, market-stimulated approaches, enterprise responsibility, coordination among different agencies, vertical policy conduction and horizontal negotiation among different stakeholders, and low carbon factors embodied evaluation system. Executed by the director of Guangyuan city, the LCB would collect, analyze the data, and coordinate the authorities at different levels and different agencies, and also participated in decision making concerning low carbon issues as well. Under this framework, the cross-cutting policy actions and measures could be conducted and implemented more smoothly from city level till to the village level at a vertical dimension with "top-down" approach, and then, the response of the lower level could be conveyed as a feed-back by "bottom-up" approach. On the other hand, at horizontal dimension, the different demands and concerns of the different stakeholders could also be taken into consideration to ensure the justice. The joint work of vertical and horizontal dimensions ensured the policy and regulation to be feasible, acceptable and full discussed, this provided a basic framework of effective governance system including policy formation, conduction, and implementation as well as performance evaluation.

The critical importance lay in that all the low carbon related work was attached into the official evaluation procedure from county level till village and community level. This gave a critical impetus for the officials to engage themselves in low carbon city building.

In addition, feasible policy actions were important. The local features should be taken full consideration while making the policy design. Similar to other pilots, Guangyuan developed a series of guidelines and special policies to promote its low carbon development, such as "Guangyuan Clean Energy Development Plan" [1], "Guidelines for Promoting Clean Energy, Developing an Industrial Garden with Sustainable Economy and Achieving low carbon development", "Development Plan for Guangyuan's Industrial Garden with Sustainable Economy"[2], "Instructions for Low Carbon Community"[3]. Moreover it completed the roadmap of low carbon development

[1] Guangyuan DRC, 2008.
[2] Guangyuan DRC, 2008.
[3] Guangyuan Low Carbon Agency, 2009.

and set up "Low Carbon Achievement Fund". In order to ensure the feasibility and acceptance of the policy actions, all these were made based on the careful consideration of its local features. With the work of multi-level governance network, the low carbon policy actions and projects were provided with priority. All the low carbon pilot cities had their clear targets, guidelines and roadmaps. However, the significance was that Guangyuan merged its policy actions into its governance network, especially linked with its official performance evaluation system which strongly reinforced the policy implementation[1].

4. Conclusions and Policy Suggestions

As discussed above, comparing with its neighbor city and the other pilots, Guangyuan was at a disadvantage position and with many constraints. The main determinants of Guangyuan's low carbon achievement are strong political willingness, an effective multi-level governance networks and a low carbon embodied evaluation system for official performance rather than the technology, fund and human resource. Less developed cities could also solve its CO2 emission dilemma while pursuing economic growth, however, from Guangyuan experience, the following should be taken into full consideration:

At some degree, less developed city might have stronger political willing to take low carbon approach to better off in city game and official competition, which is the first fundamental driver to take low carbon actions. Considering the domino effect of preference, the rationality of the first leader of local government is critical important. A climate-friendly minded city leader is a fundamental factor of low carbon city building.

According to China's existing administrative features, "top-down" is the main approach in policy making and official performance evaluation process. Therefore, an effective multi-level governance network is critical essential. Guangyuan's low carbon policy actions are undergoing based on a multi-dimension framework. It gains both the efficiency and effectiveness as it provides the smooth conveying of response and

[1] According to the interview with the cadres and citizen, April, 2013.

debates from the different stakeholders in horizontal dimension and maintains the effective conduction of low carbon policy from the city level till to the village level in a vertical dimension. Guangyuan experience shows, in order to gain the support from the majority of citizen and ensure the justice, selecting a joint approach of "top-down+ bottom-up"(mainly by top-down in China currently) with a well-matched governance network is a feasible and fair-minded choice, as citizens' response and support is vital important to keep the low carbon actions acceptable and sustainable.

Guangyuan's low carbon surprise indicates that economic level, technology capacity and human resources are important factors for low carbon development, but not dominant conditions, less developed city can also take the lead in low carbon initiative and solve its CO2 dilemma. As such, less developed cities should be taken enough consideration into national low carbon development strategy.

As most of the less developed cities are still in a low-middle development stage, they have the combined tasks as urbanization, industrialization and living standards upgrading. This will cause even more demand of carbon emissions there than developed cities. Therefore, to avoid the carbon lock-in effect from a possible early stage in less developed areas is urgent. It's the right time to take low carbon transition at this stage to take the "late-mover" advantage.

Low carbon policy actions should tune up to the local features. It's necessary to analyze the low carbon potential and local features before strategies and policy actions making.

In addition, China's existing evaluation system for local officials puts too much stress on GDP[1]. This will badly undermine the officials' enthusiasm on low carbon development. That's why some low carbon pilots couldn't reach their expectation. It's urgent to attach the critical importance of low carbon factors into the official evaluation system[2], especially for the city level as it is the core unit of low carbon deployment[3].

[1] Within Guangyuan municipality, there are low carbon favorable evaluation standards for the local officials from county level till to village level, but for the officials at municipal level and above, the low carbon factors are still excluded.
[2] In August 2014, China NDRC issued that the carbon intensity should be taken account into the evaluation system at provincial and district levels, whereas it is still missing at a city level.
[3] According to the interview with the officials of China NDRC, July, 2013.

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