CHINA SUSTAINABLE DEVELOPMENT INDICATOR SYSTEM

2017 REPORT

THE EARTH INSTITUTE
COLUMBIA UNIVERSITY

CCIEE
中国国际经济交流中心
CHINA CENTER FOR INTERNATIONAL ECONOMIC EXCHANGES

China Sustainable Development Indicator System: 2017 Report

July 2017

Prepared by:

The Research Program on Sustainability and Management at the Earth Institute, Columbia University

& The China Center for International Economic Exchanges (CCIEE)

Authors:

- Dr. GUO Dong, Director of the Earth Institute China Initiative, Associate Director of the Research Program on Sustainability Policy and Management, Associate Research Scholar, the Earth Institute
- Kelsie DeFrancia, Assistant Director of the Research Program on Sustainability Policy and Management
- Dr. Satyajit Bose, Associate Director of Columbia's Master of Science in Sustainability Management, Associate Director of the Research Program on Sustainability Policy and Management
- Alison Miller, Deputy Director of Management, the Earth Institute
- Hayley Martinez, Program Manager, the Earth Institute
- WANG Jun, Director General, Department of Information, Research Fellow, CCIEE
- ZHANG Huanbo, Director, Department of Economic Research, Associate Research Fellow, CCIEE
- LIU Xiangdong, Deputy Director, Department of Economic Research, Associate Research Fellow, CCIEE

Project Advisors:

- Dr. Steven Cohen, Executive Director of the Earth Institute, Columbia University
- ZHANG Dawei, Vice Chairman and Secretary General, China Center for International Economic Exchanges

Research assistance provided by: WU Minyi, SONG Mingyuan, WANG Jia, YAN Xinjia, QIN Yu, GAO Juan, Sylricka Foster, Zenia Montero, QIN Ling, and WU Shuangshuang

The Earth Institute's Research Program on Sustainability Policy and Management is focused on building a research base to apply to real-world sustainability issues, with an emphasis on analysis at the organizational level. We seek to address the fundamental challenges facing professionals and policy makers implementing sustainability strategies and provide the data necessary for decision making. Our research cuts across sectors, geographies, and industries.

The China Center for International Economic Exchanges (CCIEE) is China's leading think tank aimed at promoting international economic research and exchanges and providing consulting services. CCIEE combines the expertise of political officials, business leaders, and academics.

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I. Introduction

Sustainability has emerged as means of addressing interconnected and complex global issues, and sustainable development is now a widely-recognized goal among nations across the globe. Reducing emissions and promoting global environmental sustainability is a shared responsibility of all countries, but China's contribution is particularly important. Although the Chinese government has worked to establish a sustainable strategy for its development, the sheer pace of China's economic growth makes it a difficult task, and a standardized system to measure and manage sustainability is needed in order to seriously assess progress. To meet this need, a new sustainability indicator framework contingent on China's unique economic development status is necessary.

Columbia University's Earth Institute and the China Center for International Economic Exchanges have developed the China Sustainable Development Indicator System (CSDIS), a ranking system that compares the sustainability performance of Chinese cities. Utilizing an integrated approach, which categorizes indicators by subject area while also considering the causal relationship among the fields, we have designed a robust new sustainability metrics framework and indicator set that covers the economic, environmental, social and institutional aspects of sustainability for Chinese cities. The research team has incorporated research and comparative analyses of existing frameworks in China and internationally, developing a framework comprised of five subject areas: 1) Economic Development, 2) Social Welfare and Livelihood, 3) Environmental Resources, 4) Consumption and Emissions, and 5) Environmental Management. Based on a total of 24 indicators within these categories, we ranked 69 Chinese cities on their sustainability performance. Our goal is that this framework and ranking will be used to help Chinese cities progress towards their sustainable development goals by showing how each individual city performs in various realms of sustainability compared to other cities and, through encouraging healthy competition and development that is not solely focused on GDP growth, help create an overall more sustainable China.

II. Background: Sustainability Metrics

Currently, sustainability indicators lack general acceptance, due first and foremost to the ambiguous definition of sustainability itself. While many take the term to mean environmental inputs and impacts, sustainability has come to include various social and governance factors as well. Sustainability has also been used to describe the "triple bottom line," or environmental, social, and economic factors. These broad definitions of sustainability indicators leave decision makers at a disadvantage as they try to navigate what to measure and manage to improve their sustainability performance. Existing work on sustainability metrics ultimately suffers from not being fully reflective of all aspects of sustainability, a lack of parsimony, and a consequent lack of broad consensus (Dahl 2012). In the long-term, we hope that sustainability indicators will be incorporated into traditional sets of urban and organizational performance measures. However, before that can happen, consensus must be achieved on a set of metrics for sustainability.

Although the concept of sustainable development has been widely accepted in China, the use of sustainability metrics is still in an early stage. Similar to what we see in the U.S., due to the lack of a clear definition of the number and applicability of the sustainability metrics that should be used, Chinese governments and private entities have a great deal of flexibility in choosing indicators, which impedes meaningful comparison on sustainability performance. This also makes it harder for decision makers to evaluate and compare the sustainability performance of different organizations, and to provide clear and standardized policy directives. A standardized and mature set of sustainability indicators and a governing framework for measuring those metrics are therefore needed in order to track, measure, and report on the progress of China's sustainable development and economic transformation. Consensus building is the hallmark of Chinese-style decision-making, making it important to achieve standardization in a country with a strong governmental and hierarchical culture.

Sustainability indicators will both guide the management of the Chinese economy and incentivize the implementation of environmental policies. These sustainability indicators must be able to define quality, evaluate both the impacts and challenges of sustainability policies, and allow for comparisons to be made across municipalities and regions. Cities play an integral role in reaching and achieving national environmental sustainability goals. Not only do city officials have fewer hurdles to overcome in passing legislation, but citizens may feel more motivated to act at the local level – the level at which they see and feel environmental impacts most profoundly. Perhaps the most compelling reason why cities have an important role to play when it comes to reaching sustainability milestones is that cities are largely responsible for the environmental issues that we see today; the rapid growth of cities (both in population and in size) results in a tremendous ecological footprint. The framework described here is based on the belief that the most reasonable way to reach national sustainable goals is to start at the city level.

III. China Sustainable Development Indicator System

The China Sustainable Development Indicator System (CSDIS) ranks 69 large and medium-sized cities based on their sustainability performance from 2013 to 2016. Our framework is comprised of 24 indicators representing five categories of sustainable development: 1) Economic Development, 2) Social Welfare and Livelihood, 3) Environmental Resources, 4) Consumption and Emissions, and 5) Environmental Management.

Our methodology is built upon the following principles:

1. Transparency: All indicators and sources are documented, as well as the weighting method, so that the most rigorous scientific standards of replicability are maintained.
2. Rules-based Data Integrity Checks: All source data is statistically reviewed for unusual fluctuations and a significant portion of all data is manually checked to multiple sources. Where there exist concerns about data integrity, specific indicators and/or cities are excluded from the ranking system.
3. Evidence-Based Weighting Methodology: Neither indicators nor categories of indicators are pre-assigned any weights. Indicator weights are determined by utilizing a 7-year history of indicator performance to estimate the cross-sectional and longitudinal variability of each indicator. Indicators which tend to be stable over time and display low cross-sectional variability are assigned statistically determined low weights since these indicators do not change much and have low power to differentiate across cities. Indicators which tend to be stable over time but which nevertheless demonstrate significant cross-

sectional variation (i.e. greater ability to differentiate between cities) are given lower weight in the index composition; these indicators measure characteristics of sustainability which are difficult for any particular city to change. A ranking that overweights such indicators would unfairly penalize cities with fixed characteristics. The weighting algorithm searches for indicators where cross-sectional rank fluctuation is possible but difficult, and shifts weight onto indicators which have high longitudinal variability within a city, provide discriminatory power, and are demonstrably possible to change for any given city.

4. Ordinality of Ranking: The ranking system does not assign a composite score to any city. It does not purport to suggest that city A is 1.5 times more sustainable than city B.
5. Non-parametric Approach: Wherever possible, our methodology eschews prior assumptions about the joint distribution of the indicators.

i. Framework Development

To develop the CSDIS, we began by conducting an extensive review of existing major international frameworks for aggregating multi-category sustainability performance indicators proposed by selected multilateral agencies, non-governmental organizations, and private corporations (presented in Appendix I).

The aggregation methodology of these frameworks vary considerably in terms of the cardinality assigned to scores, the weighting accorded to different categories of indicator, as well as the underlying emphasis of goal measurement. Many index systems are not transparent about the actual weights used, and when they are transparent, there is no justification for the choice of weights. Additionally, many ranking systems are not confined to ranking, but also purport to score cities, thereby implicitly propagating an untested distance metric in city comparisons. For example, take a city sustainability index that produces a score, which is a sum of the city's performance in multiple categories. Since each city receives a score, the implication is that a city with a score of 1500 is 50% better than a city with a score of 1000. However, the score is an artefact of the underlying variability and joint cross-sectional distribution of the composite indicators chosen. Increasing the weight of an indicator that has a high cross-sectional standard deviation will widen the range of composite scores, and shift rankings. A transparent methodology that ensures that statistically noisy indicators have lower weights in the overall index composition is crucial. Other frameworks assume that each category and/or each indicator must carry equal weight. While this approach seems agnostic with respect to emphasis on different aspects of sustainability, in reality, the choice of category and/or indicator effectively determines the weights without any scientific basis. Finally, some frameworks do not reveal the underlying weights, simply listing a range of categories and indicators that comprise the index.

Our methodology and underlying principles were designed to address the aforementioned issues by developing an innovative indicator system that takes into account the volatility of data across time and geographic location, which most existing urban sustainability indicator systems do not.

In defining the indicator categories for our framework (economic development; social welfare and livelihood; environmental resources; consumption and emissions; and environmental management), we began with the widely accepted "triple bottom line" of economic, social, and environmental classifications that many of these systems use. However, we also felt that given the myriad environmental problems China faces, it is important to make a nuanced distinction between the available stock of environmental resources and the flow of those resources, and their implications in the form of consumption and emissions. We added a fifth distinct category of environmental management since China has set ambitious environmental protection and conservation targets, and has also made tremendous efforts in combating environmental degradation.

ii. Data Collection

We began by collecting data for 87 candidate indicators for the CSDIS, which represented a wide range of the most common elements of sustainable development. The first round of data collection began in June 2016, collecting data for those 87 indicators across 70 cities from 2009 to 2014. The second round of data collection began in January 2017, collecting data for the year 2015.

The data for these indicators was gathered from China National Knowledge Infrastructure (CNKI), CEIC China Premium Database, and the Economy Prediction System (EPS), described below. In the second round, to double check the data reporting accuracy and update data for the year of 2015, we also manually searched Statistical Yearbooks at national, provincial, and city levels, journals and other review articles.

Data Sources

- China National Knowledge Infrastructure (CNKI): CNKI is a project that was first launched in 1996 by Tsinghua University and Tsinghua Tongfang Company. It serves as the key national information construction project, and is supported by China's Ministry of Education, Ministry of Science, the Communication Department of the Communist Party of China, and the General Administration of Press and Publication. Since 1999, CNKI has developed online databases, and it continues to build a comprehensive China Integrated Knowledge Resources System, which includes journals, doctoral dissertations, master's theses, proceedings, newspapers, yearbooks, statistical yearbooks, e-books, patents, and standards. CNKI has become the largest and most-used academic online library in China. It gives access to the full-text China Academic Journals database (including full-text articles from over 2,000 journals from first issue to date), and most of the Statistical Yearbooks at national, provincial, and city levels used in our study (TTKN 2014).

- CEIC China Premium Database: This database is product of the CEIC Data founded in 1992 as part of the Euromoney Institutional Investor group. It provides statistics on over 300,000 time-series records on macroeconomic, performance of various sectors and industries in China. It also offers selected datasets such as natural resources, environmental protection, and finance (CEIC 2017).

- Economy Prediction System (EPS): The database, founded in 2008, includes over 40 sub-databases categorized by region and industry, covering various topics in economic, development, and culture in China. It has been widely used by universities such as Harvard University and Hong Kong Chinese University, financial companies, governments, etc. Our study extracts data from the China City Database, one of the sub-databases of EPS, which uses primary data from the Chinese National Statistics Bureau. It has offered social and economic data for 314 cities in China since 1984 (EPS Data 2017).

iii. Data Synthesis

After the completion of the first round of data collection, we refined our 87 candidate indicators to create a more consistent indicator system that was adjusted for exogenous contextual factors such as disturbances from economic crises and natural disasters. Moreover, we called on opinions of recognized experts to select indicators that could reflect the most common problems in the process of urban development, including environmental degradation, heavy reliance on natural resources, affordability, congestion, etc. We also refined our indicator set based on data availability and the reliability of data sources. In this process, the research team had to remove one city, Dali, from an initial list of 70 cities due to data challenges.

This resulted in our final framework comprised of 24 indicators in the five categories of 1) Economic Development, 2) Social Welfare and Livelihood, 3) Environmental Resources, 4) Consumption and Emissions, and 5) Environmental Management, presented in Table 1 below. A full definition of each indicator, its calculation, data source, and policy relevance is found in Appendix II.

In total, we compiled a comprehensive database for 69 major and medium cities with viable data on these 24 indicators from 2009 to 2015 (the most recent year that data has been made available in official yearbooks). In order to detect reporting errors, we checked the fluctuation of data series by calculating the discrepancies between two consecutive years. If the difference was larger than 50 percent of the value of the previous year, we verified the primary source in the second round. If different data sources reported different information for the indicator, the research team reconciled the two sources.

Table 1: CSDIS Final Indicator Set *(full definitions found in Appendix II)*

CATEGORY	INDICATOR*	
Economic Development	• Service Sector Added Value %	• Unemployment %
	• Value Added per Built Hectare	• Labor Productivity
	• Science and Technology Expenditure p.c.	• GDP Growth %
Social Welfare & Livelihood	• Housing-to-Income Ratio	• Education Expenditure %
	• Health Expenditure %	• Physician Availability
	• Pension Coverage	• Road Area p.c.
Environmental Resources	• Urban Green Space p.c.	• Days Meeting Air Quality Index Level 2
	• Water Resources p.c.	• Inhalable Particulate Matter Concentration
Consumption & Emissions	• Water Consumption per Unit of GDP	• Sulfur Dioxide Emissions per ¥ Value Added
	• Energy Consumption per Unit of GDP	• Wastewater Discharge per ¥ Value Added
Environmental Management	• Environmental Protection Expenditure %	• Industrial Solid Waste Utilization
	• Domestic Sewage Treatment %	• Energy Intensity Improvement

**%: percent; p.c.: per capita; ¥: renmibi/yuan*

iv. Weighting Strategy

Our weighting strategy is innovative in that the initial weights have been computed with respect to the indicator's stability across cities and years.

Stability is defined as low volatility with regards to a city's ranking for any given indicator across time. That is, indicators with smaller standard deviation of city ranks over seven years are less prone to data errors. Therefore, these indicators are more likely to be accurate representations of a city's sustainability performance. For instance, urban green space per capita has the smallest standard deviation of 3, which implies that for each city, in general, the change in ranking on urban green space per capita is relatively small over the 7-year period. Our normalized weighting system assigns higher weights to indicators with less volatility. This method makes the ranking more comparable among cities and make it easier to track the cities' sustainable development.

Specifically, 69 cities are ranked on each of the 24 indicators X_i (where i = 1 to 24), and then over 7 years. Then, the ranks' standard deviations for every indicator over 7 years are calculated as follows:

$$\sigma_{ci} = \sqrt{\frac{1}{7}\sum_{j=1}^{7}(R_{cij} - \mu_{ci})}$$

where σ_{ci} denotes the rank standard deviation of city c (c = 1 to 69) and indicator i, R_{cij} denotes the rank of city c, indicator i, and year j (j = 1 to 7), and μ_{ci} denotes the mean rank of city c and indicator i of 7 years.

Next, indicator standard deviations σ_i are obtained by:

$$\sigma_i = \frac{\sum_{c=1}^{69} \sigma_{ci}}{69}$$

A higher σ_i implies higher fluctuations across years and cities.

Lastly, the weight of each indicator is calculated by taking the inverse of its standard deviation σ_i, and dividing it by the sum of the all inversed standard deviations, as follows, where W_i denotes weight for indicator i:

$$W_i = \frac{1/\sigma_i}{\sum_{i=1}^{24} 1/\sigma_i}$$

Less volatile indicators are therefore rewarded with higher weights. Table 2 lists the weights for the 24 indicators and for the five categories.

v. Scoring Methods

After indicator weights are calculated, standardization is usually performed to aggregate indicators with different units into a composite score.

The most widely-used standardization method converts individual scores into z-scores by subtracting the mean from the raw data and then dividing it by the standard deviation. It enables the comparison among indicators with different units by converting their raw scores to the number of standard deviations away from the group mean. This normalization of raw scores has been widely applied in standardized testing, such as the ACT and SAT scores in the United States. However, there are also drawbacks to this method. One disadvantage is the nonlinear relationship between the raw score and the converted score. A relatively small change closer to the mean will result in a large change in converted score, while a large change farther away from the mean will result in only a slight change in the converted score. The uneven distribution is not ideal for sustainability ranking of cities.

Min-Max rescaling is also used in standardization. This method involves transforming raw data by subtracting from it the minimum value and then dividing the difference by the difference between the maximum and minimum values. Other sustainability related indices such as the Environmental Performance Index (EPI) and Urban China Initiative (UCI) have adopted this method. However, rescaling is very sensitive to outliers or extreme values, and it works best when the underlying data is normally distributed. Observing our data, many of the indicators, such as wastewater discharge, are rather unevenly distributed (Allen et al. 2001).

We therefore decided to rank cities by their performance on each indicator first and then use their ranks as raw scores. The overall score is then a weighted arithmetic average of ranks of the 24 indicators. Therefore, the smaller final score would indicate a better performance on sustainability compared to other cities, while a larger final score would indicate a worse performance compared to other cities.

Table 2: CSDIS Indicator Set and Weighting

CATEGORY	#	INDICATOR	WEIGHT*
Economic Development (23.87%)	1	Service Sector Added Value %	6.67%
	2	Value Added per Built Hectare	5.07%
	3	Science and Technology Expenditure p.c.	4.50%
	4	Unemployment %	2.93%
	5	Labor Productivity	2.88%
	6	GDP Growth %	1.83%
Social Welfare & Livelihood (30.24%)	7	Housing-to-Income Ratio	6.91%
	8	Health Expenditure %	5.03%
	9	Pension Coverage	4.91%
	10	Education Expenditure %	4.67%
	11	Physician Availability	4.64%
	12	Road Area p.c.	4.07%
Environmental Resources (17.98%)	13	Urban Green Space p.c.	7.56%
	14	Water Resources p.c.	5.13%
	15	Days Meeting Air Quality Index Level 2	3.11%
	16	Inhalable Particulate Matter Concentration	2.19%
Consumption & Emissions (20.31%)	17	Water Consumption per Unit of GDP	7.19%
	18	Energy Consumption per Unit of GDP	5.32%
	19	Sulfur Dioxide Emissions per ¥ Value Added	4.48%
	20	Wastewater Discharge per ¥ Value Added	3.32%
Environmental Management (7.61%)	21	Environmental Protection Expenditure %	2.28%
	22	Domestic Sewage Treatment %	2.19%
	23	Industrial Solid Waste Utilization	1.72%
	24	Energy Intensity Improvement	1.42%

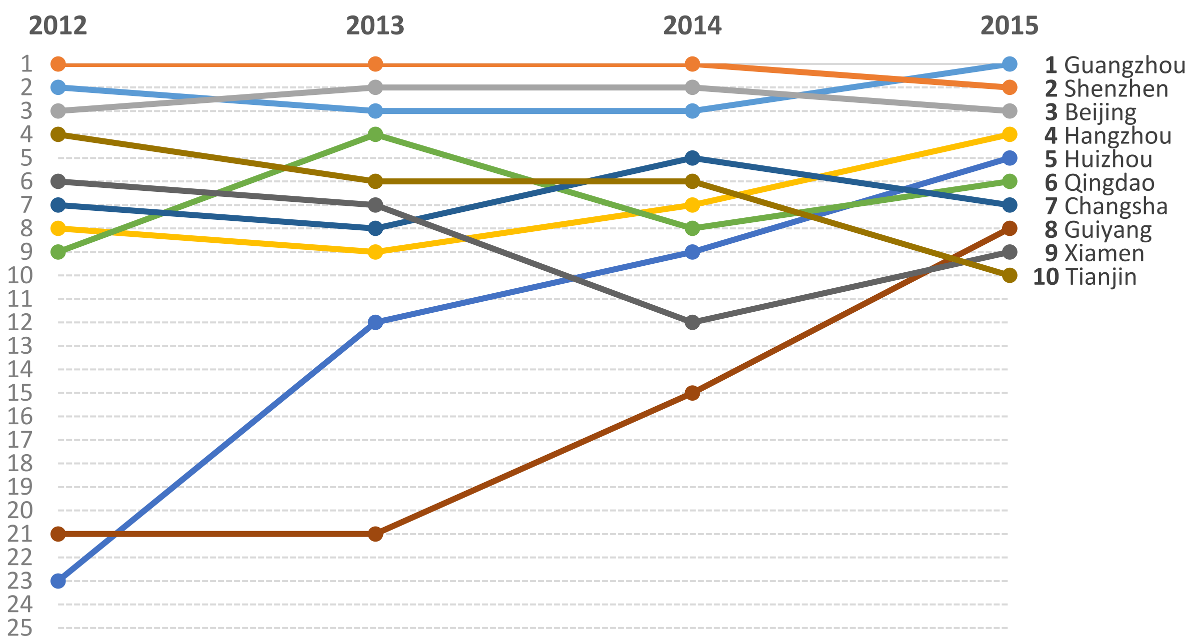
*The overall weighting from this table adds up to 100.01%, as some of the indicators have been rounded to the nearest 0.01%. However, this should not impact the overall ranking in any substantial way.

IV. Ranking

We now present the ranking results for the China Sustainable Development Indicator System (CSDIS) for 69 large and medium-sized Chinese cities for the years 2012, 2013, 2014, and 2015,[1] in Table 3. The top 10 cities in overall sustainability are shown in Figure 1.

Our rankings over these years reveal that coastal cities often rank high in overall sustainability, and are often the most economically advanced in China. Contrary to industrialized cities inland, coastal cities tend to have better environmental quality. Cities in central and western China tend to rank low on sustainability, as they are not as advanced as coastal cities economically, often due to the lack of transportation and trade benefits that come from being a port city. Albeit quickly catching up on this front, these cities are experiencing greater environmental degradation, in terms of air, water, and soil, without the benefits of being on the coast. Although governments in major cities such as Beijing and in the most polluted cities such as Shijiazhuang and Zhengzhou have made commendable efforts in pollution abatement and environmental conservation, these efforts have not been sufficient to offset the damages imposed by rapid economic growth and urbanization.

Figure 1: Top 10 Sustainable Chinese Cities, 2012-2015



[1] Data was available for earlier years, however 2012 saw a large change in measurement standards for many of the indicators that we included. Since cities often take different approaches and speed in adjusting to national standards, we decided to start our ranking in 2012 to avoid inconsistency in measurement across cities.

Table 3: China Sustainable Development Indicator System (CSDIS) Ranking 2012-2015

CITY		2012	2013	2014	2015
广州	Guangzhou	2	3	3	1
深圳	Shenzhen	1	1	1	2
北京	Beijing	3	2	2	3
杭州	Hangzhou	8	9	7	4
惠州	Huizhou	23	12	9	5
青岛	Qingdao	9	4	8	6
长沙	Changsha	7	8	5	7
贵阳	Guiyang	21	21	15	8
厦门	Xiamen	6	7	12	9
天津	Tianjin	4	6	6	10
无锡	Wuxi	5	5	4	11
三亚	Sanya	10	11	10	12
烟台	Yantai	14	10	22	13
武汉	Wuhan	16	15	16	14
宁波	Ningbo	18	19	13	15
南京	Nanjing	12	16	14	16
上海	Shanghai	11	13	11	17
昆明	Kunming	20	18	21	18
温州	Wenzhou	34	28	19	19
济南	Jinan	25	27	24	20
成都	Chengdu	13	17	17	21
金华	Jinhua	28	26	18	22
郑州	Zhengzhou	27	29	29	23
合肥	Hefei	22	31	27	24
西安	Xi'an	32	33	30	25
福州	Fuzhou	30	30	23	26
海口	Haikou	24	24	34	27
南昌	Nanchang	26	22	20	28
重庆	Chongqing	29	23	26	29
徐州	Xuzhou	37	32	25	30
扬州	Yangzhou	36	34	32	31
长春	Changchun	19	25	28	32
包头	Baotou	35	38	33	33
沈阳	Shenyang	15	20	31	34
呼和浩特	Hohhot	33	39	42	35
南宁	Nanning	38	40	39	36
大连	Dalian	17	14	36	37
宜昌	Yichang	49	45	45	38
北海	Beihai	44	35	35	39
乌鲁木齐	Urumuqi	43	42	41	40

CITY		2012	2013	2014	2015
银川	Yinchuan	39	37	38	41
太原	Taiyuan	31	44	46	42
泉州	Quanzhou	40	36	37	43
兰州	Lanzhou	46	52	49	44
蚌埠	Bengbu	52	51	47	45
洛阳	Luoyang	48	49	43	46
桂林	Guilin	57	48	58	47
安庆	Anqing	53	61	57	48
西宁	Xining	47	56	53	49
济宁	Jining	50	46	50	50
九江	Jiujiang	58	55	44	51
唐山	Tangshan	51	57	54	52
石家庄	Shijiazhuang	42	47	51	53
哈尔滨	Harbin	45	53	48	54
常德	Changde	61	60	60	55
遵义	Zunyi	64	59	61	56
吉林	Jilin	41	41	40	57
秦皇岛	Qinhuangdao	56	50	52	58
韶关	Shaoguan	65	64	62	59
襄阳	Xiangyang	62	58	55	60
赣州	Ganzhou	63	63	64	61
湛江	Zhanjiang	54	54	56	62
泸州	Liuzhou	68	67	63	63
南充	Nanchong	66	69	68	64
丹东	Dandong	55	43	59	65
牡丹江	Mudanjiang	59	65	66	66
岳阳	Yueyang	67	66	65	67
平顶山	Pingdingshan	69	68	69	68
锦州	Jinzhou	60	62	67	69

i. Ranking by Major Component of Sustainable Development

As shown in Table 4, major cities along China's east and south coast are performing the best on economic development, apart from Beijing, Wuhan and Lanzhou. Beijing, as the capital of China, has always been one of the leading cities on economic performance indicators. Wuhan is the capital of Hubei Province, and is a major industry hub in inland China. Lanzhou has a surprising position on the list, considering it is the capital city of

Gansu Province in western China, where economic development generally lags behind those in the east. However, its ranking on the economy is boosted by its vibrant and growing service sector.

Table 4: Top 10 Cities on Economic Development, 2015

CITY		2015
广州	Guangzhou	1
深圳	Shenzhen	2
杭州	Hangzhou	3
北京	Beijing	4
南京	Nanjing	5
上海	Shanghai	6
武汉	Wuhan	7
三亚	Sanya	8
天津	Tianjin	9
兰州	Lanzhou	10

The top Chinese cities on social welfare are mostly inland cities, as illustrated in Table 5. None of the cities apart from Tianjin overlap with the top cities on economic development. This is a rather surprising result given it is usually the economically advanced cities that have more resources at their disposal for social wealth provision and improvement.

Table 5: Top 10 Cities on Social Welfare & Livelihood, 2015

CITY		2015
贵阳	Guiyang	1
惠州	Huizhou	2
银川	Yinchuan	3
青岛	Qingdao	4
济南	Jinan	5
西安	Xi'an	6
天津	Tianjin	7
宜昌	Yichang	8
无锡	Wuxi	9
太原	Taiyuan	10

Table 6 demonstrates that, consistent with popular perception, cities in Southern China, especially coastal cities, tend to be resource rich and generally perform better on environmental quality.

Table 6: Top 10 Cities on Environmental Resources, 2015

CITY		2015
广州	Guangzhou	1
杭州	Hangzhou	2
深圳	Shenzhen	3
惠州	Huizhou	4
三亚	Sanya	5
福州	Fuzhou	6
南昌	Nanchang	7
长沙	Changsha	8
厦门	Xiamen	9
海口	Haikou	10

Table 7 shows the best performing cities on efficient use of resources, such as water and energy, SO_2 emissions and wastewater discharge. The list is comprised of mainly major cities, which suggests that they are population centers with significant economic activities, yet these cities have also been leading in resource saving and emission control techniques.

Table 7: Top 10 Cities on Consumption and Emissions, 2015

CITY		2015
北京	Beijing	1
深圳	Shenzhen	2
青岛	Qingdao	3
广州	Guangzhou	4
烟台	Yantai	5
天津	Tianjin	6
长沙	Changsha	7
成都	Chengdu	8
合肥	Hefei	9
厦门	Xiamen	10

As shown in Table 8, coastal cities such as Shenzhen, Huizhou, Haikou, and Xiamen tend to spend more resources and efforts on environmental conservation, as they are also major tourist cities. In addition, Jinan, Shijiazhuang, Tianjin, Zhengzhou, and Pingdingshan are some of the most polluted cities, especially with respect to air. It is perhaps reassuring to see that these cities are leading in efforts to combat their severe environmental problems.

Overall, what is surprising and also alarming is the lack of leadership by northeastern cities in any of the five components of sustainable development. Cities such as Shenyang, Changchun, and Harbin used to be the industrial heart of China, and are now lagging behind the development of southern and inland cities. They are also plagued by some of the worst environmental problems, such as poor air quality, yet they do not rank among those making the most effort to address those problems.

Table 8: Top 10 Cities on Environmental Management, 2015

CITY		2015
济南	Jinan	1
石家庄	Shijiazhuang	2
天津	Tianjin	3
郑州	Zhenzhou	4
惠州	Huizhou	5
深圳	Shenzhen	6
平顶山	Pingdingshan	7
常德	Changde	8
海口	Haikou	9
厦门	Xiamen	10

ii. Comparison with International Cities

As we are still lacking an internationally agreed-upon standard for measuring sustainability, it is unlikely that the indicators we use for Chinese cities are also available and are measured in the same way for other cities across the world. Therefore, instead of replicating the entire framework for other cities around the world, we identified common indicators in each of the five categories to compare Chinese and international cities on their relative sustainability performance. We used five international cities - New York, Tokyo, London, Hong Kong and Paris - as benchmarks, in an attempt to find the gaps on urban sustainable development between Chinese cities and advanced cities in the rest of the world and provide an international reference for Chinese cities during this process.

To compare them briefly in terms of economic development, environment, and social welfare, we selected the following key indicators from different categories: Unemployment %, Service Sector Added Value %, Pension Coverage, Physician Availability, Days Meeting Air Quality Index Level 2, Energy Consumption per Unit of GDP, Sulfur Dioxide Emissions per ¥ Value Added, and Domestic Sewage Treatment %. By comparing each indicator of the sub-categories, we found that the main gaps between Chinese cities and their international counterparts are in environmental categories, and more specifically in consumption, emissions, and environmental quality. We carried out a limited comparison of resource indicators, due to the geographical differences and development status. Selected global cities have much better air quality, as well as energy efficiency and waste management than the majority of China's cities in our analysis. The results of each subcategory are summarized as follows.

Economy

On unemployment rate, a crucial economic indicator, almost all of China's cities have lower rates than international cities from 2009 to 2011 despite the effect of the financial crisis in 2008. This reflects the potential of China's economic boom and a strong work force demand in most cities. However, China's real unemployment rate may be much higher than the official rate, which is counted by registered unemployment figures (Feng 2015). For instance, in coastal cities, millions of migrants looking for jobs without hukou or residency permits are not included in the official accounting.

The indicator "Service Sector Added Value %" reflects the divergent shares of the service industry in China's and foreign countries' economy. Studies have shown that modern economies are increasingly dominated by service industries, and the service economy is one of the most significant manifestations of economic structural transformation, a key objective emphasized in the China's new Five-Year Plan. The comparison shows that the selected international cities would have been ranked in the top 10 of our list - the service sector contributed to over 90% of GDP in Hong Kong and Tokyo in 2011. Within China, Beijing has the highest share of service sector, 76.07% of its GDP, while over 80% of China's cities have a service sector added value to GDP ratio lower than 50%. We should note that the composition of the service sector among Chinese cities is very heterogeneous, from human services, tourism, retail, and hospitality to financial services, technology, health, and education. Strategic development of the service sector, adjusted for local economic and environmental resources, plays a significant role in job creation and inputs for the rest of the economy, thus affecting overall investment.

Environment

Resources: Given the rising concern of China's air pollution in major cities, we compare the air quality in China's cities with that in global cities by days that have reached national standards of air quality. The result shows that southern and less industrialized cities, such as Haikou, Kunming, Guangzhou, and Fuzhou, have better air quality than that of the five international cities. On the other hand, more developed cities located away from the coast or in northern China, such as Tangshan, Jining, and Luoyang, have experienced more serious air pollution. Within the international cohort, we observed significant differences in air quality; in our framework, Tokyo would rank 10^{th} while Paris would rank 60^{th} in 2011.

Consumption & Emissions: On "Energy Consumption per Unit of GDP," all five international cities perform better than Chinese cities according to our results. Some of China's cities, such as Wulumuqi, Shenyang, and Tangshan, had over 50 times more energy consumption compared to the international cohort.

"Sulfur Dioxide Emissions per ¥ Value Added" is a key measurement on the industrial air pollution level, and all five international cities rank in the top 10 on this indicator. In the most polluted cities in China, the emission amount was over 100 times more than the international and cleanest Chinese cities, however the gap between the most polluted and least polluted has been closing slowly.

Management: New York and London both reached 100% on "Domestic Sewage Treatment %," with Tokyo, Hong Kong and Paris achieving 99.5%, 93% and 93% by 2011. Within China in 2011, we had 26 cities with above 90% domestic sewage treatment rate, with a national average above 80%.

Social Welfare

Four of the five international cities reached 100% on "Pension Coverage" by 2009, while Shenzhen performed best among all China's cities at 72%. The average pension coverage in China was only about 23%, where urban birth rates have fallen rapidly, large proportion of working population are retiring, and many rural migrants work informally in cities.

As for "Physician Availability", foreign cities have a much larger number than all of China's cities. One plausible explanation is that the population density in China's cities was higher. Though China had fewer doctors per capita, most cities have increased average life expectancy and government spending on health care increased significantly over the past decade.

V. City Narratives

We now profile the 69 cities ranked in the CSDIS. These narratives provide a discussion of how each individual city performs in various realms of sustainability compared to other cities, its top 3 and bottom 3 indicator rankings, and a snapshot of its demographics, geography, and development status. The cities are detailed descending by rank.

1. Guangzhou

Land Area: 7,435 km^2 **Population:** 13.5 million **GDP:** 1,810.04 billion RMB	Guangzhou is the capital of the Guangdong Province in southern China and one of the most populous cities in the country. Located at the confluence of two rivers of the Pearl River system, it is a major transportation hub and leading commercial port. It is also an important center of regional and international trade, and has a strong service sector and automobile industry. It experiences a subtropical climate and a basin-like landscape, which was greatly reshaped by rapid urbanization in the 1980s and 1990s. It has long been the cultural, political, and economic center of southern China (Hong Kong Trade Development Council 2017; Pong 2009).

Guangzhou ranks #1 in overall sustainability. Guangzhou performed well on "Urban Green Space p.c." (#1), "Pension Coverage" (#2), and "SO_2 Emissions per ¥ Value Added" (#4). However, Guangzhou performed poorly on "Education Expenditure %" (#65), "Environmental Protection Expenditure %" (#65), and "Health Expenditure %" (#60).

Guangzhou's overall ranking increased to #1 in 2015. Although Guangzhou' rankings in housing affordability, road congestion, and energy consumption worsened, it improved in labor productivity, water resources, and domestic sewage treatment.

2. Shenzhen

Land Area: 2,050 km^2 **Population:** 11.38 million **GDP:** 1,750.3 billion RMB	Shenzhen is a coastal city in southern Guangdong Province bordering Hong Kong. It has been one of the fastest growing cities in the world since opening trade with the West in the 1970s, and was designated the first Economic Special Zone of China in 1980. Its ports contribute to its recognition as a trade and transportation hub, and it has also become an important center for innovation and technology. It has both a strong service sector and strong industrial sector (HKTDC 2017; Library of Congress 2015).

Shenzhen ranks #2 in overall sustainability. Shenzhen performed well on "Science and Technology Expenditure p.c." (#1), "Pension Coverage" (#1), and "Road Area p.c." (#1). However, Shenzhen performed poorly on "Health Expenditure %" (#66), "Education Expenditure %" (#63), and "Housing-to-Income Ratio" (#63).

Shenzhen's overall ranking declined by one position in 2015. Shenzhen worsened in housing affordability, education expenditure, and environmental protection expenditure, but improved in industrial solid waste utilization, built area added value, and GDP growth.

3. Beijing

Land Area: 16,411 km^2 **Population:** 21.71 million **GDP:** 1,736.8 billion RMB	Beijing, the capital of China, is recognized as the political, economic, educational, and cultural center of the country. Beijing is a major transportation hub and is home to many strong sectors, including real estate, information technology, financial services, import and export businesses, and automobile production, with its service sector accounting for nearly 80% of the city's GDP. Since its founding, the city has been well developed economically, but due to continued growth, air quality is a severe issue. In order to address this, many of the city's industries began to close down in the 2000s. Beijing's city population is highly educated, with about seven times the number of college students as the national average (HKTDC 2017; Leese 2009; Pong 2009).

Beijing ranks #3 in overall sustainability, performing well in economic development, but lagging in road congestion, housing price, and air quality.

Specifically, Beijing excelled in "Service Sector Added Value %" (#1), "Unemployment %" (#1), and "Science and Technology Expenditure %" (#2). However, Beijing performed poorly on "Road Area p.c." (#68), "Housing-to-Income Ratio" (#67), and "Days Meeting Air Quality Index Level 2" (#64).

Beijing's performance in these three indicators, road area, housing affordability, and air quality, are most responsible for its minor drop in overall rank. However, efforts in energy efficiency and environmental expenditure have helped to arrest a larger drop in rank.

4. Hangzhou

Land Area: 16,596 km^2 **Population:** 9.01 million **GDP:** 1,005.02 billion RMB	One of China's seven ancient capitals, Hangzhou is capital of the Zhejiang Province and one of the most economically thriving cities in the Yangtze River Delta. The industrial sector, primarily manufacturing, accounts for a large portion of Hangzhou's GDP, and the city strongly encourages business growth and foreign investment. Additionally, Hangzhou has a rich cultural heritage and is known for its beautiful natural scenery. A large number of famous scenic areas and historical monuments make tourism an important pillar of its service sector (HKTDC 2017; Library of Congress 2015; Pong 2009).

Hangzhou ranks #4 in overall sustainability, experiencing a strong economy but falling behind in some indicators of environmental management and quality.

Specifically, Hangzhou performed well on "Unemployment %" (#3), "Pension Coverage" (#4), and "Physician Availability" (#4). However, Hangzhou performed poorly on "Wastewater Discharge per ¥ Value Added" (#58), "Health Expenditure %" (#56), and "Energy Intensity Improvement" (#53).

Hangzhou's overall ranking has improved slightly, primarily due to improvement in water consumption, GDP growth, and education expenditure, although it worsened in air quality and health expenditure.

5. Huizhou

Land Area: 11,200 km^2 **Population:** 4.6 million **GDP:** 314 billion RMB	Situated in the southeastern part of the Guangdong Province, the city of Huizhou is a famous historical and cultural city within the Pearl River Delta. Huizhou is well-known for its abundance of natural resources, and there are more than 900 "scenic spots" in the city and surrounding Huizhou region, making tourism an important industry. Huizhou is also one of China's major coastal ports and has a large industrial industry, which accounted for over half of its GDP in 2015 (HKTDC 2017).

Huizhou ranks #5 in overall sustainability. Huizhou performed well on "Days Meeting Air Quality Index Level 2" (#4), "Inhalable Particulate Matter Concentration" (#6), and "Water Resources p.c." (#9). However, Huizhou performed poorly on "Service Sector Added Value %" (#55), "Labor Productivity" (#54), and "Physician Availability" (#53).

Huizhou's overall ranking improved, primarily due to improvement in health expenditure, science and technology expenditure, and water consumption. However, it worsened in industrial solid waste utilization, service sector added value, and wastewater discharge.

6. Qingdao

Land Area: 10,654 km^2 **Population:** 9.1 million **GDP:** 930.01 billion RMB	Qingdao is a major seaport of China, located in the south of the Shandong peninsula. The industry sector makes up nearly 40% of the city's GDP, with major industries including electronics, petrochemicals, and food and beverage processing. The nation's largest beer producer, Tsingtao Brewery, is located in Qingdao. The service sector, specifically tourism, is an important part of the city's GDP, and Qingdao is also rich in natural resources (HKTDC 2017; Pong 2009).

Qingdao ranks #6 in overall sustainability. Qingdao performed well on "Water Consumption per Unit of GDP" (#1), "Wastewater Discharge per ¥ Value Added" (#6), and "Pension Coverage" (#9). However, Qingdao performed poorly on "Water Resources p.c." (#69), "Environmental Protection Expenditure %" (#68), and "Health Expenditure %" (#58).

Qingdao's overall ranking improved slightly, primarily due to improvement in education expenditure, energy intensity, and air quality, although worsened in environmental protection expenditure, urban green space, and labor productivity.

7. Changsha

Land Area: 11,819 km^2 **Population:** 7.43 million **GDP:** 851.01 billion RMB	Changsha is the capital of the Hunan Province and is located adjacent to the Xiang River. Changsha has emerged as the economic, political, and cultural center of Hunan Province, due to the government's establishment of a national economic and technical development zone in 1992. This resulted in improved transportation facilities and created an "economic circle" with other cities in Hunan that comprise over 70% of the province's GDP. Today, Changsha is the commercial and financial center of the province, with the service sector comprising nearly half of the city's GDP, and the industrial sector accounting for over 40% (HKTDC 2015, Pong 2009).

Changsha ranks #7 in overall sustainability. Changsha performed well on "Domestic Sewage Treatment %" (#1), "Housing-to-Income Ratio" (#2), and "Wastewater Discharge per ¥ Value Added" (#2). However, Changsha performed poorly on "Health Expenditure %" (#65), "Education Expenditure %" (#61), and "Industrial Solid Waste Utilization" (#48).

Changsha's overall ranking has remained fairly stable. Although it worsened in air quality, environmental protection expenditure, and energy intensity, Changsha improved in road congestion, unemployment, and built area added value.

8. Guiyang

Land Area: 8,034 km^2 **Population:** 4.62 million **GDP:** 289.1 billion RMB	Guiyang is an inland city and the capital of the Guizhou Province, serving as the province's economic, cultural, educational, and technological center. Guiyang is known for its natural scenery and unique ethnic customs, and tourism makes up a major part of the city's large service sector (HKTDC 2017).

Guiyang ranks #8 in overall sustainability. Guiyang performed well on "GDP Growth %" (#2), "Domestic Sewage Treatment %" (#4), and "Housing-to-Income Ratio" (#8). However, Guiyang performed poorly on "Industrial Solid Waste Utilization" (#65), "Value Added per Built Hectare" (#59), and "Energy Consumption per Unit of GDP" (#58).

Guiyang's overall ranking has improved, primarily due to improvement in water consumption, housing affordability, and road congestion, although it worsened in unemployment, service sector GDP, and health expenditure.

9. Xiamen

Land Area: 1,575 km^2 **Population:** 3.86 million **GDP:** 346.6 billion RMB	Xiamen, one of China's first five special economic zones, is a coastal city and the commercial hub of southern Fujian Province. Its port provides an important domestic transportation network. Xiamen's largest industry is electronics, with major international investors in this sector, and the city also leads in the production of engineering machinery. The city is known for its unique culture, architecture, mild climate, and relatively low pollution (HKTDC 2017; Pong 2009).

Xiamen ranks #9 in overall sustainability, performing well in environmental quality. Specifically, Xiamen performed well on "Days Meeting Air Quality Index Level 2" (#1), "Inhalable Particulate Matter Concentration" (#4), and "Energy Intensity Improvement" (#5). However, Xiamen performed poorly on "Labor Productivity" (#66), "Wastewater Discharge per ¥ Value Added" (#65), and "Housing-to-Income Ratio" (#64).

Xiamen's overall ranking has declined slightly, primarily due to worsened housing affordability, GDP growth, and energy consumption, although it has improved in energy intensity, and education and health expenditures.

10. Tianjin

Land Area: 11,917 km^2 **Population:** 15.47 million **GDP:** 1,333.9 billion RMB	Tianjin is a coastal city 50 miles east of Beijing, located in Bohai Bay, one of China's biggest economic regions. It is at the center of several new national development strategies in China and is part of the Beijing-Tianjin-Hebei Megaregion Development Strategy, a key feature of the Chinese president's economic development plan. Tianjin is an important port city and industrial center, and has a rapidly growing service sector and tourism industry (HKTDC 2017).

Tianjin ranks #10 in overall sustainability, performing well in some indicators of economic development, but experiencing a decline in environmental resources and air quality.

Specifically, Tianjin performed well in "Domestic Sewage Treatment %" (#2), "Water Consumption per Unit of GDP" (#4), and "Science and Technology Expenditure %" (#4). However, Tianjin performed poorly on "Unemployment %" (#68), "Water Resources p.c." (#65), and "Inhalable Particulate Matter Concentration" (#58).

Tianjin's overall ranking has slightly declined, primarily due to poorer performance in air quality. However, it has improved its ranking in domestic sewage treatment, health expenditure, and labor productivity.

11. Wuxi

Land Area: 4,627 km^2 **Population:** 6.51 million **GDP:** 851.8 billion RMB	Wuxi is located in the Jiangsu Province in the Yangtze River Delta. Wuxi is one of China's wealthiest regions, with an industry sector comprising nearly half of the city's GDP. The region has close economic ties to Shanghai, good transportation infrastructure, high levels of education, and is also famous for tourism (HKTDC 2017; Pong 2009).

Wuxi ranks #11 in overall sustainability, performing well on road congestion and housing affordability, but lagging in government expenditure on other social services.

Specifically, Wuxi excelled in "Road Area p.c." (#2), "Housing-to-Income Ratio" (#3), and "Value Added per Built Hectare" (#3). However, Wuxi performed poorly on "Health Expenditure %" (#68), "Education Expenditure %" (#66), and "Days Meeting Air Quality Index Level 2" (#59).

Wuxi's overall ranking has declined, primarily due to worsened urban green space, water consumption, and wastewater discharge, although it improved in water resources, pension coverage, and physician availability.

12. Sanya

Land Area: 1,920 km^2 **Population:** 0.75 million **GDP:** 43.6 billion RMB	Sanya is China's southernmost city, located at the southern tip of Hainan Island and known for beautiful beaches and coastal scenery. It has well-developed facilities for tourism, which constitutes a significant portion of the city's GDP (HKTDC 2017).

Sanya ranks #12 in overall sustainability, experiencing good air quality and environmental quality, but lagging in housing affordability and economic performance.

Sanya performed well on "Inhalable Particulate Matter Concentration" (#1), "Industrial Solid Waste Utilization" (#1), and "Days Meeting Air Quality Index Level 2" (#5). However, Sanya performed poorly on "Housing-to-Income Ratio" (#69), "Value Added per Built Hectare" (#69), and "Environmental Protection Expenditure %" (#67).

Sanya's overall ranking has remained fairly stable. Although it worsened in water resources, labor productivity, and built area added value, Sanya improved in number of physicians, unemployment, and GDP growth.

13. Yantai

Land Area: 13,748 km^2 **Population:** 7.0 million **GDP:** 644.6 billion RMB	Yantai is located in the middle of the Shandong Peninsula. The industry sector, primarily automobiles and shipbuilding, is the economic driver of the city, but it also has a significant tourism industry. It is known for having a pleasant climate and beautiful landscapes, with national parks and national preservation areas as key attractions (HKTDC 2017).

Yantai ranks #13 in overall sustainability. Yantai performed well on "Energy Intensity Improvement" (#1), "Water Consumption per Unit of GDP" (#3), and "Housing-to-Income Ratio" (#6). However, Yantai performed poorly on "Domestic Sewage Treatment %" (#62), "Health Expenditure %" (#57), and "Education Expenditure %" (#56).

Yantai's overall ranking has improved slightly, primarily due to an improvement in energy intensity, urban green space, and air quality, although it worsened in domestic sewage treatment, number of physicians, and pension coverage.

14. Wuhan

Land Area: 8,494 km^2 **Population:** 10.6 million **GDP:** 1,090.6 billion RMB	Wuhan, the capital of the Hubei province, is one of the most economically important cities in the Yangtze River Delta and one of the most important inland ports in China. Though originally established as a heavy industry base, Wuhan also has strong scientific, educational, and tourism sectors. It also has a thriving commercial sector, though its economic development has grown more slowly than other cities in China. Though the city has taken advantage of its flat terrain and hydraulic environment, these features have also made Wuhan vulnerable to flooding (HKTDC 2017; Leese 2009; Pong 2009).

Wuhan ranks #14 in overall sustainability. Wuhan performed well on "Science and Technology Expenditure p.c." (#7), "Housing-to-Income Ratio" (#10), and "Labor Productivity" (#15). However, Wuhan performed poorly on "Days Meeting Air Quality Index Level 2" (#63), "Education Expenditure %" (#62), and "Environmental Protection Expenditure %" (#49).

Wuhan's overall ranking has remained fairly stable. Although Wuhan improved in built area added value, labor productivity, and science and technology expenditure, it worsened in pension coverage and air quality.

15. Ningbo

Land Area: 9,816 km^2 **Population:** 7.83 million **GDP:** 800.36 billion RMB	Ningbo is a coastal city in the Zhejiang Province, and was one of the first coastal cities to be opened to the world. Ningbo is regarded as one of China's most prosperous and has become a major shipping and fishing center. Industry remains as the city's primary economic driver, and its historical temples and lakes make tourism an important part of its service sector (HKTDC 2017).

Ningbo ranks #15 in overall sustainability. Ningbo performed well on "Pension Coverage" (#7), "Science and Technology Expenditure p.c." (#9), and "Water Consumption per Unit of GDP" (#10). However, Ningbo performed poorly on "Energy Intensity Improvement" (#67), "Domestic Sewage Treatment %" (#60), and "Urban Green Space p.c." (#53).

Ningbo's overall ranking has risen slightly, primarily due to improvement in education expenditure, air quality, and environmental protection expenditure. However, its improved ranking has been arrested due to poor performance in health expenditure, energy consumption, and energy intensity.

16. Nanjing

Land Area: 6,587 km^2 **Population:** 8.24 million **GDP:** 972.1 billion RMB	Nanjing is the capital of Jiangsu Province and is the largest port in inland Asia, providing an important east-west transportation artery. It is the province's hub for trade and education. Heavy industry makes up the core of the city's rather large industry sector, and the financial industry is the most important pillar of the city's significant service sector (HKTDC 2017; Pong 2009).

Nanjing ranks #16 in overall sustainability, performing well on urban infrastructure, but lacking in social spending.

Specifically, Nanjing performed well on "Urban Green Space p.c." (#5), "Science and Technology Expenditure p.c." (#8), and "Road Area p.c." (#8). However, Nanjing performed poorly on "Domestic Sewage Treatment %" (#67), "Education Expenditure %" (#59), and "Health Expenditure %" (#59).

Nanjing's overall ranking dropped slightly, primarily due to worsened labor productivity, energy intensity, and wastewater discharge, although it improved in water resources, GDP growth, and energy consumption.

17. Shanghai

Land Area: 6,340.5 km^2 **Population:** 24.15 million **GDP:** 1,952.9 billion RMB	Shanghai is a historical commercial and financial center of China at the heart of the Yangtze River Delta. The city has been expanding rapidly, with areas of factories, warehouses, and farmland converted into advanced business and financial centers. Shanghai's has a subtropical monsoon climate, and its port, unfrozen all year around, is one of the largest in China. The service sector makes up the majority of Shanghai's GDP, and the city plays an important role in China's heavy industries (HKTDC 2017; Pong 2009).

Shanghai ranks #17 in overall sustainability. Shanghai performed well on "Science and Technology Expenditure p.c." (#3), "Service Sector Added Value %" (#5), and "Pension Coverage" (#5). However, Shanghai performed poorly on "Housing-to-Income Ratio" (#68), "Road Area p.c." (#62), and "Value Added per Built Hectare" (#62).

Shanghai's overall ranking has dropped, primarily due to poorer performance in water consumption, air quality, and wastewater discharge, although Shanghai did improve in water resources, sulfur dioxide emissions, and unemployment.

18. Kunming

Land Area: 21,473 km^2 **Population:** 6.68 million **GDP:** 396.8 billion RMB	Kunming is the capital of the Yunnan province and is a major tourist destination. It is known for having a temperate climate and great ethnic diversity, with natural attractions such as Dianchi Lake and the Stone Forest. Tourism is the most important pillar of Kunming's service sector, which accounts for over half of the city's GDP. The city is also the center of the province's politics, economics and culture, and is an important hub for trade with Southeast Asian countries (HKTDC 2017; Library of Congress 2015).

Kunming ranks #18 in overall sustainability. Kunming performed well on “Energy Consumption per Unit of GDP” (#1), “Days Meeting Air Quality Index Level 2” (#3), and “Physician Availability” (#6). However, Kunming performed poorly on “Industrial Solid Waste Utilization” (#67), “Value Added per Built Hectare” (#60), and “SO_2 Emissions per ¥ Value Added” (#57).

Kunming’s overall ranking has improved slightly, primarily due to improved rankings in water consumption, labor productivity, and energy consumption. However, it has worsened in education expenditure, GDP growth, and unemployment.

19. Wenzhou

Land Area: 12,065 km^2 **Population:** 9.12 million **GDP:** 461.8 billion RMB	The city of Wenzhou, on the southeastern coast of the Zhejiang Province, was the first city in China to establish a market economy and has strong domestic and international business networks. It has long been one of China’s most densely populated regions, with mountains comprising over 70% of its territory, limiting arable land. Shoe manufacturing is an important economic industry, along with tourism, with natural attractions including the Nanxi River Scenic Area and Yandang Mountain (HTDC 2017; Pong 2009).

Wenzhou ranks #19 in overall sustainability. Wenzhou performed well on “Unemployment %” (#8), “Energy Consumption per Unit of GDP” (#8), and “Value Added per Built Hectare” (#12). However, Wenzhou performed poorly on “Housing-to-Income Ratio” (#66), “Environmental Protection Expenditure %” (#62), and “Labor Productivity” (#61).

Wenzhou’s overall ranking has improved since 2012, primarily due to improvement in air quality and GDP growth, though it has worsened in built area added value, sulfur dioxide emissions, and energy consumption.

20. Jinan

Land Area: 8,177 km^2 **Population:** 7.13 million **GDP:** 610.02 billion RMB	Jinan is the capital of the Shandong Province, and the province’s major hub for transportation and commerce. Since the 1990s, Jinan has seen extraordinary growth rates, matching those of Shanghai. It has a strong industry sector and fast-growing service sector. Its tourism industry contributes significantly to its service sector, and the city experiences four distinct seasons, with hot and wet summers and cold and dry winters (HKTDC 2017; Pong 2009).

Jinan ranks #20 in overall sustainability, experiencing poor air quality, though it is making significant efforts to alleviate that problem.

Specifically, Jinan performed well on “Energy Intensity Improvement” (#3), “Road Area p.c.” (#6), and “Physician Availability” (#8). However, Jinan performed poorly on “Inhalable Particulate Matter Concentration” (#68), “Days Meeting Air Quality Index Level 2” (#67), and “Water Resources p.c.” (#60).

Jinan’s overall ranking improved slightly, primarily due to improvement in pension coverage, number of physicians, and energy intensity, although it worsened in air quality and wastewater discharge.

21. Chengdu

Land Area: 12,119 km^2 **Population:** 14.7 million **GDP:** 1,080.1 billion RMB	Chengdu, capital of the Sichuan province, is an inland city situated on the western edge of the Sichuan Basin, serving as a major center for commerce, finance, transportation, and communication in western China. From 1993 to 1998, the landscape, environment, and living conditions in the city were greatly improved by the dredging of the Funan River, which circles the city, and the construction of parks along its banks. Chengdu has a rather large industry sector but is primarily a service-oriented economy, home to many universities and research institutions and a strong tourism industry (HKTDC 2017; Pong 2009).

Chengdu ranks #21 in overall sustainability. Chengdu performed well on “Domestic Sewage Treatment %,” (#6) “SO_2 Emissions per ¥ Value Added,” (#7) and “Physician Availability” (#13). However, it performed poorly on “Environmental Protection Expenditure %” (#63), “Days Meeting Air Quality Index Level 2” (#58), and “Labor Productivity” (#58).

Chengdu’s overall ranking has declined slightly, primarily due to a worsened performance in road congestion, GDP growth, and unemployment, although it did improve in domestic sewage treatment, science and technology expenditure, and sulfur dioxide emissions.

22. Jinhua

Land Area: 10,942 km^2 **Population:** 5.45 million **GDP:** 340.23 billion RMB	Jinhua is an inland city located in the central part of the Zhejiang Province. It is rich in forest resources, and animal husbandry is one of its major industries. Its industry sector makes up nearly 40% of its GDP, while tourism is a main pillar of its service sector (HKTDC 2017).

Jinhua ranks #22 in overall sustainability. Jinhua performed well on “Value Added per Built Hectare” (#1), “Unemployment %” (#4), and “Water Resources p.c.” (#10). However, Jinhua performed poorly on “Labor Productivity” (#68), “Urban Green Space p.c.” (#68), and “Energy Intensity Improvement” (#56).

Jinhua’s overall ranking has improved slightly, primarily due to improvement in air quality and pension coverage, though it worsened in industrial solid waste utilization, energy intensity, and sulfur dioxide emissions.

23. Zhengzhou

Land Area: 7,446 km^2 **Population:** 9.57 million **GDP:** 731.2 billion RMB	Zhengzhou is the capital of Henan Province, serving as a hub for commerce, finance, transportation, and resource distribution in central China. It is a rapidly growing city for which the industry sector makes up over 40% of its GDP, with main industries including food manufacturing, automobile manufacturing, and information technology (HKTDC 2017).

Zhengzhou ranks #23 in overall sustainability, experiencing poor environmental quality, though it has made significant efforts to address those issues.

Specifically, Zhengzhou performed well on “Environmental Protection Expenditure %” (#2), “Energy Intensity Improvement” (#6), and “Water Consumption per Unit of GDP” (#9). However, Zhengzhou performed poorly on “Inhalable Particulate Matter Concentration” (#69), “Days Meeting Air Quality Index Level 2” (#68), and “Water Resources p.c.” (#66).

Zhengzhou’s overall ranking improved slightly, primarily due to improvement in road congestion, environmental protection expenditure, and service sector added value, although it worsened in air quality and housing affordability.

24. Hefei

Land Area: 11,408 km^2 **Population:** 7.79 million **GDP:** 566 billion RMB	Hefei, the capital of the Anhui Province, is an inland city lying between the Yangtze River and the River Huai, a location which gives it an important role in linking central China with the coastal region. It has the largest industrial base in the province, with major industries including automobile manufacturing, equipment manufacturing, and information technology (HKTDC 2017).

Hefei ranks #24 in overall sustainability. Hefei performed well on “Road Area p.c.” (#3), “Wastewater Discharge per ¥ Value Added” (#5), and “GDP Growth %” (#7). However, Hefei performed poorly on “Unemployment %” (#55), “Service Sector Added Value %” (#53), and “Health Expenditure %” (#49).

Hefei’s overall ranking dropped in 2013, primarily due to worsened health expenditure, air quality, and energy intensity. However, Hefei improved in 2015, primarily due to improvement in urban green space, energy consumption, and GDP growth.

25. Xi’an

Land Area: 9,983 km^2 **Population:** 8.71 million **GDP:** 580.1 billion RMB	Xi’an is the capital of the Shaanxi Province, located along the Silk Road between Europe and Eastern Asia. Because of its location, the population of Xi’an is highly international and diverse, creating a vibrant center of the province's politics, economy and culture. Though it has a well-educated population, Xi’an has suffered from its citizens choosing to move to coastal provinces for work. Its service sector makes up 60% of its GDP, the most significant part of its economy, with a large tourism industry due to its historical significance in China (HKTDC 2017; Pong 2009).

Xi’an ranks #25 in overall sustainability. Xi’an performed well on “Service Sector Added Value %” (#10), “Physician Availability” (#10), and “Pension Coverage” (#13). However, Xi’an performed poorly on “Inhalable Particulate Matter Concentration” (#61), “Energy Intensity Improvement” (#61), and “Unemployment %” (#54).

Xi’an’s overall ranking has risen slightly, primarily due to improvement in science and technology expenditure, housing affordability, and industrial wastewater discharge. However, it worsened in energy intensity, built area added value, and education expenditure.

26. Fuzhou

Land Area: 12,154 km^2 **Population:** 7.5 million **GDP:** 561.8 billion RMB	Fuzhou, the capital and one of the largest cities of the Fujian province, is a riverine port city historically renowned for its hot springs, jasmine, and banyan trees. The city was one of the earliest to be granted approval for an Economic and Technological Development Zone in 1986, and this, along with cross-strait investment, has made it one of China's most prosperous cities. Fuzhou's largest industry is the electronic and information technology industry, with the machinery industry developing rapidly, due in large part to investment from Taiwan. Heavy industry continues to be developed, with clean energy sources such as hydropower being a key resource to that development (HKTDC 2017; Pong 2009).

Fuzhou ranks #26 in overall sustainability. Fuzhou performed well on "Wastewater Discharge per ¥ Value Added" (#4), "Days Meeting Air Quality Index Level 2" (#8), and "Inhalable Particulate Matter Concentration" (#8). However, Fuzhou performed poorly on "Environmental Protection Expenditure %" (#60), "Housing-to-Income Ratio" (#59), and "Health Expenditure %" (#51).

Fuzhou's overall ranking improved slightly from 2012 to 2014, primarily due improvement in education expenditure, industrial solid waste utilization, and physician availability. However, it declined slightly in 2015, primarily due to worsened domestic sewage treatment and environmental protection expenditure.

27. Haikou

Land Area: 2,305 km^2 **Population:** 2.2 million **GDP:** 116.2 billion RMB	Haikou is the capital of the tropical island province of Hainan. Its agricultural sector is made up of the production of tropical fruits and plants, and the tourism industry is the most important part of its large service sector. Built as a port city, Haikou serves as the political, economic, cultural, and transportation center of the province, with more than half of the island's total trade still going through its ports (HKTDC 2017; Pong 2009).

Haikou ranks #27 in overall sustainability. Haikou performed well on "Service Sector Added Value %" (#2), "Inhalable Particulate Matter Concentration" (#2), and "Physician Availability" (#3). However, Haikou performed poorly on "Labor Productivity" (#69), "Water Consumption per Unit of GDP" (#69), and "Energy Intensity Improvement" (#68).

Haikou's overall ranking declined in 2014, primarily due to worsened science and technology expenditure, energy consumption, and education expenditure. However, it improved in 2015, primarily due to improvement in urban green space, education expenditure, and environmental protection expenditure.

28. Nanchang

Land Area: 7,402 km^2 **Population:** 5.3 million **GDP:** 400 billion RMB	Nanchang is an inland city and the capital of the Jiangxi Province, with one of the largest ports in inland China. It is the political, cultural, and economic center of the province, and provides cargo service to nearby cities. Its industry sector accounts for over 40% of the city's GDP, with automobiles being its most significant industry (HKTDC 2017).

Nanchang ranks #28 in overall sustainability. Nanchang performed well on "Energy Consumption per Unit of GDP" (#4), "Domestic Sewage Treatment %" (#5), and "GDP Growth %" (#15). However, Nanchang performed poorly on "Environmental Protection Expenditure %" (#64), "Energy Intensity Improvement" (#59), and "Unemployment %" (#53).

Nanchang's overall ranking increased from 2012 to 2014, primarily due to an improvement in sulfur dioxide emissions and labor productivity, however it declined again in 2015, primarily due to worsened road congestion and pension coverage.

29. Chongqing

Land Area: 82,400 km^2 **Population:** 30.16 million **GDP**: 1,250.5 billion RMB	Chongqing is one of China's old industrial bases, with heavy industry still making up a significant portion of its GDP. Chongqing's economy took off in the early 2000s, when massive public works were constructed and the city experienced a real estate boom. In recent years, many top multinational companies have set up operations in the city, though Chongqing has faced problems from rapid urbanization. Ecological management of the Three Gorges Dam project is an ongoing issue; over one million people from the reservoir area were relocated to Chongqing in 2007. The majority of Chongqing is still rural, with the urban population accounting for roughly 60% of its total population (HKTDC 2017; Pong 2009).

Chongqing ranks #29 in overall sustainability. Chongqing performed well on "GDP Growth %" (#4), "Health Expenditure %" (#9), and "Unemployment %" (#11). However, Chongqing performed poorly on "Labor Productivity" (#67), "Road Area p.c." (#66), and "Physician Availability" (#56).

Chongqing's overall ranking declined slightly in 2015, primarily due to worsened rankings in water consumption, education expenditure, and energy intensity. However, a further drop was arrested by improved performance in service sector added value, built area added value, and energy consumption.

30. Xuzhou

Land Area: 11,765 km^2 **Population:** 8.67 million **GDP:** 531.99 billion RMB	Xuzhou is located in the northwest of the Jiangsu Province on the Grand Canal, the longest artificial river in the world. Its location makes Xuzhou Port an important energy transfer port. The city's economy is dominated by the industry sector, which includes equipment manufacturing, energy, and food processing (HKTDC 2017).

Xuzhou ranks #30 in overall sustainability. Xuzhou performed well on "Energy Consumption per Unit of GDP" (#6), "Industrial Solid Waste Utilization" (#8), and "Wastewater Discharge per ¥ Value Added" (#11). However, Xuzhou performed poorly on "Pension Coverage" (#69), "Inhalable Particulate Matter Concentration" (#60), and "Days Meeting Air Quality Index Level 2" (#55).

Xuzhou's overall ranking has improved slightly, primarily due to better performance on wastewater discharge, road congestion, and industrial solid waste utilization. However, further improvement was arrested by worsened pension coverage and health expenditure.

31. Yangzhou

Land Area: 6,591 km^2 **Population:** 4.49 million **GDP:** 401.7 billion RMB	Yangzhou is located in the Jiangsu Province on the west bank of the Grand Canal, and was formerly the main route for transportation between Beijing and the Yangtze River Valley. The city has a rich historical and cultural legacy that attract tourists, but is less well-known to foreigners than other nearby cities in the province, which has perhaps contributed to it lagging behind those cities economically. Yangzhou's economy is primarily made up of a mix of heavy and light industry, and it is an important provincial petrochemicals base (HKTDC 2017; Pong 2009).

Yangzhou ranks #31 in overall sustainability. Yangzhou performed well on "Value Added per Built Hectare" (#8), "GDP Growth %" (#9), and "Wastewater Discharge per ¥ Value Added" (#13). However, Yangzhou performed poorly on "Education Expenditure %" (#57), "Physician Availability" (#57), and "Domestic Sewage Treatment %" (#57).

Yangzhou's overall ranking improved slightly in 2015. Although Yangzhou worsened in total labor productivity and energy consumption, it improved in housing affordability, water resources, and GDP growth.

32. Changchun

Land Area: 27,711 km^2 **Population:** 7.54 million **GDP:** 553 billion RMB	Changchun is the capital of the Jilin Province, known for its many universities, colleges, and scientific institutes, as well as automobile manufacturing. Its fertile soil lends to an abundant agricultural sector and it is the largest granary in China, accounting for 6% of the country's total grain output. The tourism industry is also an important part of its service sector (HKTDC 2016).

Changchun ranks #32 in overall sustainability. Changchun performed well on "Wastewater Discharge per ¥ Value Added" (#1), "Housing-to-Income Ratio" (#13), and "Energy Intensity Improvement" (#14). However, Changchun performed poorly on "Education Expenditure" (#54), "Days Meeting Air Quality Index Level 2" (#51), and "Inhalable Particulate Matter Concentration" (#50).

Changchun's overall ranking has declined, primarily due to worsened labor productivity and air quality, although it improved in unemployment and spending on science and technology.

33. Baotou

Land Area: 27,768 km^2 **Population:** 2.83 million **GDP:** 372.2 billion RMB	Baotou, located in northern China, is the largest industrial city in the Inner Mongolia Autonomous Region and the second largest economy of the region. It is rich in mineral resources, specifically metal, and its largest industrial sector is made up of the iron and steel industry, aluminum processing, and equipment manufacturing, among others (HKTDC 2017).

Baotou ranks #33 in overall sustainability. Baotou performed well on "Housing-to-Income Ratio" (#1), "Labor Productivity" (#11), and "Environmental Protection Expenditure %" (#11). However, Baotou performed poorly on "Education Expenditure %" (#69), "Health Expenditure %" (#69), and "SO_2 Emissions per ¥ Value Added" (#68).

Baotou's overall ranking improved slightly, primarily due to improvement in air quality, although it worsened in energy intensity and GDP growth.

34. Shenyang

Land Area: 13,308 km^2 **Population:** 7.3 million **GDP:** 727.2 billion RMB	Shenyang is the capital of Liaoning Province, one of northeast China's major industrial centers, and an educational hub of the region. Though it underwent a deep economic crisis as a result of the restructuring of its large state enterprises, it is the largest industrial production base in the province and serves as a as a transportation hub to other major provinces and cities. Its major industries include equipment manufacturing and automobiles (HKTDC 2017; Pong 2009).

Shenyang ranks #34 in overall sustainability. Shenyang performed well on "Pension Coverage" (#10), "Wastewater Discharge per ¥ Value Added" (#10), and "Housing-to-Income Ratio" (#11). However, Shenyang performed poorly on "Energy Consumption per Unit of GDP" (#68), "GDP Growth %" (#67), and "Education Expenditure %" (#67).

Shenyang's overall ranking has declined, primarily due to worsened emissions and air quality. A further drop was arrested by improved performance in road congestion, domestic sewage treatment, and energy intensity.

35. Hohhot

Land Area: 17,224 km^2 **Population:** 3.06 million **GDP:** 309.05 billion RMB	Hohhot, the capital of the Inner Mongolia Autonomous Region, is an important passage and a hub-city linking Beijing with northwestern China. The industrial sector makes up just over 20% of the city's GDP, with dairy processing being one of Hohhot's major industries. It is also home to one of the largest thermal power plants in Asia, and tourism is an important part of its service sector (HKTDC 2017).

Hohhot ranks #35 in overall sustainability. Hohhot performed well on "Housing-to-Income Ratio" (#4), "Service Sector Added Value %" (#4), and "Urban Green Space p.c." (#6). However, Hohhot performed poorly on "Industrial Solid Waste Utilization" (#68), "SO_2 Emissions per ¥ Value Added" (#65), and "Education Expenditure %" (#64).

Hohhot's overall ranking has declined, primarily due to worsened air quality, environmental protection expenditure, and wastewater discharge, although it improved in domestic sewage treatment, road congestion, and housing affordability.

36. Nanning

Land Area: 22,099 km^2 **Population:** 6.99 million **GDP:** 341 billion RMB	Nanning is an inland city and the capital of the Guangxi Zhuang Autonomous Region, known for lush tropical foliage. Agriculture and food processing are Nanning's major industries, but the largest contributor to the city's GDP is the service sector, which includes tourism and trade (HKTDC 2017).

Nanning ranks #36 in overall sustainability. Nanning performed well on "Industrial Solid Waste Utilization" (#5), "Days Meeting Air Quality Index level 2" (#15), and "Water Resources p.c." (#16). However, Nanning performed poorly on "Pension Coverage" (#66), "Domestic Sewage Treatment %" (#61), and "Water Consumption per Unit of GDP" (#56).

Nanning's overall ranking has improved slightly, primarily due to improvement in environmental protection expenditure, industrial solid waste utilization, and wastewater discharge, although it worsened in pension coverage, labor productivity, and service sector added value.

37. Dalian

Land Area: 13,237 km^2 **Population:** 5.94 million **GDP:** 773.2 billion RMB	Dalian is located at the southern tip of the Liaodong peninsula and is an important port city for industry, trade, and tourism. As most of northeastern China's trade flows through its ports, it is an important center for shipping and logistics. Though traditionally a heavy manufacturing city, Dalian is striving to become a high tech and business hub, and its service sector now accounts for over half of the city's GDP. It is known for generally lower housing prices compared to other major cities, as well as beautiful coastlines that attract tourists (HKTDC 2017; Library of Congress 2015; Leese, 2009).

Dalian ranks #37 in overall sustainability. Dalian performed well on "Labor Productivity" (#5), "Water Consumption per Unit of GDP" (#7), and "Housing-to-Income Ratio" (#15). However, Dalian performed poorly on "Education Expenditure %" (#68), "Wastewater Discharge per ¥ Value Added" (#67), and "GDP Growth %" (#66).

Dalian's overall ranking has declined significantly, primarily due to worsened water resources and government expenditure in public services. A further drop in ranking was arrested in 2015 primarily due to improved labor productivity, air quality, and environmental protection expenditure.

38. Yichang

Land Area: 21,084 km^2 **Population:** 4.12 million **GDP:** 338.5 billion RMB	Yichang is located on the Yangtze River in the Hubei Provice, and is known as the largest hydroelectricity base in China. It is home to both the Three Gorges Dam, the largest hydroelectric power station in the world, and the Gezhouba Dam. Hydropower production contributes to the city's industrial sector, which makes up half of the city's GDP. The Three Gorges Dam area is also a major tourist attraction that contributes to Yichang's important service sector (HKTDC 2017).

Yichang ranks #38 in overall sustainability. Yichang performed well on "Energy Intensity Improvement" (#4), "Housing-to-Income Ratio" (#5), and "Unemployment %" (#5). However, Yichang performed poorly on "Industrial Solid Waste Utilization" (#69), "Service Sector Added Value %" (#66), and "Labor Productivity" (#64).

Yichang's overall ranking improved, primarily due to an improvement in science and technology expenditure, number of physicians, and air quality, although it worsened in labor productivity, sulfur dioxide emissions, and environmental protection expenditure.

39. Beihai

Land Area: 3,337 km^2 **Population:** 1.63 million **GDP:** 89.2 billion RMB	Beihai is located in the Guangxi province of southwestern China on the bank of the Beibu Gulf. It serves as a connection between South China and Southeastern Asia and has a well-developed port. Fishing is a major industry for the city, as well as petrochemicals, due to the Beibu Gulf being one of the major oil and gas bases in China (HKTDC 2017).

Beihai ranks #39 in overall sustainability. Beihai performed well on "GDP Growth %" (#3), "Energy Consumption per Unit of GDP" (#5), and "Inhalable Particulate Matter Concentration" (#7). However, Beihai performed poorly on "Science and Technology Expenditure %" (#69), "Service Sector Added Value %" (#64), and "Pension Coverage" (#62).

Beihai's overall ranking improved in 2013, primarily due to improvement in housing affordability, industrial solid waste utilization, and industrial wastewater discharge. However, it declined slightly in 2015, primarily due to worsened science and technology expenditure, water resources, and health expenditure.

40. Urumqi

Land Area: 14,876 km^2 **Population:** 2.67 million **GDP:** 263.2 billion RMB	Urumqi is the capital of the Xinjiang Uygur Autonomous Region in northwestern China, located at the foot of the Tianshan Mountain. Formerly an important hub on the Silk Road, Urumqi is now a major trade and distribution center in central Asia, with the service sector being its main economic driver. It has rich forests and grasslands, as well as resources such as fossil fuels, minerals, and wind energy (HKTDC 2017).

Urumqi ranks #40 in overall sustainability. Urumqi performed well on "Service Sector Added Value %" (#3), "Physician Availability" (#5), "Urban Green Space p.c." (#7). However, Wulumuqi performed poorly on "Energy Consumption per Unit of GDP" (#69), "Energy Intensity Improvement" (#69), and "Value Added per Built Hectare" (#68).

Urumqi's overall ranking has risen slightly, primarily due to improved rankings in domestic sewage treatment, road congestion, and unemployment. However, Urumqi worsened in labor productivity and government expenditure on science and technology and environmental protection.

41. Yinchuan

Land Area: 9,491 km^2 **Population:** 2.16 million **GDP:** 149.4 billion RMB	Yinchuan, the capital of the Ningxia Hui Autonomous Region, is well known for its history and culture. It also has beautiful natural scenery, such as Sha Lake and Suyuokou National Forest, which makes tourism an important part of its service sector. Yinchuan's industrial sector accounts for almost half of its GDP, and crude oil is one of its major products. It has the lowest annual rainfall of any of China's provincial capitals (HKTDC 2017; Leese 2009).

Yinchuan ranks #41 in overall sustainability. Yinchuan performed well on "Energy Consumption per Unit of GDP" (#3), "Urban Green Space p.c." (#4), and "Housing-to-Income Ratio" (#7). However, Yinchuan performed poorly on "Water Resources p.c." (#67), "Industrial Solid Waste Utilization" (#66), and "Labor Productivity" (#65).

Yinchuan's overall ranking has declined slightly, primarily due to worsened science and technology expenditure, service sector added value, and air quality, although it did improve in energy consumption, water consumption, and education expenditure.

42. Taiyuan

Land Area: 6,988 km^2 **Population:** 4.32 million **GDP:** 273.5 billion RMB	Taiyuan is an inland city and the capital of the Shanxi Province. Taiyuan is rich in mineral resources and is the largest coal mining center in China, which constitutes much of its industrial sector, along with metallurgy, petrochemicals, and electric power, among others. However, the service sector, led by wholesale, retail, and finance, is the largest contributor to Taiyuan's economy (HKTDC 2017).

Taiyuan ranks #42 in overall sustainability. Taiyuan performed well on "Physician Availability" (#1), "Service Sector Added Value %" (#8), and "Urban Green Space p.c." (#11). However, Taiyuan performed poorly on "Industrial Solid Waste Utilization" (#64), "Water Resources p.c." (#64), and "Value Added per Built Hectare" (#64).

Taiyuan's overall ranking has declined. Though it improved on road congestion, GDP growth, and domestic sewage treatment, Taiyuan significantly worsened in air quality, housing affordability, and wastewater discharge.

43. Quanzhou

Land Area: 11,015 km^2 **Population:** 8.51 million **GDP:** 613.8 billion RMB	Quanzhou, Fujian Province's largest metropolitan region, is located in in the southeast part of the province beside the Taiwan Strait. It has an efficient multimodal transportation system and an international port that serves both cargo and passenger ships. Quanzhou's industry sector makes up over half of its GDP and it is the largest manufacturing base in the province. It is traditionally known for its textiles, garment, and footwear industries, and it also has an emerging petrochemical industry (HKTDC 2017).

Quanzhou ranks #43 in overall sustainability, performing well in environmental quality but poorly in social and environmental expenditures.

Specifically, Quanzhou performed well on "Days Meeting Air Quality Index Level 2" (#2), "Value Added per Built Hectare" (#2), and "Road Area p.c." (#7). However, Quanzhou performed poorly on "Physician Availability" (#67), "Service Sector Added Value %" (#61), and "Urban Green Space p.c." (#61).

Quanzhou's overall ranking improved slightly in 2013, primarily due to improvement in air quality and labor productivity. However, it declined in 2015, primarily due to worsened energy consumption, environmental protection expenditure, and domestic sewage treatment.

44. Lanzhou

Land Area: 13,085.6 km^2 **Population:** 3.69 million **GDP:** 209.6 billion RMB	Lanzhou is the capital of the Gansu Province and a major city along the "New Silk Road," a major transport route between Europe and China. Given its location, it is an important commercial and distribution hub in Gansu, making the service sector the largest contributor to the city's economy. Lanzhou is also rich in mineral resources and it is famous for fruit production, though its agricultural sector is relatively small (HKTDC 2017).

Lanzhou ranks #44 in overall sustainability. Lanzhou performed well on "Environmental Protection Expenditure %" (#7), "Service Sector Added Value %" (#9), and "Industrial Solid Waste Utilization" (#13). However, Lanzhou performed poorly on "Water Resources p.c." (#68), "Value Added per Built Hectare" (#67), and "Energy Consumption per Unit of GDP" (#64).

Lanzhou's overall ranking has improved slightly, primarily due to an improved ranking in water consumption, science and technology expenditure, and pension coverage. However, a larger improvement was arrested by worsened water resources, wastewater discharge, and road congestion.

45. Bengbu

Land Area: 5,952 km^2 **Population:** 3.29 million **GDP:** 125.3 billion RMB	Bengbu is located in the northeastern part of Anhui Province on the Huai River. The Jing-Hang Canal connects its port to many major cities, such as Shanghai. It has a significant agricultural sector, which supports the city's textile industry and food and beverage manufacturing. Bengbu's industrial sector accounts for over 40% of the city's GDP, and it has received major investments to develop its auto parts and pharmaceutical industries (HKTDC 2017).

Bengbu ranks #45 in overall sustainability. Bengbu performed well on "GDP Growth %" (#10), "Health Expenditure %" (#11), and "Education Expenditure %" (#11). However, Bengbu performed poorly on "Value Added per Built Hectare" (#65), "Pension Coverage" (#64), and "Service Sector Added Value %" (#63).

Bengbu's overall ranking improved slightly, primarily due to improvement in urban green space, wastewater discharge, and energy intensity, although it worsened in air quality, pension coverage, and environmental protection expenditure.

46. Luoyang

Land Area: 15,208 km^2 **Population:** 6.74 million **GDP:** 346.9 billion RMB	Luoyang is located in western Henan Province and is one of the Four Great Ancient Capitals of China. It has a convenient railway network and the second largest industrial sector in Henan after Zhengzhou. Industry, primarily advanced manufacturing and new materials processing, accounts for over 40% of the city's GDP (HKTDC 2017).

Luoyang ranks #46 in overall sustainability. Luoyang performed well on "Wastewater Discharge per ¥ Value Added" (#17), "Water Consumption per Unit of GDP" (#21), and "GDP Growth %" (#21). However, Luoyang performed poorly on "Inhalable Particulate Matter Concentration" (#62), "Industrial Solid Waste Utilization" (#61), and "Days Meeting Air Quality Index Level 2" (#59).

Luoyang's overall ranking has remained fairly stable. Luoyang improved its ranking in service sector added value, GDP growth, and health expenditure, but worsened in housing affordability, environmental protection expenditure, and domestic sewage treatment.

47. Guilin

Land Area: 27,809 km^2 **Population:** 4.96 million **GDP:** 194.3 billion RMB	Guilin is a scenic city situated on the Li River in the northeast of the Guangxi Zhuang Autonomous Region. It has a comprehensive transportation system and serves as a regional hub for trade and logistics. Important industries include equipment manufacturing, electronic information, and automobile manufacturing. The service sector is an important part of Guilin's economy, primarily due to its tourism industry. The city is one of the most famous tourist destinations in China and has two highest-level nationally-designated scenic spots (HKTDC 2017).

Guilin ranks #47 in overall sustainability. Guilin performed well on "Water Resources p.c." (#1), "Health Expenditure %" (#10), and "Days Meeting Air Quality Index Level 2" (#10). However, Guilin performed poorly on "Water Consumption per Unit of GDP" (#66), "Service Sector Added Value %" (#60), and "Urban Green Space p.c." (#60).

Guilin's overall ranking has improved, primarily due to improvement in physician availability, air quality, and housing affordability, although it has worsened in value added per built hectare, GDP growth, and road area.

48. Anqing

Land Area: 15,398 km^2 **Population:** 4.59 million **GDP:** 141.7 billion RMB	Anqing, located in southwestern Anhui Province, is a major port city on the Yangtze River. It is rich in mineral resources and is an important base for the production of cotton, crops, and aquatic products. Its large industrial sector accounts for over 40% of Anqing GDP, and many large enterprises have set up production lines in the city (HKTDC 2017).

Anqing ranks #48 in overall sustainability. Anqing performed well on "Health Expenditure %" (#3), "Education Expenditure %" (#5), and "Water Resources p.c." (#7). However, Anqing performed poorly on "Pension Coverage" (#67), "Water Consumption per Unit of GDP" (#65), and "Urban Green Space p.c." (#63).

Anqing's overall ranking declined in 2013, primarily due to worsened domestic sewage treatment and air quality, though its ranking improved in 2015, primarily due to improvement in unemployment, service sector added value, and government spending on science and technology.

49. Xining

Land Area: 7,665 km^2 **Population:** 2.01 million **GDP:** 113.2 billion RMB	Xining is the capital city of the Qinghai Province. Reforms since the mid-1980s have stimulated economic migration, contributing to increasing urbanization and industrialization of the area. These activities and resources led to an industry centered on machinery, textiles, chemicals, building materials, metallurgy, and leather and food processing, comprising nearly 40% of the city's GDP. Xining is also rich in mineral resources and has become a major tourist attraction (HKTDC 2017; Leese 2009).

Xining ranks #49 in overall sustainability. Xining performed well on "Industrial Solid Waste Utilization" (#1), "Environmental Protection Expenditure %" (#3), and "GDP Growth %" (#6). However, Xining performed poorly on "Unemployment %" (#69), "Water Consumption per Unit of GDP" (#68), and "Energy Consumption per Unit of GDP" (#66).

Xining's overall ranking worsened in 2013, primarily due to a worsened education expenditure and air quality, however it improved slightly in 2015, primarily due to improvement in science and technology expenditure, industrial solid waste utilization, and wastewater discharge.

50. Jining

Land Area: 10,684.9 km^2 **Population:** 8.3 million **GDP:** 401.3 billion RMB	Jining is a culturally important city located in southern Shandong Province. Cultural attractions make tourism an important part of Jining's service sector. Industry is the city's dominant sector, accounting for over 40% of the city's GDP. Its abundance of coal and freshwater resources benefit the city's major industries of coal chemicals, equipment manufacturing, and energy, among others (HKTDC 2017).

Jining ranks #50 in overall sustainability. Jining performed well on "Energy Intensity Improvement" (#2), "Road Area p.c." (#4), and "Labor Productivity" (#8). However, Jining performed poorly on "Days Meeting Air Quality Index Level 2" (#65), "Inhalable Particulate Matter Concentration" (#64), and "Wastewater Discharge per ¥ Value Added" (#60).

Jining's overall ranking has remained fairly consistent. Although it improved in energy intensity, water resources, and urban green space, it worsened in built area added value, water consumption, physician availability, and environmental protection expenditure.

51. Jiujiang

Land Area: 18,887 km^2 **Population:** 4.83 million **GDP:** 190.3 billion RMB	Jiujiang is located in the northern part of the Jiangxi Province along the Yangtze River. Its port is one of the largest in the Yangtze River Valley, providing both cargo and domestic services to other major cities. Its industrial sector accounts for 45% of its GDP, with main industries that include metallurgy, textiles, petrochemicals, and shipbuilding (HKTDC 2017).

Jiujiang ranks #51 in overall sustainability. Jiujiang performed well on "Road Area p.c." (#5), "Water Resources p.c." (#5), and "Health Expenditure %" (#7). However, Jiujiang performed poorly on "Energy Intensity Improvement" (#63), "Wastewater Discharge per ¥ Value Added" (#62), and "Industrial Solid Waste Utilization" (#62).

Jiujiang's overall ranking improved slightly, primarily due to improvement in air quality, science and technology expenditure, and labor productivity, although it worsened in domestic sewage treatment, pension coverage, and urban green space.

52. Tangshan

Land Area: 13,472 km^2 **Population:** 7.8 million **GDP:** 610.3 billion RMB	Tangshan is located in the eastern part of the Hebei Province and contains a regional port that provides domestic and international cargo services to countries in Asia and Europe. The city has the highest GDP in the province, accounting for 20% of the province's total GDP. Tangshan has been an important industrial city since the Qing Dynasty, with over half of the city's GDP coming from the industrial sector (HKTDC 2017).

Tangshan ranks #52 in overall sustainability. Specifically, Tangshan performed well on "Labor Productivity" (#3), "Environmental Protection Expenditure %", and "Housing-to-Income Ratio" (#9)". However, Tangshan performed poorly on "Energy Consumption per Unit of GDP" (#65), "Inhalable Particulate Matter Concentration" (#64), and "GDP Growth %" (#64).

Tangshan's overall ranking worsened in 2013, but has since improved slightly. Although it worsened in science and technology expenditure, built area added value, and water consumption, it improved in education expenditure and air quality.

53. Shijiazhuang

Land Area: 15,848 km^2 **Population:** 10.7 million **GDP:** 544.1 billion RMB	Shijiazhuang is an inland city and the capital of the Hebei Province. It is one of China's major biopharmaceutical bases, with other major industries including chemicals, information technology, and equipment manufacturing. From 2008-2011 the city began to address problems stemming from rapid development and population growth through a plan to increase green areas and improve its transportation infrastructure (HKTDC 2017).

Shijiazhuang ranks #53 in overall sustainability, performing poorly on air quality, though it has made significant efforts towards environmental management and conservation.

Specifically, Shijiazhuang performed well on "Labor Productivity" (#1), "Environmental Protection Expenditure %" (#1)," and "Domestic Sewage Treatment %" (#14). However, Shijiazhuang performed poorly on "Inhalable Particulate Matter Concentration" (#67), "Unemployment %" (#67), and "Days Meeting Air Quality Index Level 2" (#66).

Shijiazhuang's overall ranking declined, primarily due to a worsened ranking in housing affordability, road congestion, and air quality. However, a further drop was arrested by improvement in industrial solid waste utilization, energy consumption, and sulfur dioxide emissions.

54. Harbin

Land Area: 53,796 km^2 **Population:** 9.61 million **GDP:** 575.1 billion RMB	Harbin is the largest and capital city of the Heilongjiang Province in the northeastern part of China, with one of the country's only inland ports. It is known for its long and cold winters, which contribute to its famous tourism industry. Harbin is also an important industrial center and has developed its foreign trade and economic and technological cooperation with many major international companies. Its nutrient-rich soil makes it valuable for cultivating food and other textile-related crops, and Harbin is a major base for production of commodity grain and an ideal place for setting up agricultural businesses (HKTDC 2017; Library of Congress 2015; Pong 2009).

Harbin ranks #54 in overall sustainability. Harbin performed well on "Industrial Solid Waste Utilization" (#7), and "Service Sector Added Value %" (#16), and "Labor Productivity" (#19). However, Harbin performed poorly on "Energy Intensity Improvement" (#62), "Unemployment %" (#61), and "Road Area p.c." (#59).

Harbin's overall ranking has declined, primarily due to worsened water consumption, health expenditure, and spending on science and technology, although it improved in pension coverage, labor productivity, and sulfur dioxide emissions.

55. Changde

Land Area: 18,189.8 km^2 **Population:** 5.84 million **GDP:** 270.9 billion RMB	Changde, in the Hunan Province, has an efficient transportation network and is an important base for agriculture, specifically crops and cotton. This lends to Changde's large industrial sector, accounting for over 40% of the city's GDP, which is primarily made up of the food, textile, and tobacco industries (HKTDC 2017).

Changde ranks #55 in overall sustainability. Changde performed well on "Energy Intensity Improvement" (#7), "Value Added per Built Hectare" (#9), and "Water Resources p.c." (#14). However, Changde performed poorly on "Housing-to-Income Ratio" (#65), "Physician Availability" (#64), and "Science and Technology Expenditure p.c." (#63).

Changde's overall ranking has improved slightly, primarily due to improvement in inhalable particulate matter concentration, domestic sewage treatment, and unemployment, although it worsened in education expenditure, days meeting Air Quality Index level 2, and industrial solid waste utilization.

56. Zunyi

Land Area: 30,762 km^2 **Population:** 6.19 million **GDP:** 216.83	Zunyi is located in the Guizhou Province. Industries including coal, tobacco and brewing make up nearly 40% of the city's GDP. The agricultural sector in the city plays a critical role in the province, accounting for one fourth of the province's grain production and 16% of the city's GDP. The service sector in Zunyi is centered on tourism, and the city is known for its waterfalls, forests, and Karst landforms, as well as for its importance to the revolutionary history of China (HKTDC 2017).

Zunyi ranks #56 in overall sustainability. Zunyi performed well on "GDP Growth %" (#1), "Education Expenditure %" (#2), and "Value Added per Built Hectare" (#5). However, Zunyi performed poorly on "Road Area p.c." (#69), "Pension Coverage" (#68), and "Urban Green Space p.c." (#64).

Zunyi's overall ranking has improved slightly, primarily due to improvement in energy intensity, air quality, and industrial wastewater discharge. However, it has worsened in service sector added value, industrial solid waste utilization, and environmental protection expenditure.

57. Jilin

Land Area: 27,711 km^2 **Population:** 4.26 million **GDP:** 239.4 billion RMB	Jilin City is located in the center of the Jilin Province. Jilin has plenty of physical resources, including hydraulic power, water resources, and the nation's second-largest mine of molybdenum. The industry sector makes up 40% of the city's GDP; petrochemicals are the largest industry, followed by automobiles, metallurgy and food processing (HKTDC 2017; Pong 2009).

Jilin ranks #57 in overall sustainability. Jilin performed well on "Environmental Protection Expenditure %" (#6), "Energy Intensity Improvement" (#12), and "Housing-to-Income Ratio" (#16). However, Jilin performed poorly on "Industrial Solid Waste Utilization" (#63), "GDP Growth %" (#61), and "Road Area p.c." (#60).

Jilin's overall ranking significantly declined in 2015, primarily due to worsened built area added value, pension coverage, and labor productivity. Jilin has seen some improvement in energy consumption and unemployment.

58. Qinhuangdao

Land Area: 7,467 km^2 **Population:** 3.07 million **GDP:** 125.0 billion RMB	Qinhuangdao is located the Hebei province and has a moderate continental climate influenced by summer monsoons. Qinhuangdao's port is ice-free and is a major port for coal transportation. The industrial sector accounts for 29% of its GDP, and includes glass manufacturing, metal pressing, and machinery (HKTDC 2017; Leese 2009).

Qinhuangdao ranks #58 in overall sustainability, performing poorly in economic development, but well in some aspects of environmental management and conservation.

Specifically, Qinhuangdao performed well on "Health Expenditure %" (#1), "Environmental Protection Expenditure %" (#5), and "Domestic Sewage Treatment %" (#8). However, Qinhuangdao performed poorly on "Wastewater Discharge per ¥ Value Added" (#68), "Science and Technology Expenditure p.c." (#66), and "Unemployment %" (#66).

Qinhuangdao's overall ranking declined slightly in 2015, due to worsened housing affordability, road congestion, and built area added value, although it improved in inhalable particulate matter concentration, health expenditure, and domestic sewage treatment.

59. Shaoguan

Land Area: 18,380 km^2 **Population:** 2.93 million **GDP:** 115 billion RMB	Shaoguan is located in the Guangdong Province and is the second largest city in Guangdong after Qingyuan. The city has foreign investors, including John Deere and Walmart, who have set up businesses there. Major industries include tobacco, toys, pharmaceuticals, as well metallurgy, electricity, steel and iron, and machinery. The overall industry sector accounts for 31% of the GDP (HKTDC 2017).

Shaoguan ranks #59 in overall sustainability. Shaoguan performed well on "Water Resources p.c." (#3), "Inhalable Particulate Matter Concentration" (#7), and "Health Expenditure %" (#8). However, Shaoguan performed poorly on "Wastewater Discharge per ¥ Value Added" (#66), "Water Consumption per Unit of GDP" (#64), and "Energy Consumption per Unit of GDP" (#62).

Shaoguan's overall ranking has improved slightly, primarily due to an improvement in air quality, environmental protection expenditure, and energy intensity, although it has worsened in physician availability, pension coverage, and road congestion.

60. Xiangyang

Land Area: 19.724 km^2 **Population:** 5.61 million **GDP:** 338.2 billion RMB	Xiangyang is located in the Hubei Province, with the Han River dividing the city between north and south. The most important pillars of the economy are auto parts production and tourism and is one of the most important bases of auto parts production in central China. Xiangyang's 2,800 year history and designation as a National Historical Cultural City makes it one of the major tourist destinations in the province (HKTDC 2017).

Xiangyang ranks #60 in overall sustainability. Xiangyang performed well on "Energy Intensity Improvement" (#9), "Labor Productivity" (#13), and "Science and Technology Expenditure p.c." (#15). However, Xiangyang performed poorly on "Service Sector Added Value %" (#65), "Road Area p.c." (#65), and "Days Meeting Air Quality Index Level 2" (#62).

Xiangyang's overall ranking declined slightly in 2015. Although Xiangyang improved its ranking in housing affordability, labor productivity, and science and technology expenditure, it worsened in air quality and physician availability.

61. Ganzhou

Land Area: 39,400 km^2 **Population:** 8.55 million **GDP:** 197.3 billion RMB	Ganzhou is located in the southern part of the Jiangxi Province and is the largest prefecture level city in the province. Metallurgy and new materials, non-metal product processing, machinery, food manufacturing, textile and electronics are the dominant industries in the city, accounting for 37% of the GDP. In particular, the city is reputed as the "capital of tungsten" and the "capital of rare earth" in China due to abundant tungsten and rare earth resources in Ganzhou (HKTDC 2017).

Ganzhou ranks #61 in overall sustainability. Ganzhou performed well on "Education Expenditure %" (#1), "Health Expenditure %" (#2), and "Water Resources p.c." (#4). However, Ganzhou performed poorly on "Physician Availability" (#69), "Urban Green Space p.c." (#67), and "Housing-to-Income Ratio" (#65).

Ganzhou's overall ranking has improved slightly, primarily due to improvement in science and technology expenditure, GDP growth, and environmental protection expenditure, although it worsened in inhalable particulate matter concentration, built area added value, and energy intensity.

62. Zhanjiang

Land Area: 12,490 km^2 **Population:** 7.24 million **GDP:** 238 billion RMB	Zhanjiang is located on the eastern coastline of the Leizhou Peninsula in the Guangdong Province. It is a port city, one of the major international ports in Guangdong, and a trade center with a well-established railway and highway network. The port contains berths for oil, mineral and containers, and also hosts a competitive fishery sector. The service sector accounts for 43% of GDP while the industry sector accounts for 34% (HKTDC 2017).

Zhanjiang ranks #62 in overall sustainability. Zhanjiang performed well on "Labor Productivity" (#2), "Inhalable Particulate Matter Concentration" (#3), and "Education Expenditure %" (#8). However, Zhanjiang performed poorly on "Urban Green Space p.c." (#66), "Environmental Protection Expenditure %" (#66), and "Energy Intensity Improvement" (#66).

Zhanjiang's overall ranking declined slightly, primarily due to worsened performance in road congestion, environmental protection expenditure, and energy consumption, although it improved in education expenditure, GDP growth, and air quality.

63. Liuzhou

Land Area: 18,597 km^2 **Population:** 3.92 million **GDP:** 229.9 billion RMB	Liuzhou is located in the northern part of the Guangxi Zhuang Autonomous Region and is a prefecture-level city. It is the second largest city in Guangxi and is the region's industrial center. Automobiles, metallurgy and machinery are the major industries, accounting for over half of the city's GDP (HKTDC 2017).

Liuzhou ranks #63 in overall sustainability. Liuzhou performed well on "GDP Growth %" (#4), "Education Expenditure %" (#4), and "Health Expenditure %" (#6). However, Liuzhou performed poorly on "Service Sector Added Value %" (#69), "Domestic Sewage Treatment %" (#68), and "Water Consumption per Unit of GDP" (#62).

Liuzhou's overall ranking has risen slightly, primarily due to improvement in energy consumption, pension coverage, and air quality. However, a further rise in ranking was arrested by worsened performance in labor productivity, domestic sewage treatment, and environmental protection expenditure.

64. Nanchong

Land Area: 12,477 km^2 **Population:** 6.36 million **GDP:** 151.6 billion RMB	Nanchong is located in the Sichuan Province. National highways and expressways and an airport increase access to other parts of the country. The city is designated as a regional hub in distributive trade and logistics. It is the second most populated city of Sichuan Province. Major industries in Nanchong include petrochemicals, machinery and related spare parts, textiles, agricultural products processing, construction materials and energy (HKTDC 2017).

Nanchong ranks #64 in overall sustainability. Nanchong performed well on "Water Resources p.c." (#2), "Education Expenditure %" (#3), and "Health Expenditure %" (#4). However, Nanchong performed poorly on "Science and Technology Expenditure %" (#68), "Service Sector Added Value %" (#67), and "Water Consumption per Unit of GDP" (#67).

Nanchong's overall ranking improved slightly, primarily due to an increased ranking in air quality and unemployment rate. However, Nanchong worsened in GDP growth, industrial solid waste utilization, and labor productivity.

65. Dandong

Land Area: 14,981 km^2 **Population:** 2.38 million **GDP:** 98.5 billion RMB	Dandong lies on the Southeastern boundary of the Liaoning Province, and is the largest Chinese border city. Its convenient access to the ocean and its abundant natural resources have made the city a major export production center. Dandong's industrial sector consists of auto parts, paper making, garments, instruments, electronics and boron chemicals (HKTDC 2017).

Dandong ranks #65 in overall sustainability. Dandong performed well on "Pension Coverage" (#12), "Water Resources p.c." (#18), and "Days Meeting Air Quality Level 2" (#22). However, Dandong performed poorly on "GDP Growth" (#69), "SO_2 Emissions per ¥ Value Added" (#69), and "Wastewater Discharge per ¥ Value Added" (#69).

Dandong's overall ranking has declined, primarily due to worsened sulfur dioxide emissions, housing affordability, and water resources, though it has seen significant improvement in health expenditure, industrial solid waste utilization, and service sector added value.

66. Mudanjiang

Land Area: 40,435 km^2 **Population:** 2.55 million **GDP:** 117.9 billion RMB	Mudanjiang is located in the southeastern part of the Heilongjiang Province, and has a vibrant sector of border trade with Russia. Moreover, it serves as a regional transport hub with a railway junction and an international airport connecting with several major Chinese cities as well as Seoul of South Korea. The industry sector accounts for about a third of the city's GDP, and includes the forestry industry, accessories for automobiles, paper making, petrochemicals, new materials, and medicine and energy sectors. The service center is larger, with a main focus on tourism, including the Jingbo Lake, the only lava dammed lake caused by volcanic eruption in China (HKTDC 2017).

Mudanjiang ranks #66 in overall sustainability. Mudanjiang performed well on "Water Resources p.c." (#6), "Industrial Solid Waste Utilization" (#10), and "Wastewater Discharge per ¥ Value Added" (#21). However, Mudanjiang performed poorly on "Environmental Protection Expenditure %" (#69), "Domestic Sewage Treatment %" (#66), and "Pension Coverage" (#63).

Mudanjiang's overall ranking has declined slightly, primarily due to worsened economic growth and government spending, though it did show some improvement in wastewater discharge, labor productivity, and air quality.

67. Yueyang

Land Area: 15,019 km^2 **Population:** 5.63 million **GDP:** 288.6 billion RMB	Yueyang is located in the northeastern part of the Hunan Province. The Dongting Lake Bridge connects Yueyang with cities in Hunan and Hubei Province.The industry sector accounted for 45% of the GDP in 2015. Petrochemicals, food and beverages, recycling and disposal, construction materials, textiles, paper making and machinery are the main industries in Yueyang, and together account for 45% of the city's GDP (HKTDC 2017).

Yueyang ranks #67 in overall sustainability. Yueyang performed well on "Value Added per Built Hectare" (#7), "Water Resources p.c." (#13), and "Energy Intensity Improvement" (#16). However, Yueyang performed poorly on "Urban Green Space p.c." (#69), "Physician Availability" (#63), and "Domestic Sewage Treatment %" (#63).

Yueyang's overall ranking has remained fairly stable. Although it showed improvement in built area added value, air quality, and housing affordability, it worsened in education expenditure, domestic sewage treatment, and water consumption.

68. Pingdingshan

Land Area: 8,867 km^2 **Population:** 4.96 million **GDP:** 168.6 billion RMB	Pingdingshan is located in the Henan Province and has a convenient transportation network. The city is rich in freshwater resources and coal, it has the largest demonstrated coal reserve in Henan Province, with an amount of 10.3 billion tons. Industry makes up 46% of the GDP including equipment manufacturing, raw chemicals and chemical products, non-metal mining, non-ferrous metallurgy, oil refining and coking (HKTDC 2017).

Pingdingshan ranks #68 in overall sustainability, performing poorly in economic indicators and environmental quality.

Specifically, Pingdingshan performed well on "Industrial Solid Waste Utilization" (#4), "Health Expenditure %" (#15), and "Domestic Sewage Treatment %" (#20). However, Pingdingshan performed poorly on "Days Meeting Air Quality Index Level 2" (#69), "Service Sector Added Value %" (#68), and "SO_2 Emissions per ¥ Value Added" (#67).

Pingdingshan's overall ranking has remained low. Although Pingdingshan improved its ranking in pension coverage, number of physicians, and industrial solid waste utilization, it worsened in built area added value, energy intensity, and unemployment.

69. Jinzhou

Land Area: 10,301 km^2 **Population:** 3.03 million **GDP:** 132.7 billion RMB	Jinzhou is located in the southwestern part of Liaoning Province and is a regional hub of distributive trade and logistics. The industry sector dominates Jinzhou's economy, led by ferrous metal smelting and rolling, petrochemicals, and agricultural products processing industries (HKTDC 2017).

Jinzhou ranks #69 in overall sustainability. Jinzhou performed well on "Health Expenditure %" (#28), and "Pension Coverage" (#32), and "Inhalable Particulate Matter Concentration" (#35). Jinzhou performed poorly on "GDP Growth %" (#68), "Physician Availability" (#68), and "Science and Technology Expenditure p.c." (#67).

Jinzhou has consistently declined in ranking, primarily due to worsened water resources, labor productivity, and science and technology expenditure, though it has improved in domestic sewage treatment, air quality, and service sector added value.

VI. Conclusion

In this publication, we have presented our China Sustainable Development Indicator System (CSDIS) and ranking results for 69 large and medium-sized Chinese cities based on their sustainability performance from 2013 to 2016. Although often hampered by the availability (or lack thereof) of data on certain indicators that are important to sustainability analyses, we carefully selected 24 indicators representing five categories of sustainable development, namely, economic development; social welfare and livelihood; environmental resources; consumption and emissions; and environmental management. In addition to the widely accepted triple-bottom-line of economy, society, and environment in describing sustainable development, we made a nuanced distinction between the available stock of environmental resources and the flow of those resources, and their implications in the form of consumption and emissions, given the myriad environmental problems China faces. We added the fifth category of environmental management since China has set ambitious environmental protection and conservation targets and has made tremendous efforts in combating environmental degradation.

Our urban sustainability ranking uses an innovative indicator weighting method which takes into account the volatility of data for each indicator across time and geographic location, which most existing urban sustainability rankings do not fully address. As a result, the environmental management category, though important, has the lowest weight at 7.61% due largely to the inconsistency in the measurement standards and collection methods of its indicators across cities and years. It is our hope that resources and other government efforts in combating environmental problems in the future will be better defined and data more accurately collected and recorded by government at all levels in China. Within the social welfare and livelihood category, we added indicators depicting housing affordability and congestion to speak to the livability of cities. These indicators are often identified by both residents and experts alike as key determinants of sustainability for densely populated urban cities.

Assessing urban sustainable development is a complex exercise that requires clear and measurable goals, accurate data, and a sound methodology. Sustainability by definition measures more than just economic growth – it encompasses multiple facets of social welfare and environmental well-being. Although China has historically focused on GDP growth as a single indicator to measure economic progress, there is no single indicator that can measure and fully capture progress in sustainable development. There is no panacea for achieving sustainability, as demonstrated by the inclusion of 24 distinct and varied indicators in our assessment. Every city should chart their own course depending on their geographic and resource constraints, while using this ranking as a guide to identify areas of weakness compared to other cities, and improve upon the areas of sustainability that can have the greatest impact.

Appendix I: Review of International Sustainability Indicator Systems

A great variety of sustainability indicator frameworks are available for policymakers to shape cities' growth strategies, and many researchers have demonstrated the positive correlation between the appropriate use of indicator systems and cities' achievements in sustainable development (e.g. Wong et al. 2006; Roy 2009; Tanguay et al. 2010). A sustainable city is commonly defined as one that has a well-balanced relationship between social welfare, economic development, and environmental protection, also known as the "triple bottom line" (Drakakis-Smith 2000).

In this section, we present a brief review of sustainability indicator systems and frameworks developed by various organizations and governments for implementing sustainability in nations and cities across the globe, which have informed the development and refinement of our own framework. Because the Triple Bottom Line (TBL) framework has been so widely adopted as a strategy to balance sustainability's "triple bottom line" of economy, society, and the environment, we have grouped systems into two sections: 1) systems that follow the TBL framework, and 2) systems that deviate from the TBL framework.

Triple Bottom Line Systems

The following frameworks and indicator systems developed by international institutions, non-governmental organizations (NGOs) and nonprofits, private corporations, and individual cities all follow the TBL framework.

From International Institutions

CSD Indicators of Sustainable Development

Since 1996, the UN Commission on Sustainable Development (CSD) has published three versions of Indicators of Sustainable Development (ISD) to further construct a coherent vision of sustainable development in the 21st century. The goal of this indicator set is to support countries "in their efforts to develop and implement national indicators for sustainable development." The ISD were developed through meetings with various international stakeholders, a pilot test, revisions, and expert review. The latest version includes 14 themes covering four pillars of sustainable development -- economic, environmental, social and institutional -- with a core set of 50 indicators. Governments that wish to tailor the indicators to respond to needs and circumstances use a matrix created by the UN to assess the readiness of available data (United Nations 2007).

Dashboard for Sustainability

The International Institute for Sustainable Development (IISD) initiated the Dashboard for Sustainability (DS) at the end of 1990 – a quantitative and graphical interpretation of the aggregate value of 19 social (e.g. child weight, immunization, crime etc.), 20 environmental (e.g. water, urban air, forest area, etc.), 14 economic (e.g. energy use, recycling, GNP, etc.) and 8 institutional indicators (e.g. Internet, Telephones, R&D expenditures) (IISD 2001). This Dashboard for Sustainability has been used by the international scientific community over the last several years and now includes data for over 200 countries. For example, the City of Padua, Italy, adopted the DS in its Local Agenda 21 Program named ''Sustainable Padua—PadovA21'' in its 2003 Local Action Plan. Sustainable Padua generated 61 indicators about environmental protection, economic development, and social promotion (Scipioni et al. 2009).

Urban Metabolism Framework

The European Environment Agency (EEA) developed the Urban Metabolism Framework to provide an analysis of urban sustainable development based on metabolic flows, rather than a performance of current status. The framework is composed of five main dimensions: urban flows, urban quality, urban patterns, and urban drivers (European Union 2015). Indicators like per capita carbon dioxide emissions from energy consumption, water intensity, GDP per capita, unemployment rate, and green space access cover the three essential aspects of sustainability. Specifically, this framework underlines the dynamic flow of urban resources and reveals how it will automatically drive the system towards equilibrium (Minx 2011). This set provides low-cost, continuous monitoring of urban metabolism in European cities. Also, it proposes a scaling framework to allow the tool to be used in cities of various sizes. Use of this framework is simple and uses readily available data sources, but it does not provide the most comprehensive measure of how sustainable a city is; it is more informative at the European level rather than at an individual city level (European Union 2015).

Global Reporting Initiative

The United Nations Environment Programme (UNEP) in association with the United States nongovernmental organization Coalition for Environmentally Responsible Economics (CERES) launched the Global Reporting Initiative (GRI) in 1997 for improving the quality, structure and coverage of sustainability reporting. The GRI is one of the most common examples of a TBL framework and was a key driver for adoption of sustainability management in industries. The third version of the GRI guideline considers a set of 84 indicators across three pillars—social, environmental and economic— with the largest emphasis placed on the social and environmental aspects (Das & Das 2014).

From NGOs & Nonprofits

Indicators for Sustainability

Indicators for Sustainability by the Canada-based NGO Sustainable Cities International (SCI) is a set of indicators to help identify drivers of sustainable development and assess their progress in global cities accurately. The creators applied a wide range of case studies of urban sustainability metrics to choose the most common and easily measured indicators for economy, environment, and social aspects. The multi-dimensional indicator set includes: underemployment rate and economic growth; green spaces, water quality, and reduction of greenhouse gas; and housing quality, education, and health (SCI 2012). This core indicator set is flexible, easy to implement, and relevant to cities regardless of size or location; the indicators cover a broad range of sustainability targets. However, little weight is given to indicators of health and governance (European Commission 2012).

Sustainable Cities Index

The Sustainable Cities Index by the United Kingdom's leading sustainable development NGO, Forum for Future, ranks the sustainability of the 20 largest cities in the United Kingdom. This Index provides a good snapshot of a city's sustainability profile by integrating the measurement of economic, social and environmental elements. The metrics of 13 variables are organized into three areas: 1) environmental performance (e.g. air quality, ecological footprint, biodiversity), 2) quality of life (e.g. life expectancy, education, unemployment), and 3) future-proofing (e.g. economy, recycling, food). The last category can reflect a dynamic process of how cities are making progress in overcoming environmental challenges. Results have shown that most cities have made steady progress since the indicators have been used (Forum for the Future 2009).

STAR Community Rating System

In the United States, the Sustainability Tools for Assessing and Rating Communities (STAR) Community Rating System has become a framework for civic leaders to incorporate sustainability management into their planning. It follows the TBL framework and includes 44 objectives specifying seven goal areas:

1. The Built Environment;
2. Climate & Energy;
3. Economy & Jobs;
4. Education, Arts, & Community;
5. Equity & Empowerment;
6. Health & Safety; and
7. Natural System.

Because there are currently no universally accepted standards for rating one sustainability goal as of greater importance or value than any other, STAR's goal areas are equally weighted at 100 points each (Singh et al. 2012). Cities like Phoenix, Arizona, Los Angeles, California, and Plano, Texas, have utilized this system in sustainable city plans to not only integrate benchmarks into development plans, but also communicate strategic objectives effectively to stakeholders (STAR 2016).

From Private Corporations

Sustainable Cities

The first Sustainable Cities index developed by Arcadis (a global design and consulting firm for natural and built assets) is aimed at using 20 indicators to balance the economic, social and environmental needs of the 50 big cities around the world. In particular, its "people" category includes literacy, education, transport, and other six social indicators; the "planet" category includes six environmental indicators such as air pollution and greenhouse gas emissions; and the "profit" category includes six economic indicators like GDP per capita and cost of doing business. Through the index, Arcadis finds out that most cities are better at being sustainable for Profit and Planet rather than People, so it offers specific direction for attention to future city development (Arcadis 2015).

Compass Index of Sustainability

The Compass Index of Sustainability by AtKisson Group (an international consultancy group specialized in sustainability) offers an inclusive sustainability rating system, which groups indicators into four quadrants like a compass (N = Nature, E = Economy, S = Society, W = Well-being) and aggregates into an Overall Sustainability Index. Indicators, which are equally weighted, are scaled on a 0-100 performance scale; scales are set by normative judgments. For aggregation, a simple averaging technique is employed (Singh et al. 2010). It was piloted as the core of the Healthy Community Initiative of Greater Orlando's "Legacy 2000" sustainability report in Orlando, Florida in 2000, where the Compass turned out to be reliable and made a significant difference in local planning, especially on the Social element. Then, the Compass proved to be a convenient communication tool about sustainable planning in other cities of the U.S. (Atkisson 2001; 2005).

Urban Ecosystem Europe

The private research institute Ambiente Italia has conducted the Urban Ecosystem Europe (UEE) Report as a comprehensive sustainability assessment of 32 European cities. As part of the report, sustainability indicators are chosen according to the ten Aalborg Commitments contents, and then aggregated into six main themes:

1. Local action for health and natural common goods;
2. Responsible consumption and lifestyle choices;
3. Planning, design and better mobility for less traffic;
4. Local to global: energy and climate change;
5. Vibrant, sustainable local economy and social equity, justice and cohesion; and
6. Local management towards sustainability and governance.

More than half of its indicators describe environmental sustainability specifically, such as particulate matter-10 concentrations, nitrogen dioxide concentrations, and the amount of municipal waste, though it also has a focus on local governance and quality of life. The 32 cities that were evaluated ranged in population size, so the indicator set can be scalable to both large and small cities (Ambiente Italia 2007).

From Cities

City of Winnipeg's Quality of Life Indicators

The City of Winnipeg's Quality of Life Indicators system is part of the International Sustainability Indicators Network (ISIN), which is a web-based network that encourages the development of indicators for sustainability (Hardi 2006). Given the mounting challenges in natural resources management, environmental protection, and social equity, the City of Winnipeg has been mobilized to generate creative solutions to achieve "orderly" sustainable development, "compact urban form," and "regional consistency" (IISD 2002; Leo & Brown 2000). It is comprehensive with a consideration of urban environment, urban economy, and individual well-being.

Melbourne's City Plan 2010

The Melbourne's City Plan 2010 for sustainable development set the long-term goals for the sustainable urbanization of the city. They have given significant attention to build: (1) a connected and accessible city, (2) an innovative and vital business city, (3) an inclusive and engaging city, and (4) an environmentally responsible city. The framework brings a "triple bottom line": economic prosperity, social equity and environmental quality, which set the basis for a set of indicators to measure the city's sustainability performance (Melbourne City Council 2010).

Systems that Deviate from the TBL

The following systems deviate from the TBL framework by excluding one or more of the three main elements of sustainability, or have a particular focus on one aspect of sustainability that significantly outweighs the others.

Focus on Environment

European Urban Indicators

The European Foundation developed the European Urban Indicators in 2003, which focuses on monitoring sustainability at an urban level, specifically from an environmental standpoint. It is a metrics system that has combined the Pressure-State-Response framework and the Charter of European Cities and Towns: Towards Sustainability issued in Aalborg in 1994. There are ten environmental indicators, such as global climate, air quality, and waste management with only 5 social indicators including urban safety, social justice, public space and heritage, citizen participation, urban mobility, and one economic indicator called economic urban sustainability (European Union 2015).

European Green Capital Award

European Green Capital Award, granted annually by the European Commission, involves twelve environmental and social indicators such as local transport, nature and biodiversity, ambient air quality, water management, energy performance, and integrated environmental management (2016). This framework places emphasis on the environment and impacts from urbanization, without balancing with the other two elements in the triple bottom line. Eligible cities need to have a population of at least 100,000 (European Union 2015). Since Stockholm won the first Green Capital Award in 2010, this sustainability rating system has enabled 37 European cities to share best practices and encourage them to introduce effective policies to solve both local and global environmental problems (Berrini 2010). Several reports are issued every year that cover methodology, best practices, and benchmarking, as well as comparing the participating cities for each indicator area (European Union 2015).

Green City Index

Siemens Organization's Green City Index (GCI) is an evaluation of the environmental sustainability of European cities; as part of the evaluation and comparison of the cities, an expert panel develop a set of 30 indicators in the following 8 categories: Transport, Energy, Environmental Governance, CO2, Water, Waste & Land Use, Buildings, and Air Quality. The indicator set covers all major areas of urban environmental sustainability, emphasizing energy and CO2 emissions. Moreover, the indicator set is structured to use publically available data and each indicator is normalized to allow comparison between cities (European Union 2015). The first project of the European Green City Index was conducted in 2009 and examined 30 major European cities from 30 countries. Among them, Copenhagen led through its sustainability performance across all categories by setting an ambitious goal to be carbon-neutral by 2025 and become "world's best cycle city" (Zheng 2013). In 2013, the index measured and rated the environmental performances of 130 cities. One key finding from the comparisons is the strong positive correlation between wealth and environmental performance (Zheng 2013). However, the GCI does not directly reflect the current social and economic situation of a city.

Environmental Performance Index (EPI)

The Environmental Performance Index (EPI), developed by joint effort from Yale University, Columbia University, and the World Economic Forum, is a method of quantifying and numerically marking the environmental performance of a state's policies. Preceded by the Environmental Sustainability Index (ESI), it includes 265 indicators that focus on two overarching environmental objectives: 1) environmental health: reducing environmental stresses to human health; and 2) ecosystem vitality: promoting ecosystem vitality and sound natural resource management. It calculates scores for each of the six core categories about environmental policies – environmental health, air quality, water resources, biodiversity and habitat, productive natural resources, and climate change (Emerson et al. 2010). All indicators are scaled from 0 to 100 and weights of the indicators are evaluated using principal component analysis and it is aggregated in the form of a weighted sum (Singh et al. 2012). This index reveals clearly how urban development can change the natural environment, yet does not address its significant effect on social and economic dimensions (Esty et al. 2008).

Focus on Society

Healthy City Index

As part of the Healthy Cities Project, the WHO European Healthy Cities Network has developed the Healthy City Index, a set of 53 indicators to measure city health, which has helped decision makers throughout the world to develop effective interventions to improve society's health in urbanization. It has environmental indicators like air pollution, water quality, and sewage collection; social indicators like mortality, public transport, and immunization rates; and economic indicators like homeless, unemployment, and poverty; but emphasizes the "health" component in sustainable development (WHO 2015). WHO has grouped the selected indicators into four main categories: health promotion, health services, social care, and environmental improvement (which includes physical, social, and economic environment) (Crown 2003).

Global Cities Indicator Program

The World Bank's Global City Indicators Program (GCIP) aims to improve the wellbeing of people living in the city and to promote social capacity building (World Bank 2009). It is a qualitative review by a panel of international experts, which predominantly focuses on the social aspect of sustainability. It is divided into two main categories: 1) City Services and 2) Quality of Life. City Services are composed of 14 themes that include education, finance, and energy. Quality of Life consists of eight themes including economy, culture, environment, social equity, and technology & innovation (World Bank 2008). GCIP first piloted its approach in Latin America and the Caribbean Region, and now has hundreds of participating cities all around the world.

Focus on Economy

Global Power City Index

The Global Power City Index by the Mori Memorial Foundation ranks 35 major cities in the world by their power to attract business and to mobilize their assets in securing economic, social, and environmental development. Although this index takes in social and environmental variables, the predominant focus is on the economic component. It adopts nine indicators under six main city strengths: economy, research and development, cultural interaction, livability, environment, and accessibility (MMF 2015).

Appendix II: Indicator Narratives

CATEGORY	#	INDICATOR
Economic Development (23.87%)	1	Service Sector Added Value %
	2	Value Added per Built Hectare
	3	Science and Technology Expenditure p.c.
	4	Unemployment %
	5	Labor Productivity
	6	GDP Growth %
Social Welfare & Livelihood (30.24%)	7	Housing-to-Income Ratio
	8	Health Expenditure %
	9	Pension Coverage
	10	Education Expenditure %
	11	Physician Availability
	12	Road Area p.c.
Environmental Resources (17.98%)	13	Urban Green Space p.c.
	14	Water Resources p.c.
	15	Days Meeting Air Quality Index Level 2
	16	Inhalable Particulate Matter Concentration
Consumption & Emissions (20.31%)	17	Water Consumption per Unit of GDP
	18	Energy Consumption per Unit of GDP
	19	Sulfur Dioxide Emissions per ¥ Value Added
	20	Wastewater Discharge per ¥ Value Added
Environmental Management (7.61%)	21	Environmental Protection Expenditure %
	22	Domestic Sewage Treatment %
	23	Industrial Solid Waste Utilization
	24	Energy Intensity Improvement

Economic Development Indicators

1) Service Sector Added Value %

Definition: The proportion of value added by the service industry in total Gross Domestic Product (GDP)

Unit of Measurement: %

Data Source and Methodology:

- Data was sourced from CEIC.
- This indicator was calculated by dividing the total value created by the service industry by the annual GDP for each city.

Policy Relevance:

The economy is made up of three industries: the primary industry (agriculture), the secondary industry (construction and manufacturing), and the tertiary industry (service sector). Stages of a country's economic development are related to broad shifts in employment, with higher economic development generally associated with a flow of labor moving from agriculture and other labor-intensive primary activities to industry and, finally, to services (Jiang 2004). This is because the return in the service sector is higher than the agricultural and the manufacturing sectors, and so the size of the service sector both in output and employment are often used as an indication of the advancement of an economy. The service sector includes jobs in retail, hotels, restaurants, information technology, finance, education, social work, entertainment, and public administration, among others.

2) Value Added per Built Hectare

Definition: Value added of secondary and tertiary industries for each unit of built area

Unit of Measurement: 10,000 yuan/hectare

Data Source and Methodology:

- Data was sourced from CEIC.
- Calculation: (Secondary Industry Value Added + Tertiary Industry Value Added) / Constructed Land Area

Policy Relevance:

In 2013, the primary industry accounted for 10% of China's GDP, the second industry accounted for 44%, and the tertiary industry contributed to 46% (National Bureau of Statistics of China 2017). Though China is still the largest agricultural economy in the world, as China becomes more urbanized, people are leaving the rural and agricultural areas and into the cities to work in secondary and tertiary industries - or in construction, manufacturing, and services. Higher added value in secondary and tertiary sectors per unit of built area imply a more efficient use of land, at least from an economic perspective.

3) Science and Technology Expenditure p.c.

Definition: Spending on science and technology per capita

Unit of Measurement: yuan

Data Source and Methodology:

- Data was sourced from CEIC, the CNKI database, and the National Statistics Bureau of China
- This indicator was calculated by dividing the total amount of municipal government expenditure on science and technology for each candidate city by the number of permanent residents.
- A per capita base is adopted to ensure more equitable comparisons among cities of different population sizes.

Policy Relevance:

Total spending on science and technology includes expenditures on scientific and technological developments and innovations by research institutes, universities, government laboratories, and technical companies. Scientific breakthroughs translate into innovative goods and services, which have the potential to provide business opportunities and change people's lives for the better. This indicator shows how a city prioritizes technology and science through investment, thereby creating jobs and promoting long-term growth.

4) Unemployment %

Definition: Unemployment rate

Unit of Measurement: %

Data Source and Methodology:

- Data was sourced from CEIC.
- This was calculated by dividing the number of registered unemployed persons at the end of each year by the number of registered unemployed persons plus the number of all employees or all eligible laborers in the workforce (including both private and public sectors) at the end of each year (National Statistics Bureau of China).

Policy Relevance:

The unemployed are members of the economically active population who are without work but available for and seeking work. By definition, a high, sustained unemployment rate indicates inefficiencies in resource allocation. The unemployment rate of a city is the broadest indicator of economic activity as reflected by the labor market. It can serve as an important socio-economic variable related to sustainability, as it is indicative of how economically active and strong the population or labor force is, and is one of the main reasons for poverty. Measurements of unemployment rates have consistently been utilized in many systems measuring sustainability (United Nations 2007).

5) Labor Productivity

Definition: The amount of GDP per person employed

Unit of Measurement: 100 yuan per person

Data Source and Methodology:

- Data was sourced from CEIC.
- This indicator is calculated by dividing total annual regional GDP by the average number of people employed.

Policy Relevance:

A city's economic capacity and economic efficiency can be assessed by looking at the GDP per person employed. GDP measures the output of the economy; labor productivity increases signal increase in social production, a reduction of poverty, and economic growth. By allocating total production to each unit of population or capita, the extent to which the rate of individual output contributes to the development process can be measured. It indicates the pace of per capita income growth and also the rate that resources are used up (United Nations 2017).

6) GDP Growth %

Definition: Gross domestic product growth rate

Unit of Measurement: %

Data Source and Methodology:

- Data was sourced from CEIC.
- This indicator is calculated by dividing the current year's GDP index by the previous year's for each measured city.

Policy Relevance:

GDP is the sum of value added by all its producers; it accounts for all domestic production. Thus, GDP remains the most dominant economic indicator there is today. The growth rate of GDP, in China, is a main measurement for the local government's annual achievements. Many other sustainability indicator sets include GDP growth rate. High GDP growth is generally considered a positive sign of economic development, but it can also be associated with higher energy consumption, exploitation of natural resources and negative impacts on environmental resources (United Nations 2017).

Social Welfare and Livelihood Indicators

7) Housing-to-Income Ratio

Definition: Ratio of housing price to GDP per capita

Unit of Measurement: ratio

Data Source and Methodology:

- Data was sourced from China Real Estate Index System (CREIS).
- Calculation: housing-to-income ratio is calculated by dividing the average annual housing price by per capita GDP.

Policy Relevance:

This indicator measures the affordability of housing in cities. The increasing middle class in cities, together with millions of migrant workers now settling into cities, have created huge demand for housing and have driven up the prices of housing in many large urban centers. Exorbitant housing prices compared to the wage of average workers places a heavy burden on residents, and leaves them worse off to enjoy other social and economic activities. Also, high housing prices dissuade skilled workers migrating to the city and decrease the labor force and productivity.

8) Health Expenditure %

Definition: Proportion of health expenditure in total GDP

Unit of Measurement: %

Data Source and Methodology:

- Data was sourced from CNKI's Chinese Economy Statistics Data Base and yearbooks from each province.
- Calculation: amount of municipal government expenditure on health services divided by total GDP

Policy Relevance:

Total health expenditure is the sum of public and private health expenditure, and it covers the provision of health services (preventive and curative), family planning activities, nutrition activities, and emergency aid designated for health, but does not include provisions of water and sanitation. Evaluating the amount of health funding, particularly in health systems or institutions that maintain the health of a population, can assess the government's commitment to the welfare and health status of its residents. Health and sustainable development are closely connected, and pollution control and health protection services have often not kept pace with economic development. As a consequence, poor health is associated with decreased productivity, particularly in the labor-intensive agricultural sector (United Nations 2017).

9) Pension Coverage

Definition: Pension coverage of residents

Unit of Measurement: %

Data Source and Methodology:

- Data was sourced from EPS and CNKI.
- This indicator was calculated by dividing the number of people with pension coverage by the number of permanent residents.

Policy Relevance:

This indicator measures the number of people covered by a pension plan and who will therefore receive a state pension upon retirement. It can indicate a wealthy society with a high individual ability to pay into its pension system, and/or that the government is investing to cover those who have limited or no ability to pay into pensions. Government expenditure in social services is particularly important for the most vulnerable populations -- low-income households, the elderly, disabled, sick, and the unemployed. Because of China's rapid urbanization and the influx of labor force from rural areas to cities, many entities and enterprises have had to restructure and reform, leaving a significant number of the population unemployed and making it important for governments to invest in social security and pension coverage (ILO 2015).

10) Education Expenditure %

Definition: Proportion of government spending on education of total GDP

Unit of Measurement: %

Data Source and Methodology:

- Data was sourced from the Statistical Yearbook for each city.
- The indicator was calculated by dividing the amount of government spending on education by total GDP.

Policy Relevance:

Government spending on education indicates a government's commitment to investing in human capital development, and allows an assessment of a government's priority for education relative to other public investments. Expansion of basic education increases employment rates and alleviates poverty, while investment in secondary education allows for increased participation in the service sector and therefore increased economic development. The United Nations believes education is a catalyst for sustainable development at all levels, and that there is an urgent need for more financing for education.

11) Physician Availability

Definition: Number of physicians per 10,000 citizens

Unit of Measurement: person

Data Source and Methodology:

- Data was sourced from CNKI's Chinese Economy Statistics Data Base and yearbooks from each province.
- Calculation: number of health workers divided by the number of residents times 10,000.

Policy Relevance:

The distribution of health workers is an important indicator for sustainable development. Many developed regions with lower relative need have higher numbers of health workers, while many less developed regions with greater burden of disease must make do with a much smaller health workforce. Because of urbanization in China, many health workers are leaving the rural areas to cities, resulting in significant shortages. Therefore, a specific measure, such as this one, can provide more context on a city's provision of public health services, which are crucial to the long-term health of its workers and residents.

12) Road Area p.c.

Definition: Amount of paved road area per person

Unit of Measurement: m^2

Data Source and Methodology:

- Data was sourced from EPS.
- Calculation: area of paved city roads divided by the number of residents.

Policy Relevance:

China's affluent middle-class residing in cities are increasingly resorting to cars for everyday travel, which has resulted in massive amount of traffic congestion in major cities. Congestion reduces economic efficiency by delaying work, imposing extra costs on transportation, as well as generating emissions, which are all obstacles to sustainability. Lacking a more direct measure for city congestion, road area per person can be used as a proxy for how much road each resident is being afforded in any given city.

Environmental Resources

13) Urban Green Space p.c.

Definition: Urban green space per capita

Unit of Measurement: hectare per 10,000 citizen

Data Source and Methodology:

- Data was sourced from CNKI's Chinese Economy Statistics Data Base and yearbooks from each province.
- Calculation: City park or green area divided by the number of residents times 10,000.

Policy Relevance:

According to the World Health Organization, urban green spaces are foundations for community engagement, recreation, and livelihood, and the China Statistical Yearbook refers it to total area occupied for green projects, including park green land, production green land, protected green land, and green land attached to institutions. Urban green spaces filter air pollution, facilitate physical exercise, and improve mental health.

14) Water Resources p.c.

Definition: Available water resources per person

Unit of Measurement: m^3 per person

Data Source and Methodology:

- Data was sourced from Water Resources Public Reports and yearbooks by each province.
- Calculation: Total water amount divided by number of residents.

Policy Relevance:

Water resources per capita refers to run-off for surface water from rainfall and recharge for groundwater shared by each person in a region in a given period, excluding transit water (Li & Pan 2012). The sustainable and effective management of water resources is crucial in a developing city. In order to provide the water resources necessary for a population, a government needs to plan across sectors. Most water is used for agricultural purposes, but poor management of water resources dedicated for public use could mean for more energy- and resource-intensive ways to provide potable water. Properly managed water is a critical component of sustainable growth, poverty reduction, and equity, and access to water services is associated with the livelihood of people.

15) Days Meeting Air Quality Index Level II

Definition: Days per year that meet China's Air Quality Index Level II standard

Unit of Measurement: number of days

Data Source and Methodology:

- Data was sourced from the China Economic and Social Statistical Database, Statistical Yearbook of Provinces and Cities, Environmental Quality Bulletin of Provinces and Municipalities.

Policy Relevance:

Air pollution is a public health threat. In China, ambient air quality has been regulated since 1982, when limits were set for Total Suspended Particulates, sulfur dioxide, nitrogen dioxide, lead, and Benzopyrene. The standard was strengthened in 1997 and in 2000. In 2012, China released a new ambient air quality standard that has set limits for Particulate Matter 2.5, in addition to the other regulated pollutants. Long-term exposure to high levels of fine particles and other substances has adverse health effects and deaths. Air pollution also carries economic costs and represents a drag on development, especially for those that are low and middle-income and in children and the elderly.

16) Inhalable Particulate Matter Concentration

Definition: Average concentration of inhalable particulate matter

Unit of Measurement: milligram per m^3

Data Source and Methodology:

- Data was sourced from the China Economic and Social Statistical Database , Statistical Yearbook of Provinces and Cities and environmental status bulletins of cities

Policy Relevance:

High population density and the concentration of heavy industries exert great pressures on the local environment. Air pollution from households, industry power stations and transportation (motor vehicles), is often a major problem. As a result, the greatest potential for human exposure to ambient air pollution and subsequent health problems occurs in urban areas. Particulate matter concentrations are a common indicator for air quality. Improving air quality is a significant aspect of promoting sustainable human settlements.

Consumption and Emissions

17) Water Consumption per Unit of GDP

Definition: Water consumption per unit of GDP

Unit of Measurement: m^3 per 10,000 yuan

Data Source and Methodology:

- Data was sourced from Water Resources Public Reports and Yearbooks by each province.
- Calculation: Total amount of water consumed in cubic meters divided by GDP.

Policy Relevance:

This indicator measures the efficiency of a city's use of water by calculating the total amount of water consumed in relation to its GDP. Regardless of size, cities consume a large amount of natural resources such as water. Because water is a finite resource that is essential for healthy ecosystems and human survival, a more efficient rate of water consumption indicates a more sustainable city.

18) Energy Consumption per Unit of GDP

Definition: Coal consumption per unit of GDP

Unit of Measurement: tons of standard coal per 10,000 yuan

Data Source and Methodology:

- Data was sourced from the Statistical Yearbook of the Provinces and Cities and the China Economic and Social Statistical Database.
- Calculation: consumption of standard coal in tons divided by GDP of each city.

Policy Relevance:

Energy is an essential resource for urban and city development, but in regards to sustainable development of cities, reconciling the necessity and demand for energy is a challenge. Energy generation and use has adverse environmental and health effects, and coal has some of the worst greenhouse gas emissions and health effects out of all available energy sources. In lieu of information for total energy use for each city, we use coal consumption per unit of GDP as a proxy.

19) SO_2 Emissions per ¥ Value Added

Definition: Industrial sulfur dioxide emissions per yuan value added

Unit of Measurement: tons per 100 million yuan

Data Source and Methodology:

- Data was sourced from CEIC; CNKI's Chinese Economy Statistics Data Base; and yearbooks from each province.
- Calculation: Sulfur dioxide emissions from industry divided by gross industrial output value.

Policy Relevance:

Generally as a result of industrial processes such as electricity generation and metal smelting, sulfur dioxide gases are emitted when fuels containing sulfur, like coal and oil, are burned. High concentrations of sulfur dioxide are associated with multiple health and environmental effects, such as asthma and other respiratory illnesses. Sulfur dioxide emissions are a major precursor to Particulate Matter (PM) 2.5 concentrations. They also impact visibility and contribute to haze, a rampant problem in Chinese cities. Thus, high levels of sulfur dioxide emissions indicate hazards for human and environmental health. Ultimately, these emissions negatively impact the sustainable development of cities.

20) Wastewater Discharge per ¥ Value Added

Definition: Industrial wastewater discharge per yuan value added

Unit of Measurement: tons per 10,000 yuan

Data Source and Methodology:

- Data was sourced from CNKI's Chinese Economy Statistics Data Base and yearbooks from each province.
- Calculation: Amount of industrial wastewater discharge divided by gross industrial output.

Policy Relevance:

The majority of wastewater discharge comes from the chemical, electric power, and textile industries, and contributes to pollution of groundwater, wetlands, and other natural bodies of water. This pollution leads to decreased water quality and adverse environmental and health effects. A high rate of wastewater discharge can indicate a city that is prioritizing industrial development over the health of its ecosystem and community.

Environmental Management

21) Environmental Protection Expenditure %

Definition: Proportion of government expenditure on environmental protection

Unit of Measurement: %

Data Source and Methodology:

- Data was sourced from the Statistical Yearbook of the provinces and municipalities and financial accounts of the provinces and municipalities.
- Calculation: Expenditure on environmental protection divided by annual total fiscal expenditure by each city.

Policy Relevance:

Environmental protection expenditure includes spending on environmental management, monitoring, pollution control, ecological conservation, reforestation, energy efficiency, and investment in renewables. Environmental protection is an integral part of sustainable development. As China urbanizes and develops, it has generated many environmental problems, such as air pollution, water pollution, and soil erosion. Not only are these problems are public health hazard, but the depletion of natural resources can limit future economic growth.

22) Domestic Sewage Treatment %

Definition: Domestic sewage treatment rate

Unit of Measurement: %

Data Source and Methodology:

- Data was sourced from the Statistical Yearbook of the cities and CEIC.
- Calculation: Domestic sewage wastewater treated divided by total wastewater.

Policy Relevance:

The domestic sewage treatment rate refers to the ratio of domestic wastewater treated by treatment plants to the quantity of wastewater during the reporting period. Treatments include oxidation, biogas digestion, and wetland treatment systems. The acceleration of urbanization in China has resulted in an increasing rate of water consumption and in turn urban domestic sewage. Therefore, wastewater or sewage treatment is an important process for an environmentally friendly growth path.

23) Industrial Solid Waste Utilization

Definition: Comprehensive utilization rate of industrial solid waste

Unit of Measurement: %

Data Source and Methodology:

- Data was sourced from the Statistical Yearbook of the cities and CEIC.

Policy Relevance:

The comprehensive utilization rate of industrial solid waste refers to the percentage of industrial solid waste utilized over industrial solid waste produced. Industrial solid waste includes liquid residues produced by industrial enterprises from the process of production, including hazardous waste, ash, tailings, radioactive residues and other waste. Utilization refers to the amount of solid waste from which useful materials may be extracted or which can be converted into usable resources, energy or other materials through reclamation, processing and recycling (Li & Pan 2012). As industrial production generates tons of solid wastes, and so the reuse and recycling of some of that waste slows the depletion of natural resources and reduce the costs and environmental impacts of solid waste disposal.

24) Energy Intensity Improvement

Definition: Annual decreasing rate of energy intensity

Unit of Measurement: %

Data Source and Methodology:

- Data was sourced from the Statistical Yearbook of provinces and cities.
- Calculation: the difference between energy consumption per unit of GDP of this year and last year divided by the energy consumption per unit of GDP of this year.

Policy Relevance:

Energy intensity improvement is the measure of increased energy efficiency of a city's economy. A lower rate of energy intensity means a lower cost of converting energy into GDP, and since different sectors have different rates of consumption and efficiency, this measure allows us to compare an economy's energy efficiency as a whole. From the 1980s to 2000, energy intensity of China fell rapidly at a rate unparalleled by any other country at a similar stage of industrialization, but since 2001, energy consumption has accelerated (Su & Thomson 2016). Increased energy consumption is associated with increased emissions and the environmental and health problems that follow, and so a decreasing rate of energy intensity would mean a more sustainable city.

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