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2015 China Green Low-Carbon City scorecard

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Abstract

In China's rapid urbanization and industrialization, cities are playing important roles in helping the country reach its climate change mitigation goal of peaking CO₂ emissions around 2030, and improving environmental quality. During the 12th Five-Year Plan (12th FYP) period (2011–2015), Chinese cities set ambitious goals and implemented diverse policies aimed at transitioning to a greener economy. The Chinese central government also set targets on a number of indicators, such as economic energy intensity and carbon intensity (e.g., CO₂ per unit GDP), and air quality (e.g., PM_{2.5} concentration). These targets are helpful for tracking implementation of individual policies or progress at a sectoral level. However, a more comprehensive and integrated approach is needed to assess progress and capture the multi-dimensional aspects of Chinese cities' transition to a greener economy, an approach that offers comparison with international best practices, as well as working with data availability in China's statistical system.

This paper presents the development of a *China Green Low-Carbon City Index*² (CGLCCI, or *City Index*) and its application to 115 Chinese cities – the largest assessment of Chinese

cities to date. The CGLCCI includes 23 key indicators across seven categories: economy, energy, industry, buildings, transportation, environment and land use, and climate policy and outreach. This paper applied the CGLCCI to benchmark the green and low-carbon development status of 115 Chinese cities in the year 2015. Data for the analysis came from government and publicly available data sources. The CGLCCI methodology provides a standardized method to benchmark each indicator, calculate overall city scores, and rank the cities.³

The results showed that the low-carbon transition in Chinese cities is still in its early stages. Compared to the best practices benchmarks, the 2015 *City Index* scores ranged from a low of 28 to a high score of 70 in 2015 (maximum score is 100). This paper also presents three top-performing cities in different stages of development and discusses how their scores across the index categories. Creating a green low-carbon index that relies on publicly available data in China, and regularly evaluating city performance, can encourage Chinese cities to learn best practices from each other, and to strengthen their goals and implementation efforts toward a green low-carbon transition.

Introduction

China has seen rapid economic growth, industrialization, and urbanization over the last 30 years. However, Chinese cities are now struggling with increasingly serious environmental pollution and the need to reduce large-scale burning of fossil fuels

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2. The term "low-carbon" means reducing emissions of the greenhouse gases carbon dioxide (CO₂) and methane (CH₄), with a focus on energy-related CO₂. The term "carbon" is used as short-hand for these GHGs throughout the paper. The term "green" recognizes multiple environmental parameters related to urbanization and climate change: air quality, water use, solid waste, transport networks, and urban green space.

3. Further details on the *City Index* methodology, its application to 115 Chinese cities, and analysis of trends over time (2010–2015), are available in Chinese and English reports from iGDP and LBNL in Spring 2017.

and mitigate climate change. China, as the world's largest emitter of CO₂, takes climate change seriously and is relying, in part, on policies in cities to implement and enforce a range of low-carbon measures.

Transitioning to a greener and low carbon economy is a key component of China's ecological civilization construction and has been incorporated into various national strategies. For Chinese cities during the 12th FYP, "green" efforts are reflected in multiple environmental parameters related to urbanization and climate change, including air quality, water use, solid waste, transport networks, and urban green space, and so on. "Low-carbon" efforts mainly focus on reducing emissions of energy-related CO₂. In 2013, State Council of China released Action Plan for Air pollution Prevention and Control covering three key regions and 10 city clusters. It laid out targets for coal consumption caps and energy structure transformation. Most of the cities issued their own action plans and roadmaps to curb air pollution. In addition, during the 12th FYP period, China launched 42 low-carbon pilots in six provinces and 36 cities, covering a wide range of geographic locations, resource conditions, economic characteristics, industrial and energy structure. These pilots have developed and implemented policies, programs, and measures to achieve low-carbon targets at the local level.

It is necessary to measure and report Chinese cities' status on progress and processes of the transition to a greener economy, in order to identify potential areas for improvement and identify top-runners to motivate their peer cities. Even though central and local governments have set single macro-level indicators, such as energy/GDP and CO₂/GDP, and reduction targets for key pollutants. China still lacks an index that offers comparison with international best practices, as well as suiting Chinese conditions, such as data availability, city resources, and economic and institutional features.

The main purpose of this study is to create an index to track the status of the transition to a greener economy. The remainder of the paper is organized as follows, section 2 introduces a brief literature review on international and Chinese low carbon city indicator systems. It is then followed by section 3 methodology. Results and discussion are presented in Section 4 including a discussion of the current situation for all selected cities and an analysis on three top-performing cities based on city groupings. The paper then concludes that CGLCCI Index is proven helpful to learn about the progresses and gaps in achieving low carbon targets in Chinese cities, lessons are concluded for cities to encourage peer learning in transitioning to a greener and low-carbon future.

Literature Review

There are several international indicator systems that compare green or low-carbon features of cities around the world. Williams et al. (2012) and Zhou and Williams (2013) reviewed 9 international low-carbon eco-city ranking systems and 7 non-ranking systems. They summarized that majority of indicator systems include common indicators of carbon intensity, energy intensity, building energy use, water consumption intensity, waste generation, waste recycling, measures of extent of transportation infrastructure, transport modes, employment, public green space, population density, health and education.

In China, there are several official indicator systems developed by some agencies at the national level, including "National Ecological Civilization Construction Indicators System", "Green Development Indicators System" and "New Urbanization Pilots Indicators System" developed by the National Development and Reform Commission (NDRC); "New Energy City Pilots Indicators System" developed by the National Energy Administration (NEA); "Regional Green Industry Transformation Pilots Indicators System" developed by the Ministry of the Industry and Information Technology (MIIT); and "Public Transport Metropolitan Pilots Indicators System" developed by the Ministry of Transportation (MOT). These indicator systems have significant variance in the conceptual framework, because these agencies only evaluate some concerns of green low carbon dimensions within their jurisdiction. These indicator systems have difficulty delivering a comprehensive evaluation of a city's green low-carbon progress.

Chinese research and academic institutions have also developed their own sets of indicators to capture and measure various green or low-carbon dimensions of cities, and they follow different methodological approaches (Tan et al., 2015). Zhuang et al. (2014) designed a city low-carbon development evaluation system with 10 indicators from four categories: low-carbon production, low-carbon consumption, low-carbon resources and low-carbon policies. Shi et al. (2013) used a city green development indicator system to assess 83 cities. In addition, some studies used city-specific indicator systems (Lei 2012; Wang et al., 2010; Fu et al., 2010; Lu et al., 2011; Chu et al., 2011). These indicator systems only focused on a single objective of evaluating environment conditions or only emphasized a single objective of carbon emission reduction. There are currently few studies using a composite index in the conceptual framework of green and low carbon city and considering international best practices for benchmarking and ranking cities.

Overall, in comparison with international indicator systems, Chinese indicatory systems are less systematic or robust in their methodology. However, international indicator systems often miss key components of the current Chinese conceptual framework on green low-carbon development strategy. For example, international city indices typically do not include the industrial sector, yet urban industry still plays a major role in energy consumption in Chinese cities. In addition, the scope of recorded statistics is different in China and abroad, therefore many international indicator frameworks face data gaps in Chinese cities. Therefore, this study presents a new *City Index* to examine energy use and carbon emissions of more than 100 Chinese cities, along with environmental and socio-economic indicators. The selected indicators have data available in China's statistical system, and the *City Index* can be easily implemented and better reflect the Chinese policy context.

Methodology

The methodology section consists of three parts: index structure, selection and grouping of cities, and data collection and processing. The index structure includes the process for developing the *City Index* system, covering the selection of categories and indicators, selection of benchmarks, weighting and maximum scoring, and standardising and performance scoring.

INDEX STRUCTURE

Selection of Categories and Indicators

The basic principles for the selection of index framework follow the definition of a green and low-carbon city, as well as common international practices and considerations of data availability in Chinese cities. This indicator system structure is largely based on the *Eco and Low-carbon Indicator Tool for Evaluating Cities* (ELITE Cities tool) developed at LBNL (Zhou, He, Williams, & Fridley, 2015), which applied an indicator evaluation criteria called SMART. In SMART framework the indicators should be specific, measurable, achievable, relevant, and timely (Doran, 1981). The majority of the indicators selected are quantitative, with exception of a few qualitative indicators on policy development. Sustainability scholars often note three primary categories: environmental, economic and social. Similar to many international studies, this index encompasses four primary categories: economy, energy and carbon, environment and land use, and climate policy and outreach. The 23 indicators were chosen in secondary category, with the consideration and compromise of key low-carbon city features and Chinese data availability.

Generally, there is a lack of commonality of indicators in sub-category. Many efforts were made to ensure that in each sub-category indicators can sufficiently resemble each other and share common goals to address particular issues. For example, in economic health category, the economic structure indicator such as the GDP share of tertiary sector was not selected. The reason behind the consideration was that it is not feasible to have a consistent economic structure among low carbon cities, despite that higher GDP share of tertiary sector usually results in less CO₂ emissions. The data for transport and building sectors are usually more challenging to collect than other sectors in China, therefore these indicators are designed to take into account of specific Chinese statistical characteristics. In transport category, ideally mode share or land use pattern could better reflect the infrastructure that is supportive for low carbon commute behaviours. Instead, the selected indicators had to be based on Chinese statistical yearbook and they are not used elsewhere. In building category, a common international indicator is to use building energy intensity (primary/final energy use/m²). In this index, a per capita intensity unit was replaced due to the inaccessibility of building area data in many Chinese cities. In environment category, a common indicator for solid waste management in China is to use “municipal solid waste treatment rate”, however, most of these treatments are dominated by unsustainable landfill or incineration. A consumption-based indicator can better reflect a low carbon way of handling of solid waste.

Benchmark Values

In a similar vein, the selection of benchmark values should ideally reflect international best practices. When this goal is difficult to achieve due to issues such as data limitation, alternatively the benchmark values are defined as 20 % better than the top 10 best-performing cities in China. As a result, the benchmark setting in the *City Index* has a mix of approaches, with CO₂ emissions per capita and per GDP, non-fossil fuel share, green building share, PM_{2.5} concentration, and municipal water consumption per capita based on international

best practices.⁴ More details of the indicator framework and benchmark values can be found in Table 1.

Weighting and Maximum Scoring

This *City Index* is designed to provide an overall score for cities based on their performance across all the indicators. A common international weighting scheme practice is to assign different or equal weighting to primary categories, and then indicators in different primary categories are assigned differing weights in determining a city's overall score. This results in the creation of a consolidated overall score, in order to rank cities against each other. The primary categories receive differing weighting, based on the assumption that it is insufficient to only focus on carbon emissions in order to achieve low carbon city goals. Economic transition and environmental sustainability also play important roles in examining the current low carbon city progress. The primary categories of the *City Index* – economy, energy and carbon, environment and land use, and policy and outreach – received 20 %, 50 %, 20 % and 10 % weighting respectively, based on policy priorities and expert interviews. The energy and carbon category is further divided into secondary categories – energy and power, industry, transportation, and building sectors – receiving 36 %, 36 %, 12 % and 16 % weighting, based on the share of each sector's final energy use in national total in 2015 (Khanna et al. 2017). In other primary categories, each indicator receives equal weighting.

A practical way of doing the scoring is to assign a maximum score of 100 for the sum of all indicators, and each indicator receives certain points based on the assigned weighting score. The following formula shows how to calculate the maximum score for each indicator:

$$S_i = 100 * w_i$$

in which

S_i maximum score for indicator i

w_i weighting for indicator i , $\sum_{i=1}^n w_i = 1$ and $0 \leq w_i \leq 1$

i indicators 1, ..., n, and n: number of indicators (currently n = 23)

Standardising and Performance scoring

The research team normalized the data collected to remove outliers. Great effort was also put to ensure data quality from various sources. Quantitative indicators were divided into direct indicators (the higher the indicator value, the better the performance) and inverse indicators (the lower the indicator value, the better the performance).

For direct indicators, if the value is below the benchmark for that indicator, the score was reduced in proportion to the difference. If the value was higher than the benchmark, a maximum score was assigned to the indicator.

4. Among these best practices, it was challenging to determine the benchmark level for municipal water consumption indicator. Unlike other indicators, the water consumption level should fall into a range. In addition, because minimum water resource availability is needed for survival and sanitary purposes, there is a minimum limit set for sufficiency. To simplify the data processing, this index applied 60 L/capita/day as the benchmark for the water consumption indicator, based on the above consideration and baseline on WHO guidelines (excluding the share of water for growing food).

Table 1. The CCGLC Index: Categories and Indicators.

Category	Indicator (Unit)	Benchmark value	Weighting	maximum scoring	
1. Economy					
Economy	(-) Energy Intensity (tce/RMB 10,000, 2005 prices)	0.23	20 %	10	
	(-) Carbon Intensity (kg CO ₂ /RMB 10,000, 2005 prices)	0.32		10	
2. Energy & Carbon					
Energy	(-) CO ₂ emissions per capita (tCO ₂ /capita, annual)	2.4	50 %	36 %	6
	(-) Primary energy consumption per capita (tce/capita, annual)	2.8			6
	(+) City non-fossil fuel share of primary energy (%)	20 %			6
Industry	(-) Industrial energy intensity (tce/RMB 10,000)	0.27	36 %	9	
	(-) Heavy industry share of industrial GDP (%)	29 %		9	
Transportation	(+) Public transportation vehicles (vehicles/10,000 people)	26.4	12 %	2	
	(+) Extent of urban rail transit lines (subway, light rail) per urban area (km/km ²)	0.04		2	
	(+) Utilization of buses and trolley buses (trips per capita, annual)	308		2	
Buildings	(+) Green buildings share of new buildings in city plans (%)	100 %	16 %	2	
	(-) Residential energy consumption per capita (kWh/capita, annual)	4,743		3	
	(-) Commercial energy consumption per employee (kWh/employee, annual)	6,576		3	
3. Environment & Land Use					
Environment	(-) Municipal solid waste per capita (ton/yr/capita)	0.31	20 %	3	
	(+) Blue sky days (% , annual)	100 %		4	
	(-) PM2.5 concentration (annual average, µg/m ³)	10		3	
	(-) Municipal daily water consumption per capita(L/capita /day)	60		3	
	(+) Environmental spending as share of city budget (%)	3 %		3	
Land use	(+) Green space per capita (m ² /capita)	100		4	
4. Climate Policy & Outreach					
	City low-carbon development/climate change plan	Yes	10 %	2.5	
	City strategy (above national targets) on renewable energy	Yes		2.5	
	City climate change resilience/adaptation plan	Yes		2.5	
	Public outreach on low carbon consumptions/lifestyles	Yes		2.5	

Note: (+) indicates the indicator is positive (higher values are better), while (-) indicates the indicator is negative.

$$I_i = S_i (X_i / Bi)$$

For inverse indicators, if the value was higher than the benchmark, the value was reduced in proportion to the difference. If the value was lower than the benchmark, the maximum score was assigned to the indicator.

$$I_i = S_i (Bi / X_i)$$

In which,

I_i score of indicator i , indicating its performance relative to the maximum score

X_i actual value for indicator i

Bi benchmark value for indicator i

The total Index score for each city was calculated with the following formula:

$$IN_j = \sum_{i=1}^n I_i$$

Where

I_i the score for each indicator i , and

IN_j the total Index score for each city j .

For example, the standardized benchmark of transportation energy use per capita receives 2 points ($100 * 50 \% * 11 \% / 3$), therefore the performing score of this indicator is 2*benchmark level/actual performance (inverse indicator). The final score of the city CGLCCI is the sum of the performing scores of each indicator.

SELECTION OF CITIES AND GROUPING

There were 115 cities analyzed in this study. These include the top 100 prefecture-level and above cities ranked by urban population size. In 2015, together they contributed 74 % of the national GDP; their population was 52 % of the national population, while energy consumption accounted for 58 % of the national total. The cities selected are very diverse, with varying population sizes, urbanization and income levels, economic development conditions, and industrial mixes. These features are important factors to consider for evaluating energy consumption, CO₂ emissions and relevant low carbon city policies. Because of this variability, it is helpful to compare the performance of groups of cities based on their social and economic features. To group cities according to these feature, Chen et al. (2006) from the Chinese Academy of Social Sciences (CASS)

developed a methodology to evaluate regional or local economic and social progress in China. The CASS methodology groups cities based on five criteria: GDP per capita, share of value added in Primary, Secondary and Tertiary industries, share of value-added in the manufacturing industry, share of employment provided by the tertiary industry, and share of urban population. Table 2 shows the details of city groups and corresponding city characteristics. Group P cities (10 of the 115 cities analyzed) are categorized as having post-industrial economies, fairly wealthy, urbanized populations and a large service sector. Group H cities (58) are cities that are undergoing an economic transition from a large industrial sector (heavy industry and manufacturing) to a more service-oriented economy. They have a slightly lower GDP per capita and level of urbanization compared to P cities. Finally, M cities (47) have economies dominated by industry and have a much lower GDP per capita and level of urbanization than both P and H cities.

DATA COLLECTION AND PROCESSING

Collecting data for 115 cities was a lengthy process. The team sourced data from national and local governments and academic literature in both English and Chinese. The data presented in this paper are mainly from the year 2015. When data in 2015 were not available, the most recent year of data were utilized.

Results and Discussion

This section presents the overall results and the distribution of the index scores for the year 2015. It also compares the performance based on socio-economic groupings of cities. Three typical top-performing cities were selected from each group, and their performance in each category of the index was examined to identify their status and potential for improvement.

RESULTS FOR THE CGLCCI INDEX IN 2015 FOR THE 115 CITIES SHOWS THE CITIES' POTENTIAL FOR IMPROVEMENT

The highest-ranking city scored 70 out of 100 whilst the worst performing city scored just 28. The median and mean index score was 45. Among 115 cities, only two cities (Shenzhen and Xia'men) had scores higher than 60 points; while 33 cities had scores between 50–50.9, and 51 cities had scores between 40 and 49.9. This distribution of scores highlights that cities have moderate to low scores, and there are the significant differences in green low-carbon performance among Chinese cities. Cities need to make more efforts to drill down into each indicator's

performance to understand actual gaps relative to the benchmarks for achieving green low-carbon development as defined by the CGLCCI index.

Figure 1 compare the average score of the 115 cities with the maximum score achieved by any one city within each categories of the index. For the *Economy*, *Transportation*, *Industry*, and *Climate Policy and Outreach* categories, the average score for all cities was less than 50 % of the maximum. The *Economy* category had lowest percentage of average score 5.1 points out of maximum 20 points. Compared to high performing cities which had a 0.23 tce/RMB 10,000 (2005 price) of economic energy intensity and 0.32 tce/RMB 10,000 (2005 price) of economic carbon intensity, the average values for the selected cities were more energy intensive and higher CO₂ emissions intensive, with actual values of 0.95 tce/RMB 10,000 (2005 price) and 1.91 tce/RMB 10,000 (2005 price) respectively.

The *Transport* category had an average score less than 50 % of maximum score (6 points). Looking closer at the indicators within this category, there was not sufficient public urban transit in the most of cities. The *Industry* category had weak performance, in that the average of the energy consumed per unit of industrial value-added economic output was 1.18 tce/RMB 10,000 (2010 price), more than four times higher than the benchmark value set at 0.27. And the average of the heavy industry share of industrial value-added economic output was 67 %, more than three times higher than the benchmark value. The *Climate Policy and Outreach* category had average score of 4.3, just below the mid-range of the maximum score (10 points), because nearly two-thirds of the selected cities still lack comprehensive low-carbon plans or climate resilience plans. For the *Energy*, *Environment & Land Use*, *Buildings*, and *Energy & Power* categories, their the average scores for all cities were more than 50 % of the maximum score. The *Environment and Land Use* category performed the best, with an average score of 12 points out of maximum 20 points, due to the fact that most of the cities' per capita solid waste generation was low, and they have met the environmental public budget targets. The *Building* category performed second-best, with an average score of 4.7 points out of maximum 8 points, in part due to the modest energy consumption in residential buildings. The *Energy and Power* category registered above the halfway mark, with an average score of 9.3 points out of maximum 18 points, partly because several cities have already met the national target of 20 % of non-fossil fuel energy in total energy mix, and 47 P cities had lower per capita CO₂.

Table 2. City groupings based on economic and urban criteria (CASS methodology).

Category	Number	Economic and Urban Characteristics
P cities	10	GDP/capita: RMB 89,793–RMB 153,819 (EUR 12,809–EUR 21,942); Urbanization rate: 75 %–100 %; share of value-added in Service sector:50 %–80 %
H cities	58	GDP/capita: RMB 33,320–RMB 146,397(EUR 4,753–EUR 20,884); Urbanization rate: 52 %–97 %; share of value-added in Service sector:31 %–75.7 %
M cities	47	GDP/capita: RMB 22,912–RMB 63,168 (EUR 3,268–EUR 9,011); Urbanization rate: 36 %–71 %; share of value-added in Service sector: 24 %–53 %

Note: The exchange rate in 2015 was EUR 1 = RMB 7.01.

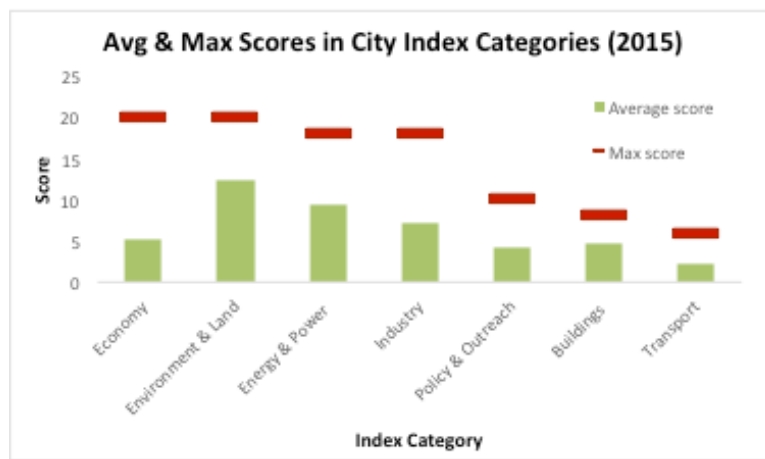


Figure 1. Average and maximum scores for each category in the City Index.

Based on the above analysis on average performance for each category, this study shows that the cities' overall performance in terms of economic energy and carbon efficiency, industrial energy efficiency and public transit is still very low compared with the benchmark levels. Although the overall performance for all cities relatively better on energy transformation, per capita energy consumption and CO₂ emissions, building energy saving and environmental conditions, there are still big gaps when compared to the best practices level. This means that it is important for municipal governments to emphasize specific initiatives aimed at improving their performance based on their social and economic features while to develop specific mid-and long-term comprehensive and strategic framework including all aspects of green and low-carbon features.

TOP-SCORING CITIES SPANNED AMONG DIFFERENT CITY GROUPINGS, SHOWING THAT CITIES WITH DIFFERENT FEATURES OF ECONOMIC AND URBAN DEVELOPMENT CAN PURSUE DIFFERENT PATHWAYS IN ACHIEVING GREEN AND LOW-CARBON ECONOMY

The P cities (wealthy, large service sector, highly urbanized) had higher scores than the other two groupings due to their more service-oriented economy. However, single top-scoring cities were found from H cities (moderate GDP per capita, heavy industry and manufacturing) and M cities (Lower GDP per capita and urbanization). The top 20 cities spanned among different city groupings, with five in P cities, seven in H cities, eight in M cities, indicating that a variety of pathways for green low-carbon development is possible.

In order to better identify the status and pathways of green low-carbon development for different city groupings, this study selected one top-performing city from each group – namely, Shenzhen from P cities, Wenzhou from H cities, and Ganzhou from M cities. This paper analyzed the performance of the three cities within each category and discusses their progress and potential.

The mega-city of Shenzhen, located in the Pearl River Delta, Guangdong province, is an economically developed city with a 100 % urban population, RMB 157,985 (EUR 22,537) of GDP per capita, and 58.8 % of value-added in the service sector in 2015. Shenzhen, with limited energy sources and environmental capacity, has oriented its economic development to be high quality and high efficiency. The city of Wenzhou,

in eastern Zhejiang province, has a population of 9.1 million, with slightly higher GDP per capita of RMB 50,809 (EUR 7,248) and urbanization rate (68 %) compared to the national level in 2015. The Wenzhou economy is transforming from industry-oriented to service sector-oriented, and it faces challenges in the transition away from heavy industry and manufacturing and environmental pollution. Wenzhou is in search of new impetus for economic development. Ganzhou is an economically underdeveloped city in the eastern province of Jiangxi, with a population of 8.6 million. The share of value-added in the tertiary sector (40.9 %), GDP per capita of RMB 23,148 (EUR 3,302) and urbanization (45.5 %) in 2015 were lower than the national levels. Ganzhou is accelerating industrialization and urbanization. Figure 2 shows the comparisons of these three cities with national levels in terms of share of value-added in the tertiary (service) sector, urbanization of the population, and GDP per capita in 2015.

The city of Shenzhen performed the best in the 2015 *City Index* with a score of 70 out of 100, largely due to the high scores in the *Economy* category, *Transport* category, and *Environment and Land Use* category. As Figure 4 shows, in the *Economy*, Shenzhen's energy intensity of 2015 was 0.23 tce/RMB 10,000 (2005 price), which has met the benchmark set at Japan's level in 2012. However, Shenzhen's carbon intensity was twice as high as the benchmark set at EU level in 2013. Shenzhen needs to pay more attention to de-carbonization of the economy. In the *Transport* category, Shenzhen performed well mostly due to significant investment in public transit (bus, subway, and light rail). In the *Environmental and Land Use* category, Shenzhen had the lowest annual average PM2.5 concentration among top performing cities in the *Index*; and among cities with population size over 10 million, Shenzhen had the best air quality. In addition, Shenzhen also had the highest environmental expenditure at a 5 % of its fiscal budget. However, Shenzhen's score in the *Energy and Power* category was quite low, revealing the fact that the energy consumption per capita and CO₂ emissions per capita are still very high.

Ganzhou city ranked 6th with a score of 58, which benefited from two categories: *Energy and Power*, and *Economy*. Within the *Energy and Power* category, CO₂ emissions per capita and primary energy consumption per capita for Ganzhou were better than the benchmark values, while the city's share of non-

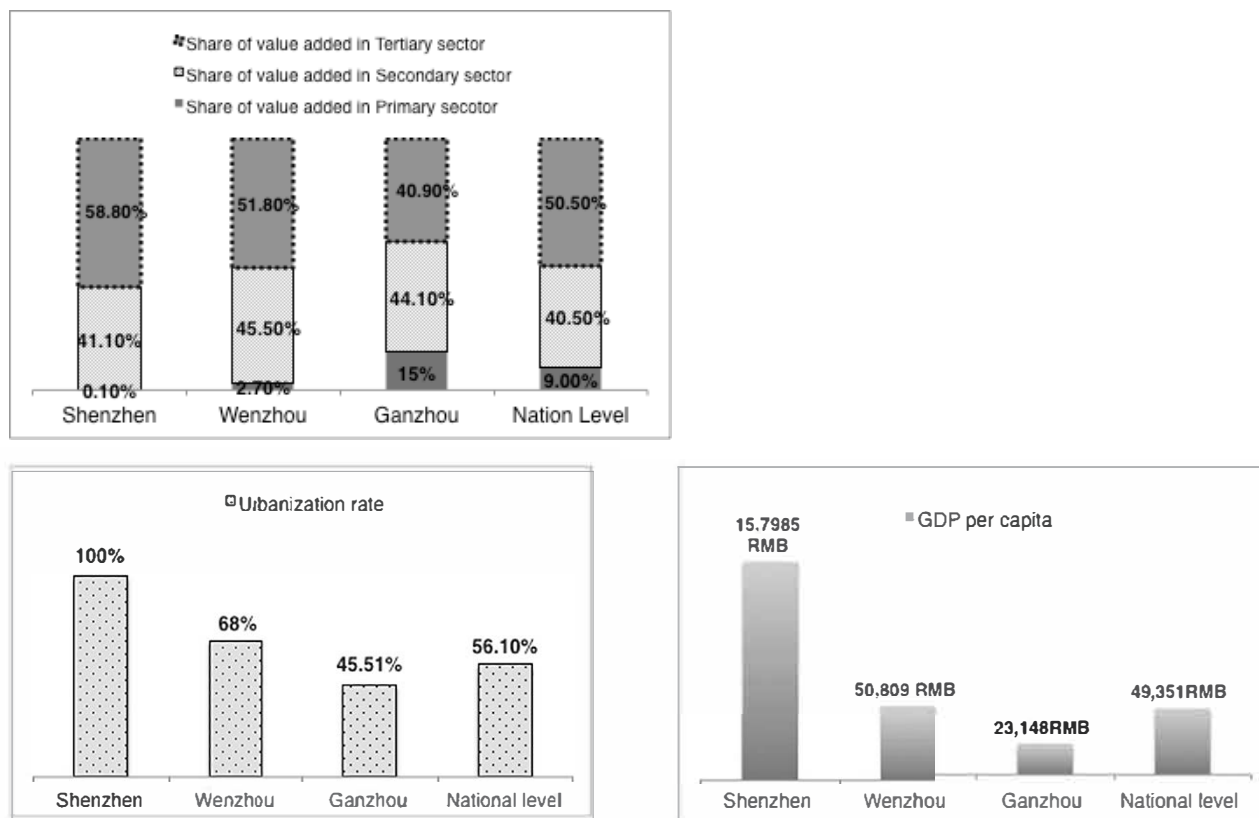


Figure 2. Comparison of Economic and Urban Characteristics among Shenzhen, Wenzhou, Ganzhou and National Levels in 2015.

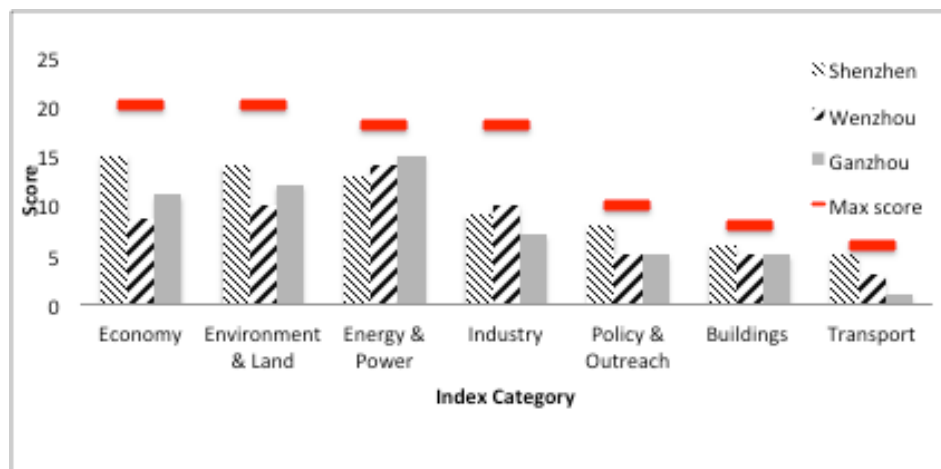


Figure 3. Index scores and maximum scores within each category for three cities.

fossil fuel in primary energy was 11 %, roughly half of the benchmark value. In the *Economy* category, Ganzhou’s energy intensity of 2015 entered the top ten scored cities with a value of 0.30 tce/ RMB 10,000 (2005 price), slightly higher than the benchmark value. However, its economic carbon intensity was 0.949, almost three times higher than the benchmark. In the *Transport* category, Ganzhou had very low scores, due to the lack of public transit infrastructure in place, and low availability and use of public transit.

Wenzhou city ranked 15th overall with a total score of 55. In the *Economy* category, energy intensity was 0.44 tce/RMB 10,000 (2005 price), and appeared in the list of top 10 best cities in this indicator. But economic carbon intensity was 0.977 kg CO₂/

RMB 10,000 (2005 price), almost three times that of the benchmark levels. Figure 3 shows that except for the *Industry* category, Wenzhou scores for each category were rather weak. In the *Industry* category, Wenzhou scored better compared to Shenzhen city and Ganzhou city, since its industrial economic energy intensity was lower than Ganzhou city, and its heavy industry share of industrial value-added economic output was lower than Shenzhen city.

Through the comparison of three top-performing cities’ economic situation and their 2015 CGLCC Index, the study found that there are similarities and differences on green and low-carbon features among these cities. Key similarities are that these three cities had relatively higher scores in the *Economy*

category with lower economic energy intensity and CO₂ emissions intensity compared to other selected cities. At the same time, these cities have their own strong areas. Shenzhen as a city with strong local public finance, performed well in the *Transportation* category and the *Environment and Land Use* category. Wenzhou had higher scores in the *Industry* category, and the initiative on “Strengthening Industry” has been a key component of its mid-and long-term city development strategy. Ganzhou performed well in the *Energy and Power* category. Ganzhou’s 2015 *City Index* score showed it performed well as a low-carbon city. However, its underdeveloped economy and higher share of value added in agriculture sector have contributed to less energy consumption. The M cities like Ganzhou are still facing the challenge of how to achieving green and low-carbon targets while balancing economic development. Economic structure change, and industry and energy structure transformation, should be the strategic priority areas of local governance for all Chinese cities. In addition, these efforts should be closely aligned with local economic and urbanization characteristics.

Conclusions

The development and application of the new *City Index* on a sample of 115 Chinese cities proved to be a useful approach in evaluating and benchmarking cities on aspects of green and low-carbon efforts. The results from analysis of these cities’ performance in the seven categories and 23 indicators in 2015, showed that city green and low-carbon transition is still at an early stage in China. Local economic profiles and political will may have played strong roles in city progress, because each city, depending on its key industries, had different priorities and drivers on green low-carbon development. Cities should be encouraged to learn best practices from each other, as well as pursue innovation for transitioning to a greener and low-carbon economy.

The *City Index* is developed from relevant and comparable indicators using widely-available data in China, making it a useful tool to study Chinese cities. We recommend local governments use the *City Index* as an assessment tool to track their performance, identify areas for improvement, and design targeted low-carbon strategies suited to their local situation. Provincial and national government agencies can also use this index to strengthen policies, provide support to cities most in need, and award top performers.

References

- Chen, J., et al., 2006. The Synthetic Evaluation and Analysis on Regional Industrialization. *Economic Research* 11: 4–15 (in Chinese).
- China’s State Council, 2015. The Suggestions on Accelerating the Construction of Ecological Civilization. Available at: http://www.gov.cn/xinwen/2015-05/05/content_2857363.htm (in Chinese).
- China’s State Council, 2014. National New-type Urbanization Plan (2014–2020). Available at: http://www.gov.cn/zhengce/2014-03/16/content_2640075 (in Chinese).
- Chu, C., et al., 2011. Planning and Technological Framework on China’s City Low-carbon Development. *Ecological Economics* 03: 45–63 (in Chinese).
- Dhakal, S., 2009. Urban Energy Use and Carbon Emissions from Cities in China and Policy Implications, *Energy Policy* (2009): 4208–4219.
- Freudenberg, M., 2003. Composite Indicators of Country Performance: A Critical Assessment. No. 2003/16. OECD Publishing, 2003.
- Fu, Y., et al., 2010. Evaluation Methodology on City Low-carbon Development China Population, Resources and Environment 8:44–47 (in Chinese).
- Huo, Z., 2012. Evaluating Guangdong’s Low-carbon City Development. *Environmental Science & Management* 4: 65–67 (in Chinese).
- Khanna, N., D. Fridley, and LX Hong. 2014. “China’s pilot low-carbon city initiative: A comparative assessment of national goals and local plans.” *Sustainable Cities and Society*, 12: 110–121.
- Lu, L., et al., 2011. Evaluation System for Tianjing’s Urban Low Carbon Planning S1: 26–31.
- Ministry of Environmental Protection of the People’s Republic of China, 2016. Circular of the State Council on Issuing the 13th Five-Year Plan for the Protection of Ecological Environment. Available at: http://www.gov.cn/zhengce/content/2016-12/05/content_5143290.htm (in Chinese).
- National Bureau of Statistics of the People’s Republic of China. 2015 Statistical Yearbook of China. China Statistical Press, Beijing. 2015 (in Chinese).
- Ohshita, S.B., N. Khanna, C. Fino-Chen, X. Lu. 2016. BEST Cities: Software User Guide. Benchmarking and Energy Saving Tool for Low-Carbon Cities, v.1.4. Berkeley CA: Lawrence Berkeley National Laboratory. English version & Chinese version. 81 pp. June.
- Ohshita, S.B., L. Price, N. Zhou, N. Khanna, D. Fridley, and X. Liu. 2015. The role of Chinese cities in greenhouse gas emission reduction. Briefing prepared by the China Energy Group, Lawrence Berkeley National Laboratory, for Stockholm Environment Institute and Bloomberg Philanthropies. September. http://www.bloomberg.org/content/uploads/sites/2/2015/09/LBNL_SEI_China_Final.pdf
- Price, Lynn, et al. 2014. “Development of an End-Use Sector-Based Low-Carbon Indicator System for Cities in China.” 2012 ACEEE Summer Study on Energy Efficiency in Buildings, Pacific Grove, CA, August 12–17 (2014).
- Shi, M. 2013. City Green Development: International Comparison and Problem Perspective. *Urban Studies* 05: 140–145 (in Chinese).
- Tan, S, et al. 2015. Development of the low-carbon city indicator (LCCI) framework.” *Energy Procedia* 75: 2516–2522.
- United Nations Department of Economic and Social Affairs (UNDESA). 2014. World Urbanization Prospects: The 2014 Revision. CD-ROM edition. <http://esa.un.org/unpd/wup/CD-ROM>.
- Wang, A. 2010. Condition and Potential on China’s Low Carbon Construction. *Urban Environment & Urban Ecology* 10: 14–17 (in Chinese).
- Wang, X. 2011. Thailand: Clean Energy for Green Low-Carbon Growth. Available at: <http://documents.worldbank.org/curated/en/576401468120848097/pdf/662200WP0p12440e0Clean0Energy0all07.pdf>.
- World Health Organization (WHO). 2006. Air Quality Guidelines: Global Update 2005: Particulate Matter, Ozone,

- Nitrogen Dioxide and Sulfur Dioxide. Available at: http://www.who.int/phe/health_topics/outdoorair/outdoorair_aqg/en/
- Zhou, N., et. al. 2015. ELITE Cities: A low-carbon eco-city evaluation tool for China. *Ecological Indicators* 48: 448–456.
- Zhou, N., et.al. 2012. China's development of low-carbon eco-cities and associated indicator systems. Berkeley, California, USA, Lawrence Berkeley National Laboratory. Available at: https://china.lbl.gov/sites/all/files/china_eco-cities_indicator_systems.pdf.
- Zhuang, G., et al. 2014. Ranking and International Comparative on China's City Low Carbon Development. *Journal of China University of Geosciences (Social Sciences Edition)* 03: 17–23 (in Chinese).
- Zhu, Q., et al. 2013. Research Progress on Low-carbon City Evaluation System. *Review of Economic Research* 14: 18–37 (in Chinese).