China Sustainable Development Indicator System

August 2019

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

&

The China Center for International Economic Exchanges

China Sustainable Development Indicator System: 2019 Report

August 2019

Prepared by:

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

& The China Center for International Economic Exchanges (CCIEE)

Project Advisors:

- Dr. Steven Cohen, Director of the Research Program on Sustainability Policy and Management, the Earth Institute, Columbia University
- ZHANG Dawei, Vice Chairman and Secretary General, China Center for International Economic Exchanges

Project Leaders:

- 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
- WANG Jun, Director General, Department of Information; Research Fellow, CCIEE

Team Members:

- 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
- Kelsie DeFrancia, Assistant Director of the Research Program on Sustainability Policy and Management
- MA Lei, China Program Officer, Research Program on Sustainability Policy and Management
- Dr. WANG Anyi, Postdoctoral Research Scholar, Research Program on Sustainability Policy and Management
- Dr. Allison Bridges, Postdoctoral Research Fellow, Research Program on Sustainability Policy and Management
- ZHANG Huanbo, Director, Institute of American and European Studies, Research Fellow, CCIEE
- LIU Xiangdong, Deputy Director, Department of Economic Research, Research Fellow, CCIEE

Research assistance provided by: WANG Jia and LIU Ziyi

THE EARTH INSTITUTE
COLUMBIA UNIVERSITY

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

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.

2910 Broadway
New York, NY 10025
spm.ei.columbia.edu

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.

No.5 Yongdingmen Inner St, Xicheng District, Beijing
www.cciee.org.cn

Table of Contents

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 and provinces. Utilizing an integrated approach, which categorizes indicators by subject area while also considering the causal relationship among the fields, we designed a robust new sustainability metrics framework and two indicator sets that cover the economic, environmental, social and institutional aspects of sustainability for Chinese cities and provinces. The research team 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 22 indicators for cities and 26 indicators for provinces within these categories, our report ranks 100 Chinese cities and 30 provinces on their sustainability performance. Our goal is that this framework and these rankings will be used to help Chinese cities and provinces progress towards their sustainable development goals by showing how each individual entity performs in various realms of sustainability compared to others and, by 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. 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. The indicator system began with a design for the city level, since 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 a more local level, be it city or province.

III. China Sustainable Development Indicator System (CSDIS)

The China Sustainable Development Indicator System (CSDIS) ranks 100 Chinese cities and 30 provinces based on their sustainability performance. Our framework is comprised of 22 indicators for cities and 26 indicators for provinces, 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 concerns exist 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 were pre-assigned any weights. Indicator weights were determined by utilizing a 5-year history of indicator performance to estimate the cross-sectional and longitudinal variability of each indicator. Indicators that tended to be stable over time or displayed low cross-sectional variability were assigned statistically-determined high weights since these indicators are statistically consistent and have high power to identify changes in rankings among cities. Indicators that tended to be stable over time but that nevertheless demonstrated significant cross-sectional variation (i.e. fairly low ability to identify changes in rankings) were 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.

The aggregation methodologies 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. In 2017, we collected data for years 2012-2015 on 70 large and medium-sized cities and 30 provincial-level administrative divisions that China's National Bureau of Statistics and other national agencies regularly report performance data on. In 2018, we increased the number of cities to 100 and collected data through 2016; this year, we have added data through 2017. The 100 cities range in population from 30.75 million down to 0.44 million.

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

- 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).
- **China Index Academy:** The China Index Academy is the largest independent property research organization, providing property and land data. The organization's databank has recorded more than 180,000 land plots, 100,000 residential projects, and nearly 50,000 commercial buildings, and it provides real-time land transaction data in 300 cities across China. It has also developed a widely-used set of housing price indices, including the House Price Index (HPI-100) in 100 major Chinese cities. The organization has cooperative relationships with the National Bureau of Statistics of China, State Housing Management Bureau, and the Real Estate Trading Center (China Index Academy 2017).

iii. Data Synthesis

After completing 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.

This resulted in our final *city* framework comprised of 22 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. In total, this year we compiled a comprehensive database for 100 cities with viable data on 22 indicators for the six most recent years that data had been made available in official yearbooks. A full definition of each indicator, its calculation, data source, and policy relevance can be found at www.urbansustainability.org.

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.[1]

[1] In 2017, our framework and ranking of 70 cities included the economic indicator of "labor productivity." However, due to difficulties in finding relevant information and the inconsistency in measurement for the additional 30 cities we added this year, we had to replace "labor productivity" with "GDP per capita", as an indicator that documents the overall economic productivity of any given city.

For the *provincial* framework, we replicated the aggregation methodology used for the city ranking system, but with an adjusted set of indicators to reflect the both the broader availability of data computed at the larger provincial level and the inherent differences in measuring sustainable development of provinces versus cities. Unlike most cities, the majority of provinces span geographically large areas. As such, provincial boundaries are more likely than city boundaries to contain within them a variety of rural and urban areas, a range of land use patterns, and diverse ecological zones. Consequently, different indicators were incorporated into the provincial ranking system and certain indicators were adjusted to reflect provincial boundaries.

This resulted in a final *provincial* framework comprised of 26 indicators in the five categories, presented in Table 2, and a comprehensive database for 30 provinces over the 5 most recent years that data has been made available in official yearbooks. A full definition of each indicator, its calculation, data source, and policy relevance can be found at www.urbansustainability.org.

iv. Weighting Strategy

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

City Indicator Set

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 ranks over five 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 5-year period. Our normalized weighting system assigns higher weights to indicators with less volatility. This method makes the ranking more comparable among cities and makes it easier to track their sustainable development.

First, the standard deviations for every indicator ranking over 5 years were calculated, as follows:

$$\sigma_{ci} = \sqrt{\frac{\sum_{j=1}^{5}(R_{cij} - \mu_{ci})^2}{5}}$$

where σ_{ci} denotes the rank standard deviation of a city *c* (*c* = 1 to 100 for cities) and indicator *i,* R_{cij} denotes the rank of *city c,* indicator *i,* and year *j* (*j* = 1 to 5), and μ_{ci} denotes the 5-year average ranking of indicator *i* by city *c.*

Next, the indicator standard deviation σ_i, measured as the average 5-year standard deviation across all cities, is calculated:

$$\sigma_i = \frac{\sum_{c=1}^{100}\sigma_{ci}}{100}$$

A higher σ_i implies higher fluctuations of an indicator across years and cities.

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

$$W_i = \frac{1/\sigma_i}{\sum_{i=1}^{22} 1/\sigma_i}$$

Less volatile indicators are therefore rewarded with higher weights. Tables 1 lists the weights for the 22 indicators of the five categories for cities.

Provincial Indicator Set

Our provincial indicator weighting strategy differs in that it emphasizes indicators' stability across provinces. At the provincial level, certain indicators are too stable over time, either due to the lack of a timely update from government reporting or due to the inherent nature of the underlining measure; for instance, urban green space tends to vary little across years. The lack of variation over time would lead to a misleadingly high weight based on longitudinal variation. Cross-sectional variation captures characteristics of sustainability that are difficult for any particular province to change. By assigning lower weights to indicators with substantial cross-sectional variation, we avoid unfairly penalizing provinces with fixed characteristics.

First, the coefficient of variation, CV_{yi}, for indicator *i* in year *y* is calculated using the formula below as follows:

$$CV_{yi} = \frac{\sigma_{yi}}{\mu_{yi}} = \frac{\sqrt{\frac{\sum_{p=1}^{30}(x_{yip} - \mu_{yi})^2}{30}}}{\mu_{yi}}$$

where x_{yip} is the absolute value of indicators *i* in year *y* for one of the 30 provinces,[2] and μ_{yi} is the average of indicator *i* across the 30 provinces in the same year.

Next, we calculate the 5-year average coefficient of variation for each indicator as CV_i as follows:

$$CV_i = \frac{\sum_{y=1}^{5} CV_{yi}}{5} = \frac{\sum_{y=1}^{5} \frac{\sigma_{yi}}{\mu_{yi}}}{5}$$

The CV_i measures the stability of indicator *i*, where greater values translate into less stability or more fluctuation of the indicator across provinces.

Finally, the weight of each indicator is calculated by taking the reciprocal of the coefficient of variation and dividing it by the sum of the reciprocals of all the coefficients of variation:

$$W_i = \frac{1/CV_i}{\sum_{i=1}^{26} 1/CV_i}$$

This weighting strategy gives higher weights to provincial indicators that have smaller cross-sectional variation or are more stable among provinces. Table 2 lists the weights for the 26 indicators of the five categories for provinces, municipalities directly under the central government and autonomous regions.

[2] These 30 provinces include municipalities directly under the central government and autonomous regions.

Table 1: CSDIS City Indicator Set and Weighting *(full definitions can be found at www.urbansustainability.org)*

CATEGORY	#	INDICATOR	WEIGHT
Economic Development (27.49%)	1	GDP p.c.	12.55%
	2	Service Sector Added Value %	6.73%
	3	Unemployment %	3.48%
	4	Science and Technology Expenditure %	2.95%
	5	GDP Growth %	1.78%
Social Welfare & Livelihood (27.04%)	6	Housing-to-Income Ratio	6.44%
	7	Physician Availability	5.90%
	8	Social Security Expenditure p.c.	5.73%
	9	Education Expenditure %	5.25%
	10	Road Area p.c.	3.72%
Environmental Resources (11.02%)	11	Water Resources p.c.	4.55%
	12	Urban Green Space p.c.	4.52%
	13	Days Meeting Air Quality Index Level 2	1.95%
Consumption & Emissions (26.23%)	14	Water Consumption per Unit of GDP	8.04%
	15	Energy Consumption per Unit of GDP	5.80%
	16	Built Area per ¥ Value Added	4.98%
	17	Sulfur Dioxide Emissions per ¥ Value Added	4.63%
	18	Wastewater Discharge per ¥ Value Added	2.78%
Environmental Management (8.22%)	19	Domestic Sewage Treatment %	2.54%
	20	Environmental Protection Expenditure %	2.13%
	21	Industrial Solid Waste Utilization %	2.10%
	22	Household Waste Harmless Treatment %	1.45%

**%: percent, p.c.: per capita, ¥: renminbi/yuan*

Table 2: CSDIS Provincial Indicator Set and Weighting *(full definitions can be found at www.urbansustainability.org)*

CATEGORY	#	INDICATOR	WEIGHT
Economic Development (20.9%)	1	Unemployment %	5.64%
	2	GDP Growth %	5.63%
	3	Service Sector Added Value %	5.60%
	4	Labor Productivity	2.45%
	5	R&D Expenditure %	1.59%
Social Welfare & Livelihood (24.4%)	6	Urban-Rural Disposable Income Ratio p.c.	7.41%
	7	Physician Availability	4.96%
	8	Internet Coverage Rate	4.22%
	9	Education Expenditure %	3.18%
	10	Social Security Expenditure p.c.	2.58%
	11	Highway Density	2.08%
Environmental Resources (7.7%)	12	Days Meeting Air Quality Index Level 2	5.70%
	13	Water Resources p.c.	1.02%
	14	Green Space p.c	0.97%
Consumption & Emissions (13.6%)	15	Built Area per ¥ Value Added	3.38%
	16	Ammonia Nitrogen Emissions per Unit of GDP	3.17%
	17	Chemical Oxygen Demand Emissions per Unit of GDP	2.32%
	18	Energy Consumption per Unit of GDP	2.17%
	19	SO^2 Emissions per ¥ Value Added	1.37%
	20	Water Consumption per Unit of GDP	1.14%
Environmental Management (33.4%)	21	Wastewater Treatment %	14.24%
	22	Household Waste Harmless Treatment %	8.97%
	23	Hazardous Waste Disposal Rate	4.25%
	24	Energy Intensity Improvement	2.39%
	25	Hazardous Waste Disposal Rate	1.96%
	26	Environmental Protection Expenditure %	1.64%

**%: percent, p.c.: per capita, ¥: renminbi/yuan*

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.

We therefore decided to rank cities and provinces 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 22 and 26 indicators for cities and provinces, respectively. Therefore, the smaller final score would indicate a better performance on sustainability compared to other cities or provinces, while a larger final score would indicate a worse performance compared to others.

IV. Ranking - Cities

The rankings of the China Sustainable Development Indicator System (CSDIS) for 100 Chinese cities in 2017 and 2018 are presented in Table 3.

Our rankings reveal that economically advanced cities like Shenzhen and Beijing, and southern and eastern coastal cities often rank high in overall sustainability. 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.

The top 10 cities in overall sustainability are Zhuhai, Shenzhen, Beijing, Hangzhou, Guangzhou, Qingdao, Changsha, Nanjing, Ningbo and Wuhan. Compared to last year's rankings, Zhuhai has remained in its top position; Shenzhen has risen two places, while Beijing dropped from second to third. Ningbo moved up into the top ten from 11th place the year prior, ranking 9th, while Wuxi fell out of the top 10. The rankings of Kunming, Nanchang, Taiyuan, Luoyang, Changde, Mianyang and Xuchang have changed significantly, all of which have risen by ten places or more; Hohhot, Yichang, Lanzhou and Jilin have all dropped by ten or more.

Table 3: China Sustainable Development Indicator System (CSDIS) City Ranking

CITY	2017 RANKING	2018 RANKING
Zhuhai	1	1
Shenzhen	4	2
Beijing	2	3
Hangzhou	3	4
Guangzhou	5	5
Qingdao	6	6
Changsha	8	7
Nanjing	10	8
Ningbo	11	9
Wuhan	7	10
Wuxi	9	11
Xiamen	15	12
Shanghai	14	13
Lhasa	13	14
Ji'nan	17	15
Suzhou	16	16
Zhengzhou	18	17
Tianjin	12	18
Hefei	21	19
Nantong	19	20
Xi'an	23	21
Yantai	20	22
Sanya	22	23
Huizhou	30	24
Guiyang	28	25
Kunming	36	26
Nanchang	37	27
Chengdu	26	28
Wenzhou	38	29
Taiyuan	43	30
Karamay	34	31
Fuzhou	25	32
Baotou	29	33
Xuzhou	32	34
Yangzhou	31	35
Hohhot	24	36
Haikou	39	37
Jinhua	33	38
Wuhu	41	39
Changchun	35	40
Dalian	40	41
Urumchi	42	42
Yichang	27	43
Beihai	51	44
Yulin	47	45
Weifang	45	46
Chongqing	44	47
Quanzhou	53	48
Nanning	50	49
Shenyang	48	50

CITY	2017 RANKING	2018 RANKING
Xining	46	51
Luoyang	62	52
Changde	67	53
Qinhuangdao	57	54
Shijiazhuang	56	55
Bengbu	54	56
Yinchuan	55	57
Xiangyang	58	58
Jiujiang	49	59
Tangshan	61	60
Mianyang	72	61
Chenzhou	63	62
Lanzhou	52	63
Xuchang	74	64
Jining	69	65
Linyi	65	66
Mudanjiang	68	67
Harbin	60	68
Huangshi	64	69
Anqing	70	70
Yueyang	76	71
Shaoguan	66	72
Jilin	59	73
Guilin	73	74
Kaifeng	78	75
Huaihua	80	76
Datong	83	77
Tongren	81	78
Zunyi	77	79
Nanyang	79	80
Ganzhou	71	81
Shantou	75	82
Pingdingshan	88	83
Luzhou	86	84
Dali	89	85
Zhanjiang	82	86
Handan	87	87
Leshan	96	88
Dandong	84	89
Tianshui	85	90
Yibin	94	91
Jinzhou	95	92
Baoding	92	93
Qujing	90	94
Guyuan	91	95
Qiqihar	97	96
Nanchong	98	97
Haidong	93	98
Weinan	99	99
Yuncheng	100	100

i. City Ranking by Major Component of Sustainable Development

As shown in Table 4, major cities along the eastern coast of China are performing the best on economic development. As the capital of China, Beijing has always been one of the leading cities on economic development indicators, as has Shenzhen after being designated a special economic zone and national comprehensive reform pilot area. Since the reform and opening up policy in China, Zhuhai has intensified the reward of scientific and technological talents through policy and enterprise technology innovation, and the economy has therefore developed rapidly.

Table 4: Top 10 Cities on Economic Development, 2018

CITY		2018
深圳	Shenzhen	1
杭州	Hangzhou	2
北京	Beijing	3
广州	Guangzhou	4
南京	Nanjing	5
珠海	Zhuhai	6
苏州	Suzhou	7
无锡	Wuxi	8
武汉	Wuhan	9
上海	Shanghai	10

The top Chinese cities on social welfare are mostly inland cities, as illustrated in Table 5. Apart from Zhuhai, none of the other cities overlap with the top cities on economic development. Economic development and social livelihood are not synchronized, showing 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. This reflects to a certain extent of the current development imbalance problem in China.

Table 5: Top 10 Cities on Social Welfare & Livelihood, 2018

CITY		2018
克拉玛依	Karamay	1
拉萨	Lhasa	2
榆林	Yulin	3
珠海	Zhuhai	4
乌鲁木齐	Urumqi	5
西宁	Xining	6
太原	Taiyuan	7
包头	Baotou	8
银川	Yinchuan	9
青岛	Qingdao	10

Table 6 demonstrates that, consistent with popular perception, cities with rich resources and better environmental performance are mainly concentrated in Guangdong, Guangxi, Jiangxi and other Southern China provinces. These cities generally have better ecological environments and rich natural landscapes. Lhasa is ranked higher in terms of green space p.c. and water resources p.c. due to their sparsely populated population compared to other cities.

Table 6: Top 10 Cities on Environmental Resources, 2018

CITY		2018
拉萨	Lhasa	1
怀化	Huaihua	2
南宁	Nanning	3
惠州	Huizhou	4
牡丹江	Mudanjiang	5
韶关	Shaoguan	6
九江	Jiujiang	7
珠海	Zhuhai	8
贵阳	Guiyang	9
泉州	Quanzhou	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, 2018

CITY	2018
深圳 Shenzhen	1
北京 Beijing	2
青岛 Qingdao	3
珠海 Zhuhai	4
上海 Shanghai	5
长沙 Changsha	6
西安 Xi'an	7
广州 Guangzhou	8
宁波 Ningbo	9
天津 Tianjin	10

As shown in Table 8, the top ranked cities on environmental management include cities where natural scenery tourism is an important industry, such as Huizhou, Zhuhai and Beihai. Cities such as Shijiazhuang, Handan and Zhengzhou have been the cities with greater environmental problems in recent years, especially in terms of air quality, but they have also tended to spend more resources and efforts on environmental conservation, ranking top on environmental management indicators.

Table 8: Top 10 Cities on Environmental Management, 2018

CITY	2018
石家庄 Shijiazhuang	1
惠州 Huizhou	2
邯郸 Handan	3
珠海 Zhuhai	4
郑州 Zhengzhou	5
天水 Tianshui	6
常德 Changde	7
金华 Jinhua	8
北海 Beihai	9
深圳 Shenzhen	10

V. Ranking - Provinces

The final results for the CSDIS for 30 Chinese provinces for 2017 and 2018 are presented in Table 9 below. The four centrally administered municipalities of Beijing, Shanghai, Tianjin, and Chongqing are included in the provincial ranking as well as the earlier city ranking, as these cities are treated as provincial-level administrative divisions. Note that the inherent differences between the nature of city and provincial boundaries, as well as the differences in constituent indicators, imply that the rankings of the cities are not directly comparable to the rankings of the provinces.

Our rankings reveal that the centrally administered municipalities and coastal provinces in the east and south tend to have higher rankings in overall sustainability performance, ranking high on both economic development and environmental management indicators compared to inland industrialized provinces. Most of the provinces that ranked top ten in overall sustainability – which are Beijing, Shanghai, Zhejiang, Jiangsu, Guangdong, Chongqing, Tianjin, Shandong, Hubei, and Anhui –are also the most economically advanced and service-sector dominated provinces in China. From last year's to this year's rankings, only one province moved into the top 10: Hubei, which is also the highest-ranked central province. Fujian was the only province to not remain in the top 10 for this year's ranking, dropping slightly from 9th to 11th place. The only western province to rank in the top 10 is Chongqing, in actuality a centrally administered municipality.

Table 9: China Sustainable Development Indicator System (CSDIS) Provincial Ranking

PROVINCE	2017 RANKING	2018 RANKING
Beijing	1	1
Shanghai	2	2
Zhejiang	3	3
Jiangsu	4	4
Guangdong	6	5
Chongqing	7	6
Tianjin	5	7
Shandong	8	8
Hubei	11	9
Anhui	10	10
Fujian	9	11
Henan	12	12
Hunan	13	13
Hainan	18	14
Guangxi	17	15
Jiangxi	21	16
Guizhou	16	17
Hebei	19	18
Yunnan	22	19
Inner Mongolia	14	20
Shaanxi	15	21
Sichuan	23	22
Liaoning	25	23
Shanxi	24	24
Ningxia	26	25
Gansu	29	26
Xinjiang	30	27
Heilongjiang	27	28
Qinghai	28	29
Jilin	20	30

i. Provincial Ranking by Major Component of Sustainable Development

Economic Development

Provinces along China's east and south coast are performing the best on economic development, while the northeast, central and western regions are relatively lagging behind. Considering that the sustainability of economic development relies mainly on driving innovation and enhancing productivity, we included "R&D Expenditure %" and "Labor Productivity" as innovation indicators. The "Service Sector Added Value %" reflects the adjustment of the economic structure. Taking into account the economic growth rate and the unemployment rate, the first-tier indicators of CSDIS reflect the sustainability of future economic development. In 2018, Beijing, Shanghai, Guangdong, Zhejiang, Jiangsu, Hainan, Chongqing, Hubei, Guizhou, and Yunnan are top ranked provinces on economic development. In contrast, the northeastern region, such as Liaoning and Inner Mongolia, shows a weaker economic development sustainability.

Social Welfare & Livelihood

The six indicators for assessing the level of social welfare and livelihood show that the municipalities directly under the central government and the eastern and central provinces have higher levels of social development; ethnic minority areas have greater room for improvement. This shows that many social resources such as medical care and education are concentrated in megacities and still need to be further improved in minority areas. In 2018, Beijing, Zhejiang, Shanghai, Jiangsu, Tianjin, Hainan, Chongqing, Hubei, Fujian, and Henan ranked top 10 in the social welfare and livelihood category,

while the western provinces such as Yunnan, Guizhou and Gansu are ranked lower, showing a weaker level of social development.

Environmental Resources

Top performers on environmental resources are mostly inland western and northeastern provinces, with Yunnan, Hainan, Qinghai, Fujian, Guizhou, Guangxi, Guangdong, Inner Mongolia, Heilongjiang and Chongqing ranked in the top 10. A higher ranking in this category indicates a higher carrying capacity of ecological resources and better protection of ecology system. Cities performing poorly include Shandong, Beijing, Henan, Hebei and other provinces with high population densities and high degrees of urbanization, which put a strain on the natural environment and its resources.

Consumption & Emissions

In terms of the control of major pollutants discharge, the coastal provinces and direct-controlled municipalities of Beijing, Shanghai, Tianjin, Jiangsu, Zhejiang, Shandong, Fujian, Shaanxi, Henan and Guangdong are the best performing. Except for Shaanxi and Henan, the rest of the provinces are located in the eastern coastal areas, as these regions prioritize higher-value-added manufacturing and the service sector. Most of the heavy industries have transferred out, and energy efficiency has been improved through technological transformation. In contrast, the central and western regions still rely on resource-intensive or labor-intensive industries, facing higher resource consumption and pollutant emissions, and putting pressure on the sustainability of the ecological environment.

Environmental Management

The top performers on environmental management – Anhui, Beijing, Shanghai, Jiangsu, Shandong, Henan, Zhejiang, Hebei, Hubei, Hunan and Chongqing – are also some of the mostly economically advanced provinces. In contrast, economically underdeveloped provinces such as Heilongjiang, Jilin and Qinghai, rank low on environmental management. The Beijing-Tianjin-Hebei region and the Yangtze River Delta regions, for example, have invested heavily in environmental protection and energy conservation in the past years, which is reflected in the improvement of various resource utilization rates and household waste harmless treatment rate. Additionally, these provinces have higher fiscal revenues, which can be put into governance for better results. In comparison, the underdeveloped areas in the west are weak in financial resources and relatively rich in energy resources, making it difficult to compete with more developed regions in terms of energy conservation and environmental protection. Overall, the level of provincial environmental governance has a certain relationship with its economic development level and urban management level, and it is also closely related to the industrial structure of each province. The central and western provinces that rely heavily on resource consumption face more difficulties, and even if investment is increased, it may not be able to obtain a higher level of environmental management.

VI. Conclusion

This publication has presented our China Sustainable Development Indicator System (CSDIS) and 2017-2018 ranking results for 100 large and medium-sized Chinese cities and 30 Chinese provinces based on their sustainability performance. Although often hampered by the availability (or lack thereof) of data on certain indicators that are important to sustainability analyses, we carefully selected 22 indicators for cities and 26 indicators for provinces, 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 that 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 for example, though important, has the lowest weight in the

city system at 8.22%, 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 cities.

Similar to the 2018 CSDIS report, we once again found an imbalance of the sustainable development characteristics across these 100 cities. While major cities along the eastern coast of China, for example, are still performing the best on economic development, it is the inland cities that tend to be the best on social welfare, a somewhat surprising result given it is usually the economically advanced cities that have more resources at their disposal for social provisions and improvement. This demonstrates that most cities, even those ranked well, have vulnerable areas of sustainable development, but these should also been seen as areas with opportunities for improvement.

Assessing urban sustainable development is a complex exercise that requires clear and measurable goals, accurate data, and a sound methodology. Sustainable development, 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 the distinct and varied indicators in our assessment. Every city or province 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 provinces, and improve upon the areas of sustainability that can have the greatest impact.