Progress and Prospects:

China's Cities Transitioning toward Energy Sustainability, and Pursuing Early Peaking of Carbon Emissions

2017 results from the 'China LOGIC' city index
('LOGIC': Low-carbon & Green Index for Cities)

Innovative Green Development Program (iGDP)
Lawrence Berkeley National Lab (LBNL)

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Forward

Cities in China are at the frontlines in the fight against global warming and domestic pollution. Cities are also the key venue for China to achieve its sustainable development goals. Already, a number of cities have committed to peak their carbon emissions earlier than 2030 (ahead of the national goal). However, these goals come with great challenges: over the coming decades, an additional 300 million people will join China's urban population; and it has been estimated that more than $1.02 Trillion USD[1] of investments for low-carbon urban projects (clean energy, efficient buildings, and green transportation) is required to achieve China's climate and environment goals between 2016 to 2020. Cities need to take extraordinary actions to get there.

In 2009, China first set a national goal for climate action; and since then, cities have done a lot of work – led by the low carbon pilot cities and provinces. Understanding these cities' progress and performance – *what actions cities have taken, whether those efforts have been effective, and which policies have driven the most change* – will help China to accelerate and achieve its goals for early carbon peaking, followed by a rapid decrease in carbon emissions to climate-safe levels.

This report introduces China "LOGIC" – a new city index system designed to measure and inform China's progress on these goals. China LOGIC is the "*Low-carbon & Green Index for Cities". It* provides a system to track progress, a database to evaluate performance, and an analytical tool to help cities identify improved solutions for low carbon and clean energy development, and early carbon peaking. The research team behind LOGIC gathered a large collection of city-level data on low-carbon development in China – data from 115 cities, across 23 low-carbon and green indicators, and characterizing cities across ten economic and demographic dimensions. Data was collected and compared across two annual sets (2010 and 2015). Overall, the analysis found that Chinese cities have made noteworthy progress and significant improvements in recent years in their green and low-carbon goals. However, important room for improvement remains. Gaps in specific performance areas will require cities to take significant actions; and these efforts can be accelerated through wide knowledge sharing and peer learning from top-performing cities. One risk area is the discrepancy between political will and actual performance. While most of China's low carbon pilot cities have done well in the LOGIC results, some pilot cities fell short in meeting their green goals. This suggests that efforts are needed to ensure the effectiveness of policy commitments. And at the same time, for all cities, the LOGIC results need to be taken as a baseline. The immediate next steps should focus on converting identified priority areas into solid action plans that can achieve the best green and low-carbon development outcomes through cost-effective implementation strategies for cities with different development needs.

Looking forward, LOGIC aims to provide ongoing and timely analysis through two-yearly updates of the city database and city index scores. Additional analysis and special case studies in the near future will help yield more insights and actionable information from the city performance data. Our team is also developing an interactive online tool that gives cities access to LOGIC, enabling them to benchmark their progress, and learn from their peers to identify new, feasible green and low-carbon actions. We hope that policy-makers will use the LOGIC tool to aid their work, and that LOGIC design updates will benefit from feedback based on real world needs and practical experience. Our goal is to help all cities in China transition to a green and low-carbon future.

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[1] *Paulson Institute, Energy Foundation China, Chinese Renewable Energy Industries Association. Green Finance for Low-Carbon Cities. Available at: https://www.bbhub.io/dotorg/sites/2/2016/06/Green-Finance-for-Low-Carbon-Cities.pdf . 2016-06/2017-10*

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Executive Summary

Chapter E1. China's Low Carbon City Policy System

China is one of the two largest economies in the world. China is also in the midst of the largest wave of urbanization the world has ever seen – with 770 million people currently living in cities, up from 190 million in 1980. China is forecasted to have more than 1 billion urban inhabitants by 2030 – which will represent 70% of China's population, and 11% of the global population living in Chinese cities[2] at that time.

China also exerts a significant influence on the environment – locally and globally. China's industrial and urban development over the past 30 years has been a miracle – lifting 700 million[3] people out of poverty, and positioning China as a global leader in manufacturing, trade, business, and urban development. But this development miracle has come with steep environmental costs. Air pollution, soil and water pollution, energy use, and carbon dioxide emissions in China are well documented, well recognized, and China's government is responding through a range of measures.

China has reached a genuine turning point. With the urban population still expected to increase by more than 300 million people over the next 15 years, Chinese cities will continue to expand – requiring more infrastructure and housing, requiring new industries and jobs, consuming more land, energy, and natural resources, and at the same time producing more waste, pollution, and emissions. The choices that Chinese city leaders and policymakers make today will significantly shape future development patterns across China's cities. This matters for city residents, for their local environments, and for the entire planet.

Cities around the world are increasingly recognized as the primary centers of resource consumption and greenhouse emissions. Cities are also on the front lines facing the most intense early effects of climate change – from intensified flooding, dangerous heat waves, or water supply shortages. But cities around the world are also the primary centers for *action.* It is at the local level of cities that real climate and environment action takes place – i.e. improving energy efficiency, shifting to renewable resources, protecting of local environments, and safeguarding human health and livelihoods. Cities across the globe are coming together to share information and practices for more sustainable and resilient urban development.

And China is already seizing this opportunity. In recent years, Chinese government agencies have established many policies and initiatives aimed at transforming economies, improving local environments, reducing pollution, and piloting new innovations for greener growth in Cities. 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. Since 2010, China's National Development and Reform Commission (NDRC) has launched low-carbon pilots in 81 cities and six provinces[4]. In 2014, the State Council issued the National New-type Urbanization Plan – setting indicators and targets for urban infrastructure and urban socio-economic development[5]. And in 2015, 21 Chinese cities joined a pledge to peak energy-related CO_2 emissions before the national target year of 2030 (Alliance of Peaking Pioneer Cities (APPC)). In the critical area of urban air quality, the Ministry of Environment Protection (MEP) and the State Council in 2012 and 2013 announced tougher controls on air pollution[6]; issued a new Atmospheric Pollution Prevention Action Plan[7]; and established a network of 500 PM2.5 monitoring stations across 70 Chinese cities. There have also been a number of sectoral measures of implemented in cities for buildings, industry, energy efficiency, and electric vehicles, among others.

China is taking these challenges seriously and is rapidly moving in the right direction to meet its green and low-carbon carbon city goals.

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[2] *China's State Council. National Population Development Plan (2016-2030). Available at: http://www.gov.cn/zhengce/content/2017-01/25/content_5163309.htm. 2017-01-25/2017-10-10 (in Chinese)*

[3] *China's State Council. China's Progress in Poverty Reduction and Human Rights. http://news.xinhuanet.com/politics/2016-10/17/c_1119730413.htm. 2016-10-17/2017-10-10*

[4] *China's National Development and Reform Commission. Available at http://www.ndrc.gov.cn (in Chinese)*

[5] *China's State Council. National New-type Urbanization Plan. Available at http://www.gov.cn/zhengce/2014-03/16/content_2640075.htm. 2014-03-16/2017-10-10*

[6] *China's Ministry of Environmental Protection. 12th Five-Year Plan on Air Pollution Prevention and Control in Key Regions. Available at: http://www.mep.gov.cn/gkml/hbb/bwj/201212/W020121205566730379412.pdf. 2012-12/2017-10-10 (in Chinese)*

[7] *China's State Council. Atmospheric Pollution Prevention Action Plan. 2013Available at: http://www.gov.cn/zwgk/2013-09/12/content_2486773.htm. 2013-09-10/2017-10-10*

Chapter E2. Introducing the China Low-Carbon and Green Index for Cities (LOGIC)

China LOGIC

Despite the above efforts, there remains a need for a practical framework to measure, report, and analyze the progress made by a city as a whole – across a full and balanced set of green and low-carbon urban indicators. This project developed the China Low-Carbon and Green Index for Cities (LOGIC) to meet that need.

LOGIC is intended to provide a holistic assessment of China's transition to both "green" and "low-carbon" urban development. "Green" indicators evaluate multiple environmental parameters related to urbanization and climate change: air quality, water use, solid waste, transport networks, and urban green space. "Low-carbon" indicators measure reduction of GHG emissions, with a focus on energy-related CO_2.

LOGIC is a new index. It builds off existing international and domestic-Chinese city indicator systems, and includes indicators commonly used internationally (see section below), but it offers a new system that more fully reflects balanced 'economic, green, and low-carbon' objectives within China's unique urban and policy context. Importantly, LOGIC relies on indicators that have publicly available data in China's statistical system.

LOGIC builds upon past work on indicator systems, including China Academy of Social Sciences' Regional or Local Economic and Social Progress Evaluation Methodologies, iGDP's City-Level Carbon Emissions Calculator, iGDP's Policy Mapping Tool, as well as 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. LOGIC is scientifically rigorous and is designed to have meaningful practical applications. The process developing LOGIC involved many rounds of data review, analysis and testing, and review by key experts in China.

The main purpose of LOGIC is to evaluate the status of environmental ("green") and low-carbon development across a range of energy use, carbon emission, and environmental and socio-economic indicators for a large number of Chinese cities. LOGIC 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. LOGIC can also inform current and future policy, and the data gathering needed to support it. The 2017 report analyzed data from 115 Chinese cities, making comparisons over the period from 2010 to 2015. The goals of the analysis and the report are to:

- Achieve a representative sampling of different kinds of Chinese cities
- Assess the state of green and low-carbon urban development in China in 2015; and look at changes in low-carbon city performance over the 2010 to 2015 time period
- Demonstrate the utility of LOGIC by exploring the index categories and indicators, as well as a few case studies in detail

Selecting Chinese *Cities* for LOGIC

LOGIC team gathered the largest collection of city-level data on low-carbon development, with data for 115 cities, 23 indicators, plus ten economic and demographic characteristics, and two annual sets of data (2010 and 2015). In order to compare patterns and trends for different kinds of cities, five different city groups were examined, with each of the 115 cities being assigned to a sub-group under each group. The groups and sub-groups are listed here:

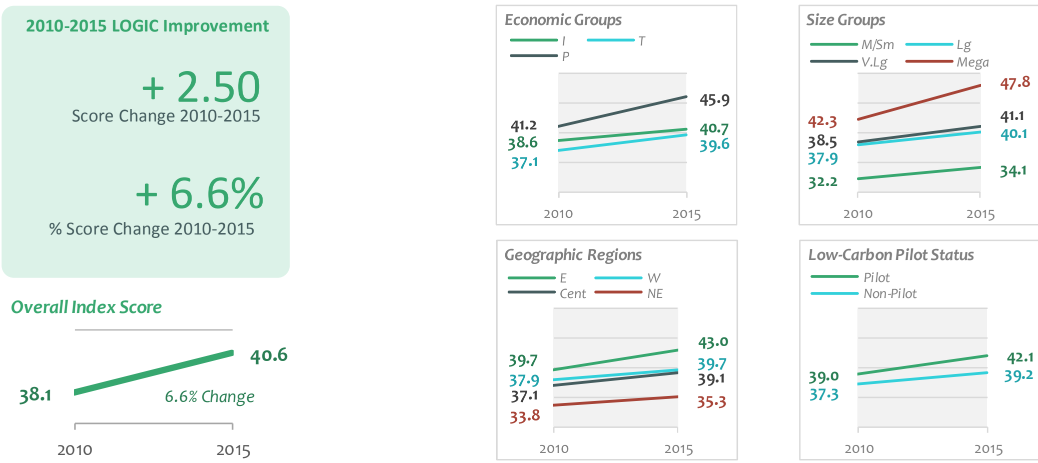
Economic Groups	**Size Groups**	**Geographic Regions**	**Low-Carbon Pilot Status**	**Functional Zone**
▪ Group P *(post-industrial)* ▪ Group I (industrial) ▪ Group T (transitional)	▪ Mega (>10M) ▪ Very Large (5-10M) ▪ Large (1-5M) ▪ Medium/Small (<1M)	▪ East ▪ Central ▪ Northeast ▪ West	▪ Low-Carbon Pilot ▪ Non-Pilot	▪ Optimized Development Zone ▪ Key Development Zone

Chapter E3. Key Findings

China's cities are getting greener – overall green and low carbon index scores improved from 2010-2015.

The average overall index score across all of China's cities grew 2.5 points, or 6.6%, from 2010 to 2015[8]. In aggregate, cities of all types saw growth in their average overall scores – the economic groups, size groups, regional groups, and policy groups in this study all saw LOGIC score growth, ranging from 4% to 13%. China's large "Mega" cities, "post-industrial" cities, and low-carbon pilot cities performed particularly well over this period. Moreover, within the LOGIC framework, 6 out of 7 Categories saw average scores increase from 2010-2015 (ranging from 1% (Energy & Power) to 30% (Economic Dimension); and 11 out of 19 indicators saw an increase (ranging from 1.7% {Heavy Industry Share} to 121% (Urban Rail Extent). The index allows exploring and understanding of these trends, along with observations, such as: how the Environment & Land Use category dropped by 4.7%, and how seven out of 19 indicators' scores dropped.

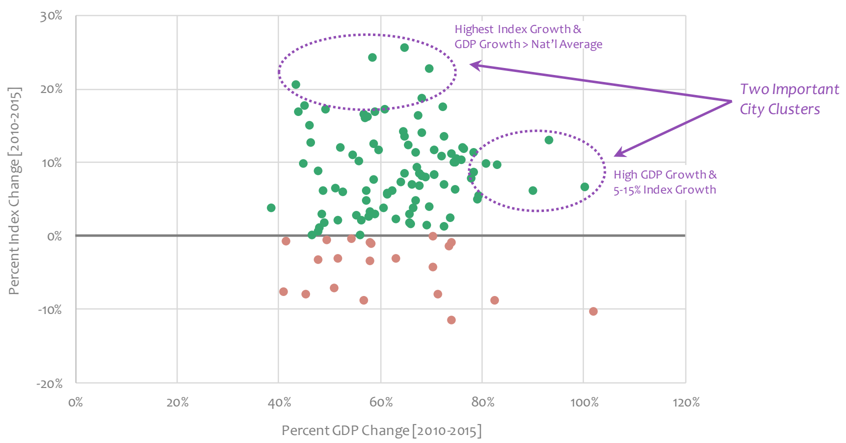
Figure 1 - LOGIC Score Changes from 2010 to 2015; Overall, and by City Groups



More than 90 out of 115 cities in the sample saw both GDP growth and LOGIC score growth over the 2010-2015 time period.

All of the 115 cities in the sample saw significant GDP growth from 2010-2015 (ranging from 40%, to greater than 100% growth over the five-year period). More than 90 of these cities also increased their LOGIC scores over the same period – some with slight increases, others with as much as a 25% increase. Among these, there are two unique clusters of high-performing cities (see Figure 2). One cluster showed the highest total GDP growth (in the 90th percentile), and also had LOGIC score growth between 5-15% over five years. Another cluster showed the highest LOGIC score growth (in the 90th percentile), and also had GDP growth that was well above the national average. Cities in both of these clusters demonstrate that green and low-carbon goals do not need to come at the expense of economic performance.

Figure 2 - Change in GDP Growth vs. Change in LOGIC Index Growth, 2010-2015; for all 115 cities in the sample



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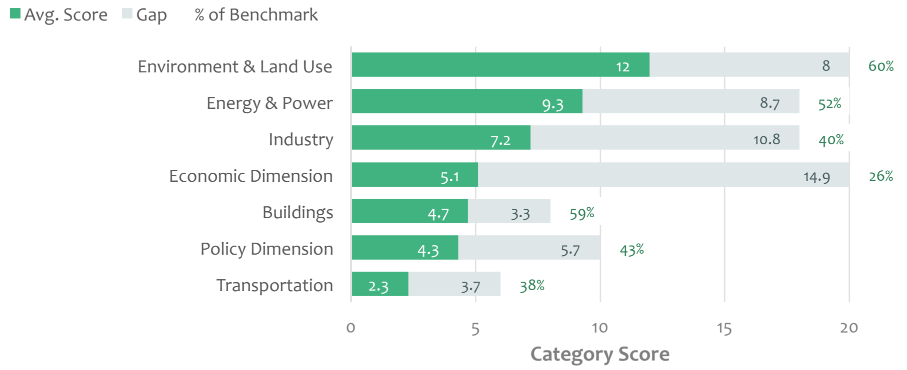
[8] *Note that in this report, LOGIC score comparisons between 2010 and 2015 exclude the 'Policy & Outreach' index category, because this category refers to planning and outreach efforts mandated after the year 2010. See further discussion in Chapter 4 of this report. However, if the Policy & Outreach category is included in the comparison, average overall LOGIC scores increased by 6.8 points, or 17.8%, from 2010 to 2015.*

Chinese cities have significant potential to improve their Green & Low Carbon performance.

While Chinese cities' LOGIC scores and economies have both grown in recent years, the average overall index score for all Chinese cities in 2015 is still only 44.9, out of 100. Chinese cities have room to improve. Yet, within the sample, some Chinese cities did achieve high scores; and the large margin between the average score, and scores achieved by China's best-performing cities indicates a positive pathway for all cities to catch up. China is early in the green & low-carbon transition of its cities and has made strong commitments to restructuring urban and economic development away from resource-intensity and pollution. Furthermore, LOGIC, by definition, is ambitious – its indicators are designed using world-class green benchmarks and are intended to push Chinese cities to do more, and quicker. LOGIC provides a scale to measure China's continuing progress; and the top-ranking cities, as well as the international benchmarks can help to point out a low-carbon path forward.

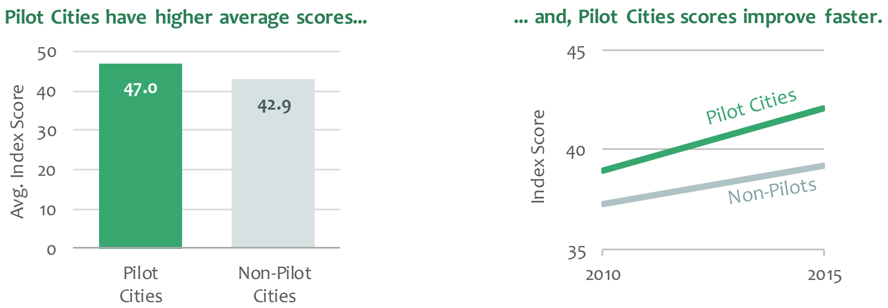
Figure 3 - Comparing Average LOGIC Scores by Category, along with performance relative to category benchmark values



China's Low-Carbon Pilot Cities have been quicker and more successful in achieving green & low-carbon results.

The average overall index sores in 2015 for *Low-Carbon Pilot Cities* was 47.0, compared to an average of 42.9 for non-pilot cities. Furthermore, *Low-Carbon Pilot Cities* make up 80% of the list of Top 20 LOGIC cities in 2015 (despite being less than half of the sample population). And, pilot cities saw a quicker increase in their scores over the 2010-2015 period – this quicker growth is true for the overall index score, as well as for most of the index categories/sub-categories[9]. Relative to all cities, China's low-carbon pilot program is working so far, although more work is required overall to fully achieve China's green and low carbon goals.

Figure 4 - – Comparing Low Carbon Pilot City and Non-Pilot City Performance; 2015 average scores, and improvement from 2010 to 2015



Cities of all types can be Top-Performers in green & low-carbon development.

Results from LOGIC indicate that cities of all types can be top-performers; and that no matter which type of city, or which category of measurement, cities can always learn from others and explore ways to be greener. Table 1 shows that the list of Top 20 LOGIC cities in 2015 includes a diverse range of cities from most *Economic Groups*, *Size Groups*, *Regions*, and policy groups (only Medium-Small cities, and Northeastern cities are not represented on the list). Furthermore, within each group, there are high performers and low; and peer cities can learn from their high-performing counterparts. Likewise, within each of the index categories/sub-categories, there is a range of city performances – high and low. Peer cities can learn specific green and low-carbon policies and actions from high-performers in any category. LOGIC can be used for city knowledge sharing, and to analyze pathways for any kind of city, across any metric.

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9 *Note: comparison of LOGIC scores between 2010 and 2015 excludes the Policy & Outreach category. See Chapter 4 for more discussion on this.*

Table 1 - List of Top 20 Cities, Ranked by 2015 Overall Index Score

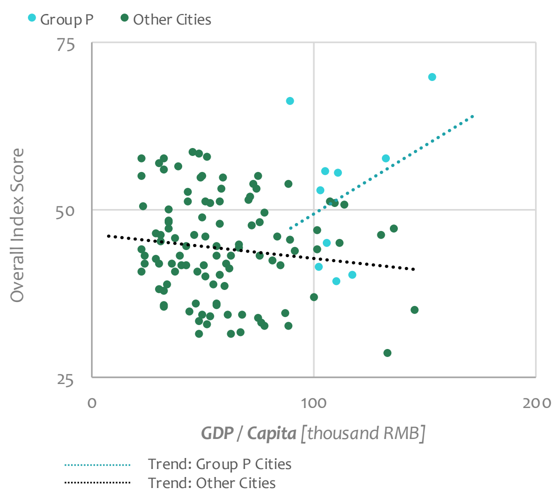
City Name	Rank, Overall Index	Overall Score	Economic Group	Size Group	Region	Low Carbon Pilot Status
Shenzhen	1	69.7	Group P	Mega	East	Pilot
Xia'men	2	66.0	Group P	Large	East	Pilot
Changde	3	58.5	Group I	Large	Central	Non-Pilot
Nanning	4	58.2	Group I	Large	West	Non-Pilot
Haikou	5	57.7	Group T	Large	East	Pilot
Ganzhou	6	57.5	Group I	Large	Central	Pilot
Guangzhou	7	57.5	Group P	Mega	East	Pilot
Shantou	8	57.4	Group T	Large	East	Pilot
Jieyang	9	56.7	Group I	Large	East	Pilot
Guilin	10	56.3	Group I	Large	West	Pilot
Zhanjiang	11	55.8	Group I	Large	East	Pilot
Beijing	12	55.5	Group P	Mega	East	Pilot
Hangzhou	13	55.3	Group P	Very Large	East	Pilot
Nanchang	14	54.8	Group T	Large	Central	Pilot
Wenzhou	15	54.8	Group T	Very Large	East	Pilot
Guangyuan	16	54.7	Group I	Large	West	Pilot
Jiangmen	17	54.5	Group I	Large	East	Pilot
Kunming	18	54.5	Group T	Large	West	Pilot
Chengdu	19	53.7	Group T	Mega	West	Non-Pilot
Yangzhou	20	53.6	Group T	Large	East	Non-Pilot

Large (but not too large) cities, and post-industrial cities are greener.

LOGIC results show that cities with larger populations have higher overall index scores – ***except*** for the largest mega cities (with populations above 11 million people), where overall index scores *decline* with increasing population. This is illustrated in Figure 5 below, with the scatter plot showing two groups of cities by population size with two trend lines going in opposite directions. One explanation for this is that generally, as cities grow, agglomeration effects allow greater efficiency (in terms or resources, transport travel times, and other urban services); but at a certain scale, large cities lose these size and efficiency benefits. Therefore, the largest mega cities will need special policy attention, and different strategies to maintain and improve green and low-carbon performance.

Also observed in LOGIC is that cities at the post industrialization stage (Group P) show a decoupling between economic growth and carbon & pollution emissions. For Group P cities: higher incomes, come with higher index scores. While for Group T and Group I cities, the reverse is true: higher incomes go with lower scores. There appears to be a turning point marking the shift in economic development pattern from manufacturing and transitioning cities (Groups T and I, which rely on heavy industry), to post-industrial cities (Group P, which focus on more efficient manufacturing and the service sector for growth). This again indicates that special attention needs to be given to cities' green and low-carbon policy actions, based on their level of economic development. An important aim will be focusing on how to improve industrial and transition cities, and how to maintain and promote the performance of wealthier post-industrial cities.

Figure 5 - LOGIC Turning Points: (left) the largest mega cities' scores decline; and (right) the wealthiest post-industrial cities' scores increase



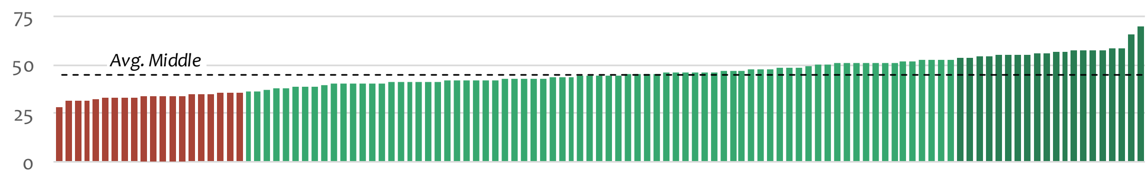
A major driver of green & low-carbon performance in Chinese cities is their Energy, Industrial, and Economic structure.

As might be expected, within the LOGIC framework, the three inter-related categories of *Economic Dimension*, *Industry*, and *Energy & Power* are assigned relatively high weights in the model (i.e. importance). This also reflects an ongoing challenge and primary driver of China's ability to pursue its green & low-carbon objectives. Looking at the 2015 LOGIC results can provide some insights. Examining the categories that contributed most to the differences between high-performing and low-performing cities shows that the *Economic Dimension*, *Industry*, and *Energy & Power* categories had the most influence. Figure 6 shows all 115 cities lined up from lowest to highest score. Beneath, the category differences that contributed to cities being among the Bottom 20 cities, the Middle Range cities, and the Top 20 cities are shown as a waterfall diagram. However, city performance overall in these three categories is relatively weaker in 2010 and 2015. This is related to China's well-known challenge of transitioning from an energy- and resource-intensive economy based on investment, heavy industry, manufacturing, and export and toward a more modern, high-tech, and high-value knowledge and service economy.

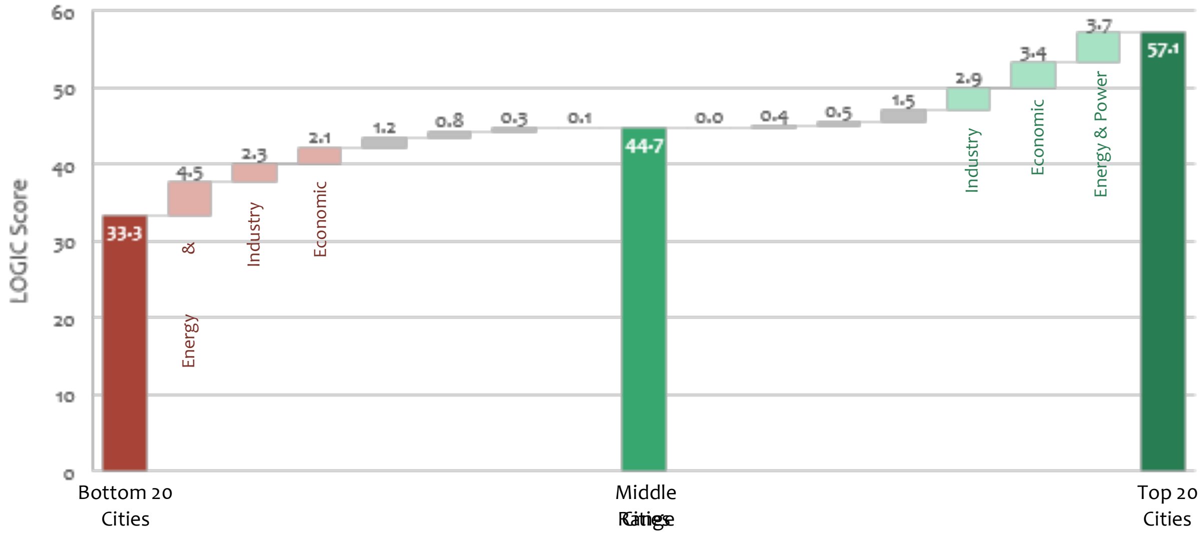
So, while overall the weak performance in the Economic Dimension category (i.e. 26% of benchmark) drag down the total index score for many/most cities, for the Top 20 cities, an improved Economic score was one of the key drivers of their higher scores. This pattern is similar for the Energy & Power and Industry categories. All three of these categories are intertwined and related to China's overall industrial and economic structure. This will continue to be a major and important area of focus in China's green & low carbon urban transition.

Figure 6 – All cities' LOGIC scores, and category contributions to Top Performing and Bottom Performing scores

(Top) Distribution of city LOGIC scores, low to high; showing Bottom 20 (red) and Top 20 (dark green)



(Bottom) Showing contributions of index categories to LOGIC score change; Bottom 20 and Top 20 cities compared to middle scoring cities.



The Environment & Land Use category also needs special attention – this was the only category to have an overall decrease in scores from 2010 to 2015.

Rapid urbanization in China has come with the cost of severe environmental degradation; and these well-known challenges (air quality, water pollution, etc.) will need a new focus on implementation of policies and the right political and economic structures to reverse this trend.

The LOGIC methodology and tool allows deep and detailed exploration of city performance: to identify promising opportunities, and to understand challenges.

LOGIC has been designed to answer key questions such as: *which types of Chinese cities perform better?* And, *what factors most determine cities' green and low carbon success?* Exploring index results and trends over time allows answers to these questions. The rest of the report is devoted to exploring these kinds of questions in more detail.

- *Which types of cities tend to perform better in the index?*
- *How does city performance vary across LOGIC component categories?*
- *What are the overall trends, and what potential policy pathways can cities pursue for green & low-carbon development?*

Chapter E4. Recommendations

LOGIC gives us a snapshot of how cities in China have been performing with respect to their green and low-carbon transition goals. Looking forward, LOGIC also helps to identify and highlight the priorities and challenges that will help China's cities to effectively pursue low-carbon development and energy sustainability in smart and effective ways. Based on the results of the 2017 LOGIC analysis, our team makes the follow recommendations for the low-carbon and green transition in China's cities:

Cities and high-level policymakers in China can use the LOGIC framework and benchmarks to accelerate their progress and promote the best green & low-carbon policy pathways according to their specific contexts and needs.

Clearly, there is no single set of solutions to apply to all cities – especially for China's cities, which vary widely in economic, population, and natural conditions. The LOGIC framework and tool can be used as a guide for cities to tailor individual pathways in their green and low-carbon transition. LOGIC's set of seven categories and 23 indicators help cities identify which aspects are important. The benchmarks and scoring process help cities to evaluate their performance against international best cases, against other cities in China, and against their own past and future performance. This helps cities to identify their strengths, and also identify key gaps for future attention. Most importantly, LOGIC includes data and scores from 115 cities across China – from different regions, different economic development stages, and different population sizes. Any city using LOGIC can identify with one of these groups, and look to the top-performing cities in each group, and in each category (energy & power, environment, transport, etc.) to make connections and find specific actions to implement in their own green and low-carbon pathway.

Cities at different stages of economic development have different priorities and should design low-carbon policies and pathways to suit their unique needs.

Analysis of the 2015 LOGIC scores indicates that the economic development stage of a city (industrial, transition, or post-industrial) plays an important role in green and low-carbon performance, and that these different types of cities all have their own unique challenges and priorities. Sample cities' economic development stages ranges widely – from cities with GDP per capita of $3,678 USD (such as Wuwei in 2015, which is still under the national average), to cities with GDP per capita of $24,690 USD (such as Shenzhen, which is above the level of 'high-income' countries[10]). In LOGIC, cities are analyzed and compared in three economic groups: Group I (industrial), Group T (transitional), and P (post-industrial). These economic groups vary in their scoring and show different patterns of performance for different index sub-categories and indicators. These differences suggest that cities need to focus on different priorities, but also that cities with similar levels of economic development can learn from each other. Industrial cities (Group I) need to focus on improving industrial energy efficiency and investing more in low-carbon and non-fossil fuel power sources (i.e. upgrading existing industrial facilities and setting high energy-efficiency standards for new industrial projects). Transitioning cities (Group T), which have somewhat higher income levels, could prioritize decarbonizing their economies, reducing the share of heavy industry in the economy, and investing in the service sector (including consumption, technology, and information-oriented growth). The post-industrial cities (Group P) need to focus on transportation systems, and energy efficiency levels in buildings, as well as promoting low-carbon lifestyles among their residents.

[10] *High Income countries are defined by the World Bank as having per capita GDP values above $12,615 USD*

- *Chinese cities should continue to demonstrate strong political leadership and ensure consistent follow-through and action on their low-carbon commitments.*

  Policy leadership and political will are critical factors for cities to achieve a green and low-carbon transition. And it is clear from the 2015 LOGIC results that China's Low-Carbon Pilot Cities performed, on average, better than non-pilot cities. Pilot cities had higher overall index scores; and for six out of seven index categories, pilot cities had higher average category scores, and faster growth between 2010 and 2015, as compared to non-pilot cities. In this regard, the policy efforts promoted through these pilot cities have been effective. However, it is interesting and surprising to note that for the *Environment & Land Use* category, pilot cities had lower scores than for non-pilot cities. Also, that among the 21 cities in China whose LOGIC scores dropped from 2010 to 2015, eight were pilot cities. This implies that so far, the low-carbon policies and actions applied in this set of cities have not been working, despite the political attention and momentum they have enjoyed. At this stage, further analysis and deeper study of these cities is required to understand the drivers behind both the most-successful and least-successful pilot cities. This will be follow up work for our team, based on the 2015 LOGIC results. However, the immediate conclusion is that political leadership is important and does make a difference (pilot cities were spurred to perform and improve faster); but the "will to be green" is not enough – the political will needs to be backed up by real actions that make a real difference in transitioning cities onto the green and low-carbon pathway. The LOGIC framework and tool gives fairly high weight to the "policy and outreach category", and can be used to track city green performance into the future.

- *As Chinese cities continue to develop and become wealthier, they should promote policies for green citizen lifestyles, backed by green urban planning and infrastructure development as the key to ensuring they can meet early carbon peaking goals.*

  China has already committed to peaking its carbon emissions before 2030, at national level. Reaching this goal will depend on the local polices and performance in hundreds of cities across China. Analysis shows that China can potentially reach its CO_2 peaking goal by 2030, at which time it is expected to have an income of $14,000 USD GDP per capita, which is lower than many developed countries. Reaching this peak level and this income level would mean that most of the cities will have developed into the post-industrial (Group P) cities analyze in this report. The 2015 LOGIC results showed that while there is an overall trend for the wealthier and more economically developed cities (i.e. Group P cities, larger cities, and cities with higher GDP) to have higher overall index scores; these cities also tended to perform worse in the *Energy & Power*, *Buildings*, *Transport*, and *Environment* index categories. This implies certainly that in order to improve in these areas, wealthier cities need new policies and action in these areas. But more importantly, if the trend is for all cities in China to become wealthier and more developed, then there is a risk that increasing wealth will come with lower performance in these key LOGIC categories. Cities and policy makers across China need to take strong actions now to avoid high energy and high carbon urban lifestyles. Cities instead need to promote more energy efficiency in buildings and transport, low-carbon lifestyles, and reductions in resource use and environmental pollution. To that end, to avoid lock-in effects cities need to start early to introduce green urban planning rules, tighter building codes and high efficiency home appliances. Cities also need to cultivate lifestyles which are less material-oriented, curb high levels of car ownership, and avoid energy waste in heating and cooling of empty houses, etc.

- *Mega-cities in China need special attention, to avoid pitfalls and backsliding on low-carbon and green development goals.*

  A number of recent reports have shown that, up to a point, as cities become bigger, their increasing population size comes with density and efficiency advantages that help to improve their green and low-carbon performance[11]. However, this beneficial trend breaks down for very large, mega cities – which tend to have weaker green and low-carbon index scores than their smaller peers. This finding was illustrated in a 2017 study by the Urban China Initiative and McKinsey and Co.[11]; and is consistent with the 2015 LOGIC results. LOGIC finds a linkage between city size, in terms of population, and index performance: up to a population of 11 million people, as a city grows, it's overall LOGIC score increases; but when city population passes a 11 million, the overall index scores decrease as population grows. In most cases, these mega cities are also the wealthier and more developed cities (i.e. Group P cities, in this study). As noted before, these larger, higher-income cities tend to have higher energy use and elevated carbon emissions in the transportation and building sectors. Therefore, LOGIC suggests that mega cities need to consider green and low-carbon transitions carefully, and differently than other, smaller cities. This includes special attention to population size and city sprawl, and consideration of the need to set development constraints (not only in terms of territory, but also population), while planning their long-term green and low-carbon development vision.

[11] *Urban China Initiative. Urban Sustainability Index – USI 2016. Available at:* www.urbanchinainitiative.org. *2017-04-13/2017-10-10*

- *Cities and high-level policymakers should continue to use comprehensive data-driven analysis to evaluate, track, and compare low-carbon and green performance.*

  Using data and indicators is critical for cities to understand their progress and performance in their green and low-carbon goals. LOGIC was built as a third-party framework and tool to serve the need for transparent and consistent data measurement and reporting for China's green transition. And the 2015 LOGIC results show the benefit of green measurement and tracking – with the ability to evaluate individual cities, or groups of cities over time, and across a wide range of index categories and indicators. Cities in China need to further employ this data-driven approach to evaluate their own plans and progress. Cities need to develop official measurement, reporting and evaluation (MRE) systems; which help to evaluate and prioritize low-carbon actions and investments. Such MRE systems can also serve as important communication tools for cities to share performance and actions with other cities, with the public, or with the international community. LOGIC can provide such a tool and platform.

- *The critical steps to turn political will into action will be for city leaders and policymakers to prepare integrated low-carbon action plans, coupled with robust policy implementation and social-economic analysis that support decision-making and concrete action.*

  The LOGIC tool provides snapshots in time to evaluate the green and low-carbon performance indicators across the different index categories. The next steps are for cities to take these results and conduct deeper, integrated cross-sector analysis to understand the real opportunities for actions in all categories; and to develop strategic action plans to implement the most cost-benefit pathways. Developing the low carbon action plans or city early peaking plans should be a practice in all cities. And improving the quality of these plans is key to really identifying actionable measures and projects to capture the best mitigation gains.

Developing the China Low-Carbon & Green Index for Cities (LOGIC)

Chapter 1. Background on City Indices and Indicator Systems

There already exist a number of international and domestic-Chinese indicator systems that can be used to assess environmental, economic, or low-carbon development in Cities. These existing indicator systems were reviewed as part of this project. Each has its strengths, but also limitations in applicability to assessing holistic green and low-carbon development on a wide scale across Chinese cities. Some of these existing indicator systems are briefly described here; along with the conclusion that there remains a strong need for a new green and low carbon index specific to China's unique development patterns, and the large-scale of China's future urban development.

International Indicator Systems

International city indicator systems include: the *Global City Indicators* (Global Cities Institute), the *Green City Index* (Siemens), the *Sustainable Cities Index* (Arcadis), as well as the *Urban Sustainability Index*, and the *Asia Green Cities Index*, among others[12]. All of these international indicator systems have certain similarities: they all aim to capture the multi-faceted performance of a city against a set of metrics related to infrastructure, environment, climate, business, and/or livability. However, there is considerable variation in the purpose, structure, and selection of individual metrics (and required data) for each of the indicator systems. Some indices focus on a specific geographic region, or a specific level of economic development. Some indices focus mainly on particular sectors, such as energy. A key conclusion from the review of international indicators is that in selecting/developing an indicator system, the categories and indicators should reflect the specific purpose of the index, the policy priorities, the potential decisions that will be informed, and the availability of data.

While the international indicator systems reviewed for this study had clear frameworks and robust methodologies, and they all had some level of global familiarity and reputation; none of these systems had the specific focus on a green and low-carbon transition in urban economies. Moreover, none of the international systems fully reflected China's unique policy objectives and agenda for a green transition. And in many cases, there was a mismatch between the international systems indicator framework, and the data publicly available within the Chinese statistical system.

China Indicator Systems

In China, existing national-level efforts at low-carbon or eco-city indicator systems include: *Eco-City Indicators* (Ministry of Environmental Protection (MEP)); and the *National Eco-Garden Indicators* (Ministry of Housing and Urban-Rural Development (MOHURD)). At the local level, governments in Tianjin, Caofeidian, Turpan New District, and Guiyang have also introduced indicator systems for cities. Also, Chinese research and academic institutions have developed a number of low-carbon or eco-city indicator systems, including: the Chinese Academy of Science (CAS), Renmin University, Tsinghua University, and MOHURD's Chinese Society for Urban Studies. These Chinese indicator systems are nearly all used for internal benchmarking or inter-city comparison on individual indicators or sectors, rather than ranking cities based on a more holistic, composite index score[13]. The indicators included in the systems mentioned above are defined based on China's national or regional standards, sector-wide best practices, or other local targets. Most of the Chinese indicator systems focus on the physical environment, including: air, energy, water, land use, and waste indicator categories. Fewer cover transport, economic, and social categories; and fewer still include CO_2 emissions or intensity.

A challenge with Chinese indicator systems is that, even while some have emphasized environment-related and economic growth indicators, they are generally found to lack systematic or robust methodologies. Another challenge with those existing Chinese indicator systems reviewed is that, while all of them of course relied on data from Chinese cities, often this data was specially collected by academics or research institutes, and not available to the public. This limits the future applicability of the indicator system because of the time and effort required for individually collecting data on so many metrics, from so many cities over time. And finally, none of the indicator systems was defined as a composite index to be widely applied to score and rank city progress on overall green and low-carbon development. As urbanization and China's drive toward "ecological civilization" continue to accelerate, a more systematic and timely indicator system is needed to continuously examine the performance and progress of Chinese cities toward the country's new urban vision.

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[12] *See: Tan et al. 2016; Williams et al. (2012); and Zhou and Williams (2013)*

[13] *See Zhou et al. 2012*

Proposing the New '*China Low-Carbon & Green Index for Cities*' (LOGIC)

To properly quantify and evaluate the current state and trends of Chines cities' transition to green and low-carbon development, a new city-index system is needed. Similar to LBNL's *Eco and Low-carbon Indicator Tool for Evaluating Cities (ELITE Cities)* tool[14]; this index applied Doran's five criteria called "SMART" (Doran, 1981[15]), and three additional principles tailored for Chinese cities. Specifically, the index follows these principles:

- **Specific**: target specific areas for improvement
- **Measurable**: quantify, with indicators of progress
- **Assignable**: specify who will do it
- **Realistic**: state what results can realistically be achieved given available resources
- **Time-related**: specify when the result can be achieved
- **Holistic**: integrating "Green" (environmental), "Low-Carbon" (climate/GHGs), and "Urban Development" (economics and policy) aspects and objectives
- **China-Specific**: uniquely tailored to China's cities and the policy context and priorities for China's continuing wave of large-scale urbanization
- **Data Practical**: reliant on data and statistics publicly available in Chinese cities

To meet these needs, the China Low-carbon & Green Index for cities (LOGIC) was developed to be a new index system, unique to China's specific urbanization and policy context.

LOGIC is based on recent related work and collaborations between the China-based Innovative Green Development Program (iGDP) and the US-based Lawrence Berkeley National Laboratory (LBNL). Recently, three tools/systems were collaboratively developed to address these needs of Chinese cities, and for specific use in China. These include the aforementioned *ELITE Cities* tool[16]; the *Benchmarking and Energy Saving Tool for Low-Carbon Cities (BEST Cities)* tool[17]; and the *Energy End-Use Low-Carbon Indicator System*[18]. 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. iGDP itself has also recently developed a Low Carbon Policy Mapping tool, and a carbon calculator tool for Chinese cities.

LOGIC builds upon the experience and methodologies of all of these tools – in addition to considering the international and Chinese indicator systems discussed above, and various recent urbanization policies in China's 13th FYP. The new LOGIC tool 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. The methodology for developing the index is briefly described in the section below. Further details can be found in other related project documents and publications.

[14] *He et al. 2013; Zhou et al. 2015*

[15] *Doran, G. T. (1981). "There's a S.M.A.R.T. Way to Write Management's Goals and Objectives", Management Review, Vol. 70, Issue 11, pp. 35-36.*

[16] *He et al. 2013; Zhou et al. 2015*

[17] *Price et al. 2014; Ohshita et al. 2014; Ohshita et al. 2016*

[18] *Price et al. 2011, Price et al. 2013*

Chapter 2. Methodology for Developing LOGIC

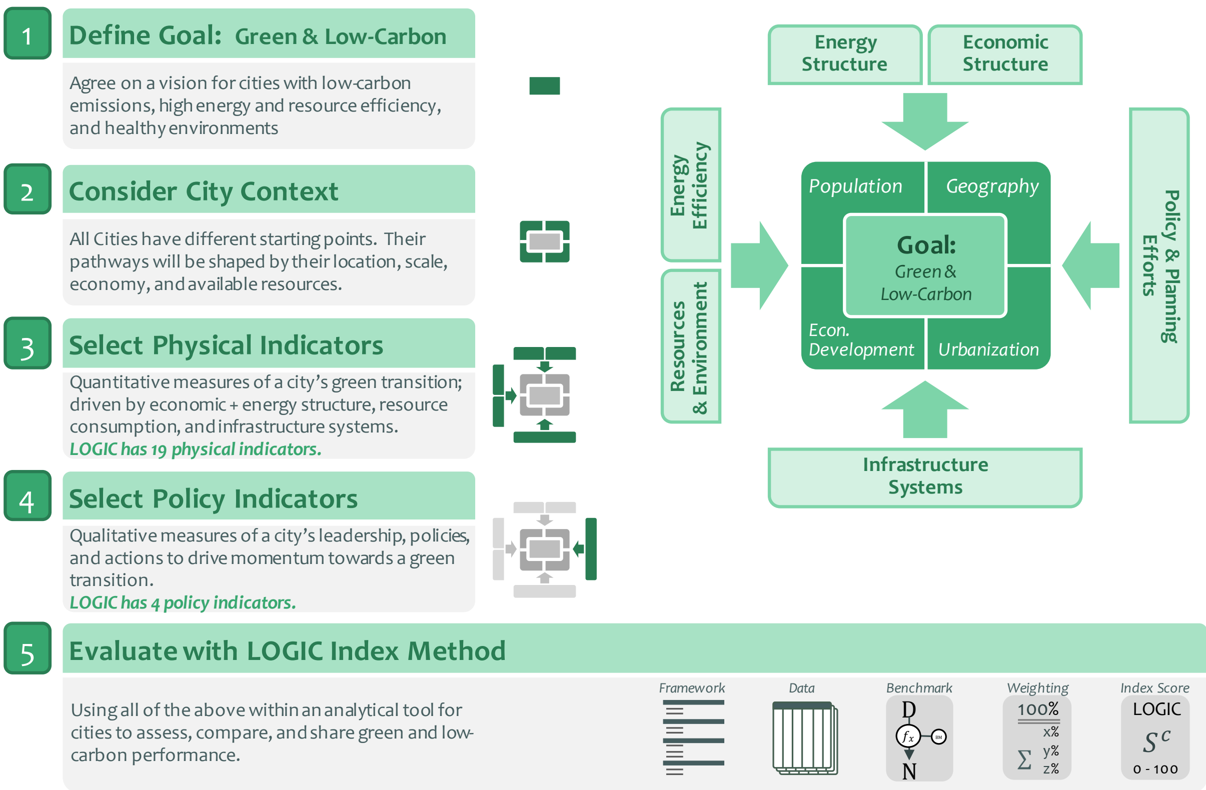
Methodological Framework

The China Low-carbon & Green Index for Cities (LOGIC) was created as a unique city indicator system to measure and track the green and low carbon transition in Chinese cities. LOGIC was designed to capture the process of *transition*: recognizing that the current state of different cities in China is in flux, recognizing the ongoing dynamic movement toward green and low-carbon goals, and recognizing the range of actors and their actions in different cities. With such a transition in mind, LOGIC was developed to track and measure progress over time.

The framework for measuring Chinese cities' progress in their transition requires five elements. Figure 7 illustrates these elements.

1. Establish that the clear goal and scope of the index is to quantify Green & Low Carbon city performance across China
2. Group cities based on context and status factors that impact their ability and opportunities to achieve green and low-carbon performance (i.e. geography, population size, economic development, urbanization rate, and policy attention).
3. Define what performance indicators need to be measured – LOGIC includes 19 integrated physical/sectoral metrics; grouped by influencers: Economic Structure, Energy Structure, Energy Efficiency, Resource Use and Environmental Quality, and Infrastructure Systems.
4. Define additional indicators that measure the efforts Chinese cities are making toward green & low-carbon transition – LOGIC includes four policy-action indicators, related to planning, budgeting, governance, and citizen engagement.
5. Evaluate and compare Chinese cities against best-practice 'benchmarks' for all of the green & low-carbon influencers, and indicators; and using publicly available data sets and carbon emission estimates.

Figure 7 – The Framework for the LOGIC Tool and Analysis



Overview of LOGIC, and the Methodology

As noted above, LOGIC is a new index. It builds off of existing international and domestic-Chinese city indicator systems; but it is developed as a new system that more fully reflects the objectives and priorities in green and low-carbon urban development in China, and that uses statistics and data which are publicly-available from Chinese cities.

The methodology behind LOGIC is relatively straightforward and follows common practices of developing multi-dimensional rating systems. The methodology is briefly described in this section. Further details can be found in the other documents and publications of this project.

Overview of LOGIC

LOGIC is a composite index, with an ***overall score*** ranging from zero to 100.

LOGIC is multi-dimensional. The index score is made up of values from ***seven categories (or subcategories)***, that reflect a full set of green and low carbon objectives. These categories and subcategories include:

- Energy & Carbon Category -- *further divided into four sub-categories, as the main sectors of energy use in a city*
  - *Energy & Power Sub-Category*
  - *Industry Sub-Category*
  - *Buildings Sub-Category*
  - *Transport Sub-Category*
- Economic Dimension Category
- Environment & Land Use Category
- Policy & Outreach Category

These categories and sub-categories are further defined by a total of ***23 indicators*** -- which are measurable green and low-carbon parameters, for which data can be collected at the city level. Figure 10 at the end of this section shows the full list of indicators.

The indicators are each defined with ***performance benchmarks***, which are standards used to convert raw city-data into the scores that make up the index. Benchmarks vary by indicator and can be defined as one of three types: 1) international best practice, 2) China national target, or 3) as the relative statistical ranking from the sample cities in this study.

All of the above categories/sub-categories and their indicators are ***weighted for relative importance***; and they are then combined to ***calculate an overall index score*** for each city. The overall index scores (and/or the breakdown of scores by category or indicator) can be used to compare individual cities, groups of cities, or performance categories over time. The general equation behind the index score calculation is shown below.

$$\text{LOGIC Score}^c = \sum_i S_i^c = f\left(D_i^c, BM_i\right) * Wt_i$$

where 'c' is an index from 1… 115 for all cities in the sample; 'i' is an index from 1… 23 for all indicators; 'S_i^c' is the score for a given city, for a given indicator; 'D_i^c' is the data value for a given city, for a given indicator; 'BM_i' is the benchmark value for a given indicator; and Wt_i is the weight value for a given indicator.

Steps in the LOGIC Development Process

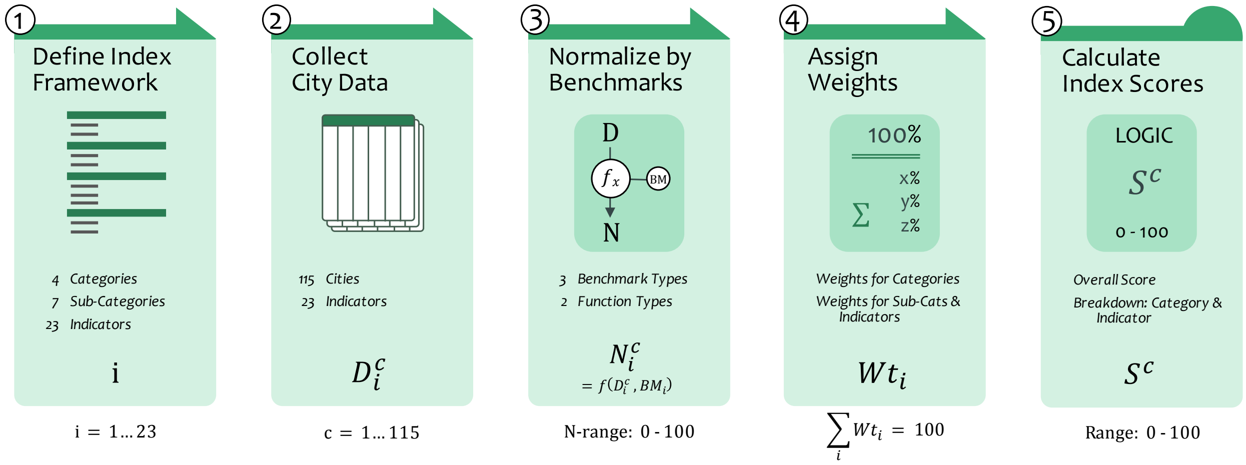
The overall process for developing and using LOGIC involves five steps, listed here. Figure 8 illustrates the steps in the methodology. Each step is described in more detail in the next section of the report.

1. *Define the Index Framework (i.e. categories, secondary sub-categories, and indictors)*
2. *City Selection and Data Collection*
3. *Define Performance Benchmarks, and Normalize City Data for Each Indicator*
4. *Assign Relative Weights (importance) to the Categories, Sub-Categories, and Indicators*
5. *Calculate the LOGIC Scores for Each City*

Throughout the development process, LOGIC was designed with the following goals and principles in mind:

- **Simplicity**: provide a convenient and meaningful overall score to rate a given city's green and low-carbon performance.
- **Relevance**: provide scores and metrics relevant to China's unique urbanization policy agenda; and relevant to informing real actions that cities can take in setting policy goals, making decisions, and planning.
- **Comparability**: provide a framework so that performance can be compared between individual cities and/or groups of cities, across the multi-dimensional index categories and indicators, as well as from year to year.
- **Data Availability:** use public data from China's statistical system: to facilitate regular updates, and future extension.
- **International Comparability**: provide consistency with other international & Chinese indicator systems, where possible.

Figure 8 - Steps in LOGIC Development Methodology



Details on the Steps in the Development of LOGIC

This section describes details of the five index development steps listed in the previous section. The descriptions here are brief: readers can refer to other project documents for fuller explanations and discussion of the methodology.

Step 1: Define the Index Framework (i.e. categories, indicators, and benchmarks)

As noted above, LOGIC is structured around seven categories and sub-categories relevant to evaluating a city's green and low carbon performance and progress. There are four primary categories; and one of the primary categories (Energy & Carbon) is further divided into four sub-categories, which represent the four major energy-using sectors in Chinese cities. The categories/sub-categories are:

- Energy & Carbon Category
  - *Energy & Power Sub-Category*
  - *Industry Sub-Category*
  - *Buildings Sub-Category*
  - *Transport Sub-Category*
- Economic Dimension Category
- Environment & Land Use Category
- Policy & Outreach Category

Each of the category/sub-categories are briefly described below. The descriptions include the relevance of the category to green and low-carbon assessment, along with a listing of the specific indicators, benchmarks, and measurement units used to define the data collection and scoring used in the index. Figure 10 at the end of this section shows the entire LOGIC framework -- including the seven categories/sub-categories, the 23 indicators, and the associated benchmarks, units, and references.

(*Note that the benchmarks and their use in the index are listed here, but that further discussion of benchmarks can be found in Step 3 of the methodology, below.*)

Energy & Power Sub-Category (Energy & Carbon Category)

The Energy & Power sub-category reflects *energy use in the city* (i.e. all consumption taking place within the administrative boundaries of the city, not just residential); and *energy inputs to the city* (i.e. considering all forms of energy, not just electricity; and potentially including nuclear power and/or renewable energy).

The Energy & Power sub-category is composed of three indicators:

Indicator (Unit)	Performance Benchmark	Notes
Energy Consumption per Capita *[tce/capita]*	▪ Benchmark: Hong Kong level (best in Asia) ▪ Value: 2.77 tce/capita	*- Industrial energy use is also included* *- Current EU best: Denmark (4.4 tce/capita)*
CO_2 Emissions per Capita *[t CO_2 /capita]*	▪ Benchmark: 20% better than the average of 10 best-performing Chinese cities in 2015 ▪ Value: 2.14 tCO_2/capita	*- Industrial energy use is also included* *- Value is close to the "Under 2 MOU": int'l pledge that global cities strive to meet* *- Compare: current EU avg. = 4.9 tCO_2/capita*
Non-Fossil Fuel Share of Primary Energy *[%]*	▪ Benchmark: Chinese National 2030 target ▪ Value: 20%	*- France, Sweden already near 40%* *- Considers all inputs of energy, not just electricity; may include nuclear and/or RE*

Category notes:

Note that the per capita energy and carbon indicators are for the city as a whole, not just residential. This is a unique feature of LOGIC, and reflective of the approach to tailor the index to China's context. Energy data includes industrial energy use in the city, as industry is a major component of Chinese urban economies, with significant industrial activity taking place within city boundaries; and given the fact that manufacturing and industry is such a large part of China's contribution to the global economy.

Industry Sub-Category (Energy & Carbon Category)

The Industry sub-category reflects the energy productivity of urban industry, as well as reliance on intensive heavy industry in the local economic structure.

The Industry sub-category is composed of two indicators:

Indicator (Unit)	Performance Benchmark	Notes
Industrial Economic Energy Intensity *[tce / 10,000 RMB]*	▪ Benchmark: 20% better than the average of 10 best-performing Chinese cities in 2015 ▪ Value: 0.27 tce / 10,000 RMB	*- Value is also 20% better than Guangzhou, best large city for industrial indicators*
Heavy Industry Share of Industrial Value-Added Economic Output *[%]*	▪ Benchmark: 20% better than the average of 10 best-performing Chinese cities in 2015 ▪ Value: 29%	*- Value is also 20% better than Guangzhou, best large city for industrial indicators*

Category notes:

Note that most international city indices do not include industry energy use. However, in Chinese cities the industry sector figures prominently, accounting for 52% of urban primary energy use, and 62% of urban CO_2 emissions[19] [20].

Transport Sub-Category (Energy & Carbon Category)

The Transport sub-category reflects the availability and use of public transit in the city.

The Transportation sub-category is composed of three indicators:

Indicator (Unit)	Performance Benchmark	Notes
Number of Public Transit Vehicles *[units / 10,000 persons]*	▪ Benchmark: 20% better than the average of 10 best-performing Chinese cities in 2015 ▪ Value: 26.4 units / 10,000 persons	*- Compare: Stockholm has 9.9 units / 10,000 persons*
Urban Rail Transit Line Extent *[km / km²]*	▪ Benchmark: 20% better than the average of 10 best-performing Chinese cities in 2015 ▪ Value: 0.04 km / km²	*- Better than Stockholm level, then lower than Japan level*
Bus Utilization *[trips / person / year]*	▪ Benchmark: 20% better than Beijing ▪ Value: 308.4 trips / person / year	*- Benchmark recognizes a balance of urban bus and rail*

Category notes:

Unfortunately, city-level data on transportation trips and mode (especially non-motorized transport, walking, and bicycling) are not regularly reported in China's current statistical system, nor are data on vehicle kilometers traveled. So, those transport indicators were not represented in LOGIC. In lieu of these desirable, commonly used (internationally) indicators, the LOGIC methodology instead substitutes indicators such as public transit vehicles per 10,000 people, and annual bus trips per 10,000 people, which are available in Chinese city-level statistical yearbooks.

Buildings Sub-Category (Energy & Carbon Category)

The Buildings sub-category reflects energy consumption in the building stock, and efforts to promote green buildings in cities.

The Industry sub-category is composed of three indicators:

Indicator (Unit)	Performance Benchmark	Notes
Residential Energy Consumption per Capita *[kWh / capita]*	▪ Benchmark: Japan average level (best in Asia) ▪ Value: 4,743 kWh / capita	*- Value allows for greater thermal comfort in Chinese cities*
Commercial Energy Consumption per Employee *[kWh / employee]*	▪ Benchmark: 20% better than the average of 10 best-performing Chinese cities in 2015. ▪ Value: 6,575 kWh / employee	*n/a*
Goal for the Share of Green Building in New Building *[%]*	▪ Benchmark: ambitious target set by several Chinese cities ▪ Value: 100%	*- Nearly 20 of the 115 sample cities have goals for 100% of new construction to be green buildings; as specified in city plans*

[19] *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.*

[20] *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*

Category notes:

Although the goal of low-carbon development is to reduce energy and carbon overall, the thermal comfort in Chinese homes is generally poor and in need of improvement. The LOGIC methodology therefore sets the residential energy consumption benchmark to the value of 4,743 kWh/capita, at the level of Japan. Japan has a residential sector that is both energy-efficient and thermally comfortable.

City-level data on building energy-use and floor area are not regularly reported in China's current statistical system. As a result, some desirable, commonly used (internationally) indicators could not be utilized, such as commercial building energy consumption per floor area. Instead, the LOGIC methodology substitutes the less common indicator of 'commercial building energy per employee', which is available in Chinese city-level statistical yearbooks.

Economy Category

The economy category is closely connected with Chinese policy targets to reduce the energy intensity and carbon intensity of economic activity.

The Economy category is composed of two indicators:

Indicator (Unit)	Performance Benchmark	Notes
Economic Energy Intensity *[tce / 10,000 RMB]*	▪ Benchmark: Japan level (2012 data, 2005 price) ▪ Value: 0.23 tce / 10,000 RMB	*- Japan as an energy-efficient, high-value economy*
Economic Carbon Intensity *[tCO_2 / 10,000 RMB]*	▪ Benchmark: EU level (2013 data, 2005 price) ▪ Value: 0.32 tCO_2 / 10,000 RMB	*- Compare: Hong Kong, Singapore, France, and Denmark 2013 values close to 0.16*

Category notes:

Another indicator, the share of the service (tertiary) sector in city GDP, was also considered in the LOGIC development, since China has established national targets for increasing the share of the service sector (in the 12th FYP, China set a target for the service sector GDP share to be 47%). However, cities across China vary widely in their economic structure; and there is no single, absolute benchmark value that would be meaningful for all cities. As an example, the northern industrial city of Baoding in Hebei province set its own target for service sector GDP share to be 34% by 2015; meanwhile the nearby national capital of Beijing had set a target for 78%. Thus, while the central government has directed cities to shift away from heavy industry and toward low-carbon economic activity, the lack of a single benchmark value leads the LOGIC methodology to exclude this service sector GDP share indicator at this time. However, the influence of economic structure is already captured somewhat by the two economy indicators in the index.

Environment & Land Use Category

The Environment & Land Use category addresses: air quality, water use, waste, urban green space, and government spending on the environment.

The Environment & Land Use category is composed of six indicators:

Indicator (Unit)	Performance Benchmark	Notes
Municipal Solid Waste per Capita (annual) *[ton / capita / year]*	▪ Benchmark: Singapore level (best in *City Green Index*) ▪ Value: 0.31 ton / capita / year	*n/a*
Blue sky days, or AQI *[%]*	▪ Benchmark: Chinese National Level 2 AQ standard ▪ Value: 100%	*n/a*
PM2.5 Concentration (annual avg.) *[ug / m3]*	▪ Benchmark: World Health Organization standard ▪ Value: 10 ug / m^3	*n/a*
Municipal Water Consumption per Capita *[L / capita / day]*	▪ Benchmark: World Health Organization guideline ▪ Value: 60 L / capita / day	*n/a*
City Budget/Spending Ratio for Energy Saving & Environment *[%]*	▪ Benchmark: Chinese national target ▪ Value: 3%	*n/a*
Green Space per Capita *[m2 / capita]*	▪ Benchmark: Hong Kong level (best in *Green City Index*) ▪ Value: 100 m^2 / capita	*n/a*

Category notes:

A common indicator for solid waste management in China is "municipal solid waste treatment rate". However, waste treatment in China is currently dominated by unsustainable landfill dumping or by incineration. Thus, the LOGIC methodology uses a consumption-based indicator (municipal waste generated per capita) to better reflect the goal of reducing solid waste, and therefore avoiding the life-cycle impacts of urban consumption and waste.

Low Carbon Policy, Climate Adaptation, and Citizen Outreach Category (Policy & Outreach)

The Policy & Outreach category acknowledges *planning and policy efforts* local governments initiated during the 12th FYP. These indicators and benchmarks recognize that green low-carbon policies may take time to implement and yield results.

The Policy & Outreach category is composed of four indicators:

Indicator (Unit)	Performance Benchmark	Notes
City Low-Carbon Development / Climate Change Plan	▪ Benchmark: Yes or No ▪ Value: Yes is good	*n/a*
City Strategy on Renewable Energy *(beyond nat'l targets)*	▪ Benchmark: Yes or No ▪ Value: Yes is good	*n/a*
City Climate Change Resilience / Adaptation Plan	▪ Benchmark: Yes or No ▪ Value: Yes is good	*n/a*
Public Outreach on Low-Carbon Lifestyle	▪ Benchmark: Yes or No ▪ Value: Yes is good	*- Has the city conducted public outreach on low-carbon lifestyle; or engaged public in low-carbon planning?*

Category notes:

The four Policy & Outreach indicators were qualitative, with responses of Yes or No. A Yes response earned maximum points for the indicator, while a No response earned zero points.

General Notes on Index Categories and Indicators

Finally, some general notes on the selection of categories and indicators in the LOGIC development:

- Most of the indicators selected for LOGIC are quantitative; only the indicators for Policy & Outreach are qualitative.
- Quantitative indicators were divided into directly proportional indicators (the higher the indicator value, the better the performance) and inversely proportional indicators (the lower the indicator value, the better the performance). Of the 19 quantitative indicators, there were eight (8) direct indicators and eleven (11) inverse indicators. See the section below on benchmarks for more details.
- 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).
- The 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.

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Step 2: City Selection and Data Collection

This study included a sample of 115 cities. Cities were selected to achieve an overall sample that was relevant, representative, and diverse. Relevant means choosing cities that are important centers in China's economic, demographic, and policy context. Representative and diverse means choosing a variety of cities across a range of regions, population sizes, income levels, urbanization and economic development levels, and industrial mixes. Some key features of the city sample population include:

- Sample includes 115 cities (out of China's 658 cities)
- Sample includes China's 100 largest cities: including seven "mega cities" (i.e. population > 10 million), and 20 "very large cities" (i.e. population between 5-10 million)
- Administratively, the selected cities are *prefecture-level and above*; including: China's four provincial-level municipalities, 15 sub-provincial cities, 16 provincial capitals, and 80 prefecture-level cities
- The selected cities accounted for: 74% of national GDP, 52% of the total national population, and 58% of China's total energy consumption (by 2015 data)
- Selected cities include China's 36 national pilot low-carbon cities (as well as 18 cities from low-carbon pilot provinces)

Note that in this study, the sample cities are defined by administrative boundaries; which typically includes a core urbanized area along with industrial and/or rural agricultural areas.

Note also that additional grouping of cities was conducted to compare LOGIC score performance and correlations across different types of cities. This grouping and the results are further discussed later in this report.

City Data Collection

Collecting data for the 115 cities in the sample, and for each of the 23 green and low-carbon indicators, was a lengthy process. Publicly available data was sourced from national and local governments, as well as from published academic literature in both English and Chinese. Data is primarily from 2010 and 2015; however, for data that could not be obtained for the year 2015, the most recent year of data was used instead. A few pertinent notes and caveats about the data collected for this study include:

- *Some cities lacked data on building energy consumption. For these, residential electricity-use at the provincial level, along with the share of tertiary sector in the local economy were used to estimate values for the Buildings Sub-Category indicators*
- *Figures for energy consumption in buildings was adjusted using 'heating degree days' and 'cooling degree hours', according to the climate coefficient of different regions (Ohshita et al. 2011[21]).*
- *In 2010, China shifted air quality monitoring from PM10 to PM2.5. For the 'PM2.5' indicator in the Environment & Land Use Sub-Category of this study, compliance with the PM2.5 standard was used for 2015 data/scores, and compliance with the PM10 standard was used for the 2010 data/scores. In effect, this indicator measures the sample cities' compliance with China's (contemporaneous) national standard. Going forward, the index will only use data for the PM2.5 standard.*
- *Many cities lacked statistics on energy-mix and carbon emissions. For indicators related to these, total energy was estimated based on a city's economic energy intensity and GDP; and CO_2 emissions were estimated using the provincial fossil fuel mix, total city energy, and fuel-specific emission factors (from China NDRC data). A more detailed inventory would yield more accurate estimates. However, this approach does capture regional carbon and energy variations, and it enables analysis of a large number of cities in a shorter period of time.*

In general, the data collection process itself was enlightening; and some advancements were made in the course of this research. One of the recommendations from this project is that more cities should develop and report their energy and carbon inventories as soon as possible.

Step 3: Define Performance Benchmarks, and Normalize City Data for Indicators

In LOGIC, the 23 indicators specify which data to be collected in each city; and all of these indicators can have different measurement units, different ranges of values, and different orders of magnitude. Before the indicators can be combined together into a composite overall index score, the indicator data from each city needs to be normalized onto a common scale. *Performance Benchmarks* are used to normalize the city data for each indicator. The Performance Benchmarks represent a best-possible reference value. And the benchmarks are used to normalize the city data to be on a common scale ranging from 100 (best) to zero (worst). Once the indicators are all on a common scale, they can be combined using relative weights to calculate a city's overall index score (see Steps 4 & 5 of the index methodology below).

The Performance Benchmark for each indicator comes from one of three types of references:

- International Best Practice – for indicators with accepted global metrics, the benchmarks come from best-in-class international cities, or from relevant international organizations' standards (e.g. water consumption via Hong Kong, or PM2.5 standards via the World Health Organization, etc.)

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[21] *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*

- China National Target – for indicators with targets or standards established by Chinese policy, the benchmarks were set at the policy target-value (e.g. renewable energy targets, and air quality blue sky standards, etc.)
- Best City in Sample Statistics – for some other indicators, especially those particular to China, the benchmarks are based on statistical data from the best-performing Chinese cities in this study's sample (typically defined as, for example, 20% better than the average of the 10 best performing cities, etc.)

Performance Benchmarks also have one of two types of 'functional relationship' to the data:

- Directly Proportional Benchmarks – "high values are good" -- the normalized indicator score is *directly proportional* to the city's performance data value. Higher data values get higher index scores. If the city's data value is below the benchmark, the score is proportional to the difference. If the value is higher than the benchmark, the maximum score value is assigned (100%).
- Inversely Proportional Benchmarks – "low values are good" – the normalized indicator score is *inversely proportional* to the city's performance data value. Lower data values get higher index scores. If the city's data value is higher than the benchmark, the score is reduced in proportion to the difference. If the value is lower than the benchmark, the maximum score value is assigned (100%).

Figure 9 – Types of Benchmarks

Indicator Benchmarks

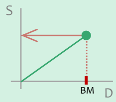
Three Types of Benchmarks

- International Best Practice
- China Policy Targets
- +20% than Best in Sample

Two Types of Functions

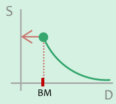
- Directly Proportional
  High Data Value = HIGH Score Value

$$S \sim \frac{D}{BM} \times 100$$



- Inversely Proportional
  High Data Value = LOW Score Value

$$S \sim \frac{BM}{D} \times 100$$



Notes on the selection of Performance Benchmarks were listed for each indicator in the *Step 1: Defining the Index Framework* section above. The benchmark reference type, reference source, and functional relationship type are listed for each indicator in Figure 10 at the end of this section. Figure 9 to the right shows a simple illustration of the behavior (and equations) of the *directly* and *inversely* proportional benchmark functional relationships.

Step 4: Assign Relative Weights to the Categories, Sub-Categories, and Indicators

LOGIC is a multi-attribute index, designed to evaluate Chinese city performance across a range of relevant green and low-carbon categories and indicators. Those categories and indicators may or may not have equal influence and importance on the overall assessment of a city's low-carbon status or progress. Giving weights to the indicators as they combine into an overall score allows for relative emphasis or importance to be assigned to each indicator (or category/sub-category of indicators).

Principles in the process of weighting include:

- Weights are assigned to show the relative importance of the categories and indicators vis-a-vis the overall index score.
- The final aim is to have an overall index score that ranges from zero (worst) to 100 (best).
- City data for each indicator was already normalized to a common scale, also ranging from zero to 100 (see Step 3).
- In this step, weights are assigned progressively in three stages: starting with primary categories, then at the sub-category level (if applicable), and finally down to the indicator level.
- The sum of all weights across indicators (as well as across primary categories) must equal 100%.

Assigning weights in an index is a subjective exercise, and different analysts may use different weights. LOGIC as a tool has been designed to allow different users to vary the weightings. In this report, the weights were assigned according to the expert judgment of the project team. All scores presented in the report assume those assigned weights. The values and determination of those weights are briefly described here. LOGIC aims to give more weight/emphasis to urban sectors and economic activity that more greatly influence energy use and carbon emissions -- and thus a city's green and low-carbon status. The weights are summarized in Figure 10, below.

Assigning Weights to Primary Categories

The four primary categories in LOGIC were assigned different weights by the project team based on each category's influence on CO_2 emissions and the environment, and considering China's stated policy goals for the economy, energy and carbon, and environmental quality. *(Note that the sum across all primary categories must equal 100%.)*

The primary categories were assigned the following weights:

- Energy & Carbon: 50%
- Economy: 20%
- Environment & Land Use: 20%
- Policy & Outreach: 10%

Assigning Weights to Sub-Categories in the Energy & Carbon category

The *Energy & Carbon* category contains four sub-categories corresponding the largest energy-consuming sectors in Chinese cities. Only the Energy & Carbon category has sub-categories. Weights for the Energy & Carbon sub-categories (sectors) were assigned quantitatively, so as to be proportional to the 2015 share of national average energy use for each sector[22]. The sum of these sub-category weights must be 100%; and these sub-category weights represent a proportional breakdown of the Energy & Carbon category weight discussed above (i.e. 50% of the total). The resulting weights for the urban energy-use sectors are:

- Energy & Power: 36%
- Industry: 36%
- Transportation: 12%
- Buildings: 16%

Assigning Weights to the Indicators

Weights assigned at the Category and Sub-category level (above), define the main value judgments used in assigning relative importance in the index. At the indicator level, most indicators received nearly equal weight within their respective category/sub-category. The full list of these weights is shown toward the right in Figure 10 at the end of this section. The final indicator weights shown represent their proportional importance to the total overall index score and are consistent with the weights first allocated to the category and sub-category levels. *Note that the sum across all indicators must equal 100%.*

Step 5: Calculate LOGIC Scores for Each City

The last step in the methodology is to calculate the composite LOGIC score for every city in the sample. The overall LOGIC score combines the normalized data from the cities, with the assigned relative weights (discussed in Step 3 and 4, above). Calculation of the overall index score for any city uses the following general equation:

$$\text{LOGIC Score}^{c} = \sum_i S_i^c = f\left(D_i^c\,,\,BM_i\right) * Wt_i$$

In the above equation:

[22] *See: Khanna et al. 2016; Ohshita et al. 2015*

'c' is an index from 1…115 for all cities in the sample;

'i' is an index from 1…23 for all indicators;

'S_i^c' is the score for a given city, for a given indicator;

'D_i^c' is the data value for a given city, for a given indicator;

'BM_i' is the benchmark value for a given indicator; and

Wt_i is the weight value for a given indicator.

Calculations take place at the indicator level and can be aggregated up to analyze and find insights at the sub-category, category, or overall score level. As noted, overall city index scores range from zero to a maximum of 100. Each indicator and category also has its own respective maximum value (as defined by the benchmarks and relative weights assigned). Cities or groups of cites can be compared as to their performance relative to these category / indicator maximums. Furthermore, LOGIC scores can be calculated for individual cities, or for groups of cities; and the scores can be calculated for any year when data is available, allowing tracking of cities' progress over time.

Further details on the calculated index scores, grouping of cities, and comparisons of index scores over time are the focus of the remaining sections of this report.

Figure 10 - LOGIC Framework: Categories, Indicators, Weights, and Benchmarks

Primary Categories		Secondary Categories		Indicators						Benchmark Value
Name	Weight	Name	Weight	Name	Unit	Type	Function	Reference	Weight	
Energy & Carbon	50%	Energy & Power	36%	CO2 / Capita	t CO2 /cap /yr	Sample Stats	Inverse	Top 10 avg, +20%	6.0%	2.14
				Energy Consumption / Capita	tce/cap / yr	International	Inverse	Hong Kong	6.0%	2.77
				Non-Fossil Fuel Energy	%	National Target	Direct	National Target	6.0%	20%
		Industry	36%	Industrial Energy Intensity	tce / 10,000 RMB	Sample Stats	Inverse	Guangzhou, +20%	9.0%	0.272
				Heavy Industry GDP Share	%	Sample Stats	Inverse	Guangzhou, +20%	9.0%	29%
		Transportation	12%	Public Trans Vehicles / 10,000 ppl	units / 10,000 person	Sample Stats	Direct	Top 10 avg, +20%	2.0%	26.4
				Urban Rail Extent	km / km2	International	Direct	Top 10 avg, +20%	2.0%	0.04
				Bus Trips / Capita	trips / person / yr	Sample Stats	Direct	Beijing, +20%	2.0%	308
		Buildings	16%	Green Buildings Share (Plan)	%	National Target	Direct	City Target	2.0%	100%
				Residential Energy / Capita	kWh / cap	International	Inverse	Japan	3.0%	4,743
				Commercial Energy / Employee	kWh / employee	Sample Stats	Inverse	Top 10 avg	3.0%	6,576
Economic Health	20%	Economic Dimension	50% each	Energy Consumption / GDP	tce / 10,000 RMB	International	Inverse	Japan, 2012	10.0%	0.23
				CO2 Emissions / GDP	tCO2 / 10,000 RMB	International	Inverse	EU, 2013	10.0%	0.32
Environment & Land Use	20%	Environment & Land Use	varies	Solid Waste / Capita	t / cap / yr	International	Inverse	Singapore, 2008	4.0%	0.31
				Blue Sky Days (or AQI)	%	National Target	Direct	National Standard	3.0%	100%
				PM2.5	µg / m3	International	Inverse	WHO Standard	3.0%	10
				Water Consumption / Capita	L / cap / d	International	Inverse	WHO Standard (min)	3.0%	60
				Energy & Enviro Budget Ratio	%	National Target	Direct	National Target	3.0%	3%
				Green Space / Capita	m2 / cap	International	Direct	Hong Kong	4.0%	100
Low Carbon Policy, Climate Adapt, & Outreach	10%	Policy Dimension	25% each	Low Carbon / Climate Plan	[Yes/No]	Y/N	Y/N	n/a	2.5%	Yes
				Renew + Alt Energy Strategy	[Yes/No]	Y/N	Y/N	n/a	2.5%	Yes
				Climate Resiliance Plan	[Yes/No]	Y/N	Y/N	n/a	2.5%	Yes
				Low Carbon Lifestyle Publicity	[Yes/No]	Y/N	Y/N	n/a	2.5%	Yes
∑ =	100.0%							∑ =	100.0%	

Chapter 3. City Selection and Grouping

As noted above, the 115 cities included in the project sample represent a diverse range of different population sizes, income levels, economic and urbanization stages, and geographies. One application of LOGIC is to compare groups of cities with similar attributes, to see if there are patterns or insights that emerge from cities of different types.

In this study, five types of *City Groupings* are defined for analysis and comparison. Each of the *City Groupings* is made up of multiple *sub-groups*; and every city in the project sample was assigned to one of the *sub-groups*, for every *Grouping*. These *Groupings* are used throughout the report to examine performance of the different city *sub-groups* across index indicators, categories, and overall. The *Groupings* and *sub-groups* are briefly defined here. Annex A includes a table showing the sub-group assignments for all cities and for each Grouping.

City Size Groups

The size of a city can be an important factor in its transition to green and low carbon development. Large cities can potentially have more resources (e.g. from business, property, and resident taxes, etc.); and yet larger cities can also be more complex, extending over a larger scale, and consuming more natural resources. Cities in China, in general, are large – and getting larger. For these reasons, it is helpful to compare the performance of cities based on their population sizes. The 115 sample cities were divided into four population-size sub-groups:

- Mega Cities – with **7** such cities in this study, these are cities with populations over 10 million.
- Very Large Cities – with **20** cities in this study, these cities have populations between five and 10 million.
- Large Cities – with **84** cities in this study, these cities have populations between one and five million.
- Medium/Small Cities – with **4** cities in this study, these are cities with less than 1 million people.

Note that there are different ways to define and calculate the size of populations in Chinese cities (城区人口). In this report, in order to rely on current publicly available statistics, the city populations were calculated as the product of city resident population (城市常驻人口) and city urbanization rate (城市化率).[23]

Economic Groups

The level of economic development achieved by a city can have great influence on its energy use, carbon emissions, industrial mix, environmental impact, and policy capacity – potentially more-so than by considering the city's size, population, or location. For this reason, it is helpful to compare the performance of cities based on their social and economic features. The Chinese Academy of Social Sciences (CASS) has developed a methodology to assess and classify Chinese cities based on economic conditions. The CASS methodology is based on five socio-economic criteria: *1) GDP per capita, 2) share of value added in primary/ secondary/ tertiary sectors, 3) share of value-add in the manufacturing sector, 4) share of primary sector employment, and 5) urban share of population.*

In this study, the CASS methodology was used to classify the 115 sample cities into one of three economic sub-groups (listed below, and defined using the cities' most recent economic data). Annex A includes a table showing the sub-group assignments for each city.

- "Post Industrial" Cities ('Group P'), with **10** such cities in this study, are categorized as relatively wealthy, with highly urbanized populations, a large service sector, and a post-industrial economy.
    - GDP/capita: between RMB 89,793 - RMB 153,819 (US$14,413-$24,690);
    - Urban share of population: 75%-100%;
    - Share of value-added from the service sector: 50%-80%
- "Transition Cities" ('Group T'), with **58** cities in the study, are undergoing an economic transition from large heavy-industry and manufacturing sectors to a more service-oriented economy. Group T cities have a slightly lower GDP per capita and urbanization rates, as compared to the Group P cities.
    - GDP/capita: between RMB 33,320 – RMB 146,397 (US$5,348 - $23,498);
    - Urban share of population: 52%-97%;
    - Share of value-added from the service sector: 31%-75.7%
- "Industrial Cities" ('Group I'), with **47** cities in the study, have industry-dominated economies, and much lower GDP per capita and urbanization rates than both Group P and Group T cities.
    - GDP/capita: RMB22,912 - RMB63,168 (US$3,677 - $10,139);
    - Urban share of population:36%-71%;
    - Share of value-added from the service sector: 24%-53%

[23] *Data source: "城市国民经济和社会发展统计公报" (from the year of 2010-2015)*

Low Carbon Pilot Status

China recently established low-carbon pilots in a selection of cities and provinces. These low-carbon pilots have been conducting energy and GHG inventories, setting emission reduction targets, preparing low-carbon action plans, and developing local standards and incentives that go beyond the national requirements[24]. The 115 cities in this study are categorized as either *pilot* or *non-pilot* cities. The map in Figure 11 shows the locations and designations of the sample cities.

- Low-Carbon Pilot Cities ("Pilot") – with **54** cities in this study (including 34 "national pilot cities", and 20 cities which are located within one of the national pilot provinces)
- Non-Pilot Cities ("Non-Pilot) – with **61** cities in this study

Geographic Regions

The 115 sample cities span across China's provinces. These include the four provincial-level municipalities (Beijing, Tianjin, Shanghai and Chongqing), as well as across China's provinces and administrative regions: Anhui (7 cities), Fujian (4), Gansu (3 cities), 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). LOGIC scores can be calculated and compared at the province level.

To look at larger geographic trends, the Chinese government's national statistical bureau uses an official methodology for geographical classification of cities into four defined *regions* (listed below). All of the 115 sample cities in the study were specified as belonging to one of these four regions. Figure 11 shows the physical locations of the cities, and the provincial boundaries.

Figure 11 – China's Provinces and Low Carbon Pilot Cities

- East Region -- **50** cities in this study
- Central Region -- **26** cities in this study
- Northeast Region -- **12** cities in this study
- West Region -- **27** cities in this study

Functional Zones

China also has groupings of cities based on regional economic development strategies. According to the official document "Planning China's New Urbanization", issued by the central government in 2016, there are criteria to categorize cities and city clusters into two zones: the "*Optimized Development Zone*", or the "*Key Development Zone*". These designations were used in this study, and each of the 115 sample cities was specified as belonging to one of the two zones. The zones are briefly described below, and Annex A lists the sample cities, and their designations for the functional zones.

- "Optimized Development Zone" Cities -- with **40** cities in this study, these cities have already developed considerably, and are now planned to focus economic development on cleaner and more service-oriented sectors, with tightened environmental requirements, and restrictions on large-scale industrial development. These cities aim to tackle existing environmental challenges from past patterns of development and improve the quality of life for residents. Areas designated as 'Optimized Development Zones' include: the region around the *Bohai Sea* (including Beijing-Tianjin-Hebei, Liaozhong, and the Shandong Peninsula); the *Yangtze River Delta* region; and the *Pearl River Delta* region.
- "Key Development Zone" Cities -- with **75** cities in this study, these cities still plan to prioritize economic development, but balanced with and social and environmental goals. These cities will purse economic growth targets, while following stricter environmental regulations. The key development areas include: Jizhongnan area (including Shijiazhuang, Baoding, Handan, and Xingtai); the Taiyuan urban agglomeration; the Huibao Eyu area; the Kazakhstan long area; the East Longhai area; the Jianghuai area; the Central Plains Economic Zone; the middle reaches of the Yangtze River (including the Wuhan urban agglomeration, the central Changsha-Zhuzhou-Xiangtan urban agglomeration, and the Poyang Lake Ecological Economic Zone); the Beibu Gulf region; the Chengdu-Chongqing region; the Qianzhong area; the Yunnan region; the Zangzhongnan area; the Guanzhong-Tianshui Area; the Lanzhou - Xining area; the Yellow River Economic Zone (including Ningxia); and the Tianshan North Slope Economic Zone.

[24] *Khanna et al. 2014*

Exploring China's Green Low-Carbon City Performance

The framework for LOGIC provides a significant amount of data on the green and low-carbon performance of Chinese cities. LOGIC allows for high-level comparisons, as well as for deeper dives into the factors and dimensions in a city that a make it a high-performer or low-performer. At the same time, LOGIC allows extensive comparisons between groups of cities, as well as their progress over time.

This section presents analysis and results from the first year of applying LOGIC to China's cities. Here, the index scores and data for all of the 115 sample cities, are analyzed, explored, and presented for the years 2015 and 2010. The exploration is data-driven, and highly visual. In the following pages, data tables, charts, and graphic figures will present different views of the city index data -- allowing discussion of the patterns and insights that emerge, revealing China's progress and prospects for its Urban Green and Low-Carbon Transition.

This results exploration section is divided into three main components:

- ***Exploring Overall Index Scores, Contributions, and Trends*** -- including the total composite index values, similarities and differences in the top 20 index cities, and performance differences in the city groupings. This section also takes a high-level view of which index categories have the most influence on the overall scores. Finally, this section looks at trends and changes in Index scores from 2010 to 2015, with special attention on the relationships between economic growth and green & low carbon index scores.
- ***Exploring Detailed Index Categories and Indicators*** -- including the overall distribution of scores within the category, an analysis of which indicators have most influence on the category, where gaps and opportunities lie for city policies in each category, how the city groups perform in each category, and how the categories and indicators changed from 2010 to 2015.
- ***Exploring Lessons from Selected Case Studies*** -- diving deeper by selecting three high-performing cities (one from each of the City Economic Groups), and exploring in more detail which factors and policies contributed the most to the city's high performance in the index – and drawing lessons for similar cities.

Chapter 4. Exploring Overall Index Scores, Contributions, and Trends

This exploration looks at the overall composite index scores – as calculated for the sample of cities as a whole, for the Top 20 best-performing cities, and for the various *City Groupings* defined in this study. The key analysis and insights from this exploration are listed here; and the following pages present more detail and data on each of these conclusions.

- **Overall Index Scores for 2015, All Cities**
  Chinese cities have significant potential to improve their Green and Low-Carbon performance.
- **Index Contributions from Categories and Sub-Categories**
  A major driver of the green and low-carbon performance in Chinese cities is their Energy, Industrial, and Economic structure.
- **Performance of the Top 20 Cities**
  Cities of all types can be Top-Performers in green & low-carbon development.
- **Performance by City Groups**
  China's Low-Carbon Pilot Cities, along with larger, wealthier, and more economically developed cities have been quicker and more successful in achieving green & low-carbon results.
- **Performance by Geographical Region**
  China's Eastern Cities, especially along the coast and in the south, have been quicker and more successful in achieving green & low-carbon results.
- **Correlating LOGIC Performance with City Attributes**
  Large (but not too large) cities, and post-industrial cities are greener; driven by economic, energy, and industry sector performance.
- **Index Growth Trends and Change: 2010-2015**
  China's cities are getting greener: the overall green and low-carbon index scores improved from 2010-2015.
- **Economic Growth and LOGIC Score Change: 2010 – 2015**
  More than 90 out of 115 cities in the sample saw both GDP growth and LOGIC score growth over the 2010-2015 time-period.

Overall Index Scores for 2015, All Cities

Chinese cities have significant potential to improve their Green and Low-Carbon performance.

The 2015 LOGIC results for overall index score and breakdown by category show that there is considerable room for improvement in green and low-carbon performance in Chinese cities. LOGIC helps to show which areas cities can focus on for improved policies and actions. Some top-level highlights from the 2015 index:

- Even best performing cities can still improve scores by 30 points or more.
- 4 out of 7 categories had average scores below 50% of their category potential (i.e. benchmark).
- The best performance in a category (Environment & Land Use) is still only at 60% of its potential/benchmark.
- While the Economic Dimension category is one of the highest weighted categories in the index (20% of assigned weights); it nonetheless had the weakest performance of any category – with an average score of only 25% of the category benchmark.

Figure 12 – High Level LOGIC statistics, 2015

115
Cities in Sample

44.8
Avg. Score, all cities

69.7
MAX Score, any city

28.4
MIN Score, any city

Across the 115 cities included in the study sample in 2015, the average LOGIC score was 44.8 points – less than half of the possible maximum score of 100.

The highest overall score obtained by an individual city was Shenzhen (Guangdong province), with a score of 69.7 points. The lowest overall score was 28.4 points, for the city of Baotou (Inner Mongolia autonomous region). Half of all cities in the study had overall index scores above 44.3 points (i.e. the sample median).

Figure 13 and Figure 15 show distributions of the overall LOGIC scores for all the 115 sample cities – as a *box plot* and a *histogram*. Both figures show the sample's wide distribution (ranging from below 30 points, and not exceeding 70 points), with a roughly bell-shaped curve, and having half of all cities concentrated in the middle-lower portion of the range. A few cities lie in the high-score, upper tail.

Figure 14 shows a breakdown of the average (across all cities) category scores for the seven index categories/sub-categories, along with the *gap* from the possible maximum score for each category (the category maximum score is based on the benchmarks and assigned weight to each category). Most categories have average scores below 50% of their maximum – indicating that there remains strong potential for Chinese cities to improve performance across the range of green and low-carbon dimensions of the index.

These top-level results show that there is a large gap between the 2015 average scores, and the scores achieved by China's best-performing cities, overall and in each category. This indicates that there is also a pathway for cities to catch up. China is early in its green & low-carbon transition; and has made strong commitments to restructuring urban and economic development away from resource-intensive and heavily-polluting production. Despite weaker performance in the economic intensity indicators, the carbon productivity in cities is still low overall, and decarbonizing the economic development pattern will be still a key priority to achieve low carbon transition in Cities.

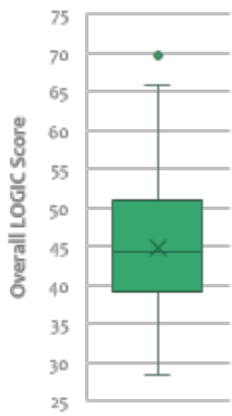


Figure 13 - Box Plot of Overall LOGIC Scores, all cities (2015)

Furthermore, LOGIC, by definition, is ambitious – the selected indicators are designed using world-class green benchmarks, to push Chinese cities to do more, and quicker. LOGIC provides a scale to measure China's continuing progress; and the top-ranking cities and international benchmarks can help point the way forward to a low-carbon pathway.

Figure 15 - Histogram of 2015 Overall Index Scores, All Cities

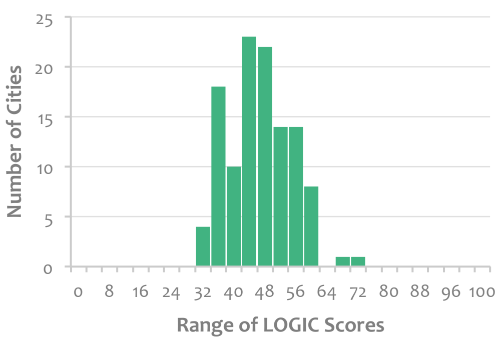
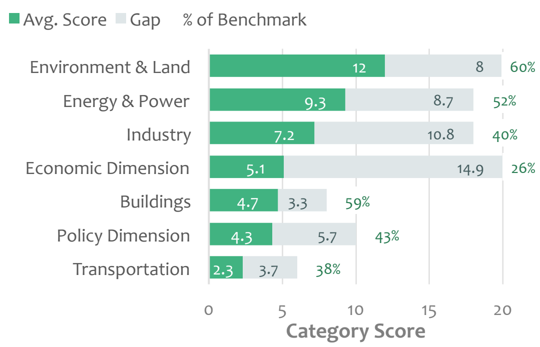


Figure 14 - Breakdown of 2015 Average Index Scores, by Index Category, All Cities



Index Contributions from Categories and Sub-Categories

A major driver of the green and low-carbon performance in Chinese cities is their Energy, Industrial, and Economic structure.

The data and scores from LOGIC's seven categories help to explore questions such as: *Which sectors or dimensions in Chinese cities have the most influence on overall green and low-carbon performance? Which categories show most variation? Which categories have the most potential for improvement?* Chapter 3 later in this report goes into greater detail for each of the categories, and their component indicators. Here, the discussion focuses on comparing the averages and distributions across categories, and their relative contributions to overall index scores.

Index performance differed across the seven categories/sub-categories in 2015. Table 2 shows summary statistics for the index categories. Figure 17 shows the distributions of city scores, by category (as direct score value (Top) and as percent of category benchmark value (Bottom). Figure 18 shows these same category distributions as histograms – as a visual profile of the number of cities at each score across the category range.

Table 2 - Index Summary Statistics by Category/Sub-Category

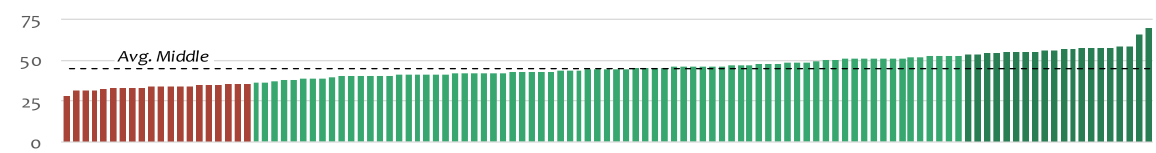
Index Category (or Sub-Category)	**Average Score**	**Category Benchmark**	**% of Benchmark**	**MAX Score** (any city)	**MIN Score** (any city)
Environment & Land Use	12.0	20	60%	15.3	8.8
Energy & Power	9.3	18	52%	17.9	2.4
Industry	7.2	18	40%	14.7	3.5
Economic Dimension	5.1	20	26%	14.6	1.4
Buildings	4.7	8	59%	8.0	1.1
Transportation	2.3	6	38%	5.5	0.1

The average scores for the index categories in 2015 are roughly consistent with the weights they were assigned in the framework – with some notable exceptions. ***The Economy category significantly underperforms its potential in the index.*** The Economy category is assigned one of the highest weights in the index (20%), but has one of the lowest average scores among categories. This drags overall scores downward. Meanwhile, more consistent with expectations, the Environment & Land Use category has one of the highest weights (20%), and also has the highest average category score. The Energy & Power and Industry categories are highly weighted (18% each), and also have the next highest average scores. Buildings and Transport categories similarly correspond with their assigned weights.

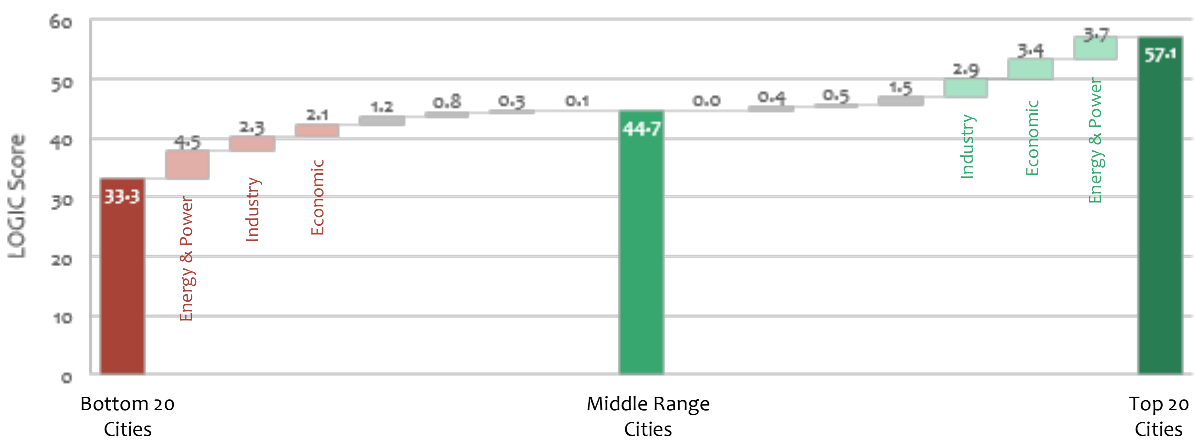
Looking at which categories contribute the most to the differences between high-performing and low-performing cities, it is seen that the Economic Dimension, Industry, and Energy & Power categories had the most influence. Figure 16 shows all 115 cities lined up from lowest to highest score. Beneath, the category differences that contributed to cities being among the Bottom 20 cities, the Middle Range cities, and the Top 20 cities are shown as a waterfall diagram. While overall, the Economic Dimension had weak performance (i.e. 26% of benchmark), for the Top 20 cities, the Economic score was one of the key drivers of better performance. This is similar for the Energy & Power and Industry categories. All three of these are intertwined and related to China's overall economic development model; and these will continue to be important areas for focus in China's green & low carbon urban transition.

Figure 16 – All cities' LOGIC scores, and category contributions to Top Performing and Bottom Performing scores

(Top) Distribution of city LOGIC scores, low to high; showing Bottom 20 (red) and Top 20 (dark green)



(Bottom) Showing contributions of index categories to LOGIC score change; Bottom 20 and Top 20 cities compared to middle scoring cities.



Examining the distribution of scores in each category also show some important differences (Figure 17, Bottom). In the Buildings, Energy & Power, and (almost) Transport categories, some cities reached the maximum possible score (100%). Meanwhile in the Economic, Environment & Land Use, and Industry categories, the highest scoring cities were well below their category maximum scores. Furthermore, most of the categories have considerably wide distributions (the span from lowest to highest score in the category) – ranging from near 10% of category maximum, to 80% or even 100%.

The histograms in Figure 18, further illustrate these points. The shape of the histogram profile for the Economy category has a peak heavily shifted to the low-end of the range; and a long, thin tail to the right – indicating some high-performing, "outlier" cities. The Environment category is different: with a smooth peak at the high end of the category score range, and no cities having a score below 40% of the category maximum. The Buildings, Industry, and Transport categories also show relatively smooth profiles, with peaks centered toward middle of category range; and long, thin tails on either side. The Energy & Power category shows the widest variation, with an uneven profile containing multiple small peaks.

Figure 17 – Box Plot Distributions by Index Category/Sub-Category

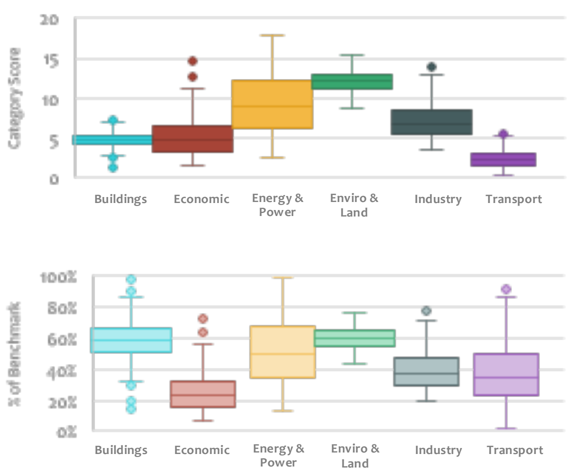


Figure 18 – Category/Sub-Category Score Histogram Distributions

Performance of the Top 20 Cities

Cities of all types can be Top-Performers in green & low-carbon development.

Results from LOGIC indicate that cities of all types can be top-performers; and that no matter which type of city, or which category of measurement, cities can always learn from others and explore ways to be greener. Examining the Top 20 performing cities in the index in 2015 helps explore patterns in which cities (or groups of cities) perform the best, and which index categories drive high scores in those best-performing cities. Table 3 lists the Top 20 cities, ranked by overall LOGIC score for 2015. These Top 20 cities had an average overall index score of 57.1 points; and a range from 69.7 (max) to 53.6 (min).

Figure 19 – Score Breakdown of Three City Sub-Sets: Top 20, All Cities, and Bottom 20

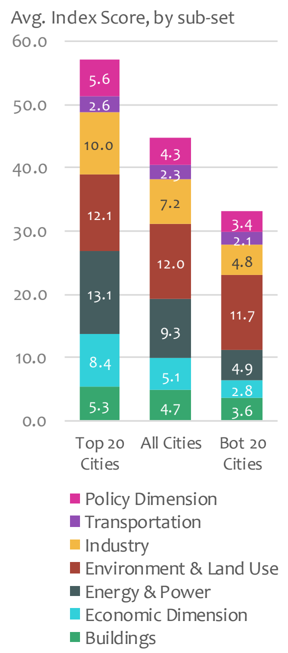


Figure 19 at the right shows the average overall index scores for the Top 20 cities (broken down by contributing index category). Also shown are similar average score breakdowns for the Bottom 20 cities, and for the sample population as a whole. In this chart, the index categories that have the most variation between Top/Bottom performing, and average cities are: Economic Dimension, Energy & Power, and Industry. Of course, these three categories were also weighted more heavily in the index framework; however, these categories show the most variation across cities in the sample. So, their contributions to high-performing city scores is significant from a policy setting perspective (see the detailed category sections later in this document). On the other hand, the Buildings, Land Use & Environment, and Transportation categories show very little variation between the Top, Bottom and Population column groups.

Finally, for each of the *City Groupings* (see Chapter 3 above), Figure 20 illustrates the proportional make-up (or 'mix') of city sub-groups, as represented in the total sample population, and as represented in the list of Top 20 ranked cities for the 2015 LOGIC results. These sub-group mixes are show as separate 100% stacked bar charts – for the overall sample population (Figure 20,Top), and for the Top 20 cities (Figure 20, Bottom). Observations on changes in the mix of cities for each Grouping are presented in the notes below the charts.

Post-Industrial cities (Group P) and Mega cities performed significantly better than their representation in the sample population. Transition cities (Group T), Very Large cities, and Medium/small cities did poorer. Eastern cities dominated the Top 10 list, and Northeastern cities did better than their numbers in the population. There were no Western cities in the Top 20. And, the Low Carbon Pilot cities did considerably better than the non-pilots.

The 2015 list of Top 20 LOGIC cities includes a diverse range of cities from most economic groups, size groups, geographic regions, and policy groups (only medium-small-sized cities, and northeast region cities are not included on the Top 20 list). Within each group, there are high performers and low; and because of this, for all types of cities, peer cities can learn from their high-performing counterparts. Likewise, within each category/sub-category, there is a range of city performances – high and low. Peer cities can learn specific green and low carbon policies and actions from high-performers in any group; and peer cities can learn from specific policies and actions in each category.

Figure 20 - Comparing the Mix of Cities in Top 20 List against Sample Population, by City Grouping

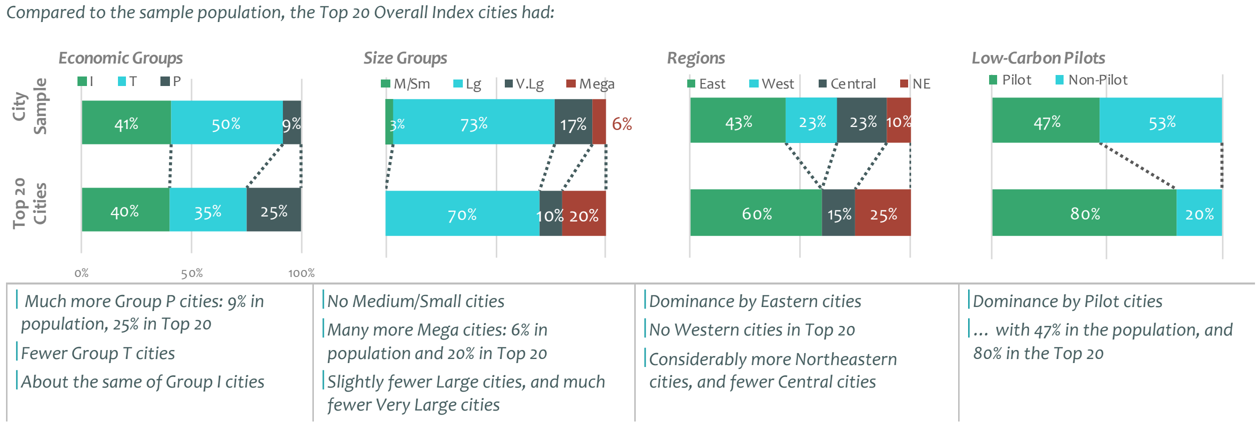


Table 3 - List of Top 20 Cities, Ranked by 2015 Overall Index Score

City Name	Rank, Overall Index	Overall Score	Economic Group	Size Group	Region	Low Carbon Pilot Status
Shenzhen	1	69.7	Group P	Mega	East	Pilot
Xia'men	2	66.0	Group P	Large	East	Pilot
Changde	3	58.5	Group I	Large	Central	Non-Pilot
Nanning	4	58.2	Group I	Large	West	Non-Pilot
Haikou	5	57.7	Group T	Large	East	Pilot
Ganzhou	6	57.5	Group I	Large	Central	Pilot
Guangzhou	7	57.5	Group P	Mega	East	Pilot
Shantou	8	57.4	Group T	Large	East	Pilot
Jieyang	9	56.7	Group I	Large	East	Pilot
Guilin	10	56.3	Group I	Large	West	Pilot
Zhanjiang	11	55.8	Group I	Large	East	Pilot
Beijing	12	55.5	Group P	Mega	East	Pilot
Hangzhou	13	55.3	Group P	Very Large	East	Pilot
Nanchang	14	54.8	Group T	Large	Central	Pilot
Wenzhou	15	54.8	Group T	Very Large	East	Pilot
Guangyuan	16	54.7	Group I	Large	West	Pilot
Jiangmen	17	54.5	Group I	Large	East	Pilot
Kunming	18	54.5	Group T	Large	West	Pilot
Chengdu	19	53.7	Group T	Mega	West	Non-Pilot
Yangzhou	20	53.6	Group T	Large	East	Non-Pilot

Performance by City Groups

China's Low-Carbon Pilot Cities, along with larger, wealthier, and more economically developed cities have been quicker and more successful in achieving green and low-carbon results.

The level of economic development achieved by a city can have great influence on it is energy use, carbon emissions, industrial mix, environmental impact, and policy capacity – potentially more-so than by considering the city's size, population, or location. As noted above, LOGIC scientifically assigns sample cities to a number of group typologies in order to analyze and better understand patterns and trends in green and low-carbon development for different kinds of cities. These methods and analysis seek meaningful policy implications by helping to explore questions such as:

- *Do China's low-carbon pilot cities perform better?*
- *Is a city's size or level of economic development a differentiator in green and low-carbon performance?*
- *Within each city group, sharing similar development factors, what are the most effective green policy measures?*

The city groupings discussed above in Chapter 3 (*i.e. pilot status, economic groups, size groups, functional zones, etc.*), and the 2015 results from LOGIC provide answers to these questions. Figure 21 and Figure 22 show the average scores and the distribution of scores (box plots) for the various city Groupings and Sub-Groups.

Note that index score data for the city groupings was tested for statistical significance[25]. Three groupings (by low-carbon pilot status, by population size, and by economic group) were determined to be statistically significant; and therefore, these groups' reported scores represent meaningful differences in group performance. On the other hand, the functional zone grouping could not be determined to be statistically significant; and therefore, was not concluded to be a meaningful driver of index score performance.

Based on the city groups' performance results, the following conclusions can be drawn:

China's Low Carbon Pilot cities do outperform non-pilot cities

Low-Carbon Pilot cities have a higher average overall index score (47.0), compared to the non-pilot city average (42.9)

The low-carbon pilot group difference is statistically significant.

Large "Mega" cities, and economically developed cities of "Group P" outperform peer cities from other sub-groups

Group P cities have a higher average overall index score (52.2)

"Group T" and "Group I" cities have similar distributions; their means could not be determined as statistically different.

Mega cities have a higher average overall index score (55.0)

The other size sub-groups have overlapping distributions; their means could not be determined as statistically different.

Functional Zones are not significant to explain index scores

Sub-group means for the Functional Groups were not determined to be significantly significant.

The score distributions for the two sub-groups have considerable overlap and ranges.

Overall there is a lot of variation within the city groupings. Within each group, city scores fall across a wide range. Therefore, beyond belonging to one of the groups, there clearly are other drivers behind a city's green and low-carbon performance. LOGIC also explores index categories, indicators, and the individual city policies and actions. These are discussed later in the report.

Figure 21 - Group Averages and Box Plot Distributions

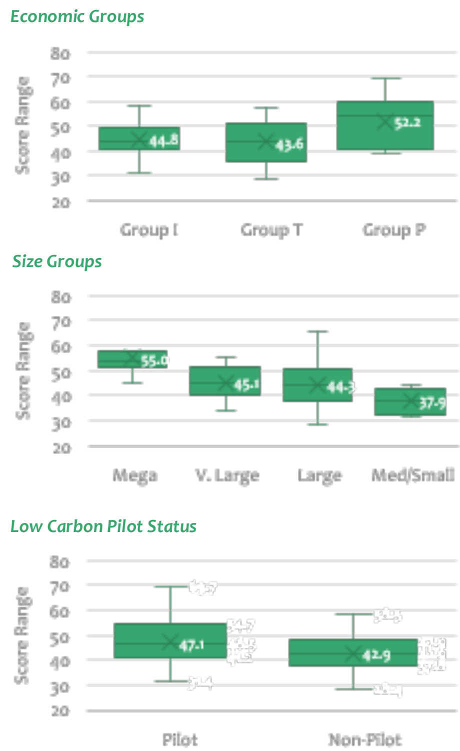


Figure 22 - Not Statistically Significant: Group Box Plot Distributions

[25] *In order to determine the statistical significance of the calculated city group averages, an Analysis of Variance (ANOVA) and Tukey Honest Significant Difference (HSD) test was run for all combinations of sub-groups within each Grouping. This test quantitatively assesses the data to assess whether calculated group statistics (e.g. mean values) can be concluded to come from statistically different populations – and therefore conclude meaningfully that city groups indeed explain index score differences.*

Performance by Geographical Region

China's Eastern Cities, especially along the coast and in the south, have been quicker and more successful in achieving green and low-carbon results.

LOGIC also explores the question: *are there regional differences in Chinese cities' green and low-carbon performance?* The maps in Figure 23 plot the locations of the 115 sample cities, and are color-coded by their 2015 overall index scores (green = high score, red = low score). The large map shows all cities; and the small side maps show the cities and scores by region. Visually, the maps show that Chinese cities in the south and along the coast tend to have higher overall index scores.

China's national statistics bureau officially divides China into four geographic regions: East, Central, Northeast, and West. However, grouping the 115 sample cities into these regions was not found to be a statistically significant explainer of city green and low-carbon performance[26]. Only the Eastern region has a clear and significant higher average index score (47.6 points). The Eastern region also has the highest maximum city score (Shenzhen, 69.4 points). However, the East region also has the greatest spread, and the largest number of cities (50) of any region. Figure 25 below shows box plots of the city distributions for each region. All regions have city scores spread across a wide range – each with relatively high performing cities, and low.

The conclusion is that there does seem to be significant north-south variation in scores; but the official Chinese region designations are not a significant explainer of city score differences. Lessons to be learned about green and low carbon improvement will come from individual best city practices; not from regional location alone.

Figure 23 – Map of Cities' Overall Index Scores (2015): all cities (left), and by City Geographic Regions (right)

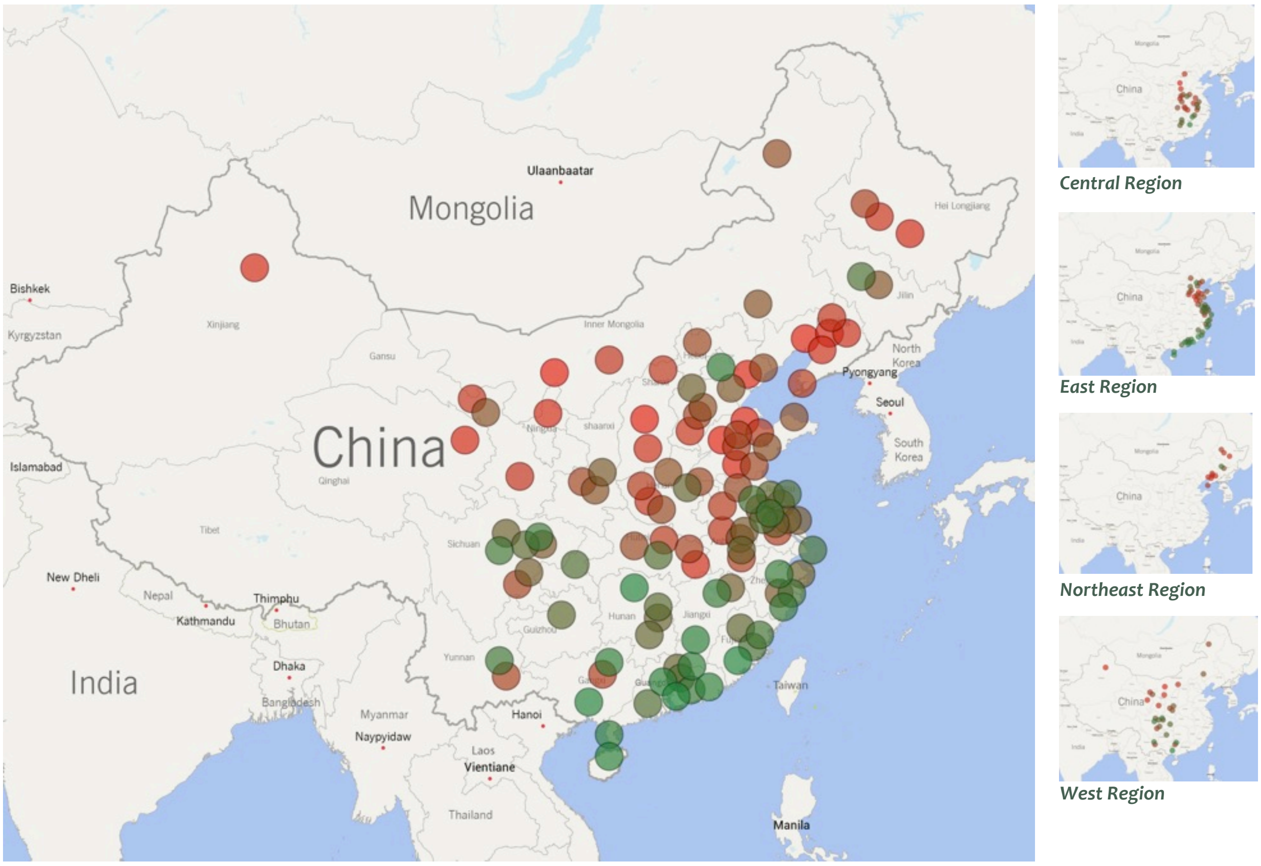
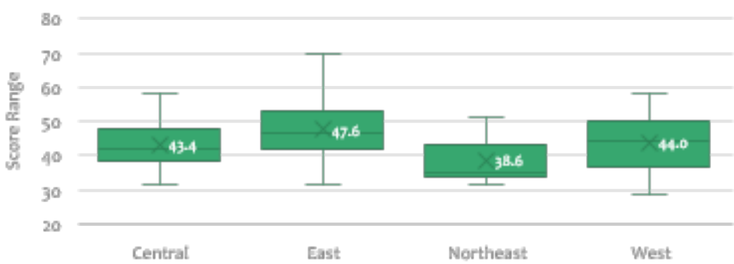


Figure 24 - Map of Top 20 Cities

Figure 25 - Distributions of City Overall Index Scores, by Region



[26] *Regional grouping of the 115 sample cities was followed by a similar ANOVA and Tukey HSD test, as discussed previously. For most sub-groups, the mean values for the four regions were not statistically significant. Only the Eastern region is significant.*

Correlating LOGIC Performance with City Attributes

Large (but not too large) cities, and post-industrial cities are greener; driven by economic, energy, and industry sector performance.

LOGIC scores are also compared to a range of economic and demographic variables from the 115 sample cities. This analysis investigates questions such as*: is there a relationship between city size and low-carbon performance?*; and, *is there a relationship between the economic structure of city and its low-carbon performance?*.

Correlating 2015 overall index scores

Data for 10 economic and demographic variables was collected from each of the 115 cities in the sample. These variables include: the cities' Land Area, Population, and extent of Urbanization; the cities' GDP, GDP per Capita, and GDP Growth rate from 2010-2015; as well as the structure of the cities' economies, as measured by the GDP Share of Agriculture, GDP Share of Secondary sector (i.e. manufacturing), GDP Share of Tertiary sector (i.e. services), and an Industrialization Index.

A simple, linear correlation analysis was performed correlating the 2015 LOGIC scores against each of the 10 economic and demographic variables. Table 4 shows the results of the correlation analysis. In Figure 26, two of the city variables, City Population and City GDP [RMB], show moderate and positive correlation with overall index scores: i.e. as either of these variables increase, the city overall index scores also increase. [Caution that this is showing *correlation*, not necessarily *causation*.] At the same time, one city variable, GDP Share of Secondary Sector, has a moderate and *negative* correlation with overall index scores (as secondary sector GDP share increases, index scores tend to *decrease*). For the other city variables, there is not much correlation with overall scores (correlation coefficients are near zero – indicating little relationship to overall score).

Figure 26 visually displays these correlations: using scatter plots of 2015 overall index scores versus the 'Population', 'GDP' and 'GDP Share – Secondary sector' variables. ***City Population shows a trend of increasing index scores for larger cities; except for very large cities (with populations above 11 million people) where overall index scores <u>decline</u> for larger cities***. One explanation for this is that as cities grow, their agglomeration effects allow greater efficiency (in terms or resources, transport travel times, and other urban services); but at a certain scale, large cities lose these size and efficiency benefits. For the plots of other variables, there is significant spread in the data across the cities, with moderate correlation to overall index scores.

This wide variability at the Overall Index Score level indicates that it is not only the size or gross GDP of a city that drives green

Figure 26 - Scatter Plots: 2015 Index Scores against Select City Variables

and low carbon performance. LOGIC is used to further investigate correlated relationships for the seven index categories, and for some of the city Groupings. These are discussed next.

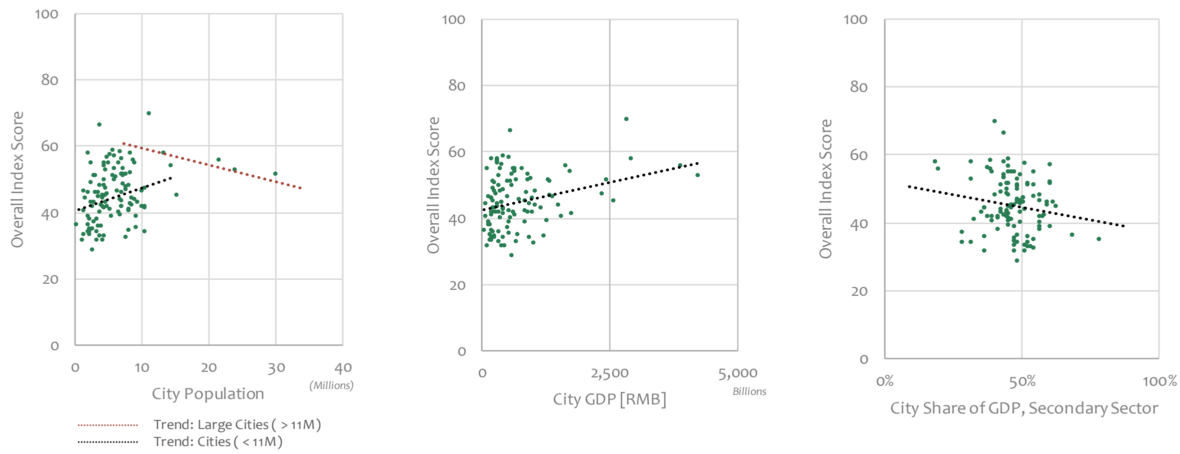


Table 4 - Correlation Matrix: 2015 Index Scores against Ten City Variables

The top, bold row shows results for the overall index scores, and the lower rows show results for the index categories/sub-categories). Positive correlation coefficients with values near to +1.0 in the table (shaded in blue) indicate that higher city variable values are related to higher index scores. Negative coefficients (shaded in orange) indicate that higher city variable values relate to lower index scores.

Index Level	GDP Growth (2010-2015)	GDP [RMB]	GDP per Capita	GDP Share: Agriculture	GDP Share: Secondary	GDP Share: Tertiary	Industrial Index	Land Area [km2]	Population	Urban-ization
Total Index Score	0.15	0.31	0.06	0.03	-0.19	0.15	-0.03	0.13	0.32	0.05
Buildings	0.03	0.22	-0.04	0.11	-0.01	-0.06	-0.09	0.23	0.29	-0.14
Economic Dimension	-0.07	0.47	0.33	-0.23	-0.22	0.32	0.23	0.06	0.39	0.26
Energy & Power	0.27	-0.16	-0.49	0.47	-0.06	-0.21	-0.50	0.02	0.07	-0.39
Environment & Land Use	0.01	-0.16	0.04	0.01	0.13	-0.10	-0.01	0.12	-0.21	0.03
Industry	0.20	0.18	0.10	-0.04	-0.09	0.11	0.06	-0.04	0.17	0.08
Policy Dimension	-0.11	0.42	0.33	-0.24	-0.23	0.33	0.24	0.18	0.28	0.26
Transportation	-0.01	0.61	0.61	-0.49	-0.29	0.52	0.55	0.13	0.37	0.58

Correlating 2015 index category scores

Some stronger relationships and insights emerge when looking at similar correlations between the city economic and demographic variables and the LOGIC category / sub-category scores. See Figure 27, and refer to the lower rows of Table 4.

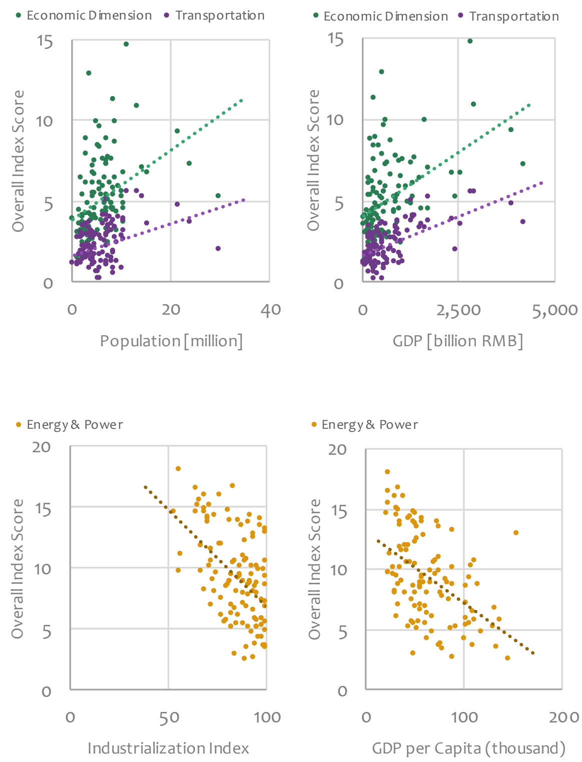
Bigger, wealthier, and more economically developed cities tend to have higher LOGIC scores; but as noted with overall scores, cities with populations over 11 million see index category scores decline with increasing city size.

- This is especially true in the Economic Dimension, Transportation, and Policy & Outreach categories.
- More compact cities (i.e. those with bigger populations, but more centralized infrastructure systems) are more efficient in terms of energy use, economic concentration, and public infrastructure – but only up to a certain point.
- Wealthier cities presumably have more resources and capacity to enact low carbon policies, implement energy efficiency and environmental protection practices, and invest in public transportation infrastructure.
- Correlation coefficients for these categories against the 'Population' and 'GDP' city variables are in the range of positive 0.3 and positive 0.6.
- Correlation coefficients for 'GDP per Capita', 'Industrial Index', and 'GDP Tertiary Share' also tend to be higher.
- See Figure 27.

Highly urbanized, industrial, and wealthy cities tend to have low scores in the Energy & Power Category

- These cities, having followed China's traditional economic development pattern, tend to be highly energy intensive, and thus perform worse in the Energy & Power category.
- Correlations for Energy & Power scores, against the city variables of 'GDP per capita', 'industrialization index', and 'urbanization' tend to be more highly negative correlated.
- Coefficients for these variables range from -0.4 to -0.5.
- See Figure 27.

Figure 27 – Selected correlation plots of city overall index scores, versus different city economic or demographic variables



There is limited correlation for city variables with the Buildings, Environment and Land Use, and Industry index categories. Correlation coefficients for these variables tend to have values near to zero.

Correlating 2015 Index Category Scores to Total Index Scores for City Economic Groups

Other relationships emerge when examining cities by Economic Group, and how the group scores in each index category relate to the overall index scores. ***For all Economic Groups, the Overall Index scores are more driven by the Economic, Energy & Power, and Industry categories than for other categories in the index***. Table 5 shows the correlation coefficients for scores in the seven categories against the total index scores, and calculated separately for the three economic groups.

Figure 28 Top shows a tight scatter plot of Economic Dimension scores vs overall scores, by group (and plots are similar for the other two categories). Of course, these are the categories with the most weight in the index framework, so they would be expected to have a strong relationship with the total scores. However, since they show both stronger correlations, and less variation than other categories, their consistency is significant.

The Transportation and Environment & Land Use categories have much weaker correlations, and much "mushier" scatter plots. Group P cities for both, have stronger correlation than the other groups (but the sample size is also lower). Performance in these categories, can lead to a wide range of outcomes in Overall Index score – there is no clear trend or pattern. See Figure 28 Bottom. The Buildings category is somewhere in between the two mentioned above. Scores and scatter-plot shapes are consistent across groups, but the coefficients are moderate, and there is considerable variability in the scatter.

Table 5 - Correlation Coefficients by Economic Group: Category Scores vs Total Index Scores

City Econ Group	*# of Cities*	Economic Dimension	Energy & Power	Industry	Buildings	Transport	Environment & Land Use	Policy Dimension
Group P	*10*	0.98	0.91	0.79	0.41	0.33	0.54	0.51
Group T	*58*	0.73	0.86	0.73	0.46	0.04	0.17	0.13
Group I	*47*	0.84	0.79	0.75	0.53	0.10	0.00	0.39
All Cities	***115***	***0.82***	***0.74***	***0.74***	***0.48***	***0.20***	***0.10***	***0.37***

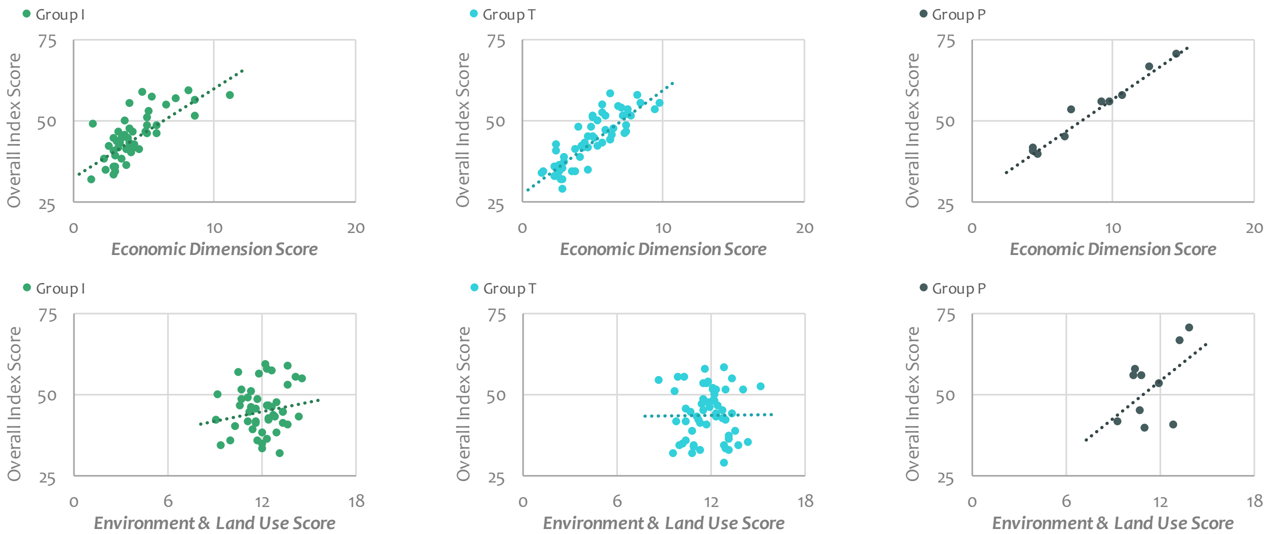


Figure 28 – Comparing Economic Groups' scatter plots of overall index scores, versus category scores: Economic (Top), Environment category (Bottom)

Correlating City GDP per Capita vs. Total Index Scores, for City Economic Groups

Cities at the post industrialization stage (Group P) observe a decoupling between economic growth and carbon & pollution emissions. In fact, there is a turning point marking the shift in economic development pattern from manufacturing and transitioning cities (Groups T and I, which rely on heavy industry), to post-industrial cities (Group P, which focus on more efficient manufacturing and the service sector for growth). Looking at the LOGIC data, for Group P cities, the correlation coefficient and scatter plot trend line are positive: cities with higher incomes, have higher index scores. However, the coefficient is not that strong, 0.34 (out of 1.0, for perfect correlation). Group T and I cities have negative correlation: higher incomes go with lower scores; but coefficients are very small (-0.15 to -0.10). The correlation coefficient for all cities (all groups) is very weak, at 0.06. Cities in Group T and Group I, though not yet reaching a decoupling point, can still achieve a balance between economic development and pollution. Table 6 shows the related correlation matrix, and Figure 29 Top shows scatter plots.

Correlating City Population vs. Total Index Scores, by City Size Group

As observed above, bigger cities tend to have higher LOGIC scores, but only up to certain point. China's largest mega cities, if sprawling without a sustainable urban planning principles and sufficient public transportation systems, experience excess energy demand and inefficient traffic jams from private vehicle ownership. Examining the LOGIC data by City Size Groups, 'Mega' cities and 'Very Large' cities have a moderate, negative correlation between Population Size, and Overall Index scores (larger population cities have lower index scores, with correlation coefficients between -0.44 and -0.33). 'Large' cities and 'Medium/Small' cities meanwhile have a moderate, positive correlation between population and index scores: larger population cities have larger index scores (correlation coefficients are 0.27 and 0.52, respectively). *[Note that Mega cities sample size is small: 7 cities; and that Medium + Small cities sample size is very small: 4 cities].* Table 7 shows the related correlation matrix, and Figure 29 Bottom shows scatter plots.

Table 6 - Correlation Matrix

City Econ Group	# of Cities	GDP per Capita [RMB]
Group P	10	0.34
Group T	58	-0.15
Group I	47	-0.10
All Cities	115	0.06

Table 7 - Correlation Matrix

City Size Group	# of Cities	Population
(1) Mega	7	-0.44
(2) Very Large	20	-0.33
(3) Large	84	0.27
(4) Medium + Small	4	0.52
All Cities	115	0.32

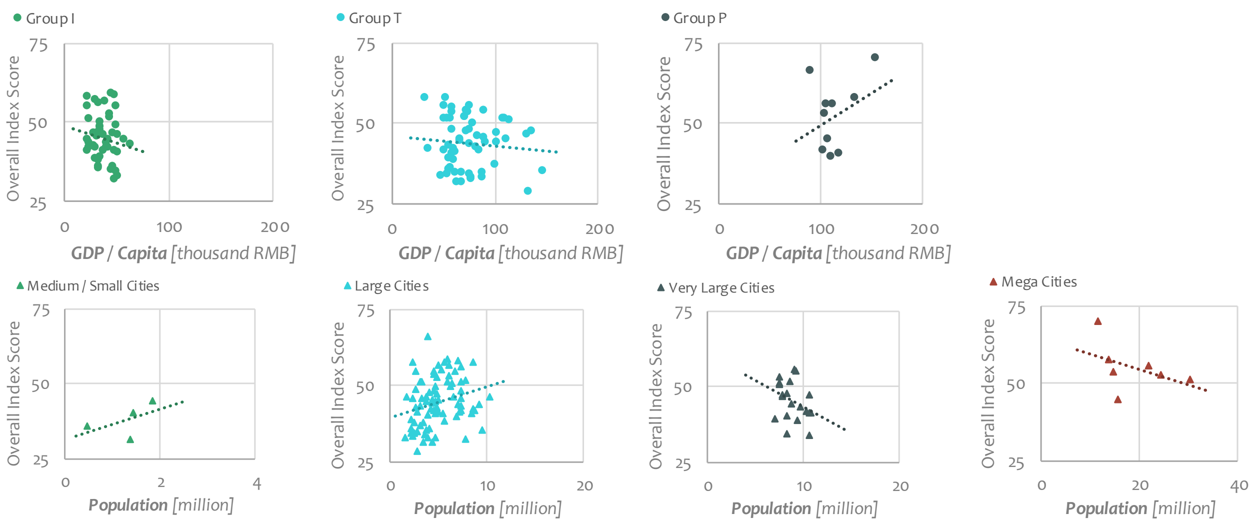


Figure 29 – City Groups' scatter plots of overall index scores, versus city variables: Econ Group vs GDP/capita (Top), and Size Group vs Population(Bottom)

Index Growth Trends and Change: 2010-2015

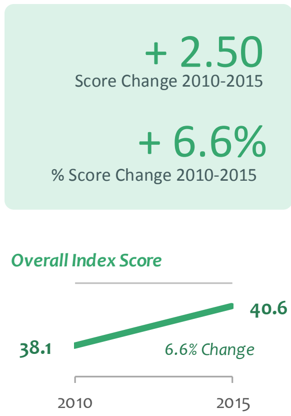
China's cities are getting greener: overall green and low-carbon index scores improved from 2010-2015.

Average overall LOGIC scores (excluding the Policy & Outreach category*) increased by 6.6% from 2015 to 2015 (total increase of 2.5 points, out of 100). The average overall index score rose from 38.1 to 40.6.

Data was collected, and scores calculated from the 115 sample cities for both 2010 and 2015. This five-year time period corresponds to the implementation of China's 12th Five Year Plan (12th FYP) – which included many reforms and initiatives around environmental protection, air quality improvement, and restructuring parts of the Chinese economy. This period also included the launch of the low-carbon pilots in 36 cities and provinces across the country. The 2010 city data used in this report therefore represents the "prior state" (i.e. before the 12FYP reforms and pilot cities were put in place); and the 2015 data can reveal progress on the green and low-carbon objectives in China, in part as a result of these initiatives.

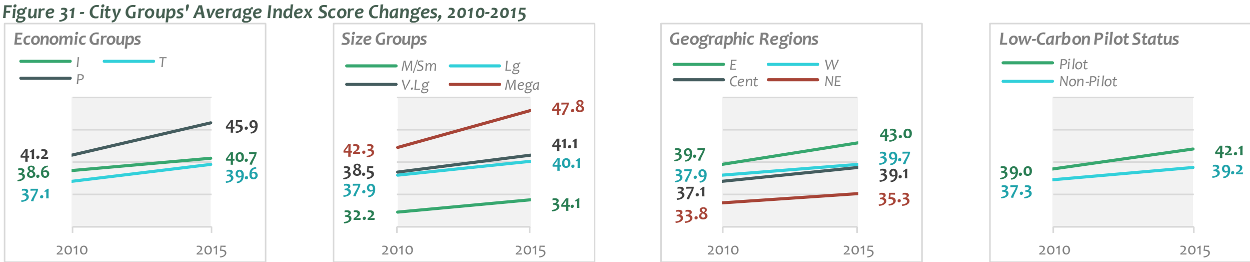
Figure 31 shows 'slope-graphs' of the average overall LOGIC score changes from 2010 and 2015 for four of the city groupings in this study. "Group P" and "Mega" cities had faster improvement in overall index scores than their peer groups. Low Carbon Pilot cities also had faster improvement than non-pilot cities. Regions all improved at near the same pace, with Eastern cities improving slightly faster.

Figure 30 - LOGIC Scores Change [2010-2015]



*One important note is that in this section (and in all sections of this report that discuss 2010 city data and LOGIC scores), the scores, values, and charts/figures presented all **exclude** contributions from the Policy & Outreach category. The four indicators in the Policy & Outreach category refer to planning documents and outreach efforts that were only mandated by the Chinese government, **after** the year 2010. Therefore, it would be misleading to compare index scores and cities with the Policy & Outreach category, as none of the cities had the measures tracked by the indicators in place. It would also skew comparisons with 2015. Therefore, the scores and values in this and subsequent sections include all categories and indicators, except the Policy & Outreach category.*

Figure 31 - City Groups' Average Index Score Changes, 2010-2015



Change in Score Values, by Secondary Category and Indicators (2010 to 2015)

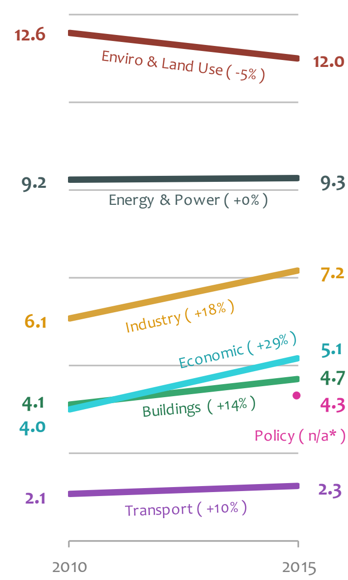
Most of the LOGIC categories and sub-categories showed varying degrees of improvement in average scores over the five-year period from 2010 to 2015. Only the Environment & Land Use category showed a decline in average score (a drop of -0.6 points, or -4.7% from 2010 to 2015). All other categories saw average score growth. Figure 32 shows a slope-graph with score changes for each category over this period. Table 8 shows a statistical summary of the category changes.

While it was observed earlier in the report that the Economic Dimension category had the lowest overall performance in the index, this category actually had the highest growth (raising 1.2 points, or 29% from its 2010 value). The Economy category improvement contributed 46% of the total index score change. Also notable is the Industry category, which increased 1.1 points (18.4%) from 2010, and contributed 44.7% of the overall index score change. The score drop in the Environment & Land Use category contributed 24% of the overall index score change.

Figure 33 shows a similar slope graph for the index indicators. This figure also shows a ranked listing of score changes (absolute change, and percent change), from biggest improvement to sharpest decline, for all of the indicators (excluding the Policy & Outreach category, as noted above).

The index indicators are discussed in more detail later in the report, but it can be seen here that there was wide variation in the indicator score changes from 2010 to 2015. Eleven index indicators saw an increase in their average scores – with the score of the highest improving indicator (Urban Rail Extent) more than doubling (+121%). At the same time, seven indicators saw their average scores decrease – ranging from a -1% drop (Solid Waste) to a -21% drop (Air Quality Blue Sky Days) from 2010 to 2015.

Figure 32 – Category Changes, 2010-2015
Category Scores

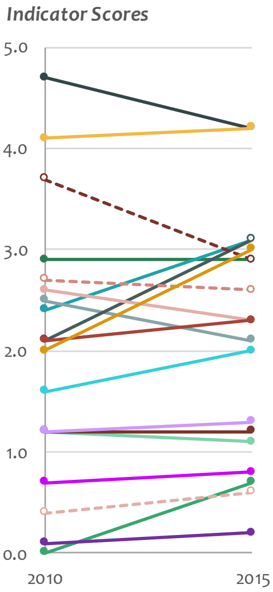


* Note: Policy Category data not avaialable for 2010

Table 8 - Statistical Summary of Index Score Change 2010-2015, by Category

Category / Sub-Category	2010 Score	2015 Score	Score Change	% Score Change	% Contrib to Total Change
Buildings	4.1	4.7	0.58	14%	23%
Economic Dimension	4.0	5.1	1.16	29%	46%
Energy & Power	9.2	9.3	0.03	0%	1%
Environment & Land Use	12.6	12.0	-0.59	-5%	-24%
Industry	6.1	7.2	1.12	18%	45%
Transportation	2.1	2.3	0.20	10%	8%
Total	**38.1**	**40.6**	**2.5**		**100%**

Figure 33 - Slope Graphs, Score and Percent Changes, and Rankings for LOGIC Indicators



Indicator	Category	2010 Score	2015 Score	Score Change	% Score Change	Rank by change
Ind. Energy Intensity	Industry	2.0	3.0	1.05	53%	1
Non-FF Energy	Energy & Power	2.1	3.1	0.95	45%	2
Energy Consump. /GDP	Economic Dimension	2.4	3.1	0.69	29%	3
CO2 Emissions /GDP	Economic Dimension	1.6	2.0	0.46	29%	4
Green Space	Environment & Land Us	2.1	2.3	0.23	11%	5
PM2.5	Environment & Land Us	0.4	0.6	0.20	56%	6
Urban Rail Extent	Transportation	0.1	0.2	0.12	121%	7
Heavy Ind. GDP Share	Industry	4.1	4.2	0.07	2%	8
Public Vehicles /10k ppl	Transportation	0.7	0.8	0.06	9%	9
Water Consump. /capita	Environment & Land Us	1.2	1.2	0.03	2%	10
Bus Trips /capita	Transportation	1.2	1.3	0.02	2%	11
Solid Waste /cap.	Environment & Land Us	2.7	2.6	-0.03	-1%	12
Res. Energy /capita	Buildings	2.9	2.9	-0.03	-1%	13
Comm. Energy /empl.	Buildings	1.2	1.1	-0.10	-8%	14
Energy & Env Budget	Environment & Land Us	2.6	2.3	-0.25	-10%	15
CO2 /capita	Energy & Power	2.5	2.1	-0.40	-16%	16
Energy Consump. /capita	Energy & Power	4.7	4.2	-0.52	-11%	17
Blue Sky	Environment & Land Us	3.7	2.9	-0.78	-21%	18
Green Bldgs. Share	Buildings	0.0	0.7	n/a*	n/a*	n/a*

** Note : no data for Green Buildings Share in 2010*

Cities with the Biggest Changes in Total Score – positive and negative

Looking closer at the cities with the biggest changes in index scores (excluding the Policy & Outreach category), Figure 34 shows the 115 sample cities ranked by total change in overall index score from 2010 to 2015. The Top 20 cities with greatest positive score change are highlighted in green on the left. Over the 2010-2015 period, there were 21 cities with negative score change (these are highlighted in red on the right of the figure). Figure 36 through Figure 38 further explore patterns in these cities. Figure 36 and Figure 37 show the Top 10 list of positive-change cities, along with stacked bar charts that compare the proportional sub-group make-up of these Top 10 change cities as compared to the make-up of the sample population, and the Top 20 scoring cities in the overall index. Figure 35 and Figure 38 show a similar list for the 21 cities with negative score change from 2010-2015.

From these figures, for economic groups, Group P cities were more represented in the list of Top 10 positive-change cities. Group M had mixed results: more cities in the Top 10 positive-change list, but also more cities in the score-decrease list. For population size groups, all city sizes were represented in the Top 10 positive-change list; but no Mega cities had their overall score decrease from 2010-2015. For geographic regions, all regions also had cities in the Top 10 positive-change list, with central and western cities doing better than their representation in overall score ranking. Low-Carbon Pilot cities were consistent in their good performance – having more cities in the Top 10 positive-change list, and fewer cities with decreasing scores. Although it is notable that still 8 out of 21cities with decreasing scores were low-carbon pilot cities.

Figure 34 - Cities Ranked by Overall Score Change from 2010 to 2015 (high to low)

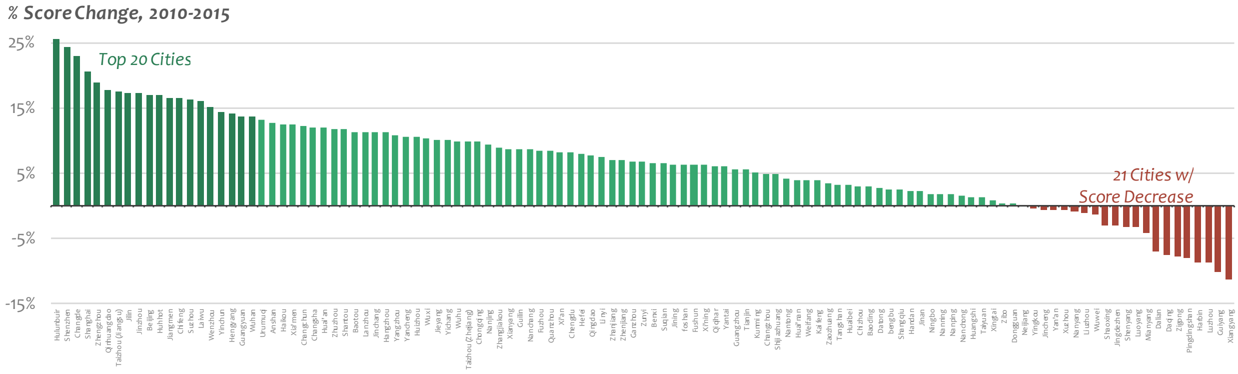


Figure 36 - Top 20 Cities by Score Change (2010 - 2015), including score and change values, and pilot status

City	2010 Scores	2015 Scores	Score Change	% Score Change	LC Pilot Status
Hulunbuir	28.1	35.3	7.2	26%	Pilot
Shenzhen	50.0	62.2	12.2	24%	Pilot
Changde	45.6	56.0	10.4	23%	Non-Pilot
Shanghai	37.5	45.2	7.7	21%	Pilot
Zhengzhou	34.0	40.4	6.4	19%	Non-Pilot
Qinhuangdao	32.2	37.9	5.7	18%	Pilot
Taizhou (Jiangsu)	37.8	44.4	6.6	18%	Non-Pilot
Jilin	33.5	39.3	5.8	17%	Pilot
Jinzhou	41.3	48.4	7.1	17%	Pilot
Beijing	41.0	48.0	6.9	17%	Pilot
Huhhot	27.2	31.8	4.6	17%	Non-Pilot
Jiangmen	42.5	49.5	7.0	17%	Pilot
Chifeng	31.6	36.7	5.2	16%	Non-Pilot
Suzhou	34.0	39.5	5.5	16%	Pilot
Laiwu	24.8	28.8	4.0	16%	Non-Pilot
Wenzhou	43.2	49.8	6.5	15%	Pilot
Yinchun	27.5	31.5	3.9	14%	Non-Pilot
Hengyang	40.0	45.7	5.6	14%	Non-Pilot
Guangyuan	41.6	47.2	5.6	13%	Pilot
Wuhan	32.0	36.3	4.3	13%	Pilot

Figure 35 - Cities with Negative Score change (2010 - 2015) including score and change values, and pilot status

City	2010 Score	2015 Score	Score Change	% Score Change	LC Pilot Status
Xiangyang	37.7	33.4	-4.3	-11%	Pilot
Guiyang	40.0	35.9	-4.1	-10%	Pilot
Luzhou	46.7	42.6	-4.1	-9%	Non-Pilot
Harbin	34.3	31.3	-3.0	-9%	Non-Pilot
Pingdingshan	33.2	30.6	-2.7	-8%	Non-Pilot
Zigong	42.2	38.9	-3.4	-8%	Non-Pilot
Daqing	32.2	29.7	-2.4	-8%	Non-Pilot
Dalian	36.7	34.1	-2.6	-7%	Pilot
Mianyang	46.4	44.4	-2.0	-4%	Non-Pilot
Luoyang	33.5	32.4	-1.1	-3%	Non-Pilot
Shenyang	32.9	31.8	-1.1	-3%	Pilot
Jingdezhen	42.4	41.0	-1.3	-3%	Pilot
Shaoxing	41.6	40.3	-1.3	-3%	Non-Pilot
Wuwei	42.0	41.4	-0.6	-1%	Non-Pilot
Liuzhou	37.9	37.5	-0.4	-1%	Non-Pilot
Nanyang	40.1	39.8	-0.4	-1%	Non-Pilot
Xuzhou	39.6	39.3	-0.3	-1%	Non-Pilot
Yan'an	41.0	40.7	-0.3	-1%	Pilot
Jincheng	29.7	29.6	-0.2	-1%	Pilot
Yingkou	31.7	31.6	-0.1	-0.4%	Pilot
Neijiang	43.4	43.4	-0.1	-0.1%	Non-Pilot

Figure 37 – Comparing the Group Makeup of Top 20 Cities by Score Change (2010 - 2015), against sample population and overall index Top 20

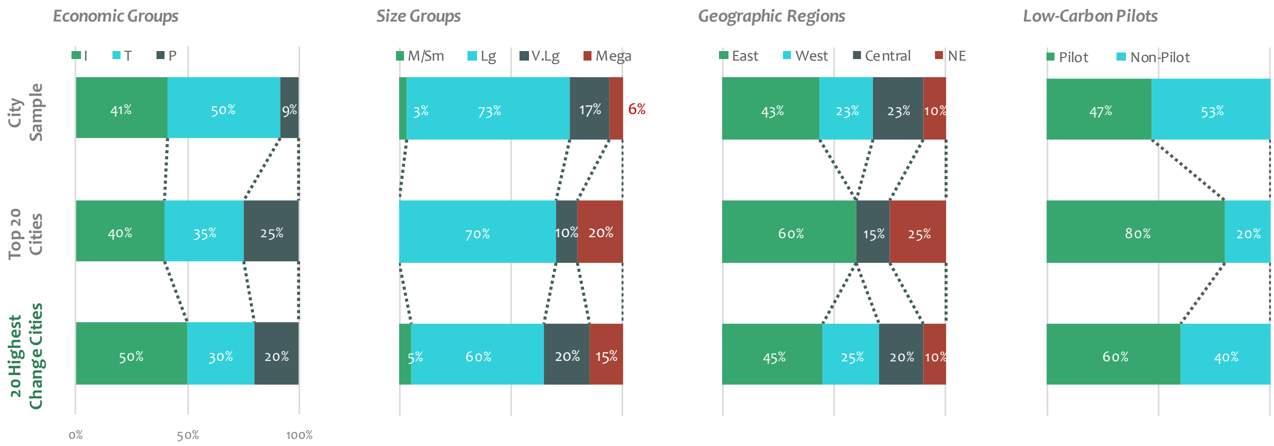
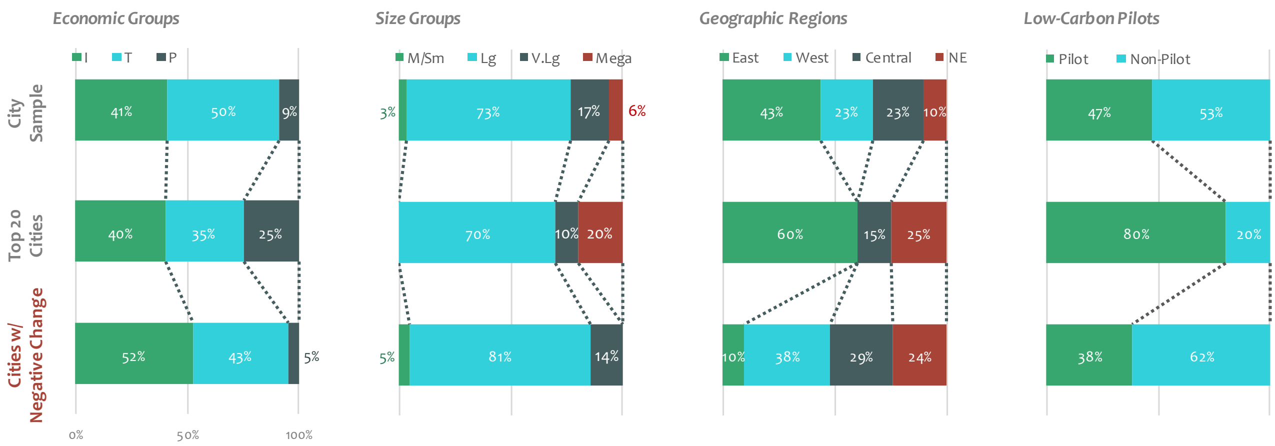


Figure 38 – Comparing the Group Makeup of the 21 Cities with Negative Score Change (2010 - 2015), against sample population and overall index Top 20



Category and Indicator Changes for Cities with the Biggest Overall Score Changes

This section looks further at the category and indicator level score changes for the three sub-sets of cities in the previous section: all-city average, Top 20 cities with highest positive change, and 21 cities with negative score change from 2010 to 2015.

Figure 39 (Center Panel) shows the average **category** score changes for the full sample population (between 2010 and 2015). As noted earlier, only the Environment & Land Use category saw a decline in scores (a drop of -0.4 points). The Left Panel shows a similar chart for the Top 20 positive-change cities -- where category scores for the Environment & Land Use category declined by less than in the overall population; and all other categories had larger average score increases (with the exception of the Transportation category, whose average score increase was considerably less). And the Right Panel of Figure 39 shows the corresponding chart for those cities with an overall drop in score over the five-year period. Here, both the Energy & Power and the Environment & Land Use categories saw significant decreases in their average scores (-1.1 points and -1.4 points, respectively). All other categories still saw some growth but significantly less in the other two sub-sets of cities in the figure.

Figure 40 shows similar score-change charts for the index **indicators**, and for the same three city sub-sets of cities as above. As noted before, in the overall population, twelve index indicators saw their average scores increase; and seven indicators saw their average scores decrease – mostly in the Environment & Land Use and Energy categories. The Top 20 positive-change cities sub-set (left panel) had four indicators with drops in scores; and interestingly, three of these indicators had score declines larger than in the overall population (CO_2 per capita, Environmental Budget Ratio, and Bus Trips). All of the other indicators had score increases, that more than made up for the few indicator losses. Finally, for the sub-set of cities with overall index score decline from 2010-2015 (right panel), there were ten indicators whose scores dropped over the five-year period; and as would be expected, all indicator score changes were considerably worse than in the other two sub-sets.

Figure 39 - Comparing Index Category Score Changes: (Top) All Cities, (Middle) Top 20 Cities, and (Bottom) Cities w/ Overall Index Score Drop 2010-2015

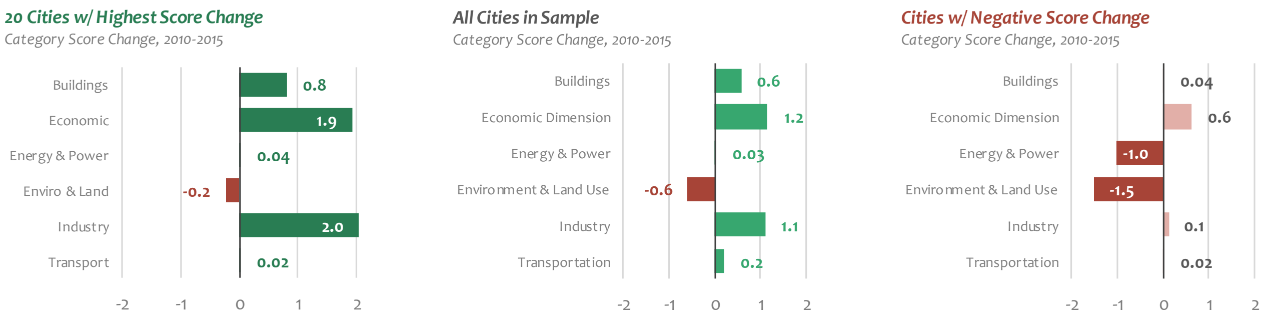
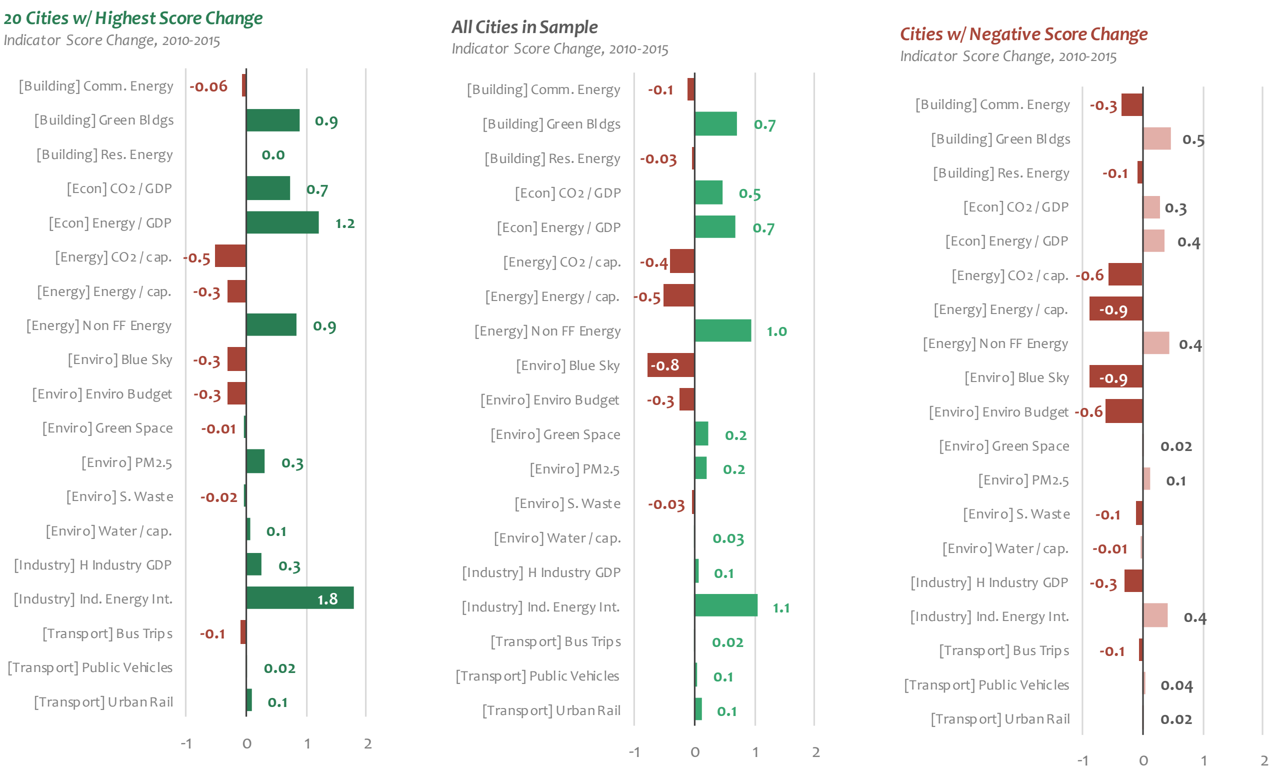


Figure 40 - Comparing Index Score Changes, by Indicator: (Left) All Cities, (Center) Top 20 Cities, and (Right) Cities w/ Overall Index Score Drop 2010-2015



Economic Growth and LOGIC Score Change: 2010 – 2015

More than 90 out of 115 cities in the sample saw both GDP growth and LOGIC score growth over the 2010-2015 time-period.

The majority of cities in the study saw both economic growth and LOGIC score growth over the period 2010 to 2015. During this time, no city had a decline in GDP (all cities had five-year GDP growth in the range of 40% to 100%); and 94 out of 115 cities had their overall LOGIC scores increase between 1% and 30%.

The relationship between recent economic growth and changes in LOGIC scores is highly relevant. China has set admirable goals to develop into a prosperous economy by 2050, while protecting local environments and citizen health, and also rapidly reducing carbon emissions. LOGIC is intended to be a measure of China's green and low-carbon economic growth transition, and is designed to explore questions such as: Are economic and low-carbon goals compatible? And, have Chinese cities' growth over the past five years come in tandem with, or at the expense of green and low-carbon status?

Figure 41 shows a scatter plot of all cities in the sample, plotting total, five-year GDP change (percentage from 2010 to 2015) along the x-axis, and total five-year percent change in LOGIC overall scores along the y-axis (excluding the Policy & Outreach category, as noted earlier). In this plot, three sub-sets of cities stand out. First, the 21 cities that had an overall drop in their LOGIC scores from 2010-2015; these are indicated in red, and were discussed in the section above. What is notable here, is that these 21 negative-change cities occur over a wide range of different GDP growth values. This indicates that high (or low) GDP growth does not necessarily lead to high or low LOGIC scores. There are other factors.

Then, there are two unique clusters of high-performing cities (see Figure 41) One cluster showed the highest total GDP growth (in the 90th percentile), and also had LOGIC score growth between 5-15% over the five years. Another cluster showed the highest LOGIC score growth (top 90th percentile), and also had GDP growth that was well above the national average. Cities in both of these clusters demonstrate that green and low-carbon goals do not need to come at the expense of economic performance. To further explore patterns among these high performing cities, and what they are doing well, Figure 42 and Figure 43 on the next page show a listing of cities from these two clusters, with their GDP and index score growth values, along with charts showing the city Groupings composition of these clusters (similar to charts shown in previous sections of this report).

The cities in the Highest-GDP—High Index Growth cluster (Figure 42) have a high proportion of large, economically 'transitioning' cities from Western China. And while more than half of the cities in this high-performing, high GDP cluster are Low Carbon Pilots, many are not low carbon pilots. Meanwhile the cities in the other cluster, the Highest Index Growth – High-GDP (Figure 43), are made up of higher proportions of Industrial or Post-Industrial cities, Large or Mega cities, and dominated by Eastern and Pilot cities. This again shows that many of the cities with the highest Index Score growth are those advanced economy, large, and eastern cities; but that these cities do not necessarily achieve greener performance at the expense of economic growth.

Finally, the scatter plots in Figure 44 show how the City Groups performed (on average) in terms of GDP Change vs. LOGIC Score Change, from 2010-2015. Notably, no groups, in aggregate, saw a drop in their average index scores over the time period. And the positive index score changes all fell within a relatively narrow band. Average GDP growth for all groups was also positive.

Figure 41 - City Relationships Between Economic Growth and LOGIC Change, 2010-2015

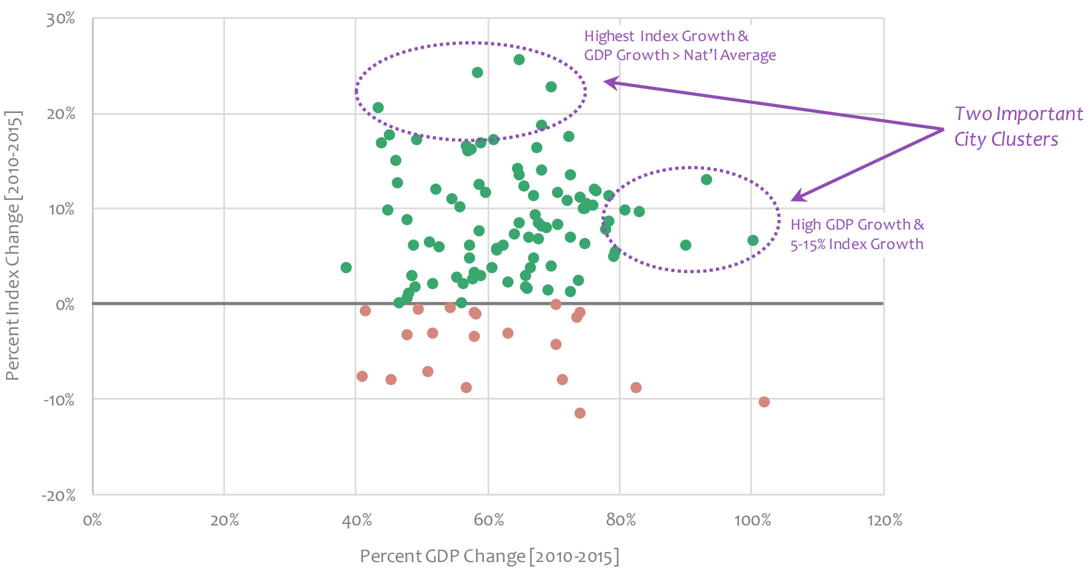


Figure 42 –Listing the Cities with Highest GDP Growth (top 90th percentile), and Significant Index Score Change (+5 to 15 %); 10 cities; and their groups

City Name	2010 Score	2015 Score	% Score Change	% GDP Change	Pilot Status
Urumuqi	25.4	28.7	13%	93%	Pilot
Lanzhou	29.6	32.9	11%	78%	Non-Pilot
Wuhu	36.0	39.5	10%	81%	Non-Pilot
Chongqing	42.0	46.1	10%	83%	Pilot
Xianyang	35.8	38.9	9%	78%	Pilot
Hefei	41.5	44.8	8%	78%	Non-Pilot
Zunyi	41.9	44.7	7%	100%	Pilot
Xi'ning	28.9	30.7	6%	90%	Non-Pilot
Tianjin	35.4	37.3	5%	79%	Pilot
Kunming	47.1	49.5	5%	79%	Pilot

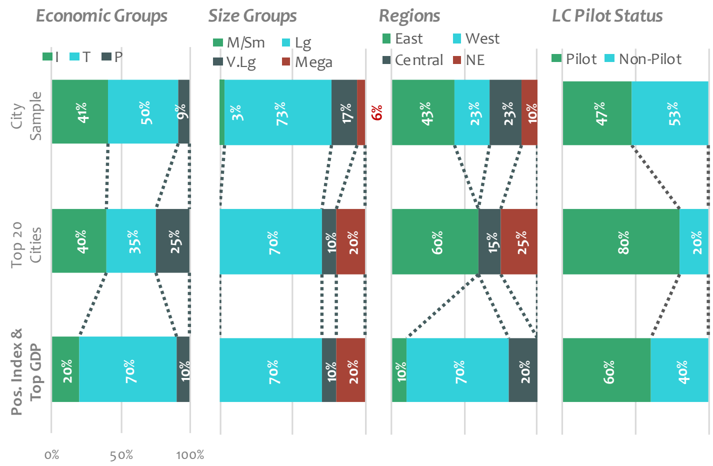


Figure 43 – Listing the Cities with Highest Index Score Change (top 90th percentile), and GDP Growth Change Above National Average; 11 cities, and their groups

City Name	2010 Score	2015 Score	% Score Change	% GDP Change	Pilot Status
Shenzhen	50.0	62.2	24%	58%	Pilot
Changde	45.6	56.0	23%	70%	Non-Pilot
Haikou	46.8	52.7	12%	59%	Pilot
Xia'men	54.3	61.0	12%	65%	Pilot
Shantou	49.1	54.9	12%	60%	Pilot
Jieyang	49.2	54.2	10%	75%	Pilot
Guilin	47.2	51.3	9%	65%	Pilot
Zhanjiang	47.4	50.8	7%	66%	Pilot
Ganzhou	49.2	52.5	7%	68%	Pilot
Guangzhou	47.4	50.0	6%	61%	Pilot
Nanning	49.8	50.7	2%	66%	Non-Pilot

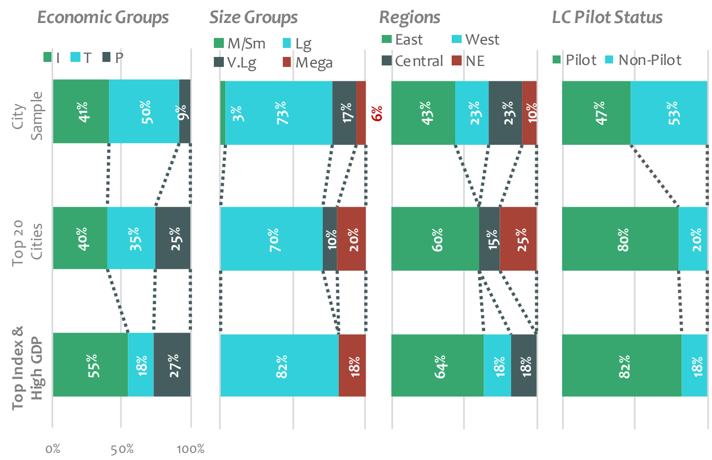
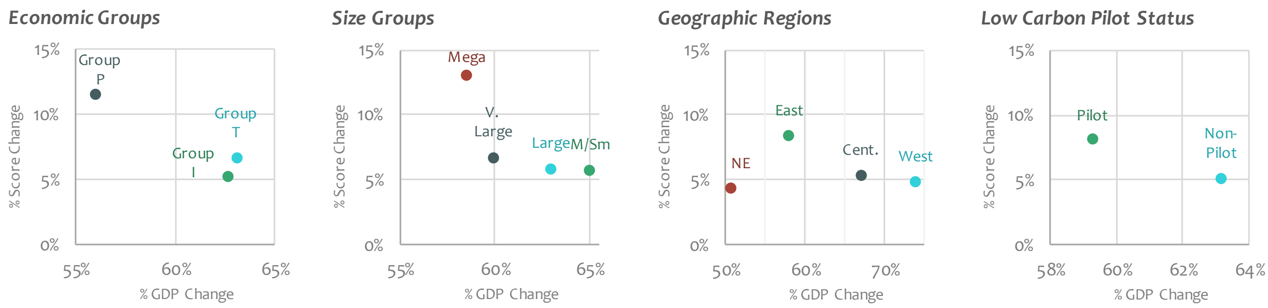


Figure 44 - City Groups Relationships Between Economic Growth and LOGIC Change, 2010-2015



Chapter 5. Exploring Detailed Index Categories & Indicators

LOGIC allows deep and detailed exploration of city performance: to identify promising opportunities, and to understand challenge areas.

This exploration looks at the categories and specific green and low carbon indicators that make up LOGIC. For each of the index categories/sub-categories (see Chapter 2 above), this includes: the overall distribution of scores within the category, an analysis of which indicators have most influence on the category, where gaps and opportunities lie for city policies in each category, how the city groups perform for each category, and how the categories and indicators changed from 2010 to 2015.

A brief summary of the key findings for each category are listed below; and further details on each category are in the pages that follow.

Economic Dimension Category

This category had the lowest performance of all categories in 2015, achieving only 25% of its benchmark value. The economic dimension indicators also had poor performance, reaching 20-30% of their benchmarks. However, the Economic Dimension did show positive improvement from 2010-2015, indicating the importance of further improving energy productivity and de-carbonization of the economy in Chinese cities.

Energy & Power -Sub-Category (Energy & Carbon Category)

This category also showed the most variation in scores among all of the index categories, but cities with higher Energy & Power scores tended to have higher overall index scores. However, Energy & Power was a weakness for post-industrial cities (Group P) and Mega cities. The three sub-category indicators had middle-range performance in 2015, with mixed change from 2010 scores. Chinese cities still have room to improve, underlining the importance of energy in green & low carbon development.

Industry Sub-Category (Energy & Carbon Category)

This category had relatively weak performance in the 2015 analysis – with composite sub-category scores, as well as indicator scores, being below the benchmark values for the majority of cities in the sample. This result reflects Chinese cities' reliance on heavy polluting industry in their economies. However, the Industry sub-category did see the second highest score growth from 2010 to 2015, and this recent momentum should be further promoted through key policies in industry and industrial energy use.

Buildings Sub-Category (Energy & Carbon Category)
This category showed mixed performance, with the majority of cities in the sample scoring just above the category benchmark value, and indicator scores varying widely. And, higher income, larger, and more developed cities dominated the 2015 performance in the Buildings sub-category.

Transport Sub-Category (Energy & Carbon Category)
Performance in the Transportation sub-category was widely variable, but on average quite low – Transport had the second lowest category score relative to its benchmark (after Economic Dimension). Some cities are doing well in providing bus services and urban rail services to citizens, but performance for the majority of cities is near or below 50% of the benchmark value. Urban rail is expensive, and not widely applied across the cities in the sample.

Environment & Land Use Category
This category had the highest average score of any in the index. However, E&LU was the only category to see a decline in average scores over the 2010-2015 period – largely driven by decreases in air quality indicators – an urgent health issue, closely linked to the combustion of coal and oil in China's industry, power generation, and the growing transport sector. Interestingly, there was no strong correlation between performance in the E&LU category and overall index scores. This suggests that cities at any level of economic development or urbanization can take actions to improve local environmental quality. Pollution abatement has been a priority in China's cities long before low-carbon development and is rising on the policy agenda. However, a large gap remains to meet the ever-evolving needs from the public to have a good environment. Government has responded to this end by tightening the air quality standard and adding PM2.5 into AQI system, and this caused the decline of average score. Cities also saw a decline in the environmental protection budget and solid waste indicators, which need to be improved.

Policy & Outreach Category
The Policy & Outreach category includes four indicators that represent the efforts that city leaders have taken in pursuing green and low carbon development in their cities. These are the only four qualitative indicators in the LOGIC model. The 2015 LOGIC results show that cities have taken positive steps issuing a number of policies, but that more work still needs to be done.

Economic Dimension Category

The Economic Dimension category is among the most important categories in LOGIC (weighted 20% in the framework). This category showed positive improvement from 2010-2015, but nonetheless had the lowest performance of all categories in 2015. The average score for all cities reached only 24% of the category benchmark; and consequently, the Economic Dimension dragged down the overall index scores for most cities. Energy productivity and de-carbonization of the economy need to further improve in order for Chinese cities to compare to low-carbon cities and countries globally.

- Figure 46 shows the distribution of city scores in the Economic category. The distributions are shifted to the lower end of the category range. The average category score is 4.8 points (only 24% of the weighted benchmark of 20 points). The middle half of cities (i.e. the 25th to 75th percentile) fall within a score range of 3.2 points (16% of benchmark) to 6.5 points (33%). The maximum score obtained by any city (Shenzhen) was a considerable outlier, at 14.6 points (73% of max). Only four cities had Economic Dimension scores above 50% of the benchmark. This is the poorest performing category of any in the 2015 index.

- However, Figure 47 shows a relatively close fitting linear relationship (R^2=0.67) between Economic category scores and overall index scores for all cities. This indicates that even though the economic category scores were low; cities which tended to do well in this category, were also likelier to have higher overall scores.

- The two indicators that make up the Economic Dimension also showed low performance. Figure 49 shows that in 2015, the indicators only reached 20-30% of their max values. 'Per Capita CO_2' emissions was the poorest performing indicator in the whole study (avg. score of 2.0 out of 10 points, or 20% of benchmark). The distributions in Figure 50 show that, consistent with the category level, both Economic indicators have narrow, roughly bell-shaped profiles centered in the lower half of the indicator range. 'CO_2 per GDP' has no cities with indicator scores above 50% of the benchmark. 'Energy Use per GDP' is slightly better: 10 cities had scores falling in a thin upper tail above 50% of the benchmark; and one city did reach the benchmark.

- The energy and carbon productivity of the Chinese cities' economies in 2015 were quite low, dragging the overall LOGIC scores significantly downwards. There is considerable room for improvement in this area.

Figure 45 - Box Plot Distribution: Category Score
[all cities, 2015 data]

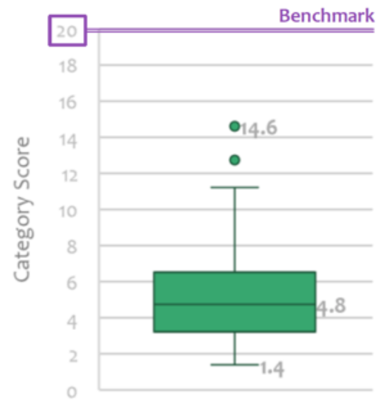


Figure 47 – Category Scores Histogram
[all cities, 2015 data]

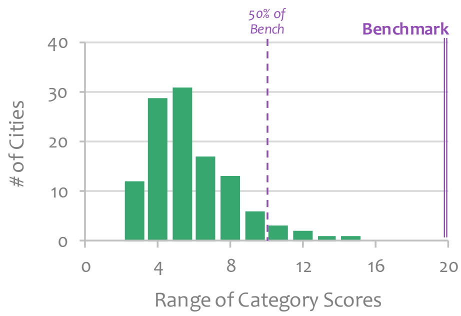


Figure 48 –Category Scores vs Overall Scores
[all cities, 2015 data]

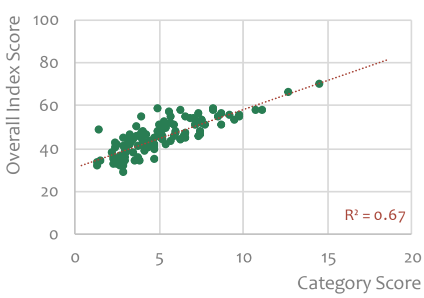


Table 9 - List of Indicators, Economic Dimension Category

Indicator Name	Benchmark		Max Score	Reference	Type
Energy Consumption / GDP	0.23	tce / 10,000 RMB	10	Japan, 2012	International
CO_2 Emissions / GDP	0.32	tCO_2 / 10,000 RMB	10	EU, 2013	International

Note: see full details of benchmarks in Chapter 2, above

Figure 49 - Economic Indicator Average Scores, and Gap from Max (2015)

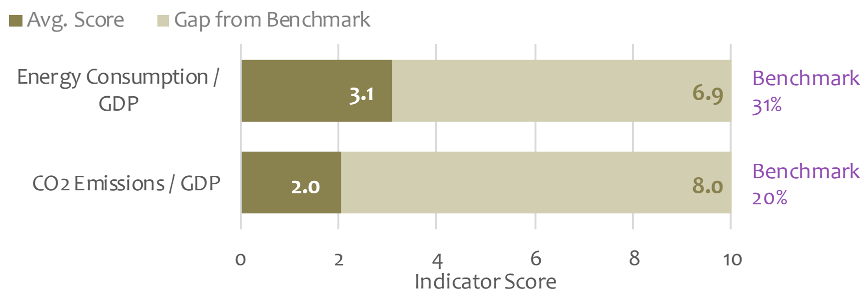
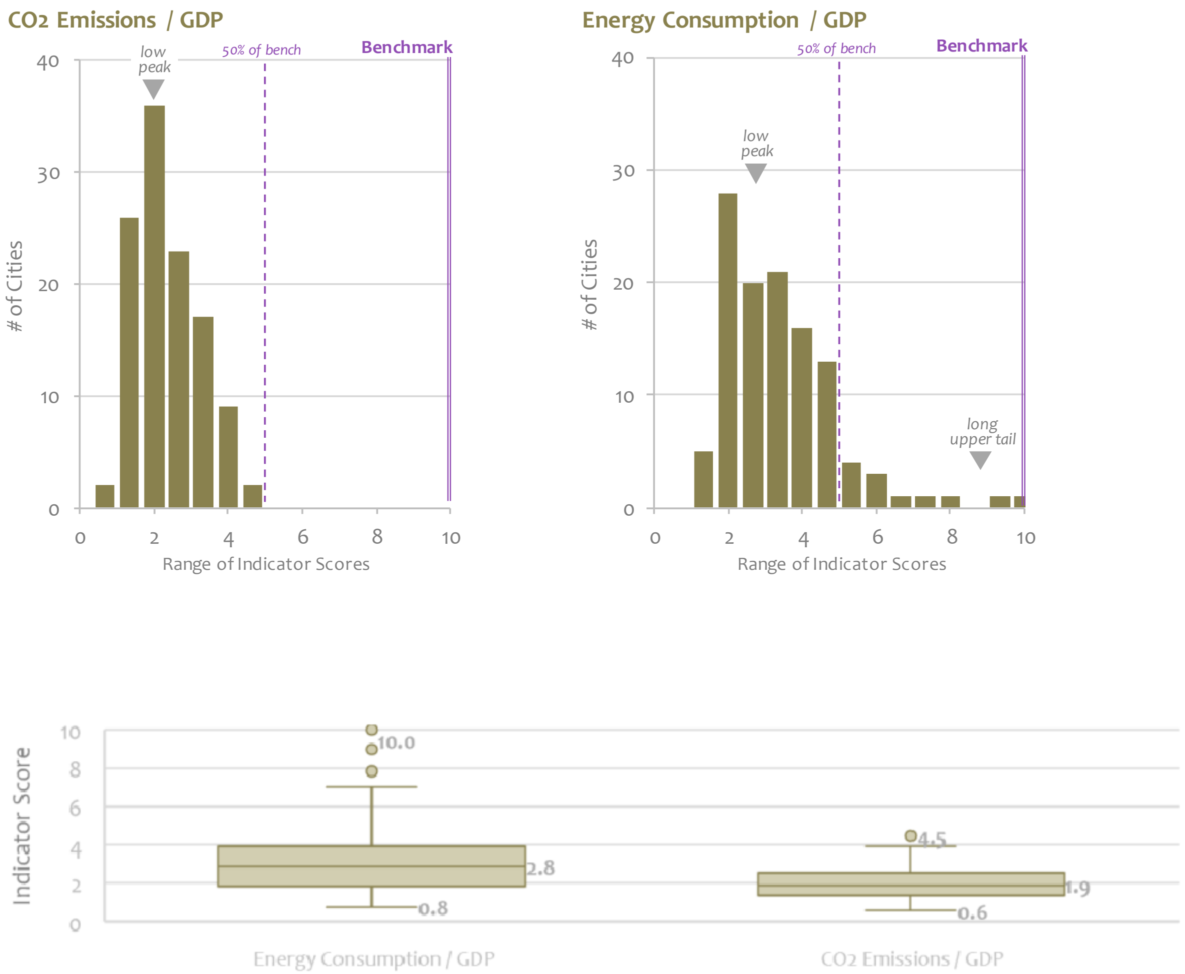


Figure 50 - Distributions of Economic Indicator Scores, 2015: (Top Row) indicator score histograms; (Bottom Row) indicator score box plots.



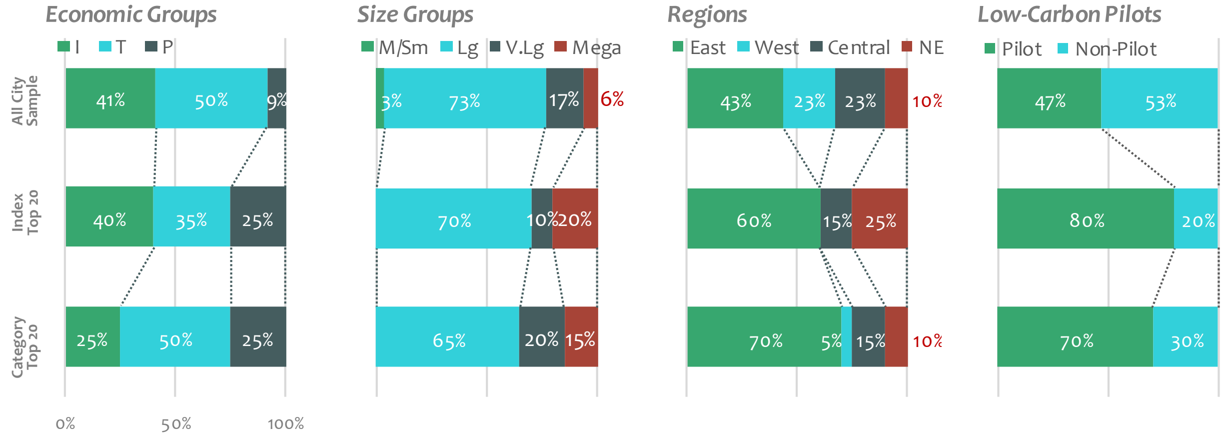
Economic Dimension Category

Table 10 - Top 20 Cities, Ranked by Economic Category Score

City Name	Econ Group	Size Group	LC Pilot Status	Overall Rank	Category Rank	Category Score	Category % of Bench	Rank of Each Indicator* CO2 /GDP	Energy /GDP
Shenzhen	P	Mega	Pilot	1	1	14.6	73%	1	1
Xia'men	P	Large	Pilot	2	2	12.7	64%	5	2
Ganzhou	I	Large	Pilot	6	3	11.2	56%	10	3
Guangzhou	P	Mega	Pilot	7	4	10.8	54%	2	5
Hangzhou	P	V.Large	Pilot	13	5	9.8	49%	24	4
Nanchang	T	Large	Pilot	14	6	9.8	49%	4	6
Taizhou (Zhejiang)	T	Large	Non-Pilot	22	7	9.5	48%	3	7
Beijing	P	Mega	Pilot	12	8	9.3	46%	7	8
Zhanjiang	I	Large	Pilot	11	9	8.8	44%	8	11
Jinzhou	I	Large	Pilot	30	10	8.7	44%	9	10
Wenzhou	T	V.Large	Pilot	15	11	8.6	43%	13	9
Shantou	T	Large	Pilot	8	12	8.3	42%	11	12
Changde	I	Large	Non-Pilot	3	13	8.3	41%	6	14
Zhenjiang	T	Large	Pilot	31	14	7.8	39%	12	15
Fuzhou	T	V.Large	Non-Pilot	21	15	7.6	38%	16	13
Changchun	T	Large	Non-Pilot	26	16	7.6	38%	14	16
Wuxi	T	Large	Non-Pilot	47	17	7.5	38%	15	21
Dongguan	T	V.Large	Pilot	40	18	7.5	37%	19	18
Guilin	I	Large	Pilot	10	19	7.4	37%	22	19
Nantong	T	Large	Non-Pilot	50	20	7.4	37%	17	23

* Note: CO_2/GDP = CO_2 Emissions / GDP ; Energy/GDP = Energy Consumption / GDP

Figure 51 - Comparing Mix of City Groups, 2015 Data: (Top Row) Sample Population, (Middle Row) Top 20 Overall Index Score, (Bottom Row) Economic Category Score



Compared to the Top 20 Overall Index cities, and the sample population, the Top 20 Economic Dimension cities had:

- *More Group P cities*
- *Fewer Group I cities*
- *Group P same % for category & Overall Index*

- *Similar make-up as for Overall Index*
- *... but w/ more V. Large*
- *... and fewer Mega and Large cities*

- *Dominance of East cities*
- *No West cities in Top Overall Index*
- *... but 5% in Econ Dimension*

- *Dominance by Pilot cities*
- *... but less than for Overall Index*

Which Cities Perform the Best in the Economic Dimension?

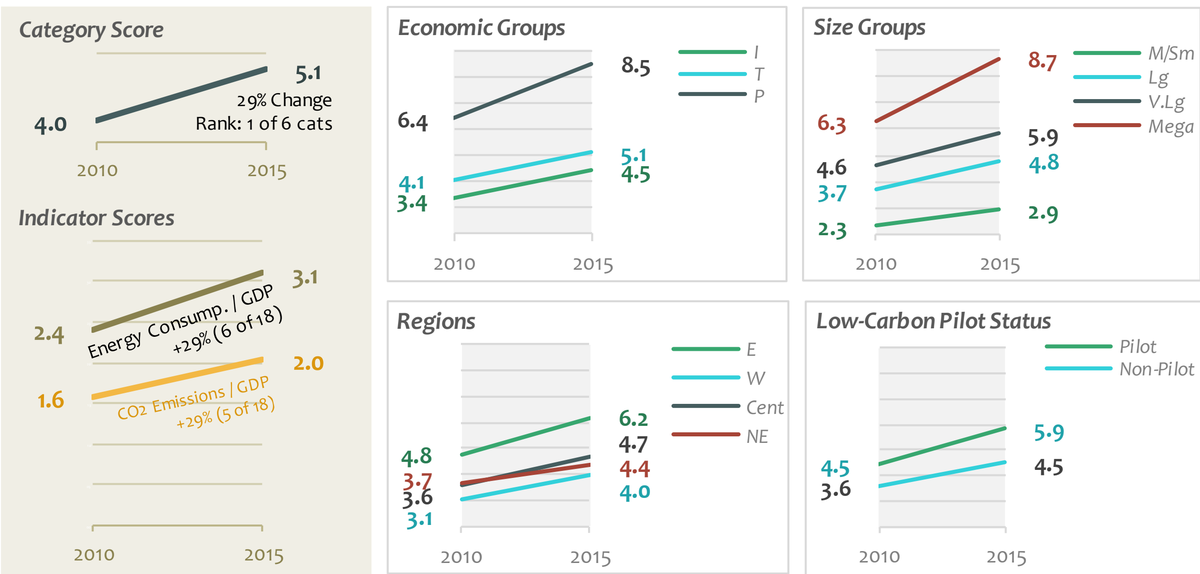
- Table 10 shows the Top 20 cities ranked by score in the Economic Dimension category. Only three of these top 20 were also ranked in the Top 5 overall scores (Shenzhen, Xia'men, and Changde). This is relatively low compared to other index categories. The remainder had high-medium overall rankings (scores from the 10's to 50's).
- For the most part, the top-ranking Economic Dimension cities are also top ranking for each indicator.
- Which city Groups perform the best? Figure 51 compares the Group make-up for three lists of cities: Top 20 Cities by Economic Dimension Score, Top 20 Cities by Overall Index Score, and Number of Cities in Sample Population. Specific notes are at the bottom of the graphic. Highlights include:
  - All city sub-groups were represented in the list of Top 20. Not all categories share this fact.
  - Group P, and Mega cities performed better than the other groups. Eastern cities performed substantially better than the other regions. And, Low Carbon Pilots dominated non-pilot cities, though not as much as for the Overall Index Score.

Changes from 2010 to 2015: Economic Dimension

Although the Economic Dimension was the weakest category in the 2015 index, it also showed the most improvement from 2010. Nearly all cities improved their CO_2 and Energy productivity. And as was mentioned earlier in the report, most cities also saw strong GDP growth over this period. This reaffirms that economic development can be green and low-carbon. This steady growth in economic indicators is positive and important, and needs to continue. Some higlights from the data include:

- The average Category score rose 29% over the five-year period (raising from 4.0 to 5.1 points). Both economic dimension indicators rose at a similar rate (and were the 5th and 6th most-improved indicators in the study). Figure 52 shows slope-graphs of the category and indicator trends.
- Figure 52 also shows slope-graphs for the city Groupings and sub-groups of the change in average Economic Dimension category score. From these slope-graphs:
  - Most of the city sub-groups had more or less even growth among their Groupings.
  - Group I, Mega cities, and Pilot cities grew slightly faster than their counterpart sub-groups (steeper slope)
- Northeast cities lagged slightly behind their counterparts in the Economic Dimension.

Figure 52 - Category Changes, 2010-2015: (Left) Overall Category and Indicators; (Right) Category by City Grouping



Energy & Power Sub-Category (Energy & Carbon Category)

- The Energy & Power sub-category is also one of the most important categories in LOGIC (weighted 18% in the framework). However, Energy & Power was a weakness for post-industrial cities (Group P) and Mega cities. This category also showed the most variation in scores among all of the index categories, but cities with higher Energy & Power scores tended to have higher overall index scores. The three sub-category indicators ranged from 35 to 70% of their benchmark values, with mixed changes from 2010-2015; indicating that cities still have room for improvement, and underlining the importance of energy in urban green & low carbon development.

- Figure 53 shows distributions of scores for all cities in the Energy & Power sub-category. The distributions are fairly wide -- ranging from 99% of the benchmark value (17.9 points, out of 18) down to 13% (2.4 points). The middle half of cities (i.e. the 25th to 75th percentile) also has a fairly wide range (from 34% of the benchmark, to 68%).

- The Energy & Power sub-category showed the most variation in scores among all of the index categories. The histogram in Figure 54, bottom shows an uneven profile, with multiple peaks or clusters of cities.

- 58 Cities had Energy & Power scores higher than 50% of the category benchmark. This is better than for other categories in the index.

- The scatter plot in Figure 55 shows a fairly tight correlation between city scores in the Energy & Power sub-category, and their overall index scores (R^2=0.54). This doubtless is influenced by E&P's high weight in the index framework; however, given the high level of variability for this category, it is clear that cities' attention to E&P factors do correlate to higher overall LOGIC performance.

- In 2015, the three indicators that make up the Energy & Power category all perform in the middle-range, with considerable variation among individual cities in 2015. Figure 56 shows the average indicator scores, and their gaps from indicator max values; and Figure 57 shows the indicators' histogram and box plot distributions.
  - 'CO_2 per capita' was the weakest indicator: on average reaching only 30% of its benchmark; and with the majority of cities falling below 50% of max score. A number of cities do form an upper tail in the distribution, with several cities reaching the benchmark maximum. This is similar to the findings for the Economic Dimension category.
  - The 'Energy consumption per capita' indicator (w/ avg. of 66% of benchmark) has a low, flat profile, with a sharp spike at the benchmark value. The 'Non-Fossil Fuel Energy' indicator (avg. of 50% of benchmark) has a wide, bell-shaped profile with a low peak. Both also have a sharp spike at the indicator benchmark value.
  - Across all 23 indicators in the study, the three E&P indicators ranked in the middle range. Although, each indicator had cities that reached its benchmark.
  - All indicators in E&P still have significant room for improvement, underlining the importance of energy in urban green and low carbon development.

Figure 53 - Box Plot Distribution: Category Score
[all cities, 2015 data]

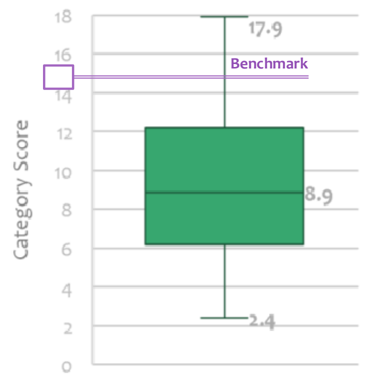


Figure 54 - Category Scores Histogram
[all cities, 2015 data]

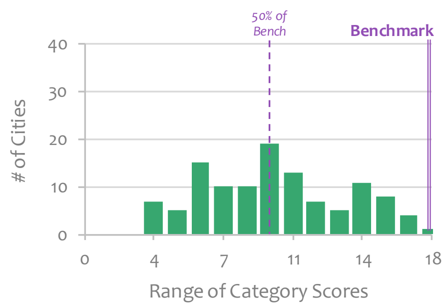


Figure 55 - Category Scores vs Overall Scores
[all cities, 2015 data]

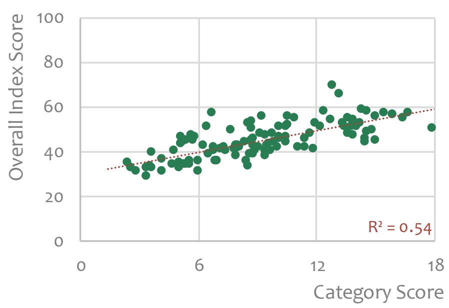


Table 11 - List of Indicators, Energy & Power Sub-Category

Indicator Name	Benchmark		Max Score	Reference	Type
Energy Consumption / capita	2.8	tce/cap / yr	6	Hong Kong	International
Non-Fossil Fuel Energy	20	%	6	National Target	National Target
CO_2 / capita	2.1	t CO_2 /cap /yr	6	Top 10 Avg +20%	Sample Statistics

Note: see full details of benchmarks in Chapter 2, above

Figure 56 – Energy & Power Indicator Average Scores, and Gap from Max (2015)

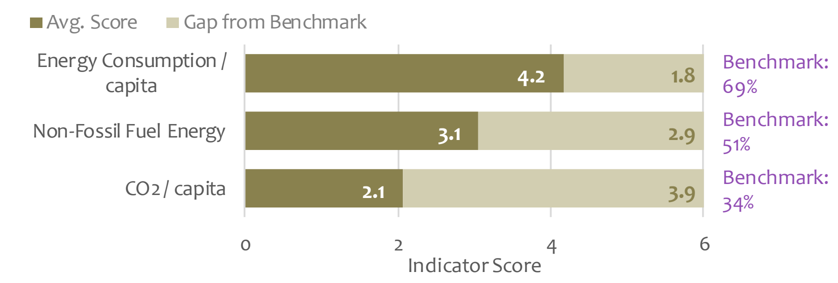
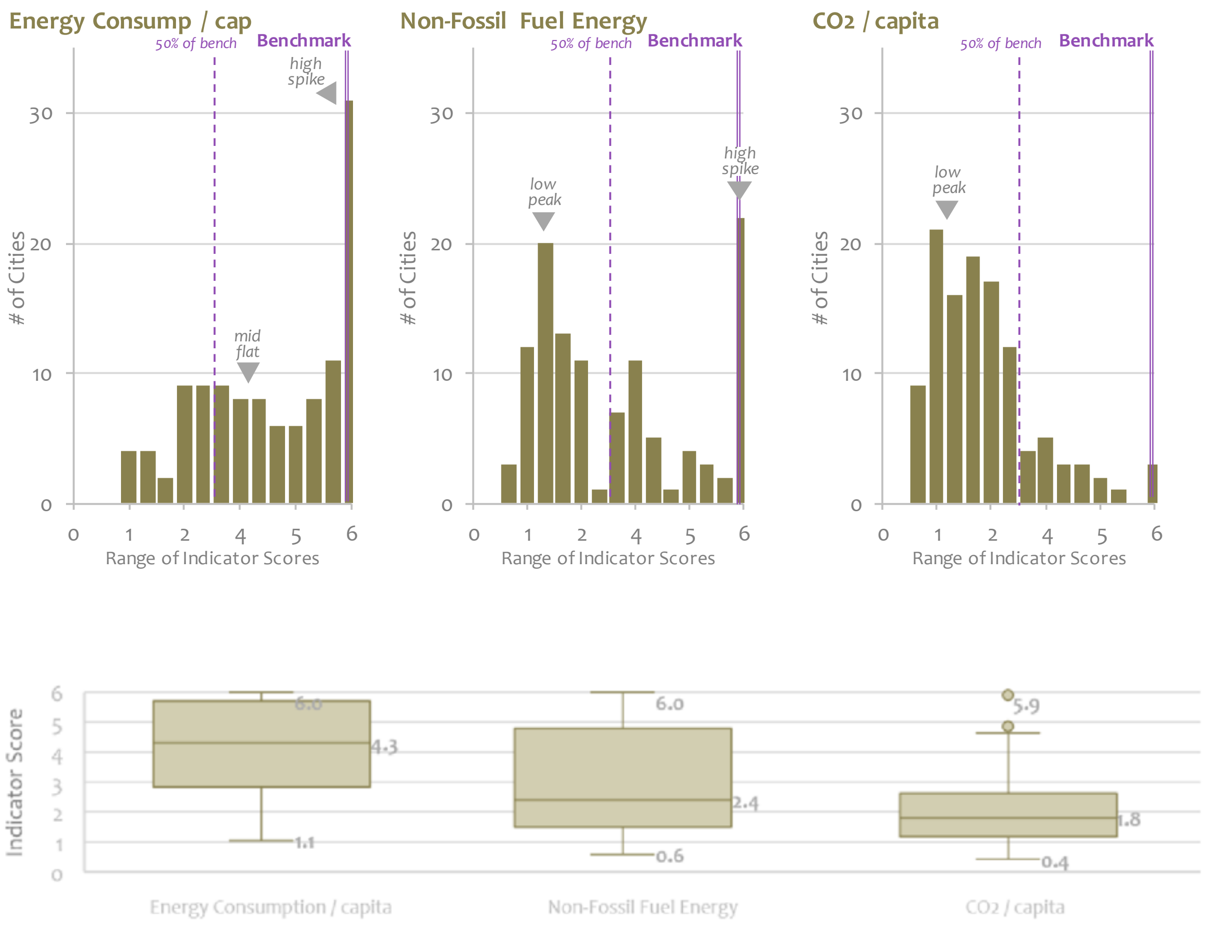


Figure 57 - Distributions of Energy & Power Indicator Scores, 2015: (Top Row) indicator score histograms; (Bottom Row) indicator score box plots.



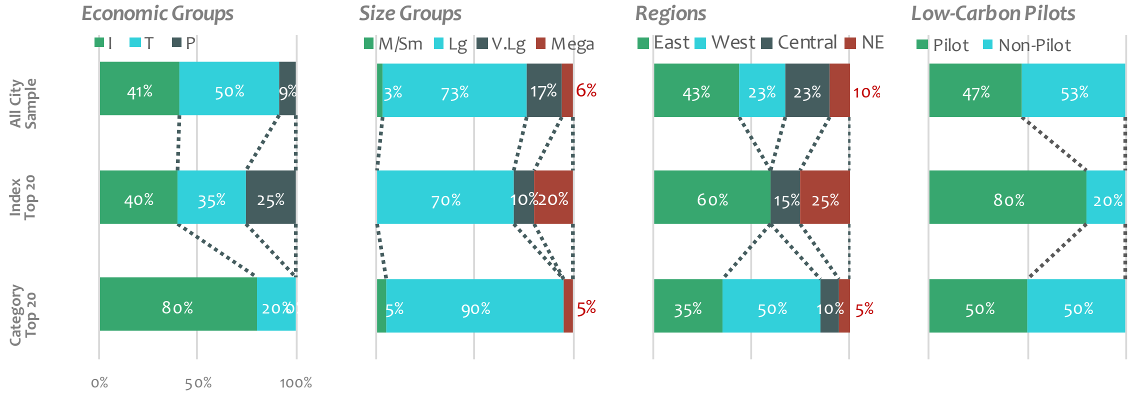
(... continued) Energy & Power Sub-Category

Table 12 - Top 20 Cities, Ranked by Energy & Power Sub-Category Score

City Name	Econ Group	Size Group	LC Pilot Status	Overall Rank	Category Rank	Category Score	Category % of Bench	Rank of Each Indicator* CO2 /cap	Energy /cap	Non-Fossil
Nanchong	I	Large	Non-Pilot	34	1	17.9	99%	3	1	1
Shantou	T	Large	Pilot	8	2	16.6	92%	5	1	1
Guangyuan	I	Large	Pilot	16	3	16.4	91%	6	1	1
Jieyang	I	Large	Pilot	9	4	15.9	88%	10	1	1
Guilin	I	Large	Pilot	10	5	15.9	88%	11	1	1
Ganzhou	I	Large	Pilot	6	6	15.4	86%	1	1	43
Luzhou	I	Large	Non-Pilot	54	7	15.0	83%	18	1	1
Zhanjiang	I	Large	Pilot	11	8	15.0	83%	2	1	51
Zunyi	I	Large	Pilot	35	9	14.8	82%	15	41	1
Nanning	I	Large	Non-Pilot	4	10	14.6	81%	20	28	1
Nanping	I	Large	Pilot	37	11	14.5	81%	21	30	1
Wuwei	I	M/S m	Non-Pilot	61	12	14.5	81%	23	1	22
Neijiang	I	Large	Non-Pilot	49	13	14.4	80%	26	29	1
Changde	I	Large	Non-Pilot	3	14	14.3	79%	4	1	44
Taizhou (Zhejiang)	T	Large	Non-Pilot	22	15	14.2	79%	17	1	28
Jinzhou	I	Large	Pilot	30	16	14.1	78%	9	1	33
Chengdu	T	Mega	Non-Pilot	19	17	13.9	77%	31	37	1
Mianyang	I	Large	Non-Pilot	44	18	13.9	77%	32	38	1
Jiangmen	I	Large	Pilot	17	19	13.8	77%	35	33	1
Yancheng	T	Large	Non-Pilot	27	20	13.8	76%	19	1	27

* Note: CO2/cap = CO2 / capita ; Energy/cap = Energy Consumption / capita ; Non-Fossil = Non-Fossil Fuel Energy

Figure 58 - Comparing Mix of City Groups, 2015 Data: (Top Row) Sample Population, (Middle Row) Top 20 Overall Index Score, (Bottom Row) Energy & Power Sub-Category Score



Compared to the Top 20 Overall Index cities, and the sample population, the Top 20 Energy & Power cities had:

- No Group P cities
- Dominated by Group I
- Fewer Group T cities

- No Very Large cities, and slightly fewer Mega cities
- Dominance by Large cities
- Mega cities did much better in Overall Index

- All regions represented
- Dominance by West cities
- ... while other regions reduced

- Even split 50/50... similar to population
- ... but Pilot cities not as well as in the Overall Index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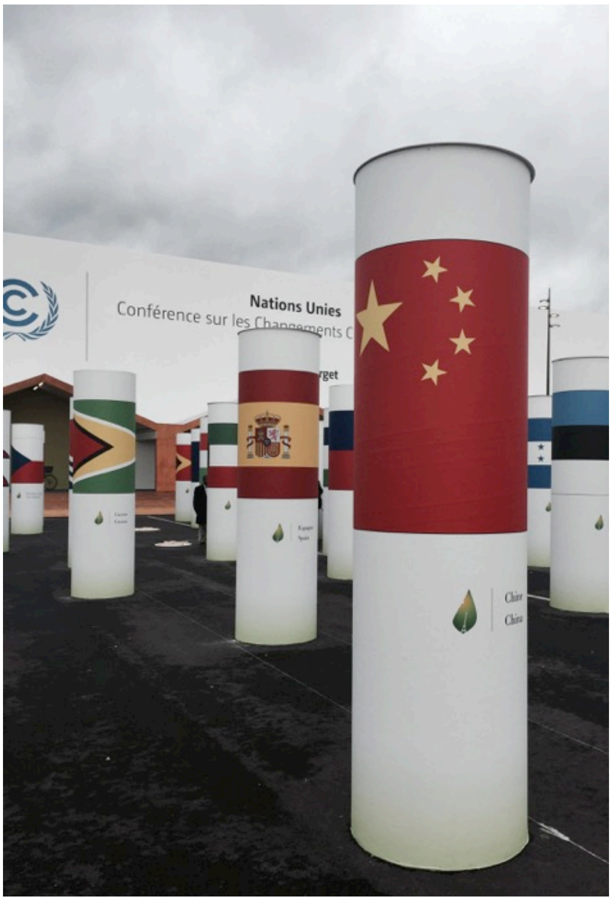
CHINA PAVILION
AT THE UN CLIMATE CHANGE CONFERENCE
联合国气候变化大会“中国角”系列边会
COP
23


China Pavilion


Nations Unies

Which Cities Perform the Best in Energy & Power?

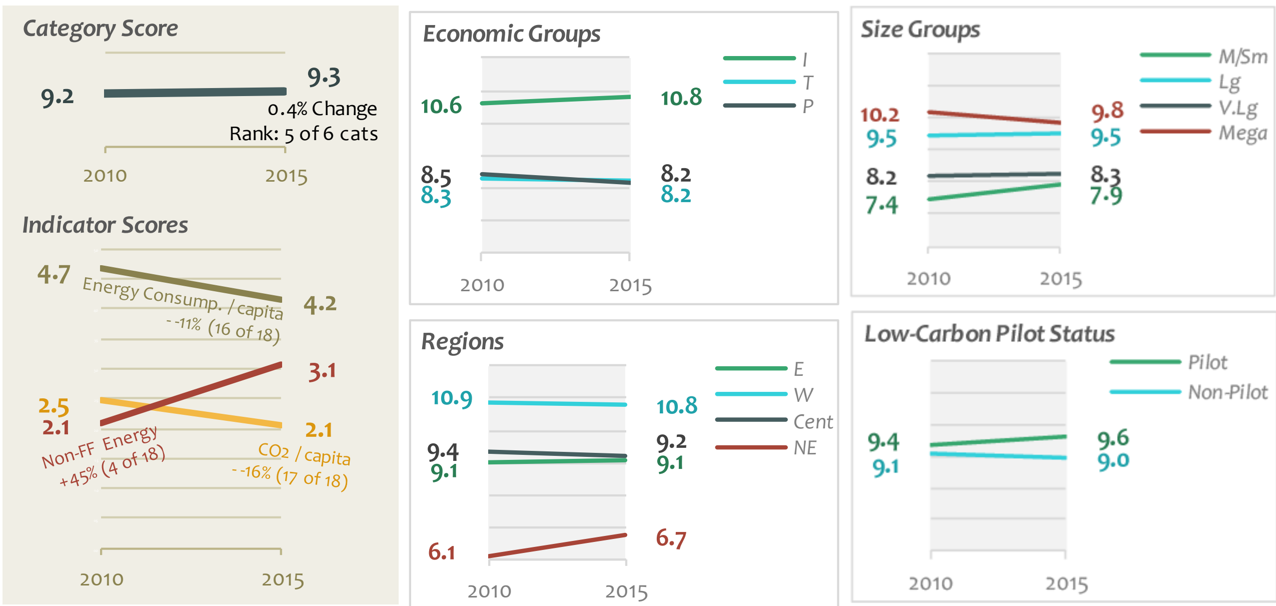
- The Top 20 cities in the Energy & Power category do not necessarily come from the top-ranking cities in the overall index. Table 12 shows only two of E&P's Top 20 cities are also in the Overall Index Top 5. Others on this list in the 20's, 30's, 40's or even 60's in the overall ranking.
- Which city Groups perform the best? Figure 58 compares the Group make-up for three lists of cities: Top 20 Cities by Energy & Power Score, Top 20 Cities by Overall Index Score, and Number of Cities in Sample Population. Specific notes are at the bottom of the graphic. Highlights include:
  - There were no Group P or Very Large cities in the Energy & Power Top 20 -- despite these groups having the best representation in the Overall Index performance. While these groups do well overall, they perform poorer for Energy & Power indicators, likely because of the higher wealth and associated electricity consumption. This will remain a challenge as China's middle class grows.
  - On the other hand, Group I, Large, and Western cities dominated the E&P Top 20 list, well above their representation in the sample population and Overall Index. Pilot and Non-Pilot cities were evenly split.

Changes from 2010 to

Changes in Energy & Power sub-category and indicator scores from 2010 to 2015 showed mixed results. Most Chinese cities are using more energy, and generating more CO_2 (driving these indicators downward). This is a trend that must be reversed in order to achieve low-carbon development. At the same time, cities are also investing more in non-fossil-fuel energy supplies (raising this indicator score). The result is that E&P category scores balance to nearly the same value in 2010 and 2015. Future attention and improvements to Energy & Power factors can significantly help LOGIC scores going forward.

- See Figure 59: The average Category score rose by only 0.4% over five years (this is the 5th largest improvement out of 6 categories). 'Energy Consumption per capita' and 'CO_2 per capita' indicator scores dropped 11% and 16%, respectively (ranked 16th and 17th out of 18 indicators for change/improvement).
- The 'Non-Fossil Fuel Energy' indicator scores rose by 45% (ranked 4th out of 18 indicators).
- Changes in Group performance for the Energy & Power category were notable (Figure 59). Group P, Group T, and Mega cities all had decreasing scores from 2010 to 2015. Group I cities increased. Pilot and Non-Pilot cities diverged, with Pilot cities increasing their scores, and non-pilot cities decreasing.

Figure 59 - Category Changes, 2010-2015: (Left) Overall Category and Indicators; (Right) By City Grouping



Industry Sub-Category (Energy & Carbon Category)

The Industry sub-category is also among the most important categories in LOGIC (weighted 18% in the framework). This category had relatively weak performance in the 2015 analysis – with the majority of cities in the sample having scores below the Industry sub-category benchmark. Both sub-category indicators had simlarly weak performance, reflecting Chinese cities' challenges in energy and carbon intensity more broadly, and are driven by reliance on heavy polluting industry in the economic structure.

- The industry sub-category change from 2010 to 2015 is promising though: Industry saw the second hightest score growth over the five year period, and this recent momentum should be further promoted through key policies in industry structure and industrial energy use.

- Figure 60 shows that the Industry sub-category has a fairly wide distribution of scores, centered at the low end, and with a long, thin upper tail. The average score for all cities was 7.2 points (or 40% of the sub-category benchmark). The middle half of cities (25th to 75th percentile) fall between 8.4 points and 5.3 points (47% to 30% of benchmark). The maximum score reached by any city was 14.7 points (82% of benchmark, by Jieyang); and the minimum score was 3.5 points (19%). No city reached the maximum possible. Out of 115 cities, only 21 had scores above 50% of the benchmark – a relatively low count.

- Figure 62 shows a scatter plot of Industry sub-category scores versus overall index scores for all cities in the sample. There is reasonable correlation between the scores (R^2=0.54); and re-enforcing the relative importance of the Industry sub-category within the index framework (having a weight of 18%).

- The two indicators that make up the Industry sub-category both had relatively weak average performance: 'Heavy Industry Share of GDP', and 'Industrial Energy Intensity' only reached 46% and 34% (respectively) of their benchmark values (Figure 63).

- Performance in these indicators is consistent with Chinese cities' challenges in energy and carbon intensity more broadly, and are driven by reliance on heavy polluting industry in the economic structure.

- The histogram distributions for both indicators are similar (Figure 64, top), showing peaks at the lower end of the scores' range; but also a thin upper tail, and a small number of cities reaching the benchmark value. Interestingly, in the list of top cities in Table 14, the high performing cities for the two indicators are not the same; and in fact, those cities with high scores (near 100% of benchmark value) in one indicator, actually had scores of around 50% in the other indicator.

- For both indicators, the majority of cities had scores below 50% of the benchmark value.

Figure 60 - Box Plot Distribution: Category Score
[all cities, 2015 data]

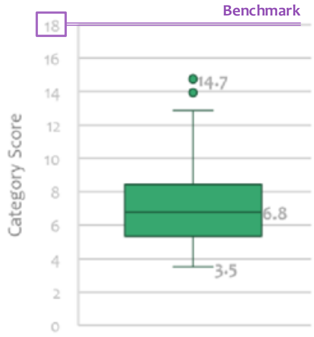


Figure 61 - Category Scores Histogram
[all cities, 2015 data]

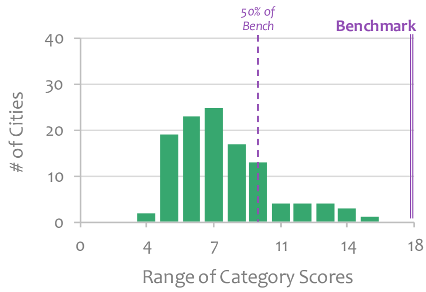


Figure 62 - Category Scores vs Overall Scores
[all cities, 2015 data]

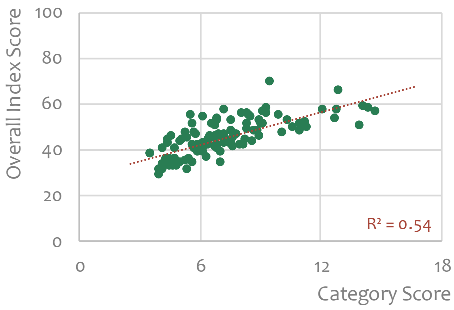


Table 13 - List of Indicators, Industry Sub-Category

Indicator Name	Benchmark		Max Score	Reference	Type
Heavy Industry GDP Share	29	%	9	Guangzhou, +20%	Sample Stats
Industrial Energy Intensity	0.27	tce / 10,000 RMB	9	Guangzhou, +20%	Sample Stats

Note: see full details of benchmarks in Chapter 2, above

Figure 63 - Industry Indicator Average Scores, and Gap from Max (2015)

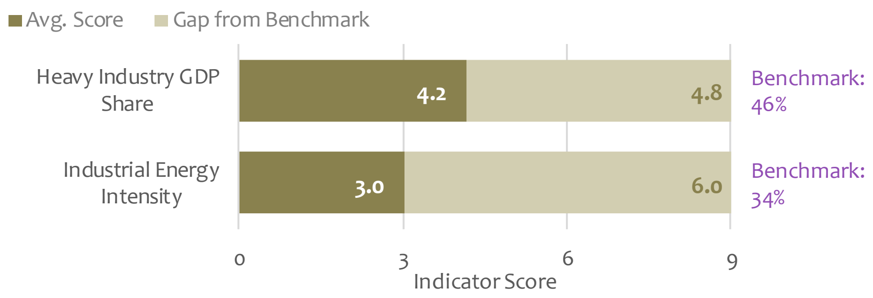
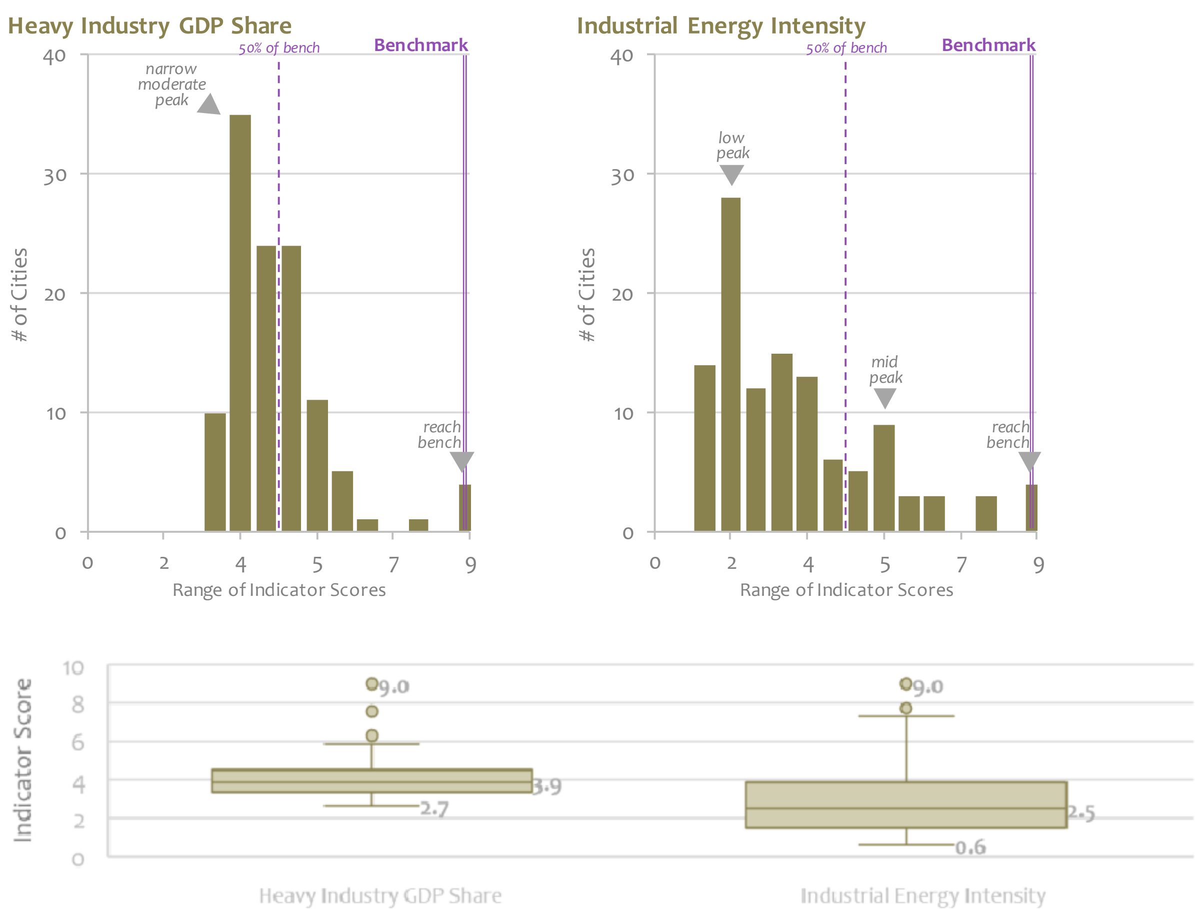


Figure 64 - Distributions of Industry Indicator Scores, 2015: (Top Row) indicator score histograms; (Bottom Row) indicator score box plots



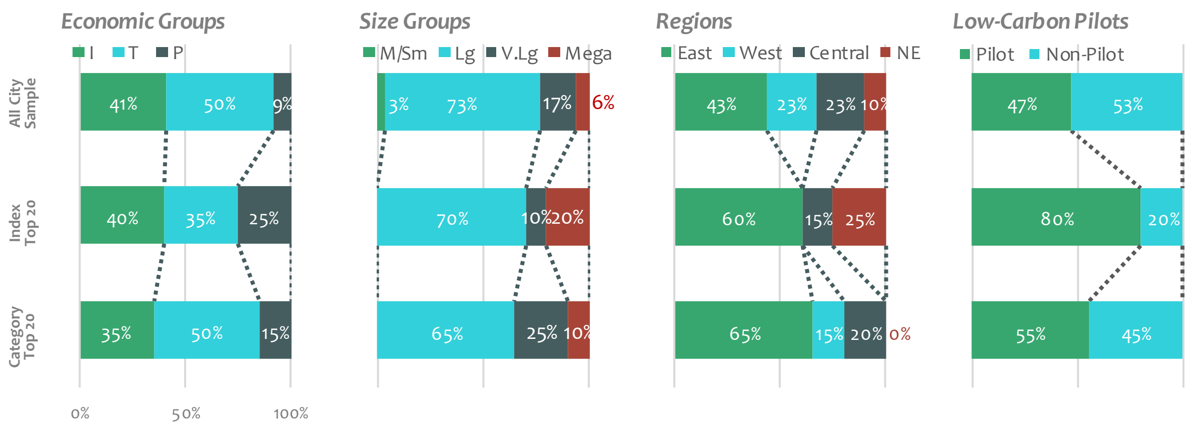
(... continued) Industry Sub-Category

Table 14 - Top 20 Cities, Ranked by Industry Sub-Category Score

City Name	Econ Group	Size Group	LC Pilot Status	Overall Rank	Category Rank	Category Score	Category % of Bench	Rank of Each Indicator * Heavy Ind.	Ind. E Intensity
Jieyang	I	Large	Pilot	9	1	14.7	82%	1	11
Haikou	T	Large	Pilot	5	2	14.3	80%	12	1
Changde	I	Large	Non-Pilot	3	3	14.1	78%	1	18
Changsha	T	V.Large	Non-Pilot	33	4	13.9	77%	20	1
Xia'men	P	Large	Pilot	2	5	12.9	72%	58	1
Shantou	T	Large	Pilot	8	6	12.8	71%	1	29
Yangzhou	T	Large	Non-Pilot	20	7	12.8	71%	64	1
Guangzhou	P	Mega	Pilot	7	8	12.1	67%	21	7
Taizhou (Jiangsu)	T	Large	Non-Pilot	36	9	11.3	63%	72	5
Quanzhou	T	V.Large	Non-Pilot	25	10	11.2	62%	5	33
Foshan	T	V.Large	Pilot	28	11	11.0	61%	30	8
Zhuzhou	T	Large	Non-Pilot	41	12	10.9	61%	70	6
Zunyi	I	Large	Pilot	35	13	10.6	59%	1	82
Suqian	I	Large	Non-Pilot	24	14	10.4	58%	17	15
Hefei	T	V.Large	Non-Pilot	42	15	10.1	56%	66	9
Wenzhou	T	V.Large	Pilot	15	16	9.9	55%	41	12
Shenzhen	P	Mega	Pilot	1	17	9.5	53%	97	10
Zhanjiang	I	Large	Pilot	11	18	9.3	52%	19	25
Nanning	I	Large	Non-Pilot	4	19	9.3	52%	32	22
Guilin	I	Large	Pilot	10	20	9.1	51%	45	21

* Note: HeavyInd. = Heavy Industry GDP Share ; Ind. EIntensity = Industrial Energy Intensity

Figure 65 - Comparing Mix of City Groups, 2015 Data: (Top Row) Sample Population, (Middle Row) Top 20 Overall Index Score, (Bottom Row) Industry Sub-Category Score



Compared to the Top 20 Overall Index cities, and the sample population, the Top 20 Industry cities had:

More Group P cities *... but not as much as in the Overall Index* *Fewer Group I; and Group T cities the same*	*More Mega and Very Large cities represented* *With slightly fewer Large cities* *But not as much as for the Overall Index*	*No Northeast cities in Industry Top 20* *... while they made up 25% of Overall Index* *More East cities, but no West cities in Overall Index*	*Slightly more Pilot cities than in population* *... but not as well as in Overall Index*

Which Cities Perform the Best in Industry?

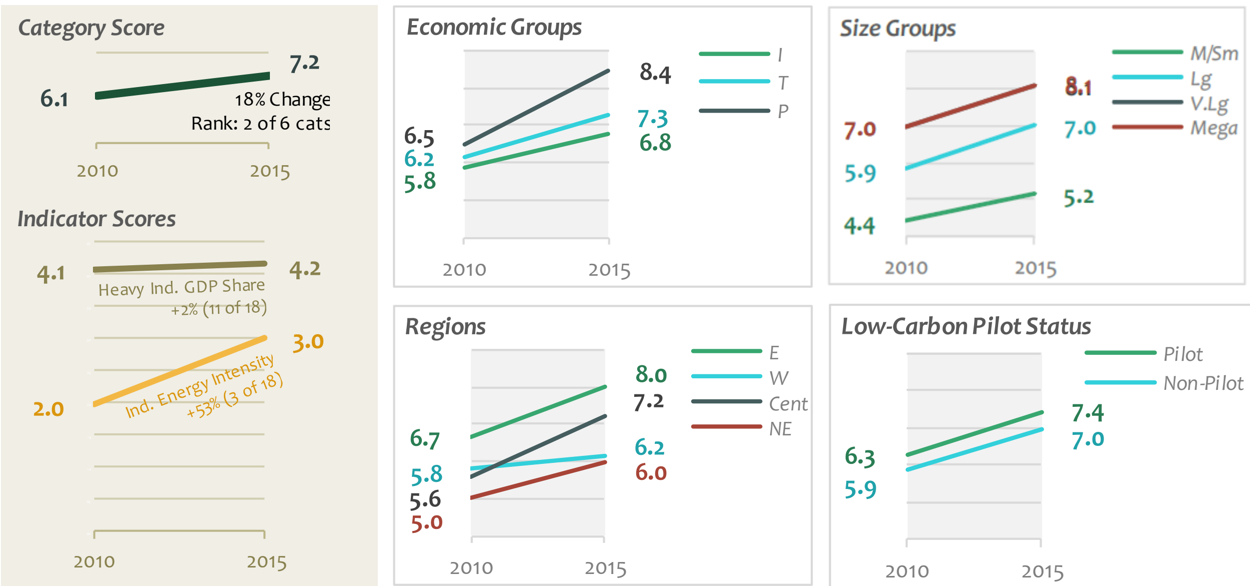
- Table 14 shows the Top 20 ranked cities in the Industry sub-category. The cities with top Industry scores also tended to rank highly in the Overall Index (all of the Top 5 Overall Index cities are in this list).
- Which city Groups perform the best? Figure 65 compares the Group make-up for three lists of cities: Top 20 Cities by Industry Score, Top 20 Cities by Overall Index Score, and Number of Cities in Sample Population. Specific notes are at the bottom of the graphic. Highlights include:
  - Group P, Very Large, and Mega cities all performed better in the Industry sub-category than their proportion in the population, but typically not as well as in the Overall Index.
  - There were no Northeastern cities in the Top 20 for Industry, although they had strong performance in the Overall Index scores. And Eastern cities again dominated among regions in this category.
  - Low Carbon Pilot cities did better than non-pilot cities; but no so well as in the Overall Index -- which is consistent with some other categories in the index.

Changes from 2010 to 2015: Industry

The Industry sub-category had one of the lower average scores among LOGIC categories in 2015; but at the same time, showed the third highest score increase between 2010 and 2015. Industry is an important category in the index, and the recent momentum for improvement should be promoted through key policies into the future. Some details can be seen in Figure 66.

- The average Industry sub-category score rose 18.4% over the 2010-2015 time period (from 6.1 points to 7.2 points in five years). This is the 2nd most improved of the six categories in the index.
- Both of the Industry indicators' average scores rose over the time period. 'Heavy Industry Share of GDP' rose by a modest 1.7% (ranked 11th out of 18 indicators for improvement). 'Industrial Energy Intensity' rose by 53.1% (ranked as the 3rd most improved indicator).
- All Groups and their city sub-groups saw positive change over the 2010-2015 period. Similar to other categories in the index, Group P city scores grew at slightly faster rates for this category than their counterparts. Pilot and Non-pilot cities improved at the same rate. Western cities grew at a relatively slower rate, falling behind Central cities.

Figure 66 - Category Changes, 2010-2015: (Left) Overall Category and Indicators; (Right) By City Grouping



Buildings Sub-Category (Energy & Carbon Category)

The Building sub-category showed mixed performance, with the majority of cities in the sample scoring above just above the category benchmark value. The sub-category indicator performance varied widely – with Residential Energy per Capita average scores achieving 90% of the benchmark, and the other two indicators reaching 35-40% of the benchmark, on average. However, two out of three indicators saw drop in scores from 2010 to 2015. Higher income, larger, and more developed cities dominated the 2015 performance in the Buildings sub-category.

- Figure 67 shows a wide distribution of scores in the Buildings sub-category – with a strong concentration of cities in the middle of the category score range (the average for all cities is 4.7, or 59% of the sub-category benchmark), and with two long, thin tails. One city reached the maximum score (Chongqing, with 8.0 points); and several cities had scores around 90% of the benchmark. The lowest score was 1.1 points (14% of benchmark). The middle-half of cities (25th to 75th percentile) fell in a narrow range between 5.2 points and 4.1 points (66% and 52% of category benchmark); and 94 out of 115 cities had scores above 50% of the category benchmark.

- There is a rough correlation between Building sub-category scores and overall index scores (Figure 69, R^2=0.23). The scatter plot has strong trend at the upper and lower bounds, but a 'mushy' middle – reflecting the concentration of cities in the narrow middle range for Buildings; but with wider variation in their overall index score performance.

- Indicator performance in the Buildings sub-category was mixed, as illustrated in Figure 70 and Figure 71.
  - The average score for all cities in the 'Residential Energy Consumption' indicator reached 90% of the benchmark value. This indicator also has an unusual profile (Figure 71): the vast majority of cities achieved the benchmark value, and there is a very thin lower tail.
  - Meanwhile, for the 'Commercial Energy Consumption' and 'Green Buildings Share' indicators, average scores reached only about 35-40% of their benchmark values. 'Commercial Energy Consumption' had a roughly bell-shaped (if somewhat uneven) distribution. And for the 'Green Buildings Share' indicator, there seem to be two groups of cities: a majority of cities with scores less than half of the Benchmark value, and a cluster of about 20 cities which fully reached the benchmark.

Figure 67 - Box Plot Distribution: Category Score
[all cities, 2015 data]

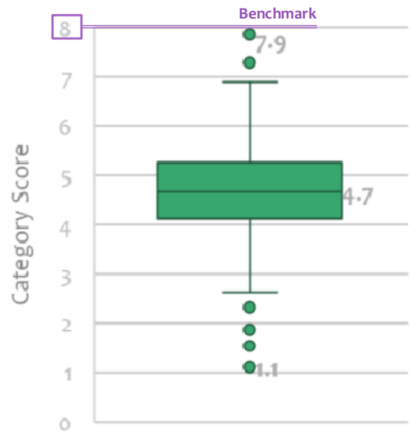


Figure 68 - Category Scores Histogram
[all cities, 2015 data]

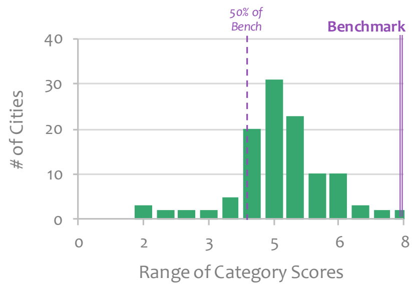


Figure 69 - Category Scores vs Overall Scores
[all cities, 2015 data]

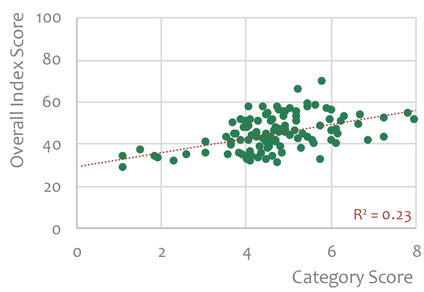


Table 15 - List of Indicators, Buildings Sub-Category

Indicator Name	Benchmark		Max Score	Reference	Type
Residential Energy / capita	4,740	kWh / cap	3	Japan	International
Commercial Energy / employee	6,580	kWh / employee	3	Top 10 Avg.	Sample Stats
Green Buildings Share	100	%	2	City Target	Nat'l Target

Note: see full details of benchmarks in Chapter 2, above

Figure 70 – Buildings Indicator Average Scores, and Gap from Max (2015)

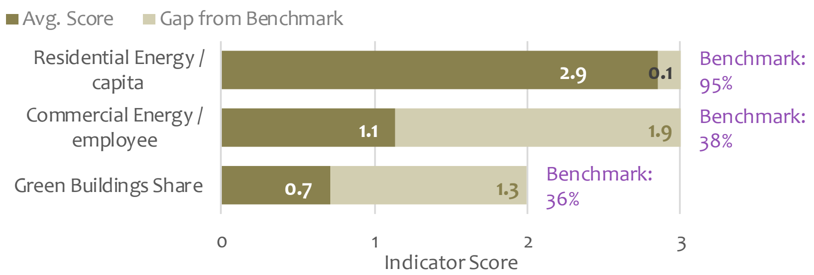
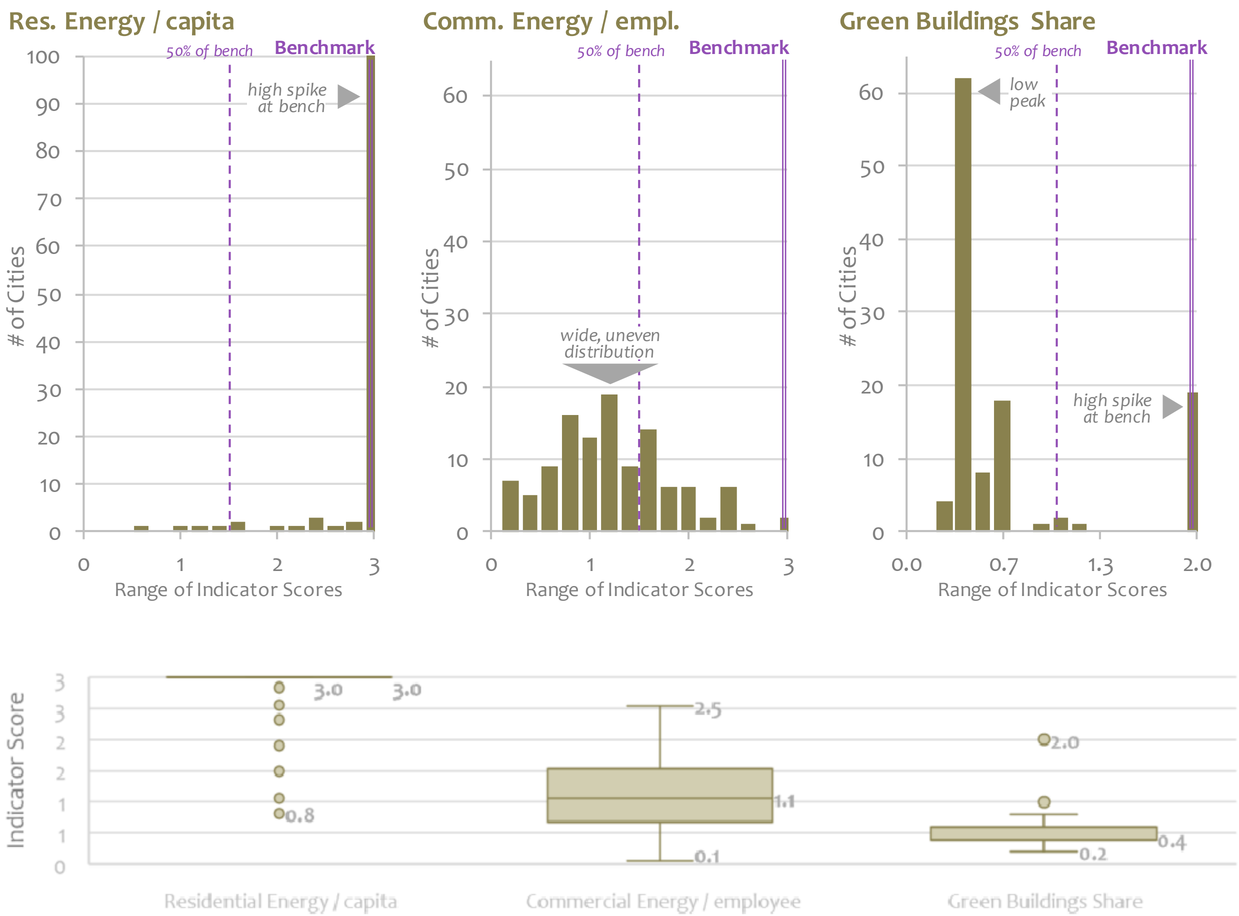


Figure 71 - Distributions of Buildings Indicator Scores, 2015: (Top Row) indicator score histograms; (Bottom Row) indicator score box plots



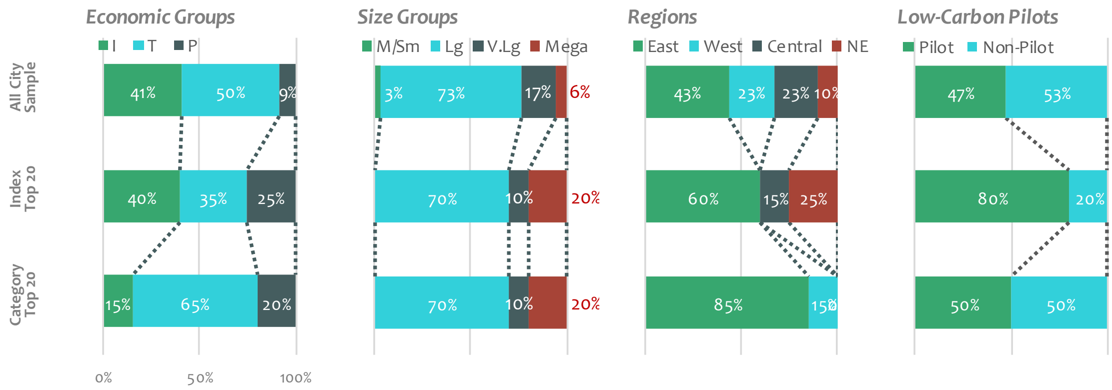
(… continued) Buildings Sub-Category

Table 16 - Top 20 Cities, Ranked by Buildings Sub-Category Score

City Name	Econ Group	Size Group	LC Pilot Status	Overall Rank	Category Rank	Category Score	Category % of Bench	Rank of Each Indicator*		
								Comm. Energy	Green Bldg.	Resid. Energy
Chongqing	T	Mega	Pilot	29	1	8.0	100%	1	1	1
Kunming	T	Large	Pilot	18	2	7.9	98%	2	1	1
Huai'an	T	Large	Pilot	68	3	7.3	91%	6	1	1
Suqian	I	Large	Non-Pilot	24	4	7.3	91%	7	1	1
Xuzhou	T	Large	Non-Pilot	71	5	6.9	86%	15	1	1
Yangzhou	T	Large	Non-Pilot	20	6	6.7	84%	20	1	1
Taizhou (Jiangsu)	T	Large	Non-Pilot	36	7	6.7	83%	21	1	1
Shanghai	P	Mega	Pilot	23	8	6.3	79%	40	1	1
Zhenjiang	T	Large	Pilot	31	9	6.3	78%	43	1	1
Changzhou	T	Large	Non-Pilot	56	10	6.2	77%	47	1	1
Suzhou	T	V.Large	Pilot	43	11	6.2	77%	49	1	1
Nanjing	P	V.Large	Non-Pilot	84	12	6.1	77%	5	23	1
Wuxi	T	Large	Non-Pilot	47	13	6.0	76%	60	1	1
Beijing	P	Mega	Pilot	12	14	6.0	75%	62	1	1
Jinan	T	Large	Non-Pilot	75	15	6.0	75%	63	1	1
Yancheng	T	Large	Non-Pilot	27	16	6.0	75%	12	21	1
Guilin	I	Large	Pilot	10	17	5.9	74%	3	50	1
Shenzhen	P	Mega	Pilot	1	18	5.8	73%	78	1	1
Nanping	I	Large	Pilot	37	19	5.8	72%	4	50	1
Zibo	T	Large	Non-Pilot	110	20	5.8	72%	81	1	1

* Note: Comm.Energy = Commercial Energy / employee ; Green Bldg. = Green Buildings Share ; Resid.Energy = Residential Energy / capita

Figure 72 - Comparing Mix of City Groups, 2015 Data: (Top Row) Sample Population, (Middle Row) Top 20 Overall Index Score, (Bottom Row) Buildings Sub-Category Score



Compared to the Top 20 Overall Index cities, and the sample population, the Top 20 Buildings cities had:

- Much more Group T cities
- More Group P cities, but not as much as in Overall Index
- Fewer Group I cities

- Considerably more Mega cities
- … and fewer Large and Very Large cities
- No medium/small cities

- No Central, nor Northeast cities in Top Buildings list
- … despite their showing in Overall Index
- Dominance by East cities

- Even 50/50 split
- … similar to population
- But dominance by Pilots in Overall Index

Which Cities Perform the Best in Buildings?

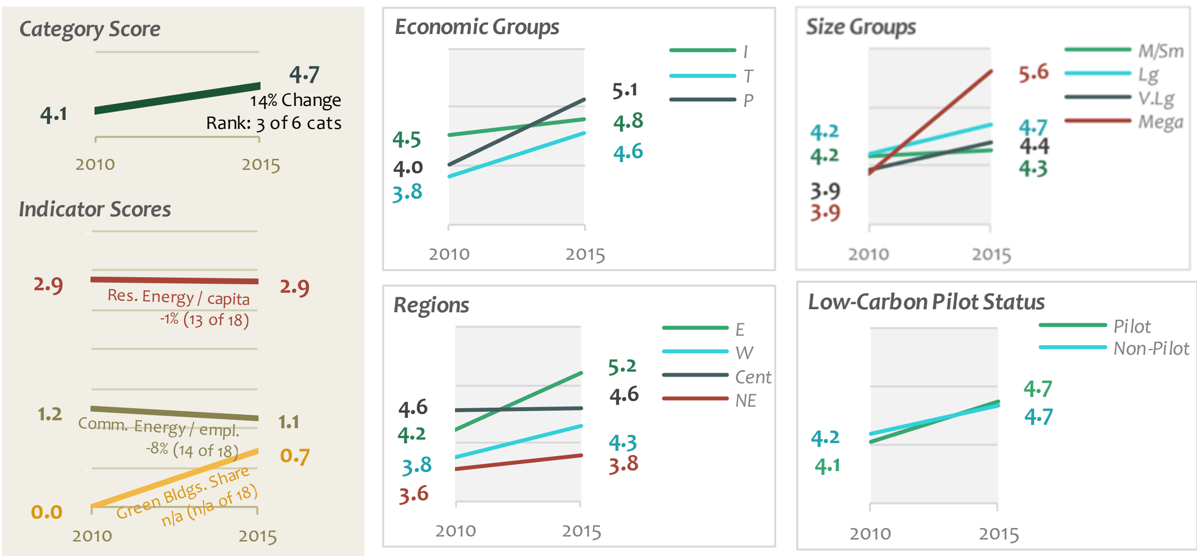
- The top-ranking cities in the Buildings sub-category were not necessarily those cities with the highest Overall Index Scores, as Table 16 shows. Only one city in the Top 5 Overall Index list (Shenzhen) is in the Buildings Top 20 (and ranked as #18). The rest of the Building Top 20 come from the middle ranks of the overall cities list.
- Which city Groups perform the best? Figure 72 compares the Group make-up for three lists of cities: Top 20 Cities by Buildings Score, Top 20 Cities by Overall Index Score, and Number of Cities in Sample Population. Specific notes are at the bottom of the graphic. Highlights include:
    - Group T cities performed considerably better in the Buildings sub-category than their representation in the population and the overall top scores. While Group P cities did better than population, though not better than in the overall index.
    - Size Groups in Building sub-sector matched performance in overall index. Mega cities did better than in their representation in the sample population. Large and Very Large cities did slightly poorer.
    - There were no Central or Northeastern cities in the Top 20; and the list was dominated by Eastern cities.
    - Pilots and non-pilots were evenly split.

Changes from 2010 to 2015: Buildings

Higher income, larger, and more developed cities dominated the 2015 performance in the Buildings sub-category, and these cities had stronger improvements from 2010 to 2015. This performance was driven by improvements in the 'Green Building Plans' indicator, and in spite of a falloff in performance in the 'Commercial Energy Consumption' indicator. See Figure 73.

- The Buildings sub-category saw a 14.1% increase in average score from 2010-2015 (from 4.1 to 4.7 points). This was the 3rd highest improvement of the 6 categories.
- This improvement in Building sub-category score was driven by the increase in score for the 'Green Building Share' indicator (from 0 points to 0.7) in the five-year period. At the same time, the scores for the other two Buildings indicators dropped: 'Commercial Energy Consumption' by -8%, and 'Residential Energy Consumption' with a slight drop of -1.1% over five years.
- All City Groups and sub-groups saw an improvement in the Building sub-category. Group P, Mega cities, and Eastern cities' Building sub-category growth considerably outpaced their respective peer groups. Low-Carbon Pilot cities started with lower scores in 2010, but overtook non-pilot cities with better scores by 2015.

Figure 73 - Category Changes, 2010-2015: (Left) Overall Category and Indicators; (Right) By City Grouping



Transport Sub-Category (Energy & Carbon Category)

Performance in the Transportation sub-category was widely variable, but on average quite low – Transport had the second lowest category score relative to its benchmark (after Economic Dimension). Some cities are doing well in providing bus services and urban rail services to citizens, but performance for the majority of cities is near or below 50% of the benchmark value. Urban rail is expensive, and not widely applied across the cities in the sample.

- Figure 74 shows a wide distribution of city scores in the Transport sub-category, with an average of 2.3 points (or 35% the benchmark value). The middle half of cities (25th to 75th percentile) ranged between 3.0 and 1.4 points (50% and 23% of benchmark). The distribution has long tails, with maximum and minimum city scores of 5.5 and 0.1 points, respectively (91% and 2% of benchmark). Thirty-two cities had scores above 50% of the Transport benchmark; but the majority were below. No city reached the benchmark score, and only 5 cities had scores above 75% of the benchmark.

- Figure 76 shows a loose scatter plot of Transport sub-category scores against overall index scores for each city; without strong correlation (R^2=0.04).

- Average scores for the three transport indicators were relatively low -- shown in Figure 77 and Figure 78.
  - The 'Bus Trips per Capita' indicator had an average score 63% of the benchmark level, and its histogram in Figure 78 (Top Row) indicates two groups of cities: the majority of cities form a wide bell-curve centered around the mid-point of the score range, and then there is a sharp peak of 20+ cities who reached the benchmark value.
  - The 'Public Transport Vehicles' indicator has most of the cities scoring around the lower-middle end of the range (average at 40% of benchmark).
  - And the 'Urban Rail' indicator shows very poor performance: an average score and sharp spike of cities at 10% of the benchmark value, with a very thin, upper tail of higher performing cities to the right. This is likely due to high cost of urban rail systems, only built by a small number of higher-income cities of different sizes.

Figure 74 - Box Plot Distribution: Category Score
[all cities, 2015 data]

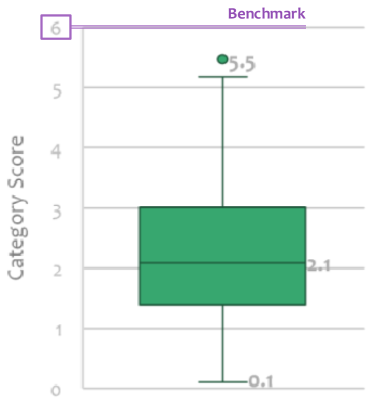


Figure 75 - Category Scores Histogram
[all cities, 2015 data]

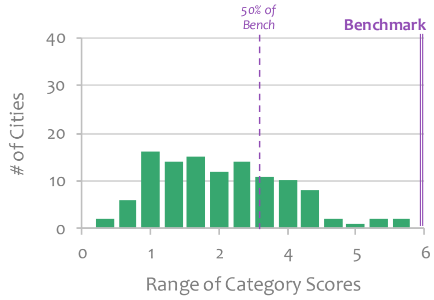


Figure 76 - Category Scores vs Overall Scores
[all cities, 2015 data]

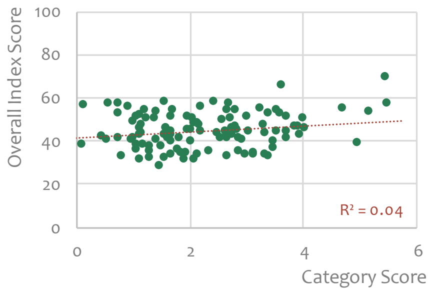


Table 17 - List of Indicators, Transport Sub-Category

Indicator Name	Benchmark		Max Score	Reference	Type
Bus Trips / capita	308	trips / person / yr	2	Beijing, +20%	Sample Stats
Public Trans Vehicle / 10k ppl	26	units / 10k person	2	Top 10 Avg. +20%	Sample Stats
Urban Rail Extent	0.04	km / km²	2	Top 10 Avg. +20%	International

Note: see full details of benchmarks in Chapter 2, above

Figure 77 – Economic Indicator Average Scores, and Gap from Max (2015)

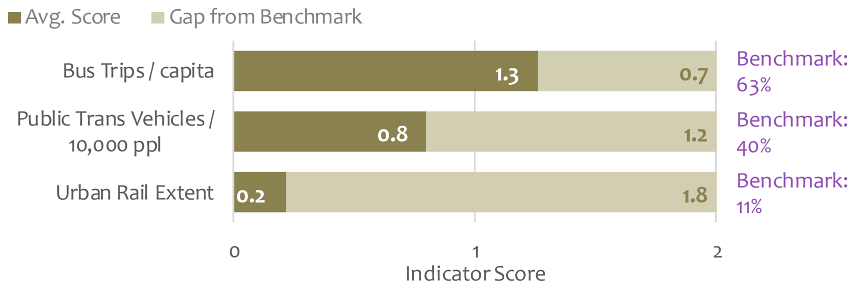


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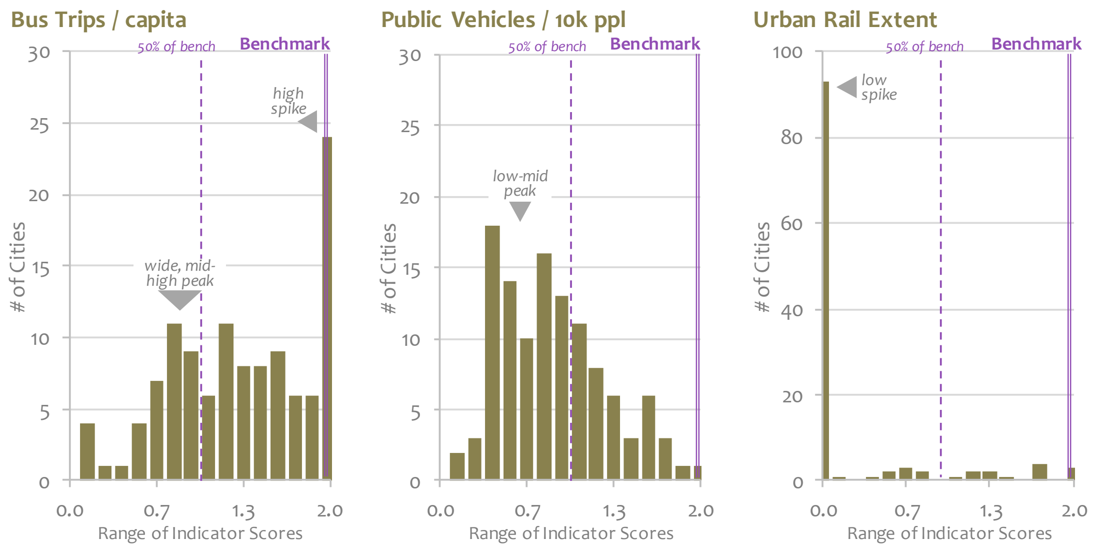
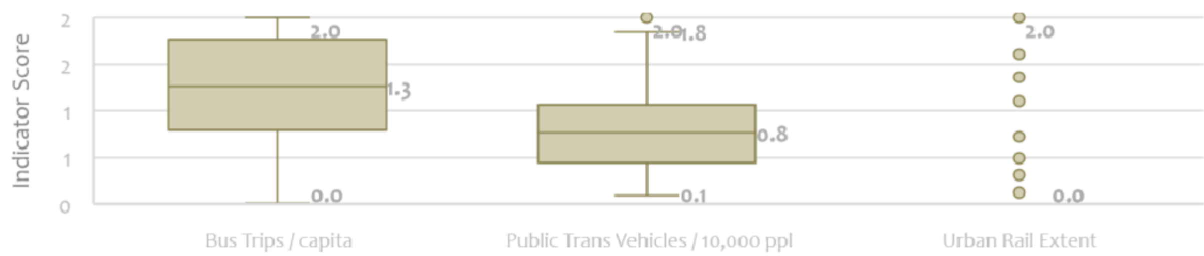
Figure 78 - Distributions of Transport Indicator Scores, 2015: (Top Row) indicator score histograms; (Bottom Row) indicator score box plots





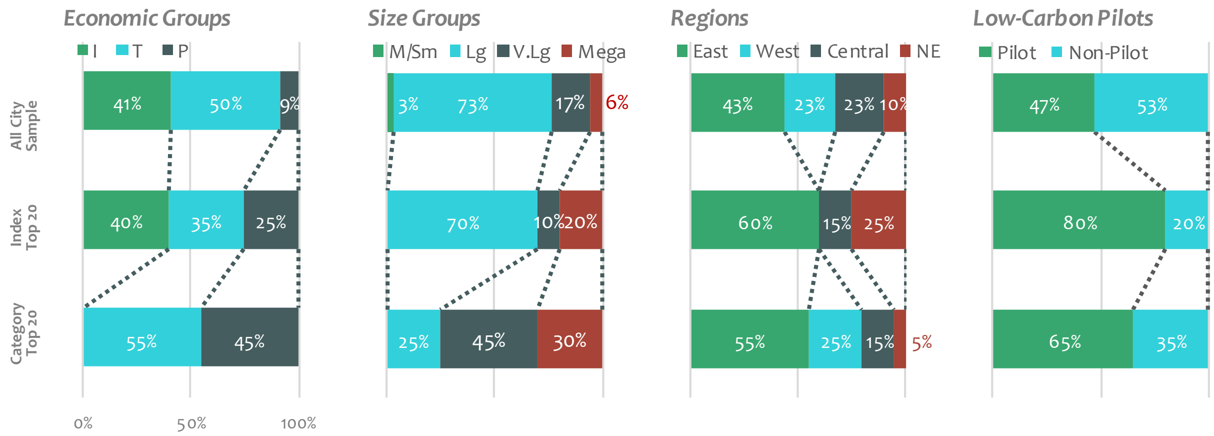
(... continued) *Transport Sub-Category*

Table 18 - Top 20 Cities, Ranked by Transport Sub-Category Score

City Name	Econ Group	Size Group	LC Pilot Status	Overall Rank	Category Rank	Category Score	Category % of Bench	Rank of Each Indicator*		
								Bus Trips	Public Trans.	Urban Rail
Guangzhou	P	Mega	Pilot	7	1	5.5	91%	1	11	1
Shenzhen	P	Mega	Pilot	1	2	5.5	91%	36	2	1
Chengdu	T	Mega	Non-Pilot	19	3	5.2	86%	1	9	6
Dalian	P	V.Large	Pilot	87	4	5.0	83%	1	18	5
Beijing	P	Mega	Pilot	12	5	4.7	78%	33	12	7
Wuxi	T	Large	Non-Pilot	47	6	4.0	67%	48	40	4
Changsha	T	V.Large	Non-Pilot	33	7	4.0	67%	41	14	12
Zhengzhou	T	V.Large	Non-Pilot	65	8	4.0	66%	30	41	9
Ningbo	T	V.Large	Pilot	45	9	3.9	65%	1	10	20
Suzhou	T	V.Large	Pilot	43	10	3.8	64%	35	35	10
Xi'an	T	V.Large	Pilot	60	11	3.7	62%	1	32	14
Foshan	T	V.Large	Pilot	28	12	3.7	62%	1	22	17
Wuhan	P	V.Large	Pilot	79	13	3.7	62%	1	24	16
Xia'men	P	Large	Pilot	2	14	3.6	60%	1	4	23
Shanghai	P	Mega	Pilot	23	15	3.6	60%	94	42	1
Tianjin	P	Mega	Pilot	55	16	3.5	59%	43	31	13
Kunming	T	Large	Pilot	18	17	3.5	59%	44	8	18
Nanjing	P	V.Large	Non-Pilot	84	18	3.5	58%	63	36	8
Huhhot	T	Large	Non-Pilot	93	19	3.5	58%	24	6	23
Xi'ning	T	Large	Non-Pilot	107	20	3.4	57%	25	7	23

* Note: BusTrips = Bus Trips / capita ; PublicTrans. = Public Trans Vehicles / 10,000 ppl ; UrbanRail = Urban Rail Extent

Figure 79 - Comparing Mix of City Groups, 2015 Data: (Top Row) Sample Population, (Middle Row) Top 20 Overall Index Score, (Bottom Row) Transport Sub-Category Score



Compared to the Top 20 Overall Index cities, and the sample population, the Top 20 Transport cities had:

No Group I cities *... yet Group I is 40% of pop and Overall Index* *Much more Group P cities*	*Much more Mega and Very Large cities* *... though V Large cities did poorer in the Overall Index* *Much fewer Large cities than in Overall Index*	*All regions represented in Top Transport list* *... but fewer NE and Central cities, and more East cities* *NE cities did better in Overall Index*	*More Pilot cities than in population* *... but not as much as in Overall Index*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Which Cities Perform the Best in Transport?

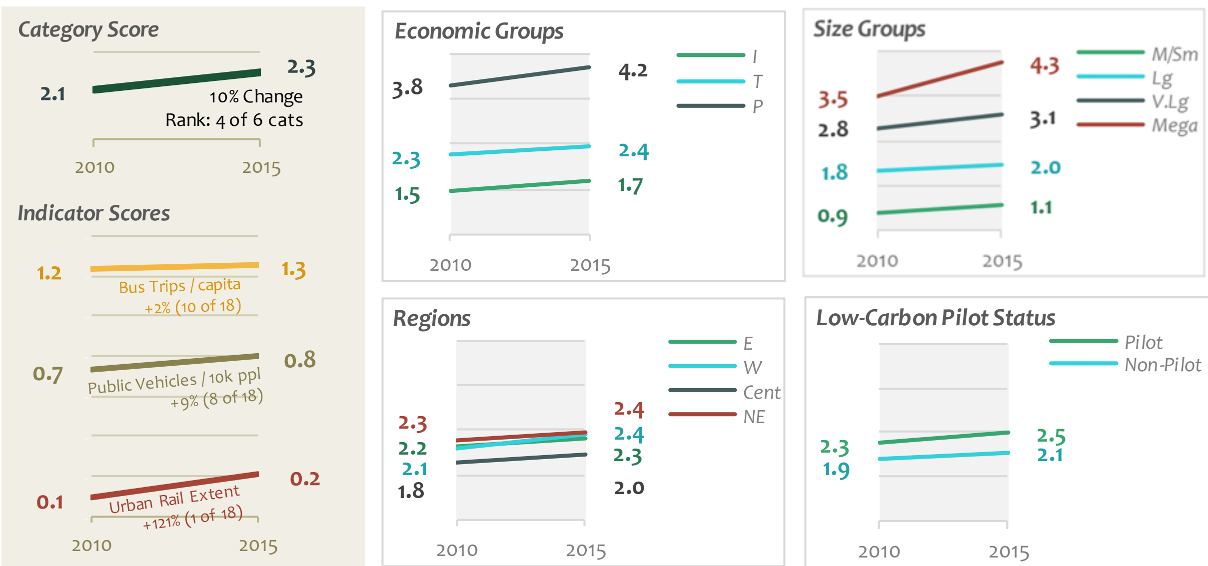
- The Top 20 cities in the Transport sub-category come from cities with a wide range of rankings in the Overall Index scores. Only two of the Top 5 overall score cities are in the Transport Top 20 list. The rest come from lower ranked cities, as shown in
-
- Table 18.
- Which city Groups perform the best? Figure 79 compares the Group make-up for three lists of cities: Top 20 Cities by Transport Score, Top 20 Cities by Overall Index Score, and Number of Cities in Sample Population. Specific notes are at the bottom of the graphic. Highlights include:
    - There are no Group I cities in the Top 20 list for the Transport sub-category. Meanwhile Group P cities, as well as Mega and Very Large cities far outperform their peers, relative to the population, and in the list of best overall scores.
    - Regional proportions are similar to the overall population, but whereas there were no Western cities in the overall index Top 20, there is a significant segment in the Transport sub-category.
    - Pilot cities performed much better than non-pilot cities, though not as well as in the overall index scores.

Changes from 2010 to 2015: Transport

The 'Urban Rail' indicator in the Transport sub-category was the fastest improving indicator in this study – rising 121% in five years, albeit from a low baseline. See Figure 80.

- Overall, the Transport sub-category saw its average score rise by 9.7% from 2010-2015, which is 4th fastest improvement out of 6 categories in the index.
- All three Transport indicators also saw average scores rise over the five-year period. The 'Urban Rail Extent' indicator was the fastest growing among all of the 23 indicators in this study – rising 121% in five years, albeit from a relatively low baseline. The 'Number of Public Transit Vehicles' and 'Bus Trips per Capita' indicators rose 8.6% and 1.8% over the period, respectively (ranked at 8th and 10th out of 18 indicators).
- Most of the city Groupings and Sub-Groups had Transport sub-category scores rising at the same rate over the study period. Mega cities had slightly faster growth in average Transport sub-category performance.

Figure 80 - Category Changes, 2010-2015: (Left) Overall Category and Indicators; (Right) By City Grouping



Environment & Land Use Category

Environment & Land Use (E&LU) is among the most important categories in LOGIC (having a weight of 20% in the index framework). E&LU performed best among all caterogies. However, E&LU was the only category to see a decline in average scores over the 2010-2015 period – largely driven by low scores in the air quality indicators – an urgent health issue, closely linked to the combustion of coal and oil in China's industry, power generation, and the growing transport sector. Interestingly, the E&LU category showed the least variation acorss cities of any of the index categories; and there was no strong correlation between performance in the E&LU category and overall index scores. Variation among E&LU indicators was wide however, with low scoring indicators balanced by higher scoring indicators. But Chinese cities will need to take care not to let air quality and water consumption further drag LOGIC scores down in the future.

- Figure 81 shows distributions of city scores in the Environment & Land Use category. E&LU has the narrowest range, and the highest average score of any category in the index. Scores range from 15.3 to 8.8 points (76% to 44% of the category benchmark, respectively). The middle half of cities (25th to 75th percentile) fall between 12.9 and 11.1 points (65% and 55% of the benchmark). However, no cities reached the maximum score for E&LU: the highest city was Quanzhou with 15.3 points (76% of the benchmark). The category histogram (Figure 82) shows a rough bell-shaped curve, peaking at the average score of 12 points (60% of benchmark), and skewed to the right of the category range. 98 out of 115 cities have E&LU scores above 50% of the benchmark.

- The scatter plot in Figure 83, shows very little correlation between scores in environment, and overall LOGIC scores (R^2=0.01). E&LU is highly weighted in the index framework, and the E&LU performance of cities falls within a narrow (and high) range. Nonetheless, this category does not seem to drive overall scores.

- Indicators in the E&LU category showed considerable variation. Figure 84 shows average scores for the six E&LU indicators, and their respective gaps from the benchmark values.

- Figure 85 shows the distribution of city E&LU scores as histograms and box plots.
  - 'Energy and Environment Budgeting' and 'Solid Waste' indicators showed similar performance: average scores around 85-90% of their benchmarks, a profile with a low- to mid-range peak, and a sharp spike of cities at the benchmark value, and most cities with scores above 50% of the benchmark.
  - The 'Blue Sky Days' and 'Green Space' indicators also had similar performance: average scores around 65-75% of their benchmarks, and uneven profiles with multiple peaks. 'Blue Sky Days' had more cities above 50% of the benchmark; 'Green Space' had fewer.
  - In general, sample cities performed poorly on the 'Water Consumption per Capita' indicator. The average score was only 40% of the benchmark.
  - Cities had the weakest performance in the 'PM2.5' indicator: average score was 13% of max, and nearly all of the cities had scores below 50% of the benchmark. The benchmark value for this indicator, though, is WHO standard, which is a long-term target for China's cities.

Figure 81 - Box Plot Distribution: Category Score
[all cities, 2015 data]

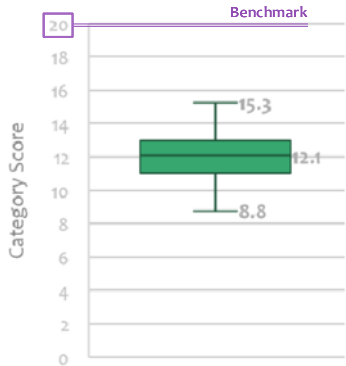


Figure 82 - Category Scores Histogram
[all cities, 2015 data]

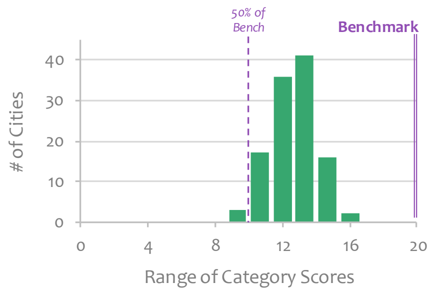


Figure 83 - Category Scores vs Overall Scores
[all cities, 2015 data]

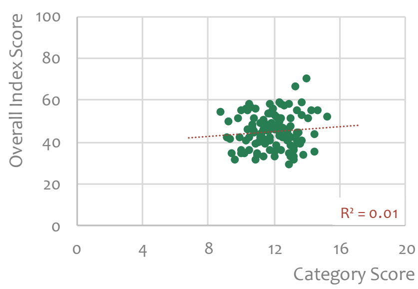


Table 19 - List of Indicators, Environment & Land Use Category

Indicator Name	Benchmark		Max Score	Reference	Type
Blue Sky Days (or AQI)	100	%	4	Nat'l Standard	National Target
Solid Waste / capita	0.31	t / cap / yr	3	Singapore, 2008	International
Energy Enviro Budget Ratio	3	%	3	National Target	National Target
Green Space / cap.	100	m^2 / cap	4	Hong Kong	International
Water Consumption / cap.	60	L / cap / d	3	WHO Standard (min)	International
PM2.5	10	µg / m^3	3	WHO Standard	International

Note: see full details of benchmarks in Chapter 2, above

Figure 84 – Environment & Land Use Indicator Average Scores, and Gap from Max (2015)

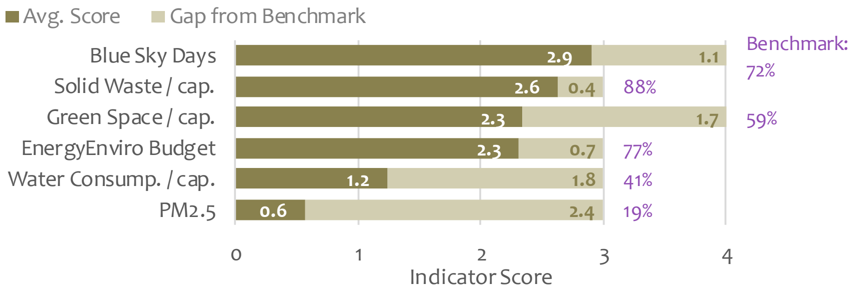
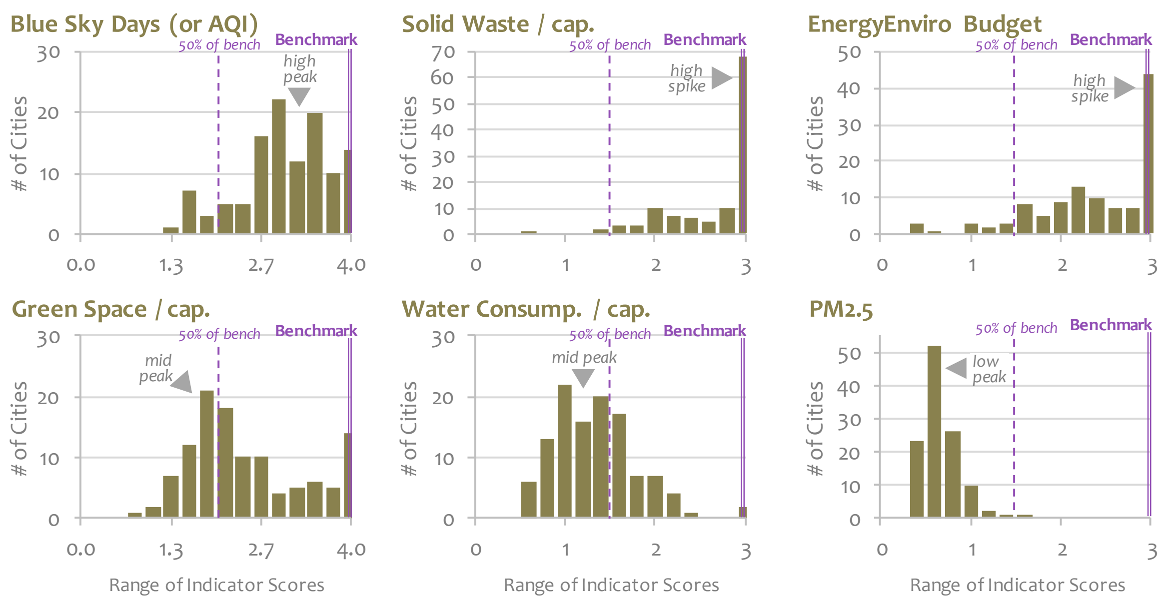
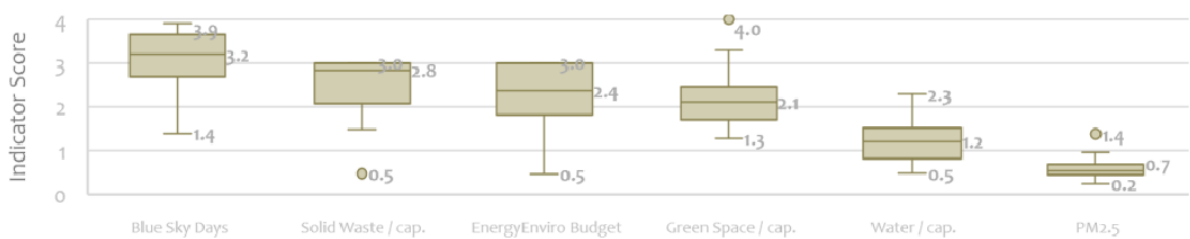


Figure 85 - Distributions of Environment & Land Use Indicator Scores, 2015: (Top Row) indicator score histograms; (Bottom Row) indicator score box plots





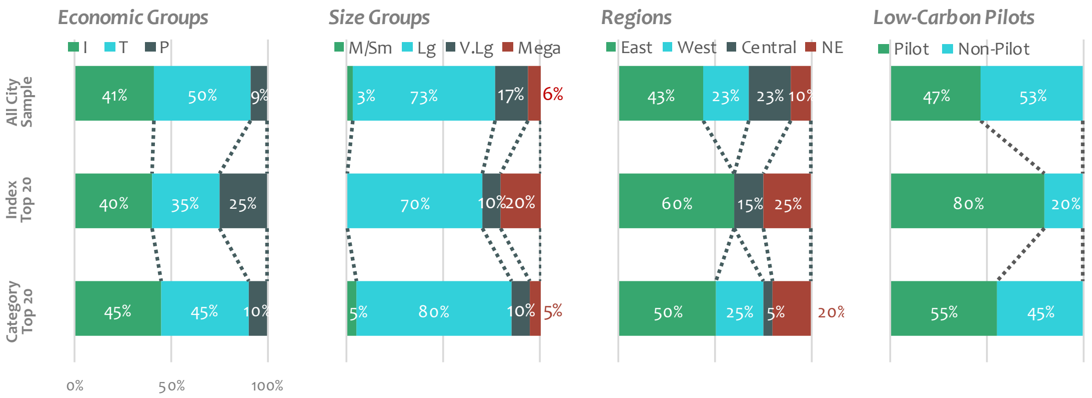
(… continued) Environment & Land Use Category

Table 20 - Top 20 Cities, Ranked by Category Score

City Name	Econ Group	Size Group	LC Pilot Status	Overall Rank	Category Rank	Category Score	Category % of Bench	Rank of Each Indicator*: Blue Sky	Env. Budget	Green Space	PM2.5	Solid Waste	Water /cap
Quanzhou	T	V.Large	Non-Pilot	25	1	15.3	76%	1	56	18	6	1	35
Jiangmen	I	Large	Pilot	17	2	14.7	73%	22	64	1	13	1	76
Daqing	T	Large	Non-Pilot	99	3	14.5	73%	23	77	1	27	1	46
Qinhuangdao	I	Large	Pilot	66	4	14.5	72%	56	1	1	82	69	48
Guangyuan	I	Large	Pilot	16	5	14.3	72%	8	43	52	2	1	73
Zhenjiang	T	Large	Pilot	31	6	14.1	71%	59	1	12	76	1	94
Shenzhen	P	Mega	Pilot	1	7	14.0	70%	7	1	16	9	102	99
Urumuqi	T	Large	Pilot	106	8	13.9	69%	29	1	13	72	107	54
Suqian	I	Large	Non-Pilot	24	9	13.8	69%	77	66	1	79	1	43
Chizhou	I	M/Sm	Pilot	83	10	13.7	69%	12	52	58	11	1	38
Nanning	I	Large	Non-Pilot	4	11	13.7	69%	19	86	1	21	67	110
Weifang	T	V.Large	Non-Pilot	89	12	13.7	68%	87	1	27	87	1	26
Chifeng	I	Large	Non-Pilot	59	13	13.5	68%	41	1	83	23	63	11
Jilin	I	Large	Pilot	58	14	13.5	67%	74	1	32	62	1	31
Yantai	T	Large	Non-Pilot	63	15	13.5	67%	34	93	19	28	1	51
Qiqihar	I	Large	Non-Pilot	81	16	13.4	67%	26	49	48	15	81	16
Kunming	T	Large	Pilot	18	17	13.4	67%	3	1	88	7	83	27
Xia'men	P	Large	Pilot	2	18	13.4	67%	1	71	1	14	113	68
Zibo	T	Large	Non-Pilot	110	19	13.3	66%	108	1	1	112	1	41
Fushun	T	Large	Pilot	94	20	13.2	66%	64	39	98	54	1	3

** Note: BlueSky = Blue Sky Days (or AQI) ; Env.Budget = Energy & Enviro Budget Ratio ; GreenSpace = Green Space / capita ; PM2.5 = PM2.5 ; SolidWaste = Solid Waste / capita ; Water/cap = Water Consumption / capita*

Figure 86 - Comparing Mix of City Groups, 2015 Data: (Top Row) Sample Population, (Middle Row) Top 20 Overall Index Score, (Bottom Row) Environment & Land Use Category Score



Compared to the Top 20 Overall Index cities, and the sample population, the Top 20 E&LU cities had:

Economic Groups	Size Groups	Regions	Low-Carbon Pilots
Similar proportions as in the sample population *… but fewer Group P, and more Group T than in the Overall Index*	*More Medium/small cities* *More Large cities, but less V. Large cities* *Mega cities did better in Overall Index than E&LU*	*More East and NE cities than in population* *… but not as well as in the Overall Index* *Fewer Central cities in both*	*More Pilot cities than in population* *… but not as many as in the Overall Index*

Which Cities Perform the Best in Environment & Land Use?

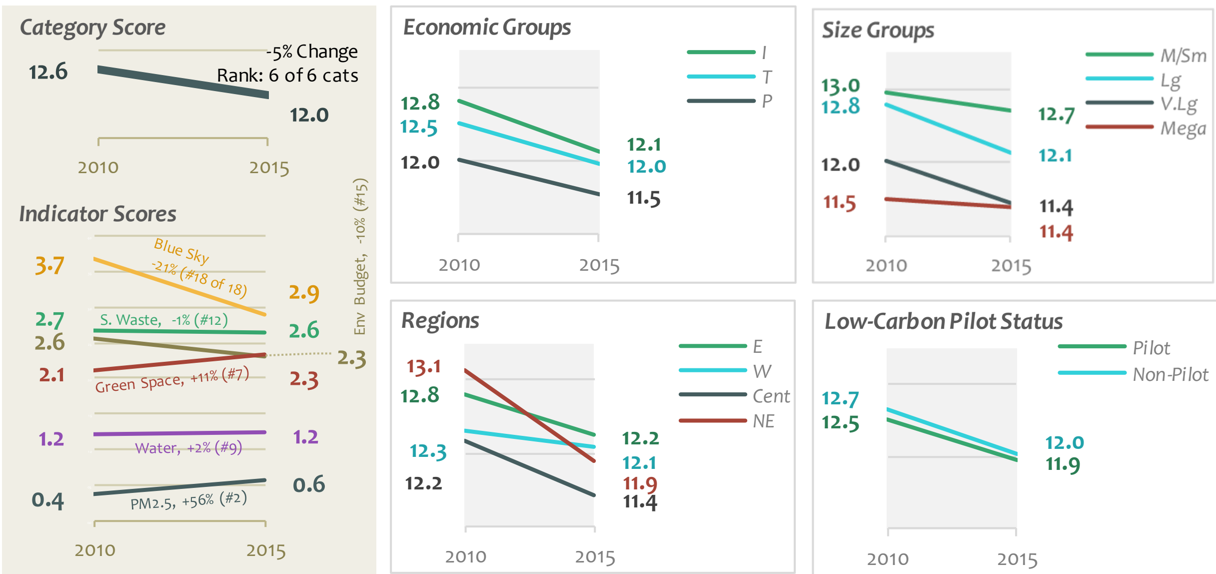
- Consistent with the variability in the E&LU category scores noted above, Table 20 shows that the Top 20 cities in the E&LU category have widely varying scores in the Overall Index. While three of the Top 5 Overall Index cities are in this list, many others are ranked around 50 or 60, or even near 100.
- Which city Groups perform the best?
-
- Figure 86 compares the Group make-up for three lists of cities: Top 20 Cities by Environment & Land Use Score, Top 20 Cities by Overall Index Score, and Number of Cities in Sample Population. Specific notes are at the bottom of the graphic. Highlights include:
  - Group P and Mega cities did poorer than their representation in the sample population, and in the Overall Index scores; Group T and Large cities did better.
  - Eastern and Northeastern cities, and Low Carbon Pilots did better than their population proportions, but not as well as in Overall Scores.

Changes from 2010 to 2015: Environment & Land Use

The Environment & Land Use category was the only category in the index to have an overall drop in scores from 2010 to 2015. Three out of six indicators saw their average scores drop over this period – overshadowing modest increases in the other indicators. All city groups and sub-groups saw their E&LU scores decrease. See Figure 87.

- The E&LU category dropped -4.7% from 2010-2015 (12.6 points to 12.0).
- 'Blue Sky Days', 'Environment Budgeting', and 'Solid Waste' indicators saw their average score decline by -21.1%, -9.7%, -1.0%, respectively (ranked 18th, 15th, and 12th out of 18 indicators in terms of change).
- The other three indicators saw growth in average scores over the period. The 'PM2.5' indicator, while having the lowest average score of any in the Category, saw the highest growth over five years (+56%). This is promising, given the urgent air pollution challenges in Chinese cities.
- All city groupings saw E&LU score declines from 2010-2015. Mega cities dropped less quickly than their peers. And Northeastern cities' scores dropped considerably faster.

Figure 87 - Category Changes, 2010-2015: (Left) Overall Category and Indicators; (Right) By City Grouping



Policy & Outreach Category

The Policy & Outreach category includes four indicators that represent the efforts that city leaders have taken in pursuing green and low carbon development in their cities. These are the only four qualitatiavie indicators in the LOGIC model. The 2015 LOGIC results show that cities have taken positivie steps issuing a number of policies, but that more work still needs to be done.

- Figure 88 and Figure 90 show the distribution of scores for all cities in the Policy & Outreach category. Given that each indicator in this category required a Yes/No response to indicate whether the city had implemented each policy or not, the scores in the Policy & Outreach category represent the number of low-carbon policies that the city has implemented.

- All of the cities had implemented at least one of the four green and low-carbon policies (yielding 2.5 points, or 25% of the total category benchmark value). Forty-nine cities had implemented only one of the four policies (2.5 points), fifty cities had implemented two of the four policies (5.0 points), and sixteen cities had implemented three of the four policies (7.5 points). None of the 115 cities implemented all four of the policies.

- The average score for all cities in the Policy & Outreach category was 4.3 points, out of 10, or 43% of the benchmark value.

- The individual indicators (i.e. low-carbon policies) had mixed results.

- All of the cities in the sample had made 'low carbon lifestyle publicity' efforts by 2015, and so all cities received the full score for this indicator.

- Meanwhile, as of 2015, none of the cities had issued formal 'climate resilience plans'; hence all cities received zero points for this indicator, and this dragged the Policy & Outreach category scores downward.

- For the other two policies, 'renewable and alternative energy strategy' and 'low carbon climate change plan, both had approximately 40 cities who had created such policies, and 70 cities who had not. Both of these indicators had average scores of around 35%.

Figure 88 - Box Plot Distribution: Category Score
[all cities, 2015 data]

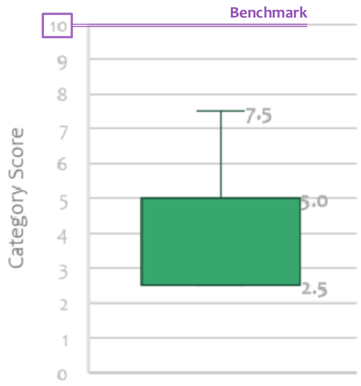


Figure 89 - Category Scores Histogram
[all cities, 2015 data]

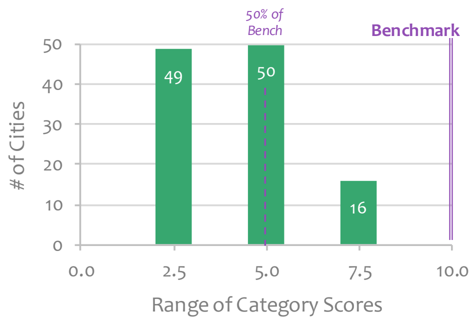


Figure 90 - Category Scores vs Overall Scores
[all cities, 2015 data]

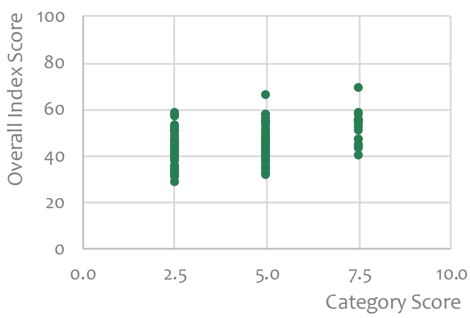


Table 21 - List of Indicators, Policy & Outreach Category

Indicator Name	Benchmark		Max Score	Reference	Type
Low Carbon Lifestyle Publicity	TRUE	[True/False]	2.5	n/a	True/False
Low Carbon / Climate Plan	TRUE	[True/False]	2.5	n/a	True/False
Renew + Alt Energy Strategy	TRUE	[True/False]	2.5	n/a	True/False
Climate Resilience Plan	TRUE	[True/False]	2.5	n/a	True/False

Note: see full details of benchmarks in Chapter 2, above

Figure 91 - Policy & Outreach Indicator Average Scores, and Gap from Max (2015)

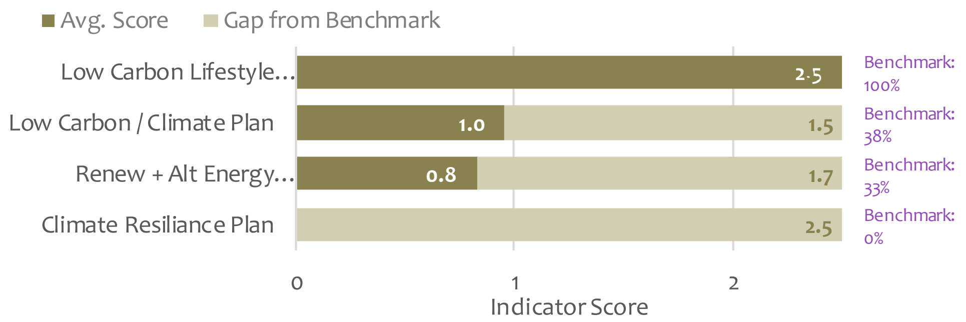
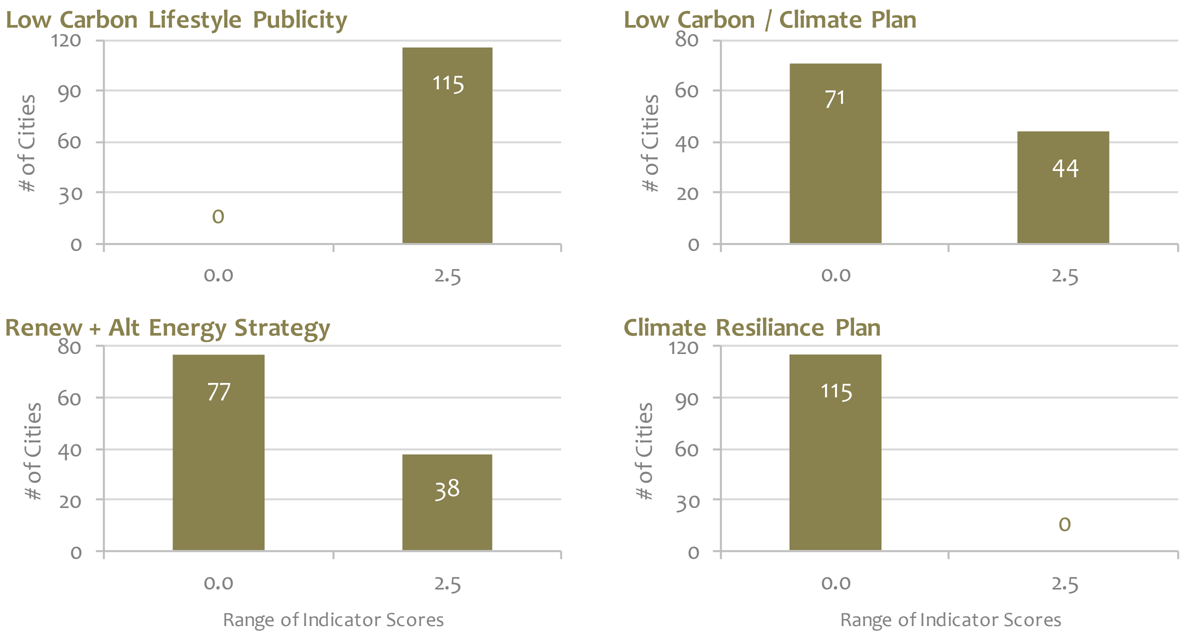


Figure 92 - Distributions of Policy & Outreach Indicator Scores, 2015: (Top Row) indicator score histograms; (Bottom Row) indicator score box plots



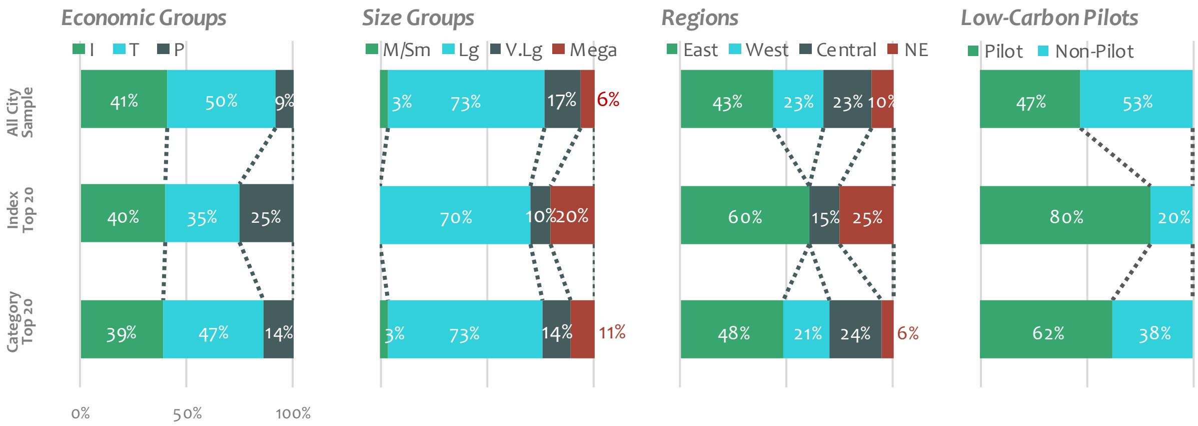
(... continued)   Policy & Outreach Category:

Table 22 - Top 20 Cities, Ranked by Policy & Outreach Category Score

City Name	Econ Group	Size Group	LC Pilot Status	Overall Rank	Category Rank	Category Score	Category % of Bench	Rank of Each Indicator*: Resil. Plan	LC Plan	LC Lifestyle	Energy Strategy
Zhenjiang	T	Large	Pilot	31	1	7.5	75%	1	1	1	1
Shanghai	P	Mega	Pilot	23	1	7.5	75%	1	1	1	1
Nanning	I	Large	Non-Pilot	4	1	7.5	75%	1	1	1	1
Beijing	P	Mega	Pilot	12	1	7.5	75%	1	1	1	1
Suzhou	T	V.Large	Pilot	43	1	7.5	75%	1	1	1	1
Chengdu	T	Mega	Non-Pilot	19	1	7.5	75%	1	1	1	1
Luoyang	I	Large	Non-Pilot	86	1	7.5	75%	1	1	1	1
Chifeng	I	Large	Non-Pilot	59	1	7.5	75%	1	1	1	1
Ningbo	T	V.Large	Pilot	45	1	7.5	75%	1	1	1	1
Guangyuan	I	Large	Pilot	16	1	7.5	75%	1	1	1	1
Shenzhen	P	Mega	Pilot	1	1	7.5	75%	1	1	1	1
Guangzhou	P	Mega	Pilot	7	1	7.5	75%	1	1	1	1
Tianjin	P	Mega	Pilot	55	1	7.5	75%	1	1	1	1
Hangzhou	P	V.Large	Pilot	13	1	7.5	75%	1	1	1	1
Hulunbuir	I	Large	Pilot	67	1	7.5	75%	1	1	1	1
Nanchang	T	Large	Pilot	14	1	7.5	75%	1	1	1	1
Taiyuan	T	Large	Non-Pilot	113	17	5.0	50%	1	45	1	1
Zhanjiang	I	Large	Pilot	11	17	5.0	50%	1	1	1	39
Wuhu	T	Large	Non-Pilot	57	17	5.0	50%	1	45	1	1
Dongguan	T	V.Large	Pilot	40	17	5.0	50%	1	45	1	1

* Note: Resil. Plan = Climate Resiliance Plan ; LC Plan = Low Carbon / Climate Plan ; LC Lifestyle = Low Carbon Lifestyle Publicity ; EnergyStrategy = Renew + Alt Energy Strategy

Figure 93 - Comparing Mix of City Groups, 2015 Data: (Top Row) Sample Population, (Middle Row) Top 20 Overall Index Score, (Bottom Row) Policy & Outreach Category Score



Compared to the Top 20 Overall Index cities, and the sample population, the Top 20 Policy & Outreach cities had:

Economic Groups	Size Groups	Regions	Low-Carbon Pilots
Similar proportions for Economic Groups as in the sample population *... but fewer Group P cities as in the Top 20 list*	*Similar proportions for the Size Groups as in the sample population* *... but more Mega cities* *... though not as much as in the Top 20 list*	*Similar proportions for the Regions as in the sample population* *... but fewer NE cities than in the Top 20 list*	*Pilots better than in population* *... but not nearly as well as for Overall Score*

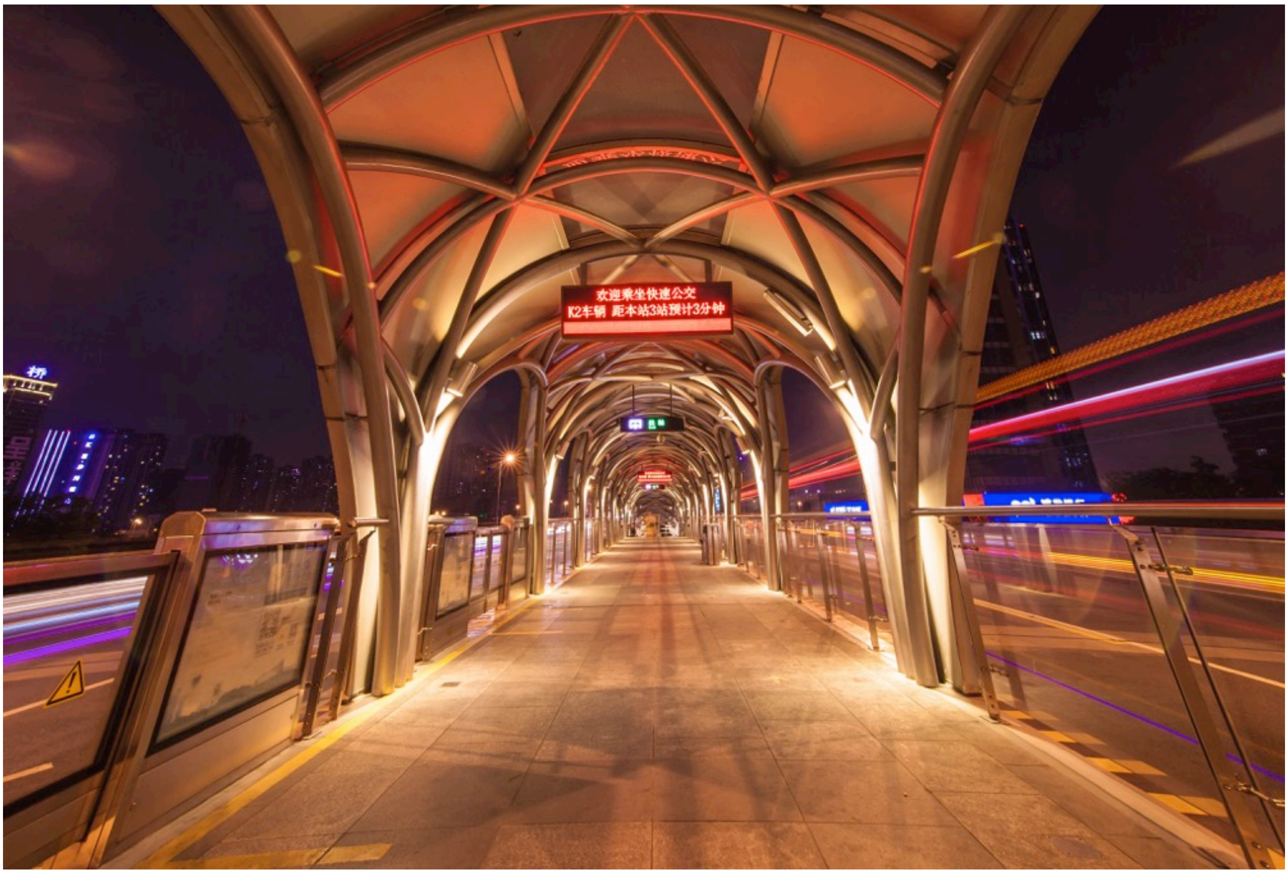
Which Cities Perform the best in Policy?

- The Policy & Outreach category shows a lot of variation in terms of which cities are highest ranking. Table 22 shows that two of the Top 5 Overall Index cities are in this list, many others are ranked around 40 or 60, or even near 100.
- Given the Yes/No nature of the Policy & Outreach category, many more cities end up having the exact same score. Sixteen cities are all have the highest score in the category, 7.5 points. But these come from different kinds of cities.
- Which city Groups perform the best? Figure 93 compares the Group make-up for three lists of cities: Top 20 Cities by Policy & Outreach Score, Top 20 Cities by Overall Index Score, and Number of Cities in Sample Population. Specific notes are at the bottom of the graphic. Highlights include:
  - For most of the city Groupings, the makeup of Top 20 scoring cities in the Policy & Outreach category were similar to the proportions in the overall population.
  - Group P cities and Mega cities perform better in the category Top 20 than their representation in the sample population, but both not as well as they performed in the Top 20 overall index list.
  - Low-carbon pilot cities performed better than their population representation, but not as well as in the Top 20 overall index.

Changes from 2010 to 2015: Policy & Outreach

This section does not apply to the Policy & Outreach category.

As was mentioned in earlier sections of this report, the four indicators in the Policy & Outreach category refer to planning documents and outreach efforts that were only mandated by the Chinese government, after the year 2010. Therefore, it would be misleading to compare index scores and cities with the Policy & Outreach category, as none of the cities had the measures tracked by the indicators in place. It would also skew comparisons with 2015. Therefore, this report only presents the LOGIC results for Policy & Outreach category for the year 2015 (above).



Chapter 6. Lessons from Selected Cities and Case Studies

This exploration looks at three case studies – diving deeper by selecting three high-performing cities (representing one city from each of the Economic Groups) and exploring in more detail which factors and policies contributed the most to the city's high performance in the index – and drawing lessons for other similar cities. The three cities are:

- ***Shenzhen****, Guangdong Province*
- ***Wenzhou****, Zhejiang Province*
- ***Ganzhou****, Jiangxi Province*

The cities of Shenzhen, Wenzhou and Ganzhou are at different economic development stages, but all are currently top green and low-carbon index performers. In the 2015 LOGIC analysis, Shenzhen was as a top economic performer and also recorded the highest overall index score of any city in the sample. The cities of Wenzhou and Ganzhou also ranked near the top of the list, largely as a result of their good performance in the carbon productivity and energy consumption indicators. However, these two cities lagged behind in terms of construction, transportation, industry, environmental conditions, and low-carbon policies. As a result, their low-carbon development is not balanced across all sectors.

If we compare the low-carbon actions and policies of these three case study cities, we can see that Shenzhen has forged a relatively clear low-carbon transition pathway, with several clear development objectives, along with supporting policies and action plans that have been adjusted for local economic conditions, industrial structure, and resources and energy consumption. And, ass national low-carbon city pilots, Wenzhou and Ganzhou have integrated the philosophy of green transition into their urban economic and social development planning; but specific policies are still designed to satisfy senior-level government, rather than with feasibility and suitability in mind. And as a result, many of their actions in different sectors are not coordinated.

The map below shows the locations of these three case study cities. And, the case studies are described in further detail in the pages that follow.

Figure 94 – Map showing locations of three case study cities

Case Study: Shenzhen

Basic Information:

Shenzhen is one of China's Special Economic Zones, national economic center cities and international cities . Its administrative area is 1,997.30 km^2; its population was 11,378,700 in 2015 (population density of 5,697 per km^2). During the 12th FYP period, Shenzhen witnessed improvements both in economic scale and quality of development. Regional GDP increased from 958.15 billion yuan in 2010 to 1.75 trillion yuan in 2015. The secondary and tertiary industrial structure optimized from 46.2: 53.7 in 2010 to 41.2: 58.8 in 2015. Per capita GDP reached 158,000 yuan (equivalent to US$25,365 at 2015's average exchange rate). GDP per km^2 and fiscal revenue both ranked first among China's big cities.

Shenzhen Basic Data

Province	Guangdong	
Population in 2015	11,378,700	[people]
Administrative Area	1,997	[km^2]
Population Density	5,697	[ppl/km^2]
GDP per Capita	157,985	[RMB]
Urbanization Rate	100	[%]
Industrial Structure	primary: 0.1% secondary: 41.2% tertiary: 58.8%	

Performance in LOGIC Index

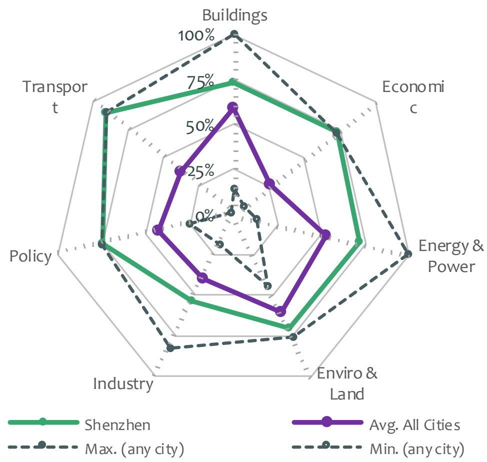
Shenzhen is an economically developed city (P class), located in the Development Zones to be Optimized, and is one of the national low-carbon pilot cities. Shenzhen ranks first in the green low-carbon index, and high in a lot of sub-indicators among 115 sample cities. Its carbon productivity ranks first, traffic and environmental conditions rank seventh, industrial sector ranks 17th, construction ranks 18th, and energy, 26th. Compared with other P-class cities (10 in total), Shenzhen performed best in terms of carbon productivity and environmental conditions, second in energy and traffic, third in industry, and fourth in construction. Every sub-indicator score is higher than the average level of sample cities.

Although Shenzhen scores far ahead of other sample cities, it still has some catching up to do with a number of indicators. According to the figure at the right, Shenzhen's transportation and construction performance are close to the best level, but there is some room for improvement in the industrial sector, environmental conditions, carbon production and energy. Specific shortfalls can be seen by comparing the actual performance of each indicator with the best level.

Shenzhen LOGIC Performance

Overall LOGIC Score	69.7
Overall Rank	1
LOGIC Change: 2010 to 2015, %	39%
Economic Group	Group P
Size Group	Mega
Region	East
LC Pilot Status	Pilot City

Category Scores, as Percent of Benchmark (%)



Policy Actions

Areas	Actions and Policies
Carbon Productivity	▪ National Integrated Support Reform Pilot Areas ▪ Ecological Conservation Performance Assessment Mechanism ▪ Promotion of upgrading traditional industries ▪ Development of circular economy and green industries
Energy	▪ Low proportion of coal in total energy consumption, and primarily used for electricity ▪ Carbon Trading System
Industry	▪ Elimination of energy-consuming, highly-polluting and backward production capacity, gradually forming an energy-saving and high-tech industry-based industrial structure ▪ Energy consumption statistics and carbon labeling system for per unit industrial products
Construction	▪ Shenzhen Special Economic Zone Regulations on Construction-Related Energy Conservation ▪ Shenzhen Municipality Provisions on Promotion of Green Buildings
Transportation	▪ Five-Year Implementation Plan on building an international-level Transit Metropolis
Environmental condition and land use	▪ Shenzhen Atmospheric Environmental Quality Improvement Plan ▪ Shenzhen Municipal Solid Waste Classification and Reduction Implementation Plan (2015-2020)
Low-carbon policies	▪ Establishment of Shenzhen Municipal Climate Change, Energy Conservation and Emission Reduction Leading Group (led by the mayor, with cooperation between different divisions) ▪ Provisions on Carbon Emissions Management of the Shenzhen Special Economic Zone ▪ Shenzhen Mid- and Long-Term Low-Carbon Development Plan (2011-2020) ▪ Shenzhen Low-Carbon Pilot City Implementation Plan ▪ Interim Measures for the Administration of Shenzhen Carbon Emissions Trading

Case Study: Wenzhou

Basic Information

Wenzhou is located on China's southeast coast in Zhejiang province, in the Yangtze River Delta region and the West Taiwan Straits Economic Zone. It is now in the late stage of industrial development. The city's administrative area is 12,065.77 km². As one of Zhejiang's three major cities, Wenzhou had a resident population of 9,117,000 in 2015 (the population density was 755.61 per km²), with an urbanization rate of 68.0%. In 2015, the city's GDP was 461.984 billion yuan, with per capita GDP, of 50,809 yuan (equivalent to US$8,158 at 2015's average exchange rate). In 2015, the industrial ratio was 2.7: 45.5: 51.8, with manufacturing dominating the economy.

Wenzhou Basic Data

Province	zhejiang	
Population in 2015	9,117,000	[people]
Administrative Area	12,065	[km²]
Population Density	756	[ppl/km²]
GDP per Capita	50,809	[RMB]
Urbanization Rate	68	[%]
Industrial Structure	primary: 2.7% secondary: 45.5% tertiary: 51.8%	

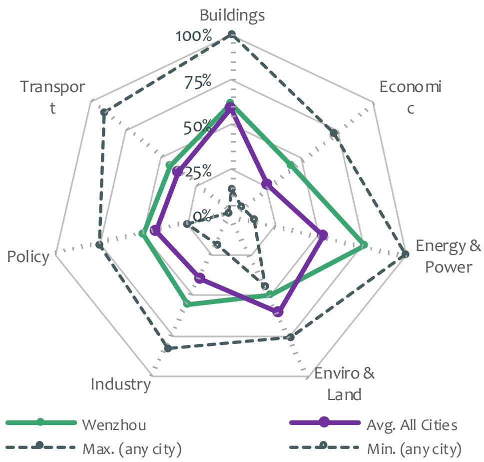
Performance in LOGIC Index

Wenzhou City ranked fourth on the green low carbon index in T cities (15th in all sample cities). From the performance of sub-indicators, apart from carbon production, energy and industrial scores, which are all above average, other indicators varied above and below the average. Sub-indicator rankings are as follows: 3rd in carbon production (11th in total), 5th in energy (21st in total), 10th in industry (16th in total), 27th in traffic (43rd in total), 18th in construction (42nd in total), and 54th in environmental and green conditions (107th in total). Generally speaking, Wenzhou performed well in the carbon production, energy and industrial sectors, but lagged behind in terms of the environment. Although Wenzhou's industrial structure depends heavily on the chemical industry, this is still based mainly on processing and manufacturing, which explains why its industrial energy consumption is relatively low, and why it ranks high in the index. As a low-carbon pilot city, Wenzhou has made the most of its low-carbon actions and policies under the national low-carbon system framework during the 12th FYP period.

Wenzhou LOGIC Performance

Overall LOGIC Score	54.8
Overall Rank	15
LOGIC Change: 2010 to 2015, %	27%
Economic Group	Group T
Size Group	Very Large
Region	East
LC Pilot Status	Pilot City

Category Scores, as Percent of Benchmark (%)



Policy Actions

Areas	Actions and Policies
Carbon Productivity	▪ Wenzhou 12th Five-Year Plan on Promoting the Development of Emerging Sectors of Strategic Importance
Energy	▪ "Double control" management on total energy consumption and energy consumption per unit of GDP ▪ Energy-saving management of key energy-using units ▪ Elimination work of "five furnace" highly-polluting fuels ▪ Ultra-low emission transformation of large coal-fired units ▪ Reduction of scattered coal consumption
Industry	▪ Elimination of backward production capacity
Construction	▪ Energy conservation reconstruction of existing buildings ▪ Renewable energy applications in construction ▪ Green building development
Transportation	▪ Large-capacity public transport skeleton dominated by urban rail transit
Environmental condition and land use	▪ Wenzhou Air Pollution Control Implementation Plan (2014-2017)
Low-carbon policies	▪ Wenzhou 12th Five-Year Plan on Developing a Low-Carbon Economy and Combating Climate Change (2011-2015) ▪ Wenzhou Implementation Plan on Low-Carbon City Pilot Work ▪ Low-Carbon City Special Funds

Case Study: Ganzhou

Basic Information

Ganzhou is an economically underdeveloped and agriculture-dependent city. Located in the south of Jiangxi Province, its administrative area is 2,993 km^2, with a population density of 3,209 per km^2. Ganzhou's GDP was 197.387 billion yuan in 2015, 23,148 yuan per capita, which is lower than the national average. Its industrial structure has been showing a trend towards a shrinking primary sector, a stable secondary sector, and an expanding tertiary sector. The ratio was 18.9: 44.4: 36.7 in 2010 and 15: 44.1: 40.9 in 2015. The resident population in 2015 was 9.6063 million people. The urbanization rate was 45.51%, lower than the national average.

Ganzhou Basic Data

Province	Jiangxi	
Population in 2015	9,606,300	[people]
Administrative Area	2,993	[km^2]
Population Density	3,209	[ppl/km^2]
GDP per Capita	23,148	[RMB]
Urbanization Rate	46	[%]
Industrial Structure	primary: 15% secondary: 44.1% tertiary: 40.9%	

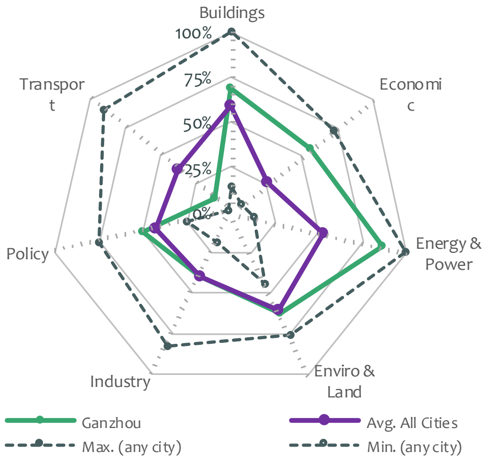
Performance in LOGIC Index

Ganzhou ranked third on the green low-carbon index among I-class cities (sixthth in all sample cities). From the performance of sub-indicators, apart from carbon production and energy, which are above average, and transportation, which was below average, other indicators varied above and below the average of sample cities. Sub-indicators in detail are: First in carbon production (3rd in total), 6th in energy (6th in total), 17th in industry (46th in total), 44th in transportation (108th in total), 6th in construction (24th in total), and 22nd in environmental and green conditions (45th in total).

Ganzhou LOGIC Performance

Overall LOGIC Score	57.5
Overall Rank	6
LOGIC Change: 2010 to 2015, %	17%
Economic Group	Group I
Size Group	Large
Region	Central
LC Pilot Status	Pilot City

Category Scores, as Percent of Benchmark (%)



Policy Actions

Areas	Actions and Policies
Carbon Productivity	▪ Ganzhou Development Plan for a Modern Service Industry (2011-2020) ▪ Ganzhou Municipal Government's Views on Promoting the Development of the Service Industry ▪ Interim Measures for Ganzhou Carbon Trading (Trial)
Energy	▪ The first batch of National New Energy Demonstration Cities and Green Energy Demonstration Counties Implementation Zones ▪ Ganzhou Development Plan on New Energy Demonstration Cities (2012-2015) ▪ Ganzhou Special Plan on the Use of Natural Gas
Industry	▪ Elimination of backward production capacity
Construction	▪ Energy conservation reconstruction of existing buildings ▪ Renewable energy applications in construction ▪ Green building development
Transportation	▪ Low investment in public transportation infrastructure due to limited government fiscal budget
Environmental condition and land use	▪ Promulgation and implementation of the Air Pollution Prevention & Control Implementation Plan
Low-carbon policies	▪ Ganzhou Low-Carbon Development Action Plan ▪ Ganzhou Low-Carbon Development Plan (2013-2020)

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Chapter 7. Conclusions and Next Steps for LOGIC

The China Low-carbon & Green Index for Cities (LOGIC) is a new city indicator system to measure and track the green and low carbon transition in Chinese cities. LOGIC builds off of existing international and domestic-Chinese city indicator systems; but it is designed to more fully reflect the green and low-carbon objectives and priorities in Chinese cities, using publicly-available statistics and data. LOGIC gives a composite score ranging from 0 to 100, made up of values from 23 green and low-carbon indicators, grouped into seven index categories: Energy & Power, Industry, Buildings, Transport, Economic Dimension, Environment & Land Use, and Policy & Outreach.

This report details the analysis and results of the 2015 LOGIC scores. In this study, data from 115 Chinese cities was collected and analyzed. The 115 cities in the project sample represent a diverse range and were categorized into five different groupings to compare cities and find patterns and insights from with similar attributes. The city groupings include: Economic Groups, Size Groups, Geographic Regions, Functional Development Zones, and Low Carbon Pilot groups.

The individual cities and groups of cities were analyzed and compared based on performance data from 2015, as well as their change in performance from 2010 to 2015. Results from the LOGIG analysis provide interesting and important insights informing city leaders and policy makers on the current progress and future prospects of Chinese cities' green and low-carbon transition.

A summary of the key findings from this report include:

- ***China's cities are getting greener*** – overall LOGIC scores in Chinese cities increased by 6.6% from 2010 to 2015.
- ***Green and Low-Carbon city improvement does not have to come at the expense of GDP*** – 90 out of 115 cities in the sample saw both GDP growth and LOGIC score growth from 2010 to 2015. And two clusters of cities in the sample stood out as having particularly impressive GDP and LOGIC score growth.
- ***China's low-carbon pilots are leading*** – the 54 pilot cities included in this study, on average, had higher LOGIC scores in 2015 than non-pilot cities, and the LOGIC score growth rate from 2010 to 2015 was faster for China's low-carbon pilot cities.
- ***Cities of all types can be top performers*** – LOGIC results consistently showed a diverse mix of cities achieving top scores in the overall index, and in each of the seven index categories. No matter a city's size, geographic location, or economic development, there are top performers who showcase best policies for China's green and low-carbon urban transition.
- ***Large (but not too large) cities, and post-industrial cities are greener*** – LOGIC results show that cities with larger populations have higher overall index scores – except for the largest mega-cities, where scores decrease with increasing population. Also, cities at the post industrialization stage show a decoupling between economic growth and carbon & pollution emissions. Therefore, the largest cities will need special policy attention, and an important aim will be focusing on how to improve the performance of more industrialized cities as they transition and grow.
- ***There is still room for improvement, and LOGIC can provide an important tool*** – the average overall LOGIC score across all Chinese cities is 44.9 out of 100, so Chinese cities still have room to improve. LOGIC as a tool, provides a useful framework and evaluation methodology for measuring and tracking green and low-carbon performance over time.
- ***Particularly important areas of focus need to be Energy & Power, Industry, and Economic structure*** – especially as cities grow larger and wealthier the policies and actions in LOGICs energy, economic, and industry categories make more of a difference between top performing and other cities.
- ***The Environment & Land Use category also needs special attention*** – this was the only category to have an overall decrease in scores from 2010 to 2015. Rapid urbanization in China has come with the cost of severe environmental degradation; and these well-known challenges (air quality, water pollution, etc.) will need a new focus on implementation of policies and the right political and economic structures to reverse this trend.

These are promising results overall. China's cities are getting greener, and there are compelling examples of how green urban development does not have to come at the expense of economic development. In order to continue this progress and further promote the best green and low-carbon lessons for cities in China, this report outlines these recommendations and next steps:

Recommendations

- Chinese cities should continue to use LOGIC as a framework for planning, measuring, and tracking performance.
- Green and low-carbon policies should be tailored to the economic development stage of the city; and LOGIC can be used to find best practices and actions to follow from other cities in any economic group, size group, or geographic region

- Political leadership has proven to be decisive in china's green and low-carbon performance (especially in pilot cities); however, political will and commitments need real actions and follow through.
- Mega cities need special attention. While for most cities, as population increases, their overall LOGIC scores also were higher; for cities above 11 million people, the opposite was true: larger populations correlated with lower LOGIC scores. Special attention needs to be given to a different set of policies and actions to avoid this trend.
- The LOGIC results are only a starting point. Cities next need to develop solid action plans for green and low-carbon transformation. The priorities, and options for pathways can be informed by LOGIC results and comparison of a city's strengths and gaps with other top performing cities in the index.
- The critical steps to turn political will into action will be for city leaders and policymakers to prepare integrated low-carbon action plans, coupled with robust policy implementation and social-economic analysis that support decision-making and concrete action.

Next Steps

Looking forward, LOGIC aims to provide ongoing and timely analysis through updates of the city database and city index scores. Furthermore, deeper analysis efforts and special case studies can help to bring more insights and recommendations from the city performance data. Our team also has plans to extend access to LOGIC by developing an interactive online tool – which will use the LOGIC methodology and datasets to help cities benchmark their progress, and learn from their peers to identify new, feasible green and low-carbon actions. It is hoped that policymakers will use the LOGIC tool to assist their work; and LOGIC can benefit from feedback and design improvements based on real world needs and practical experience. Our goal is to help all cities in China to transit to a green and low carbon future, and potentially provide lessons for other developing cities around the world.

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Annex A: List of City Group Assignments

City Name	Province	Economic Group	Size Group	Region	LC Pilot Status	Functional Zone
Anshan	Liaoning	Group T	Large	Northeast	Low Carbon Pilot	Optimized Devp't Zone
Baoding	Hebei	Group I	Large	East	Low Carbon Pilot	Key Devp't Zone
Baotou	Inner Mongolia	Group T	Large	West	Non-Pilot	Key Devp't Zone
Beijing	Beijing	Group P	Mega	East	Low Carbon Pilot	Optimized Devp't Zone
Bengbu	Anhui	Group I	Large	Central	Non-Pilot	Key Devp't Zone
Benxi	Liaoning	Group T	Large	Northeast	Low Carbon Pilot	Optimized Devp't Zone
Changchun	Jilin	Group T	Large	Northeast	Non-Pilot	Key Devp't Zone
Changde	Hunan	Group I	Large	Central	Non-Pilot	Key Devp't Zone
Changsha	Hunan	Group T	Very Large	Central	Non-Pilot	Key Devp't Zone
Changzhou	Jiangsu	Group T	Large	East	Non-Pilot	Optimized Devp't Zone
Chengdu	Sichuan	Group T	Mega	West	Non-Pilot	Key Devp't Zone
Chifeng	Inner Mongolia	Group I	Large	West	Non-Pilot	Key Devp't Zone
Chizhou	Anhui	Group I	Medium/Small	Central	Low Carbon Pilot	Optimized Devp't Zone
Chongqing	Chongqing	Group T	Mega	West	Low Carbon Pilot	Key Devp't Zone
Dalian	Liaoning	Group P	Very Large	Northeast	Low Carbon Pilot	Optimized Devp't Zone
Daqing	Heilongjiang	Group T	Large	Northeast	Non-Pilot	Key Devp't Zone
Datong	Shanxi	Group I	Large	Central	Non-Pilot	Key Devp't Zone
Dongguan	Guangdong	Group T	Very Large	East	Low Carbon Pilot	Optimized Devp't Zone
Foshan	Guangdong	Group T	Very Large	East	Low Carbon Pilot	Optimized Devp't Zone
Fushun	Liaoning	Group T	Large	Northeast	Low Carbon Pilot	Optimized Devp't Zone
Fuzhou	Fujian	Group T	Very Large	East	Non-Pilot	Key Devp't Zone
Ganzhou	Jiangxi	Group I	Large	Central	Low Carbon Pilot	Key Devp't Zone
Guangyuan	Sichuan	Group I	Large	West	Low Carbon Pilot	Key Devp't Zone
Guangzhou	Guangdong	Group P	Mega	East	Low Carbon Pilot	Optimized Devp't Zone
Guilin	Guangxi	Group I	Large	West	Low Carbon Pilot	Key Devp't Zone
Guiyang	Guizhou	Group T	Large	West	Low Carbon Pilot	Key Devp't Zone
Haikou	Hainan	Group T	Large	East	Low Carbon Pilot	Key Devp't Zone
Handan	Hebei	Group I	Large	East	Non-Pilot	Key Devp't Zone
Hangzhou	Zhejiang	Group P	Very Large	East	Low Carbon Pilot	Optimized Devp't Zone
Harbin	Heilongjiang	Group T	Very Large	Northeast	Non-Pilot	Key Devp't Zone
Hefei	Anhui	Group T	Very Large	Central	Non-Pilot	Optimized Devp't Zone
Hengyang	Hunan	Group I	Large	Central	Non-Pilot	Key Devp't Zone
Huai'an	Jiangsu	Group T	Large	East	Low Carbon Pilot	Key Devp't Zone
Huaibei	Anhui	Group I	Large	Central	Non-Pilot	Key Devp't Zone
Huai'nan	Anhui	Group I	Large	Central	Non-Pilot	Key Devp't Zone
Huangshi	Hubei	Group I	Large	Central	Low Carbon Pilot	Key Devp't Zone
Huhhot	Inner Mongolia	Group T	Large	West	Non-Pilot	Key Devp't Zone
Huizhou	Guangdong	Group T	Large	East	Low Carbon Pilot	Optimized Devp't Zone
Hulunbuir	Inner Mongolia	Group I	Large	West	Low Carbon Pilot	Key Devp't Zone
Jiangmen	Guangdong	Group I	Large	East	Low Carbon Pilot	Optimized Devp't Zone
Jieyang	Guangdong	Group I	Large	East	Low Carbon Pilot	Key Devp't Zone
Jilin	Jilin	Group I	Large	Northeast	Low Carbon Pilot	Key Devp't Zone
Jinan	Shandong	Group T	Large	East	Non-Pilot	Optimized Devp't Zone
Jinchang	Gansu	Group I	Medium/Small	West	Low Carbon Pilot	Key Devp't Zone
Jincheng	Shanxi	Group I	Large	Central	Low Carbon Pilot	Key Devp't Zone
Jingdezhen	Jiangxi	Group I	Large	Central	Low Carbon Pilot	Key Devp't Zone
Jining	Shandong	Group I	Large	East	Non-Pilot	Key Devp't Zone
Jinzhou	Liaoning	Group I	Large	Northeast	Low Carbon Pilot	Optimized Devp't Zone
Kaifeng	Henan	Group I	Large	Central	Non-Pilot	Key Devp't Zone
Kunming	Yunnan	Group T	Large	West	Low Carbon Pilot	Key Devp't Zone
Laiwu	Shandong	Group I	Medium/Small	East	Non-Pilot	Key Devp't Zone
Lanzhou	Gansu	Group T	Large	West	Non-Pilot	Key Devp't Zone
Linyi	Shandong	Group T	Very Large	East	Non-Pilot	Key Devp't Zone
Liuzhou	Guangxi	Group T	Large	West	Non-Pilot	Key Devp't Zone
Luoyang	Henan	Group I	Large	Central	Non-Pilot	Key Devp't Zone

Luzhou	Sichuan	Group I	Large	West	Non-Pilot	Key Devp't Zone
Mianyang	Sichuan	Group I	Large	West	Non-Pilot	Key Devp't Zone
Nanchang	Jiangxi	Group T	Large	Central	Low Carbon Pilot	Key Devp't Zone
Nanchong	Sichuan	Group I	Large	West	Non-Pilot	Key Devp't Zone
Nanjing	Jiangsu	Group P	Very Large	East	Non-Pilot	Optimized Devp't Zone
Nanning	Guangxi	Group I	Large	West	Non-Pilot	Key Devp't Zone
Nanping	Fujian	Group I	Large	East	Low Carbon Pilot	Key Devp't Zone
Nantong	Jiangsu	Group T	Large	East	Non-Pilot	Optimized Devp't Zone
Nanyang	Henan	Group I	Large	Central	Non-Pilot	Key Devp't Zone
Neijiang	Sichuan	Group I	Large	West	Non-Pilot	Key Devp't Zone
Ningbo	Zhejiang	Group T	Very Large	East	Low Carbon Pilot	Optimized Devp't Zone
Pingdingshan	Henan	Group I	Large	Central	Non-Pilot	Key Devp't Zone
Qingdao	Shandong	Group T	Large	East	Low Carbon Pilot	Optimized Devp't Zone
Qinhuangdao	Hebei	Group I	Large	East	Low Carbon Pilot	Optimized Devp't Zone
Qiqihar	Heilongjiang	Group I	Large	Northeast	Non-Pilot	Key Devp't Zone
Quanzhou	Fujian	Group T	Very Large	East	Non-Pilot	Key Devp't Zone
Shanghai	Shanghai	Group P	Mega	East	Low Carbon Pilot	Optimized Devp't Zone
Shangqiu	Henan	Group I	Large	Central	Non-Pilot	Key Devp't Zone
Shantou	Guangdong	Group T	Large	East	Low Carbon Pilot	Key Devp't Zone
Shaoxing	Zhejiang	Group T	Large	East	Non-Pilot	Optimized Devp't Zone
Shenyang	Liaoning	Group T	Very Large	Northeast	Low Carbon Pilot	Optimized Devp't Zone
Shenzhen	Guangdong	Group P	Mega	East	Low Carbon Pilot	Optimized Devp't Zone
Shijiazhuang	Hebei	Group T	Very Large	East	Low Carbon Pilot	Key Devp't Zone
Suqian	Jiangsu	Group I	Large	East	Non-Pilot	Key Devp't Zone
Suzhou	Jiangsu	Group T	Very Large	East	Low Carbon Pilot	Optimized Devp't Zone
Taiyuan	Shanxi	Group T	Large	Central	Non-Pilot	Key Devp't Zone
Taizhou	Jiangsu	Group T	Large	East	Non-Pilot	Optimized Devp't Zone
Taizhou	Zhejiang	Group T	Large	East	Non-Pilot	Optimized Devp't Zone
Tangshan	Hebei	Group T	Large	East	Non-Pilot	Optimized Devp't Zone
Tianjin	Tianjin	Group P	Mega	East	Low Carbon Pilot	Optimized Devp't Zone
Urumuqi	Xinjiang	Group T	Large	West	Low Carbon Pilot	Key Devp't Zone
Weifang	Shandong	Group T	Very Large	East	Non-Pilot	Optimized Devp't Zone
Wenzhou	Zhejiang	Group T	Very Large	East	Low Carbon Pilot	Key Devp't Zone
Wuhan	Hubei	Group P	Very Large	Central	Low Carbon Pilot	Key Devp't Zone
Wuhu	Anhui	Group T	Large	Central	Non-Pilot	Optimized Devp't Zone
Wuwei	Gansu	Group I	Medium/Small	West	Non-Pilot	Key Devp't Zone
Wuxi	Jiangsu	Group T	Large	East	Non-Pilot	Optimized Devp't Zone
Xia'men	Fujian	Group P	Large	East	Low Carbon Pilot	Key Devp't Zone
Xi'an	Shanxi	Group T	Very Large	West	Low Carbon Pilot	Key Devp't Zone
Xiangyang	Hubei	Group T	Large	Central	Low Carbon Pilot	Key Devp't Zone
Xianyang	Shanxi	Group I	Large	West	Low Carbon Pilot	Key Devp't Zone
Xingtai	Hebei	Group I	Large	East	Non-Pilot	Key Devp't Zone
Xi'ning	Qinghai	Group T	Large	West	Non-Pilot	Key Devp't Zone
Xuzhou	Jiangsu	Group T	Large	East	Non-Pilot	Key Devp't Zone
Yan'an	Shanxi	Group I	Large	West	Low Carbon Pilot	Key Devp't Zone
Yancheng	Jiangsu	Group T	Large	East	Non-Pilot	Optimized Devp't Zone
Yangzhou	Jiangsu	Group T	Large	East	Non-Pilot	Optimized Devp't Zone
Yantai	Shandong	Group T	Large	East	Non-Pilot	Optimized Devp't Zone
Yichang	Hubei	Group T	Large	Central	Low Carbon Pilot	Key Devp't Zone
Yinchun	Ningxia	Group T	Large	West	Non-Pilot	Key Devp't Zone
Yingkou	Liaoning	Group T	Large	Northeast	Low Carbon Pilot	Optimized Devp't Zone
Zaozhuang	Shandong	Group I	Large	East	Non-Pilot	Key Devp't Zone
Zhangjiakou	Hebei	Group I	Large	East	Non-Pilot	Optimized Devp't Zone
Zhanjiang	Guangdong	Group I	Large	East	Low Carbon Pilot	Key Devp't Zone
Zhengzhou	Henan	Group T	Very Large	Central	Non-Pilot	Key Devp't Zone
Zhenjiang	Jiangsu	Group T	Large	East	Low Carbon Pilot	Optimized Devp't Zone
Zhuzhou	Hunan	Group T	Large	Central	Non-Pilot	Key Devp't Zone
Zibo	Shandong	Group T	Large	East	Non-Pilot	Optimized Devp't Zone
Zigong	Sichuan	Group I	Large	West	Non-Pilot	Key Devp't Zone
Zunyi	Guizhou	Group I	Large	West	Low Carbon Pilot	Key Devp't Zone

China LOGIC Index

Low-Carbon & Green Index for Cities (LOGIC)

"LOGIC" is a new city index system and analytical tool designed to measure and inform China's progress on improved solutions for low-carbon and green development, including goals around clean energy and early carbon peaking.

LOGIC provides policymakers, researchers and investors in the fields of energy, environment, and low carbon planning to evaluate and track the progress and prospects for China's transition to greener cities.

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About innovative Green Development Program

iGDP's advances innovative policies and actions to promote green growth at the subnational level. We create analytical tools, share professional knowledge, and facilitate multidisciplinary dialogues that foster integrated solutions for regions, cities and communities. To tackle the challenge of climate change, we find solutions at the intersection between the economy, environment and energy, and look for innovations in policy and business. iGDP was launched with funding and operational support from Energy Foundation China. iGDP is the executing agency of the Green and Low Carbon Development Think Tank Partnership and committee member of Green Finance Committee of the China Society for Finance and banking. ***http://new.igdp.cn/***

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Founded in 1988, Lawrence Berkeley National Laboratory's China Energy Group works collaboratively with researchers in China and around the world to understand the dynamics of China's energy use. Our research focuses on the analysis of energy use and related emissions trends, technologies, and policies focusing on China's cities, buildings, appliances, industry, transportation, and power sectors to produce scientific data and analyses that informs researchers and policymakers in the U.S., China, and globally. ***https://china.lbl.gov/***

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