China Sustainable Development Indicator System

2023 Report

COLUMBIA CLIMATE SCHOOL
THE EARTH INSTITUTE

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

PHILIPS

TEAM

China Sustainable Development Indicator System: 2023 Report

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The Earth Institute's Research Program on Sustainability Policy and Management, part of the Columbia Climate School, 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.

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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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China Sustainable Development Indicator System (CSDIS)

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 tracks the sustainability progress of the country and 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 comprising 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 for cities and 42 indicators for provinces within these categories, our report ranks 110 Chinese cities and 30 provinces on their sustainability performance and tracks the sustainability performance of China as a whole. We also conduct sustainability comparison studies between Chinese cities with other large international cities. 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.

Background

Sustainable development refers to the ability to meet the needs of the present generation without compromising the ability of future generations to meet their own needs. Embracing sustainable development is an essential approach to promote the long-term prosperity and growth of human society. It concerns economic, social, and environmental issues and involves a global community of shared destiny. In the face of global challenges such as climate change, resource depletion, and environmental pollution, sustainable development has become a consensus in the international community. At the United Nations Conference on Environment and Development in 1992, the international community first clearly proposed the concept of sustainable development. In the pursuit of achieving sustainable development, it is necessary for people to commit to environmental protection and resource management, promote the coordinated development of the economy and society, advocate for innovation and technological advancement, and strengthen international cooperation, collectively propelling the sustainable development of human society.

Since China signed the "2030 Agenda for Sustainable Development," it has taken the sustainable development goals as its own development objectives, actively promoting the implementation of sustainable development and providing global experiences for reference. China highly recognizes the importance of sustainable development to both the nation and the world. As the world's largest developing country, its emphasis and efforts towards sustainable development have been under close scrutiny. In recent years, President Xi Jinping has, on multiple occasions in important meetings and speeches, profoundly expounded on the necessity of sustainable development. He emphasized that "sustainable development is the golden key to solving global issues and is the point of greatest interest convergence and the best point of cooperation for all parties."

Sustainable urban development has become an integral part of sustainable development, with its significance and position becoming increasingly prominent. Particularly for a vast economy like China, sustainable urban development can address the pressures of continuous population growth, improve the quality of life for urban residents, attract more people to the cities for growth and living, and enhance the competitiveness and influence of cities. From the perspective of population growth, cities, as centers of population aggregation, must achieve sustainable development. Failure to do so will exert immense pressure on the city's environment, resources, and society. From the standpoint of socio-economic development, with the continuous increase in urban population, problems in urban life are becoming increasingly pronounced. Sustainable urban development is the essential pathway to resolve various urban development issues and address the concerns of people's livelihoods. In terms of environmental protection, cities are one of the primary sources of environmental pollution. Sustainable urban development can fundamentally address the problem of urban environmental pollution, enhance the efficiency of urban resource utilization, and consequently improve the city's ecological functions. Therefore, researching sustainable urban development holds significant practical relevance for China to achieve its sustainable development goals.

China is one of the countries with the largest population in the world. With China's rapid economic growth, its major cities have shown diverse development trajectories. Generally speaking, through various measures in recent years, significant achievements have been made in promoting the country's sustainable development. Whether in terms of energy or environmental protection, China has made remarkable progress, effectively reducing air pollution. However, China still faces issues related to its energy structure, and environmental pollution remains a concern. Therefore, accelerating energy transformation, strengthening environmental protection, and improving people's livelihoods remain crucial tasks for China's sustainable development. The foundation for development and the challenges faced vary across China's cities. Although the "2030 Agenda for Sustainable Development" clearly outlines the 17 global goals for sustainable development, the focus and difficulties for each country differ. Thus, there's a need to study a set of sustainable urban development evaluation indicators tailored to China's unique circumstances, enabling cities to chart their paths based on specific situations. Building on existing research and combining various methodologies, we approached this issue from five aspects: economic development, social welfare, resource environment, consumption emissions, and environmental governance. We established 24 measurement indicators. Building on top of previous research, this year we expanded our city samples to include all cities with an urban permanent population exceeding 5 million and essentially incorporated cities that are innovative demonstration zones for the national sustainable development agenda. We added a ranking and detailed analysis for the sustainable development of 110 Chinese cities, providing data support and scientific guidance for urban sustainable development. The top 10 provinces in terms of urban sustainability are Beijing, Shanghai, Zhejiang Province, Guangdong Province, Tianjin, Chongqing, Fujian Province, Hainan, Jiangsu, and Hubei. Among China's 110 major and medium-sized cities, the top ten cities in the comprehensive ranking for sustainable development are: Hangzhou, Zhuhai, Wuxi, Qingdao, Nanjing, Beijing, Shanghai, Guangzhou, Jinan, and Suzhou. Hangzhou has been ranked first in the overall sustainable development ranking for three consecutive years.

Framework, Methodology, and Data Collection

The China Sustainable Development Indicator System (CSDIS) ranks 110 Chinese cities and 30 provinces based on their sustainability performance. Our framework comprises 24 indicators for cities and 42 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, 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 artifact 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 different 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 maintained the framework through 2019. In 2020, we supplemented our measure on urban traffic infrastructure and congestion by working with AliResearch to incorporate the "Peak Congestion Delay Index" developed by *Amap* (a navigation app) using real-time data. In 2021, we further expanded the set of indicators to include "Physician Availability" and "Proportion of Residents between Age 0 and 14", and replaced "Fiscal Expenditure on Education as a % of GDP" with "Teacher-to-Student Ratio during Compulsory Education", "Number of Days with Good Air Quality" with "Annual Average Air Quality Index". In 2022 and 2023, we further expanded the sample cities to include the city of Ordos in Inner Mongolia and nine other cities according to their population, to reach a sample of 110 cities that are more representative with regards to geographic location, demographic characteristics, and social-economic development.

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. 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.

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 the 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.

The five categories (Level-1 Indicators) we look at through this CSDIS framework are *economic development*, *social welfare & livelihood, environmental resources, consumption and emissions,* and *environmental management*. The country-level indicators (Table 1) and the province-level indicators (Table 2) are virtually identical with slight difference in weights. At city-level (Table 3), as a result of data availability and discrepancies in statistics, we reached a more varied set of indicators compared to the national and provincial frameworks. Cities develop rapidly depending on their own policies and population expansion; therefore, it is even more important for us to study about the sustainable development structure for cities.

Table 1: CSDIS National Indicators and Weights

Level-1 Indicator	Level-2 Indicator	Level-3 Indicator	Weight
Economic Development (25%)	Innovation	Contribution Rate of Scientific and Technological Progress	2.08%
		R&D Expenditure as % of GDP	2.08%
		Intellectual Property per 10,000 People	2.08%
	Structural Improvement	High-Technology Industry Revenue as % of Industrial Added Value	3.13%
		Digital Economy Added Value as % of GDP*	0.00%
		ICT Added Value as % of GDP	3.13%
	Stable Growth	GDP Growth %	2.08%
		Total Labor Productivity	2.08%
		Working Age Population as % of Total Population	2.08%
	Economic Openness	Utilized Foreign Investment per Capita	3.13%
		Total Import and Export per Capita	3.13%
Social Welfare & Livelihood (15%)	Education & Culture	Education Expenditure as % of GDP	1.25%
		Average Schooling of Labor Force	1.25%
		Public Cultural Institutions per 10,000 People	1.25%
	Social Security	Basic Social Security Coverage	1.88%
		Social Security and Employment Expenditure per Capita	1.88%
	Public Health	Average Life Expectancy	0.94%
		Government Health Expenditure per Capita	0.94%
		Incidents of Notifiable Infectious Diseases in Categories A and B	0.94%
		Medical Personnel per 1,000 People	0.94%
	Equality	Poverty Rate	1.25%
		Urban-Rural Disposable Income Ratio	1.25%
		Gini Coefficient	1.25%
Environmental Resources (10%)	Land Resources	Carbon per Capita*	0.00%
		Forest Area per Capita	0.83%
		Arable Land per Capita	0.83%
		Wetland Area per Capita	0.83%
		Grassland Area per Capita	0.83%
	Water Resources	Water Resource per Capita	1.67%
		Proportion of River Sections at Level-I, -II, -III Water Quality	1.67%
	Air Quality	Proportion of Days with Air Quality at or Above Standard	3.33%
	Biodiversity	Biodiversity Index*	0.00%
Consumption and Emissions (25%)	Land Consumption	Secondary and Tertiary Industries Added Value per Unit of Built Area	4.17%
	Water Consumption	Water Consumption per Unit of Industrial Added Value	4.17%
	Energy Consumption	Energy Consumption per Unit of GDP	4.17%
	Main Pollutant Emissions	Chemical Oxygen Demand Emissions per Unit of GDP	1.04%
		Ammonia Nitrogen Emissions per Unit of GDP	1.04%
		SO_2 Emissions per Unit of GDP	1.04%

		Nitrogen Oxides Emissions per Unit of GDP	1.04%
	Industrial Hazardous Waste Production	Hazardous Waste per Unit of GDP	4.17%
	Greenhouse Gas Emission	CO_2 Emissions per Unit of GDP	2.08%
		Share of Renewable Energy in Primary Energy	2.08%
Environmental Management (25%)	**Governance Input**	Ecological Construction Investment as % of GDP*	0.00%
		Fiscal Environmental Expenditure as % of GDP	2.08%
		Pollution Control Investment to Capital Investment Ratio	2.08%
	Wastewater Utilization Rate	Recycled Water Utilization Rate*	0.00%
		Urban Sewage Treatment Rate	4.17%
	Solid Waste Treatment	Utilization Rate of Industrial Solid Waste	4.17%
	Hazardous Waste Treatment	Hazardous Waste Disposal Rate	4.17%
	Exhaust Gas Treatment	Exhaust Gas Treatment Rate*	0.00%
	Garbage Treatment	Harmless Treatment Rate of Household Waste	4.17%
	Reduction of Greenhouse Gas Emissions	Annual Rate of Decline in Carbon Intensity	2.08%
		Annual Rate of Decline in Energy Intensity	2.08%

**: These indicators are included in the country-level sustainability framework, but data are not currently available. Therefore, 0.00% weights are currently assigned to them, and will be updated once specific data are available in the future.*

Table 2: CSDIS Provincial Indicators and Weights

Level-1 Indicator	Level-2 Indicator	Level-3 Indicator	Weight
Economic Development (25%)	**Innovation**	Contribution Rate of Scientific and Technological Progress*	0.00%
		R&D Expenditure as % of GDP	3.75%
		Intellectual Property per 10,000 People	3.75%
	Structural Improvement	High-Technology Industry Revenue as % of Industrial Added Value	2.50%
		Digital Economy Added Value as % of GDP*	0.00%
		e-Business Revenue as % of GDP	2.50%
	Stable Growth	GDP Growth %	2.08%
		Total Labor Productivity	2.08%
		Working Age Population as % of Total Population	2.08%
	Economic Openness	Utilized Foreign Investment per Capita	3.13%
		Total Import and Export per Capita	3.13%

Social Welfare & Livelihood (15%)	Education & Culture	Education Expenditure as % of GDP	1.25%
		Average Schooling of Labor Force	1.25%
		Public Cultural Institutions per 10,000 People	1.25%
	Social Security	Basic Social Security Coverage	1.88%
		Social Security and Employment Expenditure per Capita	1.88%
	Public Health	Average Life Expectancy*	0.00%
		Government Health Expenditure per Capita	1.25%
		Incidents of Notifiable Infectious Diseases in Categories A and B	1.25%
		Medical Personnel per 1,000 People	1.25%
	Equality	Poverty Rate	1.88%
		Urban-Rural Disposable Income Ratio	1.88%
		Gini Coefficient*	0.00%
Environmental Resources (10%)	Land Resources	Carbon per Capita*	0.00%
		Forest Area %	0.83%
		Arable Land Area %	0.83%
		Wetland Area %	0.83%
		Grassland Area %	0.83%
	Water Resources	Water Resource per Capita	1.67%
		Proportion of River Sections at Level-I, -II, -III Water Quality	1.67%
	Air Quality	Proportion of Days with Air Quality at or Above Standard	3.33%
	Biodiversity	Biodiversity Level*	0.00%
Consumption and Emissions (25%)	Land Consumption	Secondary and Tertiary Industries Added Value per Unit of Built Area	4.00%
	Water Consumption	Water Consumption per Unit of Industrial Added Value	4.00%
	Energy Consumption	Energy Consumption per Unit of GDP	4.00%
	Main Pollutant Emissions	Chemical Oxygen Demand Emissions per Unit of GDP	1.00%
		Ammonia Nitrogen Emissions per Unit of GDP	1.00%
		SO_2 Emissions per Unit of GDP	1.00%
		Nitrogen Oxides Emissions per Unit of GDP	1.00%
	Industrial Hazardous Waste Production	Hazardous Waste per Unit of GDP	4.00%
	Greenhouse Gas Emission	CO_2 Emissions per Unit of GDP*	0.00%
		Share of Electricity Consumption from Renewable Sources	4.00%
Environmental Management (25%)	Governance Input	Ecological Construction Investment as % of GDP*	0.00%
		Fiscal Environmental Expenditure as % of GDP	2.50%
		Pollution Control Investment to Capital Investment Ratio	2.50%
	Wastewater Utilization Rate	Recycled Water Utilization Rate*	0.00%
		Urban Sewage Treatment Rate	5.00%
	Solid Waste Treatment	Utilization Rate of Industrial Solid Waste	5.00%

	Hazardous Waste Treatment	Hazardous Waste Disposal Rate	5.00%
	Exhaust Gas Treatment	Exhaust Gas Treatment Rate*	2.50%
	Garbage Treatment	Harmless Treatment Rate of Household Waste	0.00%
	Reduction of Greenhouse Gas Emissions	Annual Rate of Decline in Carbon Intensity*	0.00%
		Annual Rate of Decline in Energy Intensity	2.50%

**: These indicators are included in the province-level sustainability framework, but data are not currently available. Therefore, 0.00% weights are currently assigned to them, and will be updated once specific data are available in the future. Therefore, of the 53 indicators listed in this table, only 42 indicators are used to compile province rankings.*

Table 3: CSDIS City Indicators and Weights

Category	Number	Indicator	Weight
Economic Development (21.66%)	1	GDP p.c.	7.21%
	2	Service Sector Added Value as % of GDP	4.85%
	3	Unemployment %	3.64%
	4	Science and Technology Expenditure as % of GDP	3.92%
	5	GDP Growth %	2.04%
Social Welfare & Livelihood (31.54%)	6	Housing-to-income Ratio	4.91%
	7	Physician Availability	5.74%
	8	Number of Hospital Beds per 1,000 People	4.99%
	9	Social Security Expenditure p.c.	3.92%
	10	Teacher-Student Ratio during Compulsory Education	4.13%
	11	Urban Road Area per Capita + Peak Congestion Delay Index	3.27%
	12	Proportion of Residents Between Age 0 and 14	4.49%
Environmental Resources (15.05%)	13	Water Resources p.c.	4.54%
	14	Urban Green Space p.c.	6.24%
	15	Average Air Quality Index	4.27%
Consumption and Emissions (23.78%)	16	Water Consumption per Unit of GDP	7.22%
	17	Energy Consumption per Unit of GDP	4.88%
	18	Built Area per Unit of Secondary and Tertiary Industry Added Value	5.78%
	19	Sulfur Dioxide Emissions per ¥ Value Added	3.61%
	20	Wastewater Emissions per ¥ Value Added	2.29%
Environmental Management (8.06%)	21	Sewage Treatment Rate	2.34%
	22	Fiscal Environmental Expenditure as % of GDP	2.61%
	23	Utilization Rate of Industrial Solid Waste	2.16%
	24	Harmless Treatment Rate of Household Waste	0.95%

**: percent, p.c.: per capita, ¥: CNY/Chinese-Yuan*

iv. Weighting Strategy

National and Provincial Indicator Weights

The national and provincial frameworks use the same weighting strategy. The weights on Level-1 indicators are first assigned according to expert opinions: Economic Development (25%), Social Welfare & Livelihood (15%), Environmental Resources (10%), Consumption and Emissions (25%), and Environmental Management (25%). For each Level-1 indicator, its weight is further equally divided and assigned to each Level-2 indicator it encloses. Subsequently, Level-3 indicators split the weights of their corresponding Level-2 indicators.

City Indicator Weights

As with the indicator sets, we applied a different weight strategy to the city indicators. Our weighting strategy for city indicators is innovative in that the initial weights were computed with respect to the indicator's stability across cities/provinces 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 ranks over five years are less prone to data errors, idiosyncratic events, and speculative policy interventions. Therefore, these indicators are more likely to be accurate representations of a city's persistent 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.

The current weights were established using the baseline year of 2019 when the project first expanded to 100 cities. These weights have remained mostly unchanged, by design, since 2019. It is important to fix the weights to allow comparability of results over time. Therefore, the research team plans on updating the indicator sets and weights approximately every five years.

To calculate the current indicator weights, first, the standard deviations for every indicator ranking over 5 years (2015-2019) were calculated, as follows:

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

In the equation above, σ_{ci} denotes the rank standard deviation of a city *c* (*c* = 1 to 100 for the baseline sample of 100 cities) and indicator *i* (*i* = 1 to 24), R_{cij} denotes the rank of city *c*, indicator *i*, and year *j* (*j* = 1 to 5 corresponding to 2015-2019), 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 inversed standard deviations:

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

Less volatile indicators are therefore rewarded with higher weights.

CSDIS Country-Level Data Analysis

Looking at the Level-1 indicators (Graph 2), three of them - Economic Development, Social Welfare, and Consumption Emissions - show a development trend similar to the overall sustainable development indicator. All three indicators reached their peak values in 2023. Specifically:

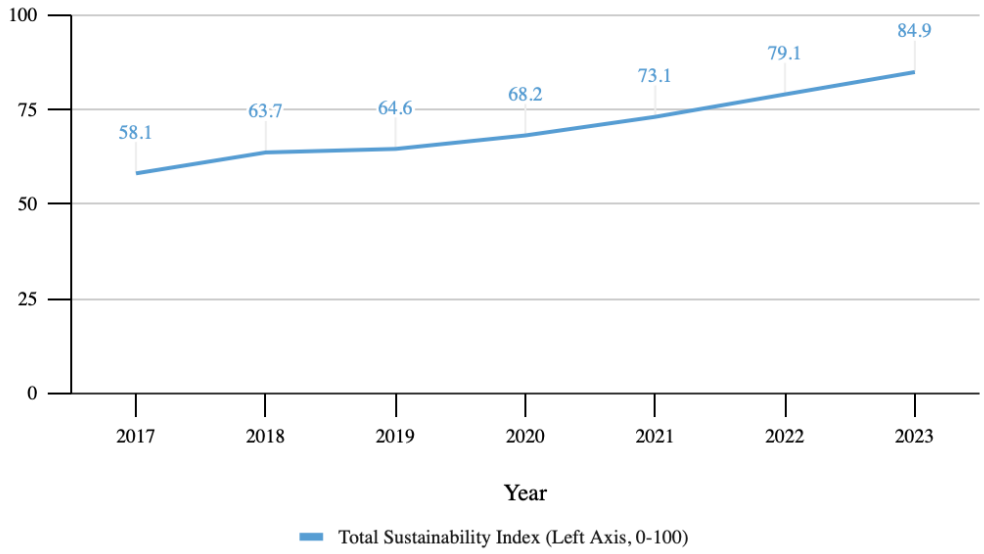
- Economic Development: Its peak value in 2023 was 87.3, a 21.6% increase from 2022, and a 50.7% rise compared to 2017.
- Social Welfare: Its peak value was 87.7 in 2023, an increase of 64.4% from the 53.3 of 2017, and a 2.7% growth from 2022.
- Consumption & Emissions: The peak value in 2023 reached 87.4, growing by 63.9% from the 53.3 of 2017, and a 7.0% rise from the previous year.

For the other two primary indicators:

- Environmental Resources: Overall, it has been on the rise. The indicator value in 2023 was 81.1, a slight decrease of 1.6% from the 82.4 peak in 2022. The value increased each year except for 2017 when it notably dropped due to extreme climatic impacts.
- Environmental Management: This indicator fluctuates while generally increasing. In 2023, it reached its highest value at 80.0, a 20.9 percentage points increase from 2017 and 1.9 percentage points up from 2022.

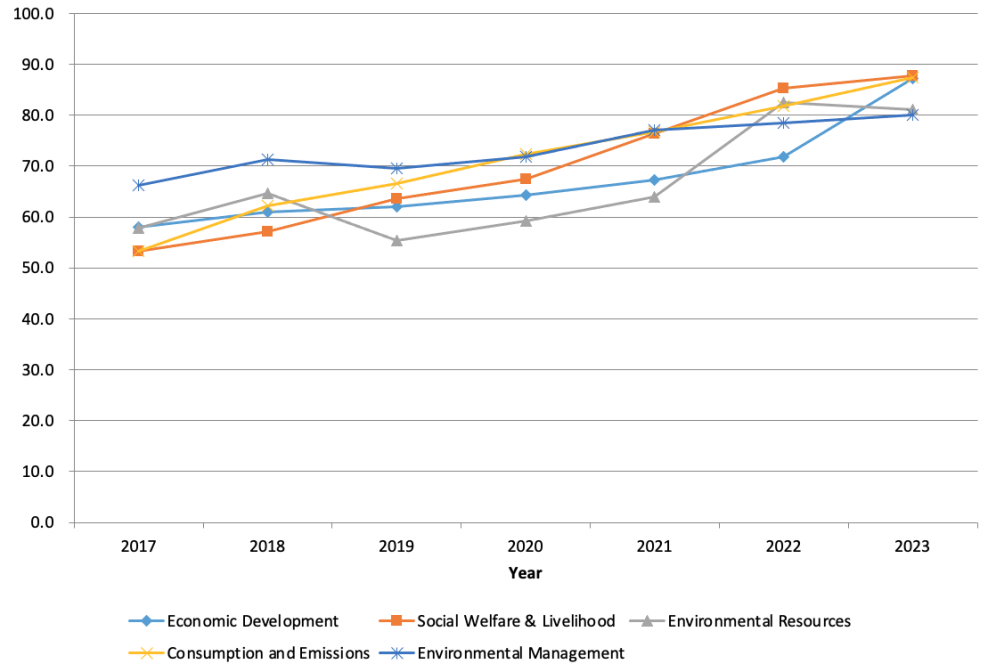
In summary, compared to 2017, all five Level-1 indicators saw significant increases in their values by 2023, fully reflecting the effective results of sustainable development from 2017 to 2023. In 2023, aside from the slight decrease in the Environmental Resources in 2023, all other aspects achieved growth, making the overall sustainable development performance in 2023 better than the previous year.

Graph 1: China Sustainable Development from 2017 to 2023



Graph 2 below shows that from 2017 to 2023, all five indicators have improved. Except for a dip in "Environmental Resources" performance in 2023, China has improved its sustainable development in all aspects.

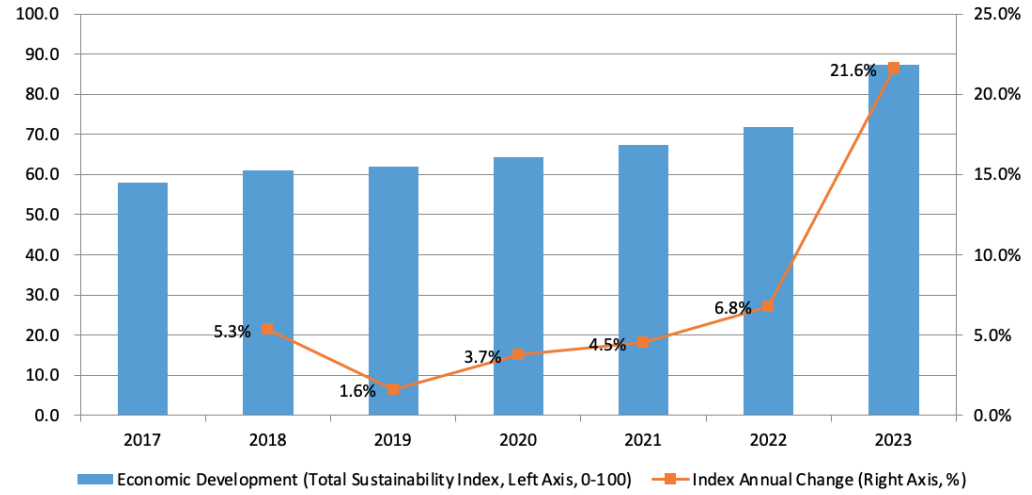
Graph 2: CSDIS First-Level Indicator Development from 2017 to 2023



Country Analysis by Major Component of Sustainable Development

Economic Development

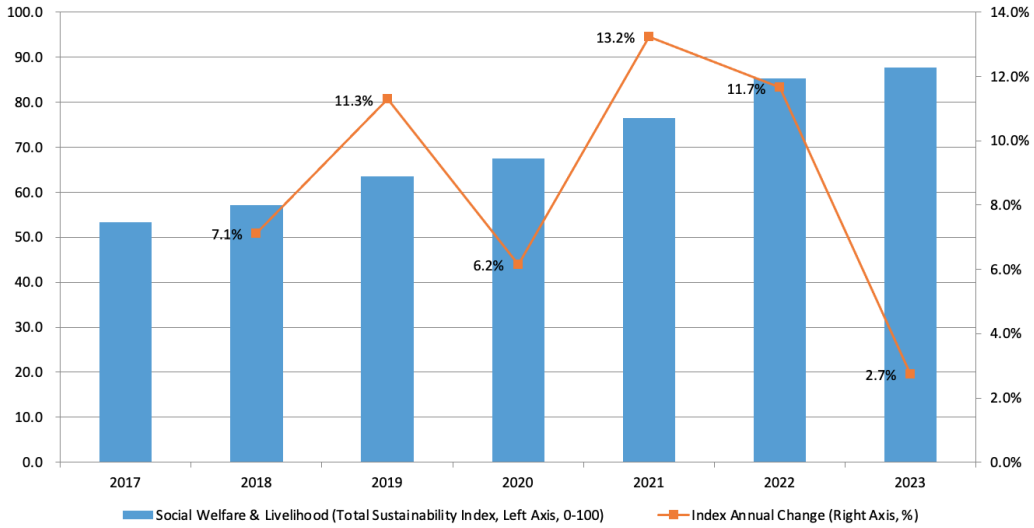
Graph 3: China's "Economic Development" from 2017 to 2023



For "Economic Development", the indicator index rose from 57.9 in 2017 to 87.3 in 2023, marking a notable growth in China's economic sector. During 2023, China's accomplishments in both economic development and pandemic control positioned it as a global leader. The year saw an impressive 21.6% growth over 2022, the highest increase since 2017. This accentuated growth reflects China's relentless efforts in fostering innovation, optimizing economic structures, and enhancing its export-import dynamics. Over the span from 2017 to 2023, the considerable increase underscores the substantial enhancement of China's economic prowess.

Social Welfare & Livelihood

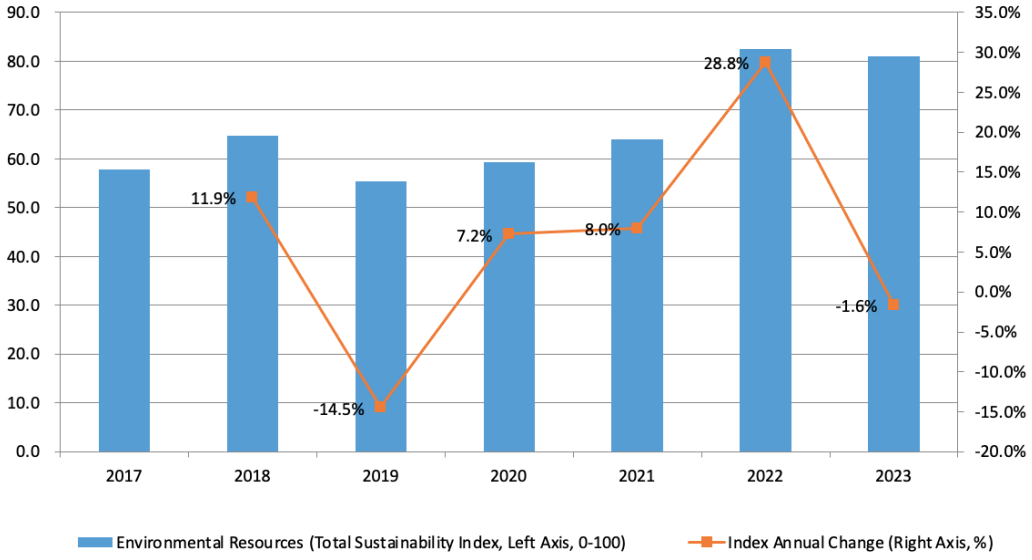
Graph 4: China's "Social Welfare & Livelihood" from 2017 to 2023



“Social Welfare & Livelihood” has had an annual increase rate of over 10% from 2017 to 2023. The index for this Level-1 indicator was 53.3 in 2017, increasing to 87.7 in 2023. Since 2017, China has made steady advancements in its infrastructure for public welfare, resulting in a consistent improvement in its social well-being indicators. China's dedication to enhancing the welfare of its citizens became evident.

Environmental Resources

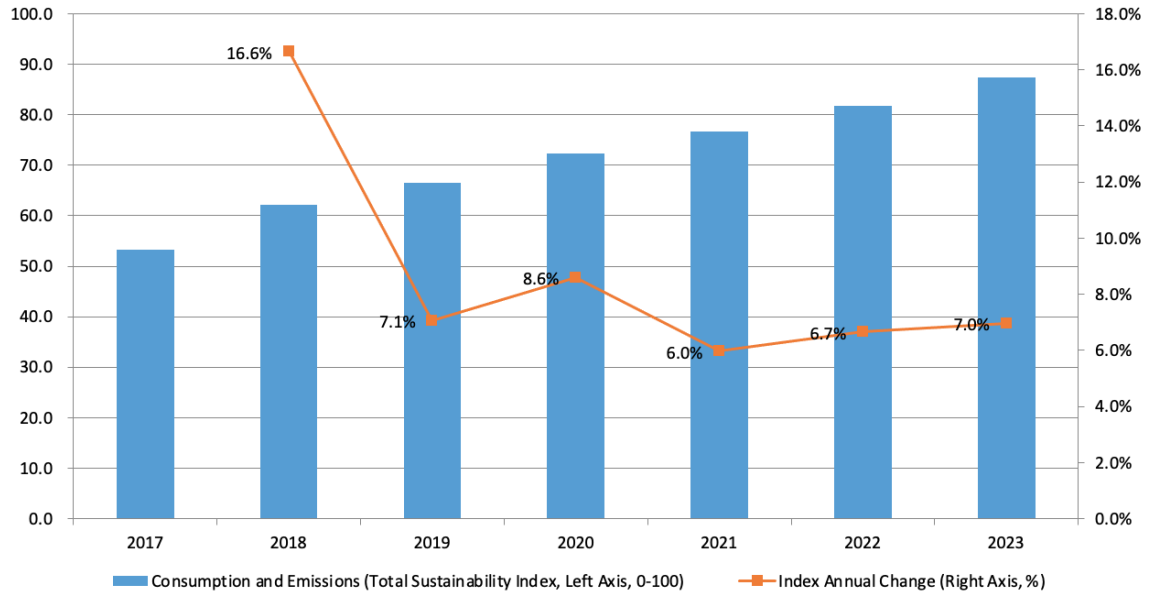
Graph 5: China’s “Environmental Resources” from 2017 to 2023



The “Environmental Resources” metrics are sensitive to the climate, depicting substantial fluctuations between different years. Specifically, both 2017 and 2023 witnessed a negative growth in this regard. However, other years showed positive growth in comparison to the preceding year. Overall, the Environmental Resources indicator index has grown from a score of 57.8 in 2017 to 81.1 by 2023, reflecting an average annual increase of 6.7%. This indicates a significant overall improvement in the condition of environmental resources over this period.

Consumption & Emissions

Graph 6: China's "Consumption & Emissions" from 2017 to 2023



The performance of "Consumption and Emissions" has continuously improved from 2017 to 2023. The index for this Level-1 indicator increased from 53.3 to 87.4 during this period. In terms of the growth rate of the index, since 2021, the annual growth rate has been increasing year by year. In 2023, the indicator's growth rate reached 7.0%, an increase of 0.3 percentage points from the 6.7% growth rate in 2022. Overall, since 2021, efforts to control emissions and consumption have intensified, leading to further improvements in the quality of the ecological environment.

Environmental Management

Graph 7: China's "Environmental Management" from 2017 to 2023

The indicator index for “Environmental Management” increased from 66.2 in 2017 to 80.0 in 2023. It reached its highest value in 2023 at 80.0, marking a 20.9% improvement from its 2017 value. Though its performance lags slightly behind other Level-1 indicators, the overall trend is positive. Generally speaking, from 2017 to 2023, the effects of environmental management and stewardship have been commendable. With intensified efforts in comprehensive ecological and environmental management, the achievements will become even more prominent in the future.

CSDIS Province-Level Data Analysis

Province-Level Ranking

Our research group calculated and ranked 30 Chinese provinces for the general CSDIS ranking (excluding Hong Kong, Macau, and Taiwan; also excluding Tibet because of lack of data). The top ten are Beijing, Shanghai, Zhejiang, Guangdong, Tianjin, Chongqing, Fujian, Hainan, Jiangsu, and Hubei. All four centrally-administered municipalities rank in this top ten list, and eight of the top ten are coastal provinces in the east. Beijing, Shanghai, Zhejian, and Guangdong continue to occupy the top four spots. Tianjin rose from 7th place last year to 5th this year, Hainan moved up from 10th to 8th, and Hubei, as an exemplar province of sustainable development in the central region of China, made a significant leap from 20th to 10th place. Coastal provinces generally rank high in terms of sustainable development, while provinces that lag behind in the rankings are primarily located in the northeastern, southwestern, and northwestern regions of the country.

Table 4: China Sustainable Development Indicator System (CSDIS) Province-Level Ranking

Province	2023 Ranking	2022 Ranking
Beijing	1	1
Shanghai	2	2
Zhejiang	3	3
Guangdong	4	4
Tianjin	5	7
Chongqing	6	5
Fujian	7	6
Hainan	8	10
Jiangsu	9	8
Hubei	10	20
Hunan	11	11
Sichuan	12	12
Jiangxi	13	14
Henan	14	16
Yunan	15	9
Shandong	16	15
Shaanxi	17	13
Anhui	18	17
Jilin	19	18
Liaoning	20	26
Guizhou	21	22
Hebei	22	19
Shanxi	23	23
Guangxi	24	24
Gansu	25	21
Inner Mongolia	26	28
Heilongjiang	27	27

Ningxia	28	30
Qinghai	29	25
Xinjiang	30	29

Provincial Ranking by Major Component of Sustainable Development

Economic Development

In 2023, the top ten provinces in Economic Development are: Beijing, Shanghai, Zhejiang, Guangdong, Tianjin, Chongqing, Fujian, Hainan, Jiangsu, and Hubei. Provinces that rank towards the end are Ningxia, Qinghai and Xinjiang.

In 2023, economies across various regions experienced steady recovery. Beijing, Shanghai, and Guangdong maintained their positions as the top three in economic development. Guangdong's GDP reached an impressive 12.44 trillion RMB (1.9 trillion USD), making it the first and only province in the country to surpass the 12 trillion RMB mark. Hubei Province stood out in its recovery compared to other regions, boasting an economic growth rate of 12.9%, the highest nationwide. This remarkable growth was partly due to the low baseline from a 5% decline in 2022, but also because of the substantial support Hubei received following the outbreak of the pandemic.

Hainan's establishment of the free trade port began to pay dividends in 2023. The province's GDP, fixed asset investment, and retail sales of consumer goods all grew rapidly, ranking among the top in the country. Hainan achieved a high growth rate of 11.2%. With their impressive performances, both Hubei and Hainan ranked among the top 10 provinces in the economic development index.

Social Welfare & Livelihood

In 2023, the top ten provinces in Social Welfare and Livelihood are: Beijing, Qinghai, Jilin, Heilongjiang, Tianjin, Shanghai, Gansu, Chongqing, Sichuan and Jiangxi. In terms of per capita government health expenditure, Beijing stands at RMB 3,212.47/person, and its per capita social security financial expenditure is RMB 4,815.84/person, ranking first and second nationally, respectively. Qinghai has a per capita government health expenditure of RMB 2,665.38/person and a per capita social security financial expenditure of RMB 5,262.64/person, ranking second and first in the nation, respectively, showcasing outstanding performance. In terms of average years of education for the working-age population, Beijing, Shanghai, and Tianjin rank in the top three, with 13.96 years, 13.07 years, and 12.49 years, respectively. Guangdong Province ranks fourth with 11.04 years.

Environmental Resources

In 2023, the top ten provinces in Environmental Resources are: Qinghai, Guizhou, Fujian, Jiangxi, Hainan, Yunan, Guangxi, Heilongjiang, Sichuan, and Hunan. Provinces that rank towards the end are Shanxi, Henan, and Tianjin.

In recent years, as the transformation of industries across various regions has deepened continuously, and the quality of China's environmental resources has improved consistently. In 2023, the national "proportion of days meeting air quality standards" was above 70%, a 4 percentage point increase compared to 2022. 14 provinces or municipalities exceeded 90%, with Hainan reaching 99.4% and Fujian reaching 99.2%. Qinghai consistently ranks first in the country for its environmental indicators, with metrics such as "Water Resource per Capita", "Grassland Area %", and "Wetland Area %" far ahead of other regions. Guizhou ranks at the forefront nationally in "Forest Area %", "Proportion of River Sections at Level-I, -II, -III Water Quality", and "Proportion of Days with Air Quality at or Above Standard". Provinces and cities such as Tianjin, Henan, and Shanxi rank lower. Many have limited natural environmental conditions, resulting in subpar performances in per capita indicators.

Consumption & Emissions

In 2023, the top ten provinces in consumption and emissions are: Beijing, Fujian, Sichuan, Guangdong, Yunan, Shanghai, Zhejiang, Chongqing, Tianjin, and Shaanxi. Provinces that rank towards the end are Qinghai, Heilongjiang, and Ningxia.

In 2023, provinces and cities across China diligently implemented and adhered to the "dual carbon" goals (peak carbon emissions by 2030 and carbon neutrality by 2060), transforming their economic development methods, advancing economic structural transformation, and achieving phased results.

Beijing's industrial structure remains notably superior. The city has effectively controlled its "Water Consumption per Unit of Industrial Added Value" and "Energy Consumption per Unit of GDP", ranking first in the country. Fujian has the lowest "Hazardous Waste per Unit of GDP", placing it at the top nationwide. In Shanghai, the "Secondary and Tertiary Industries Added Value per Unit of Built Area" reached RMB 39.80 billion/km^2, marking the highest land resource utilization rate in the country. Guangdong and Yunnan rank 4th and 5th respectively in terms of stable performances in major pollutant emissions and energy consumption.

Heilongjiang needs further improvement in areas like "Secondary and Tertiary Industries Added Value per Unit of Built Area", "Ammonia Nitrogen Emissions per Unit of GDP", and "SO2 Emissions per Unit of GDP". Ningxia's "Energy Consumption per Unit of GDP" reached 1.91 tce/10,000 RMB, indicating that its energy consumption efficiency needs enhancement.

Environmental Management

In 2023, the top ten provinces in environmental management are: Zhejiang, Henan, Hainan, Hebei, Guangdong, Hunan, Shandong, Jiangsu, Shanghai, Shandong, and Anhui. Provinces that rank towards the end are Qinghai, Sichuan and Xinjiang.

Zhejiang excelled in Environmental Management indicators across the board. Beijing ranked first nationally with its "Pollution Control Investment to Capital Investment Ratio" at 2.66%. Inner Mongolia recorded the country's highest "Annual Rate of Decline in Energy Intensity" at 8.3%. Fujian's energy intensity declined by 0.9%, while Qinghai declined by 7%. Both provinces urgently need to enhance their energy usage structure and improve energy efficiency.

Regarding the "Utilization Rate of Industrial Solid Waste", five provinces in China have achieved rates exceeding 90%. However, Shanxi lagged behind with its rate at only 40.5%, which significantly impacted its ranking.

Overall, China's environmental governance and protection levels have seen an overall improvement. The vast majority of provinces have achieved a "Hazardous Waste Disposal Rate" and "Harmless Treatment Rate of Household Waste" of 100%. Additionally, the "Urban Sewage Treatment Rate" reached over 90% across the board.

CSDIS City Data Analysis

City Ranking

Building on previous research, this year's study expanded the sample of cities under investigation. It now includes all cities with an urban resident population exceeding 5 million. Moreover, cities that are part of the national sustainable development agenda's innovative demonstration zones have been essentially incorporated. As a result, the city sample has expanded to rank and conduct detailed analysis on the sustainable development of 110 cities in China.

In the 2023 comprehensive rankings for urban sustainable development, the top ten cities are, in order: Hangzhou, Zhuhai, Wuxi, Qingdao, Nanjing, Beijing, Shanghai, Guangzhou, Jinan, and Suzhou. Cities in the economically advanced regions of

the Yangtze River Delta, Pearl River Delta, the capital metropolitan area, and the eastern coastal areas continue to showcase high levels of comprehensive sustainable development.

Table 5 presents the 2023 overall sustainability rankings of 110 cities in China. Hangzhou has maintained its top position for three consecutive years, emerging as a leader in urban sustainable development in China. Zhuhai's sustainable development level is second only to Hangzhou's, ranking 2nd, a rise of one position compared to the previous year. Wuxi moved up from the 4th position last year to the 3rd this year. Both Qingdao and Suzhou have risen by two positions, currently ranking 4th and 10th, respectively. Compared to last year, Nanjing's ranking dropped from the 2nd position to the 5th. Changsha dropped out of the top ten, while Suzhou reclaimed its spot in the top ten for sustainable development rankings. Overall, the rankings for the top ten cities did not experience significant changes compared to 2022.

Table 5: China Sustainable Development Indicator System (CSDIS) City Ranking

2023 Ranking	City	2023 Ranking	City
1	Hangzhou	56	Xiangyang
2	Zhuhai	57	Yangzhou
3	Wuxi	58	Baotou
4	Qingdao	59	Tongren
5	Nanjing	60	Jining
6	Beijing	61	Foshan
7	Shanghai	62	Ganzhou
8	Guangzhou	63	Tangshan
9	Jinan	64	Beihai
10	Suzhou	65	Dongguan
11	Changsha	66	Nanning
12	Ningbo	67	Shaoguan
13	Shenzhen	68	Huangshi
14	Hefei	69	Huizhou
15	Wuhu	70	Zunyi
16	Zhengzhou	71	Xuchang
17	Wuhan	72	Chengde
18	Nanchang	73	Huaihua
19	Yantai	74	Nanyang
20	Taiyuan	75	Lanzhou
21	Xuzhou	76	Yibin
22	Nantong	77	Hohhot
23	Dalian	78	Luzhou
24	Huzhou	79	Linyi
25	Chongqing	80	Guilin
26	Yichang	81	Qinhuangdao
27	Weifang	82	Mudanjiang
28	Lhasa	83	Guyuan
29	Tianjin	84	Shijiazhuang
30	Chengdu	85	Zaozhuang
31	Guiyang	86	Leshan
32	Fuzhou	87	Harbin
33	Karamay	88	Nanchong
34	Sanya	89	Heze
35	Xiamen	90	Datong
36	Haikou	91	Kaifeng
37	Yulin	92	Jilin
38	Xi'An	93	Pingdingshan
39	Wenzhou	94	Yinchuan

40	Jinhua	95	Zhanjiang
41	Kunming	96	Qujing
42	Yueyang	97	Haidong
43	Ordos City	98	Shantou
44	Changde	99	Tianshui
45	Luoyang	100	Dali
46	Jiujiang	101	Fuyang
47	Ürümqi	102	Qiqihar
48	Shenyang	103	Lincang
49	Mianyang	104	Zhoukou
50	Changchun	105	Dandong
51	Anqing	106	Baoding
52	Quanzhou	107	Weinan
53	Xining	108	Handan
54	Bengbu	109	Yuncheng
55	Chenzhou	110	Jinzhou

City-Level Sustainable Development Balance

Looking at the five main sustainable development categories (Level-1 indicators), similar to the provincial ranking, city rankings also exhibit an imbalanced development with regards to the various aspects of sustainability. In Graph 8, each bar illustrates the range between the highest and lowest ranking for each city across the five Level-1 indicators. The lengths of the bars in the graph—longer representing more imbalance—show that most cities still have a long way to go for achieving a more balanced sustainable development.

Zhuhai stands out as the No.2 in overall sustainable development. Among the top ten cities, it boasts the most balanced growth all around. It ranks 7th in Resource Environment, 9th in both Economic Development and Environmental Management, and 10th in Consumption and Emission. However, despite these impressive numbers, Zhuhai's performance in Social Welfare & Livelihood is relatively lagging.

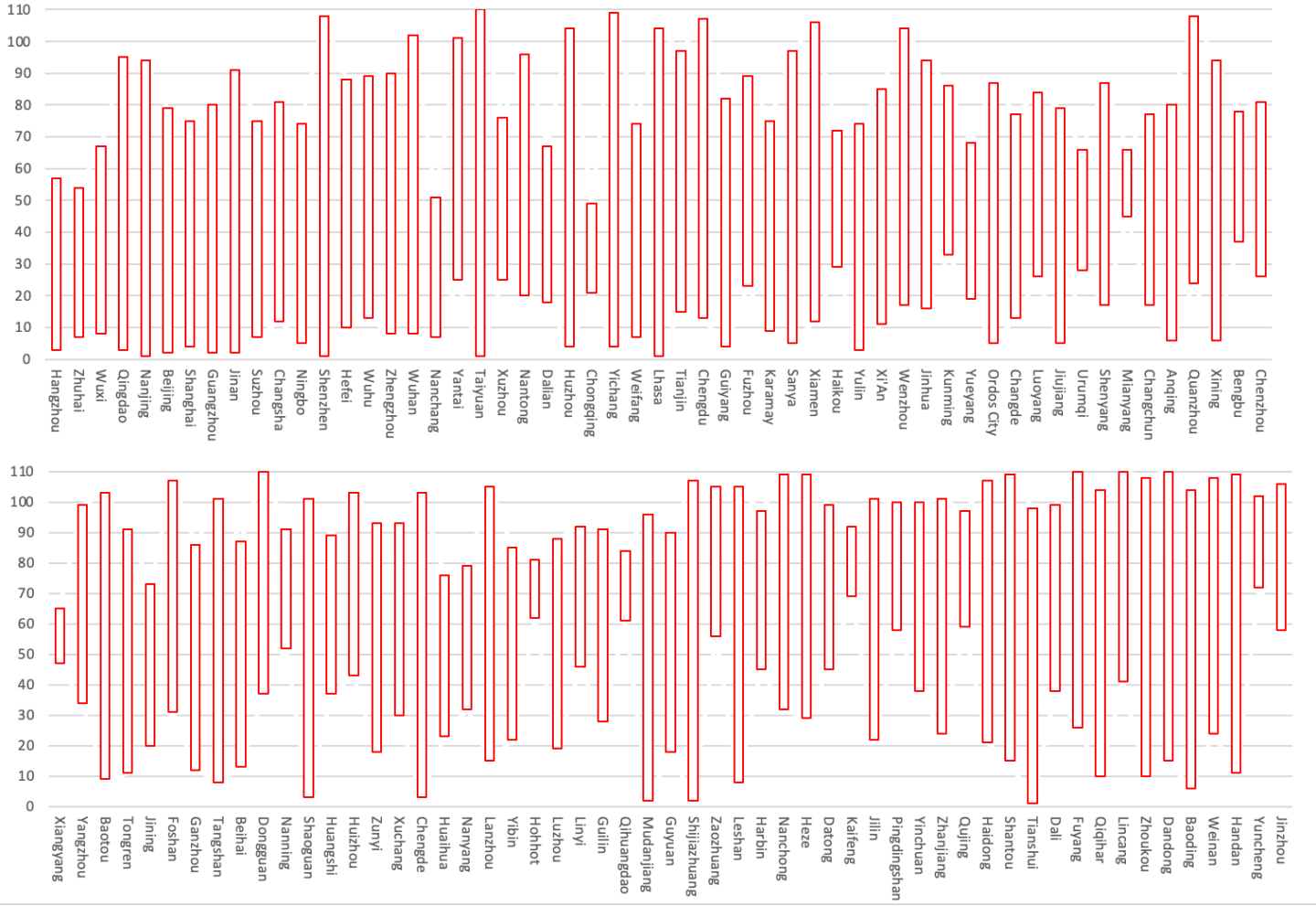
Shenzhen and Taiyuan, while ranking high in overall sustainability, show pronounced disparities in their sustainable growth models. Shenzhen excels in Consumption and Emission, where it is ranked first. However, its performance in the social aspect is falling behind most cities (108th). On the other hand, Taiyuan excels in the social aspect, securing the top spot, but its Environment Resources performance is at the very last of 110 cities.

Nanjing maintains a trend consistent with its previous years; despite its high overall ranking, it exhibits an imbalanced sustainable development. Particularly, the city’s Environmental Management aspect leaves much to be desired, placing it at the 94th position.

Qingdao also exposes its weak links in sustainability. The city showcases an excellent performance in the Consumption and Emission (ranking 3rd). However, its efforts in Environmental Management need significant improvement, as evidenced by its 95th rank. Lastly, Beijing, the nation's capital, holds an impressive place in the Consumption and Emission

sector (2nd). However, the capital's Environment Resource and Environmental Management aspects have much room for improvement (both ranked 79th).

Graph 8: CSDIS City Development Balance Graph



City Ranking by Major Component of Sustainable Development

Economic Development

City	Ranking
Nanjing	1
Guangzhou	2
Hangzhou	3
Shanghai	4
Shenzhen	5
Beijing	6
Suzhou	7
Wuhan	8
Zhuhai	9
Hefei	10

In 2023, the ranking of cities remained broadly to that of 2022. Notably, Shanghai and Wuhan emerged as cities that have made significant strides in economic development quality. When looking at the economic landscape of China, cities in the eastern region continue to demonstrate the strongest overall economic performance, particularly those cities situated along the Yangtze River basin and in the Pearl River Delta area. Nanjing has maintained its top position in economic development for two consecutive years. In 2023, it continued to lead, boasting commendable rankings in several individual metrics such as "Per Capita GDP" and "Unemployment Rate", ranked 6th and 8th respectively. Guangzhou's economic performance trailed closely behind Nanjing. Hangzhou has consistently been in the top five for Economic Development over the past three years. Shanghai and Wuhan, for the first time since 2021, made their way into the top ten in Economic Development rankings, advancing by 8 and 9 positions respectively, primarily due to significant improvements in the "GDP Growth Rate" and "Unemployment Rate". Cities like Shenzhen, Beijing, Suzhou, and Zhuhai exhibited strong performances in the "Per Capita GDP" and "Science and Technology Expenditure as % of GDP", all ranked within the top ten.

Social Welfare & Livelihood

City	Ranking
Taiyuan	1
Jinan	2
Yulin	3
Yichang	4
Ordos City	5
Xining	6
Weifang	7
Tangshan	8
Baotou	9
Nanjing	10

In 2023, the ranking of cities excelling in social welfare and people's livelihoods showcased a wide geographic distribution. Aside from Nanjing, all cities that performed well in the social aspect ranked outside the top ten in economic development. This indicates that economic growth and advancements in social welfare improvement do not always proceed in tandem, and that compromises and tradeoffs may occur between the two. When compared to the previous year's list of top ten cities in terms of social welfare, there has not been a significant shift in the 2023 rankings. Weifang and Tangshan made their debut as leading cities in social welfare. Taiyuan maintained its top spot in the social welfare rankings for three consecutive years. Other cities such as Jinan, Yulin, Yichang, and Xining saw minor fluctuations in their rankings in the field of social welfare, but they have consistently remained in the top ten over the past three years.

Environmental Resources

In 2023, cities with better performance in Environmental Resources are primarily located in the southern provinces. These cities are blessed with abundant natural resources and a pleasant ecological environment, boasting more green spaces per ten thousand residents and relatively superior air quality. Lhasa has consistently topped the list of cities with the most habitable ecological environment for four consecutive years, scoring high on various indices related to resources and the environment. Mudanjiang maintained its second-place ranking in the field of Environmental Resources for the second consecutive year. After dropping out of the top cities with a favorable ecological living environment in 2022, Guiyang rose to the 7th this year, making a comeback into the top ten, more attention is needed as it is not aligned with economic development.

City	Ranking
Lhasa	1
Mudanjiang	2
Shaoguan	3
Guiyang	4
Jiujiang	5
Anqing	6
Zhuhai	7
Leshan	8
Karamay	9
Qiqihar	10

Consumption & Emissions

In 2023, the rankings of cities leading in energy-saving and emission-reduction efficiency remained generally consistent with the previous year, albeit with some slight shifts in order. Cities that demonstrated outstanding performances on individual metrics such as “Water Consumption per Unit of GDP”, “Energy Consumption per Unit of GDP”, “Sulfur Dioxide Emissions per ¥ Value Added”, and “Wastewater Emissions per ¥ Value Added” were mainly found among the larger cities. These cities prioritize efficient resource use and reduction in consumption and emissions, thus ranking high on the list. Both Shenzhen and Beijing have consistently ranked 1st and 2nd for three consecutive years in terms of consumption and emissions. Specifically, Shenzhen excels in "Water Consumption per Unit of GDP" and "Sulfur Dioxide Emissions per ¥ Value Added," being 1st in both metrics. Beijing stands out in "Energy Consumption per Unit of GDP" and "Sulfur Dioxide Emissions per ¥ Value Added", securing the 1st and 2nd spots respectively.

City	Ranking
Shenzhen	1
Beijing	2
Qingdao	3
Hangzhou	4
Ningbo	5
Shanghai	6
Guangzhou	7
Wuxi	8
Suzhou	9
Zhuhai	10

Environmental Management

In the 2023 rankings, there was a significant fluctuation in the rankings of cities leading in environmental governance compared to the previous year. Chengde, Huzhou, Sanya, Baoding, Zhengzhou, Zhuhai, and Zhoukou emerged as the new frontrunners in environmental governance. Tianshui and Shijiazhuang have consistently held the top two spots in environmental governance for two consecutive years. Tianshui ranks fairly high in various individual indicators, with a notably strong performance in the "centralized treatment rate of sewage treatment plants." Meanwhile, Shijiazhuang stands out in two particular metrics: "fiscal energy-saving and environmental protection expenditure as a percentage of GDP" and the "centralized treatment rate of sewage treatment plants."

Zhengzhou, Zhoukou, and Nanchang show a relatively balanced performance across different metrics in environmental management, without any noticeable weaknesses.

City	Ranking
Tianshui	1
Shijiazhuang	2
Chengde	3
Huzhou	4
Sanya	5
Baoding	6
Nanchang	7
Zhengzhou	8
Zhuhai	9
Zhoukou	10

International City Comparison

International City Comparison Analysis

We compared the average sustainability performance of our 110 Chinese cities in the CSDIS ranking, as well as that of Hangzhou - the No.1 in overall ranking, with several international cities - New York, São Paulo, Paris, Barcelona, Eindhoven, Moscow, Singapore, Hong Kong, Dubai, Cairo, and Cape Town - to identify gaps in sustainability performance between Chinese cities and others around the world. To facilitate cross-country comparison, we used a subset of the CSDIS city indicators for which there was available data for most cities. Due to the difference in statistics published by each country, readers should keep in mind that the indicator comparisons in this section may not comprehensively reflect the sustainability performance and achievements of the local governments, but serve to provide a snapshot that illustrates the gaps among the selected cities and regions in the various aspects of urban sustainability. We will spend more paragraphs in this section looking into the sustainability agenda and policy interventions the various cities are committed to across the five domains of urban sustainability - economic development, social welfare and livelihood, emissions and consumptions, environmental resources, and environmental management.

Throughout these case studies, we find some convergence of policy initiatives across the cities in terms of urban sustainability. First of all, transition to a “green economy” is frequently set as an overall development goal by cities in both developed and developing countries. This transition entails the evolvement of the economic structure to be more service-based and knowledge-based; to become an urban economy that uses resources circularly, achieves a positive feedback loop between the investment in clean technologies and their adoption; and to create job opportunities while at the same time prepare the labor force with relevant skills. Second, the international cities are unanimously striving to reduce vehicular emissions to improve air quality and reduce carbon footprint. Common initiatives include restrictions on vehicles with internal combustion engines, promotion of electric vehicles (especially for public transportation), and development and optimization of bicycle infrastructures to encourage sustainable commuting. Third, the global cities are actively developing clean energy, often using innovative solutions to address the limited land resources. These include waste-to-energy plants that reduce the dependence on landfills while generating electricity, wastewater treatment plants utilizing biogas produced during water treatment to generate electricity, and floating solar farms on reservoirs to make optimal use of limited land resources. Last, green infrastructures such as green roofs, and floodplains with vegetated bioswales are actively incorporated in urban planning to improve water and energy efficiency, reduce urban heat island effects, and enhance climate resilience.

Meanwhile, we also see from the case studies that the past COVID-19 pandemic exposed the vulnerability of large urban centers and highlighted the eminent need to develop capacities to respond to such global scale epidemics in a more prepared way, particularly on the economic and social aspects. Finally, our Moscow case study, and the pessimistic outlook for many of the city’s sustainability initiatives, has illustrated the limitation of local governments on urban sustainability management. In addition to the financial and political influence from higher levels of jurisdictions, the Moscow case shows that geopolitical reasons and conflicts with neighboring countries could also significantly hamper local sustainability efforts. It reiterates the fact that peace is the prerequisite for sustainable development.

Figure 1: Leading Cities in Major Components of Sustainable Development

Economic Development	Social Welfare & Livelihood	Environmental Resources	Consumption & Emissions	Environmental Management
GDP Growth Rate **#1:** New York **Tertiary Industry to GDP Ratio** **#1:** Hong Kong **Unemployment Rate in Rural Areas** **#1:** Hangzhou	**Urban Road Area per Capita** **#1:** Paris **Housing-to-Income Ratio** **#1:** Barcelona **Teacher to Student Ratio in Middle and Elementary School** **#1:** Hong Kong **Population: Age 0-14** **#1:**	**Urban Green Space per 10,000 People** **#1:** Cape Town **Air Quality** **#1:** New York	**Water Consumption per Unit of GDP** **#1:** Singapore **Energy Consumption per Unit of GDP** **#1:** Barcelona	**Centralized Treatment Rate of Sewage Treatment** **#1:** Barcelona, New York, Paris **Harmless Treatment Rate of Domestic Waste:** Most cities have reached 100%

International Cities

Figure 2: International City Comparison Map

New York, United States

Indicator	New York	Hangzhou	Chinese Avg.
Population (million)	19.76	12.20	7.00
GDP (billion USD)	1992.78	280.63	105.84
GDP Growth Rate (%)	9.35	8.49	7.90
Service Sector Added Value (%)	84.88	67.85	52.20
Unemployment Rate (%)	7.00	2.34	2.85
Road Area (m^2 per capita)	22.95	11.48	14.82
House-Income Ratio (price per m^2 / GDP per capita)	0.06	0.19	0.16
Teacher-Student Ratio	1:12.5	1:13.9	1:14.3
Population: Age 0-14 (%)	20.50	13.32	17.55
Urban Green Space (m^2 per capita)	13.58	46.42	43.68
Air Quality (PM2.5 annual mean, ug/m^3)	8.30	28.00	31.00
Water Consumption (tons/10,000 USD)	12.43	106.02	318.00
Energy Consumption (tce/10,000 USD)	0.45	1.90	3.61
Domestic Sewage Treatment Rate (%)	100.00	97.13	96.98
Household Waste Harmless Treatment Rate (%)	100.00	100.00	99.92

Notes. Data source: Publicly available data sources, see reference for detail. Data year: 2021.

The New York metropolitan area (or Tri-State area) is the largest metropolitan area in the United States with a population of 19.76 million in 2021,[1] and is also one of the largest metropolitan areas in the world. Its GDP in 2021 totalled at USD 1,992.8 billion, exceeding the national GDP of some major economies such as Brazil, Australia and the Republic of Korea.[2] Its economy is predominantly service industry, which contributes around 85% of the metropolitan area's GDP. It is a hub to multiple industries such as finance, international trade, pharmaceuticals, publishing, entertainment, and fashion. It is the metropolitan area with the largest foreign-born population in the world.

At the center of the metropolitan area, the City of New York's sustainability agenda has been guided by a series of strategic plans under the efforts of several mayors. In 2007, Mayor Bloomberg launched the PlaNYC with the goal of strengthening the economy, combating climate change, and enhancing the quality of life for residents. PlaNYC's more than 100 initiatives specifically targeted areas of housing, public space and urban green space, transportation, energy, water supply, air and water quality, brownfield management, solid waste management, and climate adaptation and mitigation.[3] It was succeeded by Mayor de Blasio's strategic plan OneNYC which focused on inclusive growth and climate action, and expanded target areas to include supporting green jobs, commitment to achieving carbon neutrality, quality of education and health care, and promoting justice.[4] Most recently, the current New York City mayor Eric Adams released the updated PlaNYC: Getting Sustainability Done, for which climate resiliency is an overarching theme and is integrated into the improvement of all economic, social, and environmental aspects of sustainability. Economically, the new PlaNYC emphasizes on preparing the workforce for green jobs, particularly those related to renewable energies, and achieving more circular use of resources in production. Environmentally, the plan aims to further promote green infrastructures such as green roofs, rain gardens, and resilient waterfront to enhance energy efficiency and improve resilience to coastal

[1] *Population of the New York-Newark-Jersey City metro area in the United States from 2010 to 2021*. (2022, February). Statista. https://www.statista.com/statistics/815095/new-york-metro-area-population/#:~:text=In%202020%2C%20about%2019.12%20million

[2] World Bank. (2023). *Gross domestic product 2022.* World Development Indicators database. https://databankfiles.worldbank.org/public/ddpext_download/GDP.pdf

[3] The City of New York. (2011). *PlaNYC: A Greener, Greater New York.* https://www.nyc.gov/html/planyc/downloads/pdf/publications/planyc_2011_planyc_full_report.pdf

[4] The City of New York. (2019). *OneNYC 2050: Building A Strong and Fair City.* https://climate.cityofnewyork.us/wp-content/uploads/2022/10/OneNYC-2050-Summary.pdf

flooding and sea-level rise, as well as the transition to a more renewable-based energy portfolio. Socially, in addition to continuing improving access to quality urban green spaces, the new plan puts more emphasis on facilitating citizens' transition to a more sustainable lifestyle such as sustainable commuting by public transit, biking, or walking, recycling of organic food waste, and building infrastructure to support these transitions.[5]

Economic Development

In 2021, with the prevalence of the COVID-19 pandemic beginning to fade away, like many other metropolitans in the world, New York's economy demonstrated a noticeable rebound, from a -3.36% decline in 2020 to a 9.35% growth. Similarly, the unemployment rate dropped from 9.9% to 7% in 2021, albeit still relatively high compared to pre-pandemic years.

Social Welfare & Livelihood

With a population of 19.76 million in 2021, the New York metropolitan area is the most populous and densely populated metropolitan area in the United States. Its resident population far exceeds the average population of Chinese cities (7 million). 20.5% of New York's population are between the ages of 0 and 14. This share of population age group is higher than the Chinese average of 17.55%. The metropolitan area has a housing-to-income ratio of 0.06, substantially lower than the average Chinese city's 0.16, despite the common perception of high housing prices in New York City. Part of the explanation lies in the higher income level of New York residents compared to the average Chinese citizens, which makes housing less of a financial burden compared to Chinese urban residents. Furthermore, the New York metropolitan area comprises a wide geographic area with varying levels of housing prices. Although the five boroughs of New York City, particularly Manhattan, often rank within the top five of the most expensive housing markets in the world,[6] a vast suburban area surrounding New York City offers more inexpensive housing to the residents. In terms of educational resources, despite the large population, the New York metropolitan area manages to maintain a teacher-to-student ratio of about 1:12.5 during compulsory education (Kindergarten - 12th Grade), which indicates a smaller class size on average compared to Chinese cities including metropolitans like Hangzhou.

The scale and efficiency of urban transportation has often been acknowledged as the catalyst of New York's success. In recent decades, this urban transportation system has been facing increasing pressure from continued rise in resident population, aging infrastructure (by 2030 almost all of New York City's infrastructure network will be a century old), and the intensifying threat of climate change impacts such as flooding, and sea-level rise. Since the Bloomberg administration, the city has recognized the urgent need to upgrade its transportation network in that the existing subway routes, river crossings, and commuter rail lines would not have the capacity to accommodate the projected one-million increase in population by 2030, let alone the resilience to withstand the intensifying hurricanes and storm surges brought about by the changing climate.[7] In the new PlaNYC launched by Mayor Adams, the modernization of the city's transportation network will not only focus on increasing its capacity, but also facilitate the transition to a more sustainable transportation system that is both more friendly and resilient to climate impacts.

Environmental Resources

New York City has more than 1,700 parks, the most famous of which is Central Park in the heart of Manhattan. Central Park covers an area of 3.4 square kilometers, is one of the world's largest man-made natural landscapes, known as the

[5] The City of New York. (2023). *PlaNYC: Getting Sustainability Done.* https://climate.cityofnewyork.us/wp-content/uploads/2023/06/PlaNYC-2023-Full-Report.pdf

[6] Parker, G. (2023, March 13). *The 20 Most Expensive Cities to Buy a Home in the World.* Money.Inc. The 20 Most Expensive Cities to Buy a Home in the World (moneyinc.com).

[7] New York City Global Partners. (2010, July 21). *Best Practice: PlaNYC: NYC's Long-Term Sustainability Plan.* Microsoft Word - NYC_Environment_PlaNYC 8-3-10 final.doc.

"lung of New York". In order to reduce the adverse impact of population growth and economic development on the environment, New York City will incorporate environmental factors into the urban development strategy, maximize the storage, infiltration and purification of rainwater in urban areas, promote the recycling of rainwater, and improve the quality of life of citizens.[8] In recent years, New York City has been actively promoting sustainable development, increasing urban green spaces and encouraging residents to adopt sustainable practices such as constructing green roofs and installing solar panels. However, due to the high population density, as of 2021, the per capita green space area of New York City is only 13.58 square meters / person, less than one-third of the per capita urban green area (46.42 square meters / person) of China's Hangzhou, and far lower than the average of Chinese cities in the same year (43.68 square meters / person). However, it is worth noting that this indicator only reflects the situation in the New York City area, and is an underestimate of the per capita green space in the entire metropolitan area with abundant suburbs that are far less populous.

The air quality in the metropolitan area can be considered exceptional, with an annual mean PM 2.5 concentration of only 8.3 $\mu g/m^3$. This not only outperforms the average Chinese city (31 $\mu g/m^3$), the best Chinese city in terms of air quality Lhasa (12 $\mu g/m^3$), and all the other international cities we studied in this report.

Consumption & Emissions

New York City is the most energy-efficient place in America, emitting fewer greenhouse gasses per capita than other places. One of the major sources of carbon emission in New York is the city's close to 10,000 buildings, taking up 5.2 billion square meters of space. The city is committed to improve energy efficiency of buildings with particular focus on public and government buildings, industrial and commercial buildings, residential buildings, building construction and electrics. As part of the city's climate legislation, Local Law 97, passed in 2019, sets progress targets of 40% emission reduction (from 2005 baseline) by 2030 and 80% reduction by 2050.[9] Additionally, New York is supporting the implementation of smart meters throughout the city to reduce peak load through real-time electricity prices.

Environmental Management

Since the closing of the Fresh Kills landfill in 2001, New York City has been shipping nearly all of its solid wastes to out-of-state facilities, leading to rising costs and environmental concerns. At the same time, the issue has become particularly salient due to concerns about the negative impact of waste on communities and the city's commitment to meet its 2050 greenhouse gas reduction targets. In 2015, New York City Mayor Bill de Blasio announced an ambitious plan to reduce garbage exports to zero by 2030 to meet the challenge of global warming.[10]

New York City's Zero Waste Initiative aims to reduce costs and waste generation through a range of measures. For example, the expansion of curbside collection of organic waste (which currently serves 100,000 households) and the addition of local waste collection sites are planned to provide this service to all New Yorkers by the end of 2018. In addition, by 2020, New York City will implement single-stream recycling of metal, glass, plastic, and paper products. Other waste management measures include the construction of a waste-to-energy plant that uses anaerobic digestion technology to convert up to 500 tons of organic waste into methane per day for heating; reducing the use of plastic bags and other non-recyclable waste, such as polystyrene foam; providing every citizen with opportunities to recycle and reduce waste; enabling all schools to achieve zero waste targets; expanding opportunities for the reuse and recycling of textile and e-waste; developing a Save-as-You-Throw program to reduce waste through application of the polluter-pays principle, and

[8] Xinhuanet. (2015, November 5). *New York City's "Green" development.* Huanqiu.com. 纽约市的"绿色化"发展 (huanqiu.com).

[9] Cohen, S. (2022, August 22). *Reducing Greenhouse Gas Emissions from NYC's Buildings.* State of the Planet. Reducing Greenhouse Gas Emissions from NYC's Buildings (columbia.edu).

[10] The City of New York. (2019). *OneNYC 2050: Building A Strong and Fair City.* https://climate.cityofnewyork.us/wp-content/uploads/2022/10/OneNYC-2050-Summary.pdf

more.[11] These measures will help New York City manage waste more effectively and achieve sustainable development goals.

São Paulo, Brazil

Indicator	São Paulo	Hangzhou	Chinese Avg.
Population (million)	22.24	12.20	7.00
GDP (billion USD)	280.96	280.63	105.84
GDP Growth Rate (%)	6.62	8.49	7.90
Service Sector Added Value (%)	70.94	67.85	52.20
Unemployment Rate (%)	13.67	2.34	2.85
Road Area (m^2 per capita)	12.32	11.48	14.82
House-Income Ratio (price per m^2 / GDP per capita)	0.20	0.19	0.16
Teacher-Student Ratio	1:23.9	1:13.9	1:14.3
Population: Age 0-14 (%)	21.01	13.32	17.55
Urban Green Space (m^2 per capita)	2.58	46.42	43.68
Air Quality (PM2.5 annual mean, ug/m^3)	16.07	28.00	31.00
Water Consumption (tons/10,000 USD)	46.07	106.02	318.00
Energy Consumption (tce/10,000 USD)	0.97	1.90	3.61
Domestic Sewage Treatment Rate (%)	62.00	97.13	96.98
Household Waste Harmless Treatment Rate (%)	97.80	100.00	99.92

Notes. Data source: Publicly available data sources, see reference for detail. Data year: 2021.

Sao Paulo is the most populous metropolitan area in Brazil. The metropolitan area's economy mainly consists of the service sector (about 71% of GDP). Its 22 million population is culturally diverse with large groups of Arab, Italian, and Japanese diasporas.

Sao Paulo's sustainability agenda is guided by the Municipal Climate Action Plan (PlanClima SP) released in 2021, with the overall objective of "[achieving] zero carbon emissions by 2050 and [adapting] the city for the future with environmental preservation and wealth".[12] The development of the PlanClima dated back to 2018, under the then-mayor of the city Bruno Covas, to align policies in partnership with the C40 Cities - a coalition of more than 100 cities around the world that pledges to keep temperature increase within 1.5 degrees celsius by the end of the century. The plan will achieve this goal through undertaking initiatives to reduce 50% of the municipality's greenhouse gas emissions by 2030, compared to 2017 levels, and implementing necessary measures to reduce social, economic, and environmental vulnerabilities for an adaptation process. The initiatives cover 43 priority areas such as renewable energy transition, public transportation, urban green infrastructure, sustainable commuting, green economy, and climate resiliency.

Economic Development

With a GDP of USD 281 million, São Paulo metropolitan area is the largest economy in Latin America. Compared to the Chinese cities, it is equivalent to major Chinese metropolitans such as Hangzhou. In 2020, at the peak of COVID-19 pandemic, Sao Paulo maintained a GDP growth of 2.6% when many regions in the developing and developed world saw economic decline. In 2021, with the economy recovering from the pandemic, Sao Paulo's growth rate rose to 6.62%. However, compared to its growth figures, Sao Paulo's unemployment rates remained at double-digits in recent years.

[11] C40 Cities. (2016, February). *C40 Good Practice Guides: New York City - Zero Waste NYC*. C40 Good Practice Guides: New York City - Zero Waste NYC - C40 Cities.

[12] City of Sao Paulo International Affairs. (2021, April 6). *PlanClima SP is a guide to initiatives in the capital with 43 prioritary areas*. PlanClima SP is a guide to initiatives in the capital with 43 prioritary areas | Secretaria de Relações Internacionais | Prefeitura da Cidade de São Paulo.

Social Welfare & Livelihood

Sao Paulo's teacher-to-student ratio was 1:23.9 in 2021. Compared with the 1:18.1 ratio in 2017, this indicates an increase in average class sizes in recent years, and more restricted educational resources compared to Chinese cities. The Brazilian government has been taking great efforts to ensure adequate educational resources, but the allocation of these resources and educational equity remain a priority in the nation's education policy. Particularly, ensuring equal access for students from disadvantaged families or regions, ensuring early detection of students at risk of dropping out and providing individualized, tailored support are among the recommended measures to improve educational equity.[13] The past pandemic posed new challenges for Brazil's and Sao Paulo's education system regarding the provision of effective and equitable remote learning opportunities for students.

In addition, the PlanClima, Sao Paulo's sustainability strategic plan calls for more integrated climate change education into current curriculum, and improving the preparedness and response capacity of health services during extreme events, especially for vulnerable populations living in peripheral areas.

Environmental Resources

The state of São Paulo, to which the city of São Paulo belongs, launched its Climate Action Plan in 2021 aiming for zero global emissions by 2050. The plan lists the policies and goals to be proposed by the city of São Paulo in environmental governance and management in the next 30 years, expressing its commitment to environmental protection. As a city at high risk of climate change, São Paulo will invest further in protecting coastal areas from floods, landslides and rising sea levels. At the same time, the city of São Paulo will improve its early warning and risk detection technology to further address the threat of climate change in the city. The city of São Paulo will also further expand the forest area, create valuable native vegetation and restoration.[14]

These sustainability initiatives are reiterated in the PlanClima, including the planting of native trees that are climate-resilient, introducing policy instruments for biodiversity conservation, natural capital, ecosystem services, and improvement of freshwater quality.

Consumption & Emissions

Sao Paulo has gradually joined other metropolitans around the world in the trend of electrification of public and private transportation. In 2019, the city introduced 15 all-electric buses that are purely powered by electricity generated from solar energy. The city is in the process of gradually replacing the municipal bus fleet with zero-emission vehicles. In 2020, the city announced the plan for expanding the renewable energy generation capacity to support its subway system. To encourage the transition to zero-emission vehicles, Sao Paulo granted an exemption from the Vehicle Property Tax to electric, hybrid and hydrogen vehicles registered in the city.[15]

According to the city's PlanClima, efforts related to consumption and emissions also include the encouragement of using bicycles as a common means of transportation, and the associated expansion of infrastructure; promoting the production and distribution of renewable energy, and distributed generation; implementing regulations on energy efficiency of buildings, acquisition of goods, and contracting of services; and improve regulations on the sharing economy.

Environmental Management

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[13] OECD. (2021). *Education Policy Outlook: Brazil.* country-profile-Brazil-2021-INT-EN (oecd.org).

[14] Sao Paulo State Government. (2021). *Sao Paulo State Climate Action Plan: Net Zero 2050.* São Paulo State Secretariat of Infrastructure and Environment. cop26_english.pdf (windows.net).

[15] REN21. (2021). Trends in Brazil: Facts from the *Renewables in Cities 2021 Global Status Report.* REN21_Cities2021_Fact-Sheet_Brazil.pdf.

In addition to the variety of legislation on energy efficiency and the sharing economy, and the establishment of the Zero Emission Zone within the city, Sao Paulo's environmental management efforts also focus on waste management and sewage. The PlanClima calls for universalizing the coverage of selective collection of solid waste, and maximizing composting. It also mandates the strengthening of monitoring and periodic reporting of data on greenhouse gasses and sewage by relevant authorities.

Paris, Frances

Indicator	Paris	Hangzhou	Chinese Avg.
Population (million)	13.05	12.20	7.00
GDP (billion USD)	940.36	280.63	105.84
GDP Growth Rate (%)	7.89	8.49	7.90
Service Sector Added Value (%)	81.86	67.85	52.20
Unemployment Rate (%)	8.10	2.34	2.85
Road Area (m^2 per capita)	31.15	11.48	14.82
House-Income Ratio (price per m^2 / GDP per capita)	0.17	0.19	0.16
Teacher-Student Ratio	1:15.0	1:13.9	1:14.3
Population: Age 0-14 (%)	19.39	13.32	17.55
Urban Green Space (m^2 per capita)	75.00	46.42	43.68
Air Quality (PM2.5 annual mean, ug/m^3)	11.10	28.00	31.00
Water Consumption (tons/10,000 USD)	77.15	106.02	318.00
Energy Consumption (tce/10,000 USD)	0.98	1.90	3.61
Domestic Sewage Treatment Rate (%)	100.00	97.13	96.98
Household Waste Harmless Treatment Rate (%)	100.00	100.00	99.92

Notes. Data source: Publicly available data sources, see reference for detail. Data year: 2021.

The Paris Metropolitan Area, surrounding France's capital city, is the economic, political, and cultural center of the nation. The metropolitan area's 13 million population is equivalent to those of major Chinese metropolitans. Its geographic area extends well beyond Paris city's jurisdiction, and even beyond the province - Ile-de-France - where Paris city is located. The economy of the metropolitan area comprises around 80% of the service industry, and contributes more than 30% of France's national GDP.

Paris' sustainability agenda is guided by its Climate Action Plan adopted by the City Council in 2018, with the overarching goal of reducing the city's carbon footprint in line with the Paris Agreement's aspirational goal of limiting global warming to 1.5°C. In achieving this goal, it is important to note that the city determines its carbon footprint using the consumption-based method which takes into account the emissions embedded within goods and services consumed by the city, therefore effectively accounting for the carbon footprint of the metropolitan area. Over 500 initiatives are outlined in the Action Plan covering four broad themes: *A carbon-neutral and 100% renewable-energy city* (focusing on energy, mobility, building, urban planning, waste and food), *A resilient city that ensures a high-quality living environment* (encompassing initiatives on improving air quality, strengthening responses to heat waves, and safeguarding biodiversity and water), *A city that is viewed as an ecosystem* (entailing energy transition, mobilization of citizens and stakeholders and good governance of the low-carbon transition), and *A city that matches its means to its ambitions* (aiming at building the economic and financial foundations for the sustainability transition).[16]

[16] C40 Knowledge. (2018, March). *Paris Climate Action Plan: Towards a carbon neutral city and 100% renewable energy.* Case Studies and Best Practice Examples. https://www.c40knowledgehub.org/s/article/Paris-Climate-Action-Plan-Towards-a-carbon-neutral-city-and-100-renewable-energy?language=en_US#:~:text=By%202030%2C%20an%20operational%20action,100%25%20reliant%20on%20renewable%20energy.

Economic Development

After a full year of the coronavirus pandemic in 2020, the French economy showed signs of recovery at the beginning of 2021. GDP in the first quarter of 2021 alone rose by 0.4 percentage points from the fourth quarter of 2020, and consumer spending rose by 1.2 percentage points.[17] For the full year of 2021, France's GDP growth reached 7.89%. Due to the lack of data on the Paris metropolitan area's growth rate in 2021, we replaced it with national values. Considering that metropolitan areas account for more than one-third of the country's economy, their economic growth rate should also be very close to 7.9%. This economic growth is comparable to the average of Chinese cities over the same period. This strong economic recovery has been largely fueled by the French government's multi-billion euro stimulus package. The amount of emergency and recovery projects planned for 2020-2022 accounted for as high as 26% of the country's GDP. These projects are designed to further safeguard public health and medical resources, and provide additional employment opportunities and financial mobility for businesses and families. In addition, the French government has also taken this opportunity to use this economic stimulus to accelerate the development of the digital economy and green economy. However, the pandemic had not completely subsided in 2021, and countries around the world, including France, were still in varying degrees of lockdown. The recovery of tourism, restaurants, and retail, on which France, especially the Paris metropolitan area depends, remains subject to many restrictions. Therefore, despite a significant recovery in GDP, the recovery of employment in the metro area has been relatively slow, and the unemployment rate has fallen by only 0.2 percentage points compared to 2020.[18]

Social Welfare & Livelihood

In recent years, in addition to financial subsidies for low-income families during the new crown epidemic, the Paris city government has signed and promoted the "C40 Cities Equity Pledge" with 40 other international cities, including Hong Kong, China. The signatory cities will be committed to promoting a community-led development model, striving to make the city's various infrastructure projects and many municipal planning more inclusive and capable of addressing climate change, achieve balanced development in the fields of environment, economy, society and health, and take into account the development needs of low-income and disadvantaged groups.[19]

Similar to previous years, our indicators show that Paris' housing-to-income ratio was lower than those of the major metropolitans in China but slightly higher than the Chinese average level in 2021. It should be noted that due to the lack of average house prices in the metropolitan areas, the Paris price-to-income ratio indicator is calculated from the housing prices of Paris city and the per capita income of the metropolitan area, so it will be higher than the actual value of the indicator in the metropolitan area. The affordability of housing in the Paris metropolitan area should actually be closer to, or even lower than, the average level of Chinese cities.

Environmental Resources

In terms of environmental resources, Paris remained far ahead of Chinese cities in measures on air quality and per capita green space. Since Mayor Anne Hidalgo took office in 2014 and Paris hosted the COP21 in 2015, the city has been committed to transform itself into one of the greenest cities in Europe. The Mayor has pledged to plant more than 170,000 trees across the capital, with 50 percent of the city covered by planted areas by 2030 (14.4% plant coverage in 2018).

[17] rfi. (2021, March 5). *French economy rebounds despite Covid-19 closures.* French economy rebounds despite Covid-19 closures (rfi.fr).

[18] Franks, J., Gruss, B., Patnam, M., & Weber, S. (2021, January 19). *Five Charts on France's Policy Priorities to Navigate the COVID-19 Crisis*. International Monetary Fund. Five Charts on France's Policy Priorities to Navigate the COVID-19 Crisis (imf.org).

[19] C40 Cities. (2023). *Equity Pledge.* Equity Pledge - C40 Cities.

Plans were also made to create four "urban forests" surrounding major landmarks such as the Hôtel de Ville, the Gare de Lyon and the Opéra Garnier.[20]

In addition to the planting of trees, the Climate and Resilience Act passed in 2021 prescribed specific regulations on urban green infrastructure. The Act requires all new and commercial buildings with an area of more than 500 square meters in each municipality to have green or renewable energy equipment on the roof. The Act covers buildings such as large warehouses, hangars, and indoor parking lots, but excludes historic buildings and buildings that are difficult to accommodate rooftop green infrastructure due to economic, technical, or cultural reasons. The Act is scheduled to enter into force on July 1, 2023, and is expected to significantly improve biodiversity, stormwater management, energy efficiency, and the urban heat island effect in major French cities, including Paris.[21]

Although Paris already has fairly good air quality (11.1 $\mu g/m^3$ of PM2.5), the government still has a number of long-term initiatives to further improve air quality, mainly focusing on reducing vehicles powered by internal combustion engines, a major source of air pollution. Back in 2011, the City of Paris pioneered the Autolib' electric car sharing service through a public-private partnership. Its business model was modeled after Velib, a bike-sharing service that had been successfully operating in Paris for many years, and was operated by a private company, Bollore, which supplied the Bollore Bluecar, an all-electric car produced by Italian car manufacturer Pininfarina. Autolib's revenue came from the paid subscription from its users. Subscribed users can enjoy electric vehicles, charging, parking in one service, and Autolib's charging stations can also charge other electric vehicles. Autolib' was highly sought after at the outset and received subscriptions that far exceeded its EV supply, causing demand for its vehicles to outstrip supply. However, over time, its popularity, usage rate, and number of users gradually declined. The main reasons for this include the increasing number of more convenient alternative modes of transportation (including ride-hailing services such as Uber), as well as poor vehicle maintenance, and the fact that empty cars were often occupied by homeless people as overnight shelters. Finally, in view of years of losses, the Paris city government took over and terminated Autolib' service in 2018, which was restructured and now operated by several operators as Mobilib'.[22] While Autolib' was still in service, in 2017, the city government began to impose restrictions on vehicles of older models (registered before 1997). This measure succeeded in reducing the number of motor vehicles in the city by 6.05% in the first half of 2018. Moving forward, the municipal government has proposed more restrictions on motor vehicles, such as a complete ban on diesel-powered cars by 2024, a ban on gasoline-powered cars by 2030, a reduction of 55,000 parking spaces per year, and zero-emission buses (pure electric or biogas) for all public transport after 2025.[23]

While restricting vehicle emissions in the city, the Paris government is also actively promoting greener modes of commuting, especially by bicycles. In 2021, Paris adopted a five-year cycling plan with a total investment of more than 250 million euros, aiming to make Paris a city where bicycles can be safely ridden and fully accessible. According to the plan, Paris will add 180 km of segregated bike lanes by 2026. 52 km of these lanes will be converted from temporary bike lanes added during the pandemic to permanent bike lanes. These lanes will be complemented by a planned 180,000 additional bicycle parking spaces - three times the total number of current parking spots. In addition, the construction of these bicycle-related infrastructure will focus in particular on important transportation hubs and main roads connecting

[20] Oliver, H. (2021, November 3). *How Paris plans to become Europe's greenest city by 2030*. TimeOut. Paris's Plan to Become Europe's Greenest City by 2030 (timeout.com).

[21] Green Roofs for Healthy Cities. (2022). *In France, a New Law Supports Green Roofs on Buildings*. Living Architecture Monitor. In France, a New Law Supports Green Roofs on Buildings (livingarchitecturemonitor.com).

[22] France 24. (2018, June 21). *France's car-sharing system Autolib' hits the end of the road.* France's car-sharing system Autolib' hits the end of the road (france24.com).

[23] Le Nevez, C. (2018, October 25). *Greener Paris: how eco initiatives are changing the French capital.* Lonely Planet. Green Paris: the eco initiatives changing the French capital – Lonely Planet - Lonely Planet.

the neighboring suburbs and the city to create better integration across the wider metro area. Lasty, more comprehensive traffic regulations related to bicycles are in the pipeline to facilitate the city's transition to more sustainable commuting.[24]

Consumption & Emissions

The municipal government has a number of long-term plans and policy measures for Paris' consumption and emissions. The aforementioned Climate and Resilience Act mandates the installation of green roofs and renewable energy in large buildings to improve the energy efficiency of buildings and the scale of renewable energy. In general, the long-term strategy on the city's energy consumption are two fold: 1) increasing the proportion and capacity of renewable energy; 2) reduce energy consumption through energy sobriety.

Paris expects to generate 45% of its electricity from renewable sources by 2030, and achieve carbon neutrality by 2050 by relying 100% on renewable or recycled energy. In 2019, the first solar thermal power plant in Paris was put into operation, capable of generating 127,000 kWh, powering 51 households each year. During the same period, another 10 solar panel facilities planned to be built will also provide Paris with enough electricity for 244 households to use 617,000 kWh of electricity a year. However, such concentrated solar power generation cannot maximize the use of solar energy in the city. According to Paris Deputy Mayor Dan Lert who is in charge of the city's ecological transition, climate plan, as well as water and energy, the city has a large potential of using solar energy to generate heat and electricity, but to fully utilize this potential requires more distributed generation. The city has carried out initiatives encouraging or incentivizing public participation in solar projects. One of the initiatives sought to involve volunteers in the installation of more than 10,000 square meters of panels on city roofs, enough to power around 800 homes. The city of Paris has also made available the roofs of municipal buildings including schools and colleges as well as social housing. As of 2021, there were about 76,000 square meters of solar panels in the city, of which more than 10,000 square meters were located on the roofs of municipal buildings. With the passing of the Climate and Resilience Act, more large buildings will install roof-top solar panels to further boost renewable energy distributed generation capacity. However, widespread installation of rooftop solar equipment in Paris is challenging. A major impediment is the large number of protected monuments and buildings in this historical and cultural city. Deputy Mayor Dan Lert said more than 95 percent of the buildings in the city are located within the protection radius centered on various historic monuments. Any modification to the exterior of the buildings within the radius requires special planning approvals.[25]

The city's effort on energy consumption reduction resonates with French Prime Minister Macron's call for energy sobriety. This approach is more radical than the energy-efficiency-oriented approach to sustainable energy in other European countries. Its core emphasis, in addition to energy efficiency, is to reduce unnecessary energy use or electricity as much as possible. One of the most typical measures Paris has taken to respond to this call is to drastically reduce its renowned public lighting. The title of "City of Lights" in Paris is a result of a series of night lighting measures implemented by Gabriel Nicolas de la Reynie, the city's first Lieutenant General of Police in the 17th century, to improve security. These measures included the installation of street lights on all the city's main streets and encouraging citizens to light candles and oil lamps on windowsills. The idea was to prevent lawbreakers from dodging the police or hiding in dark alleys, therefore reducing the crime rate. Today, Paris' municipal lighting, landscape lighting, and many historic buildings and landmarks set by light have become the icons of Paris, such as the midnight Eiffel Tower, the glass pyramid of the Louvre, and the Hôtel de Ville. However, these lighting demands a huge amount of electricity. Public lighting is the second largest electricity consumer in Paris after indoor climate control (heating and cooling) in buildings, accounting for 31% of annual electricity expenditure. Therefore, in response to France's energy sobriety, Paris has greatly shortened the hours of its public lighting. The lights

[24] O'Sullivan, F. (2021, October 22). *Inside the New Plan to Make Paris '100% Cyclable'*. Bloomberg. How Paris Will Become '100% Cyclable' - Bloomberg.

[25] Bauer-Babef, C. (2021, April 16). *Paris looks to citizen power to speed up energy transition*. EURACTIV. Paris looks to citizen power to speed up energy transition – EURACTIV.com.

of the Eiffel Tower are turned off at 11:45 p.m. two hours early, the Pyramid of the Louvre is also turned off at 11:30 p.m., and other municipal landmarks such as the Paris City Hall (Hôtel de Ville) are turned off at 10:00 a.m. The glass windows along the streets of major department stores are also turned off around 10 o'clock. In addition to public lighting, municipal buildings, including courthouses and museums, will stop hot water supply for toilets and limit indoor heating to below 18º. Combining the energy-saving measures of all the above government agencies and municipal facilities, the city is expected to reduce its energy consumption by about 8%, and the energy-saving effect will be more obvious if the citizens follow suit.[26]

The driving force behind the energy sobriety of Paris and even France is, on the one hand, the long-term sustainable need to reduce energy consumption and carbon emissions. On the other hand, there are more urgent reasons. One of the reasons is the energy gap caused by the cessation of Russian gas supplies as a result of the conflict between Russia and Ukraine since 2022, which has brought about an energy gap in France and even Europe. The second reason is the shortage of French nuclear power supply due to technical reasons. EDF has long been on the world's largest nuclear power grid. Its total of 56 reactors generate more power than is needed in France, making France a net exporter of electricity over the years. However, in 2022, multiple nuclear power plants found cracks or corrosion in the coolant pipes for the reactors, resulting in 26 reactors being taken offline for maintenance. This nuclear power shortage even pushed France to rely on electricity imports at least temporarily.

Environmental Management

As a member of the C40 Cities Network, Paris is committed to advancing policy measures in all areas of sustainable development to achieve the Paris Agreement's 1.5ºC climate target. In terms of solid waste, Paris and 26 other cities have signed a joint development pledge "Towards Zero Waste Accelerator" to create cleaner cities and a circular economy. The pledge includes actions to reduce food waste (especially at the retail and consumer end), reduce overproduction of food, encourage food donation, make more efficient use of food waste (e.g. as agricultural feed, compost, or biofuel), further implement sustainable corporate procurement, reduce single-use plastics and other raw materials, and improve the recycling of raw materials in the construction industry.[27]

Barcelona, Spain

Indicator	Barcelona	Hangzhou	Chinese Avg.
Population (million)	1.64	12.20	7.00
GDP (billion USD)	91.18	280.63	105.84
GDP Growth Rate (%)	5.50	8.49	7.90
Service Sector Added Value (%)	57.31	67.85	52.20
Unemployment Rate (%)	9.70	2.34	2.85
Road Area (m^2 per capita)	12.57	11.48	14.82
House-Income Ratio (price per m^2 / GDP per capita)	0.04	0.19	0.16
Teacher-Student Ratio	1:11.9	1:13.9	1:14.3
Population: Age 0-14 (%)	14.00	13.32	17.55
Urban Green Space (m^2 per capita)	17.42	46.42	43.68
Air Quality (PM2.5 annual mean, ug/m^3)	12.80	28.00	31.00
Water Consumption (tons/10,000 USD)	9.66	106.02	318.00
Energy Consumption (tce/10,000 USD)	0.10	1.90	3.61
Domestic Sewage Treatment Rate (%)	100.00	97.13	96.98
Household Waste Harmless Treatment Rate (%)	100.00	100.00	99.92

[26] Kostov, N. (2022, October 9). *Paris Cuts the LIghts to Save Energy. Will It Help?* Wall Street Journal. Paris Cuts the Lights to Save Energy. Will It Help? - WSJ

[27] C40 Cities. (2023). *Towards Zero Waste Accelerator*. Towards Zero Waste Accelerator - C40 Cities.

Notes. Data source: Publicly available data sources, see reference for detail. Data year: 2021.

Barcelona is the capital and largest city of the Catalonia region, and the second largest metropolitan area of Spain, after Madrid. It is the cultural, economic and financial center of southwestern Europe. It is a major tourist destination due to the city's rich architectural heritage, and a major transport hub in this region of Europe with the Port of Barcelona being one of Europe's principal seaports and busiest European passenger port.

Barcelona's overall sustainability agenda is a localized version of the United Nation 2030 Agenda. The city localizes the sustainable development goals and their target indicators to be aligned with the city's performance indicators.[28]

Economic Development

Barcelona has been promoting the concept of Smart City since 2010 and is committed to changing its urban construction model and planning, and further utilizing the digital economy to improve its urban services. The city's economy was hit hard by the COVID-19 pandemic and registered a -10% GDP growth. In 2021, the economy was in a recovery, showing 5.5% growth, but still below the pre-pandemic level. The city government had taken multiple measures to assist local businesses to survive through the pandemic. This includes, for instance, the acquisition of venues from the stores and restaurants that were closed down, and then rented them out at low prices, and the provision of subsidies for unemployed citizens. For those that were unemployed during the pandemic, the city subsidized up to 70% of their pre-unemployment earnings within the first six months of unemployment, and 50% of earnings beyond 180 days.

In addition to keeping the economic wellbeing of firms and citizens above the water during the pandemic, the Barcelona government was also taking the opportunity of economic recovery and reactivation to implement the *Green Deal roadmap*. The Green Deal designated six poles (or conglomerates within the city) - the Zona Franca, Montjuïc, Barcelona city center, 22@ district, Besòs hub and South Diagonal Scientific Node - to be the major hotspots for the reactivation and transition to a green economy.[29] Key policy areas of the Green Deal included growing the digital economy, attracting talent, strengthening local commerce, quality tourism that is respectful and responsible towards the community, establishing electric cars as a mobility element, and fostering the circular economy.[30]

Social Welfare & Livelihood

Since 2021, Barcelona has launched a number of social and well-being initiatives, as part of the city's 2030 Agenda, to address loneliness among the elderly and developmental needs of children and minors. One in five people living in the city is aged 60 or over, and by 2030, it will be one in three.[31] The city has launched a community action project Radars to actively combat unwanted loneliness among senior citizens. The essential idea of the Radars Project is to build a prevention network with local residents, retailers, volunteers and professionals to create a more humane and solidarity neighborhood for the elderly. The project calls on participants to be alert to the daily dynamics of elderly people they know and to contact the project if they detect any change in the everyday routine, behavior or aspect of those elderly people. The Project is currently being implemented in nine of the city's ten districts, and is monitoring 489 elderly people, in collaboration with 164 of the city's associations, 642 local neighborhood participants and 324 retailers. With support from the Barcelona Pharmacies Association, some two hundred of the city's pharmacies have joined the programme as

[28] Barcelona City Council. (2020). *Barcelona's 2030 Agenda. SDG targets and key indicators*. Agenda 2030 of Barcelona. SDG Targets and Key Indicators.pdf.
[29] Ajuntament de Barcelona. (2022, March 7). *Barcelona explains its new economic model for 2030*. Politico. Barcelona explains its new economic model for 2030 – POLITICO.
[30] Ajuntament de Barcelona. (2021, April 30). *Barcelona Green Deal: 672 million euros in investment between now and 2023.* Info Barcelona. Barcelona Green Deal: 672 million euros in investment between now and 2023 | Info Barcelona | Barcelona City Council.
[31] Vlvas, E., & Soler, L. N. (2023, April 21). *Evolving demographics.* Barcelona Metropolis. Evolving demographics | Barcelona Metròpolis | Barcelona City Council.

well.[32] Furthermore, the Play Plan for public spaces aims to improve and diversify more than 900 children's play areas in the city for them to be recreational areas and venues of social gathering for both the young and old.[33]

Environmental Resources

Barcelona's new Sustainable Urban Mobility Plan continues the city's effort to significantly reduce vehicle emissions, in order to ensure that the concentration of the main urban atmospheric pollutants remain below the thresholds recommended by the World Health Organisation. In the case of particulate matters, achieving the WHO levels (e.g., $PM_{2.5}$ concentration of 10 $\mu g/m^3$) remained to be challenging, given the diversity of the emission sources for this pollutant (dust, ash, soot, metallic particles, cement, pollen, etc.). Even during the most extensive period of the COVID-19 lockdown, the city exceeded the recommended level for $PM_{2.5}$ and barely achieved it for PM_{10}.[34]

Consumption & Emissions

In January 2020, the city of Barcelona declared a climate emergency and accelerated a series of changes involving all players in the city, to be the leader among the world's cities in combating climate change.[35]

In terms of energy consumption, Barcelona continued to move forward with the city's transition to renewable energy. It began to roll out the Sustainable Energy Mechanism (MES) in 2021. The MES is an instrument to aid and accelerate the city's energy transition alongside private investors. Its objective is to boost the capacity of solar energy in the city based on private initiatives, focusing on projects that use both large spaces (such as the roofs of industrial buildings and warehouses, office buildings or other places in the city) and terrace roofs and rooftops of residential buildings. This is a financial investment mechanism where a budget of EUR 50 million will be offered by Barcelona City Council and awarded to different projects presented by investors approved by the City Council. The selection criteria focus on the investor's experience and expertise in photovoltaic installations and energy renovation. The MES mandates that the business model should not rely on co-financing by the owners of the building. The investors will assume the full cost of the investment (including the awarded amount) and will recover it through the surplus energy or the energy savings generated by the financed operations.[36]

Water resources have always been a salient sustainability issue of Barcelona, as the city went through a serious drought in 2008. The city has strived to use no more water than is strictly necessary. According to the Barcelona 2030 Agenda, the city will continue to improve the efficiency of water consumption and set the target of 150 liters per inhabitant per day of urban water consumption by 2030.[37]

Environmental Management

Barcelona's wastewater treatment plant has a 100% centralized treatment rate and regulates its operations by establishing a resilient sewage network to absorb floodwater, rainwater, and sewage volumes, and to avoid pollution of

[32] Ajuntament de Barcelona. (n.d.). *Retailers, come along and take part in the Radars Project!* [Retailers, come along and take part in the Radars Project!] | Barcelona Commerce.
[33] Barcelona City Council. (2021). *Annual monitoring and evaluation report on the Barcelona 2030 Agenda (Voluntary Local Review 2021)*. barcelona_2021_en.pdf (unhabitat.org).
[34] Barcelona City Council. (2020). *Barcelona's 2030 Agenda. SDG targets and key indicators*. Agenda 2030 of Barcelona. SDG Targets and Key Indicators.pdf.
[35] Ajuntament de Barcelona. (n.d.). *This is not a drill: Barcelona climate emergency declaration.* Climate emergency declaration | Barcelona City Council.
[36] Barcelona City Council. (2021). *Annual monitoring and evaluation report on the Barcelona 2030 Agenda (Voluntary Local Review 2021)*. barcelona_2021_en.pdf (unhabitat.org).
[37] Barcelona City Council. (2020). *Barcelona's 2030 Agenda. SDG targets and key indicators*. Agenda 2030 of Barcelona. SDG Targets and Key Indicators.pdf.

river and sea due to excess discharge. At the same time, Barcelona implements 100% harmless waste treatment, and has built green landscapes on top of landfill sites, while continuing to reduce the proportion of waste diverted to landfills.

Eindhoven, Netherlands

Indicator	Eindhoven	Hangzhou	Chinese Avg.
Population (million)	0.77	12.20	7.00
GDP (billion USD)	51.58	280.63	105.84
GDP Growth Rate (%)	7.38	8.49	7.90
Service Sector Added Value (%)	49.25	67.85	52.20
Unemployment Rate (%)	3.30	2.34	2.85
Road Area (m^2 per capita)	-	11.48	14.82
House-Income Ratio (price per m^2 / GDP per capita)	0.09	0.19	0.16
Teacher-Student Ratio	1:16.5	1:13.9	1:14.3
Population: Age 0-14 (%)	14.80	13.32	17.55
Urban Green Space (m^2 per capita)	161.00	46.42	43.68
Air Quality (PM2.5 annual mean, ug/m^3)	10.90	28.00	31.00
Water Consumption (tons/10,000 USD)	71.18	106.02	318.00
Energy Consumption (tce/10,000 USD)	0.88	1.90	3.61
Domestic Sewage Treatment Rate (%)	99.50	97.13	96.98
Household Waste Harmless Treatment Rate (%)	-	100.00	99.92

Notes. Data source: Publicly available data sources, see reference for detail. Data year: 2021.

Eindhoven is located in the province of North Brabant in the south of the Netherlands. The Eindhoven metropolitan area is bordered to the east and west by the Venlo and Tilburg metropolitan areas. With a population of 767,000 in 2020, the Eindhoven metropolitan area is the fifth largest metropolitan area in the Netherlands, after the capital Amsterdam, Rotterdam, The Hague and Utrecht.

At the time of Dutch independence from Napoleon's French occupation in 1815, Eindhoven was a relatively economically backward agricultural village with a population of just over 1,000. Its cheap land and labor were ideal for the industrialization of the newly born Kingdom of the Netherlands. Throughout the 19th century, Eindhoven grew into an industrialized town dominated by the textile and tobacco industries. In 1891, two brothers, Anton and Gerard Philips, founded a small factory in Eindhoven for the manufacture of carbon filament light bulbs. This small factory would later grow into a giant in the electrical industry - known to the world as Phillips. Throughout the 20th century, Eindhoven's development was closely linked to Philips. Philips established its first research center (NatLab) in 1914, and its existence not only brought technological breakthroughs to Philips, but also attracted a large number of industrial and technological companies to gather in the Eindhoven region. Today, Eindhoven is a key technology hub in the Netherlands. In 2005, the metropolitan area accounted for one-third of Hollands' research expenditures, and one-quarter of the metropolitan area's jobs were related to technology or information technology companies. What was once a Philips research laboratory has now expanded into the High Tech Campus Eindhoven, an example of innovative cooperation between companies and industries in the region.

Economic Development

Since the outbreak of the COVID-19 pandemic, the Netherlands government has carried out an array of measures to mitigate the pandemic's adverse impacts on business and economy. Some of these major measures have continued into the 2021 recovery. The more general support includes allowing deferred tax payment for businesses, with a generous payback scheme. Additionally, the Temporary Emergency Scheme for Job Retention (NOW) scheme compensates part of the wage costs of businesses whose turnover has dropped by at least 20%. For small- and medium-sized enterprises (SMEs) and self-employed people, the Fixed Costs Grant Scheme (TVL) provides grants to those losing more than 30% of their

turnover. Self-employed people could further claim income support under the Self-employment Income Support and Loan Scheme (TOZO) if their income drops below the minimum income standard. The TOZO scheme also provides working capital loans to self-employed entrepreneurs if they face liquidity problems.[38]

In 2021, as the economy began to recover from the pandemic, the GDP growth of the Eindhoven metropolitan area was 7.38%. Unemployment dropped from 3.6% in 2020 to 3.3%. These growth and unemployment figures are very close to the Chinese cities, and outperforms our other international comparison cities. Part of the reason for Eindhoven's economic resilience during the pandemic can be attributed to its economic structure with a high contribution from high-tech industries and their related manufacturing, which were less adversely affected by the pandemic compared to the service sector (only accounts for 49% of the metropolitan area's GDP).

Social Welfare & Livelihood

Based on our indicators, which reflect national statistics due to the lack of metropolitan-level data, cities in the Netherlands have relatively more limited educational resources compared to their Chinese counterparts. Educational equity and the allocation of educational resources faced significant challenges during the pandemic. According to research conducted by the Dutch National Student Association, the remote learning during the lockdown g has seriously affected the quality of their classes and courses through lack of personal assistance, discussion and practical experience. More than 7% of students at all levels of education encountered delays in completing their studies.

The National Education Programme launched by the Dutch government in 2021 planned to invest an extra EUR 8.5 billion across the educational spectrum, from primary education to higher education, with particular focus on increasing educational resources, and loans and subsidies for low-income students. At the same time, some recommendations have been proposed by the National Youth Council including the revision of the student loan system to re-introduce the basic grants that can be used to compensate students who have run up debts due to the current loan system, the optimization of curriculum and mode of learning with specific focus on social and emotional skills, personal development, citizenship, media skills, sex education (including gender diversity), and the design of more accessible, hybrid form of learning.

Environmental Resources

Eindhoven's efforts on improving the city's environmental resources can be highlighted by the High Tech Campus Eindhoven (HTCE). The HTCE has evolved from Phillips' original NatLab to an industrial ecosystem of more than 235 companies and 12,000 employees. The HTCE's sustainability roadmap aims for achieving carbon neutrality by 2025 and becoming the most sustainable high tech campus in Europe. A key focus on HTCE's sustainability roadmap is biodiversity. The campus has implemented various measures including placing insect hotels and beehives on campus grounds, using grazing sheep instead of lawn mowers to manage grasslands, outfitting the new parking garage with a nesting wall for breeding swallows, and installing sensors at the foot of trees to monitor water.

In addition to biodiversity, to minimize the emissions from vehicles, the HTCE has installed 85 charging stations on the Campus for electric cars, begun using electric buses as transport to and from the Campus, provided 150 bicycles for use on Campus, and built a charging station for hydrogen cars.[39]

Outside of the High Tech Campus, Eindhoven has been the pioneer of experimenting innovative methods to improve air quality, such as through active air purification systems dubbed the "Lungs of the City". Since 2017, the city has installed batteries of these air purification devices at pollution hotspots such as underground parking, tunnels, and subway stations,

[38] SDG Nederland. (2021). *Fifth Dutch National SDG Report: Sustainable Development in the Netherlands*. Fifth Dutch National SDG Report (sdgnederland.nl).

[39] High Tech Campus. (2019, May 28). *Sustainability Roadmap: turning High Tech Campus Eindhoven into Europe's greenest Campus.* Sustainability Roadmap: turning High Tech Campus Eindhoven into Europe's greenest Campus.

where high concentrations of particulate matter and high levels of exposure converge. The initial pilot demonstrated that the installation of these air purification systems are both financially and technically feasible, and that they can be easily integrated into existing urban infrastructure. Evaluations showed that these "Lungs of the City" significantly reduced particulate matters and the associated health risk, although the magnitude of pollution reduction varied by locations, building density, weather conditions, and local traffic intensity.[40]

Consumption & Emissions

Nationwide, the Netherlands government has set the target of 27% renewable energy and 49% reduction in carbon emissions by 2030. Although the Netherlands Environmental Assessment Agency deemed there to be a long way to go toward these targets,[41] cities and neighborhoods are taking the initiatives to develop renewable energy capacity and improve energy efficiency. For instance, the High Tech Campus Eindhoven has achieved 100% green electricity and green gas, 85% of the thermal energy storage is used, and 77% of Campus buildings received energy efficiency label. Furthermore, the Campus plans to install solar panels on the roofs of all campus buildings, install movement sensors that automatically shut down lights and heating when rooms are not used, and install LED lighting in all Campus parking garages.[42]

Environmental Management

Building a circular economy or achieving circular use of resources is a key cornerstone of the Netherlands' sustainability agenda. The water authorities are preparing a strategy to achieve circularity, with the goal of 50% reduction in use of primary resources with a negative environmental impact by 2030. They also set the target of having all wastewater treatment plants achieving energy neutrality by 2025 through biogas production in their wastewater treatment plants, and providing potential for renewable energy generation on their premises and surface waters, which will also contribute to further reductions in carbon emissions.[43]

Inside the High Tech Campus Eindhoven, 99.7% of all Campus waste is collected and processed in separate streams. A convertor is planned to be installed to transform food swill and waste into compost. Shredded paper is recycled and made into paper towels and toilet paper for Campus bathrooms.[44]

[40] Eindhoven University of Technology. (2021, November 8). *Air quality in Eindhoven, Netherlands significantly improves with 'Lungs of the City'.* Phys.org. Air quality in Eindhoven, Netherlands significantly improves with 'Lungs of the City' (phys.org).
[41] SDG Nederland. (2021). *Fifth Dutch National SDG Report: Sustainable Development in the Netherlands*. Fifth Dutch National SDG Report (sdgnederland.nl).
[42] High Tech Campus. (2019, May 28). *Sustainability Roadmap: turning High Tech Campus Eindhoven into Europe's greenest Campus.* Sustainability Roadmap: turning High Tech Campus Eindhoven into Europe's greenest Campus.
[43] SDG Nederland. (2021). *Fifth Dutch National SDG Report: Sustainable Development in the Netherlands*. Fifth Dutch National SDG Report (sdgnederland.nl).
[44] High Tech Campus. (2019, May 28). *Sustainability Roadmap: turning High Tech Campus Eindhoven into Europe's greenest Campus.* Sustainability Roadmap: turning High Tech Campus Eindhoven into Europe's greenest Campus.

Moscow, Russia

Indicator	Moscow	Hangzhou	Chinese Avg.
Population (million)	12.64	12.20	7.00
GDP (billion USD)	332.81	280.63	105.84
GDP Growth Rate (%)	4.70	8.49	7.90
Service Sector Added Value (%)	54.10	67.85	52.20
Unemployment Rate (%)	2.60	2.34	2.85
Road Area (m^2 per capita)	-	11.48	14.82
House-Income Ratio (price per m^2 / GDP per capita)	0.15	0.19	0.16
Teacher-Student Ratio	1:12.8	1:13.9	1:14.3
Population: Age 0-14 (%)	17.71	13.32	17.55
Urban Green Space (m^2 per capita)	-	46.42	43.68
Air Quality (PM2.5 annual mean, ug/m^3)	-	28.00	31.00
Water Consumption (tons/10,000 USD)	269.39	106.02	318.00
Energy Consumption (tce/10,000 USD)	5.36	1.90	3.61
Domestic Sewage Treatment Rate (%)	-	97.13	96.98
Household Waste Harmless Treatment Rate (%)	-	100.00	99.92

Notes. Data source: Publicly available data sources, see reference for detail. Data year: 2021.

Located in the far west of Russia, Moscow is the country's capital and political center, as well as Russia's most populated city.[45] Between 2010 and 2019, the city took great strides towards sustainable development, and was commended by the Organisation for Economic Co-operation and Development (OECD) for their significant progress in reducing poverty and income equality, and in improving public transportation, health and education outcomes in the city.[46] As of 2019, Moscow has instituted 3 main strategies for sustainable development – the Master Plan 2010 - 2035, which promotes "balanced urban development" that strikes a balance between providing access to green spaces, creating efficient transportation infrastructure and quality housing; the Investment Strategy 2035, which aims to create a positive investment climate for urban development; and Smart City 2030, which aims to advance urban development through the use of digital technologies.[47] It is unclear how implementation progress on these strategies have been affected by Russia's invasion of Ukraine since February 2022.[48]

Economic Development

Imposed sanctions on Russia due to its invasion of Ukraine since February 2022 have weakened the Russian economy, although by not as much as predicted. Russia's GDP shrank by 2.1% in 2022, with the World Bank and OECD predicting further shrinkage of the Russian economy in 2023.[49] In 2023, Russia's GDP was valued at US$1860 billion, while the GDP

[45] Moscow | History, Geography, Population, & Map | Britannica. (n.d.). Retrieved November 9, 2023, from https://www.britannica.com/place/Moscow

[46] OECD. (2019). *2nd OECD Roundtable on Cities and Regions for the SDGs: Issue Notes.* https://www.oecd.org/cfe/cities/Moscow-Issue-Note.pdf

[47] *ibid.*

[48] European Council. (2023, October 12). *Impact of sanctions on the Russian economy.* https://www.consilium.europa.eu/en/infographics/impact-sanctions-russian-economy/

[49] European Council. (2023, October 12). *ibid.*

Korsunskaya, D., Marrow, A., & Marrow, A. (2023, April 14). *Russia raises 2023 GDP growth forecast, longer-term outlook worsens.* Reuters. https://www.reuters.com/markets/europe/russian-economy-ministry-improves-2023-gdp-growth-forecast-2023-04-14/

per capita was US$13,000.[50] The unemployment rate in Russia has remained low throughout, and is forecasted to stay at a low rate of 3.5% between 2023 - 2026.[51] Russia's economy ministry is predicting a slight recovery of the economy in 2024, bolstered by consumer demand and spending.[52]

Social Welfare & Livelihood

According to the OECD, Moscow showed notable improvements in areas related to the Sustainable Development Goals (SDGs) between 2010 and 2018.[53] During this time period, Moscow reduced the percentage of individuals in the city making an income below subsistence level from 10% to 7.2%, the unemployment rate from 1.8 to 1.3%, and halved the mortality rate of newborns and children below the age of 5 to 5 per 1000 live births.

Moscow also made strides in improving the public transport system, for example through the launch of an improved bus transportation network in the city center in 2016, which helped to cut down bus waiting times by half from 16 minutes to 8 minutes, and increased commuter flow by 40%. Moscow also joined 35 other cities worldwide in signing the C40 Green and Healthy Streets declaration, to pledge to reduce transport-related carbon emissions by decarbonizing the transport network within the city.[54] To facilitate this, Moscow is extending its more than 850 kilometer-long bike route to create a circular 'Green Circle' cycling network that connects Moscow's parks by 2024-2025. Given that emissions from private transportation account for around 80% of air pollution in Moscow, these improvements are aimed at helping to reduce air pollution and greenhouse gas emissions in Moscow, which fell by 18% between the years 2013 and 2018. However, it is important to note that Moscow is no longer a C40 signatory city as of 2023, which may have implications on the implementation progress of their emission reduction commitments.[55]

Environmental Resources

In addition to improving Moscow's public transport network, as part of Moscow's C40 Green and Healthy Streets declaration, Moscow is also creating new green areas by establishing 8.4 kilometers of river walks and 106 park zones that will cover 1444 hectares of land. Since 2013, Moscow has also implemented a large-scale landscaping program known as the "Million Trees" project, which aims to increase the amount of green spaces in Moscow and create a pleasant urban environment. The program has resulted in the planting of over 90,400 trees and 1.8 million bushes between 2013 and 2018, at a cost of approximately US$48 million. In addition, the project encourages audience participation by allowing Moscow citizens to decide where and which species to plant, and has engaged a total of 1.5 million people by 2018. Through the "Million Trees" program, Moscow has increased the proportion of green spaces and reduced greenhouse gas emissions by almost 2 million tons of carbon dioxide equivalent through tree planting activities.[56] Since 2018, Moscow's Department of Natural Resource Management and Environmental Protection aimed to continue the "Million Trees" program by greening community spaces around Moscow, but progress is unknown given that Moscow is no longer a C40 signatory.

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[50] International Monetary Fund. (n.d.). *Russian Federation*. Retrieved November 9, 2023, from https://www.imf.org/en/Countries/RUS

[51] Korsunskaya, D., Marrow, A., & Marrow, A. (2023, April 14). *ibid.*

[52] *ibid.*

[53] OECD. (2019). *ibid.*

[54] C40 Cities. (n.d.). *C40 Green and Health Streets Declaration: How cities are creating streets that put people first.* https://www.c40.org/wp-content/uploads/2022/03/C40-Green-and-Healthy-Streets-Declaration_Public-progress-report_Feb-2022.pdf

[55] *Cities Archive—C40 Cities.* (n.d.). Retrieved November 15, 2023, from https://www.c40.org/cities/?gclid=CjwKCAiA3aeqBhBzEiwAxFiOButZ5JHkbD5b8K7-egz_xzxEdbyICJHUEHlJ1FlX-tShsYiX_NAucxoCog4QAvD_BwE

[56] C40 Cities. (2018, May). *The Million Trees project.* https://www.c40.org/case-studies/the-million-trees-project/

Consumption & Emissions

In 2021, Russia was named the third highest emitter of historic greenhouse gas emissions by Carbon Brief, contributing 6.9% of cumulative carbon dioxide emissions since 1850.[57] Russia is currently the fourth largest emitter of greenhouse gasses, emitting 1.92 billion tons of carbon dioxide equivalent (GCO2e) in 2019,[58] or 11.7 tons of carbon dioxide equivalent per capita in 2021.[59] Russia's emissions per GDP in 2020 was 0.4kg per PPP $ of GDP, twice the world's average in the same year.[60]

As part of Moscow's C40 Green and Healthy Streets declaration, Moscow has also pledged to achieve net zero greenhouse gas emissions within the borders of the old capital. In order to achieve this, the Moscow government is intending to replace Moscow's bus fleet with electric buses – as of 2022, the state-owned transport operator was operating 1000 electric buses on 52 bus routes, with plans to put into service another 600 electric buses by the end of the year. There are also plans to introduce emission standards for freight transport within the city, and to begin a transition towards zero emission freight transport. In addition, Moscow is planning to install 600 electric vehicle charging stations in the city by the end of 2023 to facilitate the city's transition towards higher electric vehicles adoption. Moscow is also developing energy efficient infrastructure and reducing the city's consumption of fossil fuels for electricity and heating as a part of this goal.

While Moscow's net zero emissions by 2030 goal is laudable, criticisms surround its implementation. Firstly, there are concerns about the city's ability to implement this goal, especially as the city's budget for such programs run out after 2023, and it is uncertain whether these programs will continue in light of Russia's involvement in the Ukraine War. There is also a lack of public data available to monitor and evaluate the success of Moscow's carbon neutrality programs. Secondly, given that the geographic boundaries of the old capital excludes industrial facilities located within Moscow, there are also concerns that the program will have limited impact on the city's overall carbon emissions.[61]

Environmental Management

Moscow generated 7.8 million tons of waste in 2017, with the number expected to rise in coming years. Based on 2020 numbers, 88% of Moscow's waste goes to landfills, with Moscow falling behind other cities in terms of recycling rate. As there are no public recycling programs in the city, only small groups of individuals and private businesses recycle their waste in Moscow.[62] Hence, in 2020, the first city-wide recycling scheme was initiated, with aims for the city to eventually achieve a 50% recycling rate. This comes at the heels of controversy with Moscow's current waste management methods, which consists of shipping out the city's trash to landfills in more rural areas, such as the Kaluga and Vladimir regions, due to environmental safety concerns.[63] It is also worth noting that waste incineration counts as a form of recycling in Russia, as long as the incineration process produces usable heat energy or electricity. In 2020, the Russian government spent $7.6

[57] The Moscow Times. (2021, October 5). *Russia Named World's 3rd-Highest Carbon Emitter in History.* The Moscow Times. https://www.themoscowtimes.com/2021/10/05/russia-named-worlds-3rd-highest-carbon-emitter-in-history-a75213

[58] Carbon Brief. (2022, September 22). *The Carbon Brief Profile: Russia.* Carbon Brief. https://www.carbonbrief.org/the-carbon-brief-profile-russia/

[59] *Russia: CO_2 emissions per capita.* (2023, November). Statista. Retrieved November 15, 2023, from https://www.statista.com/statistics/1271434/carbon-dioxide-emissions-per-capita-russia/

[60] The World Bank. (2023). *ibid.*

[61] Oshchepkov, M. (2021, June 16). *Russia Spotlight City: Moscow.* Climate Scorecard. https://www.climatescorecard.org/2021/06/russia-spotlight-city-moscow/

[62] Euronews. (2020, January 2). *No time to waste? Moscow begins recycling its rubbish.* Euronews. https://www.euronews.com/2020/01/02/no-time-to-waste-moscow-begins-recycling-its-rubbish

[63] Gershkovich, E. (2019, February 3). *Thousands Protest Against Moscow's Plan to Dump Its Trash in Russian Regions.* The Moscow Times. https://www.themoscowtimes.com/2019/02/03/thousands-come-out-in-protest-against-moscows-plan-to-dump-its-trash-on-russian-regions-a64376

billion dollars building 25 waste-to-energy plants, which has also been met with controversy.[64] Moscow's Trash Reform Plan also does not currently include any proposed strategies for reducing the total amount of waste produced in the city.[65]

Hong Kong, China

Indicator	Hong Kong	Hangzhou	Chinese Avg.
Population (million)	7.41	12.20	7.00
GDP (billion USD)	443.46	280.63	105.84
GDP Growth Rate (%)	7.20	8.49	7.90
Service Sector Added Value (%)	93.70	67.85	52.20
Unemployment Rate (%)	5.20	2.34	2.85
Road Area (m^2 per capita)	6.34	11.48	14.82
House-Income Ratio (price per m^2 / GDP per capita)	0.33	0.19	0.16
Teacher-Student Ratio	1:11.8	1:13.9	1:14.3
Population: Age 0-14 (%)	10.90	13.32	17.55
Urban Green Space (m^2 per capita)	98.74	46.42	43.68
Air Quality (PM2.5 annual mean, ug/m^3)	16.17	28.00	31.00
Water Consumption (tons/10,000 USD)	31.03	106.02	318.00
Energy Consumption (tce/10,000 USD)	0.66	1.90	3.61
Domestic Sewage Treatment Rate (%)	93.80	97.13	96.98
Household Waste Harmless Treatment Rate (%)	100.00	100.00	99.92

Notes. Data source: Publicly available data sources, see reference for detail. Data year: 2021.

Hong Kong is a vibrant city, and a major gateway to Mainland China. It is one of the Special Administrative Regions of China that enjoys executive, legislative and independent judicial power, including that of final adjudication, and its political system. Hong Kong's economy is characterized by free trade, low taxation and minimum government intervention. It is the world's 10th largest trading economy, with the mainland of China as its most significant trading partner. Hong Kong is also a major service economy (93.7% contribution to GDP), with particularly strong links to mainland China and the rest of the Asia-Pacific region.

The city's sustainability strategies are embedded in its Climate Action Plan 2050, announced in 2017. The Action Plan sets out the decarbonisation target of reducing Hong Kong's carbon intensity by 65% to 70% by 2030 from 2005 levels. According to the city's Secretary for the Environment, Wong Kam-sing, the most prominent sources of carbon emissions are electricity, transportation, and waste, each accounting for 66%, 18% and 7% of Hong Kong's total 2019 emissions. Correspondingly, the Action Plan's focus will be around four major strategies: *Net-zero electricity generation, Energy saving and green buildings, Green transport,* and *Waste reduction.*[66]

Economic Development

Hong Kong has a well-established market economic system, advanced financial and legal systems, and strong economic resilience and competitiveness. In 2021, although Hong Kong was still suffering from the impact of the COVID-19 epidemic, with the adoption of widespread vaccination and more reasonable pandemic control measures, Hong Kong's economy gradually recovered, registering a 7.2% GDP growth. The Hong Kong Government has always been committed to promoting a green, environmentally friendly and sustainable economy. In recent years, the government has put forward

[64] *Russia's Trash-Burning Plants Could Fuel Unrest, Greenpeace Warns.* (2020, May 18). The Moscow Times. https://www.themoscowtimes.com/2020/05/14/russias-trash-burning-plants-could-fuel-unrest-greenpeace-warns-a70278

[65] *Moscow's Trash Reform Equates Incineration With Recycling.* (2019, December 17). The Moscow Times. https://www.themoscowtimes.com/2019/12/17/moscows-trash-reform-equates-incineration-with-recycling-a68632

[66] The Government of the Hong Kong Special Administrative Region. (2021, October 8). *Government announces Hong Kong's Climate Action Plan 2050*. Government announces Hong Kong's Climate Action Plan 2050 (with photos) (info.gov.hk).

a number of specific measures to promote the development of innovation and technology industries and attract key companies and talents. The city released the "Hong Kong Innovation and Technology Development Blueprint" in 2022 to set out a roadmap for how Hong Kong would support the growth of this sector in the future.

Social Welfare & Livelihood

As one of the most densely populated cities in the world, Hong Kong had a total population of 7.41 million at the end of 2021, about 61% of Hangzhou's population and was slightly more populous than the average cities in mainland China (7.00 million). Residents aged 0-14 accounted for 10.9% of Hong Kong's population. The proportion of this population age group is slightly lower than those of Chinese cities (average 17.55%). This population age group is the dependents in the present, but labor force in the future and the key driver of the city's sustained growth. Furthermore, a younger population structure also implies that the economy and labor force in the future could better support the medical and health needs of senior citizens.

In recent years, the Hong Kong government has increased investment in the education sector, and has introduced a series of educational reform measures to improve the quality of education and promote the all-round development of students, such as improving teacher training and professional development, and providing more educational resources. In 2021, the Teacher-to-Student Ratio in primary and secondary schools in Hong Kong was 1:11.8, higher than that in Hangzhou (1:13.9).

Hong Kong is a highly urbanized area with dense economic activities and population, relatively limited water and land resources, resulting in a very limited land area for buildings. At the same time, economic opportunities and high-quality public service facilities have attracted a large number of people, fuelling the continuous demand for housing. In 2021, Hong Kong's Housing-to-Income Ratio was 0.33, the highest among all selected international cities, and twice the average of Chinese cities, illustrating the substantial financial burden for local citizens on housing. Similarly, due to limited land resources and limited space for road construction, the per capita urban road area in Hong Kong in 2021 was about 6.34 square meters, at the low end of selected cities.

Environmental Resources

Urban green areas are part of the urban ecosystem, they provide a variety of ecosystem services to the city, play a key role in creating a healthy and livable urban environment and promoting the sustainable development of the city. In recent years, the Hong Kong government has adopted a number of policies and measures to create a pleasant, comfortable and elegant urban environment. The Hong Kong government has put forward the *Hong Kong 2030+: Towards a Planning Vision and Strategy Transcending 2030*, which sets out the territorial spatial development strategy for the city beyond 2030. One of the key strategies is to increase the city's green space and protect the natural environment. At the same time the government plans to promote the Urban Forest Initiative, which intends to create a forest ambience in the city through the planting of trees and vegetation, and is committed to improving the accessibility and coverage of the public transport system and infrastructure for bicycles.

Furthermore, the *Green Transportation* pillar of Hong Kong's Climate Action Plan 2050 sets the long-term target of achieving zero vehicular emissions and zero carbon emissions in the transport sector before 2050. The city plans to achieve these long-term goals through the electrification of vehicles and ferries, and the development of clean-energy transportation and improvements in traffic management. Hong Kong also plans to cease the new registration of fuel-propelled and hybrid private cars in 2035 or earlier. Lastly, in addition to promoting electric buses and commercial vehicles, the government also plans to collaborate with automobile manufacturers and other stakeholders in the next three years to test out hydrogen fuel cell electric buses and heavy-duty vehicles.

Consumption & Emissions

In 2020, the Hong Kong government released the Town Planning Ordinance and the Waste Disposal Ordinance to strengthen waste management and promote resource recycling. In 2021, a specific timetable was set for achieving carbon neutrality, with a view to halving Hong Kong's carbon emissions by 2035 compared to 2005 levels. In 2022, the Hong Kong government continued to formulate a number of new measures to move towards "carbon neutrality", such as energy conservation, green transportation, and waste reduction for all.

In the Climate Action Plan 2050, two pillars are most relevant to Consumption and Emissions: *Net-zero electricity generation* and *Energy saving and green buildings*. For the *Net-zero electricity generation*, key initiatives include phasing out coal for daily electricity generation, increasing the share of renewable energy from 7.5% to 10% in the fuel mix for electricity generation by 2035, and to 15% afterwards. For *Energy saving and green buildings*, the city plans to reduce the overall electricity consumption of buildings through improving buildings' energy efficiency and promoting a low-carbon lifestyle. The specific target is to reduce the electricity consumption of commercial buildings by 30% - 40% and that of residential buildings by 20% - 30% from the 2015 level by 2050. Half of these building energy reductions are expected to be achieved by 2035.

Environmental Management

According to the Climate Action Plan 2050, Hong Kong strives to achieve the long-term target of carbon neutrality in waste management before 2050. An eminent priority for the local government is to develop adequate waste-to-energy facilities by 2035, in order to reduce the reliance on landfills for municipal waste disposal. The government will also further promote waste reduction and recycling, and expects to implement waste charging in 2023 and regulate disposable plastic tableware in phases from 2025 onwards.

Wastewater treatment is a key component of urban sustainable development. Effective treatment and management of wastewater can reduce environmental pollution, and improve circular use of water resources. In 2020, the Hong Kong government issued the Sustainable Water Supply Blueprint, which aims to ensure the sustainability and security of Hong Kong's water supply. The key goals of the Blueprint include improving water supply efficiency, enhancing water resource management and promoting rainwater harvesting. At the same time, the city has proposed a sewage treatment plan for 2025 to increase sewage treatment rates and reduce the impact on the marine ecosystem.

Singapore, Singapore

Indicator	Singapore	Hangzhou	Chinese Avg.
Population (million)	5.45	12.20	7.00
GDP (billion USD)	396.99	280.63	105.84
GDP Growth Rate (%)	7.60	8.49	7.90
Service Sector Added Value (%)	69.40	67.85	52.20
Unemployment Rate (%)	3.50	2.34	2.85
Road Area (m^2 per capita)	15.89	11.48	14.82
House-Income Ratio (price per m^2 / GDP per capita)	0.19	0.19	0.16
Teacher-Student Ratio	1:12.1	1:13.9	1:14.3
Population: Age 0-14 (%)	14.48	13.32	17.55
Urban Green Space (m^2 per capita)	60.45	46.42	43.68
Air Quality (PM2.5 annual mean, ug/m^3)	12.00	28.00	31.00
Water Consumption (tons/10,000 USD)	7.92	106.02	318.00
Energy Consumption (tce/10,000 USD)	1.16	1.90	3.61
Domestic Sewage Treatment Rate (%)	93.00	97.13	96.98
Household Waste Harmless Treatment Rate (%)	100.00	100.00	99.92

Notes. Data source: Publicly available data sources, see reference for detail. Data year: 2021.

With a land mass of slightly over 700 square kilometers, Singapore is a small island nation located at the southernmost tip of the Malay Peninsula in Southeast Asia.[67] Despite its small size, more than 5 million people from four major communities (Indian, Malay, Chinese and Eurasian) inhabit this city state, which is also a major hub for financial services, international trade, and manufacturing. Since the 1960s, Singapore has pursued an aggressive land reclamation strategy to enlarge its small size, increasing its land mass by 22% between 1965 and 2015.[68] Land reclamation has also been used to combat the threat of rising sea levels, as most of the island nation lies less than 15m above sea level.[69] Singapore's small size and limited natural resources has not stopped the city state from positioning itself as a sustainability hub, and Singapore aims to become a leading provider of green finance and other services in the region and help facilitate Asia's transition towards a low-carbon future.

Economic Development

As one of Asia's largest business and financial hubs,[70] Singapore has one of the highest GDP per capita in the region. In 2022, Singapore had a nominal GDP of USD 466.8 billion and a GDP per capita of USD 133,416.[71] Manufacturing contributes a significant amount to Singapore's GDP (21.6%), and as do the trade and finance sectors (19.3% and 13.5% respectively). Compared to 2021, Singapore's GDP growth has slowed significantly from 8.9% in 2021 to 3.6% in 2022 due to slowing global trade and weakening global finance conditions and despite high domestic demand for goods and services, a trend which is projected to continue into 2023.[72] China holds some influence over Singapore's economic development, with China's border openings expected to bolster external demand for Singapore's tourism services and trade in the second half of 2023. Yet, Singapore's unemployment rate remains low at 2.1%,[73] which is also lower than the average unemployment rate in China of 2.9%.

Social Welfare & Livelihood

In the Economist Intelligence Unit's 2022 Worldwide Cost of Living Survey, Singapore (tied with New York) was ranked the most expensive city in the world. This coincides with current high inflationary pressures in Singapore due to both global and domestic factors.[74] In terms of living environment, with a total land area of 733.2 square kilometers and a population of 5.6 million people, Singapore has one of the highest average population densities of the world at 7,688 people per square kilometer.[75] Despite this high density, Singapore maintains a high green coverage of nearly 50%, earning itself the

[67] Government of Singapore. (2023, November 6). *About Singapore.* Ministry of Foreign Affairs Singapore. http://www.mfa.gov.sg/Overseas-Mission/Ministry-of-Foreign-Affairs---Permanent-Mission-of-the-Republic-of-Singapore/About-Singapore.

[68] Lim, T. S. (2017, April 4). *Land From Sand: Singapore's Reclamation Story*. National Library, Singapore. https://biblioasia.nlb.gov.sg/vol-13/issue-1/apr-jun-2017/land-from-sand.

[69] WorldData.info. (n.d.). *Singapore: Country Data and Statistics.* https://www.worlddata.info/asia/singapore/index.php.

[70] Government of Singapore. (2023, August 18). *Economy & Prices*. Department of Statistics Singapore. http://www.singstat.gov.sg/publications/reference/singapore-in-figures/economy.

[71] The Economist Group. (2023, June 6). *Singapore Briefing Sheet*. Economist Intelligence. https://country.eiu.com/article.aspx?articleid=1243310107&Country=Singapore&topic=Summary&subtopic=Briefing+sheet.

[72] Tian, S. & Villaruel, M. L. (2023). Singapore. In *Asian Development Outlook April 2023*. Asian Development Bank, Manila. https://www.adb.org/sites/default/files/publication/863591/sin-ado-april-2023.pdf.

[73] Economist Intelligence Unit. (2023, June 6). *Singapore Briefing Sheet.* https://country.eiu.com/article.aspx?articleid=1243310107&Country=Singapore&topic=Summary&subtopic=Briefing+sheet.

[74] Government of Singapore. (2022, December 7). *Singapore: Is It Really the Most Expensive Place to Live?* https://www.gov.sg/article/singapore-is-it-really-the-most-expensive-place-to-live.

[75] World Population Review. (n.d.). *Countries by Population Density | Countries by Density 2023*. https://worldpopulationreview.com/country-rankings/countries-by-density.

moniker of "Garden City".[76] Singapore enjoys good air quality, with 99.5% of all days in 2021 showing 'good' and 'moderate' air quality according to the standards set by the Pollutant Standards Index (PSI).[77] 63.1% of Singaporeans aged 25 years and above have post-secondary qualifications and at least 12.1 years of schooling, making it a highly educated society,[78] and the average student-teacher ratio in Singaporean secondary schools is 12.1,[79] higher than China's average of 14.1. Singapore also has world class road and public transport infrastructure, with an average of 4900 meters of roadways per square kilometer of land compared to Asia's average of 520 meters.[80]

Environmental Resources

Green spaces within Singapore are managed by National Parks Board (NParks), a statutory board under the Singapore government. In 2021, Singapore released a Green Plan for 2030, which set concrete targets under 5 key pillars – City in Nature, Sustainable Living, Energy Reset, Green Economy and Resilient Future – to help manage Singapore's resources and ensure development takes place sustainably.[81] As of 2021, Singapore contained 143 hectares of skyrise greenery, 370 km of park connectors, 170 km of nature ways – all within less than 740 square kilometers of landmass, and at least 93% of Singaporean households live within a 10-minute walk to a park.[82]

Under the Singapore Green Plan, Singapore hopes to achieve a park provision ratio of 0.8ha/1000 population, create at least 200 hectares of skyrise greenery, 500 km of park connectors, and ensure that 100% of households live within a 10-minute distance from a park by 2030. To support this, in 2021, NParks also launched an Ecological Profiling Exercise to study Singapore's green spaces, identify and preserve important areas for ecological connectivity. In 2020, NParks launched new biodiversity impact assessment (BIA) guidelines, which protects Singapore's green spaces and ecological areas by mandating the conduct of a BIA at any planned development site which intersects with a green space, and by setting stronger guidelines on how impact to flora and fauna due to construction is quantified.[83] This came at the tail of a nationwide controversy in 2020, when public outrage mounted online over the erroneous clearance of 4.5 hectares of forested woodlands without prior approval.[84] Despite Singapore's strong track record in managing its environmental resources, the country currently does not have any laws in place mandating the conduct of Environmental Impact Assessments (EIAs) prior to development projects, lagging behind China in this regard.[85]

Consumption & Emissions

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[76] Ministry of Foreign Affairs. (2018). *Towards a Sustainable and Resilient Singapore.* https://sustainabledevelopment.un.org/content/documents/19439Singapores_Voluntary_National_Review_Report_v2.pdf.

[77] Government of Singapore. (2023, August 18). *Society*. Department of Statistics Singapore. http://www.singstat.gov.sg/publications/reference/singapore-in-figures/society.

[78] *ibid*.

[79] Statista. (2022, November). *Singapore: Student-Teacher Ratio in Secondary Schools 2021.* https://www.statista.com/statistics/970330/student-teacher-ratio-secondary-schools-singapore/.

[80] WorldData.info. (n.d.). *Transport and Infrastructure in Singapore*. https://www.worlddata.info/asia/singapore/transport.php.

[81] Tan, A. (2020, October 25). *New Biodiversity Impact Assessment Guidelines Introduced as Part of EIA Review*. The Straits Times. https://www.straitstimes.com/singapore/environment/new-biodiversity-impact-assessment-guidelines-introduced-as-part-of-eia-review.

[82] National Parks Board. (n.d.). *Sustainability Report.* https://www.nparks.gov.sg/portals/annualreport/sustainability-report/index.htm.

[83] Tan, A. (2020, October 25). *ibid.*

[84] Zheng, Z. (2021, February 24). *All You Need to Know about Erroneous Clearance of Kranji Woodland*. Mothership. https://mothership.sg/2021/02/kranji-woodland/.

[85] Wu, Q., Zhou, Y., Yue, Q., Lai, J., Pang, Z., Zhang, F., & King & Wood Mallesons. (2021, August 1). *Environmental Law and Practice in China: Overview.* Thomson Reuters Practical Law. https://content.next.westlaw.com/practical-law/document/I020626f01cb611e38578f7ccc38dcbee/Environmental-Law-and-Practice-in-China-Overview?viewType=FullText&transitionType=Default&contextData=(sc.Default).

Data from the International Energy Agency (IEA) in 2018 showed that Singapore ranks 126 out of 142 countries in terms of carbon dioxide emissions per dollar GDP, indicating low carbon intensity. In comparison, China was ranked 17th on the same list.[86] Singapore however ranks much higher in terms of emissions per capita at 27th place among 142 countries with over 8 tons of carbon dioxide emitted per capita (China holds the 39th position with over 6 tons of carbon dioxide per capita). The industry and power sectors make up over 85% of Singapore's primary carbon emissions, due to the heavy reliance of Singapore's economy on its refining and petrochemical sector.[87] Under Singapore's Green Plan 2030, Singapore also supports internationally set targets of reaching net zero and 50% reduction in carbon emissions in the aviation and maritime sectors respectively by 2050 through the adoption of clean energy (electric and bio-fuel based) forklifts, tractors, airside vehicles and harbor craft in Singapore's maritime and aviation ports.[88]

Under Singapore's Green Plan, Singapore also aims to achieve 2 gigawatt-peak of solar energy deployment by 2030 to help further reduce Singapore's reliance on natural gas, which currently accounts for 95% of Singapore's electricity needs. To combat space constraints, solar panels are deployed on rooftops and in reservoirs – Singapore has one of the world's largest floating solar farms (60 megawatt-peak) in its Tengah reservoir, and more floating solar farms are in the works for future deployment.[89] In December 2022, Singapore also successfully deployed 200 megawatt-hour of Energy Storage Systems on an offshore island to improve resilience of the electricity grid and support renewables adoption.

Singapore also has set targets in place for reducing the energy consumption of desalination and other industrial processes through improvements in energy efficiency, especially within Singapore's housing districts and waste treatment facilities. Singapore's Building and Construction Authority (BCA) has also created a Singapore Green Building Masterplan in 2021, which aims to green 80% of the city's buildings by 2030 through mandating minimum environmental sustainability standards for buildings, co-funding energy efficiency retrofits, and incentivizing high energy performance of buildings using BCA's Green Mark 2021 certification.[90] Singapore is also accelerating the deployment of electric vehicles (EVs) by building more charging points – 60,000 by 2023, bringing the EV per charging point ratio to four to one – and by reducing the cost of EV purchase through tax reductions via changes in Certificate of Entitlement (COE) regulations on car ownership.[91]

Environmental Management

Despite Singapore's world class waste collection and disposal system, Singapore's existing 350-hectare landfill is projected to run out of space for waste disposal by 2035. Under Singapore's Sustainable Blueprint (2015), Singapore has set targets to increase the recycling rate to 70% (further broken down to a 30% target for domestic recycling rate and 81% for non-domestic) to reduce the amount of waste sent to landfill per day by 30% by 2030.[92] In 2020, Singapore also instituted the Resource Sustainability Act to regulate e-waste and packaging waste through the implementation of Extended Producer

[86] National Climate Change Secretariat Singapore. (n.d.). *Singapore's Emissions Profile*. https://www.nccs.gov.sg/singapores-climate-action/Singapores-Climate-Targets/singapore-emissions-profile/.
[87] *ibid.*
[88] Singapore Green Plan 2030. (2023, September 22). *Our Targets*. https://www.greenplan.gov.sg/targets.
[89] Chen, L. (2021, July 14). *Singapore Unveils One of the World's Biggest Floating Solar Panel Farms*. Reuters. https://www.reuters.com/business/energy/singapore-unveils-one-worlds-biggest-floating-solar-panel-farms-2021-07-14/.
[90] Building and Construction Authority. (2023, April 27). *Green Building Masterplans*. https://www1.bca.gov.sg/buildsg/sustainability/green-building-masterplans.
[91] Park, K. (2022, May 2). *A Change to Car-Ownership Rights Could Spur EVs in Singapore*. Bloomberg. https://www.bloomberg.com/news/newsletters/2022-05-02/electric-car-ownership-rights-change-in-singapore-in-may-l2on42lo
[92] Ministry of the Environment and Water Resources. (n.d.). *Zero Waste Masterplan Singapore*. https://www.mse.gov.sg/resources/zero-waste-masterplan.pdf.

Responsibility.[93] Under this framework, companies are required to submit packaging data and plans to the National Environmental Agency to incentivize reductions in packaging waste. From 2024, the Ministry of Environmental and Water Resources will also mandate the segregation of food waste on a commercial and industrial level.

Cape Town, South Africa

Indicator	Cape Town	Hangzhou	Chinese Avg.
Population (million)	4.76	12.20	7.00
GDP (billion USD)	29.78	280.63	105.84
GDP Growth Rate (%)	0.6	8.49	7.90
Service Sector Added Value (%)	80.00	67.85	52.20
Unemployment Rate (%)	27.00	2.34	2.85
Road Area (m^2 per capita)	-	11.48	14.82
House-Income Ratio (price per m^2 / GDP per capita)	-	0.19	0.16
Teacher-Student Ratio	1:30.8	1:13.9	1:14.3
Population: Age 0-14 (%)	23.70	13.32	17.55
Urban Green Space (m^2 per capita)	178.65	46.42	43.68
Air Quality (PM2.5 annual mean, ug/m^3)	14.17	28.00	31.00
Water Consumption (tons/10,000 USD)	81.77	106.02	318.00
Energy Consumption (tce/10,000 USD)	0.66	1.90	3.61
Domestic Sewage Treatment Rate (%)	-	97.13	96.98
Household Waste Harmless Treatment Rate (%)	-	100.00	99.92

Notes. Data source: Publicly available data sources, see reference for detail. Data year: 2021.

Cape Town is South Africa's legislative capital (the country's executive capital is Pretoria, judicial capital being Bloemfontein). It is the second largest city of South Africa, after Johannesburg. The city contributed about 10% of South Africa's GDP and accounted for 11.1% of the country's employment in 2019. The city's economy depends heavily on the service sector which accounted for 80% of the Gross Value-added in 2019, with finance, retail and real estate the leading contributors.[94]

In 2017, Cape Town hosted the first United Nations World Data Forum which led to the launch of the Cape Town Global Action Plan for Sustainable Development Data. The Action Plan provides a framework for planning and building the statistical capacity needed to achieve the 2030 Agenda and to mobilize funding for the modernization of national statistical systems across the world.[95] The city's sustainability agenda is guided by its Carbon Neutral 2050 Commitment, which identifies the major sources of carbon emissions of the city and lays out the solutions to be implemented.[96]

Economic Development

Before the COVID-19 pandemic, Cape Town's GDP growth had mostly been above South Africa's national growth rate in the past decade, except for a brief fall down in 2017/2018 due to the severe drought that hit the Western Cape region. However, despite exhibiting above national growth rate, the trend of Cape Town's growth has been following the national growth closely on a downward trajectory - from a 4% real growth rate in 2011 to below 1% in 2019. The pandemic and the subsequent lockdown delivered a heavy blow to the South African economy, dragging growth down to a negative 6.4%

[93] Ministry of Sustainability and the Environment. (2020, July 30). *The Resource Sustainability Act.* https://www.mse.gov.sg/resource-room/category/2020-07-30-resource-sustainability-act/.

[94] City of Cape Town. (2021a). *State of Cape Town Report 2020*. State o Cape Twn Report (capetown.gov.za).

[95] United Nations. (n.d.). *Cape Town Global Action Plan for Sustainable Development Data*. Sustainable Development Goals. Cape Town Global Action Plan for Sustainable Development Data — SDG Indicators (un.org).

[96] City of Cape Town. (2020). *The City of Cape Town's Carbon Neutral 2050 Commitment.* Carbon_Neutral_2050_Commitment.pdf (capetown.gov.za).

in 2020. The lockdown and restriction to movement posed significant challenges to business owners of and people employed in the retail and trade industry, particularly the semi-skilled and unskilled workers who comprise a large share of the growing informal sector of Cape Town's economy (the informal sector accounted for 12.4% of employment in 2019) and tend to lower income.[97]

Furthermore, there is a clear disparity between the economic sectors that drive GDP growth and those that drive employment growth in Cape Town. Specifically, finance and real estate, the leading GDP contributors in the service sector, are not among the top 10 industries by employment. A major reason for this disparity is the widening gap between the skills demanded by industries and those currently possessed by the labor force. Industries like ICT and business services are among the fastest growing in Cape Town's economy. The skills required by the relevant occupations are almost exclusively on the higher end of the skills spectrum. According to the *State of Cape Town Report, 2020*, the top skills demanded by Cape Town's growing industries - such as Perl/Python/Ruby, Java Development, Mac, Linux, and Unix Systems, Microsoft Application Development - are mostly related to ICT. This mismatch between the demand and supply of skills manifested as the approximately 22% unemployment rate (in 2019), which stands out to be the highest among all our comparison cities. However, compared to other South African metropolises, Cape Town has consistently had the lowest unemployment rate. The city's latest Inclusive Economic Growth Strategy plans to address this skills gap through partnering with industries to provide a range of learner and training programs, opportunities for internships and skills development, and tools for job seeking.[98]

Social Welfare & Livelihood

Since 1990, Africa has embarked on a track of rapid urbanization, chiefly driven by population growth and the reclassification of rural settlements. Africa's population is projected to double between now and 2050, surpassing South Asia as the world's most populous developing region.[99] Two-thirds of this population increase will be absorbed by urban areas.[100] In Cape Town, the city's population has steadily increased at an annual rate of around 2% over the past five years.[101]

The COVID-19 pandemic reminded the world of the public health challenges that arrive along with urbanization. Cape Town's Health Department collaborated with other agencies during the pandemic to allocate additional support to health response, operate screening and testing, augment cleansing and sanitation services, while continuing to provide routine primary healthcare services at all primary care clinics. Other than the COVID-19 pandemic, HIV/Aids has been another major public health concern for South African cities. Cape Town's main efforts in coping with HIV/Aids include preventing mother-to-child transmission and improving access to antiretroviral treatment (ART) which is critical for maintaining a healthy quality of life for HIV-positive people. Between 2015 and 2019, Cape Town had increased 32.6% access to ARTs.[102]

Urban safety, especially organized crime and gang violence, is another key issue and obstacle for Cape Town residents' quality of life and economic development. The city has the highest rate of contact crime, robbery, and murder rate in South Africa, with an overall crime rate almost double the rest of the country. To more effectively address the public safety

[97] City of Cape Town. (2021a). *ibid.*

[98] City of Cape Town. (2021a). *ibid.*

[99] Thurlow, J., Dorosh, P., & Davis, B. (2019). Demographic Change, Agriculture, and Rural Poverty. In Campanhola, C., & Pandey, S. (Eds.) *Sustainable Food and Agriculture.* The Food and Agriculture Organization of the United Nations (FAO), Rome, Italy. DOI: https://doi.org/10.1016/B978-0-12-812134-4.00003-0.

[100] Kanos, D., & Heitzig, C. (2020, July 16). *Figures of the week: Africa's urbanization dynamics*. Brookings. Figures of the week: Africa's urbanization dynamics | Brookings.

[101] City of Cape Town. (2021a). *ibid.*

[102] *ibid.*

concern, the municipal (Cape Town) and provincial (Western Cape) governments are working together to launch the Law Enforcement Advancement Plan to provide better training, equipment, and personnel deployment.

In terms of urban transportation, Cape Town's integrated transport infrastructure network includes 1,014 km of rail, 32 km of dedicated bus lanes for the BRT system, 450 km of cycling lanes and 109 pedestrian bridges. Despite the over 90% accessibility of these infrastructures, transport using private vehicles is still prevalent among citizens, leading to significant traffic congestion. The city's countermeasure to this issue is the revised Municipal Spatial Development Framework (MSDF) which prioritizes the optimization of transport infrastructure at the urban inner core, seeking to induce an inward growth by bringing people closer to jobs, and jobs closer to people.[103] Furthermore, the COVID-19 pandemic spurred the prevalence of working from home among citizens, even after the pandemic. The persistence of remote working will likely help reduce the demand for urban transportation and traffic congestion.

Another major aspect of urban planning regarding Social Welfare and Livelihood is affordable housing. As the city is aiming toward an inward growth with better integration of and connection between residents and jobs, it also pays attention to the inclusion of the urban poor. The city recognises that state-subsidized affordable housing units are mostly located on the urban edge, which reproduces spatial segregation of the poor. A more compact and inclusive city requires affordable social housing available at locations with easy and inexpensive access to job opportunities within urban centers. The Joe Slovo Park in Milnerton area has already been in the midst of this inclusive transition, although mostly through private initiatives with landlords developing affordable backyard dwellings for low-income residents to take advantage of the area's proximity to job opportunities and transportation.[104] Formal public initiatives such as the Human Settlements Strategy is being implemented by the city to facilitate densification of existing areas through changes in zoning regulations. The goal of this initiative is to create better-integrated human settlements, accommodating a range of income groups and household types, while also creating affordable and inclusionary housing on well-located land close to public transport and job opportunities.[105]

Environmental Resources

In Cape Town, poor air quality results from various social, economic and environmental factors, including unpaved roads and pavements (contributing to high concentrations of particulate matter), burning of wood or paraffin for heating and cooling, veld fires, and motor vehicles. More severe air pollution is often observed in low-income areas occupied by historically disadvantaged communities, who show a higher prevalence of respiratory illness. Without the active air purification systems like those installed in Eindhoven, the improvement of Cape Town's air quality will be achieved as co-benefits from the city's efforts on emission reduction and enhancing urban biodiversity.

The Biodiversity Network (BioNet) is a fine-scale systematic biodiversity plan for Cape Town. It designates approximately 85,000 ha of land (34.18% of the municipality) as critical biodiversity areas to be conserved. By 2020, more than 55,000 ha, or 65% of these areas had been conserved. In addition to the BioNet, the city's green space includes the coastline, public parks, and greenbelts, with a total of more than 1,349 ha of natural public green space.

Consumption & Emissions

In 2017, Cape Town's per capita carbon emission was 5 tCO_2e. Over half of the city's carbon emissions came from electricity use, mainly due to South Africa's coal-based grid electricity. From energy consumption's perspective, transportation took

[103] *ibid.*

[104] *ibid.*

[105] City of Cape Town. (2021b). Human Settlements. *Directorate Executive Summary of the Service Delivery and Budget Implementation Plan 2020/2021.* https://resource.capetown.gov.za/documentcentre/Documents/City%20strategies,%20plans%20and%20frameworks/6_Directorate_Executive_Summary_20202021_HumanSettlements.pdf.

the largest share (62%) in the city's total energy consumption, with private vehicles accounting for 61% of the transport energy consumption. The city's latest Carbon Neutral 2050 Commitment identifies key strategies for reducing energy consumption and the associated carbon emissions from three main areas: buildings, energy, and transport. The main strategies for the buildings sector include the optimization of energy efficiency, switching to clean energy sources, use and reuse of low-carbon building materials, and striving for carbon neutrality for all buildings.[106] In 2018, Cape Town, along with Durban, Johannesburg, and Tshwane, launched the Net Zero Carbon Buildings Accelerator aiming at achieving net zero carbon new buildings by 2030 and all buildings by 2050.[107] For the energy sector, the focus is on supporting the uptake of renewable energy and to ensure the affordability and security of energy. At the same time, the city has begun wide adoption of smart meters for municipal facilities, with approximately 847 smart meters installed in 557 facilities. Lastly, for urban transportation, the Carbon Neutral Commitment 2050 calls for improved spatial planning to reduce the frequency and distance of trips, aided by a more efficient and integrated public transport system. Additionally, the city plans on encouraging more active-mobility and non-motorized transport, while achieving all vehicles powered by clean fuel sources by 2050.[108]

In terms of water consumption, Cape Town has been vulnerable to periodic droughts. The most recent drought lasted from 2015 to 2018 and was considered a one-in-400-years event in terms of severity, bringing the city to the brink of running out of water.[109] The city survived this severe drought through the joint efforts of its citizens and administrators. Daily water saving efforts were guided by public communications which prescribed daily per capita water consumption targets based on accurately measured dam levels. Citizens were encouraged to reduce shower times, as well as toilet flushes, and refrain from using drinking water for gardening. The city also communicated a moving forecast of whether "day zero" was being pushed out as a result of successful water saving measures. Meanwhile, the government's effort mainly focused on improving water distribution efficiency and reducing water loss through pressure management in urban water distribution networks.[110] Moving forward, the city is continuing to address water security through improving water distribution and consumption efficiency by upgrading infrastructure to minimize water losses and utilizing smart meters to inform efficient use of water. At the same time, the city is developing alternative water sources, such as reusing treated effluent from wastewater, groundwater abstraction and desalination, to reduce its dependence on surface water (dams).

Environmental Management

In the aspect of Environmental Management, one of the key areas of focus for Cape Town is solid waste management. Like other major metropolitan cities, Cape Town is striving to reduce the city's reliance on landfills which are reaching their full capacity. One strain of these efforts falls on the development of waste-to-energy facilities at landfills. For instance, the extraction and flaring facilities at the Vissershok and Coastal Park landfills have electricity generation capacity of 7 MW and 2 MW respectively, from biogas produced by the landfills. Another strain of initiatives centers on separating organic waste from the waste stream. The city has distributed 22,000 free composting containers to residents to compost their organic food waste at home. Additionally, the city conducted a six-month trial of the separate collection or drop-off of organic food waste in the two low-income communities of Langa and Wolwerivier, which saw a total of 20.5 tons of organic food waste diverted from landfill between October 2019 and March 2020. In the long run, the city aims at achieving a circular economy that generates local jobs and keeps materials at their highest value for as long as possible.

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[106] City of Cape Town. (2020). *ibid.*

[107] C40 Cities. (2023). *C40 Cities South Africa Buildings Programme*. https://www.c40.org/what-we-do/scaling-up-climate-action/energy-and-buildings/c40-cities-south-africa-buildings-programme/.

[108] City of Cape Town. (2020). *ibid.*

[109] Hill-Lewis, G. (2023, March 22). *Cape Town: Lessons from managing water scarcity.* Brookings. https://www.brookings.edu/articles/cape-town-lessons-from-managing-water-scarcity/.

[110] *ibid.*

Dubai, United Arab Emirates

Indicator	Dubai	Hangzhou	Chinese Avg.
Population (million)	3.48	12.20	7.00
GDP (billion USD)	108.19	280.63	105.84
GDP Growth Rate (%)	5.70	8.49	7.90
Service Sector Added Value (%)	51.60	67.85	52.20
Unemployment Rate (%)	3.10	2.34	2.85
Road Area (m^2 per capita)	-	11.48	14.82
House-Income Ratio (price per m^2 / GDP per capita)	-	0.19	0.16
Teacher-Student Ratio	-	1:13.9	1:14.3
Population: Age 0-14 (%)	14.85	13.32	17.55
Urban Green Space (m^2 per capita)	12.78	46.42	43.68
Air Quality (PM2.5 annual mean, ug/m^3)	44.00	28.00	31.00
Water Consumption (tons/10,000 USD)	370.11	106.02	318.00
Energy Consumption (tce/10,000 USD)	0.55	1.90	3.61
Domestic Sewage Treatment Rate (%)	-	97.13	96.98
Household Waste Harmless Treatment Rate (%)	-	100.00	99.92

Notes. Data source: Publicly available data sources, see reference for detail. Data year: 2021.

The city of Dubai is the capital of the Emirate of Dubai, United Arab Emirates, and the most populous city in the UAE. Its economy size and structure are comparable to the average of Chinese cities, but its GDP per capita is significantly higher than that of Chinese cities.

Dubai's sustainability agenda is shaped by both the national-level Green Agenda - 2030 and the local Dubai Plan 2021. The UAE's Green Agenda - 2030 is a long-term plan to achieve the goals of sustainable development in the UAE and make its economy more environment-friendly, with particular focus on building a competitive knowledge economy and green economy, social development and quality of life, sustainable environment and valued natural resources, clean energy and climate action, and green life and sustainable use of resources.[111] Dubai Plan 2021 is the city's development plan beyond 2021, which focuses on six themes: The people (city of happy, creative and empowered people), The society (an inclusive and cohesive society), The experience (the preferred place to live, work and visit), The place (a smart and sustainable city), The economy (a pivotal hub in the global economy), and The government (a pioneering and excellent government).[112]

Economic Development

In terms of economic development, the Dubai government has always been committed to establishing the city as a leading global trade, logistics, tourism and financial center, as well as the "Capital of Islamic Economy". In recent years, Dubai's economic development has focused on forming an innovation- and productivity-oriented, diversified economic growth model, and continuously improving the overall business environment to attract more foreign investment. Under the UAE Green Agenda 2030, the National Green Innovation Program and the Green Diversification Program are specifically designed to build the foundation for a knowledge-based green economy. The National Green Innovation Program focuses on supporting higher education and training for green fields and specialities, while the Green Diversification Program anchors on financial support for green manufacturing and green industries.[113]

Social Welfare & Livelihood

[111] UAE Government. (2023, September 12). *The UAE's Green Agenda - 2030*. The UAE's Green Agenda - 2030 | The Official Portal of the UAE Government.

[112] UAE Government. (2022, November 24). *Dubai Plan 2021*. Dubai Plan 2021 | The Official Portal of the UAE Government.

[113] UAE Government. (2023, September 12). *ibid.*

Three of the six themes of the Dubai Plan 2021 are related to social welfare and livelihood of citizens. In this area, the core of the Dubai government's work is to provide good education, health care, housing and security to residents; to ensure that citizens have ample opportunities for personal development; and to provide residents with a wealth of cultural and recreational facilities.[114]

For education specifically, the UAE Green Agenda 2030 calls for the integration of green economy and sustainable development in school curriculum, and the introduction of new vocational training courses at the national and local levels. The Agenda also plans to provide a more comprehensive classification of green jobs under the existing job categorization, and offer incentives for new graduates to take green jobs.

Environmental Resources

In 2021, there were more than 8 million square meters of lawns, more than 5 million trees (including shrubs), and 930 kilometers of green belts in downtown Dubai, giving the land-scarce city of Dubai nearly 13 square meters of green space per capita. However, air pollution in Dubai is worse than in Chinese cities.

The Natural Capital & Resilience Program, under the Green Agenda 2030, encompasses a group of initiatives on improving the monitoring and regulatory oversight of groundwater, terrestrial and marine habitats, sewage discharge, and air quality. The Environmental Goods & Services Program focuses more on sustainable consumption, and plans to develop national eco-labels for products and services, promote environmental goods and services exports and capacity development, implement green public procurement policy.

Consumption & Emissions

According to our indicators, Dubai's "water consumption per unit of GDP" is higher than that of Chinese cities, but its energy intensity is better than that of all 110 Chinese cities in our sample. Energy efficiency and energy transition are at the heart of the UAE's sustainability strategy. Its long-term goals for 2050 are to improve energy efficiency by 40%, reach 50% clean energy, and reduce carbon emissions by 70%. Correspondingly, Dubai's medium- and long-term energy and water targets include 25% renewable energy in energy mix, 30% energy savings, 30% water savings by 2030, and 75% clean energy in energy mix by 2050.[115]

When it comes to energy saving, Dubai's main approach is to introduce stricter management of energy consumption in buildings. In line with the Dubai government's strategic plan, the Dubai Municipality introduced the Green Building Regulations and Specifications (GBR&S) in 2011 as a mandatory requirement for new buildings in the city. In 2020, GBR&S was replaced by the Al Sa'fat – Dubai Green Building System which includes a set of mandatory requirements for all new buildings to obtain the Silver Sa'fa. Buildings with higher performances may acquire the Golden or Platinum Sa'fa.[116] In addition to the buildings, other initiatives intended to reduce energy consumption include optimizing the design of power stations, upgrading gas turbines in water desalination units, and reducing transmission loss in the grid.

Environmental Management

Dubai's most notable project in recent years in terms of environmental management, especially solid waste, is the completion and operation of the Dubai Waste Management Centre (DWMC). DWMC is currently the largest waste-to-energy plant in the world, consisting of five production lines. At the beginning of 2023, two production lines began operation, processing 2,000 tons of solid waste and generating 80 MWh of electricity each day. By 2024, with all five

[114] The Executive Council of Dubai. (n.d.). *Dubai Plan 2021.* Government of Dubai. www.dubaiplan2021.ae :: Dubai Plan 2021.
[115] Emirates Green Building Council. (n.d.). *UAE Sustainability Initiatives*. UAE Sustainability Initiatives | EmiratesGBC.
[116] Dubai Municipality. (2023, January 23). *Al Sa'fat – Dubai Green Building System*. Al Sa'fat – Dubai Green Building System (dm.gov.ae).

production lines in operation, DWMC will reach the full capacity of absorbing 5,666 tons of solid waste per day and generating 200 MWh of electricity.[117]

Cairo, Egypt

Indicator	Cairo	Hangzhou	Chinese Avg.
Population (million)	21.32	12.20	7.00
GDP (billion USD)	82.88	280.63	105.84
GDP Growth Rate (%)	3.29	8.49	7.90
Service Sector Added Value (%)	52.50	67.85	52.20
Unemployment Rate (%)	7.40	2.34	2.85
Road Area (m^2 per capita)	4.29	11.48	14.82
House-Income Ratio (price per m^2 / GDP per capita)	-	0.19	0.16
Teacher-Student Ratio	1:22.7	1:13.9	1:14.3
Population: Age 0-14 (%)	33.05	13.32	17.55
Urban Green Space (m^2 per capita)	3.00	46.42	43.68
Air Quality (PM2.5 annual mean, ug/m^3)	46.50	28.00	31.00
Water Consumption (tons/10,000 USD)	176.25	106.02	318.00
Energy Consumption (tce/10,000 USD)	3.23	1.90	3.61
Domestic Sewage Treatment Rate (%)	65.00	97.13	96.98
Household Waste Harmless Treatment Rate (%)	-	100.00	99.92

Notes. Data source: Publicly available data sources, see reference for detail. Data year: 2021.

Located in the northeastern corner of Africa, Egypt is renowned for its rich historical and cultural heritage, with world-famous ancient monuments such as the Pyramids of Giza, the Sphinx, and the temples of Luxor. Egypt's long-spanning, thousand-year history has led it to be referred to as the "cradle of civilization",[118] with Cairo, Egypt's capital, being one of the ancient centers of the Islamic world.[119] Modern day Egypt, however, faces several threats from climate change – the country is projected to experience critical water shortage by the year 2050, exacerbated by transboundary water disputes such as over Ethiopia's creation of the Grand Ethiopian Renaissance Dam (GERD) on the Nile, which will have cascading impacts on Egypt's water supply downstream.[120] In addition, Egypt's natural resources, such as arable land, biodiversity and fossil fuels, are threatened by Egypt's rapidly rising population and urban expansion – Cairo, for example, is reportedly the world's fastest growing city.[121]

In 2016, the Egyptian government launched their Sustainable Development Strategy: Egypt Vision 2030, which sets out Egypt's goals for inclusive economic, social, and environmental development in alignment with the United Nation's Sustainable Development Goals (UN SDGs).[122] Said to be inspired by the ancient Egyptian Civilization, Egypt Vision 2030 sets out goals, targets, and indicators for developing Egypt's renewable energy sector, improving energy efficiency and managing Egypt's environmental resources, including a target to reduce greenhouse gas emissions from the energy sector

[117] Dubai Municipality. (n.d.). *Dubai Waste Management Centre to start initial operations in 2023*. Dubai Waste Management Centre to start initial operations in 2023 (dm.gov.ae).

[118] African Development Bank. (2023). *Egypt Economic Outlook.* African Development Bank Group. https://www.afdb.org/en/countries/north-africa/egypt/egypt-economic-outlook

[119] UNESCO World Heritage Centre. (2023). *Historic Cairo.* UNESCO World Heritage Centre. https://whc.unesco.org/en/list/89/

[120] Kwasi, S. (2022). *Race to sustainability? Egypt's challenges and opportunities to 2050*.

[121] Barthel, P.-A., & Monqid, S. (2011). Introduction. Cairo and sustainability: A provocative issue? (I. Debacq, Trans.). *Égypte/Monde Arabe, 8*, Article 8. https://doi.org/10.4000/ema.2970

[122] *Egypt Vision 2030.* (n.d.). Retrieved October 17, 2023, from http://www.cairo.gov.eg/en/GovernorsCVs/sds_egypt_vision_2030.pdf.

by 10% in 2030 from 2016 levels.[123] In tandem with their sustainable development plans, the Egyptian government has also invested in building "fourth generation cities", which were designed to be powered by renewable energy, incorporate green spaces, and integrate environmental management with technology for a more sustainable living environment.[124] Finally, as the host nation of COP27 in November of 2022, Egypt has secured nearly $10 billion in funding for its climate initiatives, highlighting the country's commitment towards investing in a more sustainable future.[125] However, Egypt's sustainability plans are not without controversy – with halting progress on Egypt's set sustainability targets, the Egyptian government has been accused of greenwashing, specifically with regards to their marketing of Egypt's environmental efforts during COP27 within a political climate where local environmental groups are frequently harassed and criminalized for their work.[126]

In this case study, we look specifically at the sustainable development policies implemented in Cairo, Egypt's capital city, and Egypt's new fourth generation cities to understand Egypt's current progress in sustainable development.

Economic Development

With a Gross Domestic Product (GDP) of US$398.4 billion in 2023, Egypt is the third largest economy in Africa.[127] Characterized by the World Bank as a lower-middle income country, the events of the Arab Spring in 2010 led to years of social and economic turbulence in Egypt, with Egypt maintaining relatively stable economic growth in recent years despite shocks caused by COVID-19 and the ongoing Ukraine War.[128] In 2021, Egypt's real GDP growth increased at a rate of 6.6%, largely driven by its construction and gas derivatives sector,[129] with more than 15% of the Egyptian economy tied directly to activities in construction.[130] This construction boom coincides with Egypt's Cities of the Future program, where Egypt is endeavoring to establish 15 new, sustainable cities that will integrate modern infrastructure, renewable energy and public transportation systems to create a more livable environment. According to Egypt's Ministry of International Cooperation, Egypt is undertaking 35 projects that will meet the UN SDG 9 of Industry, Innovation and Infrastructure at an investment of $5.9 billion.[131]

Furthermore, given that Egypt's economic outlook remains unclear due to rising inflation and the depreciation of the Egyptian pound against international currencies, and that GDP growth in Egypt is projected to slow to 4.4% over the 2022-2023 period, private sector investment in Egypt's new, green cities may be key to improving Egypt's economic health.[132] For example, the $40 billion project to create the New Administration Capital (NAC), which lies 45 kilometers east of Cairo

[123] IEA. (2022, February 15). *Sustainable Development Strategy: Egypt Vision 2030 – Policies.* IEA. https://www.iea.org/policies/14823-sustainable-development-strategy-egypt-vision-2030.
[124] Egypt's Ministry of International Cooperation. (2023). *Egypt's New Cities: A Blueprint for Sustainability in the Middle East.* Bloomberg. https://sponsored.bloomberg.com/article/ministry-of-international-cooperation/egypts-new-cities.
[125] Lewis, A. (2023, July 20). *Egypt growth forecast cut, currency expected to slip further | Reuters*. Reuters. https://www.reuters.com/world/africa/egypt-growth-forecast-cut-currency-seen-slipping-further-2023-07-20/.
[126] Human Rights Watch. (2022, September 12). *Egypt: Government Undermining Environmental Groups | Human Rights Watch.* https://www.hrw.org/news/2022/09/12/egypt-government-undermining-environmental-groups
[127] International Monetary Fund. (2022). *Arab Republic of Egypt and the IMF*. IMF. https://www.imf.org/en/Countries/EGY
[128] Lewis, A. (2023, July 20). *ibid.*
[129] African Development Bank. (2023). *Egypt Economic Outlook.* African Development Bank Group. https://www.afdb.org/en/countries/north-africa/egypt/egypt-economic-outlook
[130] Egypt's Ministry of International Cooperation. (2023). *ibid.*
[131] *ibid.*
[132] African Development Bank. (2023). *ibid.*

and will be home to government ministries and foreign embassies, is anticipated to create 2 million new jobs.[133] Thus far, Egypt's unemployment rate has remained at a stable rate of 7.2%.[134]

Social Welfare & Livelihood

Egypt's population surpassed 100 million in 2019, with the majority of the population living in the urban centers of Cairo and Alexandria and along the Nile. Cairo's population density is by far the highest in Egypt at 52,751 people per square kilometer with a population of over 10 million inhabiting an area of less than 200 square kilometers.[135] When taking into account the people living within the greater Cairo region, Cairo's population numbers increase to over 20 million. In comparison, Shenzhen, China's most densely populated city, has a population density of around 7000 people per square kilometer.[136] Furthermore, due to urban sprawl, the average amount of green space per capita in Cairo is low at 0.74m^2 per capita and shrinking every year, well below the World Health Organization's recommended standard of 8.26 m^2 per capita.[137] As such, the creation of new Egyptian cities such as the New Administrative Capital, which is being built to accommodate over 6 million people, promises to relieve Cairo's overcapacity by shifting embassies, government agencies and ministries, the parliament, and the presidential compound out of Cairo while also establishing new housing infrastructure.[138]

In the new cities, improved master planning promoting integrated use of space, such as by locating residences, shops, and services together, aims to reduce the need for private transportation and to promote the use of public transport.[139] Al Alamein New City (ANC), which is being developed on the northern coast of Egypt in collaboration with the United Nations Habitat Achieving Sustainable Urban Development program, includes prioritizing implementing a "world-class public transportation system" as part of the infrastructure and planning guidelines of the city.[140] In Cairo, the Cairo Transport Authority is working with EBRD Green Cities on a Green City Action Plan, which will dedicate €25 million to the rehabilitation and upgrade of Cairo's existing metro line.[141] Cairo is also developing two new monorail lines that will link the city with surrounding urban communities, including the New Administrative Capital City,[142] and also has a $200 million agreement with the World Bank to build an electric bus fleet.[143]

Environmental Resources

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[133] Egypt's Ministry of International Cooperation. (2023). *ibid.*

[134] African Development Bank. (2023). *ibid.*

[135] Galal, S. (2023, June 23). *Egypt: Population density by governorate.* Statista. https://www.statista.com/statistics/1230835/population-density-by-governorate-in-egypt/

[136] Yang, Y. (2023). *China's top 10 cities in population density*. https://www.chinadaily.com.cn/a/202210/09/WS6341fc40a310fd2b29e7b5e3.html

[137] Sherif, S. (2022). *Alternative Policy Solutions | Cairo's Green Sprawl: The Move of Urban Green Space towards Exclusivity.* https://aps.aucegypt.edu/en/articles/947/cairos-green-sprawl-the-move-of-urban-green-space-towards-exclusivity

[138] Menshawy, M. (2021, July 5). *Why is Egypt building a new capital?* Al Jazeera. https://www.aljazeera.com/opinions/2021/7/5/why-is-egypt-building-a-new-capital

[139] Attia, S. (2019). Al Alamein New City, a Sustainability Battle to Win. In S. Attia, Z. Shafik, & A. Ibrahim (Eds.), *New Cities and Community Extensions in Egypt and the Middle East: Visions and Challenges* (pp. 1–18). Springer International Publishing. https://doi.org/10.1007/978-3-319-77875-4_1

[140] *ibid.*

[141] EBRD Green Cities. (2023). *Cairo » EBRD Green Cities.* https://www.ebrdgreencities.com/our-cities/cities/cairo/

[142] Alstom. (2023). *The Monorail story for greater Cairo.* Alstom. https://www.alstom.com/monorail-story-greater-cairo

[143] The World Bank. (2023, September 19). *Development Projects: Greater Cairo Air Pollution Management and Climate Change Project - P172548 [Text/HTML].* World Bank. https://projects.worldbank.org/en/projects-operations/project-detail/P172548

Developing Egypt's public transportation systems will have a significant impact on improving air quality. Egypt's annual average PM2.5 levels in 2019 was almost 14 times higher than the World Health Organization's recommended average.[144] In Cairo specifically, the majority of pollutants are attributed to road transport (33%), followed by the agricultural sector, industrial emissions and waste management. Hence, the Greater Cairo Air Pollution Management and Climate Change Project for Egypt, supported by the World Bank, has pledged $200 million to combat air pollution and increase future resilience to pollutants by reducing emissions from key sectors and monitoring Cairo's existing pollutants.[145] New cities, like ANC, are also designed with air circulation and pollution reduction in mind, incorporating green corridors to absorb pollutants and reduce emissions, and positioning key roads to improve airflow.[146]

The abundance of green spaces can also play an important role in improving air quality. As a rapidly urbanizing city, Cairo faces a shortage of open green spaces. Hence as part of Egypt Vision 2030, increasing the amount of green space per capita within Egyptian cities, including Cairo, is one of the key goals of Egypt's urban development.[147] At the same time, the Ministry of Environment and the Egyptian Environmental Affairs Agency are also trying to incorporate more green spaces into Cairo's informal settlements, neighborhoods and schools – however, both at a national and city level, clear implementation plans have not been defined, hindering the process of achieving these goals.[148] In the new cities, more green areas, such as public parks and play areas in the neighborhood, are also designed to increase vegetation cover. In ANC specifically, green spaces are designed to represent about 13% of the entire area of the city, achieving a green space per capita of 15 m^2, which is higher than the minimum per capita average of 9 m^2.[149]

Consumption & Emissions

In 2021, Egypt's carbon dioxide emissions per capita was 2.3t, compared to China's 6t.[150] Egypt's carbon dioxide emissions per GDP was 0.2kg per PPP $ of GDP in 2020, which was comparable to the world average in the same year (0.2kg per PPP $ of GDP).[151] Based on Egypt's Sustainable Development Strategy, less than 5% of Egypt's current fuel mix comes from renewables – oil and gas makes up 41% and 53% of Egypt's fuel mix respectively, with coal, hydroelectric, and other renewables making up 2%, 3% and 1% of the remaining mix respectively.[152] Hence, Egypt plans to develop an integrated energy strategy for the country by 2030 by restructuring the energy sector, developing its existing infrastructure and expanding its renewable energy sector. Through these efforts, Egypt aims to generate 42% of electricity through renewable energy by 2035, and the government has also introduced a solar Feed-in-Tariff program to accelerate investments in solar generation.[153] Renewable energy is also expected to be a large component of Egypt's 4th generation cities, with more than $4.6 billion spent on 30 projects that support clean and affordable energy being carried out in Egypt's smart cities.[154]

Environmental Management

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[144] Clean Air Fund. (n.d.). *Cairo and air pollution.* Clean Air Fund. Retrieved November 2, 2023, from https://www.cleanairfund.org/clean-air-africas-cities/cairo/

[145] The World Bank. (2023, September 19). *ibid.*

[146] Attia, S. (2019). *ibid.*

[147] *Egypt Vision 2030. ibid.*

[148] Keleg, M. M., Butina Watson, G., & Salheen, M. A. (2022). A critical review for Cairo's green open spaces dynamics as a prospect to act as placemaking anchors. *URBAN DESIGN International, 27*(3), 232–248. https://doi.org/10.1057/s41289-022-00193-x

[149] Attia, S. (2019). *ibid.*

[150] Ritchie, H., Roser, M., & Rosado, P. (2020). *CO_2 and Greenhouse Gas Emissions.* Our World in Data. https://ourworldindata.org/co2/country/egypt

[151] The World Bank. (2023). *World Bank Open Data.* World Bank Open Data. https://data.worldbank.org

[152] *Egypt Vision 2030. ibid.*

[153] *ibid.*

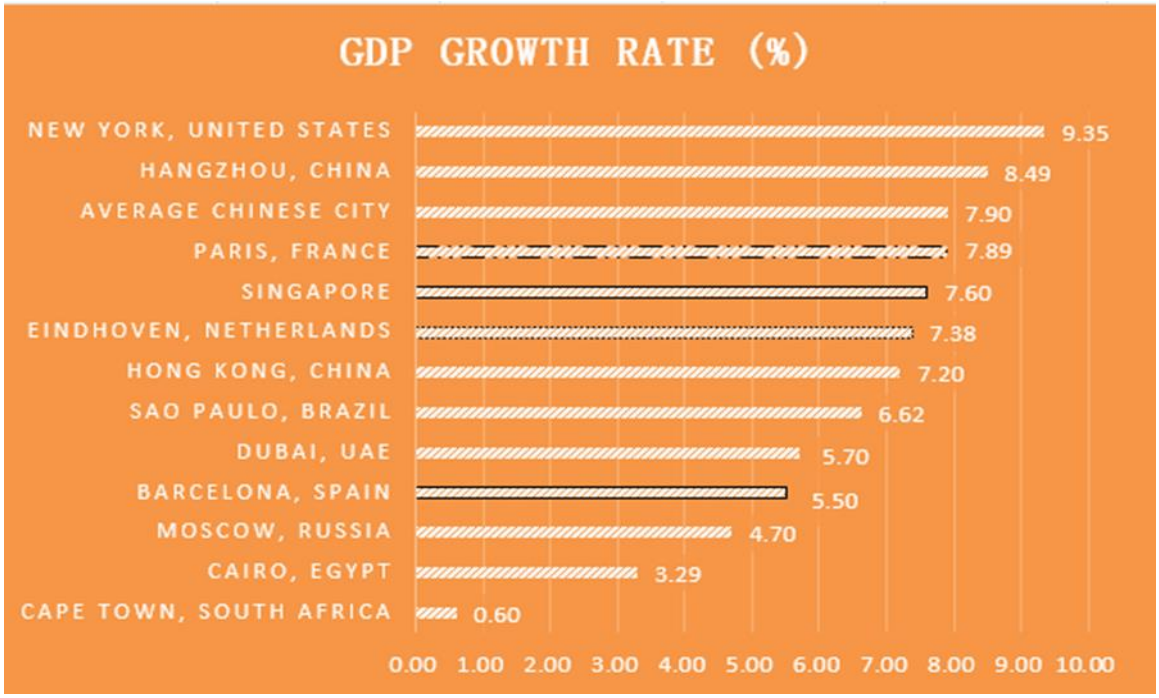
[154] Egypt's Ministry of International Cooperation. (2023). *ibid.*

Currently, Egypt only regularly collects about 20% of their solid waste and treats 7% of their hazardous waste. Hence, the government has set a goal in Egypt Vision 2030 to collect and manage 80% of the nation's waste with a 90% efficiency rate by 2030, and to develop a system for disposing of 100% of Egypt's hazardous waste by ensuring treatment, recycling, and final disposal.[155] In the second half of 2020, Egypt issued its first sovereign green bond – the first of its kind in the Middle East and North Africa – dedicating more than 50% of the first round of proceeds from the $750 million bond to wastewater management.[156] The Greater Cairo Air Pollution and Climate Change Management Project will also support Cairo's waste management ambitions by providing funding to build an integrated solid waste management facility in Cairo, while closing and rehabilitating an old adjacent dumpsite, although progress on this project is currently stalled.[157] New cities, such as ANC, will also introduce new sanitary and waste management facilities to help reduce the contamination of groundwater and soil from improper waste disposal.[158]

Categorical Comparison

The following graphs compare the international cities, along with Hangzhou and average Chinese cities, over each of the indicators. In general, Chinese cities perform well in economic development, whereas the seven international cities are more developed and perform better in consumption and emissions as well as environmental management. All cities perform rather equally on environmental resources and social welfare and livelihood.

Economic Development

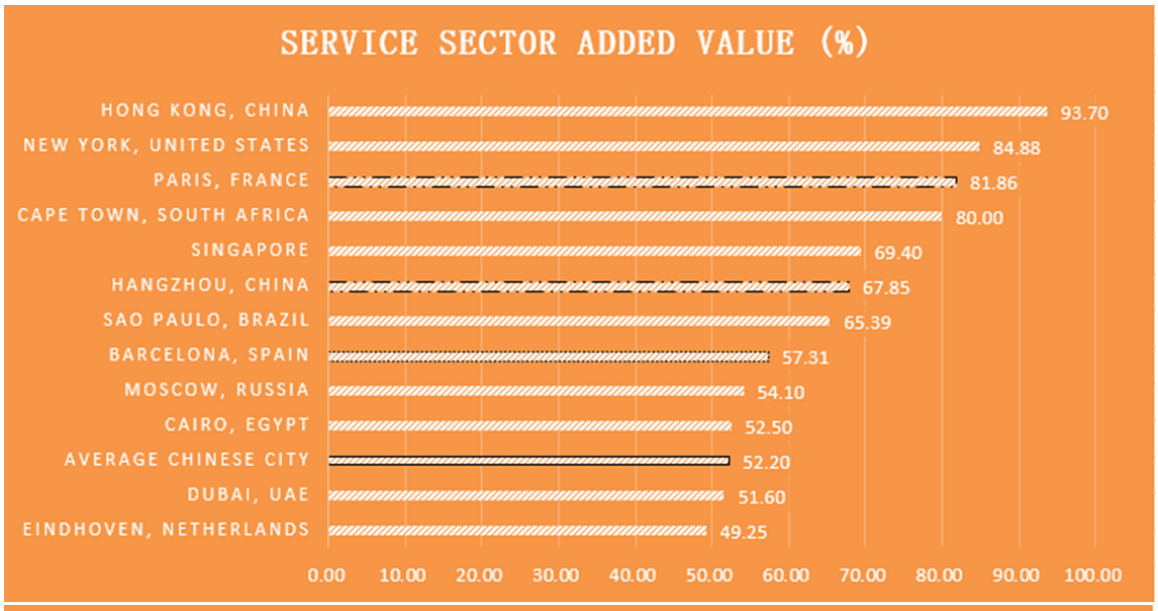


[155] *Egypt Vision 2030. ibid.*

[156] Wes, M. (2022, April 19). *Egypt: Acting Against Climate Change for A Healthier, More Prosperous Future.* https://www.worldbank.org/en/news/opinion/2022/04/19/-egypt-acting-against-climate-change-for-a-healthier-more-prosperous-future

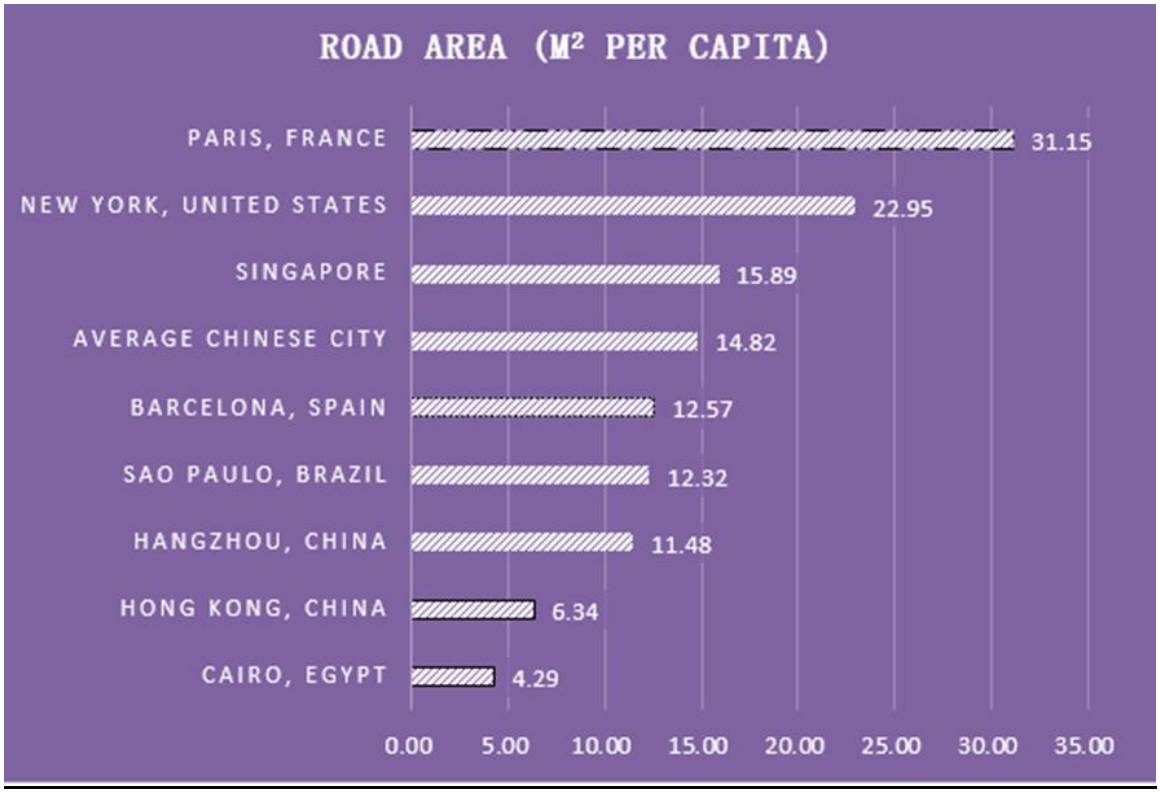
[157] The World Bank. (2023, September 19). *ibid.*

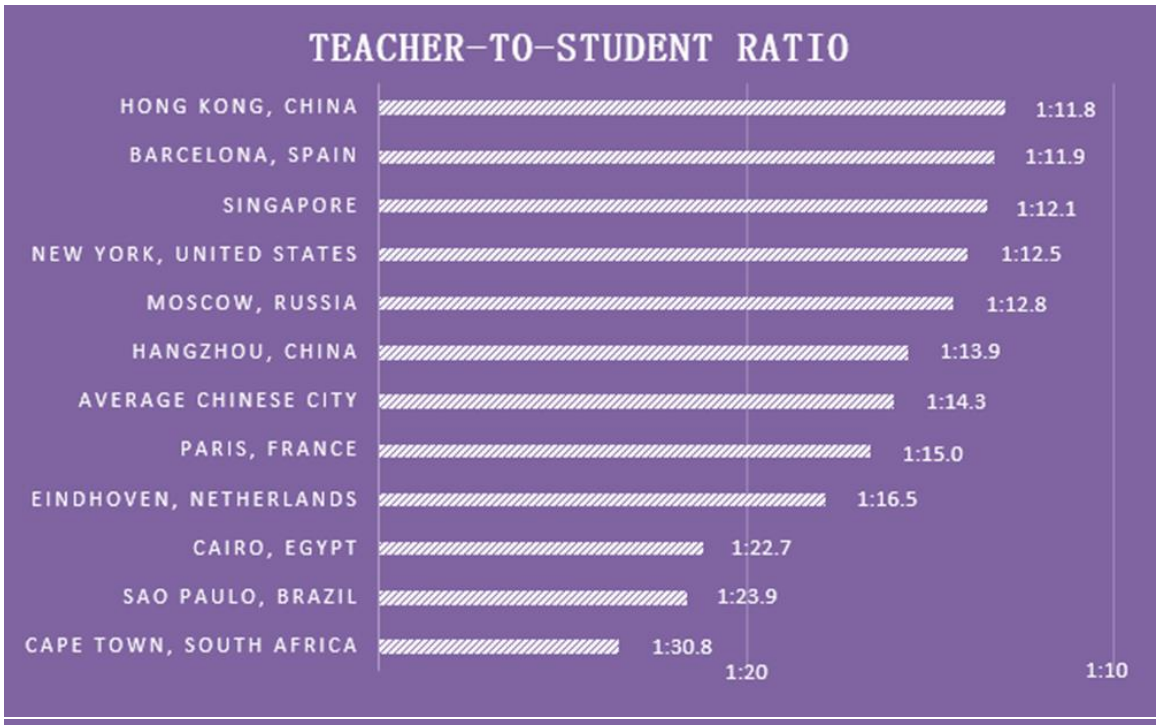
[158] Attia, S. (2019). *ibid.*

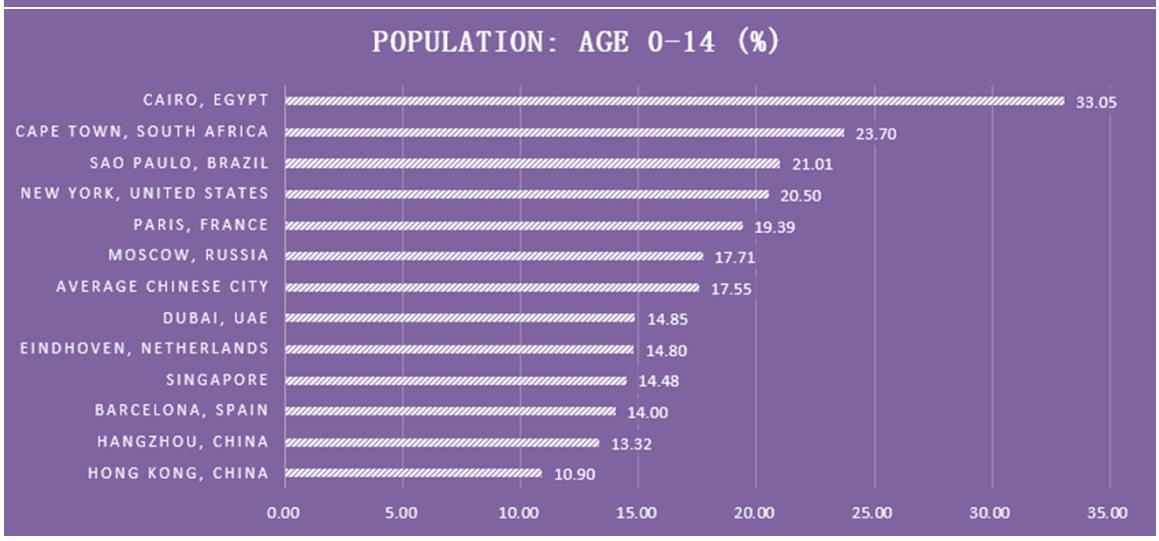

SERVICE SECTOR ADDED VALUE (%)
HONG KONG, CHINA 93.70
NEW YORK, UNITED STATES 84.88
PARIS, FRANCE 81.86
CAPE TOWN, SOUTH AFRICA 80.00
SINGAPORE 69.40
HANGZHOU, CHINA 67.85
SAO PAULO, BRAZIL 65.39
BARCELONA, SPAIN 57.31
MOSCOW, RUSSIA 54.10
CAIRO, EGYPT 52.50
AVERAGE CHINESE CITY 52.20
DUBAI, UAE 51.60
EINDHOVEN, NETHERLANDS 49.25
0.00 10.00 20.00 30.00 40.00 50.00 60.00 70.00 80.00 90.00 100.00

UNEMPLOYMENT RATE (%)
HANGZHOU, CHINA 2.34
MOSCOW, RUSSIA 2.60
AVERAGE CHINESE CITY 2.85
DUBAI, UAE 3.10
EINDHOVEN, NETHERLANDS 3.30
SINGAPORE 3.50
HONG KONG, CHINA 5.20
NEW YORK, UNITED STATES 7.00
CAIRO, EGYPT 7.40
PARIS, FRANCE 8.10
BARCELONA, SPAIN 9.70
SAO PAULO, BRAZIL 13.67
CAPE TOWN, SOUTH AFRICA 27.00
0.00 5.00 10.00 15.00 20.00 25.00 30.00

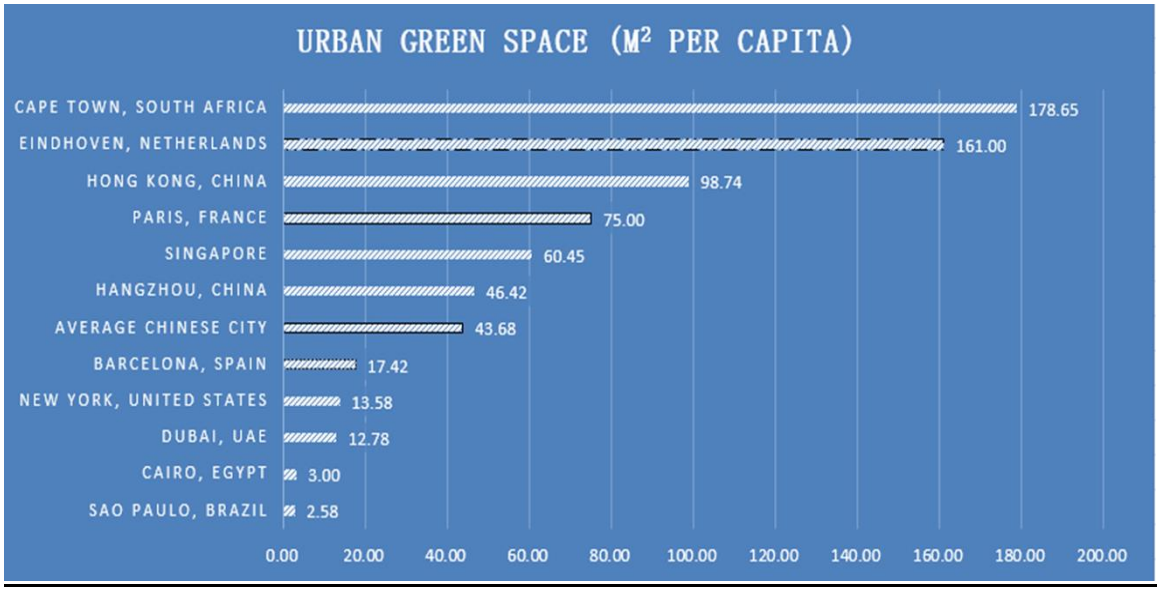
Social Welfare & Livelihood

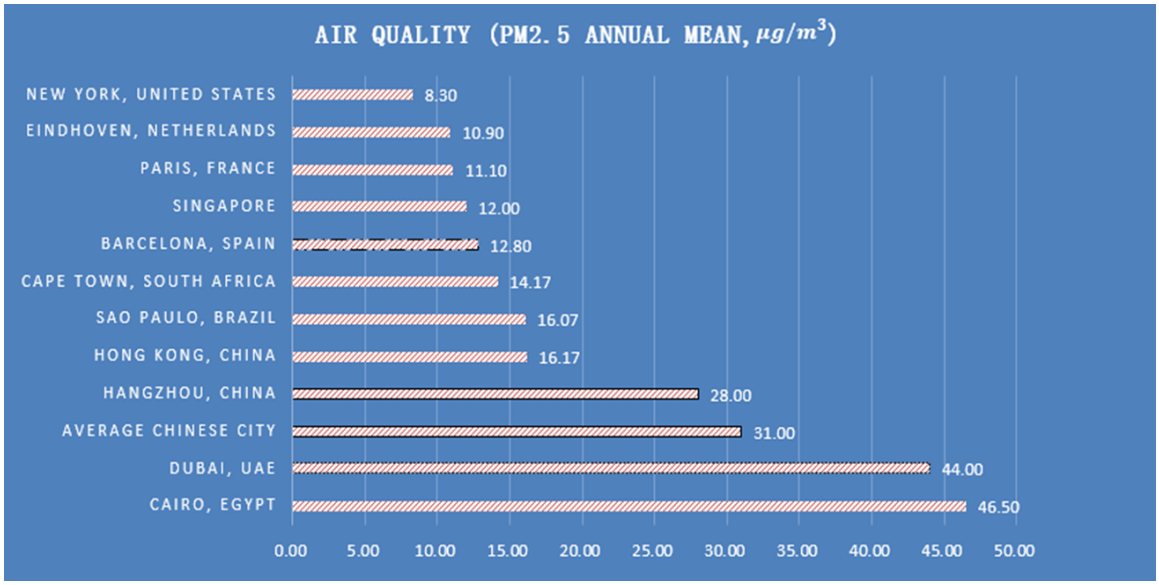



TEACHER-TO-STUDENT RATIO
HONG KONG, CHINA
1:11.8
BARCELONA, SPAIN
1:11.9
SINGAPORE
1:12.1
NEW YORK, UNITED STATES
1:12.5
MOSCOW, RUSSIA
1:12.8
HANGZHOU, CHINA
1:13.9
AVERAGE CHINESE CITY
1:14.3
PARIS, FRANCE
1:15.0
EINDHOVEN, NETHERLANDS
1:16.5
CAIRO, EGYPT
1:22.7
SAO PAULO, BRAZIL
1:23.9
CAPE TOWN, SOUTH AFRICA
1:30.8
1:20
1:10

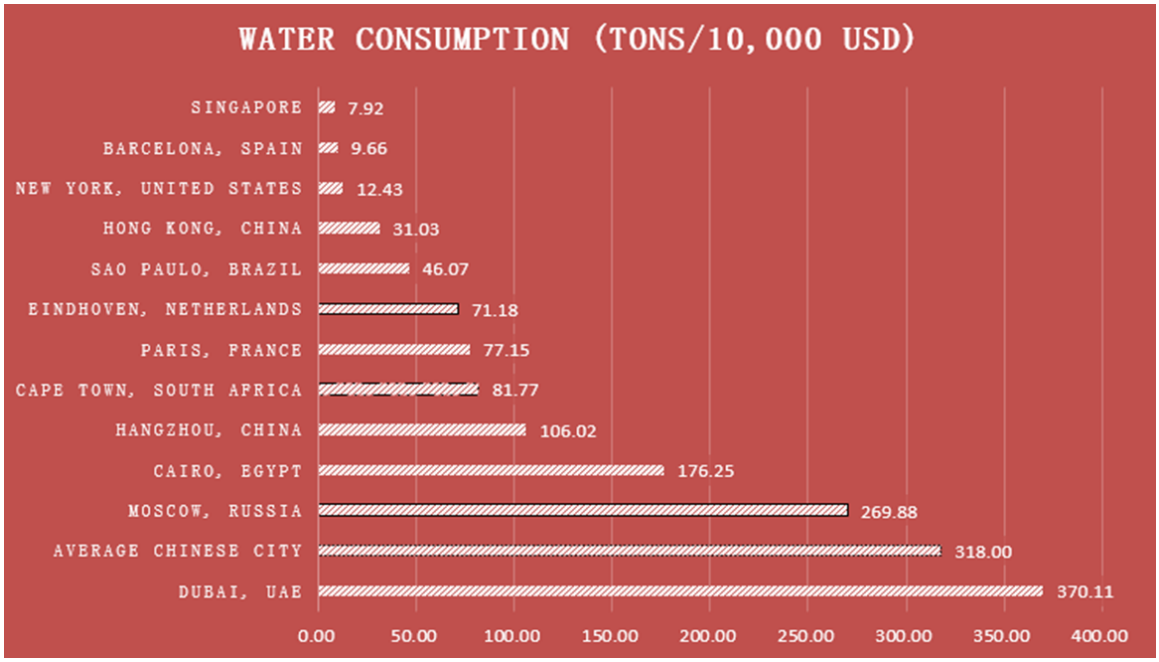

POPULATION: AGE 0-14 (%)
CAIRO, EGYPT
33.05
CAPE TOWN, SOUTH AFRICA
23.70
SAO PAULO, BRAZIL
21.01
NEW YORK, UNITED STATES
20.50
PARIS, FRANCE
19.39
MOSCOW, RUSSIA
17.71
AVERAGE CHINESE CITY
17.55
DUBAI, UAE
14.85
EINDHOVEN, NETHERLANDS
14.80
SINGAPORE
14.48
BARCELONA, SPAIN
14.00
HANGZHOU, CHINA
13.32
HONG KONG, CHINA
10.90
0.00
5.00
10.00
15.00
20.00
25.00
30.00
35.00

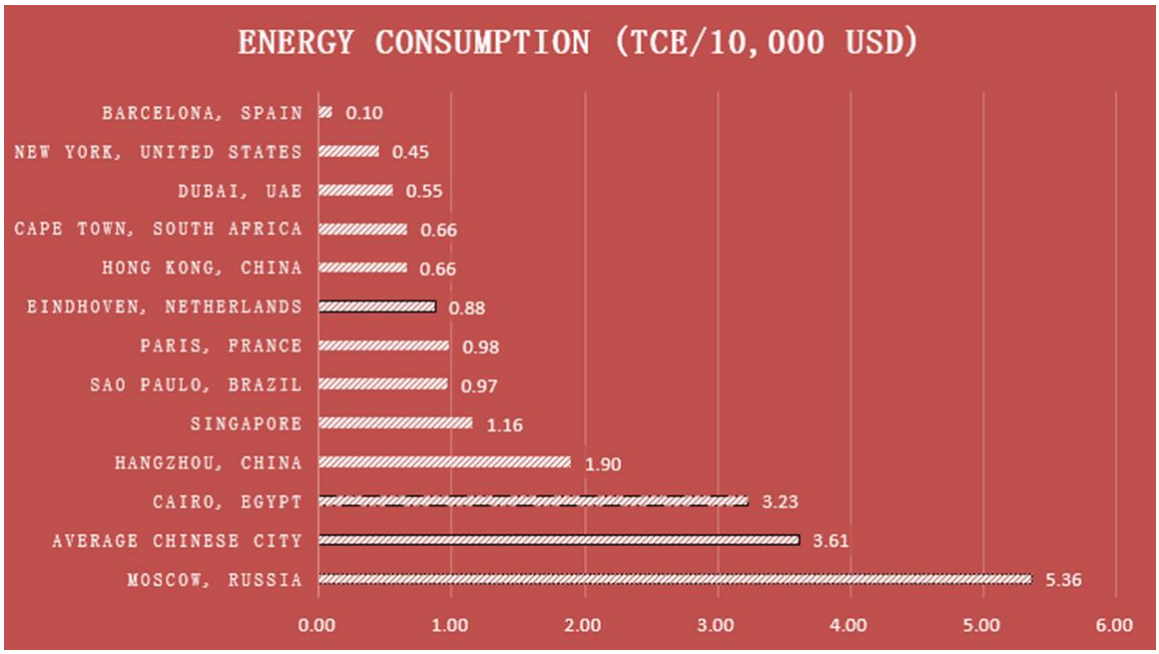
Environmental Resources



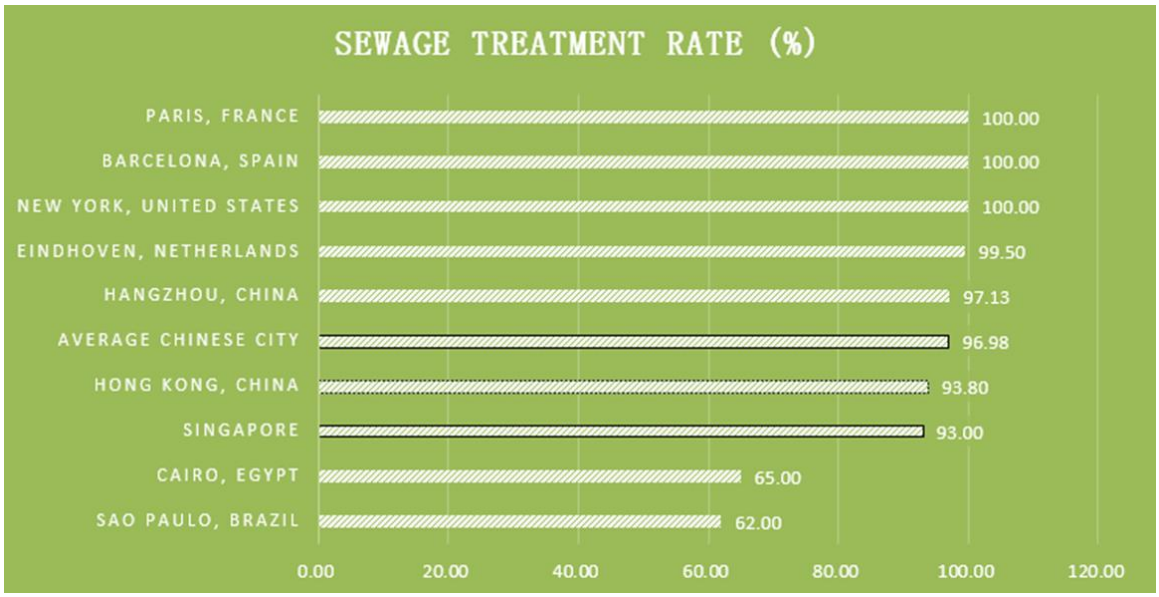


Consumption & Emissions





Environmental Management


SEWAGE TREATMENT RATE (%)
PARIS, FRANCE
BARCELONA, SPAIN
NEW YORK, UNITED STATES
EINDHOVEN, NETHERLANDS
HANGZHOU, CHINA
AVERAGE CHINESE CITY
HONG KONG, CHINA
SINGAPORE
CAIRO, EGYPT
SAO PAULO, BRAZIL
100.00
100.00
100.00
99.50
97.13
96.98
93.80
93.00
65.00
62.00
0.00
20.00
40.00
60.00
80.00
100.00
120.00

HOUSEHOLD WASTE HARMLESS TREATMENT RATE (%)
HANGZHOU, CHINA
HONG KONG, CHINA
SINGAPORE
PARIS, FRANCE
NEW YORK, UNITED-STATES
BARCELONA, SPAIN
AVERAGE CHINESE CITY
SAO PAULO, BRAZIL
100.00
100.00
100.00
100.00
100.00
100.00
99.92
97.80
96.50
97.00
97.50
98.00
98.50
99.00
99.50
100.00
100.50

Conclusion

This publication has presented our China Sustainable Development Indicator System (CSDIS) and 2023 ranking results for 110 large and medium-sized Chinese cities and 30 Chinese provinces based on their sustainability performance, as well as country-level sustainable development analysis. Although often hampered by the availability (or lack thereof) of data on certain indicators that are important to sustainability analyses, we carefully selected indicators for cities, provinces, and the country, 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. 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 governments at all levels in China. 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.

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