China Green Low-Carbon City Index

Report on the Performance of 100+ Cities (2010-2015)

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Acronyms and Abbreviations

ACEEE	American Council for an Energy Efficient Economy
APPC	Alliance of Peaking Pioneer Cities
BEST Cities	Benchmarking and Energy Saving Tool for Low Carbon Cities
CAS	Chinese Academy of Sciences
CASS	Chinese Academy of Social Sciences
CGLCI or *City Index*	*China Green Low-Carbon City Index*
CH_4	methane
CO_2	carbon dioxide
DOE	Department of Energy
ELITE Cities	Eco and Low-carbon Indicator Tool for Evaluating Cities
FYP	Five-Year Plan
GDP	Gross domestic product
GHG	Greenhouse gas
iGDP	Innovative Green Development Program
LBNL	Lawrence Berkeley National Laboratory
MEP	Ministry of Environmental Protection
MOF	Ministry of Finance
MOHURD	Ministry of Housing and Urban-Rural Development
NBS	National Bureau of Statistics
NDRC	National Development and Reform Commission
$PM_{2.5}$	Particulate Matter, diameter 2.5 microns or less

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Preface

Cities emit the majority of the world's greenhouse gases, and they are also the place where innovations can be developed, piloted, and implemented quickly. China is undergoing rapid urbanization and experiencing a rise in energy use and emissions, along with significant environmental consequences, as a result. Chinese cities are striving to reduce their emissions and develop green and low carbon cities. How are these efforts progressing? To date, there has not been a tracking and evaluation mechanism in place, and cities are not always sure of their own progress or aware of how they compare to other cities. It is important for these cities to benchmark themselves against peers, track their own progress year by year, and also share experiences and best practices.

Our research team, consisting of the U.S.-based Lawrence Berkeley National Laboratory (LBNL) and the China-based research think-tank Innovative Green Development Program (iGDP), after survey and consultation with experts in both the U.S. and China, decided to develop an indicator system and ranking mechanism that can be used to address the issues described above. The new *China Green Low-Carbon City Index* builds upon past work on indicator systems, including LBNL's Benchmarking and Energy Saving Tool for Low Carbon Cities (BEST Cities) and the Eco and Low-carbon Indicator Tool for Evaluating Cities (ELITE Cities) tools, and the City Scorecard developed by the American Council for an Energy-Efficient Economy (ACEEE).

In developing a scientifically rigorous and meaningful City Index with practical applications, we encountered a number of barriers: data availability and quality, choice of indicators, difference in the understanding of methodologies, selection of weighting factors, etc. The process took many rounds of data review, analysis and testing, and reviewing by key experts in China. In the end, the team gathered the largest collection of city-level data on low-carbon development, with data for 115 cities, 23 indicators plus 8 city characteristics, and two annual sets of data (2010 and 2015).

When the preliminary results were ready, we vetted them with a number of Chinese city mayors and government officials. Some city mayors were not happy about their ranking results and raised questions. But in the end, they praised the work as it provides an unbiased, third-party evaluation, and can motivate them to do better in the future. This report presents the development and methodology of the City Index, along with key findings. We look forward to further analysis and application of the *China Green Low-Carbon City Index*.

-- *Nan Zhou, Leader, China Energy Group, LBNL*

Executive Summary

With more than half of humanity now living in cities, there is growing recognition of the role cities play in contributing to and combatting climate change. As centers of resource demand, the fossil fuel consumption of cities is responsible for nearly 70% of energy-related greenhouse gas (GHG) emissions globally. The 50 largest cities collectively rank as the world's third largest emitter of energy-related GHG emissions, after China and the U.S. (IEA 2016; World Bank 2012). With rapid urbanization in the world's most populous countries, notably China and India, cities are searching for strategies to ease energy consumption, de-carbonize their economies, protect environmental quality, and enhance their resilience in a changing climate.

The China Green Low-Carbon City Index

The main purpose of the new *China Green Low-Carbon City Index* (CGLCI, or *City Index*) is to evaluate the status of green and low-carbon development for a large number of Chinese cities.[1] Chinese cities are formulating plans and implementing programs to address national initiatives, especially the national low-carbon pilot program for 36 cities and six provinces.[2] However, there is not yet an established framework for measuring, reporting, or evaluating low-carbon progress across Chinese cities, despite the development of a number of Chinese and international city indicator systems. The new *China City Index* highlights energy use and carbon emissions of Chinese cities, along with environmental and socio-economic indicators. We selected metrics (indicators) that have data available in China's statistical system, are commonly used internationally, and reflect Chinese policy goals. (See Table ES-1.) We then benchmarked and ranked Chinese cities in terms of their status and progress, identified potential areas for improvement, and identified top-runners.

Accomplishments in Data Gathering and Methodology

The *China Green Low-Carbon City Index* represents the most extensive collection of this type of data on Chinese cities to date, including data on 23 indicators and 8 city characteristics, for 115 cities, for two years spanning the 12th Five Year Plan (FYP) period (2010 and 2015). The methodology for the City Index balances meaningful, comparable indicators with data availability, offering the possibility for widespread use across Chinese cities. The methodology also recognizes that the Industry sector is still the largest energy consumer and CO_2 emitter in many Chinese cities. The inclusion of benchmarking in the *City Index* enables tracking of city performance relative to international best practice, national policy targets, and top-runners in China. The scoring system of the *City Index* enables comparative ranking across Chinese cities, informing local policy action and public awareness, as well as provincial and national policies and programs. Additional analysis on sub-groups of cities (by city tiers and economic characteristics), and on city sectors (energy, buildings, industry, etc.), provides more detailed insight.

[1] By "low-carbon" we mean reducing emissions of carbon dioxide (CO_2) and methane (CH_4), with a focus on energy-related CO_2. The term "carbon" is used as short-hand for these GHGs throughout the report. By "green" we recognize multiple environmental parameters related to urbanization and climate change: air quality, water use, solid waste, transport networks, and urban green space.

[2] In early 2017, China expanded its low-carbon pilot cities program, adding 45 more cities.

Table ES-1: Structure of the *China Green Low-Carbon City Index*

Category	**Indicator (Unit)**	**Benchmark value [1]**	***Max score***
1. Economy			***[20]***
Economy	(-) Energy Intensity (tce/10,000 RMB, 2005 prices)	0.23	***10***
	(-) Carbon Intensity (kg CO_2/10,000 RMB, 2005 prices)	0.32	***10***
2. Energy & Carbon			***[50]***
Energy & Power	(-) CO_2 emissions per capita (tCO_2/ capita, annual)	2.4	***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/RMB10,000)	0.27	***9***
	(-) Heavy industry share of industrial GDP (%)	29%	***9***
Transport	(+) Public transportation vehicles (vehicles/10,000 people)	26.4	***2***
	(+) Extent of urban rail transit lines 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%	***2***
	(-) Residential energy consumption per capita (kWh/ capita, annual)	4,743	***3***
	(-) Commercial energy consumption per employee (kWh/ service sector employee, annual)	6,576	***3***
3.Environment & Land Use			***[20]***
Environment	(-) Municipal solid waste per capita (t/capita/year,)	0.31	***3***
	(+) Blue sky days (%, annual)	100%	***4***
	(-) PM2.5 concentration (µg/m3, annual average)	10	***3***
	(-) Municipal daily water consumption per capita (minimum 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. Policy & Outreach			***[10]***
Policy & Outreach	City low-carbon development / climate change plan	Yes	***2.5***
	City renewable energy strategy (beyond national targets)	Yes	***2.5***
	City climate change resilience / adaptation plan	Yes	***2.5***

	Public outreach on low-carbon lifestyle	Yes	***2.5***

Notes: (+) means indicator is positive (higher values are better), while (-) means indicator is negative.
[1] Benchmark levels based on a mix of international and Chinese standards and best practice. Details in main report.

Key Findings

Signs of Improvement. *City Index* scores from 2010 to 2015 show improvement of most cities in green low-carbon development during the 12th FYP, confirming trends observed at the national and provincial levels in China.

More Effort Needed Overall. All cities – even the highest ranked cities in the *City Index* – have much work ahead to become green and low-carbon. The best performer in the Index, Shenzhen, had a score of 70 out of 100 (in 2015), while the average (mean) score for all 115 cities was 45 and the lowest score 28. (See Table ES-2.)

Table ES-2. City Index Summary Statistics (2015)

	Total Score	Economy	Energy & Power	Industry	Transport	Buildings	Env & Land Use	Policy & Outreach
Index Max	***100***	*20*	*18*	*18*	*6*	*8*	*20*	*10*
max score	**69.7**	14.6	17.9	14.7	5.5	8.0	15.3	7.5
avg score	**44.9**	**5.1**	**9.3**	**7.2**	**2.3**	**4.7**	**12.0**	**4.3**
min score	**28.4**	1.4	2.4	3.5	0.1	1.1	8.8	2.5

De-Carbonizing the Economy and Industry. Overall, cities had the weakest performance in the Economy and Industry categories. Many cities still have carbon-intensive economies, and energy-intensive industry. Although per capita indicators in the Energy & Power category led to slightly better scores in that category, these sectors are still dominated by coal and oil.

Buildings and Transport Are Challenged by Rapid Urbanization. Overall, cities had better performance in the Buildings category and weak performance in the Transport category. Low-carbon pilot cities made impressive investments in public transit, but rapid urbanization is outpacing transit development in other places. Modest Residential building energy consumption raised scores in the Buildings category.

Mixed Environmental Performance, Severe PM2.5 Pollution a Persistent Problem. Overall, cities had moderate performance in the waste and environmental spending indicators, and weaker scores in water consumption and green space indicators. Severe particulate matter pollution in many cities led to the worst scores in the air quality indicators in the Environment category.

Policy & Outreach an Important Step. A mix of high-performing and low-performing cities in the City Index (overall) had launched low-carbon planning and public outreach by the end of the 12th FYP (2015). However, none of the 115 cities had yet established a formal climate adaptation or resilience plan.

Geographical Spread of Top Scoring Cities, with Concentration in East and South Central. Figure ES-1 provides a map of the Top 50 cities in the City Index. There is a fairly wide geographical distribution of these top-scoring cities, from #18-ranked Kunming (Yunnan province) in the Southwest, to #23-ranked Changchun (Jilin province) in the Northeast. Many of the top performers were concentrated in the East and South Central regions of China, such as #7-ranked Guangzhou and #23-ranked Shanghai.

Low-Carbon Pilot Cities Show Higher Scores and Greater Improvement. Low-carbon pilot cities are prominent among the top scoring cities in 2015, from #29-ranked Chongqing to #1-ranked Shenzhen (Guangdong province). Low-carbon pilot cities had an average score higher than non-pilot cities in the year 2015, and they showed greater improvement during the 12th Five-Year Plan (FYP) than non-pilot cities.

Figure ES-1. Map of Top 50 Cities in the *China Green Low-Carbon City Index*, 2015

Recommendations

We recommend that the *City Index* be used as a tool to track annual progress in green low-carbon development during the 13th FYP (2016 to 2020) and beyond. The results of the *City Index* can be used by local government agencies to identify areas for improvement and to prioritize and implement low-carbon strategies suited to their local situation. Provincial and national government agencies can use the Index to strengthen policies, provide support to cities most in need, and award top performers.

In terms of energy and carbon savings, we recommend empowering cities to generate or contract for renewable electricity and heat, which address multiple urban challenges of air quality, power supply, and energy efficiency. At the same time, more effort is needed to reduce the energy intensity and carbon intensity of urban industry and the economy, such as utilizing waste heat to provide district heating for the city. Thirdly, transit-oriented requirements for developers are needed, as well as mixed-use zoning with clusters of nearby amenities, to shift urbanization onto low-carbon pathways.

1. Introduction

With more than half of humanity now living in cities, there is growing recognition of the role cities play in contributing to and combatting climate change. As centers of resource demand, the fossil fuel consumption of cities is responsible for nearly 70% of energy-related greenhouse gas (GHG) emissions globally. The 50 largest cities collectively rank as the world's third largest emitter of energy-related GHG emissions, after China and the U.S. (World Bank 2012). With rapid urbanization in the world's most populous countries, notably China and India, cities face crucial development decisions to follow low-carbon pathways. At the same time, cities experience climate impacts in very real and specific ways, from intensified flooding to dangerous heat waves and levels of smog, spurring cities to enhance their resilience. City climate networks are expanding internationally and domestically. The prominence of cities at COP21 in Paris[3]—with the *Climate Summit for Local Leaders*, more than 400 city signatories to the global *Compact of Mayors*, and 167 signatories to the *Under 2 MOU*[4]—shows how localities can leverage climate action at all levels of governance.

1.1. Green Low-Carbon Development in China's Cities

What is green low-carbon development? By "low-carbon" we mean reducing emissions of the GHGs carbon dioxide (CO_2) and methane (CH_4), with a focus on energy-related CO_2. The term "carbon" is used as short-hand for these GHGs throughout the report. By "green" we recognize multiple environmental parameters related to urbanization and climate change: air quality, water use, solid waste, transport networks, and urban green space.

Seeking to manage the impacts of rapid urbanization, Chinese government agencies have initiated multiple programs and policies in the past decade. During the 11th Five Year Plan (FYP), China's Ministry of Housing and Urban/Rural Development (MOHURD) launched an eco-city pilot program to promote urban sustainability. In 2010, China's National Development Reform Commission (NDRC) launched a program for Low-Carbon Pilot Cities and Provinces. During the 12th FYP, the low-carbon pilot program grew to 36 cities and six provinces. These cities have been conducting energy and GHG inventories, setting targets, preparing low-carbon action plans, and developing local standards and incentives that go beyond national requirements (Khanna et al. 2014). In early 2017, China expanded its low-carbon pilot cities program, adding

[3] For highlights of city actions at COP21, see: http://www.wri.org/blog/2015/12/cop21-highlights-importance-city-actions-climate-fight

[4] Supporters from 167 local jurisdictions representing 1.09 billion people signed the Under 2 MOU, which aims to reduce GHG emissions to 2 tCO_2e/capita and limit global warming to 2°C. See: http://under2mou.org/coalition/

45 more cities.[5]

In 2012, tougher controls on air pollution were announced in the *12th FYP for Air Pollution Prevention and Control* (MEP et al. 2012). In 2013, the State Council issued implementation details in a new *Atmospheric Pollution Prevention Action Plan* (State Council 2013) and established a network of 500 $PM_{2.5}$ monitors across 70 Chinese cities.[6] In March of 2014, the State Council issued the *National New-type Urbanization Plan (2014–2020)* (State Council 2014), which set targets for urban infrastructure and urban socio-economic development. And to complement China's bilateral and international climate pledges in 2015, 21 Chinese cities joined the Alliance of Peaking Pioneer Cities (APPC), pledging to peak energy-related CO_2 emissions before the national target year of 2030.[7] The "peaking pledges" recognize that Chinese cities are still developing and building infrastructure to accommodate the influx of urban residents, which means that emissions are likely to increase in the near-term but need to plateau and then decline as soon as possible.

1.2. Purpose of the *China Green Low-Carbon City Index* (CGLCI)

Although Chinese cities are formulating plans and implementing programs to address the national initiatives discussed above, there is not yet an established framework for measuring, reporting, or analyzing city progress. The main purpose of the *China Green Low-Carbon City Index* (CGLCI, or City Index) is to evaluate the status of environmental ("green") and low-carbon development for a large number of Chinese cities. To accomplish this evaluation, the City Index examines energy use and carbon emissions of Chinese cities, along with environmental and socio-economic indicators. We selected metrics (indicators) that have data available in China's statistical system, are commonly used internationally, and reflect Chinese policy targets. We then benchmarked and ranked Chinese cities in terms of their status and progress, identified potential areas for improvement, and identified top-runners. The City Index can be used to track city performance over time, in conjunction with policy cycles, recognizing that low-carbon development requires both immediate and sustained action. The City Index can also inform current and future policy, and the data gathering needed to support it.

While other city indicator systems have been developed internationally, they typically have been applied to only a relatively small number of cities in China, and their data requirements often have not meshed well with China's statistical system or policy targets. Indicator systems developed within China have encountered limitations as well, with too few indicators to sufficiently inform government decisions, or too many indicators for widespread application across China's 658 cities. Their scope varies, and they may address environmental indicators, or

[5] A list of the 45 new pilot cities, including their CO_2 peaking target year, is available (in Chinese) at: http://www.sdpc.gov.cn/gzdt/201701/W020170124374455942791.pdf
[6] For a summary of the 2013 air pollution action plan, see: https://www.nrdc.org/experts/barbara-finamore/china-pledges-tackle-air-pollution-new-plan
[7] For more information, see the APPC Secretariat website: http://appc.ccchina.gov.cn/ and the APPC fact sheet by iGDP: http://www.igdp.cn/webproduct/pubtext?id=13

low-carbon indicators, but not both. And most of the Chinese indicator systems lack composite scoring or ranking. Thus there has been an urgent need for an indicator system to swiftly and comprehensively track green low-carbon development across numerous Chinese cities, in a way that informs policy and action.

2. Review of City Indicator Systems

2.1. International indicator systems

There are several international indicator systems that compare the low-carbon development levels of cities around the world, including the Global Cities Institute's *Global City Indicators*, Siemens's *Green City Index*, Arcadis's *Sustainable Cities Index*, the *Urban Sustainability Index* and others (Tan et al. 2016). Some systems benchmark or rank performance across cities at a single point in time, while others use historical performance in the same city to track progress over time. Some indicator systems focus on particular city sectors, such as the energy sector, which adds greater detail. For example, the American Council for an Energy Efficiency Economy's *City Energy Efficiency Scorecard* (ACEEE 2015) gathers detailed information on U.S. city energy efficiency policies and implementation over time and provides an annual ranking. However, a focus on a single sector limits an indicator system's ability to assess the overall status of a city's low-carbon development.

Regardless of the type, the process for developing an indicator system is similar and involves defining the goals of the analysis, defining the scope of analysis, choosing a conceptual framework for reporting, reviewing potential indicators, finalizing a list of indicators, selecting benchmarks and scoring (if a ranking system), analyzing the results, and presenting the results to the intended target audience. Williams et al. (2012) and Zhou and Williams (2013) reviewed 9 international low-carbon eco-city ranking systems and 7 non-ranking systems. A summary of their key findings in terms of indicator categories, indicator selection, weighting and aggregating, and benchmark criteria is provided below.

Categories:

- Indicator systems prioritize issues and topics through the **selection of primary categories of policy importance** (e.g. energy and climate), **secondary categories to refine** primary categories (e.g. urban industry) and the selection of indicators (e.g. CO_2 emissions per unit of GDP)
- **Eight common primary categories** that were found across almost all of the international indicator systems are: energy and climate; water quality, availability and treatment; air quality; waste; transportation; land use and urban form; demographics and social health; economic well-being.

Indicator selection:

- **Number of indicators** varies by system, but ranking systems (across many cities) tend to have fewer indicators to reduce data collection and analysis cost.

- **City population** was often used as **normalizing denominator** to enable comparability across cities, while **GHG emissions were the most commonly used numerator** in low-carbon indicator systems.
- Majority of eco-city 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.
- **Selection criteria for indicators** vary significantly across systems, while the key common criteria include relevance, data availability, and comparability. Other studies included selection criteria such as links with management and policy, and spatial and temporal scales of applicability.
- **Quantitative metrics** account for the majority of indicators, but measurements of policy and planning activities may also be included through binary policy indicators (Yes/No) or qualitative policy indicators based on expert review and evaluation.

Weighting and Aggregating:

- Indicators may be **weighted overtly, implicitly, or equally** depending on the indicator system. Implicit weighting where indicators are grouped into categories to derive an aggregate total score is the most common, and the *Asia Green Cities Index* (EUI 2011) is an example.

Benchmark Criteria:

- Indicator performance can be based on **pre-set goals derived from target values and thresholds** or **relative values that rely on comparisons** to past performance or the performance of other cities. Relative values are used most commonly in international indicator systems, and benchmark values are used when a policy target or health-based standard is available.

In summary, there are commonalities among existing indicator systems. But there is substantial variance in the conceptual framework of eco-city and low-carbon city indicator systems, as well as the specific categories and indicators within each system, reflecting the purpose of the index, policy priorities, and data availability.

2.2. Chinese city indicator systems

As the concepts of low-carbon and eco-cities gain more attention in China, more indicator systems to evaluate these cities have emerged (Zhou et al. 2012). At the national level, there are the Ministry of Environmental Protection (MEP)'s *Eco-city Indicators system* and the Ministry of Housing and Urban-Rural Development (MOHURD)'s *National Eco-Garden Indicators system*. Local governments have also introduced indicator systems for cities including Tianjin, Caofeidian, Turpan New District, and Guiyang. Other low-carbon eco-city indicator systems in China are those developed by research and academic institutions such as the Chinese Academy of Science (CAS), Renmin (Peoples) University, Tsinghua University, and MOHURD's Chinese Society for Urban Studies.

While other eco-city or low-carbon indicators systems may exist, the systems mentioned above have been utilized by government agencies or widely cited by researchers. A comparison of these indicator systems in Zhou et al. (2012) found that nearly all are used for internal benchmarking or inter-city comparison on individual indicators, rather than determining a composite index core or ranking cities based on a composite score.

Most of these Chinese indicator systems focus on the physical environment and include air, energy, water, land use, and waste indicator categories. Fewer cover transport, economic, and social categories. The water category had the largest number of indicators, followed by energy, waste, and land use. The air quality and transport categories had the fewest indicators among the eight major categories. The most common subcategories (used in more than six of the indicator systems) were air quality, water quality, waste treatment, water resources, and public green land use. Within the energy category, the five most common subcategories are renewable and clean energy, energy security, carbon intensity, energy intensity, and sectoral energy (e.g. industry, buildings, transportation). Only seven indicators were connected directly with CO_2 emissions or intensity, and these were included in only three systems. Energy and carbon indicators mostly used measures of economic productivity (e.g. CO_2 per unit GDP), physical or spatial intensity (e.g. energy per unit of steel), or per capita (e.g. CO_2 per person).
There were three main sources for choosing indicators and setting benchmark values, namely: national or regional standards, sector-wide best practices, or other targets driven by local conditions or performance needs. Most of the systems set benchmarks based on expert input and review, and used equal weighting for selected indicators.

The number of indicators in each of the Chinese systems varies greatly, ranging from a low of only five indicators in the Renmin University and Tsinghua University indicator systems based on international indexes, to a high of 146 indicators in the *China City Sustainable Development Indicators system* developed by CAS. The use of too many indicators may complicate efforts to gather data and track progress.

2.3. The need for a ranking indicator system for Chinese cities

Even though systematic international indicator systems exist and there is growing attention to environmental progress and low-carbon development in Chinese cities, there are significant gaps between the approaches and methodologies used for international and Chinese indicator systems to date. Chinese indicator systems have emphasized the physical environment and economic indicators, but generally lack systematic or robust methodologies. Individual indicators are utilized as policy targets, such as economic carbon emissions intensity (CO_2 per unit GDP) in the 12th and 13th Five-Year Plans, but no composite index has been widely applied to score and rank city progress on overall green low-carbon development. In addition, relatively new Chinese policies on urbanization and “ecological civilization” have created additional needs for policy-relevant indicator systems at the city level. As urbanization continues to accelerate, a more systematic and timely indicator system is needed to examine the performance and progress of Chinese cities toward the country's new urban vision.

A number of collaborative efforts have been underway to address these needs of Chinese cities. These include the *Eco and Low-carbon Indicator Tool for Evaluating Cities* (**ELITE Cities**) tool (He et al. 2013; Zhou et al. 2015); the *Benchmarking and Energy Saving Tool for Low-Carbon Cities* (**BEST Cities**) tool (Price et al. 2014; Ohshita et al. 2014; Ohshita et al. 2016); and the *Energy End-Use Low-Carbon Indicator System* (Price et al. 2011, Price et al. 2013) developed by Lawrence Berkeley National Laboratory with Chinese collaborators for use in China. The ELITE Cities and BEST Cities tools were designed with benchmarking capabilities, and The ELITE Cities and the End-Use Low-Carbon Indicator System were designed to provide a composite score and ranking across localities.

3. Methodology

The new *China Green Low-Carbon City Index* (CGLCI, or *City Index*) builds upon the ELITE Cities tool and the BEST Cities tool, which considered the international and Chinese indicator systems discussed above, as well as recent urbanization policy in China's 13th FYP. The new City Index is designed for widespread use across Chinese cities, to track progress on major policy targets, and to raise awareness of environmental quality and low-carbon development in Chinese cities.

3.1. Index Structure: Categories, Indicators, Benchmarks, and Scoring

Categories

Based on all of the considerations above, we chose four primary categories for the *City Index*. The **Energy and Carbon** category represents energy end-use and transformation (e.g. power generation) and corresponding CO_2 emissions. This category was further divided into secondary categories of energy end-use and transformation sectors: Energy and Power, Industry, Transportation, and Buildings. Whereas most international city indices do not include industry, the industry sector figures prominently in Chinese cities, accounting for 52% of urban primary energy and 62% of urban CO_2 emissions (Khanna et al. 2016; Ohshita et al. 2015). The **Economy** category is closely connected with Chinese policy targets to reduce the energy intensity and carbon intensity of the economy. The **Environment and Land Use** category addresses air quality, water use, waste, urban green space, and government spending on the environment. Finally, the **Policy and Outreach** category acknowledges planning and policy efforts of local government that were initiated during the 12th FYP and may yield further results in the future. See Table 1 for the structure of the *China Green Low-Carbon City Index*, including categories, indicators, benchmark values, and scores.

Indicators

Most of the indicators selected for the *City Index* are quantitative; only the indicators for Policy and Outreach are qualitative. To balance the level of detail with the effort for data collection and analysis, a total of 23 indicators were selected. Roughly two-thirds of the indicators are commonly found in international indicator systems, such as CO_2 emissions per capita, residential energy consumption per capita, extent of urban rail transit lines (km rail per city area in km^2), particulate matter concentration (annual average PM2.5 $\mu g/m^3$), and urban green space per capita (m^2/person). Other indicators are specific to Chinese cities and collected in Chinese statistics, such as Blue Sky Days (based on Chinese air quality standards) and industrial energy intensity.

In the **Economy** category, we chose two indicators that are prominent in Chinese policy: economic energy intensity (measured in metric tons of coal equivalent (tce) per 10,000 RMB of GDP), and economic carbon intensity (metric tons of CO_2 per unit GDP). We considered the share of the service (tertiary) sector in city GDP as an indicator, since China has established national targets for increasing the share of the service sector. In the 12th FYP, China had a target of 47% for the share of the service sector in national GDP. However, cities vary widely in their economic structure, and there is no single absolute benchmark value that is meaningful for all cities. For example, the northern industrial city of Baoding in Hebei province targeted a service sector share of 34% by 2015, while the nearby national capitol of Beijing had a target of 78% (iGDP Policy Mapping 2016). Thus while the central government has set targets directing cities to shift to low-carbon economic activity, away from heavy industry, the lack of a single benchmark value led us to leave out the service sector indicator in the *City Index* at this time. In addition, the influence of economic structure is already captured somewhat by the two Economy indicators in the *City Index*.

City-level data on Building energy and area, and on Transportation trips and mode, are not regularly reported in China's current statistical system are therefore difficult to obtain. As a result, some desirable, commonly used indicators could not be utilized, such as commercial building energy consumption per floor area, or transport mode share. Instead, we substituted indicators such as commercial building energy per service sector employee, public transit vehicles per 10,000 people, and annual bus trips per 10,000 people, which are available in Chinese city-level statistical yearbooks.[8]

In the Environment category, a common indicator for solid waste management in China is "municipal solid waste treatment rate." However, waste treatment is currently dominated by unsustainable landfill dumping or by incineration. Thus we chose a consumption-based indicator (municipal waste generated per capita) to better reflect the goal of reducing solid waste, to avoid life-cycle impacts of municipal consumption.

Benchmark Values

The benchmark values for the *City Index* represent a mix of approaches. For indicators that had targets or standards established in Chinese policy, such as renewable energy targets and air quality (Blue Sky Days) standards, the benchmark was set at the target. For indicators such as $PM_{2.5}$ concentration and water consumption per capita, the benchmarks are health-based, from

[8] For further discussion of the indicators and their availability in China, see Price et al. 2011; Zhou et al. 2012.

the World Health Organization. Benchmarks for other indicators are based on China's best performing cities, especially for indicators that are particular to China. For such indicators, the benchmark is set at 20% better than the average of the 10 best performing cities. This approach is similar to "top-runner" or "reach" standards used in energy efficiency policy, whereby standards are set based on the top performers, and even they are challenged to improve. The basis for each indicator is provided in the notes for Table 1. For further information about the lengthy review process informing these benchmarks, see Zhou et al. (2015).

Table 1: Structure of the *China Green Low-Carbon City Index*

Category	**Indicator (Unit)**	**Benchmark value [basis]**	***Max score***
1. Economy			***[20]***
Economy	(-) Energy Intensity (tce/10,000 RMB, 2005 prices)	0.23 [a]	***10***
	(-) Carbon Intensity (kg CO_2/10,000 RMB, 2005 prices)	0.32 [b]	***10***
2. Energy & Carbon			***[50]***
Energy & Power	(-) CO_2 emissions per capita (tCO_2/ capita, annual)	2.4 [c] [d]	***6***
	(-) Primary energy consumption per capita (tce/capita, annual)	2.8 [e]	***6***
	(+) City non-fossil fuel share of primary energy (%)	20% [f]	***6***
Industry	(-) Industrial energy intensity (tce/RMB10,000)	0.27 [c] [g]	***9***
	(-) Heavy industry share of industrial GDP (%)	29% [c]	***9***
Transport	(+) Public transportation vehicles (vehicles/10,000 people)	26.4 [c] [h]	***2***
	(+) Extent of urban rail transit lines per urban area (km/km^2)	0.04 [i]	***2***
	(+) Utilization of buses and trolley buses (trips per capita, annual)	308 [j]	***2***
Buildings	(+) Green buildings share of new buildings in city plans (%)	100% [k]	***2***
	(-) Residential energy consumption per capita (kWh/ capita, annual)	4,743 [j]	***3***
	(-) Commercial energy consumption per employee (kWh/ service sector employee, annual)	6,576 [c]	***3***
3.Environment & Land Use			***[20]***
Environment	(-) Municipal solid waste per capita (t/capita/yr,)	0.31 [m]	***3***
	(+) Blue sky days (%, annual)	100% [n]	***4***
	(-) PM2.5 concentration (μg/m3, annual average)	10 [o]	***3***
	(-) Municipal daily water consumption per capita (minimum L/capita /day)	60 [p]	***3***
	(+) Environmental spending as share of city budget (%)	3% [q]	***3***
Land use	(+) Green space per capita (m^2/capita)	100 [r]	***4***
4. Policy & Outreach			***[10]***
Policy & Outreach	City low-carbon development / climate change plan	Yes	***2.5***
	City strategy on renewable energy (beyond national targets)	Yes	***2.5***
	City climate change resilience / adaptation plan	Yes	***2.5***
	Public outreach on low-carbon lifestyle	Yes [s]	***2.5***

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

Basis for Benchmark values in Table 1:
[a] Energy Intensity benchmark set at level of Japan, as energy-efficient high-value economy.
[b] Carbon Intensity benchmark set at level of the EU in 2013. France, Denmark, Hong Kong, and Singapore are 0.16, the best low-carbon regions with high-value economies.
[c] Benchmark set at 20% better than the average of 10 best-performing Chinese cities in 2015.
[d] Per capita CO_2 emissions benchmark is close to the "Under 2 MOU" international city pledge. Current EU avg = 4.9 tCO_2/capita.
[e] Energy per capita benchmark at level of Hong Kong, best in Asia. Current best in EU is Denmark at 4.4 tce/capita.
[f] Benchmark for Non-fossil Primary Energy is set at the Chinese National 2030 Target of 20%. France, Sweden already near 40%.
[g] Industrial Energy Intensity benchmark is, coincidentally, also 20% better than Guangzhou, best of large Chinese cities.
[h] For comparison, Public Transit Vehicle Deployment in Stockholm is 9.9 vehicles/10,000 people, while 20% better than average of Top 10 Chinese cities is 25.2.
[i] Urban Rail Density benchmark set at 0.04 km/km^2 for entire city; China national target in GB 50220-specifies 4.0 km/km^2 for city center.
[j] Bus Utilization benchmark set at 20% better than Beijing, recognizing a balance of bus and rail.
[k] Benchmark for Green Building share of new construction in City Plan is set at 100%, which is a target in several Chinese cities.
[l] Residential Energy per capita benchmark at level of Japan, to allow for increased residential comfort.
[m] Municipal Solid Waste per capita benchmark set at level of Singapore, best in Asia Green City Index.
[n] Benchmark for Blue Sky Days is set to meet the Chinese National Level 2 air quality standard.
[o] Benchmark for PM2.5 is the World Health Organization (WHO) standard.
[p] Water Consumption benchmark is set at sufficient water level in WHO guidelines.
[q] Environmental Budget benchmark is set to Chinese national target of 3%.
[r] Green Space per capita benchmark set to level of Hong Kong, best in Asia Green City Index.
[s] City conducted public outreach campaigns on low-carbon lifestyle or engaged the public in low-carbon planning.

Scoring and Weighting

Some index scoring systems address the urban environment broadly and are un-weighted or give equal weighting to each category, such as ELITE Cities (discussed above). The *China Green Low-Carbon City Index* gives more attention – and scoring weight – to the sectors and economic activity that influence energy use and carbon emissions.

The maximum total score for the *China City Index* was set at 100 points, for ease of use. The four primary categories in the *City Index* were assigned different weighting based on each category's influence on CO_2 emissions and the environment, considering China's policy goals for the economy, energy and carbon, and environmental quality. The primary categories were assigned the following weighting: Economy 20%, Energy and Carbon 50%, Environment and Land Use 20%, and Policy and Outreach 10%.

The Energy and Carbon category (50 points) contains four sub-categories corresponding to city sectors: Energy and Power, Industry, Transportation, and Buildings. The weighting of the sub-categories (sectors) was based on the national average share of each urban sector's final energy use in 2015 (Khanna et al. 2016; Ohshita et al. 2015).[9] The resulting weighting of urban sectors used in the *City Index* is: Energy and Power 36% (36% of 50 = 18 points), Industry 36% (18 points), Transportation 12% (6 points), and Building sector 16% (8 points). Within each of the other primary categories, each indicator received nearly equal weighting. See Figure 1 for a distribution of scores among each category.

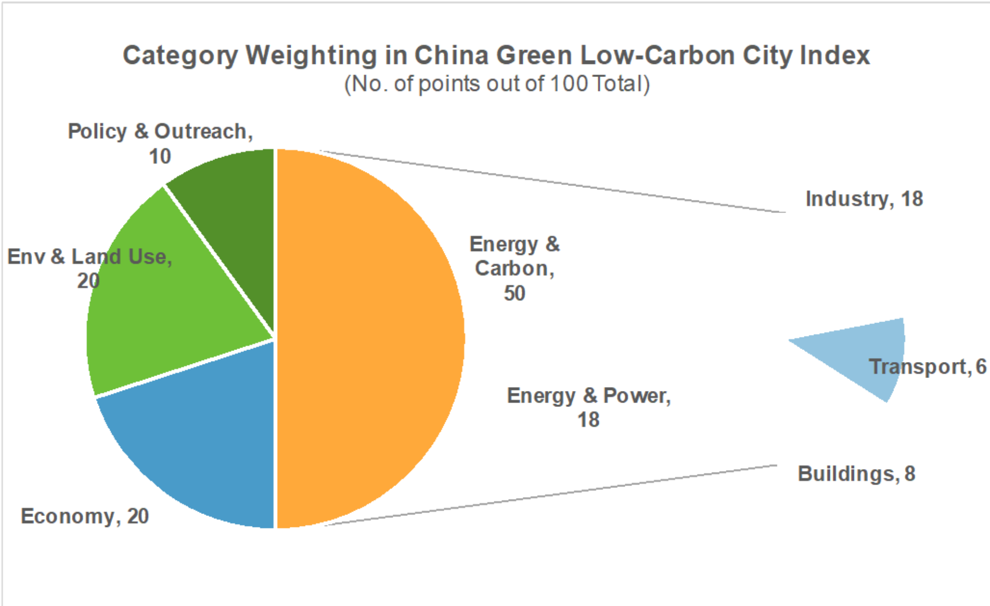

Figure 1. Category Weighting in the *China Green Low-Carbon City Index*

The following formula was used to calculate the maximum value for each indicator, based on the weighting discussed above:

$$S_i = 100 * w_i$$

S_i = maximum score for indicator i ;

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

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

Qualitative indicators were the four (4) indicators for Policy and Outreach, with responses of Yes or No (see the bottom of Table 1). A Yes response earned maximum points, while a No response earned zero points.

[9] Small adjustments were made to the urban sector shares to balance and round off the number of points for the indicators in each sub-category. For example, the Energy and Power sector accounted for 34% of urban energy in 2015, which would have allotted 17 points in the Index. To assign equal and whole numbers of points to each of the three indicators in the Energy and Power sub-category, a small adjustment was made, allotting 18 points to the sub-category, resulting in 6 points for each indicator.

Quantitative indicators were divided into positive indicators (the higher the indicator value, the better the performance) and negative indicators (the lower the indicator value, the better the perforance). As Table 1 shows, there were eleven (11) negative indicators and eight (8) positive indiators.

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

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

For negative 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 .

3.2. Selection and Grouping of Cities

China currently has 658 cities, including four provincial-level municipalities, 15 sub-provincial cities, 269 prefecture-level cities, and 370 county-level cities. The cities are defined by administrative boundaries and level of governance, and they typically include a core urbanized area along with industrial or rural agricultural areas within their administrative boundaries.

Taking into account the challenges of data acquisition and the goals of this research, we selected 115 cities at the prefecture-level and above for the City Index. In terms of administrative level, the sample cities include the four provincial-level municipalities, 15 sub-provincial cities, 16 provincial capitals and 80 prefecture-level cities. In terms of population, the sample cities include the 100 largest cities, with six mega-cities (population > 10 million) and 21 very large cities (population 5-10 million). The selected cities include 34 of the 36 **low-carbon pilot cities** and 20 cities in the six low-carbon pilot provinces in China's national low-carbon pilot program (noted in **bold** in tables in this report).[10]

Figure 2 shows the location of cities selected for the City Index, noting the pilot low-carbon cities in green, and non-pilot cities in orange. Selected cities span China's provinces. They are located in the four provincial-level municipalities (Beijing, Tianjin, Shanghai and Chongqing), and across China's provinces and provincial administrative regions: Anhui (7 cities), Fujian (4), Gansu (3), Guangdong (9), Guangxi (3), Guizhou (2), Hainan (1), Hebei (7), Henan (5), Heilongjiang (3), Hubei (5), Hunan (4) , Jilin (2), Jiangsu (12) Jiangxi (3), Liaoning (7), Inner Mongolia (4), Ningxia (1), Qinghai (1), Shandong (9), Shanxi (3), Shaanxi (3), Sichuan (7), Xinjiang (1), Yunnan (1) and Zhejiang (5).

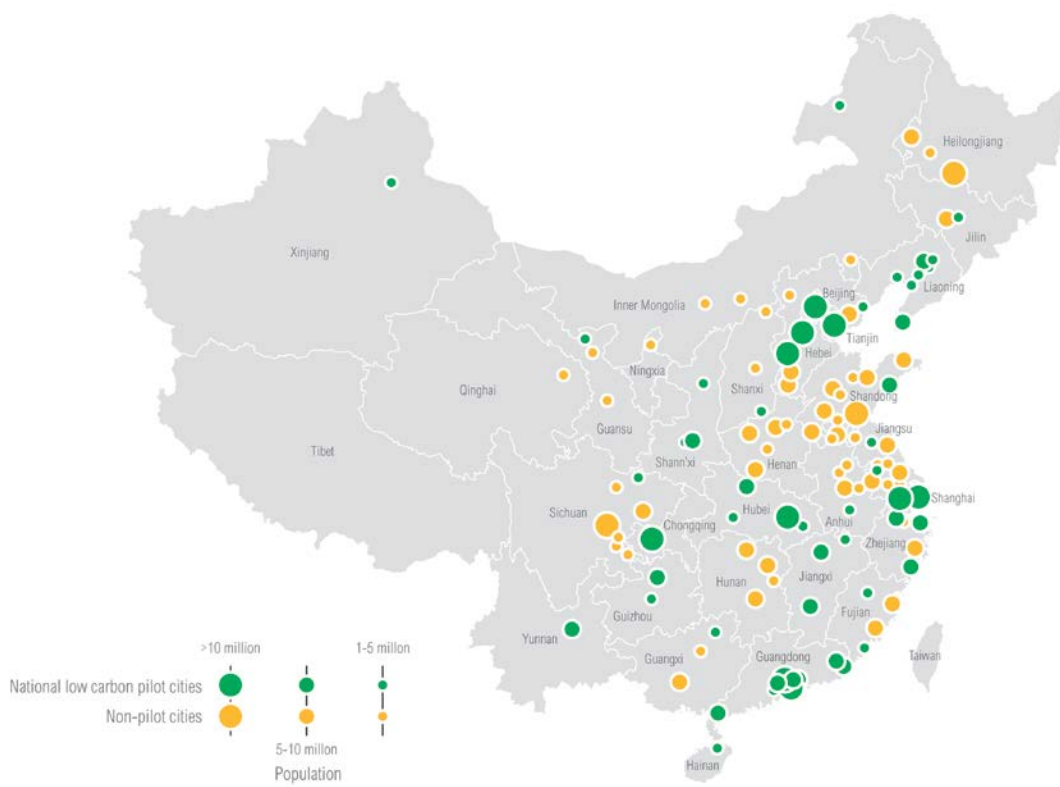

Figure. 2 Map of Cities in the *China Green Low-Carbon City Index*

Note: Green represents the Low-Carbon Pilot Cities (dots) and Provinces (shaded areas). Orange dots represent non-pilot cities. The size of the dot corresponds to population size (>=10 mil, 5-10 mil,1-5 mil) .

Recognizing that low-carbon development may proceed differently across cities depending on their size, economic structure, and resources, we examined methods for grouping similar cities,

[10] In early 2017, China expanded its low-carbon pilot cities program, adding 45 more cities. Future versions of the *China Green Low-Carbon City Index* will analyze the progress of the newest low-carbon pilots.

to compare their scores and ranking in the *China Green Low-Carbon City Index*. After considering geographical grouping, or a simple grouping based one or two aggregate indicators such as population or GDP per capita, we found that simple grouping methods didn't have sufficient explanatory power for the City Index results. We then examined two multi-criteria grouping methods based on urbanization and economic development characteristics. In the future, other types of cluster analysis could be considered.

The first method, developed by researchers at Chinese Academy of Social Sciences, or CASS (Chen et al. 2006), focuses on the extent of industrialization in a city. The CASS multi-criteria grouping method, developed specifically for China, considers five characteristics: GDP per capita; the output value ratio of the primary and secondary economic sectors; the proportion of manufacturing industry value-added to the total commodity production sector value-added output; the urban share of the population; and the employment proportion of the primary economic sector (i.e., agriculture, resource extraction). Table 2 summarizes the city groupings for the City Index, based on application of the CASS economic and urbaniztion criteria, utilizing 2015 data. Group P cities (of which there are 10 cities analyzed in the *City Index*) are categorized as having post-industrial economies, fairly wealthy, urbanized populations and a large service sector. Group H cities (58 cities) are cities which are undergoing an economic transformation from a large industrial sector (heavy industry and manufacturing) to one dominated by the service sector. They have a slightly lower GDP per capita and less urbanization compared to P cities. Finally, M cities (47 cities) have economies dominated by industry and have a much lower GDP per capita and urbanization than both P and H cities.

Table 2: City Index CASS groupings based on economic and urbanization characteristics

Group	Number of cities	Economic and Urban Characteristics (2015 data)
P cities	10	GDP/capita: RMB 89,793 - RMB 153,819 (US$14,413-$24,690); Urban population share: 75%-100%; Service sector share of value-added: 50%-80%
H cities	58	GDP/capita: RMB33,320 - RMB146,397 (US$5,348 - $23,498); Urban population share: 52%-97%; Service sector share of value-added: 31%-75.7%
M cities	47	GDP/capita: RMB22,912 - RMB63,168 (US$3,677 - $10,139); Urban population share: 36%-71%; Service sector share of value-added: 24%-53%

Note: 2015 exchange rate = 6.227 RMB/US$ (OECD database).

The second method, oft-used in business and investment circles, and familiar to government officials and the public, is that of City Tiers. Although grouping by City Tier is common, there is not one definitive methodology. We reviewed multiple sources, including analysis by Chinese City Development Research Association (2016} and an interactive graphical website on city tiers by the South China Morning Post (SCMP 2016). Three key characteristics used to define City Tiers are: size of GDP, administrative level of government, and population size. Table 3 summarizes the characteristics and value ranges used by SCMP on 2013 data, representing city conditions mid-way through the time period we analyzed for the City Index. The overall Tier is based on the average of the three categories. Tier 1 cities are the largest and wealthiest, with most reporting directly to the central government, namely: Beijing, Tianjin, Shanghai, and Chongqing, plus Guangzhou and Shenzhen in the Pearl River Delta.

Table 3. City Index grouping by City Tiers

Group	Number of Cities	GDP (2013)	Administration	Urban Population (2013)
Tier 1	6	>= 48 billion RMB (>= $US300 billion)	report directly to central government	> 15 million
Tier 2	31	11 bil – 47 bil RMB (US$68 bil - US$299 bil)	provincial and sub-provincial capital cities	3 - 15 million
Tier 3	51	3 bil – 10 bil RMB (US$18 bil - US$67 bil)	prefectural capital cities	1.5 - 3 million
Tier 4	27	< 3 bil RMB (<US$17 billion)	county-level cities	<1.5 million

Based on SCMP 2016; data is from 2013. Note that some organizations designate five city tiers. The overallTier is based on the average of the three characteristics (GDP, administrative level, and population). 2013 exchange rate = 6.196 RMB/US$ (OECD database).

3.3. Data Collection and Processing

The data used for calculation of the City Index were gathered from official national and local statistics and published research literature. For data that could not be obtained for the year 2015, the most recent year of data was used instead. For cities that lacked data on building energy consumption, we estimated the building indicators based on residential electricity use at the provincial level and the share of tertiary sector in the local economy. The energy consumption of buildings was adjusted for heating degree days and cooling degree hours, according to the climate coefficient of different regions (Ohshita et al. 2011). For the Particulate Matter air quality indicator, we used compliance with $PM_{2.5}$ standards in 2015, and used compliance with PM_{10} standards for 2010, since China shifted its PM monitoring in 2012 from PM_{10} to $PM_{2.5}$.

Many cities lacked readily available statistics on energy mix and carbon emissions.
For these cities, we estimated their total energy based on economic energy intensity and city GDP. We then estimated each city's CO_2 emissions based on the fossil fuel mix at the provincial level, fuel-specific emission factors established by the NDRC to estimate CO_2 emissions in China,[11] and total city energy. The approach utilized here captures regional variations in the carbon intensity of energy supply and it enables analysis of a large number of cities. To obtain more accurate emissions estimates that a more detailed inventory would provide, we recommend that more cities develop and report their energy and carbon inventories as soon as possible.

[11] The NDRC emission factors are based on typical Chinese fuel quality and therefore give a better estimate of CO_2 emissions than the generic IPCC emission factors. See Lewis et al. 2015.

4. Index Results and Analysis

The *China Green Low-Carbon City Index* results presented here are based on the largest set of Chinese cities analyzed to date. We provide the overall *City Index* scores and ranking for 2015, and the change in scores over the 12th FYP period (2010 to 2015). We compare the performance of cities in the national low-carbon city pilot program versus non-pilot cities. We then analyze city economic characteristics and performance on the *City Index* and examine city performance within each category. Appendix A provides the detailed 2015 *City Index* scores for all 115 cities analyzed.

4.1. Moderate Scores, Large Potential for Improvement

Overall, the results of the *City Index* for the year 2015 show moderate to low scores, ranging from a high of 69.9 to a low of 28.4 out of 100 points, with the median at 44 and the mean at 45 points. Only two cities had scores higher than 60 points, while 51 cities had scores between 40 and 49.9 (see Figure 3 and Table 2). The distribution of scores indicates that some cities are making progress, yet overall much effort is still needed for cities to realize green low-carbon development as defined by the *City Index*. While no threshold score makes a city 'green' or 'not green', and achieving the maximum score of 100 is challenging for any city at the present time, scores in the 80s and 90s would show greater progress.

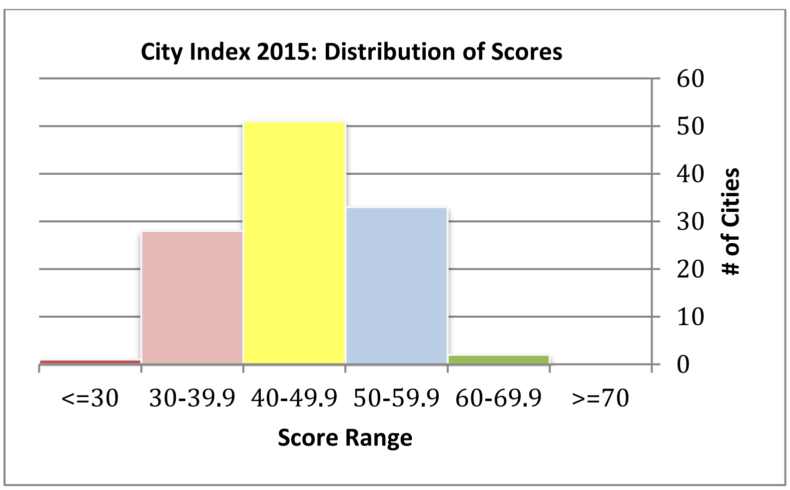

Figure 3. City Index 2015: Distribution of Scores

Looking at average scores within each category of the *City Index* (see Table 4), we found that cities had the lowest average score in the Economy category (5.1 out of 20 points max), owing to energy-intensive industrial economies in many cities, as well as the large variation among the energy intensity and carbon intensity of the cities' economies. The Transportation category also had a low average score (2.3/6 points), due to limited public transit in the majority of the cities, despite well-developed public transit in some best performing cities. The Industry category scored slightly better on average (7.2/18). The average score on Policy and Outreach was just below the half-way mark (4.3/10). The Energy and Power category scored just above the half-way mark (9.3/18), affected by the large share of coal in China's electric power generation and industry, but lifted up by several Chinese cities that have already met the national target for a 20% share of non-fossil energy in total primary energy. The Building sector performed slightly better (4.7/8), due in part to the modest energy consumption in Chinese homes. Somewhat surprisingly, despite the severe air pollution impacting many cities, the Environment and Land Use category had the best average score, slightly above the half-way mark (12.0/20). Solid waste generation per capita is low compared to other countries, and many cities are meeting their environmental budget targets. Refer back to Table 1 to see the full list of indicators in each category.

Table 4. City Index Summary Statistics (2015)

	Total Score	Economy	Energy & Power	Industry	Transport	Buildings	Envi & Land Use	Policy & Outreach
Index Max	***100***	*20*	*18*	*18*	*6*	*8*	*20*	*10*
avg	**44.9**	**5.1**	**9.3**	**7.2**	**2.3**	**4.7**	**12.0**	**4.3**
avg % of max score	***45%***	*26%*	*52%*	*40%*	*38%*	*59%*	*60%*	*43%*
median	**44.3**	**4.8**	**8.9**	**6.8**	**2.1**	**4.7**	**12.1**	**5.0**
max	**69.7**	14.6	17.9	14.7	5.5	8.0	15.3	7.5
min	**28.4**	1.4	2.4	3.5	0.1	1.1	8.8	2.5

4.2. Top Scoring Cities Show Geographical Spread, with Coastal Concentration in East and South Central Regions

Figure 4 provides a map with the location and rank of the Top 50 cities in the *City Index* in 2015. The map shows a concentration of top-scoring cities in the Eastern coastal provinces of Jiangsu, Zhejiang, and Fujian, and the South Central coastal province of Guangdong. With numerous coastal cities having relatively high-value economies that are shifting away from heavy industry, it isn't surprising they scored well on several low-carbon indicators. Interestingly, the map also reveals the geographical spread of top-scoring cities. In addition to the range along the Eastern and South Central coastal provinces, top-scoring cities are found in other South Central provinces (Hunan, Guangxi, and Hainan), in Southwestern provinces (Sichuan and Yunnan), as well as Beijing in the North and Jilin province in the Northeast. The geographical spread shows that cities in any part of the country can pursue green low-carbon development.

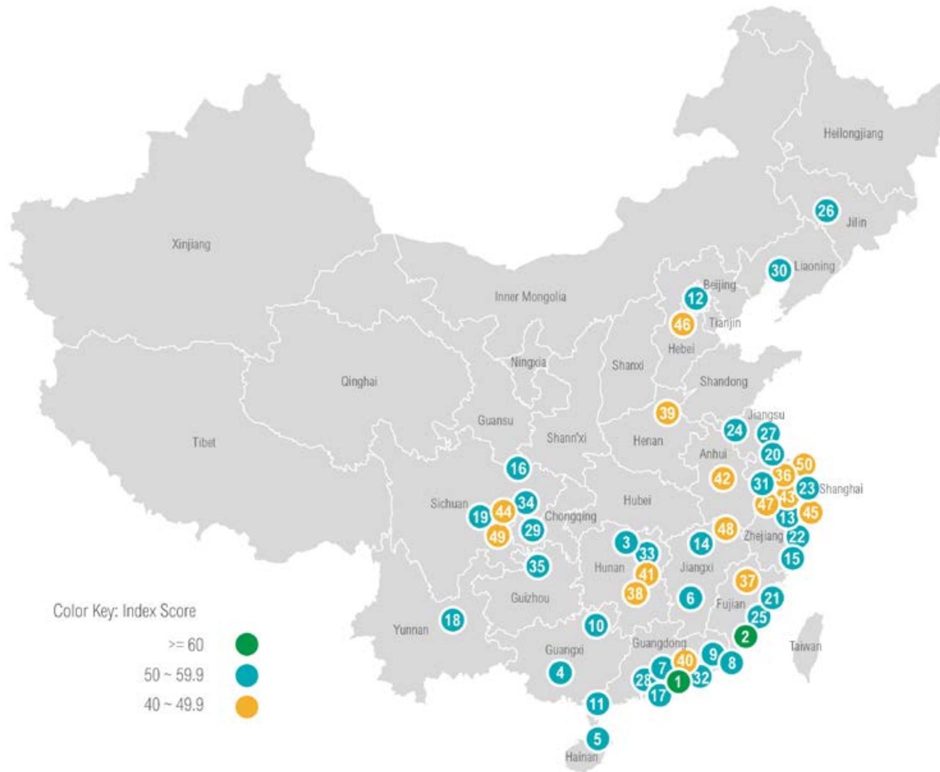

Figure 4. Map of Top 50 Cities in the *China Green Low-Carbon City Index*, 2015

4.3. Top Scoring Cities Span Socio-economic Tiers

Figure 5 shows a rank-order view of the Top 50 cities in the *City Index* in 2015, grouped by City Tier.[12] Figure 5 also shows the variation in category scores across the cities. Complementing this figure, Table 5 lists the Top 50 Cities, along with their total *City Index* score, ranking among all cities analyzed for the City Index, their socio-economic Tier, and their location (province and region).

The top two scoring cities in 2015, #1 Shenzhen (Tier 1, Guangdong province) and #2 Xia'men (Tier 2, Fujian province), had relatively high scores in multiple categories, especially Energy & Power and Buildings. Shenzhen also scored well in Transport, due to its investments in public transit. Xia'men also scored highly in the Industry category, as it has little heavy industry and a strong tourist economy. But even these top scorers had only reached three-quarters of the benchmarks in the Economy, Environment & Land Use, and Policy & Outreach categories.

[12] We used the City Tier designation in 2013, mid-way through the 12th FYP.

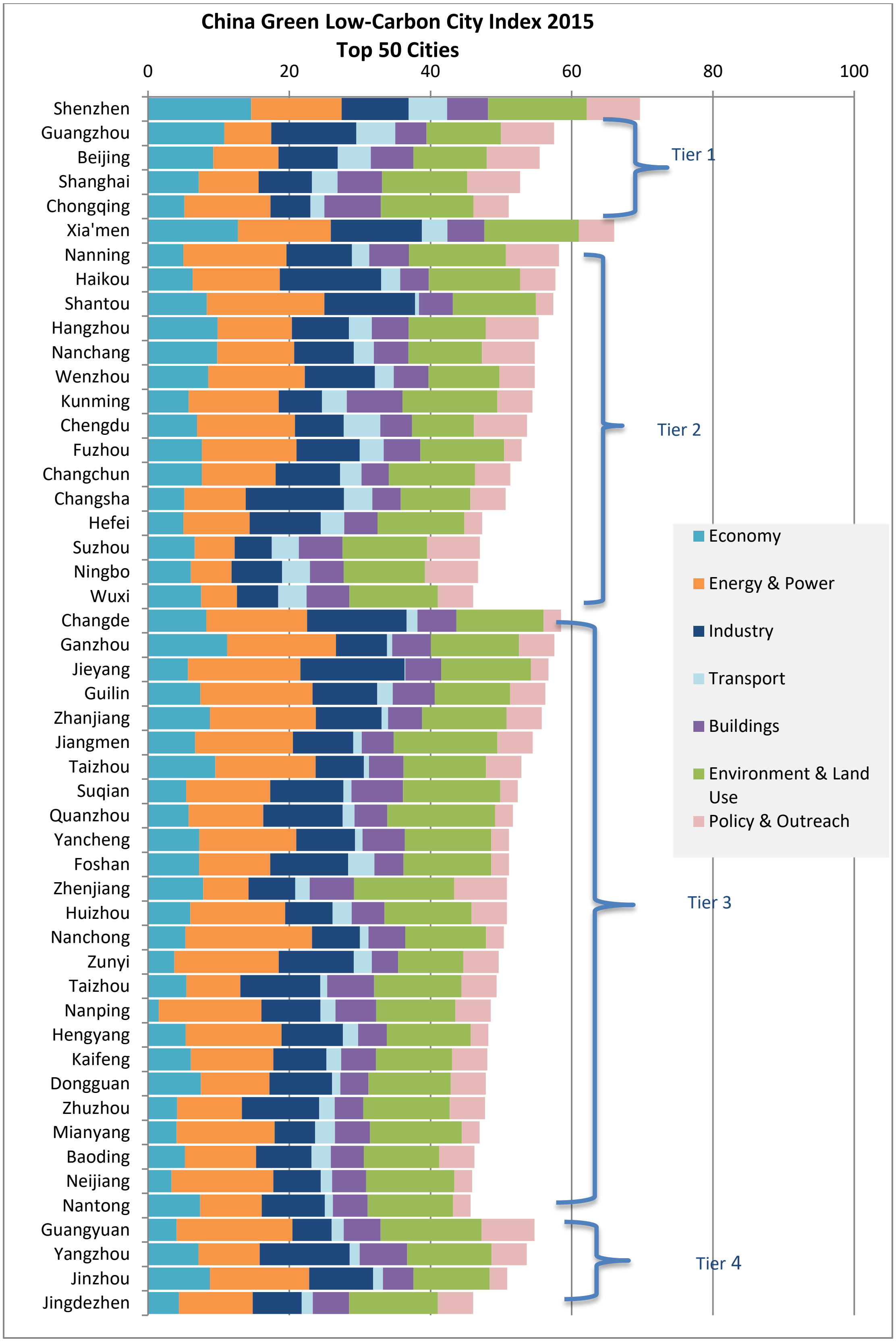

Figure 5. *China Green Low-Carbon City Index* 2015: Top 50 Cities, Grouped by Tier.

Table 5. Top 50 Cities in the *China Green Low-Carbon City Index* (2015)

Index Rank	City Name	Province	Region	Total Score (100 max)	Low-Carbon Pilot City	City Tier (2013)
1	**Shenzhen**	Guangdong	SC	70	C	i
2	**Xia'men**	Fujian	E	66	C	ii
3	Changde	Hunan	SC	58	X	iii
4	Nanning	Guangxi	SC	58	X	ii
5	Haikou	**Hainan**	SC	58	CP	ii
6	**Ganzhou**	Jiangxi	E	58	C	iii
7	**Guangzhou**	**Guangdong**	SC	57	C	i
8	Shantou	**Guangdong**	SC	57	CP	ii
9	Jieyang	**Guangdong**	SC	57	CP	iii
10	Guilin	Guangxi	SC	56	C	iii
11	Zhanjiang	**Guangdong**	SC	56	CP	iii
12	**Beijing**	Beijing	N	55	C	i
13	**Hangzhou**	Zhejiang	E	55	C	ii
14	**Nanchang**	Jiangxi	E	55	C	ii
15	**Wenzhou**	Zhejiang	E	55	C	ii
16	**Guangyuan**	Sichuan	SW	55	C	iv
17	Jiangmen	**Guangdong**	SC	54	CP	iii
18	**Kunming**	Yunnan	SW	54	C	ii
19	Chengdu	Sichuan	SW	54	X	ii
20	Yangzhou	Jiangsu	E	54	X	iv
21	Fuzhou	Fujian	E	53	X	ii
22	Taizhou	Zhejiang	E	53	X	iii
23	**Shanghai**	Shanghai	E	53	C	i
24	Suqian	Jiangsu	E	52	X	iii
25	Quanzhou	Fujian	E	52	X	iii
26	Changchun	Jilin	NE	51	X	ii
27	Yancheng	Jiangsu	E	51	X	iii
28	Foshan	**Guangdong**	SC	51	CP	iii
29	**Chongqing**	Chongqing	SW	51	C	i
30	Jinzhou	Liaoning	NE	51	CP	iv
31	**Zhenjiang**	Jiangsu	E	51	C	iii
32	Huizhou	**Guangdong**	SC	51	CP	iii
33	Changsha	Hunan	SC	51	X	ii
34	Nanchong	Sichuan	SW	50	X	iii
35	**Zunyi**	Guizhou	SW	50	C	iii
36	Taizhou	Jiangsu	E	49	X	iii
37	**Nanping**	Fujian	E	49	C	iii
38	Hengyang	Hunan	SC	48	X	iii
39	Kaifeng	Henan	SC	48	X	iii
40	Dongguan	**Guangdong**	SC	48	CP	iii
41	Zhuzhou	Hunan	SC	48	X	iii
42	Hefei	Anhui	E	47	X	ii
43	**Suzhou**	Jiangsu	E	47	C	ii
44	Mianyang	Sichuan	SW	47	X	iii
45	**Ningbo**	Zhejiang	E	47	C	ii
46	**Baoding**	Hebei	N	46	C	iii
47	Wuxi	Jiangsu	E	46	X	ii
48	**Jingdezhen**	Jiangxi	E	46	C	iv
49	Neijiang	Sichuan	SW	46	X	iii
50	Nantong	Jiangsu	E	46	X	iii

Notes: Cities (C) or provinces (CP) in **bold** font are part of the national Low-Carbon pilot program.
Regions: E = East, NE = Northeast, NW = Northwest, SC = South Central, SW = Southwest.
Cities scoring 60 or higher are shaded in green; scores in the 50s, blue.,; scores in the 40s, yellow.

The rest of the Top 10 cities in the *City Index* in 2015 are: #3 Changde (Tier 3, Hunan), #4 Nanning (Tier 2, Guangxi), #5 Haikou (Tier 2, Hainan), #6 Ganzhou (Tier 3, Jiangxi), #7 Guangzhou (Tier 1, Guangdong province), #8 Shantou (Tier 2, Guangdong), #9 Jieyang (Tier 3, Guangdong), and #10 Guilin (Tier 3, Guangxi). All of the Top 10 cities are in the East or South Central regions. But the Top 10 cities span the socio-economic Tiers, with two cities in Tier 1, four in Tier 2, and four in Tier 3, indicating that a variety of pathways for green low-carbon development are possible.

How did China's Tier 1 cities fare in the ranking? The Pearl River Delta mega-cities Guangzhou and Shenzhen were the top Tier 1 cities, with strong showing in the Economy category (see Table 6). Beijing and Shanghai ranked in the middle of Tier 1 cities, due to higher energy and carbon intensity, as well as higher per capita energy and carbon. The lowest-scoring among the Tier 1 cities were #32-ranked Chongqing and #56-ranked Tianjin (see Table 6). Chongqing was weakest in the Economy category, due to relatively high energy use and carbon intensity for its moderate-value economy. But Chongqing scored fairly well in the Energy & Power category, due to a higher share of renewable energy, and modest per capita energy consumption. The lowest-scoring Tier 1 city, Tianjin, was the only city of the group to not participate in the low-carbon pilot program. In addition to a more carbon-intensive energy mix, Tianjin had higher energy consumption in Buildings and worse air quality than most other Tier 1 cities.

Table 6. Tier I Cities: City Index Ranking and Scores (2015)

Rank Within Tier	***Low-C Pilot City***	***Index Rank***	***City Name***	***Province***	***Region***	***Total Score (100 max)***	***Economy (20 max)***	***Energy & Power (18 max)***
1	C	**1**	**Shenzhen**	**Guangdong**	SC	**70**	15	13
2	C	**7**	**Guangzhou**	**Guangdong**	SC	**57**	11	7
3	C	**12**	**Beijing**	**Beijing**	N	**55**	9	9
4	C	**23**	**Shanghai**	**Shanghai**	E	**53**	7	8
5	C	**29**	**Chongqing**	**Chongqing**	SW	**51**	5	12
6	C	**55**	**Tianjin**	**Tianjin**	N	**45**	7	5

Note: Cities or provinces in **bold** font are part of the national Low-Carbon pilot program.
Regions: E = East, NE = Northeast, NW = Northwest, SC = South Central, SW = Southwest.

4.4. Cities' Performance Improved during the 12th FYP Period

From analyzing the change in *City Index* scores for 115 cities from the year 2010 to the year 2015 (closing year of the 12th FYP period), we found that cities' overall scores improved for all but three of the 115 cities. The average *City Index* score increased by 6.4 points, or 17% (see Table 7). The change in median total score was less (5.8 points or 15%), indicating that some high-achieving cities lifted the average scores. The Economy category showed a notable improvement of 29% on average; but as the discussion above pointed out, the Economy category still had the poorest performance in the *City Index* in 2015, due to relatively high energy intensity and carbon intensity of cities' economies. The categories with the next largest improvement were Industry at 18% and Buildings at 14%. The Energy & Power category showed zero improvement on average (and a 5% decline in median score). This analysis suggests that although Chinese cities improved energy efficiency of their industrial sector and pursued lighter industry, their scores would increase if they used more renewable energy and improved the energy and carbon intensities of their economies. The only category that saw a decline during the 12th FYP was Environment & Land Use, which dropped 7% on average, due to persistent air pollution problems along with a tightening of standards to address those problems.

Table 7. Change in City Index Scores during the 12th FYP (2010 – 2015)

	Total Score	Total Score	Economy	Energy & Power	Industry	Transport	Buildings	Environment & Land Use
	Δ %	**Δ pts**	**Δ %**	**Δ %**	**Δ %**	**Δ %**	**Δ %**	**Δ %**
average (mean)	**17%**	**6.4**	**29%**	**0%**	**18%**	**10%**	**14%**	**-7%**
median	15%	5.8	31%	-5%	15%	3%	16%	-8%

Note: % change in Policy & Outreach score not calculated since all scores were 0 in 2010.

Table 8 examines the contribution of each category to the improvement in total score. The category with the greatest improvement was Policy and Outreach, as Chinese cities developed low-carbon plans and public campaigns during the 12th FYP period. Chinese cities went from zero points in 2010 to an average increase of 4.3 points in this category, contributing 67% of the *City Index* improvement from 2010 to 2015. The next largest contributing categories were the Economy, adding 1.2 points (18%) to the average score, and Industry, adding 1.1 points (17%) to the average score. The other categories contributed less than 10% each, while the Environment and Land Use category saw a decline in average score of -1.0 points (detracting 15% from the change in total score), due to ongoing air pollution and the establishment of stricter air quality standards in 2012.

Table 8: Improvement in Policy & Outreach, Economy, Raised Index Scores (2010 – 2015)

	Total Score	Economy	Energy & Power	Industry	Transport	Buildings	Environment & Land Use	Policy & Outreach
Change in Avg Index Scores (Δ pts)	**6.4**	1.2	0.0	1.1	0.2	0.6	-1.0	4.3
Contribution of Category to Total Score (Δ%)	--	18%	1%	17%	3%	9%	-15%	67%

4.5. Low-Carbon Pilot Cities Among Top Scorers, Had Higher Average Score and More Improvement

Among the Top 10 scorers in the *City Index* in 2015, five cities participated in the national low-carbon pilot program as pilot cities, and three more in pilot provinces, accounting for eight of ten top scorers (see Table 5). Of the Top 50 cities in the *City Index*, 20 were low-carbon pilot cities and nine were cities located in low-carbon provincial pilots; in total, the pilots accounted for 29 (58%) of the Top 50 performers., When all 115 cities are considered, the pilot cities had a higher average *City Index* score, compared to non-pilot cities. The average *City Index* score for the low-carbon pilot cities in 2015 was 47.0, while the average score for the non-pilot cities was 42.9. Low-carbon pilot cities had a noticeably better performance in the Economy, and Policy & Outreach, categories.

Eight of the ten most improved cities (based on % improvement of *City Index* score) were low-carbon pilot cities: Beijing, Hulunbuir, Jilin, Qinghuangdao, Shanghai, Shenzhen, Suzhou, and Urumqi. On average, the low-carbon pilot cities showed greater improvement (% change) in their scores during the 12th FYP. The average *City Index* score for pilot cities increased by 19.5% from 2010 to 2015, while the average score for non-pilot cities increased by 14.1%. Overall, the national pilot program has increased attention and promoted progress in low-carbon development.

5. City Performance within each Category

To gain further insight from the *City Index* results, we analyzed performance within each category. We examined the top performers in each category, looked for trends within economic groupings of cities (CASS grouping and city Tiers), and looked for correlations between particular indicators and city characteristics. We also considered the performance of low-carbon pilot cities versus non-pilot cities, and looked at the time trend across the 12th FYP period. Here we provide highlights of that analysis. Appendix A provides the detailed 2015 *City Index* scores for all 115 cities analyzed.

5.1. Economy

The Economy category had a strong influence on the *City Index*, counting for 20 points maximum out of 100. A key finding within the Economy category is that nearly all of the 115 cities we analyzed reduced the energy intensity (energy/GDP) and carbon intensity (CO_2/GDP) of their economies during the 12th FYP. While this improvement occurred, Chinese cities continued to experience strong economic growth. Economic growth rates for all of the 115 cities remained above 7%, and two-thirds of the cities enjoyed growth rates higher than 10%. This finding re-affirms that economic development can be low energy and low carbon.

Table 9 shows the ten top-scoring cities in the Economy category in 2015, noting their overall rank in the *City Index*, their location, socio-economic groups, and if they were a low-carbon pilot city. Half of these cities were ranked in the top ten of the City Index overall: Shenzhen, Xia'men, Ganzhou (Jiangxi province), Guangzhou, and Hangzhou, reflecting the weighting of the Economy category in the *City Index* (20 points maximum out of the 100 point Index total score). Nine of the Top 10 in the Economy category were low-carbon pilot cities or in low-carbon pilot provinces. Interestingly, the top-scoring cities in the Economy category represented all of the city Tiers and CASS groups, from Tier 1 Guangzhou in the South to Tier 4 Jinzhou of Liaoning province in the Northeast.

Another key finding is that the Economy category was the weakest in the *City Index*, in terms of performance relative to the benchmarks. For economic energy intensity, the benchmark was set at the level of Japan in 2012, at 0.23 tce/10,000 RMB (fixed at 2005 price). In comparison, the average of all 115 cities analyzed was 0.95 tce/10,000 RMB, roughly four times higher than the benchmark. The top performing city, Shenzhen, met this benchmark; however, the average of the top ten cities was more energy-intensive than the benchmark, at 0.35 tce/10,000 RMB.

Table 9. Top-Scoring Cities in the Economy Category (2015)

Overall Index Rank	City Name	Economy (20 max)	Province	Region	Low-C Pilot	City Tier (2013)	*CASS Group*
1	Shenzhen	**14.6**	Guangdong	SC	C	i	*P*
2	Xia'men	**12.7**	Fujian	E	C	ii	*P*
6	Ganzhou	**11.2**	Jiangxi	E	C	iii	*M*
7	Guangzhou	**10.8**	Guangdong	SC	C	i	*P*
13	Hangzhou	**9.8**	Zhejiang	E	C	ii	*P*
14	Nanchang	**9.8**	Jiangxi	E	C	ii	*H*
22	Taizhou	**9.5**	Zhejiang	E	X	iii	*H*
12	Beijing	**9.3**	Beijing	N	C	i	*P*
11	Zhanjiang	**8.8**	Guangdong	SC	CP	iii	*M*
30	Jinzhou	**8.7**	Liaoning	NE	CP	iv	*M*

Note: Cities (C) or provinces (CP) in **bold** font are part of the national Low-Carbon pilot program.
Regions: E = East, NE = Northeast, NW = Northwest, SC = South Central, SW = Southwest.

Economic carbon intensity fared worse. The benchmark was set at the level of the European Union in 2013, at 0.32 tCO_2/10,000 RMB (at 2005 fixed price). Hong Kong, Singapore, France, and Denmark already had even lower carbon intensities at that time (close to 0.16 tCO_2/10,000 RMB). Yet the average of the Chinese cities in 2015 was 1.91 tCO_2/10,000 RMB, nearly six times higher than the benchmark. And even the top-performing Chinese cities were still twice as high as the benchmark. Energy saving and de-carbonization of the economy need to increase for Chinese cities to compare to low-carbon cities and countries globally.

5.2. Energy and Power

The three indicators for the Energy and Power category of the *City Index* are energy per capita, CO_2 per capita, and non-fossil share of primary energy. The per capita energy and carbon indicators are for the city as a whole, not just residential, so they reflect all the energy consumption activity taking place within the administrative boundaries of the city. The benchmark for CO_2 per capita was set at 2.4 tCO_2/capita (annual), which is 20% better than the ten best scoring Chinese cities in the City Index, and is also close to the "Under 2 MOU" pledge of 2 tCO_2/capita that cities around the world are striving to meet. For comparison, a recent EU city average was 4.9 tCO_2/capita. The 115 cities analyzed for the *City Index* had an average of 9.7 and a median of 8.0 tCO_2/capita in the year 2015. In most cities, per capita CO_2 emissions increased from 2010 to 2015, a trend that must be reversed to achieve low-carbon development.

The non-fossil share of primary energy considers all forms of energy input to the city, not just electricity, and it may include nuclear power as well as renewable energy. The benchmark for this indicator was set at the Chinese national 2030 target of 20%. The top-scoring cities had already achieved near 40% non-fossil share of primary energy, while the average across all 115 Chinese cities was 11%, roughly half of the benchmark value.

The Chinese cities with the best scores in the Energy and Power category were mostly Tier 2 and Tier 3 cities with higher shares of renewable energy and lower per capita CO_2 emissions. The best performers were the Tier 3 city of Nanchong in Sichuan province (scoring 18 out of 20 points maximum) and the Tier 2 city of Shantou in Guangdong province (17 points). Other cities in the provinces of Sichuan, Guangdong, Guangxi, Jiangxi, Guizhou, and Fujian earned scores of 15 or higher.

Table 10. Energy & Power Indicators for Tier 1 Cities (2015)

Index Rank	*City Name*	*Energy & Power Score (18 max)*	*Province*	*CO2 per capita (benchmark = 2.4 tCO2/cap)*	*Non-fossil share of Primary energy (benchmark = 20%)*
1	**Shenzhen**	13	**Guangdong**	8.8	18%
29	**Chongqing**	12	**Chongqing**	5.4	13%
12	**Beijing**	9	Beijing	6.7	6%
23	**Shanghai**	8	Shanghai	10.6	12%
7	**Guangzhou**	7	**Guangdong**	8.1	3%
55	**Tianjin**	5	Tianjin	10.5	3%

Note: Cities (C) or provinces (CP) in **bold** font are part of the national Low-Carbon pilot program.

How did Tier 1 cities perform in the Energy and Power category? Table 10 shows that Shenzhen was the best of the Tier 1 cities in the year 2015 with 13 points (out of 18), followed closely by

Chongqing. Shenzhen[13] was nearing the national target for non-fossil energy, while Chongqing had the lowest CO_2 per capita emissions of the group. Yet even Chongqing needs to cut its per capita emissions by nearly half to reach the benchmark. The other Tier 1 cities lagged behind, with Tianjin showing the worst performance.

5.3. Industry

The first indicator for the Industry category is Industrial economic energy intensity, similar to city-wide energy intensity, but focused on the urban Industry sector and expressed as the energy consumed per unit of industrial value-added economic output. The benchmark was set at 0.27 tce/10,000 RMB, which is 20% better than Guangzhou, the best-performing large city; this benchmark is also close to 20% better than the ten top-scoring cities for this indicator. The average of all cities we analyzed was 1.18 (in the year 2015), more than four times higher than the benchmark for Industrial energy intensity.

The second indicator is the Heavy industry share of industrial value-added economic output, an indicator of economic structure and the reliance on an energy-intensive economy. The benchmark was set at 29%, at 20% better than Guangzhou, also 20% better than the ten top-scoring cities in the *City Index*. The average of all cities was 67%, more than three times higher than the benchmark. See Table 11.

Table 11. Top-Performing Cities in Industry Category (2015)

Index Rank	*City Name*	*Industry Score (18 max)*	*Province*	*Low-C Pilot*	*City Tier 2013*	*Industrial Energy Intensity**	*Heavy % of Industry VA*	*Industry % of City GDP*
9	Jieyang	**14.7**	**Guangdong**	CP	iii	0.43	29%	*59%*
5	Haikou	**14.3**	**Hainan**	CP	ii	0.19	49%	*11%*
3	Changde	**14.1**	Hunan	X	iii	0.48	23%	*41%*
33	**Changsha**	**13.9**	Hunan	X	ii	0.16	53%	*44%*
2	**Xia'men**	**12.9**	Fujian	C	ii	0.25	68%	*39%*
8	Shantou	**12.8**	**Guangdong**	CP	ii	0.64	28%	*47%*
20	Yangzhou	**12.8**	Jiangsu	X	iv	0.25	70%	*59%*
7	**Guangzhou**	**12.1**	**Guangdong**	C	i	0.34	54%	*29%*
36	Taizhou	**11.3**	Jiangsu	X	iii	0.32	74%	*66%*
25	Quanzhou	**11.2**	Fujian	X	iii	0.67	35%	*55%*

Notes: Cities (C) or provinces (CP) in **bold** font are part of the national Low-Carbon pilot program.

[13] Despite their proximity, Shenzhen and Guangzhou have different energy structures. Shenzhen has a larger share of electricity and natural gas than Guangzhou. Nuclear power and natural gas power accounted for 85.37% of total electricity generation in Shenzhen in 2015, while coal consumption accounted for 6.5% (based on Shenzhen Low-Carbon Pilot Assessment Report). Shenzhen's energy consumption mainly depends on imported electricity. In comparison, Guangzhou had a coal share of 24% in 2014 (based on Guangzhou Low-Carbon Development Action Plan).

*Units on Industrial Energy Intensity are tce/10,000 RMB, at fixed 2005 prices. The benchmark value is 0.27. The benchmark for Heavy Industry share of Industrial VA is 29%.

Although the average performance of all the cities in the Industry category was weak compared to the benchmarks, we did observe an 18% improvement in mean scores from 2010 to 2015. (The improvement in median scores was less, at 15%, indicating that some high achievers raised the average.) During the 12th FYP, the national government set improvement targets for industrial energy intensity, which were then allocated to the provinces and to cities. Supporting policies at all levels of government, including financial incentives, helped to achieve the industrial targets.

Table 11 shows the ten best-performing cities in the Industry category, including their Industry score, *City Index* rank, location, and tier, along with the values of the industrial indicators and the industrial share of city GDP. All the top-performers in the Industry category are in the East or South Central regions, and most are low-carbon pilot cities. Beyond those similarities, they span all four socio-economic tiers, from Tier 1 city Guangzhou, to Tier 4 city Yangzhou. These two cities also showed significant improvement in the Industry category from 2010 to 2015. Some of the cities in Table 11 owe their good performance to energy-efficient high-value industry (low industrial energy intensity). Others scored well due to their economic structure, having lower shares of Industrial value-added from heavy industry, as well as having a small share of industry in the city's economy overall. One possible interpretation of the lack of significant correlation between city type and performance in the Industrial category, is that no matter a city's type of economic development, it is possible to gain economic value from either low-energy or energy-intensive industry.

5.4. Transport

The three indicators in the Transport category emphasize the availability and use of public transit: Deployment of public transit vehicles, Extent of urban rail, and Bus utilization (refer to Table 3). Unfortunately, data on non-motorized transport (trips made by walking or bicycling) were not readily available for all 115 cities analyzed, nor were data on mode share or vehicle kilometers traveled, so those transport indicators were not represented in the *City Index*. Due to the type of indicators available, cities that have prioritized and invested in ample public transit (bus, subway, light rail) performed well in the Transport category. See Table 12.

Table 12. Top-Scoring Cities in the Transport Category (2015)

Index Rank	*City Name*	*Transport Score (6 max)*	*Province*	*Region*	*Pilot City*	*City Tier*	*CASS Group*
7	**Guangzhou**	**5.5**	**Guangdong**	SC	C	i	*P*
1	**Shenzhen**	**5.5**	**Guangdong**	SC	C	i	*P*
19	**Chengdu**	**5.2**	Sichuan	SW	X	ii	*H*
87	Dalian	**5.0**	**Liaoning**	NE	CP	ii	*P*
12	**Beijing**	**4.7**	Beijing	N	C	i	*P*
47	**Wuxi**	**4.0**	Jiangsu	E	X	ii	*H*

33	**Changsha**	**4.0**	Hunan	SC	X	ii	*H*
65	**Zhengzhou**	**4.0**	Henan	SC	X	ii	*H*
45	**Ningbo**	**3.9**	Zhejiang	E	C	ii	*H*
43	**Suzhou**	**3.8**	Jiangsu	E	C	ii	*H*

Note: Cities (C) or provinces (CP) in **bold** font are part of the national Low-Carbon pilot program.

The top ten scoring cities in the Transport category in 2015 are shown in Table 12. These cities are a mix of low-carbon pilot cities and non-pilot cities. There is a wide variety in the location of the cities, in every region of China, from Dalian in the Northeast to Chengdu in the Southwest. The best performing cities in Transport include three Tier 1 cities and seven Tier 2 cities. In terms of the CASS grouping, considering multiple economic and urbanization criteria, these cities are a mix of P-type cities (wealthy, large service sector, highly urbanized) and H-type cities (moderate GDP per capita, industry still a large part of the economy). These cities also have quite a large spread in terms of their overall rank in the *City Index*, from #1-ranked Shenzhen to #87-ranked Dalian.

So what explains the high Transport scores among this wide variety of cities? There is a correlation between scores in the Transport category and GDP per capita. The wealthiest cities (P cities) had relatively high Transport scores, mainly due to investments in public transit. Although Shanghai had the greatest extent of urban rail, it had less bus ridership than Beijing or Guangzhou, scoring 3.6/6 as a result.

During the 12th FYP period, H-type cities (moderate urbanization, moderate GDP per capita) made the best *improvements* in the public transit indicators; four of the top five improved cities in the Transport category are H-type cities. Of the cities in Table 12, Wuxi (Jiangsu province) and Chengdu (Sichuan province) increased their Transport scores by 75% and 90%, respectively, through development of public transit. In contrast, a few cities saw their Transport scores decline between 2010 and 2015, as public transit lagged behind the increase in urban population.

5.5. Buildings

The Building category was characterized by three indicators in the *City Index*: Residential energy consumption per capita, Commercial energy consumption per service sector employee, and goal for the share of Green building in new building. The average Residential energy consumption per capita for all 115 cities was 2,805 kWh/capita (for all forms of energy, expressed in units of kWh[14]), while the ten lowest consuming cities had an average of only 522 kWh/capita. The goal of low-carbon development is to reduce energy and carbon overall, and cities around the world

[14] Residential Building Energy per capita included all forms of energy used in the buildings. The calculations involved excluding liquid fuels (100% gasoline and 95% diesel) noted in the statistical yearbooks and attributable to transport. Energy data were converted from physical units to coal equivalent, and then converted to kWh, using conversion factors from China Energy Statistical Yearbook (NBS 2016).

need to strive for Zero Net Energy (ZNE) buildings. However, the thermal comfort in Chinese homes is generally poor and in need of improvement at present. We therefore chose a 'convergence' approach[15] for Residential buildings and set the benchmark at 4,743 kWh/capita, at the level of Japan, which has a Residential sector that is relatively energy efficient and thermally comfortable.[16] As a result, many cities earned the maximum score for the Residential building indicator.

For Commercial building energy, a widely-used indicator is energy per building area. Since data on building area are not readily available for Chinese cities, we used the less common indicator of Commercial building energy per service sector employee, and set the benchmark at 20% better than the ten top-scoring cities, at a value of 6,576 kWh/employee. The top performing cities for this indicator are in the Southwest (Chongqing), South Central (Nanning), and East (Nanjing). The average performance across all 115 cities was 30,553 kWh/employee, 4.5 times higher than the benchmark, indicating a large potential for improvement in Commercial buildings.[17]

Nearly 20 cities of the 115 cities analyzed have set a goal for 100% of new buildings to be Green buildings; thus 100% is the benchmark for this indicator. The cities with this goal include: Changde, Zhenjiang, Zibo, Wuxi, and Suzhou, as well as four of the six Tier 1 cities (Shanghai, Beijing, Shenzhen, and Chongqing).

Table 14. Top-Scoring Cities in the Building Category (2015)

Index Rank	City Name	Buildings (8 max)	Province	Region	Pilot City	City Tier	*CASS Group*
29	**Chongqing**	8.0	Chongqing	SW	C	i	*H*
18	**Kunming**	7.9	Yunnan	SW	C	ii	*H*
68	**Huai'an**	7.3	Jiangsu	E	C	iii	*H*
24	Suqian	7.3	Jiangsu	E	X	iii	*M*
71	Xuzhou	6.9	Jiangsu	E	X	iii	*H*
20	Yangzhou	6.7	Jiangsu	E	X	iv	*H*
36	Taizhou	6.7	Jiangsu	E	X	iii	*H*
23	**Shanghai**	6.3	Shanghai	E	C	i	*P*
31	**Zhenjiang**	6.3	Jiangsu	E	C	iii	*H*
56	Changzhou	6.2	Jiangsu	E	X	iii	*H*
43	**Suzhou**	6.2	Jiangsu	E	C	ii	*H*
84	Nanjing	6.1	Jiangsu	E	X	ii	*P*

[15] Contraction and Convergence is an approach to global climate change mitigation that highlights equity and the principle of 'common but differentiated responsibility' in the UNFCCC; see: www.gci.org.uk
[16] For comparison, the average energy use in homes in China is roughly 3,800 kWh/capita, in Japan 4,700, and in the EU 6,800 kWh/capita (annual, IEA data).
[17] Note that a climate correction was done on Residential building energy, but not on Commercial building energy, since the share of heating and cooling in total building energy is better known for the residential sector.

47	Wuxi	6.0	Jiangsu	E	X	ii	*H*
12	**Beijing**	6.0	Beijing	N	C	i	*P*
75	Jinan	6.0	Shandong	E	X	ii	*H*
27	Yancheng	6.0	Jiangsu	E	X	iii	*H*

Note: Cities (C) or provinces (CP) in **bold** font are part of the national Low-Carbon pilot program.

Table 14 shows the top performers in the Buildings category in the year 2015 (scoring 6 points or higher out of 8 points). Chongqing and Kunming (Southwest region) top the list. Cities in Jiangsu province otherwise dominate the top performers, and low-carbon pilot cities are prominent. Three Tier 1 cities are among the top scorers in the Building category: Chongqing, Shanghai, and Beijing. The other cities in Table 14 span the socio-economic tiers, from Tier 2 cities Nanjing and Suzhou (Jiangsu province) and Jinan (Shandong province); to Tier 3 cities Huai'an, Suqian and Taizhou (Jiangsu province); even one Tier 4 city, Yangzhou (Jiangsu province).

There is a weak negative correlation between the Buildings score and GDP per capita, income per capita, and urban density. The scores in the Building category worsened as GDP per capita increased (wealthy P cities had some of the worst scores). This may be due to increased energy consumption in the Buildings sector with growing wealth; the trend could be mitigated with stronger standards for building and appliance efficiency. The influence of the growing service sector on per capita building energy is not clear and deserves further analysis.

5.6. Environment and Land Use

The Environment and Land Use category had a prominent influence on the *City Index*, counting for a maximum of 20 out of 100 points. The top performing cities in this category scored 15 points out of 20, while the average for all cities was 12.3 points.

Table 15 summarizes the indicators in the Environment and Land Use category, their benchmarks, and city performance for each indicator (top performers and average of all cities). For the municipal Waste indicator, the average of all cities was near the benchmark, set at the level of Singapore as best among wealthy Asian countries. Cities also performed well in the Environmental Spending indicator, with the average of all cities meeting the benchmark of 3% of city budget. In the Water indicator, cities used more than twice the minimum amount of water considered sufficient by the WHO. Top performing cities did better than the benchmark of 100 m^2/capita for urban green space, while the 64 m^2/capita average of all 115 cities was below. The worst scores were in the air quality indicators. Cities were in compliance with China's Level 2 air quality standards (i.e., "Blue Sky Days") only 72% of the days in 2015, on average. Worst of all were particulate matter concentrations ($PM_{2.5}$). Even the top cities had annual average $PM_{2.5}$ concentrations of 35 $\mu g/m^3$, more than three times higher than the World Health Organization guideline of 10 $\mu g/m^3$, while the average of all cities was six times higher.

Persistent and severe air pollution in many Chinese cities is an urgent health issue, closely linked to combustion of coal and oil, in industry, power generation, and the growing transport sector. Furthermore, the air quality score generally worsened during the 12th FYP period, as the air quality standards become stricter with a shift to monitoring finer particulates ($PM_{2.5}$) in 2012 compared to monitoring PM_{10} in 2010.

Table 15. Benchmarks and City Performance in the Environment and Land Use Category (2015)

Max points	***3***	***4***	***3***	***3***	***3***	***4***
Indicator	Municipal solid waste per capita	Blue sky days	$PM_{2.5}$ Conc. (annual avg)	Municipal water consumption per capita	Ratio of Spending on energy saving & env. in city budget	Green space per capita
units	t/capita/year	%	μg/m^3	L/capita/day	%	m^2/capita
Benchmark	**0.31**	**100%**	**10**	**60**	**3%**	**100**
20% better than Top 10 Cities	*0.11*	*78%*	*35*	*65*	*7%*	*192*
Average (all cities)	0.33	72%	60	167	3%	64

Low-carbon pilot cities generally had the most improvement in the Environment and Land Use category during the 12th FYP period. Interestingly, the Environmental and Land Use scores did not show strong correlation with GDP per capita, income per capita, or population density. Nor did the scores show any strong correlation with economic development characteristics, i.e., all city groupings performed roughly the same. One implication of these findings is that cities at any level of economic development or urbanization may struggle with environmental problems—or take action to improve air quality, water use, and waste management, and to expand urban greenery, to improve overall environmental quality.

5.7. Policy and Outreach

The Policy and Outreach category tracks the establishment of policies and public outreach related to energy and climate, through four qualitative (Yes/No) indicators: City low-carbon development / climate change plan; City strategy on renewable energy (beyond national targets); City climate change resilience / adaptation plan; Public outreach on low-carbon lifestyle. Cities scored 2.5 points for each plan or program, for a maximum of 10 points in the City Index. Because policies take time to implement and yield results, this category give points for effort, to acknowledge the early steps in green low-carbon development.

Analysis of the 115 cities in the *City Index* found that low-carbon pilot cities are establishing more climate policy, more energy planning, and more public outreach than non-pilot cities. Local governments in wealthier cities (P-type cities) are undertaking more low carbon planning and public outreach. However, most cities do not have detailed energy plans, nor do they have authority over power generation to pursue renewable energy. In addition, none of the Chinese cities analyzed for the *City Index* have yet completed climate change adaptation or resilience plans; as a result, the top scores in this category are 7.5 out of 10 points.

Table 15 shows the top performing cities in the Policy and Outreach category, with scores of 7.5 points out of a maximum of 10. These include cities with an overall high ranking in the City Index, such as Tier 1 cities Shenzhen and Guangzhou, as well as Tier 2 cities Nanning and Hangzhou. Interestingly, cities with relatively poor ranking in the City Index overall had launched new energy and climate policies by the year 2015; these include Hulunbuir (a Tier 4 city in Inner Mongolia, ranked #67 overall) and Luoyang (a Tier 4 city in Henan, ranked #86 overall), as well as Tier 1 city Tianjin (ranked #55). In addition to spanning all the socio-economic Tiers, the top performers in Policy and Outreach are located in nearly every region of China. They also represent a mix of low-carbon pilot cities and non-pilot cities. The wide variation of cities illustrates that poor and wealthy cities, service-oriented cities and heavily industrialized cities, can take policy action and engage in public outreach to pursue low-carbon development.

Table 15. Top Performing Cities in the Policy & Outreach Category (2015)

2015 Index Rank	*City Name*	*Policy & Outreach Score (10 max)*	*Province*	*Region*	*Low-Carbon Pilot City*	*City Tier 2013*
1	**Shenzhen**	**7.5**	**Guangdong**	SC	C	i
4	**Guangzhou**	**7.5**	**Guangdong**	SC	X	i
7	**Nanning**	**7.5**	Guangxi	SC	C	ii
12	**Hangzhou**	**7.5**	Zhejiang	E	C	ii
13	**Beijing**	**7.5**	Beijing	N	C	i
14	**Nanchang**	**7.5**	Jiangxi	E	C	ii
16	**Guangyuan**	**7.5**	Sichuan	SW	C	iv
19	Chengdu	**7.5**	Sichuan	SW	X	ii
23	**Shanghai**	**7.5**	Shanghai	E	C	i
31	**Zhenjiang**	**7.5**	Jiangsu	E	C	iii
43	**Suzhou**	**7.5**	Jiangsu	E	C	ii
45	**Ningbo**	**7.5**	Zhejiang	E	C	ii
55	**Tianjin**	**7.5**	Tianjin	N	C	i
59	Chifeng	**7.5**	Inner Mongolia	N	X	iii
67	**Hulunbuir**	**7.5**	Inner Mongolia	N	C	iv
86	Luoyang	**7.5**	Henan	SC	X	iv

Note: Cities (C) or provinces (CP) in **bold** font are part of the national Low-Carbon pilot program.

Because the *City Index* was designed to swiftly evaluate a large number of Chinese cities, the policy indicators focused on whether or not plans and programs were underway. More detailed examination of the strength of plans, their implementation experience, and the effectiveness of public outreach is being done through other analyses. Evaluations thus far include: Khanna et al. 2014; iGDP 2015;; and Su et al. 2016. For detailed analysis of low-carbon city policies, see the interactive policy mapping website of the Innovative Green Development Program (iGDP 2016). Future work on the *China City Index* may include a more in-depth characterization of policy strength and outreach effectiveness, along the lines of the ACEEE City Energy Efficiency Scorecard (ACEEE 2015).

6. Conclusions and Recommendations

6.1. Accomplishments in Data Gathering and Methodology

- The *China Green Low-Carbon City Index* represents the most extensive collection of this type of data on Chinese cities to date, including data on 23 indicators and 8 city characteristics, for 115 cities, for two years spanning the 12th FYP period (2010 and 2015).
- The methodology developed for the *City Index* balances meaningful, comparable indicators with data availability, offering the possibility for widespread use across Chinese cities. Whereas most other city indicator systems lack analysis of urban industry, the *China City Index* recognizes that in many Chinese cities, the Industry sector is still the largest energy consumer and CO_2 emitter.
- The inclusion of benchmarking in the *City Index* enables tracking of city performance relative to international best practice, national policy targets, and top-runners in China.
- The scoring system of the *City Index* enables comparative ranking across Chinese cities, informing local policy action and public awareness, as well as provincial and national policies and programs.
- Additional analysis on sub-groups of cities (by city tiers and economic characteristics), and on city sectors (energy, buildings, industry, etc.), provides more detailed insight.

6.2. Key Findings

Signs of Improvement. *City Index* scores from 2010 to 2015 show improvement of most cities in green low-carbon development during the 12th FYP, confirming trends observed at the national and provincial levels in China.

More Effort Needed Overall. However, all cities – even the highest ranked cities in the *City Index* – have much work ahead to become green and low-carbon. The best performer in the Index, Shenzhen, had a score of 71 out of 100 (in 2015), while the average (mean) score for all 115 cities was 45 and the lowest score 28.

De-Carbonizing the Economy and Industry. Overall, cities had the weakest performance in the Economy and Industry categories. Many cities still have carbon-intensive economies, and energy-intensive industry. Though per capita indicators in the Energy & Power category led to slightly better scores in that category, these sectors are still dominated by coal and oil.

Buildings and Transport Are Challenged by Rapid Urbanization. Overall, cities had better performance in the Buildings category, and weak performance in the Transport category. While some cities—especially low-carbon pilot cities—have made impressive investments in public transit and non-motorized transport, rapid urbanization is outpacing transit development in other places. Modest Residential building energy consumption raised scores in the Buildings category, while more effort is needed in Commercial buildings and Green building.

Mixed Environmental Performance, Severe $PM_{2.5}$ Pollution a Persistent Problem. Overall, cities had moderate performance in the waste and environmental spending indicators, and weaker scores in water consumption and green space indicators. Severe particulate matter pollution in many cities led to the worst scores in the air quality indicators in the Environment category.

Policy & Outreach an Important Step. A mix of high-performing and low-performing cities in the *City Index* (overall) had launched low-carbon planning and public outreach by the end of the 12th FYP (2015). However, none of the 115 cities had yet established a formal climate adaptation or resilience plan.

6.3. Recommendations for Further Analysis and Use of the *City Index*

Utilize, Inform, Communicate. We recommend utilizing the *City Index* as a tool to track annual progress in China's green low-carbon development during the 13th FYP (2016 to 2020) and beyond. The results of the *City Index* can be used by local government agencies to identify areas for improvement and to prioritize and implement low-carbon strategies suited to their local situation. Provincial and national government agencies can also use the *City Index* to strengthen policies, provide support to cities most in need, and award top performers. Government agencies could utilize the City Index as part of public outreach efforts. As soon as 2016 data becomes available, analysis of that year with the *City Index* is a clear next step. An on-line platform, in the form of an interactive website, would be another valuable step for sharing information from the *City Index* and raising awareness on green, low-carbon development.

Enhance Data Gathering and Indicators. To better utilize the *City Index* in urban planning and infrastructure decisions, we recommend enhancing the indicators on Transportation and Land Use, which would necessitate collection of additional data. A survey project would be a useful next step; eventually the data would be best collected by cities and relevant statistical bureaus in China, on a regular basis. In the Transportation category, we recommend data gathering on transport mode share—including non-motorized transport. Physical infrastructure Indicators related to Transportation could include Access to Public Transit, and Extent of Pathways for walking or biking. Indicators on transport behavior and energy could include Mode Share (Non-Motorized Trips, Transit, Shared Vehicles, and Private Vehicles). Collection of data on trip lengths by mode would provide even more useful information for low-carbon urban planning.

In the Land Use category, more attention is needed to population density and distribution, and to proximity and accessibility. The following additional data gathering and indicators related to Land Use and urban form would be helpful: Mixed-Use Zoning and Access to Amenities (such as grocery shops and restaurants, retail shops, schools, banks, post office, and activity centers), These indicators can help to reduce vehicle kilometers traveled (VKT), CO_2, and air pollution, as well as improve quality of urban life.[18] These indicators related to clustered density and transport accessibility are more important than simple "population density," because they convey more information about the distribution of people in a city and their ability to utilize walking and biking and public transit. In addition to the simple indicator of Urban Green Space, Urban Forest Canopy would be a more specific indicator related to green infrastructure and carbon sequestration aspects of Urban Form. To maintain comparability over time in the *City Index*, any changes in indicators would necessitate a scoring revision in the *Index*, as well as new analysis of past years and the current year.

Strengthen Benchmarks. Many of the benchmarks in the *China City Index* are based on best practice, yet are quite ambitious compared to current conditions in many Chinese cities, notably the Energy Intensity and Carbon Intensity benchmarks in the Economy category. Other benchmarks, such as those based on existing policy and standards, could be strengthened. To encourage greater de-carbonization of energy supply in cities, a higher benchmark for non-fossil energy (even more ambitious than the national target) could be set in the Energy and Power category. In the same category, the benchmark for CO_2 Emissions per Capita could be rounded down to 2.0 tCO_2/capita (annual), to align with the international effort of the "Under 2 MOU" for cities. Similarly, the benchmark for Residential energy consumption per capita could be tightened to promote Zero Net Energy (ZNE) buildings. In addition, the benchmark for Environmental Spending could be raised in the Environment and Land Use category, to encourage cities to make investments beyond the minimum requirement. To maintain comparability over time in the City Index, changes in benchmark values would necessitate new analysis of past years as well as the current year.

Analyze implementation. Analysis of the past progress of 115 Chinese cities with the *City Index* raised many interesting questions about how and why cities performed as they did. We look to conduct further analysis on policy implementation, to better understand how cities are making improvements in their environment and low-carbon development. The success stories—and pitfalls to avoid—can then be shared across cities.

[18] For more guidelines on green and smart urban development, see: http://energyinnovation.org/greensmart/

6.4. Recommendations for Chinese Cities

Efficiency, Industry, and Economy. More effort is needed to reduce the energy intensity and carbon intensity of urban industry and the economy. However, relocating industrial enterprises beyond city boundaries won't solve the problem of GHG emissions. Rather, further improvements in industrial energy efficiency and production quality are needed, even as cities pursue deeper changes in economic structure. Utilizing waste heat from industry and power generation to provide district heating for the city is one such strategy. Improving the quality of materials and goods produced, to avoid waste and lessen life-cycle energy, is another important strategy.

Renewable Energy. Empowering cities to generate or contract for renewable electricity and heat (and other forms of energy) would address multiple urban challenges. Giving cities greater authority to pursue renewable energy could accelerate China's achievement of renewable energy targets. The shift away from carbon-intensive and highly polluting fossil fuels would also address the inter-connected challenges of air pollution, power generation, and industrial emissions.

Environment, Land Use, and Transport. In the Transport, Environment, and Land Use categories, city efforts to prioritize walking, biking, and low-carbon public transit in urban development are needed improve air quality and reduce energy consumption and emissions. In the closely related category of Land Use, transit-oriented requirements for developers are needed, as well as mixed-use zoning with clusters of nearby amenities. These strategies will direct urbanization onto low-carbon pathways, as well as increase the quality of urban life.

7. References

Statistical data on the 115 cities analyzed for the *City Index*: are publicly available in the following documents on the websites of municipal statistical agencies:

City Statistical Yearbooks (2011 and 2016).

Statistical Communiqués on Economic and Social Development (2010 and 2015).

Additional information was reviewed on cities participating in the national program for low-carbon pilot cities. The following documents are publicly available on the websites of those municipal governments:

Low Carbon Pilot City Work Plans.

American Council for an Energy Efficient Economy (ACEEE). 2015. *The 2015 City Energy Efficiency Scorecard*. Prepared by David Ribeiro, Virginia Hewitt, Eric Mackres, Rachel Cluett, Lauren M. Ross, Shruti Vaidyanathan, and Sarah Zerbonne. ACEEE Report U1502. May.

Chen, JG , QH Huang, , and HW Zhong. 2006. "Comprehensive Evaluation and Analysis of the Process of Industrialization in China." *Chinese Academy of Social Sciences*, vol. 6. (in Chinese).

Chinese City Development Research Association. 2016. The 2016 ranking results for 338 Chinese cities. Issued by CBN Weekly. http://wwww.chinacity.org.cn/csph/csph/299460.html.

Economist Intelligence Unit (EUI). 2011. *Asian Green City Index: Assessing the Environmental Performance of Asia's Major Cities*. Report prepared by the Economist Intelligence Unit Ltd. for Siemens AG. Munich, Germany.

Economist Intelligence Unit (EUI). 2009. *European Green City Index*. Report prepared by the Economist Intelligence Unit Ltd. for Siemens AG. Munich, Germany.

He, G., N. Zhou, C. Williams, and D. Fridley. 2013. "ELITE Cities: A Low- Carbon Eco-City Evaluation Tool for China." *Proceedings of the 2013 eceee Summer Study*. Toulon: European Council for an Energy Efficient Economy. http://proceedings.eceee.org/visabstrakt.php?event=3&doc=3-399-13 .

Innovative Green Development Program (iGDP). 2015. Low Carbon Cities in China: National Policies and City Action Factsheets (in English and Chinese). Online: http://www.igdp.cn and http://www.efchina.org/Attachments/Report/report-cemp-20151020/iGDP_CityPolicyFactsheet_EN.pdf

Innovative Green Development Program (iGDP). 2016. Policy Mapping of Chinese Low-Carbon Cities. Interactive website: http://www.cepm.igdp.cn/

International Energy Agency (IEA). 2016. Energy Technology Perspectives 2016: Towards Sustainable Urban Energy Systems . http://www.iea.org/etp/

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.

Lewis, J., D.G. Fridley, L.K. Price, H.Y. Lu, J. P. Romankiewicz. 2015. "Understanding China's non–fossil energy targets." Science **27** Vol. 350, Issue 6264, pp. 1034-1036.

Ministry of Environmental Protection (MEP), National Development and Reform Commission (NDRC), and Ministry of Finance (MOF). 2012. *Twelfth Five-Year Plan on Air Pollution Prevention and Control in Key Regions*. Issued on December 5, 2012. English translation by Clean Air Alliance of China (CAAC): http://en.cleanairchina.org/product/6285.html

Ministry of Housing and Urban–Rural Development (MOHURD), P.R. China. 2015. *China urban construction statistical yearbook 2014.* Beijing: China Planning Press.

National Bureau of Statistics (NBS) of the People's Republic of China. 2016. *China City Statistical Yearbook 2015*. Beijing: China Statistical Press.

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 & 中文版. 81 pp. June.

Ohshita, S.B., C. Fino-Chen, L.X. Hong, N. Khanna. 2014. *BEST Cities: Software User Guide. Benchmarking and Energy Saving Tool for Low-Carbon Cities*. Berkeley CA: Lawrence Berkeley National Laboratory. English version & 中文版. 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

Ohshita, S.B., L. Price, and ZY Tian. 2011. "Target Allocation Methodology for China's Provinces: Energy Intensity in the 12th Five-Year Plan." Lawrence Berkeley National Laboratory, Report No. LBNL-4406E. 70 pp. March. In English and Chinese. Online: http://china.lbl.gov/publications/target-allocation-methodology-provinces-china

Price, L., N. Zhou, D. Fridley, H.Y. Lu, L.X. Hong, C. Fino-Chen, J. Ke, S. Ohshita, H. Min, Y. Zhou. 2014. "Energy-Efficiency and Greenhouse Gas Mitigation Policy Options: Assisting Chinese Cities in Prioritizing and Choosing Strategies." *Proceedings of the American Council for an Energy Efficient Economy (ACEEE), Summer Study 2014*.

Price, L., N. Zhou, D. Fridley, S. Ohshita, HY Lu, N. Zheng, and C. Fino-Chen. 2013. "Development of a Low-Carbon Indicator System for China." *Habitat International* **37** (January): 4–21. doi:10.1016/j.habitatint.2011.12.009.

Price, L., N. Zhou, D. Fridley, S.B. Ohshita, HY Lu, N. Zheng, C. Fino-Chen. 2011. "Development of a Low-Carbon Indicator System for China." Lawrence Berkeley National Laboratory, Report. LBNL-5243E. (English version & 中文版). September.

South China Morning Post (SCMP). 2016. Urban legend: China's tiered city system explained. Interactive graphical website: http://multimedia.scmp.com/2016/cities/

State Council. 2013. *Atmospheric Pollution Prevention Action Plan*. Issued 10 September 2013. Online: http://www.gov.cn/zwgk/2013-09/12/content_2486773.htm

State Council. 2014. *National New-type Urbanization Plan (2014–2020)*. Issued 16 March 2014. Press release (English): http://news.xinhuanet.com/english/china/2014-03/16/c_133190495.htm

Su, MR, Y Zheng, XM Yin, MQ Zhang, XM Wei, X Chang, Y Qin. 2016. "Practice of low-carbon city in China: The status quo and prospect." *Energy Procedia* **88**: 44 – 51.

Tan, S., J. Yang, J. Yan, C. Lee, H. Hashim and B. Chen. 2016. "A holistic low carbon city indicator framework for sustainable development." *Applied Energy*, In Press.

United Nations Development Program (UNDP), Tongji University, Xinhua News Agency. 2015. *2015 CHINA SUSTAINABLE CITIES REPORT: Measuring Ecological Input and Human Development*. UNDP. Report.

Williams, C., N. Zhou, G. He., and M. Levine. 2012. "Measuring in All the Right Places: Themes in International Municipal Eco-City Index." *Proceedings of the 2012 ACEEE Study on Energy Efficiency in Buildings*. Pacific Grove: 12 – 17 August 2012.

World Bank. 2012. *Sustainable low-carbon city development in China*. Axel Baeumler, Ede Ijjasz-Vasquez, and Shomik Mehndiratta, eds. Washington, D.C.

Zhou, N., G. He, C. Williams and D. Fridley. 2015. "ELITE Cities: A low-carbon eco-city evaluation tool for China." *Ecological Indicators* 48: 448-456.

Zhou, N. and C. Williams. 2013. "An International Review of Eco-City Theory, Indicators, and Case Studies." LBNL Report 6153-E. Berkeley: Lawrence Berkeley National Laboratory.

Zhou, N., G. He, and C. Williams. 2012. "China's Development of Low-Carbon Eco-Cities and Associated Indicator Systems." LBNL-5873E. Berkeley, California: Lawrence Berkeley National Laboratory.

APPENDIX A

Table A1. 2015 Green Low-Carbon China City Index Scores for 115 Cities (Alphabetical Order)

Note: City names and provinces in **bold** text are in the national low-carbon pilot program. Cities are color-coded based on their Total Score in the *City Index*:
Green >=60. Blue 50 - 59.9. Yellow 40 - 49.9. Pink <=39.9.

Index Rank	City Name	Province	Region	Total Score	Economy	Energy & Power	Industry	Transport	Buildings	Env & Land	Policy & Outreach
			Max score	*100*	*20*	*18*	*18*	*6*	*8*	*20*	*10*
112	Anshan	**Liaoning**	NE	31	3	6	4	2	4	10	3
46	**Baoding**	Hebei	N	46	5	10	8	3	5	11	5
115	Baotou	Inner Mongolia	N	28	3	3	4	1	1	13	3
12	**Beijing**	Beijing	N	55	9	9	8	5	6	10	8
52	Bengbu	Anhui	E	46	6	11	7	3	5	11	3
108	Benxi	**Liaoning**	NE	33	3	4	4	3	4	13	3
26	Changchun	Jilin	NE	51	8	10	9	3	4	12	5
3	Changde	Hunan	SC	58	8	14	14	2	5	12	3
33	Changsha	Hunan	SC	51	5	9	14	4	4	10	5
56	Changzhou	Jiangsu	E	45	5	6	7	3	6	13	5
19	Chengdu	Sichuan	SW	54	7	14	7	5	4	9	8
59	Chifeng	Inner Mongolia	N	44	3	10	4	2	4	14	8
83	**Chizhou**	Anhui	E	40	3	9	4	1	5	14	5
29	**Chongqing**	**Chongqing**	SW	51	5	12	6	2	8	13	5
87	Dalian	**Liaoning**	NE	39	5	4	6	5	4	11	5
99	Daqing	Heilongjiang	NE	35	3	2	5	2	3	15	5
91	Datong	Shanxi	N	38	2	8	4	2	5	13	5
40	Dongguan	**Guangdong**	SC	48	7	10	9	1	4	12	5
28	Foshan	**Guangdong**	SC	51	7	10	11	4	4	12	3

Index Rank	City Name	Province	Region	Total Score	Economy	Energy & Power	Industry	Transport	Buildings	Env & Land	Policy & Outreach
			Max score	***100***	***20***	***18***	***18***	***6***	***8***	***20***	***10***
94	Fushun	**Liaoning**	NE	**36**	3	7	4	2	4	13	3
21	Fuzhou	Fujian	E	**53**	8	13	9	3	5	12	3
6	**Ganzhou**	Jiangxi	E	**58**	11	15	7	1	5	12	5
16	**Guangyuan**	Sichuan	SW	**55**	4	16	6	2	5	14	8
7	**Guangzhou**	**Guangdong**	SC	**57**	11	7	12	5	4	11	8
10	**Guilin**	Guangxi	SC	**56**	7	16	9	2	6	11	5
80	**Guiyang**	Guizhou	SW	**41**	4	8	7	3	3	11	5
5	Haikou	**Hainan**	SC	**58**	6	12	14	3	4	13	5
98	Handan	Hebei	N	**35**	3	7	4	2	4	12	3
13	**Hangzhou**	Zhejiang	E	**55**	10	11	8	3	5	11	8
105	Harbin	Heilongjiang	NE	**34**	4	6	7	3	2	10	3
42	Hefei	Anhui	E	**47**	5	9	10	3	5	12	3
38	Hengyang	Hunan	SC	**48**	5	14	9	2	4	12	3
68	**Huai'an**	Jiangsu	E	**43**	5	9	6	1	7	12	3
92	Huai'nan	Anhui	E	**38**	4	9	3	1	5	12	3
88	Huaibei	Anhui	E	**39**	3	9	7	1	5	12	3
103	Huangshi	**Hubei**	SC	**34**	3	5	5	2	4	9	5
93	Huhhot	Inner Mongolia	N	**37**	3	4	6	3	2	13	5
32	Huizhou	**Guangdong**	SC	**51**	6	13	7	3	5	12	5
67	**Hulunbuir**	Inner Mongolia	N	**43**	3	6	7	2	4	13	8
17	Jiangmen	**Guangdong**	SC	**54**	7	14	9	1	5	15	5
9	Jieyang	**Guangdong**	SC	**57**	6	16	15	0	5	13	3
58	Jilin	Jilin	NE	**44**	4	8	5	3	5	13	5

Index Rank	City Name	Province	Region	Total Score	Economy	Energy & Power	Industry	Transport	Buildings	Env & Land	Policy & Outreach
			Max score	***100***	***20***	***18***	***18***	***6***	***8***	***20***	***10***
75	Jinan	Shandong	E	**41**	4	7	6	3	6	10	5
95	**Jinchang**	Gansu	NW	**36**	4	6	5	1	3	12	5
100	**Jincheng**	Shanxi	N	**35**	2	5	4	2	4	12	5
48	**Jingdezhen**	Jiangxi	E	**46**	4	10	7	2	5	13	5
82	Jining	Shandong	E	**40**	5	7	6	1	4	12	5
30	Jinzhou	**Liaoning**	NE	**51**	9	14	9	1	4	11	3
39	Kaifeng	Henan	SC	**48**	6	12	8	2	5	11	5
18	**Kunming**	**Yunnan**	SW	**54**	6	13	6	4	8	13	5
114	Laiwu	Shandong	E	**31**	1	3	5	1	5	13	3
97	Lanzhou	Gansu	NW	**35**	2	8	5	3	4	11	3
74	Linyi	Shandong	E	**42**	5	10	7	1	5	11	3
85	Liuzhou	Guangxi	SC	**40**	2	9	6	2	6	12	3
86	Luoyang	Henan	SC	**40**	4	7	5	2	5	10	8
54	Luzhou	Sichuan	SW	**45**	4	15	5	2	5	12	3
44	Mianyang	Sichuan	SW	**47**	4	14	6	3	5	13	3
14	**Nanchang**	Jiangxi	E	**55**	10	11	8	3	5	10	8
34	Nanchong	Sichuan	SW	**50**	5	18	7	1	5	11	3
84	Nanjing	Jiangsu	E	**40**	4	5	6	3	6	13	3
4	Nanning	Guangxi	SC	**58**	5	15	9	2	6	14	8
37	**Nanping**	Fujian	E	**49**	2	15	8	2	6	11	5
50	Nantong	Jiangsu	E	**46**	7	9	9	1	5	12	3
69	Nanyang	Henan	SC	**42**	4	10	8	0	5	13	3
49	Neijiang	Sichuan	SW	**46**	3	14	7	2	5	12	3

Index Rank	City Name	Province	Region	Total Score	Economy	Energy & Power	Industry	Transport	Buildings	Env & Land	Policy & Outreach
			Max score	***100***	***20***	***18***	***18***	***6***	***8***	***20***	***10***
45	**Ningbo**	Zhejiang	E	**47**	6	6	7	4	5	12	8
96	Pingdingshan	Henan	SC	**36**	3	6	5	1	5	10	5
62	**Qingdao**	Shandong	E	**44**	6	5	7	3	4	12	5
66	**Qinhuangdao**	Hebei	N	**43**	4	8	4	2	5	14	5
81	Qiqihar	Heilongjiang	NE	**40**	4	10	7	1	4	13	3
25	Quanzhou	Fujian	E	**52**	6	11	11	2	5	15	3
23	**Shanghai**	Shanghai	E	**53**	7	8	8	4	6	12	8
73	Shangqiu	Henan	SC	**42**	4	11	8	1	6	9	3
8	Shantou	**Guangdong**	SC	**57**	8	17	13	1	5	12	3
53	Shaoxing	Zhejiang	E	**45**	7	10	7	2	4	10	5
101	Shenyang	**Liaoning**	NE	**34**	5	5	5	3	4	10	3
1	**Shenzhen**	**Guangdong**	SC	**70**	15	13	9	5	6	14	8
77	**Shijiazhuang**	Hebei	N	**41**	5	8	7	3	4	11	5
24	Suqian	Jiangsu	E	**52**	5	12	10	1	7	14	3
43	**Suzhou**	Jiangsu	E	**47**	7	6	5	4	6	12	8
113	Taiyuan	Shanxi	N	**31**	3	4	4	2	2	11	5
36	Taizhou JS	Jiangsu	E	**49**	5	8	11	1	7	12	5
22	Taizhou ZJ	Zhejiang	E	**53**	10	14	7	1	5	12	5
111	Tangshan	Hebei	N	**32**	2	3	5	2	4	11	5
55	**Tianjin**	Tianjin	N	**45**	7	5	7	4	4	11	8
106	**Urumuqi**	Xinjiang	NW	**34**	3	4	4	3	1	14	5
89	Weifang	Shandong	E	**39**	4	7	6	1	5	14	3
15	**Wenzhou**	Zhejiang	E	**55**	9	14	10	3	5	10	5

Index Rank	City Name	Province	Region	Total Score	Economy	Energy & Power	Industry	Transport	Buildings	Env & Land	Policy & Outreach
			Max score	***100***	***20***	***18***	***18***	***6***	***8***	***20***	***10***
79	**Wuhan**	Hubei	SC	**41**	4	7	8	4	4	9	5
57	Wuhu	Anhui	E	**45**	5	9	8	2	5	12	5
61	Wuwei	Gansu	NW	**44**	4	15	6	1	4	11	3
47	Wuxi	Jiangsu	E	**46**	8	5	6	4	6	13	5
60	Xi'an	**Shaanxi**	NW	**44**	5	10	8	4	4	11	3
107	Xi'ning	Qinghai	NW	**33**	1	8	4	3	2	11	3
2	**Xia'men**	Fujian	E	**66**	13	13	13	4	5	13	5
90	Xiangyang	**Hubei**	SC	**38**	3	9	6	0	4	11	5
76	Xianyang	**Shaanxi**	NW	**41**	4	11	6	2	5	11	3
64	Xingtai	Hebei	N	**43**	3	10	5	3	5	13	5
71	Xuzhou	Jiangsu	E	**42**	4	7	6	2	7	13	3
51	**Yan'an**	**Shaanxi**	NW	**46**	5	10	5	3	5	13	5
27	Yancheng	Jiangsu	E	**51**	7	14	8	1	6	12	3
20	Yangzhou	Jiangsu	E	**54**	7	9	13	1	7	12	5
63	Yantai	Shandong	E	**44**	6	5	9	2	5	13	3
70	Yichang	**Hubei**	SC	**42**	3	9	8	3	4	13	3
104	Yinchuan	Ningxia	NW	**34**	2	5	5	3	5	13	3
102	Yingkou	**Liaoning**	NE	**34**	4	5	6	2	4	11	3
109	Zaozhuang	Shandong	E	**33**	3	5	5	1	4	12	3
72	Zhangjiakou	Hebei	N	**42**	3	8	6	3	5	13	5
11	Zhanjiang	**Guangdong**	SC	**56**	9	15	9	1	5	12	5
65	Zhengzhou	Henan	SC	**43**	6	8	7	4	4	11	3
31	**Zhenjiang**	Jiangsu	E	**51**	8	6	7	2	6	14	8

Index Rank	**City Name**	**Province**	**Region**	**Total Score**	Economy	Energy & Power	Industry	Transport	Buildings	Env & Land	Policy & Outreach
			Max score	***100***	***20***	***18***	***18***	***6***	***8***	***20***	***10***
41	Zhuzhou	Hunan	SC	**48**	4	9	11	2	4	12	5
110	Zibo	Shandong	E	**32**	3	3	4	1	6	13	3
78	Zigong	Sichuan	SW	**41**	3	12	6	2	5	12	3
35	**Zunyi**	Guizhou	SW	**50**	4	15	11	3	4	9	5