China Sustainable Development Indicator System

2024 Report

COLUMBIA CLIMATE SCHOOL
THE EARTH INSTITUTE

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

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China Sustainable Development Indicator System: 2024 Report

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Prepared by:

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

The China Center for International Economic Exchanges (CCIEE)

Philips China

Lenovo

China Champions of Climate Action (C Team)

Project Advisors:

- Dr. Steven Cohen, Director of the Research Program on Sustainability Policy and Management, the Earth Institute, Columbia University
- Dr. Satyajit Bose, Associate Director of Columbia's Master of Science in Sustainability Management; Associate Director of the Research Program on Sustainability Policy and Management
- NING Jizhe, Member of the Standing Committee of the 14th National Committee of the Chinese People's Political Consultative Conference (CPPCC), Deputy Director of the Economic Committee, Vice-Chairman of CCIEE, Former Deputy Director of the National Development and Reform Commission (NDRC), Former Director of the National Bureau of Statistics
- ZHANG Dawei, Former Vice Chairman of CCIEE, Former Vice Governor of the People's Government of Henan Province, Former Deputy Director of the Standing Committee of the People's Congress of Henan Province
- WANG Yiming, Vice-President and Director of the Academic Committee of CCIEE and former Deputy Director of the Development Research Center of the State Council
- LI Tao, Vice President of Philips Greater China

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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.

61 Claremont Ave, Suite 525
New York, NY 10115
spm.ei.columbia.edu

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

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

Project Leaders:

- Dr. GUO Dong, Associate Director of the Research Program on Sustainability Policy and Management, the Earth Institute, Columbia University
- Dr. LIU Xiangdong, Deputy Director, Department of Research Management and Information Services, CCIEE
- Dr. WANG Jun, Chief Economist, Huatai Securities Asset Management
- Dr. CHEN Yan, Deputy Director, Department of Research Management and Information Services, CCIEE
- Dr. WANG Anyi, Associate Research Scholar, Research Program on Sustainability Policy and Management
- WANG Yanchun, Deputy Editor-in-Chief, Caijing Magazine
- LIU Kexin, Senior Corporate Social Responsibility Manager, Philips Greater China
- WANG Xuan, Director of ESG and Sustainability, Lenovo
- ZHANG Jian, Vice-Dean, Institute of Climate Change and Sustainable Development, Tsinghua University

Columbia University Team Members:

- Tal Henig-Hadar, Program Manager, Research Program on Sustainability Policy and Management
- Dr. MENG Xingyuan, Graduate Research Assistant, Teachers College
- CHAI Sen, Graduate Research Assistant, Henan University School of Economics
- Akshay Malhotra, Graduate Research Assistant, School of Professional Studies
- Sylvia Gan, Graduate Research Assistant, School of International and Public Affairs
- Yu-wei Lee, Graduate Research Assistant, School of Professional Studies
- BI Zhuoran, Graduate Research Assistant, School of Professional Studies
- ZHAO Teng, Graduate Research Assistant, Mailman School of Public Health
- Drew Reetz, Undergraduate Research Assistant
- Amy Xiaoqian Chen, Undergraduate Research Assistant
- SU Xiaoya, Research Intern, School of Foreign Studies, Central University of Finance and Economics
- Kayden Hansong, Research Intern, Horace Mann School

CCIEE Team Members:

- LIU Meng, Associate Researcher
- ZHAI Yujia, Associate Researcher
- CUI Baiyang, Director, Postdoctoral Research Program
- WANG Jing, Associate Researcher
- WANG Jia, Research Intern, Open University of China
- DU Marui, Postdoctoral Researcher
- ZHANG Jian, Editor, Language & Culture Press

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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 53 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 53 indicators for provinces and country-level analysis, 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%

Level-1 Indicator	Level-2 Indicator	Level-3 Indicator	Weight
	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%
	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%

Level-1 Indicator	Level-2 Indicator	Level-3 Indicator	Weight
Consumption and Emissions (25%)	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	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%

Category	Number	Indicator	Weight
(23.78%)	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 Total Sustainability Index (Graph 1), all five indicator categories of Economic Development, Social Welfare, Environmental Resources, Consumption and Emissions, and Environmental Management have demonstrated an upward trend since 2017.

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 2024. Specifically:

- Economic Development: The Economic Development Indicator increased from 57.8 in 2017 to 83.9 in 2024, with an average annual growth rate of 5.5%, and a year-on-year increase of 3.3% compared to 2023. Despite being affected by the pandemic and external pressures, China's actual economic growth rate in 2024 reached 3%, higher than that of major economies. At the same time, import and export trade maintained stable growth, and prices and employment remained stable.
- Social Welfare: The Social Welfare Indicator rose to a eight-year high of 87.4 in 2024, an increase of 12.7% year-on-year, with an average annual growth rate of 7.3% since 2017. In recent years, China has continued to promote the progress of social undertakings and improve public services, which has led to a continuous improvement in the livelihood of its people. The sense of gain, happiness, and security among the population has been significantly enhanced.
- Consumption & Emissions: The Consumption and Emissions Indicator saw rapid growth, reaching 93.6 in 2024, an increase of 19.4% year-on-year, with an average annual growth rate of 9.7% since 2017. These increases are the highest among the five sub-indicators. This is mainly due to the Chinese government's strong focus on promoting energy conservation and emission reduction, and the introduction of various policies to control pollutants and greenhouse gas emissions, including the dual-control system on energy consumption intensity and total energy consumption, and the total pollutant emission control system.

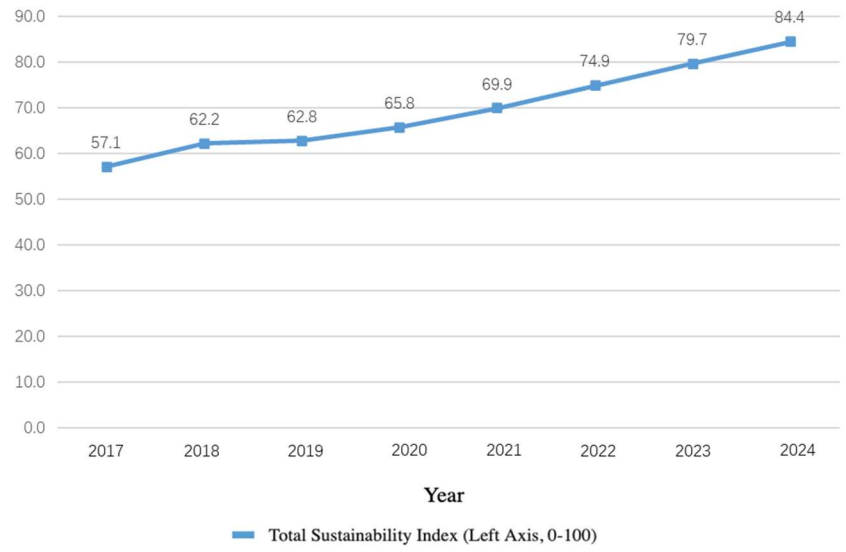
For the other two primary indicators:

- Environmental Resources: In 2024, the Environmental Resources Indicator reached 76.3, a 4.9% year-on-year decline, mainly due to a decrease in indicators such as wetland area per capita and water resources. Since 2017, this indicator has fluctuated but has shown a general upward trend, with an average annual growth rate of about 3.9%.
- Environmental Management: In 2024, the Environmental Management Indicator decreased to 77.3, a 4.1% year-on-year decline, primarily due to a reduction in governance investment and the rate of decrease in energy

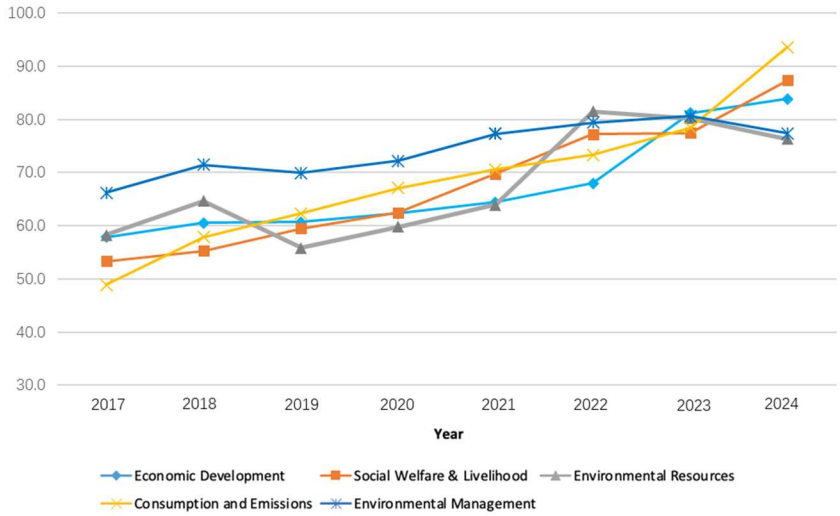
intensity. However, the indicator has shown an average annual growth rate of 2.2% since 2017, reflecting China's continuous improvement in ecological environmental governance capabilities and levels of governance.

In summary, compared to 2017, all five Level-1 indicators saw significant increases in their values by 2024, fully reflecting the effective results of sustainable development from 2017 to 2024. In 2024, aside from the decreases in Environmental Resources and Environmental Management, all other aspects achieved growth, making the overall sustainable development performance in 2024 better than the previous year.

Graph 1: China Sustainable Development from 2017 to 2024



Graph 2: CSDIS First-Level Indicator Development from 2017 to 2024



CSDIS Province-Level Data Analysis

Province-Level Ranking

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

	2024 Ranking	2023 Ranking
Beijing	1	1
Shanghai	2	2
Guangdong	3	4
Chongqing	4	6
Zhejiang	5	3
Tianjin	6	5
Fujian	7	7
Jiangsu	8	9
Hainan	9	8
Hunan	10	10+

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).[1] In 2024, the top 10 provinces in China's provincial-level sustainable development rankings are Beijing, Shanghai, Guangdong, Chongqing, Zhejiang, Tianjin, Fujian, Jiangsu, Hainan, and Hunan. Beijing and Shanghai maintain their leading positions, and Hunan has entered the top ten. Overall, the eastern region[2] has higher comprehensive sustainable development rankings, with eight provinces and cities in the top ten. The western and central regions each have one province or city among the top ranks, while the northeastern region shows relatively weaker development.

In terms of Economic Development, the top 10 provinces and cities are Beijing, Shanghai, Guangdong, Tianjin, Zhejiang, Jiangsu, Fujian, Chongqing, Shandong, and Hubei. Among them, the rankings of the top six provinces have not changed compared to 2023. In terms of Social Welfare, the top 10 provinces and cities (autonomous regions) are Beijing, Qinghai, Jilin, Heilongjiang, Shanghai, Tianjin, Xinjiang Uygur Autonomous Region, Gansu, Liaoning, and Jiangxi. Among them, the rankings of the top four provinces have not changed compared to 2023. In terms of Environmental Resources, the top 10 provinces and cities (autonomous regions) are Qinghai, Guizhou, Fujian, Yunnan, Guangxi Zhuang Autonomous Region, Hainan, Jiangxi, Sichuan, Heilongjiang, and Jilin. Among them, the rankings of the top three provinces have not changed compared to 2023. In terms of Consumption and Emissions, the top 10 provinces and cities are Beijing, Yunnan, Fujian, Sichuan, Guangdong, Zhejiang, Shanghai, Chongqing, Shaanxi, and Tianjin. Beijing remains in the leading position, and Yunnan rose from 5th place in 2022 to 2nd place. In terms of Environmental Management, the top 10 provinces and cities are Beijing, Chongqing, Tianjin, Hainan, Guangdong, Shandong, Anhui, Henan, Shanghai, and Shanxi. Compared to 2023, Beijing, Chongqing, and Tianjin have shown significant improvements in governance and protection, rising to the top three positions in the rankings, while Henan dropped from 2nd place to 9th place.

[1] Complete ranking of all 30 provinces can be found at: http://urbansustainability.org/provincial-rankings/.

[2] The specific divisions of the eastern, central, western, and northeastern regions involved in the statistics are as follows: The eastern region consists of 10 provinces (municipalities): Beijing, Tianjin, Hebei, Shanghai, Jiangsu, Zhejiang, Fujian, Shandong, Guangdong, and Hainan. The central region consists of 6 provinces: Shanxi, Anhui, Jiangxi, Henan, Hubei, and Hunan. The western region consists of 11 provinces (autonomous regions, municipalities): Inner Mongolia, Guangxi, Chongqing, Sichuan, Guizhou, Yunnan, Shaanxi, Gansu, Qinghai, Ningxia, and Xinjiang. The northeastern region consists of 3 provinces: Liaoning, Jilin, and Heilongjiang.

CSDIS City Data Analysis

City Ranking

In the 2024 comprehensive rankings for sustainable development among cities, the top ten cities are Zhuhai, Qingdao, Hangzhou, Guangzhou, Beijing, Shanghai, Nanjing, Wuxi, Changsha, and Hefei. These cities are all located in China's most economically active regions: the Pearl River Delta, the Capital Metropolitan Area, the Yangtze River Delta, and provincial capital cities.

Table 5 shows the comprehensive rankings of sustainable development for selected Chinese cities in 2024. Zhuhai has surpassed Hangzhou to rank first, becoming the new leader in sustainable development among Chinese cities. Qingdao's sustainable development level has improved by two positions, ranking second. Hangzhou, which was first last year, has dropped to third place. The main reason for this is that economic development was relatively stable, and the GDP growth rate slowed significantly, causing its growth rate ranking to drop notably, with a growth rate of only 1.5% that year. Additionally, Hangzhou faces an increase in the unemployment rate, a challenge common to many large cities, which contributed to its decline in the comprehensive ranking for sustainable development.

Guangzhou has risen four places to rank fourth this year, mainly due to significant improvements in the rankings for Environmental Resources and Environmental Management. The top ten rankings for cities in 2024's comprehensive sustainable development have changed: Jinan and Suzhou have fallen out of the top ten, while Changsha and Hefei, from central China, have entered the top ten rankings for sustainable development this year.

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

Rank	City	Rank	City	Rank	City	Rank	City	Rank	City	Rank	City
1	Zhuhai	11	Jinan	31	Wenzhou	51	Chenzhou	71	Dongguan	91	Jilin
2	Qingdao	12	Ningbo	32	Taiyuan	52	Mianyang	72	Yibin	92	Leshan
3	Hangzhou	13	Suzhou	33	Shenyang	53	Anqing	73	Nanyang	93	Datong
4	Guangzhou	14	Yantai	34	Xuzhou	54	Yangzhou	74	Chengde	94	Dali
5	Beijing	15	Shenzhen	35	Nantong	55	Hohhot	75	Linyi	95	Kaifeng
6	Shanghai	16	Yulin	36	Dalian	56	Changchun	76	Huaihua	96	Fuyang
7	Nanjing	17	Ordos	37	Yueyang	57	Beihai	77	Mudanjiang	97	Baoding
8	Wuxi	18	Wuhu	38	Haikou	58	Foshan	78	Guyuan	98	Qiqihar
9	Changsha	19	Zhengzhou	39	Tianjin	59	Xining	79	Guilin	99	Tianshui
10	Hefei	20	Xiamen	40	Lhasa	60	Jining	80	Lanzhou	100	Nanchong
		21	Fuzhou	41	Xi'an	61	Nanning	81	Shijiazhuang	101	Zhanjiang
		22	Huzhou	42	Luoyang	62	Ganzhou	82	Zunyi	102	Haidong
		23	Guiyang	43	Quanzhou	63	Tangshan	83	Zaozhuang	103	Shantou
		24	Chongqing	44	Sanya	64	Huangshi	84	Yinchuan	104	Dandong
		25	Chengdu	45	Changde	65	Huizhou	85	Luzhou	105	Lincang
		26	Karamay	46	Kunming	66	Bengbu	86	Harbin	106	Handan
		27	Weifang	47	Baotou	67	Xiangyang	87	Qinhuangdao	107	Zhoukou
		28	Nanchang	48	Urumqi	68	Tongren	88	Heze	108	Jinzhou
		29	Wuhan	49	Jinhua	69	Shaoguan	89	Qujing	109	Weinan
		30	Yichang	50	Jiujiang	70	Xuchang	90	Pingdingshan	110	Yuncheng

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 Zhuhai - the No.1 in overall ranking, with nine cities from both developed and developing countries - Tokyo, Sydney, San Francisco, Oslo, Baku, Delhi, Moscow, 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, and wastewater treatment plants utilizing biogas produced during water treatment to generate electricity. Fourth, many cities are focusing on buildings to reduce energy consumption and carbon emission, through establishing more stringent building energy standards, or retrofitting old buildings with energy efficient or clean energy solutions. Particularly, municipal buildings are often chosen as the pioneers of implementing these emission reduction measures, such as Tokyo’s and San Francisco’s plan on phasing out natural gas from municipal buildings. 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.

Additionally, we find that local policymakers are developing sustainability strategies and initiatives by specifically targeting the prominent local issues while taking advantage of local strengths. Noticeable and innovative sustainability policy initiatives include the ambitious plan of Tokyo and San Francisco to phase-out natural gas in municipal buildings and infrastructure, the Blue-Green Factor building code in Oslo that integrates green infrastructure with residential buildings and community planning, San Francisco's efficient construction waste recycling management and the city’s up to 80% solid waste diversion rate, Delhi’s neighborhood clinics (Mohalla Clinics) and the city’s solar energy incentive plan, Cape Town’s initiatives on affordable housing for the urban poor and the city’s successful measures in face of water crises, and the pioneering “fourth generation cities” surrounding Cairo.

Meanwhile, the past COVID-19 pandemic and our Moscow case study - and the pessimistic outlook for many of the city’s sustainability initiatives – also reminds us of the limitation of local governments on urban sustainability management, as well as the detrimental impacts of geopolitical conflicts and global crises on local sustainability efforts.

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:** Oslo **Tertiary Industry to GDP Ratio** **#1:** Cape Town **Unemployment Rate in Rural Areas** **#1:** Zhuhai	**Urban Road Area per Capita** **#1:** Oslo **Housing-to-Income Ratio** **#1:** Oslo **Teacher to Student Ratio in Middle and Elementary School** **#1:** Oslo **Population: Age 0-14** **#1:** Cairo	**Urban Green Space per 10,000 People** **#1:** Cape Town **Air Quality** **#1:** Oslo	**Water Consumption per Unit of GDP** **#1:** Sydney **Energy Consumption per Unit of GDP** **#1:** Cape Town	**Centralized Treatment Rate of Sewage Treatment** **#1:** Multiple cities have reached 100% **Harmless Treatment Rate of Domestic Waste:** Most cities have reached 100%

International Cities

Figure 2: International City Comparison Map

Tokyo, Japan

Indicator	Tokyo	Zhuhai	Chinese Avg.
Population (million)	37.27	2.48	7.00
GDP (billion USD)	876.05	60.13	107.05
GDP Growth Rate (%)	0.95	2.30	3.15
Service Sector Added Value (%)	71.40	53.81	51.54
Unemployment Rate (%)	2.60	2.36	2.89
Road Area (m^2 per capita)	6.14	20.07	15.23
House-Income Ratio (price per m^2 / GDP per capita)	0.15	0.13	0.13
Teacher-Student Ratio	1:15.7	1:16.0	1:14.3
Population: Age 0-14 (%)	11.60	16.10	16.69
Urban Green Space (m^2 per capita)	-	127.40	44.99
Air Quality (PM2.5 annual mean, ug/m^3)	9.00	17.00	29.00
Water Consumption (tons/10,000 USD)	154.71	93.12	301.21
Energy Consumption (tce/10,000 USD)	1.88	2.45	3.63
Domestic Sewage Treatment Rate (%)	92.10	99.21	97.19
Household Waste Harmless Treatment Rate (%)	-	100.00	99.96

Notes. Data source: Publicly available data sources, see reference for detail. Data year: 2022.

Since the establishment of the Edo Shogunate in 1603, Tokyo Prefecture (also known as Tokyo Metropolis or Tokyo City) has served as Japan's capital, evolving into one of the world's megacities. With a population of approximately 13.5 million, Tokyo metropolis represents over 10% of the nation's populace. Not only is it Japan's economic and cultural epicenter, but also its political and administrative core. The national Cabinet, ministries, Diet, Supreme Court, and central bank all reside within the city. Tokyo's gross prefectural domestic product in the 2019 fiscal year totaled around 115.7 trillion Japanese yen (USD$1.1 trillion), contributing roughly to 21% of the nation's GDP. The wholesale and retail trade sector leads the prefecture's economy, closely followed by real estate. The National Capital Region (also known as the Tokyo Metropolitan Area, or Greater Tokyo Area) encompasses Tokyo and the seven surrounding prefectures of Saitama, Chiba, Kanagawa, Ibaraki, Tochigi, Gunma, and Yamanashi. Tokyo's metropolitan area population stood at 37.27 million and is home to around 30% of Japan's population.

The climate of Tokyo is represented by hot, humid summers and dry winters, excluding the islands, which have a different climate.[3]

Economic Development

Tokyo's industrial landscape is characterized by its stability and robustness, hosting a plethora of major corporations spanning various sectors such as automotive, machinery, medicine, and healthcare, alongside a thriving community of small and medium-sized enterprises renowned for their cutting-edge manufacturing and environmental technologies. The Tokyo Metropolitan Area stands as a beacon for financial prowess. It attracts top-tier financial institutions with advanced techniques and serves as a magnet for exceptional talent in finance, investment, and information sectors from across the globe. The city's focus lies in enhancing asset management and FinTech to bolster Tokyo's growth and foster an ecosystem of innovation. Economically, the Tokyo Metropolitan Area boasts the second highest GDP globally at USD$1,600 billion, maintaining its premier position for over five decades. The staggering scale of household financial assets in Japan, totaling JPY¥1,800 trillion (USD$17 trillion), not only fuels Japan's economic expansion but also augments growth prospects across Asia. The government's proactive policies in capital market utilization have spurred increased investment across all sectors, from individual investors to institutional giants, propelling economic dynamism to unprecedented heights. Tokyo's stock

[3] *TOKYO'S HISTORY, GEOGRAPHY, AND POPULATION.* (n.d.). Tokyo Metropolitan Government. Retrieved April 29, 2024, from https://www.metro.tokyo.lg.jp/ENGLISH/ABOUT/HISTORY/history03.htm.

market stands as a global powerhouse, renowned for its unparalleled liquidity and quality, with a staggering 3,700 listed companies (second globally). Its total market value of JPY¥600 trillion (USD$5.5 trillion) ranks it third worldwide and first in Asia. Furthermore, Tokyo leads Asia with a daily stock trading value of JPY¥3 trillion (USD$27.5 billion), underscoring its pivotal role in the global financial landscape.[4]

Social Welfare & Livelihood

Tokyo constitutes a mere 0.6% of Japan's total land area. Despite its modest size, Tokyo boasts the highest population density among Japan's prefectures, with 6,158 individuals per square kilometer. This bustling metropolis has become synonymous with urban vitality and dynamism.

As of October 1, 2010, Tokyo's population stood at a staggering 13.159 million, according to the National Census conducted by the Statistics Bureau, Ministry of Internal Affairs and Communications. This populace is segmented into three distinct age brackets: the child population (ages 0 - 14) comprising 1.48 million; the working-age populace (ages 15 - 64) totaling 8.85 million; and the aged demographic (ages 65 and over) numbering 2.64 million. Notably, the proportion of elderly residents has surpassed the United Nations threshold for an "aged society," hovering around 20.4% and indicating Tokyo's progression toward a "super-aged society."[3]

In recent years, Tokyo's real estate market has witnessed remarkable appreciation, particularly within its 23 wards. The average property price in these districts surged to 114.83 million yen (USD$777,630), marking a notable 39.4% increase from the preceding year and surpassing the 100 million yen milestone for the first time. This unprecedented surge reflects a broader trend, with prices skyrocketing by 60.8% over the past five years. Conversely, the number of units sold in the capital region declined by 9.1% in the previous year, reaching its lowest level since 1992.[5] In 2022, the average monthly income for working households in Tokyo Prefecture amounted to approximately JPY¥684,000 (USD$4,379.06). Although this figure represents a decline from the previous year's decade-high, it underscores Tokyo's status as a global economic powerhouse.[5]

Regarding education, Japan’s elementary schools maintain a student-teacher ratio of about 1:16, and continue to exhibit improvements. This figure outperforms the global average of 21.75 students per teacher across 132 countries, reflecting Japan's commitment to quality education.[6]

Tokyo's efficient transportation network, anchored by its extensive train and subway system, facilitates seamless travel throughout the city. Operated primarily by JR East and Tokyo Metro, with supplementary services provided by Toei Subway, these networks offer convenient access to diverse destinations within the capital and its environs. Notable lines, such as the Yamanote Line, Ginza Line, and Tozai Line, exemplify Tokyo's commitment to accessibility and connectivity, enhancing the daily lives of residents and visitors alike.[7]

Environmental Resources

[4] *The Organization of Global Financial City Tokyo.* (n.d.). FinCity.Tokyo. Retrieved April 17, 2024, from https://fincity.tokyo/en/strength/economic/

[5] Yamaguchi, K. (2024, January 25). *Tokyo apartment prices hit record at nearly $800000 in 2023*. Nikkei Asia. Retrieved April 29, 2024, from https://asia.nikkei.com/Business/Markets/Property/Tokyo-apartment-prices-hit-record-at-nearly-800-000-in-2023.

[6] *Japan Student teacher ratio, primary school - data, chart | TheGlobalEconomy.com*. (n.d.). The Global Economy. Retrieved April 29, 2024, from https://www.theglobaleconomy.com/Japan/Student_teacher_ratio_primary_school/.

[7] *Your Essential Guide to the Transport System in Tokyo*. (2023, November 28). Housing Japan. Retrieved April 29, 2024, from https://housingjapan.com/blog/your-essential-guide-to-seamless-travel-in-tokyo/.

Tokyo has a humid subtropical climate, characterized by hot, humid summers and mild winters. The city's urban landscape has limited ecological diversity compared to natural habitats, but there are still pockets of green spaces and parks throughout the city. Tokyo Bay, a prominent feature of the city, supports various marine species and ecosystems.[8]

Dry spells occur in Tokyo approximately every decade, contributing to its status as the world's largest water-stressed metropolis. Since 1970, Tokyo has experienced a rising frequency of low rainfall years, alongside a notable trend towards extremes in precipitation, including both excessively high and low events. Furthermore, diminished snowfall and earlier thaw occurrences exacerbate the challenges faced by the city. Tokyo's vulnerability to natural disasters like earthquakes and floods further compounds these issues, often leading to disruptions in water supply and sewage networks. Addressing water scarcity lies at the heart of Tokyo's water resource management efforts. In response, the government has undertaken significant expansions in water infrastructure, alongside initiatives promoting water efficiency and conservation. Moreover, fostering a culture of water consciousness and establishing a dedicated emergency water services unit equipped to manage shortages round-the-clock are integral parts of the city's strategy. Demonstrating a commitment to integrated water resource management, the Japanese government has enacted policies facilitating coordinated development and stewardship of water, land, and associated resources. This holistic approach, coupled with effective governance and access to technical expertise and financial resources, has empowered Tokyo to surmount its water-related challenges. Tokyo grapples with a multifaceted water management landscape, contending with issues ranging from scarcity to pollution. To address these concerns, the city has adopted a suite of measures, including prudent water usage practices and cutting-edge wastewater treatment technologies. Furthermore, Tokyo has embraced green infrastructure initiatives, such as rainwater harvesting and permeable pavements, to counteract the adverse effects of urbanization on its water resources.[9]

Tokyo, like many other urban centers, confronts the profound challenges posed by climate change, encompassing a spectrum of impacts from extreme weather phenomena to escalating temperatures and sea-level ascent. Over recent years, the city has witnessed a surge in the frequency and ferocity of heatwaves, typhoons, and torrential downpours. In response, Tokyo has embarked on a proactive trajectory, devising comprehensive climate adaptation strategies aimed at fortifying resilience and curbing greenhouse gas emissions. The escalating rate of sea-level rise, averaging 5 mm annually along Japan's coastline since 1993, presents a looming threat with projected continuity throughout the 21st century. This trend imperils a significant portion of Tokyo's populace and industrial output, heightening the susceptibility to inundation, groundwater encroachment, and coastal erosion. The potential consequences loom large, with projections indicating a loss of 90% of Japan's sandy beaches with a mere 1-meter rise in sea levels, accompanied by staggering economic repercussions estimated at USD$115 billion annually. Japan's climate narrative further unfolds with a palpable uptick in mean temperatures by 1.0°C over the past century, accompanied by a proliferation of scorching days exceeding 35°C, particularly felt in Hokkaido where average winter temperatures have surged by 1.3°C. This climatic shift manifests in diminishing frost occurrences and a reduction in the frequency of cold spells, coupled with a noticeable decline in snowfall and an alarming surge in the frequency and intensity of heavy rainfall episodes. These phenomena entail far-reaching ramifications, extending from burgeoning financial outlays for preventative measures to the precarious exposure of assets totaling up to a staggering USD 1 trillion against a backdrop of sea-level escalation. Moreover, the intensification of typhoons augments wind-related losses by 67% to 70%, while the degradation of freshwater ecosystems, compounded by shifts in temperature and precipitation, poses a threat to fish production and harvests due to increases in chemical nutrients. Furthermore, the burgeoning demand for water supply, projected to rise by 1.2% to 3.2% with a 3°C warming,

[8] *Tokyo Climate, Weather By Month, Average Temperature (Japan)*. (n.d.). Weather Spark. Retrieved May 14, 2024, from https://weatherspark.com/y/143809/Average-Weather-in-Tokyo-Japan-Year-Round.

[9] *Achieving urban water security in Tokyo.* (n.d.). International Conference on Sustainable Development. Retrieved May 14, 2024, from https://ic-sd.org/wp-content/uploads/2020/11/Mukhnaam-Kaur-Chattha.pdf.

underscores the imperative for proactive measures to safeguard Tokyo's water security amidst the evolving climate landscape.[10]

Tokyo's air quality is shaped by a myriad of factors, spanning from transportation emissions to industrial operations, all under the influence of its geographical setting. Despite commendable strides made in recent decades to curb air pollution, challenges persist, particularly concerning particulate matter ($PM_{2.5}$) and nitrogen dioxide (NO_2) concentrations, notably during peak traffic and industrial periods. To address these issues, Tokyo has enacted stringent measures, including vehicle emission standards, bolstered public transportation infrastructure, and embraced green building initiatives to mitigate pollution and enhance air quality. Regarding its air quality metrics, Tokyo maintained an average $PM_{2.5}$ reading of 11.7 $\mu g/m^3$ throughout 2019, positioning it within the "good" range, a classification necessitating $PM_{2.5}$ levels between 10 to 12 $\mu g/m^3$. While this achievement reflects commendable progress, it's worth noting that achieving and maintaining such standards demand vigilance, as even minor fluctuations can tip the balance. Despite the city's ongoing urbanization and industrialization, which have altered its landscape significantly, Tokyo has managed to reduce pollution levels compared to its industrial heyday. However, vestiges of this era remain, with industrial facilities contributing to elevated $PM_{2.5}$ and PM_{10} levels, along with emissions of nitrogen dioxide (NO_2) and sulfur dioxide (SO_2). While regulations governing fuel standards have curbed emissions from factories, vehicular emissions remain a primary concern, exacerbated by the sheer volume of vehicles on Tokyo's roads, surpassing 4 million in 2014 and likely increasing since then. Despite these challenges, Tokyo has witnessed notable improvements in pollution levels over the years. Incremental reductions, such as the decrease in $PM_{2.5}$ levels from 13 $\mu g/m^3$ in 2017 to 11.7 $\mu g/m^3$ in 2019, underscore the city's commitment to cleaner air. With the continued implementation of effective initiatives and policies, Tokyo stands poised to further enhance its air quality, aspiring to meet the World Health Organization's ambitious standards for clean air.[11]

Consumption & Emissions

Tokyo has also made efforts to reduce its carbon footprint over the years. Despite being one of the most populous cities in the world, Tokyo has implemented various measures to curb greenhouse gas emissions. For example, the city has invested in energy-efficient infrastructure, promoted public transportation, and encouraged the use of renewable energy sources. Tokyo's carbon footprint reduction efforts reflect its commitment to sustainable development and environmental stewardship.

Tokyo stands at the forefront of global urban sustainability efforts, spearheading initiatives aimed at bolstering energy efficiency, optimizing waste management, and fostering green infrastructure. At the heart of its mission lies a commitment to combating climate change, exemplified by the Tokyo Metropolitan Government's (TMG) ambitious pledge to achieve zero emissions by 2050. Recognizing the urgent imperative to curb rising temperatures and combat climate change, the TMG has embarked on a comprehensive city-wide decarbonization endeavor. This multifaceted approach encompasses a spectrum of transformative measures spanning energy, urban infrastructure, and land use, all geared towards slashing carbon emissions at their source. A pivotal aspect of Tokyo's strategy involves meticulously tracing the origins of CO_2 emissions, both internal and external to the city. Internally, focus areas include power generation and various urban activities such as fuel consumption and waste incineration. Externally, factors like the production and transportation of goods, as well as forest deforestation, also contribute to the carbon footprint. The TMG's strategic roadmap prioritizes carbon emission reduction as a precursor to full-scale decarbonization, laying the groundwork for Tokyo's ambitious zero-CO_2 vision.

[10] *Nippon Changes.* (n.d.). Climate impacts threatening Japan today and tomorrow. Retrieved May 14, 2024, from https://www.wwf.or.jp/activities/lib/pdf_climate/environment/WWF_NipponChanges_lores.pdf.

[11] *Tokyo Air Quality Index (AQI) and Japan Air Pollution*. (2024, February 1). IQAir. Retrieved May 14, 2024, from https://www.iqair.com/us/japan/tokyo.

Amidst the looming specter of the climate crisis, Tokyo's proactive stance sets a precedent for global urban sustainability efforts, underpinned by comprehensive policies targeting key sectors. Addressing seven pivotal dimensions ranging from renewable energy to waste reduction, Tokyo's bold leadership extends to inclusive engagement initiatives that mobilize residents, businesses, and organizations alike. Embracing cutting-edge technologies and fostering an ecosystem of innovation, Tokyo charts a course toward a future where sustainability is synonymous with urban living. By charting a course towards zero emissions, Tokyo edges closer to its vision of a fully sustainable, green metropolis, setting a compelling example for cities worldwide to follow suit.[12]

Tokyo is also considering phasing out natural gas usage in municipal buildings and infrastructure to further reduce emissions. This could involve retrofitting existing buildings with energy-efficient technologies and transitioning to electric alternatives powered by renewable energy sources. By reducing reliance on natural gas and promoting renewable energy, Tokyo can contribute to its emissions reduction goals and combat climate change. Retrofitting existing buildings in Tokyo to transition away from natural gas usage would require careful planning and implementation. This may involve upgrading heating, cooling, and lighting systems to improve energy efficiency and reduce emissions. Tokyo's government could incentivize building owners to invest in energy-efficient upgrades and provide support for the adoption of renewable energy technologies. Tokyo has already made significant investments in renewable energy sources, such as solar power and wind energy. By expanding its use of renewable energy, Tokyo can further reduce its carbon footprint and contribute to a more sustainable energy future. Investing in renewable energy infrastructure and technologies also creates opportunities for economic growth and job creation in Tokyo's green energy sector.[13]

Environmental Management

Tokyo, akin to numerous other bustling metropolises, has committed to ambitious waste diversion objectives to curtail the volume of waste destined for landfills. While specific targets may fluctuate, Tokyo aims to elevate recycling rates and champion waste reduction endeavors. Japan's intricate waste management infrastructure offers invaluable insights globally: from segregating polystyrene to repurposing packaging for pharmaceuticals, the nation showcases a comprehensive approach to recycling. The inception of the Basic Act for Establishing a Sound Material-Cycle Society (Basic Recycling Act) in 2000 underscores Japan's dedication to promoting the 3Rs (Reduce, Reuse, Recycle) and fostering proper waste management. Designating every October as 3R Promotion Month, this legislative framework facilitates a concerted effort towards sustainable practices. Innovative initiatives abound, such as supermarkets featuring PET bottle shredders, incentivizing patrons with shopping tokens in exchange for plastic, thereby mitigating emissions associated with waste collection. The recycled PET resin finds new life in an array of products, spanning from textiles and floor coverings to pristine bottles. Furthermore, the advent of waste sorting apps equipped with comprehensive guides and reminders streamlines the process for residents, enhancing participation in waste management practices. Despite Japan ranking second only to the US in per capita plastic packaging waste generation, the nation's proactive waste management strategies, underscored by a robust societal awareness, substantially mitigate plastic leakage into the environment. Of the 9.4 million tonnes of plastic waste annually produced by Japan, the government reports a recycling rate of 25%, with 57% incinerated for energy recovery and 18% consigned to landfill or incinerated. Japan's limited landmass necessitates judicious waste management, resulting in a predominant reliance on waste incineration. While this practice yields electricity, it also raises concerns due to emissions of harmful gasses, including dioxins. Over the past two decades, Japan

[12] Toh, C. K. (2022). Tokyo's city sustainability: Strategy and plans for net zero emissions by 2050. *IET Smart Cities*. https://doi.org/10.1049/smc2.12033.

[13] International Energy Agency. (2021). *Japan 2021 - Energy Policy Review*. https://iea.blob.core.windows.net/assets/3470b395-cfdd-44a9-9184-0537cf069c3d/Japan2021_EnergyPolicyReview.pdf.

has made significant strides in emission reduction through technological advancements, underscoring its commitment to safeguarding public health and the environment.[14]

Sydney, Australia

Indicator	Sydney	Zhuhai	Chinese Avg.
Population (million)	5.03	2.48	7.00
GDP (billion USD)	340.34	60.13	107.05
GDP Growth Rate (%)	1.30	2.30	3.15
Service Sector Added Value (%)	63.30	53.81	51.54
Unemployment Rate (%)	4.15	2.36	2.89
Road Area (m^2 per capita)	32.45	20.07	15.23
House-Income Ratio (price per m^2 / GDP per capita)	0.22	0.13	0.13
Teacher-Student Ratio	1:13.4	1:16.0	1:14.3
Population: Age 0-14 (%)	18.20	16.10	16.69
Urban Green Space (m^2 per capita)	-	127.40	44.99
Air Quality (PM2.5 annual mean, ug/m^3)	8.00	17.00	29.00
Water Consumption (tons/10,000 USD)	14.95	93.12	301.21
Energy Consumption (tce/10,000 USD)	1.06	2.45	3.63
Domestic Sewage Treatment Rate (%)	93.00	99.21	97.19
Household Waste Harmless Treatment Rate (%)	99.74	100.00	99.96

Notes. Data source: Publicly available data sources, see reference for detail. Data year: 2022.

Sydney, the capital city of New South Wales (NSW), Australia, is a vibrant metropolis renowned for its stunning harbor, iconic landmarks, and diverse cultural landscape. The metropolitan area, known as the Greater Sydney, spans an area of approximately 4,775 square miles (12,367 square kilometers), and is home to about 5.3 million residents, making it one of the largest and most populous urban areas in Australia.[15] The City of Sydney local area covers 26.15 square kilometers and is a vital economic hub and tourism gateway for Australia.

Economic Development

Sydney's economy is dynamic and multifaceted, serving as a major financial, commercial, and cultural hub in the Asia-Pacific region. In 2021/22 Greater Sydney generated an estimated economic output of over USD 490 billion which represented 23% of Australia's GDP.[16]

It is a large financial and business services hub of Australia, with a concentration of jobs within the multimedia and communications industries, tourism, hospitality and cultural industries. Health care and social assistance industry represent the highest share of total Greater Sydney jobs (13%) followed by professional, scientific and technical services (12.7%), retail trade (9.2%) and education and training (8.4%). The total labor force for Greater Sydney, as per the 2021 census was around 2.56 million. The labor force represents around a fifth of the total national workforce.[16]

Sydney is of strategic significance to Australia's economic prosperity in the following areas.

[14] *This Japanese word is helping the country recycle and waste less*. (2019, August 16). The World Economic Forum. Retrieved May 14, 2024, from https://www.weforum.org/agenda/2019/08/the-japanese-have-a-word-to-help-them-be-less-wasteful-mottainai/.

[15] *Greater Sydney 2021 Census All persons QuickStats*. (n.d.). Australian Bureau of Statistics. Retrieved May 14, 2024, from https://www.abs.gov.au/census/find-census-data/quickstats/2021/1GSYD.

[16] *The City at A Glance.* (2023, December 7). City of Sydney. Retrieved May 14, 2024 from https://www.cityofsydney.nsw.gov.au/guides/city-at-a-glance.

Financial Center: Sydney boasts a thriving financial sector, anchored by the presence of major banks, financial institutions, and the Australian Securities Exchange (ASX). The city's central business district, including areas like Barangaroo and Martin Place, serves as a prominent financial hub, attracting domestic and international investors.

Innovation and Technology: Sydney's technology and innovation ecosystem is flourishing, supported by leading research institutions, start-up incubators, and tech accelerators. The city is home to a burgeoning tech scene, with companies specializing in fintech, biotech, artificial intelligence, and renewable energy driving innovation and entrepreneurship.

Tourism and Hospitality: Sydney's picturesque beaches, iconic landmarks such as the Sydney Opera House and Harbour Bridge, and vibrant cultural events attract millions of tourists annually, contributing significantly to the city's tourism industry. The hospitality sector, including hotels, restaurants, and entertainment venues, plays a vital role in Sydney's economy, providing employment opportunities and driving economic growth.

Infrastructure Development: Sydney is undergoing extensive infrastructure development projects aimed at enhancing connectivity, transportation, and urban livability. Major initiatives include the Sydney Metro expansion, WestConnex motorway project, and revitalization of public spaces and waterfront precincts.

Social Welfare & Livelihood

Sydney's social welfare programs prioritize the well-being and livelihoods of its diverse population, addressing various social and economic challenges.

Education**:** Sydney offers a high-quality education system, with a wide range of public and private schools, vocational training institutions, and world-renowned universities. The city's education sector focuses on providing accessible and equitable learning opportunities to students of all backgrounds, fostering academic excellence and skill development.

Healthcare: Sydney's healthcare system provides comprehensive medical services through public hospitals, private clinics, and healthcare facilities. Accessible healthcare services, preventive care programs, and medical research initiatives contribute to the overall health and well-being of Sydney's residents.

Social Support Programs: Sydney implements social support programs to assist vulnerable individuals and communities, including affordable housing initiatives, homelessness prevention services, and food assistance programs. For instance, the Food Support Grant ensures access and supply to healthy food across communities. This program provides assistance for support under two tiers - large scale and small scale projects and recently awarded $1.5 million in grants to 12 organizations to help with food and essential items for diverse communities over 2024. Such initiatives aim to address socio-economic disparities and promote social inclusion and equality.[17]

Housing: The NSW state government's efforts to boost housing density (apartments around train stations) has been met with opposition by local residents who argue that construction of high rise buildings will harm the environment and compromise the city's heritage. However, with strong population growth, rising immigration and limited supply, the city is constrained with lack of new sufficient projects to fulfill demand leading to skyrocketing housing prices severely impacting the cost of living.[18]

Environmental Resources

[17] *Food Support Grant.* (n.d.). City of Sydney. Retrieved May 14, 2024 from https://www.cityofsydney.nsw.gov.au/community-support-funding/food-support-grant.

[18] Panday, S., & Partis, E. (2024, March 13). *Sydney Faces Growing Pains as Its Housing Crisis Deepens*. Bloomberg. https://www.bloomberg.com/news/articles/2024-03-13/sydney-faces-a-housing-crisis-apartments-could-help-but-it-s-facing-a-backlash.

Sydney is committed to environmental conservation and sustainability, implementing initiatives to mitigate climate change, preserve natural resources, and enhance environmental resilience.

Sydney prioritizes green infrastructure development through its Greening Sydney Strategy, which includes urban parks, green spaces, and biodiversity conservation areas, to enhance environmental quality and promote ecological resilience. Tree planting initiatives, water conservation measures, and green building standards contribute to Sydney's sustainable urban planning efforts. Australia has the world leading National Australian Built Environment Rating System (NABERS) scheme, which rates the performance of many building classes. The minimum energy performance standards for new buildings and major retrofits of existing buildings are defined in the National Construction Code. The city also has the Green Star sustainability rating and certification system and has been a member of the Green Building Council since 2003.

Sydney addresses the impacts of climate change through climate adaptation strategies, such as coastal resilience measures, flood mitigation projects, and emergency response plans. The city's commitment to climate action and resilience building aims to protect communities, infrastructure, and natural ecosystems from climate-related risks and hazards.

Consumption & Emissions

As of 2018–19, Sydney recorded net greenhouse gas emissions (GHG) of 136.6 million tons carbon dioxide equivalent ($tCO_{2\text{-}e}$).[19] The City of Sydney declared a climate emergency in June 2019, stating that climate change poses a serious risk to the people of Sydney. Since 2020, Sydney has been at the forefront of climate action, implementing ambitious plans and initiatives to mitigate greenhouse gas emissions, enhance environmental resilience, and transition to a low-carbon economy.[20]

The NSW Climate Change Fund was established in 2007 under the *Energy and Utilities Administration Act 1987* to provide funding that reduces greenhouse gas emissions and the impacts of climate change associated with water and energy activities. In 2019–20, the fund invested AUD 229 million (USD 159 million) to deliver programs that support households, businesses and communities to reduce energy consumption and carbon emissions and become more resilient to a changing climate.[21]

The City of Sydney was certified carbon-neutral - the first local government in Australia - in 2011. The city continued to join the global efforts to combat climate change by unveiling its Energy and Climate change plan in 2021. This comprehensive strategy outlines a roadmap to achieve net-zero carbon emissions across the city by 2050. The plan encompasses various sectors, including energy, transportation, buildings, waste management, and urban planning, and sets specific targets and milestones for emission reduction.[22] The targets include:

- 70% reduction in greenhouse gas emissions by 2030 from 2006 baseline
- Net zero emissions by 2035
- 50% of electricity demand met by renewable sources by 2030

[19] *NSW State of the Environment – Greenhouse Gas Emissions.* (n.d.). NSW Environment Protection Authority. Retrieved May 14, 2024 from https://www.soe.epa.nsw.gov.au/all-themes/climate-and-air/greenhouse-gas-emissions.

[20] *Climate emergency response*. (2019, June 24). City of Sydney. Retrieved May 15, 2024 from https://www.cityofsydney.nsw.gov.au/strategies-action-plans/climate-emergency-response.

[21] *NSW Climate Change Fund*. (n.d.). NSW Government. Retrieved May 15, 2024 from https://www.energy.nsw.gov.au/nsw-plans-and-progress/government-strategies-and-frameworks/taking-action-climate-change/nsw.

[22] *Energy and climate change*. (n.d.). City of Sydney. Retrieved May 15, 2024 from https://www.cityofsydney.nsw.gov.au/environmental-action/energy-and-climate-change#:~:text=Our%20environmental%20strategy%202021%2D2025,by%20renewable%20sources%20by%202030.

Sydney has set a role model for others by fueling 100% of electricity requirements from municipal buildings by renewable energy - solar and wind energy. This incorporates all city-owned properties, including 115 buildings, community halls and office buildings, 75 parks, five pools and 23,000 street lights, and the Sydney Town Hall. The switch has been made through a ten-year power purchase agreement with Australian retailer Flow Power.[23] This achievement is way above the targets attained by the state government (19% renewables).[24] Transport sector remained the biggest energy user at 47% of total energy use in NSW and the Australia Capital Territory (ACT).

Transportation Electrification: Recognizing the transportation sector as a significant contributor to carbon emissions, Sydney is promoting the electrification of public and private transportation. The city is investing in electric vehicle charging infrastructure, incentivizing the purchase of electric vehicles, and expanding public transit services to reduce reliance on fossil fuel-powered vehicles.[25]

In terms of water consumption, the NSW Government has formulated the Greater Sydney Water Strategy (Implementation Plan 2022-2025) to provide guidance for delivering sustainable and resilient water services for the next 40 years, proactive planning to combat climate events such as drought and extreme weather, through improved water conservation and efficiency, optimizing desalination plant, and new infrastructure that would enhance rainfall-independent supply.[26]

Environmental Management

Since 2004, the residential population in the city has increased by 67%. Local jobs had increased by 54.3% and, pre-Covid, there were 1.3 million people in the city per day. For a growing city with a large populace including residents, businesses, and tourists, recycling and waste management are two prominent issues. Sydney produces over 3.5 million tons of waste every year.[27] The NSW Waste and Resource Recovery Report deduced that more than 50% of NSW's waste came from Sydney alone and only 40% of it is recycled. To tackle the issue, Sydney is making efforts to educate residents on options for recycling. The Waste Strategy and Action Plan 2017-2030 is an ambitious plan to reduce waste in the city over the coming decade drastically. The plan aims at achieving the long-term goal of zero waste through six priorities: *promote innovation to avoid waste, improve recycling outcomes, sustainable design, clean and clear streets, better data management*, and *future treatment solutions*.[28]

San Francisco, United States

Indicator	San Francisco	Zhuhai	Chinese Avg.
Population (million)	**7.50**	**2.48**	**7.00**
GDP (billion USD)	**654.73**	**60.13**	**107.05**
GDP Growth Rate (%)	**1.20**	**2.30**	**3.15**

[23] Wray, S. (2020, July 6). *Sydney switches to 100 percent renewable energy*. Cities Today. https://cities-today.com/sydney-switches-to-100-percent-renewable-energy/.

[24] *NSW State of the Environment - Energy Consumption*. (n.d.). NSW Environment Protection Authority. Retrieved May 14, 2024 from https://www.soe.epa.nsw.gov.au/all-themes/human-settlement/energy-consumption.

[25] *EV Charging Program*. (2024, June 3). NSW Government. Retrieved May 15, 2024 from https://www.transport.nsw.gov.au/projects/current-projects/ev-charging-program#:~:text=Transport%20for%20NSW%20is%20delivering,and%20wherever%20they%20need%20to.

[26] Department of Planning and Environment. (n.d.). *Greater Sydney Water Strategy: Implementation Plan 2022-2025.* Retrieved May 15, 2024 from https://water.nsw.gov.au/__data/assets/pdf_file/0020/527312/greater-sydney-water-strategy-implementation-plan.pdf.

[27] Schutz, B. (2023, October 10). *An In-Depth Look at Sydney's Waste and Recycling Statistics*. Best Price Skip Bins. https://bestpriceskipbins.com.au/sydney-waste-and-recycling-statistics/.

[28] *Leave Nothing to Waste: Waste Strategy and Action Plan 2017-2030.* (n.d.). City of Sydney. Retrieved May 15, 2024 from file:///C:/Users/wang1/Downloads/Leave%20nothing%20to%20waste%20strategy%20and%20action%20plan%2020172030.pdf.

Service Sector Added Value (%)	**-**	**53.81**	**51.54**
Unemployment Rate (%)	**3.40**	**2.36**	**2.89**
Road Area (m^2 per capita)	**-**	**20.07**	**15.23**
House-Income Ratio (price per m^2 / GDP per capita)	**0.12**	**0.13**	**0.13**
Teacher-Student Ratio	**1:21.1**	**1:16.0**	**1:14.3**
Population: Age 0-14 (%)	**11.50**	**16.10**	**16.69**
Urban Green Space (m^2 per capita)	**1.83**	**127.40**	**44.99**
Air Quality (PM2.5 annual mean, ug/m^3)	**8.50**	**17.00**	**29.00**
Water Consumption (tons/10,000 USD)	**18.97**	**93.12**	**301.21**
Energy Consumption (tce/10,000 USD)	**1.24**	**2.45**	**3.63**
Domestic Sewage Treatment Rate (%)	**100.00**	**99.21**	**97.19**
Household Waste Harmless Treatment Rate (%)	**100.00**	**100.00**	**99.96**

Notes. Data source: Publicly available data sources, see reference for detail. Data year: 2022.

The San Francisco Bay Area, commonly known as the Bay Area, is a metropolitan region that surrounds the San Francisco and San Pablo estuaries in Northern California. The region encompasses metropolitan areas such as San Francisco-Oakland (12th largest in the U.S.), San Jose (31st largest), along with smaller urban and rural areas. Overall, the Bay Area consists of nine counties, 101 cities, and 7,000 square miles. The nine counties are Alameda, Contra Costa, Marin, Napa, San Francisco, San Mateo, Santa Clara, Solano, and Sonoma. The United States Census Bureau considers the Bay Area a Combined Statistical Area (CSA) with approximately 7.5 million people, including the nine counties bordering San Francisco Bay as well as Santa Cruz and San Benito Counties, making it the sixth largest CSA in the United States.[29]

In 2002, San Francisco set an ambitious sustainability strategic plan of achieving 75% waste diversion (from landfills) by 2010 and laid the groundwork for a long-term aspiration of zero waste. Remarkably, the city surpassed its initial goal two years ahead of schedule. This plan included strict sustainability laws, partner collaborations, and achieving an impressive diversion rate exceeding 80% and effectively halving its disposal rates. This milestone marked a pivotal moment in San Francisco's commitment to sustainable management and set a precedent for the city's commitment to environmental sustainability.[30]

Economic Development

In 2022, the economic prowess of the San Francisco Bay Area reached a formidable milestone, with a robust GDP totaling 654.73 billion U.S. dollars. This marked an impressive increase of 65.17 billion U.S. dollars over the preceding two years, covering the challenging period of the COVID-19 pandemic in 2020.

Over the decade spanning from 2001 to 2011, the Bay Area exhibited a consistent trajectory of GDP growth. However, the economic landscape underwent a transformative shift in 2012, catapulting into an era of unprecedented expansion. This meteoric rise is attributed to the flourishing tech sector and the presence of high-value corporations headquartered in Silicon Valley, a pivotal hub within the Bay Area renowned as the epicenter of the global technology industry. Distinguished entities such as Google, Facebook, eBay, and Apple call Silicon Valley home. Moreover, California clinched the top spot in the nationwide GDP ranking, boasting a staggering 3.59 trillion U.S. dollars in GDP for the year 2022.[29]

As of 2023, San Francisco maintains a commendable low unemployment rate of approximately 3%, 0.8 percentage points below the national level and 1.7 percentage points below the state level according to data from the California Employment Development Department (EDD). This figure represents a marginal uptick from the 2019 average unemployment rate of 2.2%. Notably, the onset of the pandemic led to a spike in unemployment, reaching a peak of 13.3% in May 2020—

[29] *San Francisco Bay Area GDP U.S. 2022*. (2023, December 8). Statista. Retrieved January 31, 2024, from https://www.statista.com/statistics/183843/gdp-of-the-san-francisco-bay-area/.

[30] *Zero Waste Case Study: San Francisco | US EPA*. (2023, November 22). Environmental Protection Agency (EPA). Retrieved February 21, 2024, from https://www.epa.gov/transforming-waste-tool/zero-waste-case-study-san-francisco.

surpassing the pre-pandemic rate by more than sixfold. Since then, the city has made a resilient recovery. This robust recovery underscores the city's resilience in the face of economic challenges.[31]

Social Welfare & Livelihood

As of the latest available data in 2018, San Francisco boasted a population density of 7,167 habitants/km^2. Demonstrating a consistent upward trajectory, the city's population density experienced an average growth rate of 1.01% since the initial recording in 2009. Projections based on historical trends suggest a continued rise, with an anticipated population density reaching 7,500 habitants/km2 by the year 2023.[32]

San Francisco's demographic makeup reflects a dynamic age distribution, with 13.4% of the population under 18, 9.6% aged 18 to 24, 37.5% falling within the 25 to 44 age bracket, 25.9% in the 45 to 64 range, and 13.6% aged 65 or older. The city boasts an average age of 38.5 years, showcasing a distinctive profile characterized by a lower percentage of children compared to other major metropolitan areas in the United States.[33]

Renowned as the vibrant epicenter of Northern California, San Francisco has consistently maintained its status as a high-priced real estate market. Even with a modest decline in prices, the cost per square foot in this densely populated city remains nearly $1,000. Noteworthy housing metrics include a housing-to-income ratio of 0.12, a median home price of $1,522,827, a median household income of $123,859, and a substantial 5-year change in median home price at +28.2%. Furthermore, 37.2% of mortgage holders allocate more than 30% of their income towards housing costs.[34]

In the realm of education, California presents a teacher-to-student ratio of 1:22:1. Along with 17 out of the other 50 jurisdictions (comprising states and the District of Columbia), California's student-teacher ratio depicts a more restricted educational resources than the national average of 1:15.5.[35]

In terms of urban transportation, the San Francisco Bay Area Rapid Transit District (BART) stands as a robust heavy-rail public transit system seamlessly connecting the San Francisco Peninsula with communities in the East Bay and South Bay. BART's extensive service currently extends to Millbrae, Richmond, Antioch, Dublin/Pleasanton, and Berryessa/North San José. Encompassing five counties—San Francisco, San Mateo, Alameda, Contra Costa, and Santa Clara—the system spans 131 miles (211 km) of track and comprises 50 stations, underscoring its integral role in facilitating urban transportation throughout the region.[36]

Environmental Resources

San Francisco's Mediterranean-type climate is meticulously characterized by mild, wet winters and warm, dry summers, fostering a habitat conducive to high biological diversity. This climatic profile plays a pivotal role in shaping the city's ecological landscape. San Francisco Bay, a vital estuary, sustains a unique ecosystem where saltwater and freshwater converge. However, the ecosystem faces imminent risks due to drastic changes in Bay inflow, leading to the exceeding of

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[31] *San Francisco Monthly Unemployment | San Francisco*. (n.d.). City of San Francisco. Retrieved February 5, 2024, from https://www.sf.gov/data/san-francisco-monthly-unemployment.

[32] *Population Density Data for San Francisco, CA - Population on the Open Data Network.* (n.d.). Open Data Network. Retrieved March 26, 2024, from https://www.opendatanetwork.com/entity/1600000US0667000/San_Francisco_CA/geographic.population.density?year=2018.

[33] *San Francisco, California Population 2024.* (n.d.). World Population Review. Retrieved February 10, 2024, from https://worldpopulationreview.com/us-cities/san-francisco-ca-population.

[34] Jones, J. (2023, October 26). *U.S. Cities With the Highest Home Price-to-Income Ratios in 2021*. Construction Coverage. https://constructioncoverage.com/research/cities-with-highest-home-price-to-income-ratios-2021.

[35] Hart, K. (n.d.). *Which U.S. States Have the Highest and Lowest Student/Teacher Ratios?* AAA State of Play. https://www.aaastateofplay.com/which-us-states-have-the-highest-and-lowest-student-teacher-ratios/.

[36] *Bay Area Rapid Transit.* (n.d.). About | Bay Area Rapid Transit. BART.gov. Retrieved March 26, 2024, from https://www.bart.gov/about.

state Water Quality Standards for various contaminants. Addressing these challenges is crucial for preserving the Bay's ecological integrity.[37]

In terms of green space, while Golden Gate Park garners international acclaim as one of the most beautiful parks globally, San Francisco boasts a diverse array of open spaces encompassing 5,384 acres, constituting 17.9 percent of the city's land. This diversity underscores the city's commitment to providing accessible and aesthetically pleasing natural environments.

San Francisco employs recycled water as a strategic resource to supplement imported water supplies. This practice, mandated by the Recycled Water Ordinance, involves using recycled water for landscape irrigation, toilet/urinal flushing, cooling, and water features. The city's commitment to maximizing recycled water usage reflects a forward-thinking approach to sustainable water management.[38]

The region experiences year-to-year variability in precipitation, with fluctuation between very wet and very dry years. Approximately 60% of the region's water supply is sourced in the Sierra Nevada, and Sierra snowmelt provides 40% of the annual water to the San Francisco Bay Delta, which is expected to be impacted by warming temperatures and changes in precipitation. The Bay Area region's characteristic wet winter will bring more intense and damaging winter storms, and, as surface temperatures continue to rise, the historic location of the freezing line in mountains will move upslope, causing more storms to fall as rain rather than snow.

San Francisco boasts a commendable air quality, consistently earning a "good" rating on the United States Air Quality Index (US AQI), indicative of a fine particulate matter ($PM_{2.5}$) concentration between 0 to 12 $\mu g/m^3$. In 2019, the city achieved an annual $PM_{2.5}$ concentration of 7.1 $\mu g/m^3$, aligning with the World Health Organization's (WHO) target of an annual reading below 10 $\mu g/m^3$. This places San Francisco on par with other metropolises like New York (7 $\mu g/m^3$), surpassing cities such as Los Angeles (12.7 $\mu g/m^3$), London (11.4 $\mu g/m^3$), and Paris (14.7 $\mu g/m^3$). The good air quality rating in San Francisco can be attributed to the city's coastal location, as well as its natural topography and having a sparse level of factories and other industrial production plants around the city limits. Air pollution in San Francisco comes primarily from transportation emissions, namely vehicles such as cars, motorbikes and trucks, as well as planes, and ships all contributing to the ambient levels of air pollution. Wildfires, which are becoming increasingly common in the Bay Area, give rise to drastic spikes of air pollution, usually occurring during summer and fall. Without taking into account the effects of potential wildfires, winter months are commonly much more polluted than the summer season, often as a result of increased heating and wood burning taking place. Additionally, cold weather conditions can affect the behavior of air pollution particles. During cold conditions, occasionally a layer of warmer air can become held above a cooler of ground-level air, known as a thermal inversion, leads the warm layer of air to act like a "cap" or a lid, trapping the air beneath for long periods of time, usually until a weather change such as winds arrives to disperse it. These inversions can therefore prolong and exacerbate existing air pollution and smog in San Francisco and the Bay Area during wintertime.[39]

The region is expected to undergo warming trends, with projected temperature increases by 3–4.5°F by 2050 and 5.5–8°F by 2100. This warming, combined with urban development in wildland-urban interfaces, raises concerns about prolonged droughts and heightened fire risks, necessitating proactive strategies for climate adaptation and mitigation.

[37] *San Francisco Bay Area Region*. (n.d.). California Climate Adaptation Strategy. Retrieved March 26, 2024, from https://climateresilience.ca.gov/regions/sf-bay-area.html.

[38] *Recycled Water Use*. (1991, November 7). San Francisco Public Utilities Commission. Retrieved February 19, 2024, from https://sfpuc.org/construction-contracts/design-guidelines-standards/recycled-water-use.

[39] *San Francisco Air Quality Index (AQI) and California Air Pollution*. (2024, February 1). IQAir. Retrieved February 19, 2024, from https://www.iqair.com/us/usa/california/san-francisco.

Currently, San Francisco stands as a global leader in urban sustainability, implementing innovative programs such as zero waste strategies, residential composting, and green waste recycling. The city's commitment to energy efficiency and renewable energy further solidifies its position as an exemplar of comprehensive urban sustainability initiatives.

Consumption & Emissions

Between 1990 and 2020, San Francisco achieved an impressive feat, slashing its carbon footprint by a substantial 48%, all while experiencing a notable 21% increase in population and a remarkable 194% surge in gross domestic product (GDP). This remarkable progress demonstrates the city's ability to effectively curtail greenhouse gas emissions while simultaneously fostering economic growth.[40] San Francisco's total greenhouse gas emissions plummeted from 7.9 million $tCO_{2\text{-}e}$ in 1990, to 4.12 million $tCO_{2\text{-}e}$ in 2022. Per capita emissions dropped from 11 $tCO_{2\text{-}e}$ to 5.1 $tCO_{2\text{-}e}$ during the same period.

The major contributors to San Francisco's emissions are derived from natural gas and electricity consumption in buildings, as well as fuel consumption in cars and trucks. Additional sources include emissions from organic waste landfilling, municipal operations, agriculture/urban soils, and wastewater treatment. In a bold move to further mitigate emissions from the municipal sector, the San Francisco Board of Supervisors took decisive action by voting to phase out natural gas usage in new and significantly renovated city buildings. Given that natural gas accounts for a substantial 99% of greenhouse gas emissions from municipal buildings, this strategic decision represents a tangible and impactful step towards achieving San Francisco's ambitious emissions reduction goals. The phase-out of natural gas usage in new city buildings would take effect immediately upon the passing of the ordinance by the San Francisco Board of Supervisors. This means that any new municipal buildings or structures undergoing significant renovations would not incorporate natural gas infrastructure. For existing buildings undergoing significant renovations, the timeline would involve retrofitting existing natural gas infrastructure to transition away from its usage. This process might include the removal of gas-powered appliances, such as water heaters, stoves, and furnaces, and their replacement with electric alternatives. The timeline for this retrofitting process could be set to ensure completion within a specific period, such as within the next 5 to 10 years. As an alternative to natural gas, electricity sourced from renewable energy would be the primary focus. San Francisco has been investing in renewable energy sources such as solar, wind, and hydroelectric power. Increasing the city's reliance on renewable electricity would not only reduce greenhouse gas emissions but also align with the city's broader sustainability goals.

Environmental Management

As mentioned in the beginning, San Francisco achieved an impressive diversion rate exceeding 80% and effectively halved its disposal rates between 2010 and 2002. This milestone marked a pivotal moment in San Francisco's commitment to sustainable waste management. However, it is important to note that San Francisco's high diversion rate is partly attributed to its inclusion of large quantities of heavy construction materials (like excavated fill and rubble) reused as infill and road base, and biosolids applied to agricultural land. These materials, along with significant amounts of paper, metal, glass, and plastic recycling, and organic composting, contribute to the city's impressive diversion figures. In contrast, other cities and countries typically compile municipal solid waste (MSW) diversion statistics not taking into account construction materials and biosolids. However, despite the fact that San Francisco's MSW diversion rate may be inflated by the unconventional statistical approach, the city's commitment in and achievement of waste management is still remarkable.

In 2006, San Francisco implemented a Construction and Demolition Debris Recovery Ordinance, compelling the recovery of materials in these sectors. The momentum continued with the introduction of the Mandatory Recycling and Composting Ordinance in 2009, which mandated the separation of recyclables, compostables, and trash by all residents. In 2018, San

[40] *San Francisco's Carbon Footprint | San Francisco Environment Department (SFE).* (n.d.). SF Environment. Retrieved February 21, 2024, from https://www.sfenvironment.org/carbonfootprint.

Francisco reaffirmed its commitment to zero waste by updating its targets, aiming to reduce solid waste generation by 15% and decrease landfill or incineration disposal by 50% by 2030.

A critical element contributing to San Francisco's success is its exclusive partnership with waste management company Recology. This collaborative approach streamlines administrative processes and facilitates a synergistic pursuit of long-term goals. In contrast, cities like New York contend with a fragmented commercial waste collection system, composed of numerous competing companies, hindering cohesive citywide initiatives.[41]

San Francisco's waste management strategy extends to an innovative three-stream collection program, encompassing commingled recyclables, compostables (including food scraps, soiled paper, and plant trimmings), and residual trash. Multilingual outreach efforts, supported by images, ensure effective communication with diverse communities.

For composting, all the city's yard waste and food scraps find a sustainable home at Jepson Prairie Organics in Vacaville, approximately 60 miles northeast of San Francisco. Here, compostables undergo meticulous processing, eventually transforming into nutrient-rich fertilizer sold to vineyards in wine country and nut growers in the Central Valley. San Francisco's holistic and forward-thinking waste management practices serve as a model for sustainable urban living and circular utilization of resources.

Oslo, Norway

Indicator	Oslo	Zhuhai	Chinese Avg.
Population (million)	1.45	2.48	7.00
GDP (billion USD)	83.54	60.13	107.05
GDP Growth Rate (%)	9.97	2.30	3.15
Service Sector Added Value (%)	41.70	53.81	51.54
Unemployment Rate (%)	3.20	2.36	2.89
Road Area (m^2 per capita)	112.80	20.07	15.23
House-Income Ratio (price per m^2 / GDP per capita)	0.06	0.13	0.13
Teacher-Student Ratio	1:9.0	1:16.0	1:14.3
Population: Age 0-14 (%)	17.27	16.10	16.69
Urban Green Space (m^2 per capita)	177.00	127.40	44.99
Air Quality (PM2.5 annual mean, ug/m^3)	7.21	17.00	29.00
Water Consumption (tons/10,000 USD)	79.24	93.12	301.21
Energy Consumption (tce/10,000 USD)	0.99	2.45	3.63
Domestic Sewage Treatment Rate (%)	-	99.21	97.19
Household Waste Harmless Treatment Rate (%)	-	100.00	99.96

Notes. Data source: Publicly available data sources, see reference for detail. Data year: 2022.

Economic Development

Oslo Metro Area, or City of Oslo, is the economic capital and political center of Norway. In 2023, the GDP of the city of Oslo was approximately EUR 79.3 billion.

From 2021 to 2022, Oslo, like the rest of Norway, experienced significant economic changes due to the pandemic. In 2021, Norway's overall economy grew positively due to the soaring prices of oil and natural gas. This growth contributed significantly to the country's GDP. Norway's overall GDP growth rate hit 8.1% that year, while the GDP of Oslo, the capital

[41] Brigham, K. (2018, July 14). *San Francisco leads the world when it comes to waste management*. CNBC. https://www.cnbc.com/2018/07/13/how-san-francisco-became-a-global-leader-in-waste-management.html.

of Norway, grew by 9.97%. Despite a temporary slowdown in all economic activities in December 2021 due to the impact of COVID-19, Norway experienced strong economic growth for the year, primarily driven by the oil and gas industry.[42][43] In 2022, Norway's economy, including Oslo, experienced significant growth, with price increases particularly apparent in energy-related products. Mainland Norway's GDP grew by 3.8% during the year.[44] From 2021 to 2022, GDP growth can be attributed to the recovery from the pandemic and rising commodity prices. Despite increasing consumer costs, national consumption power remained robust.

In 2022, Oslo's economy grew significantly, driven by high oil and natural gas prices. In addition, the service industry that recovered from the pandemic also significantly contributed to GDP growth, as the sector accounts for 41.7% of Oslo's GDP. Despite rising inflation and interest rates, the overall domestic consumption is still growing. With the support of the government's strong measures, employment continued to increase, and the growth gradually slowed down toward the end of 2022.[44] Between 2021 and 2022, Oslo also saw an improvement in its unemployment rate. According to Statistics Norway, the average unemployment rate in Oslo in mid-July 2021 was approximately 4.2%,[45] while in 2022, Oslo's unemployment rate dropped to 3.2%.[46] The decline in unemployment reflects Norway's economic recovery from the pandemic.

Social Welfare & Livelihood

Our indicator shows that Oslo's housing-to-income ratio is approximately 0.065. This is comparable to European and North American cities previously reported, such as Barcelona, Eindhoven, and New York, but is substantially lower than the Chinese city average ratio, and ratios of Asian metropolitans like Hong Kong, Tokyo, and Singapore. On the one hand, housing prices in Oslo are not particularly high (EUR 7,225/m^2 unit price is lower than many Chinese cities). On the other hand, the income levels of residents in Oslo are typically higher than those of the Chinese citizens, making housing relatively more affordable in Oslo.[47]

In terms of education, among the available information, the teacher-student ratio in primary and secondary schools in Norway is 1:9. This is higher than both the Chinese average (1:14.3) and the best performing city in China, Qiqihar (1:10.4), suggesting more abundant educational resources.

Oslo provides universal healthcare services, ensuring all residents have access to essential medical care through the National Insurance Scheme. This includes the assignment of a General Practitioner (GP) to every resident, facilitating primary care and referrals for specialized treatment. Emergency medical services are also easily accessible across the city.[48]

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[42] Von Hirsch, E. (2022b, February 16). *Strong resurgence in the Norwegian economy in 2021*. SSB. https://www.ssb.no/en/nasjonalregnskap-og-konjunkturer/nasjonalregnskap/statistikk/nasjonalregnskap/artikler/strong-resurgence-in-the-norwegian-economy-in-2021.

[43] International Monetary Fund. (2022). NORWAY/2022 ARTICLE IV CONSULTATION—PRESS RELEASE; STAFF REPORT; AND STATEMENT BY THE EXECUTIVE DIRECTOR FOR NORWAY: IMF Country Report No. 22/304. In *International Monetary Fund*. Retrieved August 3, 2024, from IMF Staff Country Reports Volume 2022 Issue 304: Norway: 2022 Article IV Consultation-Press Release; Staff Report; and Statement by the Executive Director for Norway (2022).

[44] Engum, J., & Von Hirsch, E. H. (2023, February 15). *Norwegian economy in 2022: High growth, high prices*. SSB. https://www.ssb.no/en/nasjonalregnskap-og-konjunkturer/nasjonalregnskap/statistikk/nasjonalregnskap/artikler/norwegian-economy-in-2022-high-growth-high-prices.

[45] Aamodt, I. (2021, September 23). *Decrease in unemployment*. SSB. https://www.ssb.no/en/arbeid-og-lonn/sysselsetting/statistikk/arbeidskraftundersokinga-sesongjusterte-tal/artikler/decrease-in-unemployment.

[46] *High inflation leads to downturn in Norwegian economy*. (2022, September 9). SSB. https://www.ssb.no/en/nasjonalregnskap-og-konjunkturer/konjunkturer/statistikk/konjunkturtendensene/articles/high-inflation-leads-to-downturn-in-norwegian-economy.

[47] *World Bank Open Data*. (n.d.). World Bank Open Data. https://data.worldbank.org/indicator/NY.GDP.MKTP.KD.ZG?locations=NO.

[48] *Healthcare services - Health care and welfare - Oslo kommune.* (n.d.). Oslo Kommune. Retrieved August 3, 2024 from https://www.oslo.kommune.no/english/welcome-to-oslo/health-care-and-welfare/healthcare-services/#toc-2.

For the senior citizens of the city, the "Action Plan for an Age-Friendly Oslo" outlines Oslo's key strategies to build an inclusive and supportive environment that allows seniors to live independently and with dignity. The city prioritizes accessible and affordable housing, including assisted living options, and offers comprehensive healthcare and social services focused on preventive care and mental health support. Transportation and mobility initiatives ensure that public transit and city infrastructure are senior-friendly. In 2022, Oslo upgraded its public transport infrastructure by introducing low-floor trams and buses and installing ramps and tactile paving at stations to improve access for individuals with disabilities. Digital accessibility was also improved with enhancements to the *Ruter* app, providing features like audio guidance for visually impaired users. As part of the transition to a fully electric public transport system, new vehicles were designed with accessibility in mind, ensuring quieter and smoother rides for all passengers. Additionally, public transport staff received training to better assist those with mobility challenges and dementia.[4950]

The city also promotes social participation through community activities, volunteer opportunities, and lifelong learning programs, while fostering respect and inclusion by addressing age discrimination. Finally, Oslo supports seniors' involvement in civic activities and ensures clear communication channels to keep them informed and engaged.[51]

Environmental Resources

In 2022, Oslo continued to prioritize urban green space as part of its commitment to sustainability and improving the quality of life for its residents. The city allocated 72% of its land to green spaces, making it one of the greenest capitals in Europe. This extensive green coverage is part of a broader strategy to combat climate change, enhance biodiversity, and provide recreational areas for the community.[52]

One of the key initiatives was the "Oslotrær" (Oslo Trees) project, which aimed to plant 100,000 trees by 2030. By 2022, the project had already planted over 3,200 trees, involving community groups and public institutions.[53] The project also integrated green spaces into urban planning through the Blue-Green Factor (BGF) norm, which started in 2014 in Oslo and Bærum as a performance-based indicator designed to ensure adequate vegetation cover and surface water management in residential projects. In application, the BGF is essentially a metric for neighborhood green space and green infrastructure based on stormwater retention, blue/green structure, biodiversity and recreation and amenities. New development projects need to achieve above average metric score in the area to be approved. Officially adopted as a city norm in 2019, the BGF has since become a national standard in Norway, supporting Oslo's environmental strategies like stormwater management, the Green Roof Strategy, and the Oslo Tree Project.[54]

Additionally, Oslo focused on restoring urban waterways, to enhance biodiversity and create more public spaces. As a country with plenty of rivers and fjords, cities in the country, including Oslo, had systematically converted waterways in urban areas to underground culvert systems, to increase usable land areas by the 1980s. However, with more understanding and recognition of the quintessential roles the waterways play, as natural habitats for wildlife and for

[49] Staropoli, A. (2023, July 10). *Both public and private transportation in Oslo are close to going fully electric*. Commercial Observer. https://commercialobserver.com/2023/07/electriciation-oslo-norway-transport/.
[50] *Accessibility*. (n.d.). Ruter. https://ruter.no/en/journey/accessibility/.
[51] *Action plans for: Age-friendly city Safe and diversified care of older people: City Government Propositions 174/17 and 175/17*. (n.d.). City of Oslo. Retrieved August 24, 2024, from https://extranet.who.int/agefriendlyworld/wp-content/uploads/2015/03/Action-plan-age-friendly-Oslo.pdf.
[52] *Which European capitals have the most green spaces?* (2023, March 2). World Economic Forum. https://www.weforum.org/agenda/2022/08/green-space-cities-climate-change/.
[53] *Oslotrær - The Oslo Trees integrated project*. (2023, August 30). Interlace Hub. https://interlace-hub.com/oslotr%C3%A6r-oslo-trees-integrated-project.
[54] *Blue Green Factor norm*. (2023, July 26). Interlace Hub. https://interlace-hub.com/blue-green-factor-norm.

biodiversity, the country has been restoring these ecosystems. This approach not only supports environmental goals but also addresses challenges like increased precipitation and storm surges due to climate change.[55]

Consumption & Emissions

In 2022, Oslo made significant progress in improving air quality and reducing carbon emissions. The city focused on reducing pollutants such as nitrogen dioxide (NO_2) and particulate matter ($PM_{2.5}$ and PM_{10}), primarily generated by road traffic and domestic heating. Oslo's air quality has improved over the years, thanks to measures like congestion tolls, environmental speed limits, and incentives for cleaner vehicles. Despite these efforts, some areas, especially those with heavy traffic, still face challenges in meeting the stricter air quality limits.[56]

Regarding carbon emissions, Oslo has been a leader in adopting green policies aimed at reducing its carbon footprint. The city aims to cut CO_2 emissions by 95% by 2030 compared to 1990 levels. In 2022, Oslo continued to promote zero-emission vehicles and increased the number of charging stations. This transition, along with the electrification of public transport and efforts to reduce private car use, has contributed to a significant reduction in greenhouse gas emissions. These initiatives have made Oslo one of the most environmentally progressive cities in Europe.[57]

In 2022, Oslo implemented several measures to conserve water due to lower-than-normal water levels in its reservoirs. The city encouraged residents to take shorter showers, turn off the water while brushing their teeth, and only use dishwashers and washing machines with full loads. They also recommended using the "small" button when flushing toilets and avoiding watering lawns or washing cars unnecessarily. These steps were part of a broader effort to prevent potential water shortages during a dry period. The City of Oslo also reduced its water consumption by cutting back on activities such as street cleaning and reducing the frequency of washing public vehicles. They also turned off non-essential water features, such as fountains, to conserve water.[58]

Environmental Management

Oslo has been at the forefront of innovative waste management practices, implementing several initiatives to reduce waste and promote sustainability.

Circular Economy Approach. Oslo is a global leader in circular waste management, where all waste is considered a resource. The city's system ensures that waste is sorted at the source and collected separately, with organic waste being converted into biogas and bio-fertilizers. This biogas powers the city's public buses and waste trucks, significantly reducing carbon emissions.[57]

Sustainable Food Management. Oslo manages food sustainably by aiming to halve meat consumption in municipal canteens and institutions by 2023, while increasing the proportion of plant-based foods like fruits, vegetables, and legumes. The city also focuses on reducing food waste per capita by 2030, supported by funding from the Klimasats grant scheme. One initiative includes creating a sharing platform for climate-friendly menus to promote sustainable food choices within the municipality. Additionally, Oslo is involved in the Horizon2020 FUSILLI project, where it collaborates with other cities to test innovative solutions for sustainable food systems.[57]

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[55] *Oslo's Ambitious Goals for the Urban Environment*. (2017, November 2). Smart Cities Connect. https://smartcitiesconnect.org/oslos-ambitious-goals-for-the-urban-environment/.

[56] *Air quality statistics - Environment status - Oslo kommune*. (n.d.). Oslo Kommune. https://www.oslo.kommune.no/politics-and-administration/statistics/environment-status/air-quality-statistics/#toc-1.

[57] *Oslo takes bold steps to reduce air pollution, improve livability*. (2018, October 22). UNEP. https://www.unep.org/news-and-stories/story/oslo-takes-bold-steps-reduce-air-pollution-improve-livability.

[58] *We need to save water - Oslo kommune*. (2022, August 11). Oslo Kommune. https://www.oslo.kommune.no/politics-and-administration/politics/press-releases/we-need-to-save-water.

Waste-to-Energy. Oslo operates one of the world's most advanced waste-to-energy plants, which incinerates non-recyclable waste to produce heat and electricity. This energy is used to sustain different functions of the city. For example, Oslo utilizes biogas produced from bio-waste and city sewage to power its buses and waste trucks.[57]

Plastic Recycling. The city has an extensive plastic recycling program that includes reverse vending machines across the city. These machines allow residents to return plastic bottles and containers in exchange for a small monetary reward, encouraging higher recycling rates.[59]

Baku, Azerbaijan

Indicator	Baku	Zhuhai	Chinese Avg.
Population (million)	2.33	2.48	7.00
GDP (billion USD)	18.27	60.13	107.05
GDP Growth Rate (%)	4.62	2.30	3.15
Service Sector Added Value (%)	32.10	53.81	51.54
Unemployment Rate (%)	5.65	2.36	2.89
Road Area (m^2 per capita)	6.65	20.07	15.23
House-Income Ratio (price per m^2 / GDP per capita)	-	0.13	0.13
Teacher-Student Ratio	1:9.7	1:16.0	1:14.3
Population: Age 0-14 (%)	23.48	16.10	16.69
Urban Green Space (m^2 per capita)	-	127.40	44.99
Air Quality (PM2.5 annual mean, ug/m^3)	28.00	17.00	29.00
Water Consumption (tons/10,000 USD)	1335.90*	93.12	301.21
Energy Consumption (tce/10,000 USD)	2.92	2.45	3.63
Domestic Sewage Treatment Rate (%)	-	99.21	97.19
Household Waste Harmless Treatment Rate (%)	-	100.00	99.96

Notes. *Reflects Azerbaijan's national water consumption per GDP, therefore include agriculture water consumption. This figure overestimates Baku's per GDP water consumption.
Data source: Publicly available data sources, see reference for detail. Data year: 2022.

Baku, the capital of Azerbaijan, stands as the country's largest city and primary economic hub. The Baku metropolitan area is Azerbaijan's sole metropolitan region, encompassing the townships on the islands of the Baku Archipelago and the industrial settlement of Neft Daşları. As of 2022, Baku's urban population was approximately 2.33 million, accounting for about 23% of the national population.

Known as the "City of Oil," Baku hosts the largest port on the Caspian Sea and serves as Azerbaijan's center for science, culture, and industry. The city is home to numerous national institutions and frequently hosts international events. Due to its strong winds, Baku is often called the "City of Winds."

In July 2018, the President of Azerbaijan launched the Baku City General Plan 2040, prioritizing sustainable urban development. This plan emphasizes the creation of a multifunctional and polycentric city, ensuring inclusivity and highlighting the importance of public transportation and infrastructure. It also calls for the implementation of clean city initiatives and environmental protection. Additionally, the plan underscores the preservation of historical sites, the development of tourism, and the promotion of emerging industries, providing guidance for Baku's sustainable development.[60]

[59] Cooper, R. (2018, August 24). *97% of plastic bottles in Norway are recycled*. Climate Action. https://www.climateaction.org/news/97-of-plastic-bottles-are-recycled-in-norway.
[60] State Committee on Urban Planning and Architecture of the Republic of Azerbaijan. (2023). *Master plan of Baku-Baku city General Plan 2040*. https://arxkom.gov.az/en/bakinin-bas-plani.

Azerbaijan's broader development policies are closely linked to the Baku metropolitan area. In early 2021, the President approved the "Azerbaijan 2030: National Priorities for Socio-Economic Development" as the strategic framework for the country's economic growth. This document aims to transform Azerbaijan into a "clean environment and country of green growth," with a focus on increasing the use of renewable energy. In May 2021, Parliament approved the Law on the use of renewable energy resources in electricity production, establishing the legal foundation for developing renewable energy projects.[61]

Economic Development

The economic and political activities of the Baku metropolitan area significantly influence the entire country. In 2022, Baku's GDP was estimated at USD$ 18.25 billion, with an unemployment rate of 5.65%.

The oil and natural gas sectors are the cornerstone industries of Azerbaijan, accounting for about 90% of the country's exports and contributing 30% to 50% of its GDP. The export of oil and gas has brought significant wealth to Azerbaijan and improved the standard of living. However, fluctuations in the oil and gas sector also have a considerable impact on the nation's economic growth. With major importing countries around the world committing to achieving net-zero greenhouse gas emissions by 2050, Azerbaijan needs to strategically transition its economy. The sharp fluctuations in oil prices in 2020 and 2021 further underscore the importance of economic and revenue diversification. Although the strategic economic transformation has a long way to go, Azerbaijan's dependence on the oil and gas industry will continue for several years.[61]

Social Welfare & Livelihood

In 2022, the population of the Baku metropolitan area was approximately 2.43 million, accounting for around 25% of the country's total population. The population of Baku consists mainly of Azerbaijanis, Armenians, Russians, and Jews. Although there is no designated state religion, the vast majority of Baku residents practice Islam. According to national data, the student-teacher ratio in Baku's primary and secondary schools is 1:9.7, superior to China's average of 1:14.3, indicating more abundant educational resources. Additionally, the proportion of the population aged 1-14 is approximately 23.48%, higher than China's average, suggesting rapid population growth. However, Baku's per capita road area is 2.85 m^2, significantly lower than China's average of 14.82, indicating that the city's transportation infrastructure does not yet meet the demands of population growth and industrial development.

To address the continuous population growth and increasing motorization rate, Baku has modernized its public transportation system based on the "Baku City General Plan 2040." This modernization focuses on the following areas: the development of underground railway networks, the improvement and expansion of roads and public transport, the construction of bicycle lane networks, and the development of transit hubs. By 2040, the total length of the underground railway network is expected to increase from the current 36.6 kilometers to 73.4 kilometers, with the number of stations rising from 46 to 51, providing a reliable and energy-efficient alternative for transport. Additionally, Baku aims to build dedicated bike lanes to meet the needs of green transportation. The total length of bike lanes is expected to reach 285 kilometers by 2040. These measures, along with the implementation of bike-sharing programs, are crucial initiatives to promote non-motorized transportation, reduce traffic congestion, and achieve energy savings and emission reductions, thus creating a greener urban transportation infrastructure.[60]

The construction of Baku's "White City" is another example of the city's sustainable development. According to a presidential decree, the former industrial area known for its oil industry, the "Black City," will be redeveloped into a modern urban area called "White City," featuring both practical and sustainable residential and commercial districts. The plan aims to provide up to 120,000 residential and commercial units, creating 240,000 workplaces. It also includes

[61] International Energy Agency. (2022, June). *Azerbaijan's energy context*. https://www.iea.org/reports/implementing-a-long-term-energy-policy-planning-process-for-azerbaijan-a-roadmap/azerbaijan-s-energy-context.

extending the existing Baku Boulevard by 10 kilometers, making it one of the largest promenades in the world. These developments will establish White City as another modern center for Baku.[62]

Environmental Resources

Baku's urban development plans increasingly incorporate public green spaces and parks, such as "Highland Park," providing citizens with ample greenery and recreational areas. These growing green spaces are essential for enhancing citizens' happiness, ensuring environmental quality, and supporting sustainable development.

Baku Boulevard, a promenade extending along the seafront, is another testament to Baku's greening initiatives. It offers lush green spaces for locals and tourists, enhancing the city's aesthetic appeal while effectively improving air quality. Municipal authorities remain committed to expanding and maintaining these parks and green spaces. These green areas are indispensable resources for sustainable development during Baku's rapid urbanization, making significant contributions to urban air purification.

Consumption & Emissions

Azerbaijan has enormous potential for renewable energy development due to its excellent solar and wind resources, as well as promising prospects in biomass, geothermal, and hydropower. Guided by the Azerbaijani government's strategic vision, Baku has begun investing in renewable energy sources such as wind, solar, and biogas. Currently, solar panels are widely installed on rooftops throughout Baku, and numerous wind farms are being constructed around the Absheron Peninsula, effectively utilizing the region's prevalent wind resources. The government aims to achieve a 30% renewable energy supply ratio by 2030, roughly double the current share. Additionally, in early 2020, the government signed infrastructure contracts for wind and solar power generation, which are currently underway.

For example, the Khizi-Absheron Wind Power Plant is expected to have an installed capacity of 240.5 MW and generate 1 billion kWh of electricity annually, saving 220 million cubic meters of natural gas and reducing CO_2 emissions by 400,000 tons per year. The project, scheduled for commercial operation in 2025, will supply electricity to 300,000 households.[63]

Investing in renewable energy technologies such as solar and wind is a key part of Baku's green transition. By collaborating with international investors and companies, Baku aims to develop its renewable energy infrastructure to provide cleaner electricity and reduce its dependence on oil and gas, diversifying its energy mix for a more sustainable future.

Baku is also striving to improve the energy efficiency of buildings and infrastructure. From 2018 to 2023, the number of streetlights in Baku doubled, with all new LED lights and older systems modernized. This project significantly reduces energy consumption.[64] The design and renovation of city buildings are meeting higher energy standards, often incorporating smart technologies to minimize waste.

The Baku government has also launched extensive public awareness campaigns to encourage residents to save energy and promote the use of energy-efficient appliances, raising awareness about reducing energy consumption. These measures effectively reduce Baku's carbon footprint, moving towards a more energy-efficient, modern green city.

In transportation, Baku strives to utilize smart city technologies to improve urban traffic and reduce its environmental impact. The project plans to implement intelligent lighting, smart parking, environmental monitoring, facial recognition, license plate recognition, and public Wi-Fi. The real-time traffic management system can effectively optimize traffic flow,

[62] Baku White City. (2024). *Baku White City - Introduction*. https://bakuwhitecity.com/en/about/on-soz.
[63] Azerbaijan Renewable Energy Agency under the Ministry of Energy of the Republic of Azerbaijan. (2022). *240 MW Khizi-Absheron Wind Power Plant*. https://area.gov.az/en/page/layiheler/cari-layiheler/240-mvt-kulek-elektrikstansiyasi.
[64] Azerbaijan Republic Executive Power of Baku City. (2023, June 12). *Over the past 5 years the number of illuminated streets in Baku has doubled*. https://baku-ih.gov.az/en/news/over-the-past-5-years-the-number-of-illuminated-streets-in-baku-has-doubled.html.

reducing parking time and emissions. The intelligent transportation system provides residents with the latest public transportation schedules and route information, making public transport more convenient and user-friendly.[65]

Environmental Management

Solid waste management is a crucial component of Baku's environmental strategy. The city has begun implementing advanced waste collection and sorting systems, focusing on increasing recycling rates. Efforts are underway to expand recycling facilities, introduce sorting at the source, and encourage public participation in recycling programs. Additionally, Baku is exploring the potential of waste-to-energy plants to generate electricity while processing waste. These initiatives aim to address the dual challenges of solid waste management and sustainable energy production, ensuring that urban development does not compromise the environment.

The Baku Waste-to-Energy Project is a successful example of the city's environmental governance strategy. The Balakhani landfill, located in the city's suburbs, had long posed significant environmental issues due to its massive size and the toxic smoke from burning waste. To address this, Baku launched the Waste-to-Energy Project. This large-scale project took over 4.8 million hours to complete and resulted in a modern waste treatment facility that converts over 500,000 tons of municipal solid waste into 230 GWh of electricity annually. This project not only resolved urgent waste management issues but also provided clean energy for the city, powering over 50,000 households.[66]

Baku emphasizes public participation and environmental awareness. The city promotes waste recycling and environmental management through various activities and programs. Environmental education is integrated into school curricula to cultivate sustainable development awareness among the younger generation. Public activities, such as tree planting days and environmental campaigns, are also common, fostering senses of community and environmental responsibility. Baku recognizes that long-term sustainable development requires citizens to understand and actively practice green concepts.

Delhi, India

Indicator	Delhi	Zhuhai	Chinese Avg.
Population (million)	16.78	2.48	7.00
GDP (billion USD)	132.86	60.13	107.05
GDP Growth Rate (%)	9.18	2.30	3.15
Service Sector Added Value (%)	48.40	53.81	51.54
Unemployment Rate (%)	5.30	2.36	2.89
Road Area (m^2 per capita)	12.82	20.07	15.23
House-Income Ratio (price per m^2 / GDP per capita)	0.16	0.13	0.13
Teacher-Student Ratio	1:28.0	1:16.0	1:14.3
Population: Age 0-14 (%)	27.00	16.10	16.69
Urban Green Space (m^2 per capita)	15.93	127.40	44.99
Air Quality (PM2.5 annual mean, ug/m^3)	98.60	17.00	29.00
Water Consumption (tons/10,000 USD)	157.37	93.12	301.21
Energy Consumption (tce/10,000 USD)	1.05	2.45	3.63
Domestic Sewage Treatment Rate (%)	95.00	99.21	97.19
Household Waste Harmless Treatment Rate (%)	-	100.00	99.96

Notes. Data source: Publicly available data sources, see reference for detail. Data year: 2022.

[65] Valiyev, A. (2021, August 6). *Building Smart Cities and Villages in Azerbaijan: Challenges and Opportunities*. https://bakuresearchinstitute.org/en/building-smart-cities-and-villages-in-azerbaijan-challenges-and-opportunities/.

[66] Islamic Development Bank. (2024, March 18). Clearing the Air: Baku's Journey from Waste Woes to Energy Wins. https://www.isdb.org/news/clearing-the-air-bakus-journey-from-waste-woes-to-energy-wins.

Delhi, officially the National Capital Territory of Delhi (NCT), is a city and a Union Territory of India containing New Delhi, the capital of India. New Delhi is an urban district located in the city of Delhi. New Delhi serves as the capital of India and the seat of all three branches of the Government of India.

National Capital Region (NCR) is a unique example of inter-state regional planning and development for a region with NCT-Delhi as its core. The NCR covers the whole of NCT-Delhi and certain districts of Haryana, Uttar Pradesh and Rajasthan, covering an area of about 55,083 km^2.

Delhi covers an area of 1483 km^2, of which 369.35 km^2 is designated as rural and 1113.65 km^2 as urban, which makes it the largest city in terms of area in the country.[67] The population density of the city is one of the highest in the world. While as per the last official census in 2011, Delhi's population was over 16 million, recent estimates indicate it to be about 33 million.[68] These estimates represent the Urban agglomeration of Delhi (called the National Capital Region), which typically includes adjacent suburban areas - Ghaziabad, Faridabad, Gurgaon, Noida, Greater Noida, Meerut and YEIDA city. NCR is the largest metropolitan area in India.

Economic Development

Delhi stands as a formidable economic powerhouse with the gross state domestic product (GSDP) expected to reach Rs 11,07,746 crore in 2023-24 (USD 134 billion), and the city's significant contribution of approximately 4% to India's GDP, cementing its position as one of the largest economic hubs in the country.[69] The city's per capita income is around $4,027 and the economic landscape is predominantly shaped by the service sector, which accounts for 85% of Delhi's GDP. Key industries driving this sector include information technology, telecommunications, finance, tourism, and retail, each contributing significantly to the city's economic prosperity.[70]

The large population of Delhi not only serves as a vast consumer base but also constitutes a robust labor force essential for sustaining economic growth.[71] The city's demographic diversity and skilled workforce attract both domestic and international businesses and thereby foster a dynamic business environment.

Infrastructure projects play a pivotal role in bolstering Delhi's economic development. Having constructed a massive network of about 392.44 km with 288 stations (including NOIDA-Greater NOIDA Corridor and Rapid Metro, Gurugram) in record time in Delhi, NCR, the Delhi Metro Rail Corporation (DMRC) stands out as a shining example of how a mammoth technically complex infrastructure project can be completed before time and within budgeted cost by a Government agency.[72] Delhi Metro was meticulously planned and executed in a phase wise manner at a time when the residents were heavily dependent on an unreliable public transit system (overloaded DTC/private buses, auto rickshaws not adhering to meter billing rules). The Metro is designed in such a way that it connects different districts of Delhi and the satellite towns and easily integrated with other modes of transport including feeder bus routes and private transportation. The recent

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[67] Government of NCT Delhi. (2024, August 16). *Chapter 19: Demographic Profile.* Economic Survey of Delhi 2022-23. ch._19_demographic_profile.pdf (delhi.gov.in).

[68] United Nations Department of Economic and Social Affairs. (2018). *World Urbanization Prospects 2018*. Population Dynamics. World Urbanization Prospects - Population Division - United Nations.

[69] "Delhi's economy to grow at 9.17% in FY24, per capita income surges by 22% to Rs 4.61 lakh." (2024, March2). The Economic Times. Retrieved May 30, 2024 from https://economictimes.indiatimes.com/news/economy/indicators/delhi-per-capita-income-rises-by-22-to-rs-4-61-lakh-economy-to-grow-at-9-17-in-fy24/articleshow/108142677.cms?from=mdr.

[70] Government of National Capital Territory of Delhi – Home Page. (n.d.). Retrieved May 30, 2024 from https://www.bing.com/ck/a?!&&p=3eb0fcfb6c0f92efc76159e6c268d4372ea9c10f4ebef3fab5735bae88e0fcadJmltdHM9MTcyODg2NDAwMA&ptn=3&ver=2&hsh=4&fclid=1c7b792f-1a3a-6dd4-3431-6c371b796c6c&psq=dehli+government&u=a1aHR0cHM6Ly9kZWxoaS5nb3YuaW4v&ntb=1.

[71] United Nations. (2024). *World Population Prospects 2024*. https://population.un.org/wpp/.

[72] *Introduction.* (n.d.). Delhi Metro Rail Corporation Ltd. Retrieved May 30, 2024 from https://delhimetrorail.com/pages/en/introduction.

corridors created have been instrumental in decongesting roads, reducing air pollution, saving fuel/parking costs and providing affordable fares for daily commuters. DMRC is the first metro system in the world to be certified by the UN to get carbon credits for reducing greenhouse gas emissions and pollution level in the city.[73]

These metro lines not only facilitate efficient transportation but also have massive potential to stimulate commercial activities, spurring investments and urban development. Metro station in a locality has been found to boost prices of residential and commercial properties. It has been a preferred mode for students, brought discipline, provided easy access to markets and historical monuments (which Delhi is specially known for) and also changed the image of public transport in the eyes of the citizens who prefer it over their private mode.

Some of the salient design features of DMRC which makes it one of the advanced urban public transportation system in the world include construction of underground tunnels, construction of underground metro stations, elevated viaduct, use of precast U-Span girders, use of special structural forms like extra-dosed bridge, selection of rolling stock, AC traction system of 25 kV and an automatic fare collection system.[74]

Additionally, initiatives such as the Delhi-Mumbai Industrial Corridor (DMIC) aim to further boost industrialization and trade, propelling Delhi's economy to greater heights.

Overall, Delhi's economic prowess, driven by its thriving service sector, burgeoning population, and strategic infrastructure investments, solidifies its status as a key player in India's economic landscape, poised for continued growth and development in the years to come.

Social Welfare & Livelihood

Delhi's social welfare initiatives cater to its diverse population, addressing key issues and focusing on vulnerable groups.

The city's education system serves over 5 million students. The expenditure on education accounted for 1.49% of Delhi's Gross State Domestic Product in 2022-23. While persistent challenges such as overcrowded classrooms, inadequate infrastructure, and disparities in access to quality education are still prevalent, multi-faceted initiatives have been taken up by the Government.[75] For instance, the New Education policy of 2020 emphasizes systematic and institutional improvement in regulation, governance and promotion of multi-disciplinary academics and research in Indian Higher Educational Institutions. Govt. of NCT of Delhi has been working to ensure inclusive and equitable quality education according to SDG4 and the 2030 Agenda. Efforts are underway to improve teacher-student ratios and educational resources, with initiatives like teacher training programs and infrastructure development projects.

Skill development initiatives in Delhi, including the "Skill Development Mission" and vocational training programs, aim to equip individuals with relevant skills for employment opportunities. However, challenges such as skill gaps, lack of industry relevance, and inadequate infrastructure hinder their effectiveness. Delhi is working on enhancing these initiatives by collaborating with industries, updating curricula to match market demands, and providing entrepreneurship training to foster self-employment.

Healthcare services in Delhi, encompassing over 1,000 healthcare facilities, aim to provide universal access to quality healthcare, though they encounter issues like overburdened hospitals, lack of specialized care in certain areas, and inequitable distribution of medical resources. The city is working to address these challenges through infrastructure expansions, upgrading medical facilities, and implementing telemedicine services. Beginning in 2015 after Aam Aadmi

[73] "Delhi Metro gets UN certification." (2011, September 26). The Hindu. Delhi Metro gets UN certification - The Hindu.
[74] Panwar, R. (n.d.). *Delhi Metro: Unique Features of the Best Railway Network in the World.* The Constructor. Delhi Metro: Unique Features of the Best Railway Network in the World – theconstructor.org.
[75] Singh, S.R. (2024, February 26). *North-east Delhi has just one school for nearly 2,800 students*. The Hindu. North-east Delhi has just one school for nearly 2,800 students - The Hindu.

Party's second term in Delhi, the transformational Mohalla Clinics (Neighbourhood Clinics) were introduced, which aim to provide affordable and hassle free access to healthcare to the residents. As of 2024, there are more than 300 Mohalla Clinics in the city. These clinics have been conceptualized as a mechanism to provide quality primary health care services accessible within the communities in Delhi at their doorstep. The services include basic medical health care on standard treatment protocols, lab investigations, preventive services, and providing health information and awareness.[76]

Environmental Resources

Despite facing environmental challenges, Delhi is actively pursuing sustainable development initiatives to preserve and enhance its natural resources. The city's green cover, including parks, gardens, and urban forests, spans over 20% of its total area.[77] Ongoing efforts such as the "Green Delhi" initiative aim to increase urban green spaces through tree plantation drives, vertical gardens, and biodiversity parks. The Delhi government is committed to expanding and preserving green areas to improve air quality, mitigate the urban heat island effect, and enhance biodiversity, as outlined in the Delhi Master Plan 2041.

Delhi is ranked the most polluted capital city in the world. Delhi's air quality is a major social and political concern in India. Air quality monitoring networks track pollution levels across the city, with spikes often observed during the post-harvest season due to stubble burning in neighboring states and during Diwali celebrations due to fireworks.[78]

Delhi's annual average $PM_{2.5}$ concentration in 2021–22 was 100 µg/m^3—20 times more than the WHO guideline of 5 µg/m^3. This is an improvement compared to the limited information available for the pre-CNG-conversion era (30% reduction in $PM_{2.5}$ concentration), immediately before and after 2010 Commonwealth Games (28% reduction), and the mid-2010s (20% reduction). These changes are a result of continuous technical and economic interventions interlaced with judicial engagement in various sectors.[79]

The city government has actively pursued measures to reduce air pollutant and emissions from the transportation sector, to address air quality and climate change concerns. The city's public transportation system, including buses, metro trains, and suburban railways, plays a crucial role in reducing traffic congestion and air pollution. Efforts to expand and improve public transit services, including the introduction of electric buses and trains, aim to promote sustainable mobility and reduce reliance on private vehicles.

Policies and incentives to promote the adoption of electric vehicles (EVs) have been introduced to reduce emissions from the transport sector.[70] Delhi has witnessed a significant increase in the number of registered EVs, with over 1.5 million electric and hybrid vehicles on the city's roads[70]. Additionally, the government provides subsidies, tax incentives, and exemptions to promote the purchase and use of EVs, contributing to a reduction in fossil fuel consumption and air pollution.[80]

Government has also taken several other steps in the recent years to improve the environment condition which includes massive focus on afforestation, installation of Anti-Smog Guns at construction sites, promotion of bio-decomposer developed by IARI Pusa for stubble management, closing of thermal power plants, deployment of Mechanical Road Sweepers (MRS) & Water Sprinklers (WS), implementation of Electric Vehicle Policy, ban on single use plastic, better management of solid waste, treatment of waste water, prohibition on open burning of garbage/dry leaves, improvement

[76] Aam Aadmi Mohalla Clinic. (2024). Welcome | Mohalla Clinics - Delhi | Official Website | Healthcare delivered to your neighborhood.
[77] Delhi Development Authority. (n.d.). Home page | Delhi Development Authority (DDA).
[78] T E R I. (2021). Does air quality from crop residue burning in close proximity to residential areas adversely affect respiratory health? TERI_Brief_Report.pdf (cpcb.nic.in).
[79] Guttikunda, S. K., Dammalapati, S. K., Pradhan, G., Krishna, B., Jethva, H. T., & Jawahar, P. (2023). What Is Polluting Delhi's Air? A Review from 1990 to 2022. *Sustainability* 2023 15(5), https://doi.org/10.3390/su15054209.
[80] "Delhi EV policy." (n.d.). Transport Department, Government of NCT of Delhi. Retrieved May 30, 2024 from transport.delhi.gov.in.

of sewage system, and stringent industrial emission norms. An Anti-Smog Gun is a device that spews fine nebulized water droplets into the atmosphere so that the smallest dust and polluted particles are absorbed. They were first tested in 2017 and have been installed in key locations ever since.

Image: Anti-Smog Gun in Delhi. An Anti-Smog Gun is a device that spews fine nebulized water droplets into the atmosphere so that the smallest dust and polluted particles are absorbed. (Image Source: PTI)

The government has also launched an innovative platform for submission of pollution related grievances which is monitored through the *Green Delhi* App, which is a user-friendly smartphone-based app with 27 government departments/agencies of Delhi on one platform.

Consumption & Emissions

Renewable energy integration is a key focus area for Delhi to reduce its carbon footprint and promote sustainable energy practices. The city aims to increase the share of renewable energy in its total energy consumption, with solar and wind power projects being prioritized for electricity generation. Delhi's renewable energy initiatives, including rooftop solar installations and utility-scale solar parks, are aimed at diversifying the energy mix and reducing dependence on fossil fuels.

Solar power capacity in the city has exceeded 250 megawatts, with numerous solar installations on rooftops, public buildings, and open spaces.

Additionally, the “Delhi Solar Policy 2024” has been recently announced in January 2024, marking a significant step in India's green energy future. This policy, a refreshed version of the Solar Policy in 2016, aims to reduce air pollution and combat inflation by providing substantial benefits to consumers who opt for rooftop solar panels. Delhi's solar power capacity currently stands at 1,500 MW, including 250 MW from rooftop plants. The government aims to increase this capacity to 4,500 MW by March 2027, making up around 20 percent of the city's electricity consumption from solar power.[81]

Residential consumers stand to gain the most from this policy, as the Chief Minister, Arvind Kejriwal, announced that those installing rooftop solar panels would enjoy zero-cost electricity bills. In addition to the existing power subsidy for those using up to 200 units per month, the Generation-based Incentives (GBI) proposed under the new policy could

[81] “AAP govt notifies new solar policy in Delhi.” (2024, May 17). Hindustan Times. Retrieved May 30, 2024, from AAP govt notifies new solar policy in Delhi | Latest News Delhi - Hindustan Times.

potentially earn residential consumers INR 700-900 (USD 9-11.4) per month.[82] Furthermore, commercial and industrial consumers will witness a 50 percent reduction in their electricity bills upon the installation of rooftop solar panels. The policy introduces various incentives, including a capital subsidy of INR 2,000 (USD 25.4) per kW for residential consumers, with a maximum limit of INR 10,000 (USD 127) per consumer. The Delhi government has allocated INR 570 crore (USD 72.5 million) for the implementation of the policy, emphasizing its commitment to a sustainable and green future.

In addition to the promotion of renewable energy, stricter regulations on energy efficiency and emissions standards have been implemented to mitigate environmental impact and promote sustainable consumption patterns in Delhi. The government has introduced measures to improve energy efficiency in buildings, industries, and appliances, thereby reducing energy consumption and greenhouse gas emissions. Additionally, initiatives to promote energy conservation, waste reduction, and recycling are being encouraged through public awareness campaigns and policy interventions to foster a culture of sustainability in the city.

Moreover, Delhi is one of the early implementers of Petrol blended with 20 percent ethanol. This E20 fuel was first rolled out on February 6, 2023, at select petrol pumps in 11 states and union territories as part of a program to increase use of biofuels to cut emissions as well as dependence on fuel imports.

Finally, in terms of water consumption, a major priority for Delhi is water conservation, given its water scarcity and pollution challenges. The city has implemented various initiatives to ensure sustainable water management, including rainwater harvesting, groundwater recharge programs, and the treatment of wastewater for reuse in non-potable applications. Delhi's wastewater treatment plants treat over 600 million gallons of wastewater daily, reducing the burden on freshwater sources and minimizing pollution in rivers and water bodies.

Environmental Management

Delhi's environmental management strategies focus on waste management, air quality monitoring, and green initiatives. The city implements advanced waste segregation and recycling systems, diverting over 80% of waste from landfills to recycling and composting facilities, yet faces challenges in managing the vast amounts of waste generated daily. The Delhi government is investing in advanced waste segregation systems, public awareness campaigns, and infrastructure improvements to further enhance waste management practices, reduce environmental pollution, and promote a circular economy.

[82] The Delhi government's GBI offers an additional monthly income for solar panel adopters. Residential consumers will receive a monthly generation-based incentive of INR 3/unit (up to 3kW plant), INR 2.5/unit (3 to 10 kW plant), and INR 1/unit (commercial users) for 5 years.

Cape Town, South Africa

Indicator	Cape Town	Zhuhai	Chinese Avg.
Population (million)	4.75	2.48	7.00
GDP (billion USD)	32.17	60.13	107.05
GDP Growth Rate (%)	1.20	2.30	3.15
Service Sector Added Value (%)	77.80	53.81	51.54
Unemployment Rate (%)	26.80	2.36	2.89
Road Area (m^2 per capita)	-	20.07	15.23
House-Income Ratio (price per m^2 / GDP per capita)	-	0.13	0.13
Teacher-Student Ratio	1:30.9	1:16.0	1:14.3
Population: Age 0-14 (%)	23.33	16.10	16.69
Urban Green Space (m^2 per capita)	179.02	127.40	44.99
Air Quality (PM2.5 annual mean, ug/m^3)	14.17	17.00	29.00
Water Consumption (tons/10,000 USD)	85.23	93.12	301.21
Energy Consumption (tce/10,000 USD)	0.69	2.45	3.63
Domestic Sewage Treatment Rate (%)	-	99.21	97.19
Household Waste Harmless Treatment Rate (%)	-	100.00	99.96

Notes. Data source: Publicly available data sources, see reference for detail. Data year: 2022.

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.[83]

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.[84] 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.[85]

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% 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 have lower income.[85]

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

[84] 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).

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

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.[85]

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.[86] Two-thirds of this population increase will be absorbed by urban areas.[87] In Cape Town, the city's population has steadily increased at an annual rate of around 2% over the past five years.[83]

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.[83]

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 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.[83] Furthermore, the COVID-19 pandemic spurred the

[86] 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.

[87] 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.

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 recognizes 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.[83] 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.[88]

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 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.[85] 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.[89] 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,

[88] City of Cape Town. (2021). 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.

[89] 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/.

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.[85]

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.[90] 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.[90] 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.

[90] 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/.

Cairo, Egypt

Indicator	Cairo	Zhuhai	Chinese Avg.
Population (million)	21.75	2.48	7.00
GDP (billion USD)	93.47	60.13	107.05
GDP Growth Rate (%)	6.70	2.30	3.15
Service Sector Added Value (%)	51.40	53.81	51.54
Unemployment Rate (%)	6.96	2.36	2.89
Road Area (m^2 per capita)	4.29	20.07	15.23
House-Income Ratio (price per m^2 / GDP per capita)	-	0.13	0.13
Teacher-Student Ratio	1:15.9	1:16.0	1:14.3
Population: Age 0-14 (%)	32.86	16.10	16.69
Urban Green Space (m^2 per capita)	3.00	127.40	44.99
Air Quality (PM2.5 annual mean, ug/m^3)	46.50	17.00	29.00
Water Consumption (tons/10,000 USD)	183.73	93.12	301.21
Energy Consumption (tce/10,000 USD)	2.92	2.45	3.63
Domestic Sewage Treatment Rate (%)	-	99.21	97.19
Household Waste Harmless Treatment Rate (%)	-	100.00	99.96

Notes. Data source: Publicly available data sources, see reference for detail. Data year: 2022.

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,"[91] with Cairo, Egypt's capital, being one of the ancient centers of the Islamic world.[92] 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.[93] 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.[94]

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).[95] 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 by 10% in 2030 from 2016 levels.[96] 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

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

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

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

[94] 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

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

[96] IEA. (2022, February 15). *Sustainable Development Strategy: Egypt Vision 2030 – Policies.* IEA. https://www.iea.org/policies/14823-sustainable-development-strategy-egypt-vision-2030.

green spaces, and integrate environmental management with technology for a more sustainable living environment.[97] 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.[98]

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.[99] 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.[98] In 2021, Egypt's real GDP growth increased at a rate of 6.6%, largely driven by its construction and gas derivatives sector,[100] with more than 15% of the Egyptian economy tied directly to activities in construction.[97] 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.[97]

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.[100] For example, the $40 billion project to create the New Administration Capital (NAC), which lies 45 kilometers east of Cairo and will be home to government ministries and foreign embassies, is anticipated to create 2 million new jobs.[97] Thus far, Egypt's unemployment rate has remained at a stable rate of 7.2%.[97]

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.[101] 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.[102] 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

[97] 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.
[98] 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/.
[99] International Monetary Fund. (2022). *Arab Republic of Egypt and the IMF*. IMF. https://www.imf.org/en/Countries/EGY
[100] African Development Bank. (2023). *Egypt Economic Outlook.* African Development Bank Group. https://www.afdb.org/en/countries/north-africa/egypt/egypt-economic-outlook
[101] Galal, S. (2023, June 23). *Egypt: Population density by governorate.* Statista. https://www.statista.com/statistics/1230835/population-density-by-governorate-in-egypt/
[102] Yang, Y. (2023). *China's top 10 cities in population density.* https://www.chinadaily.com.cn/a/202210/09/WS6341fc40a310fd2b29e7b5e3.html

capita.[103] 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.[104]

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.[105] 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.[105] 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.[106] Cairo is also developing two new monorail lines that will link the city with surrounding urban communities, including the New Administrative Capital City,[107] and also has a $200 million agreement with the World Bank to build an electric bus fleet.[108]

Environmental Resources

Developing Egypt's public transportation systems will have a significant impact on improving air quality. Egypt's annual average $PM_{2.5}$ levels in 2019 was almost 14 times higher than the World Health Organization's recommended average.[109] 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.[108] 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.[105]

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.[95] 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.[110] 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

[103] 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

[104] 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

[105] 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

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

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

[108] 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

[109] 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/

[110] 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

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.[105]

Consumption & Emissions

In 2021, Egypt's carbon dioxide emissions per capita was 2.3t, compared to China's 6t.[111] 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).[112] 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.[95] 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.[95] 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.[97]

Environmental Management

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.[95] 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.[113] 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.[108] 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.[105]

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

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

[113] 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

Moscow, Russia

Indicator	Moscow	Zhuhai	Chinese Avg.
Population (million)	21.75	2.48	7.00
GDP (billion USD)	93.47	60.13	107.05
GDP Growth Rate (%)	6.70	2.30	3.15
Service Sector Added Value (%)	51.40	53.81	51.54
Unemployment Rate (%)	6.96	2.36	2.89
Road Area (m^2 per capita)	4.29	20.07	15.23
House-Income Ratio (price per m^2 / GDP per capita)	-	0.13	0.13
Teacher-Student Ratio	1:15.9	1:16.0	1:14.3
Population: Age 0-14 (%)	32.86	16.10	16.69
Urban Green Space (m^2 per capita)	3.00	127.40	44.99
Air Quality (PM2.5 annual mean, ug/m^3)	46.50	17.00	29.00
Water Consumption (tons/10,000 USD)	183.73	93.12	301.21
Energy Consumption (tce/10,000 USD)	2.92	2.45	3.63
Domestic Sewage Treatment Rate (%)	-	99.21	97.19
Household Waste Harmless Treatment Rate (%)	-	100.00	99.96

Notes. Data source: Publicly available data sources, see reference for detail. Data year: 2022.

Located in the far west of Russia, Moscow is the country's capital and political center, as well as Russia's most populated city.[114] 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.[115] 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.[115] It is unclear how implementation progress on these strategies have been affected by Russia's invasion of Ukraine since February 2022.[116]

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.[116] In 2023, Russia's GDP was valued at US$1860 billion, while the GDP per capita was US$13,000.[117] The unemployment rate in Russia has remained low throughout, and is forecasted to stay at a low rate of 3.5% between 2023 - 2026.[118] Russia's economy ministry is predicting a slight recovery of the economy in 2024, bolstered by consumer demand and spending.[118]

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

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

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

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

[118] Korsunskaya, D., Marrow, A., & Marrow, A. (2023, April 14). *Russian economy ministry improves 2023 GDP growth forecast.* Nasdaq. Russian economy ministry improves 2023 GDP growth forecast.

Social Welfare & Livelihood

According to the OECD, Moscow showed notable improvements in areas related to the Sustainable Development Goals (SDGs) between 2010 and 2018.[115] 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.[119] 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.[120]

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.[121] 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.

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.[122] Russia is currently the fourth largest emitter of greenhouse gasses, emitting 1.92 billion tons of carbon dioxide equivalent ($GtCO_2e$) in 2019,[123] or 11.7 tons of carbon dioxide

[119] 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

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

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

[122] 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

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

equivalent per capita in 2021.[124] Russia's emissions per GDP in 2020 was 0.4kg per PPP US$ of GDP, twice the world's average in the same year.[112]

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.[125]

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.[126] 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.[127] 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 billion dollars building 25 waste-to-energy plants, which has also been met with controversy.[128] Moscow's Trash Reform Plan also does not currently include any proposed strategies for reducing the total amount of waste produced in the city.[129]

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[124] *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/

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

[126] 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

[127] 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

[128] *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

[129] *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

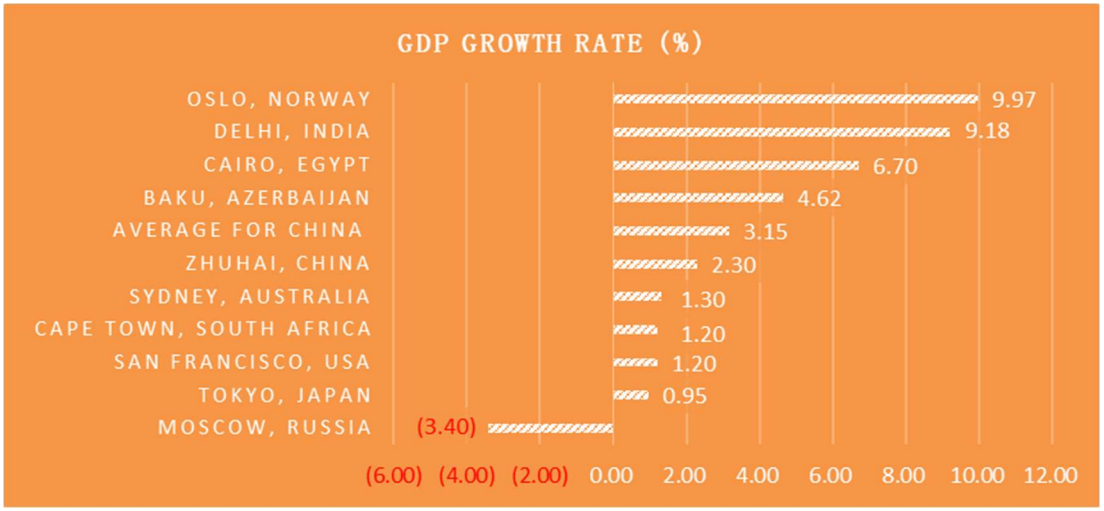
Categorical Comparison

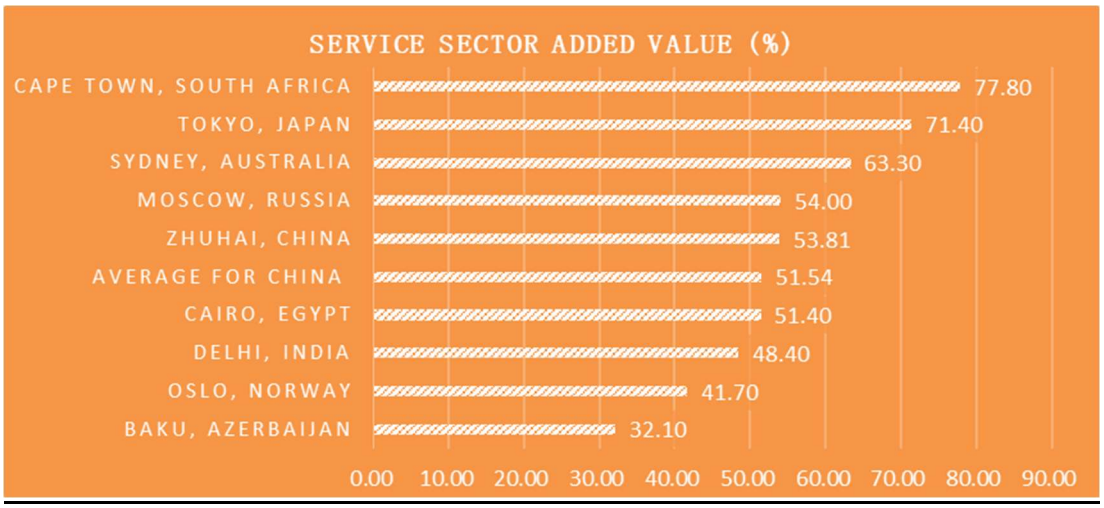
The following graphs compare the international cities, along with the top-performing Chinese city – Zhuhai - and average Chinese cities, over each of the indicators, and summarizes some of the converging urban sustainability policy initiatives across the international cities.

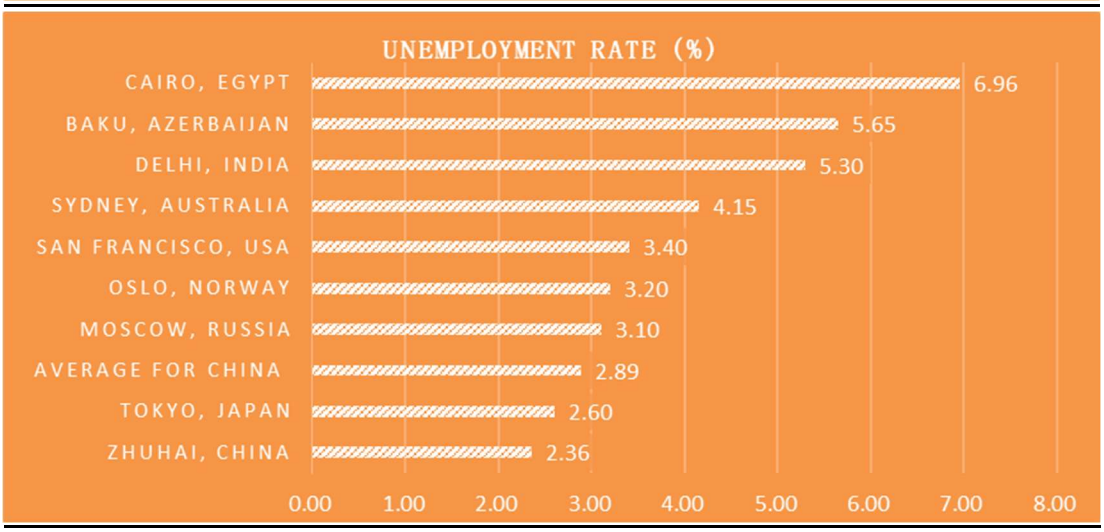
Economic Development

Unlike in previous years, Chinese cities no longer outperform international cities on most indicators of economic development in 2022. On the one hand, the average economic growth rate of Chinese cities slips from 7.9% in 2021 to 3.15% in 2022. On the other hand, some international cities, such as Oslo and Delhi, have demonstrated a strong post-pandemic economic rebound, reaching growth rates close to 10%, outperforming the top growth rate of China's 110 cities - Qujing. However, despite the slowdown in the economic upturn, unemployment rates in Chinese cities remain contained at levels lower than those of most international cities. Among the comparison cities, only Tokyo's unemployment rate is below 3% and lower than the average of Chinese cities. In addition, Cape Town's urban unemployment rate is not included in the comparison because it has a different measurement than the other cities. Cape Town publishes a broad unemployment rate - which includes in the unemployed population those outside the labor market, such as college students, housewives, people idling at home, and those working in the informal sector. These populations that do not participate in the labor market are usually not classified as unemployed for the purposes of unemployment statistics. As a result, this broad unemployment rate for Cape Town, South Africa would appear to be much higher (at 26.8%) than other cities. Cape Town's choice of statistics also reflects the government's greater focus on labor market participation, especially structural unemployment due to the skills mismatch between supply and demand in the labor market, as discussed earlier.

Finally, in the area of economic development, many cities are investing in infrastructure to expand jobs and boost the economy, especially infrastructure projects that integrate green development, as in the case of the "fourth generation cities" surrounding Cairo.

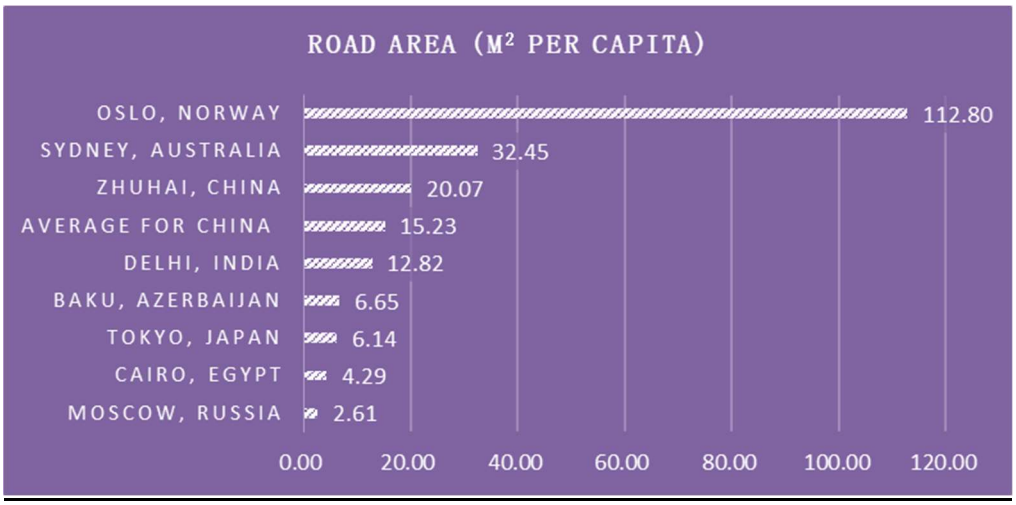


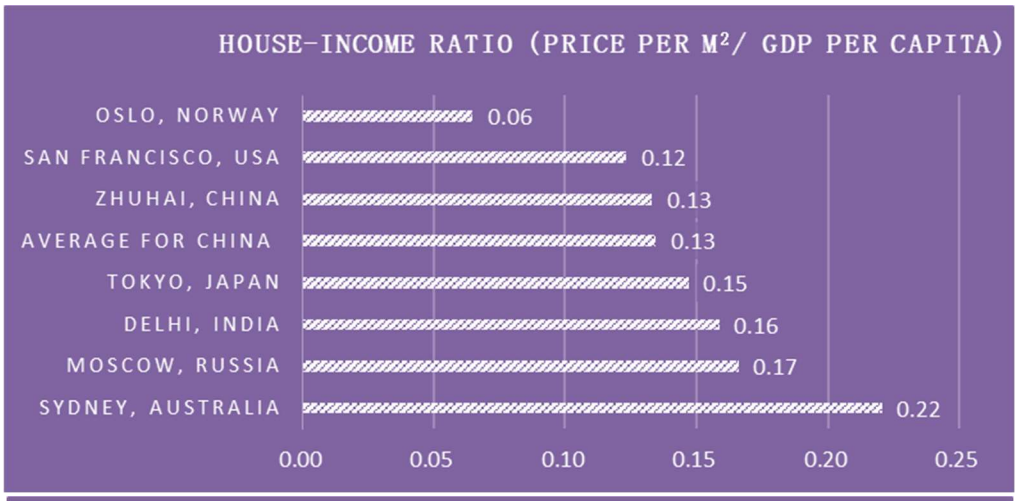


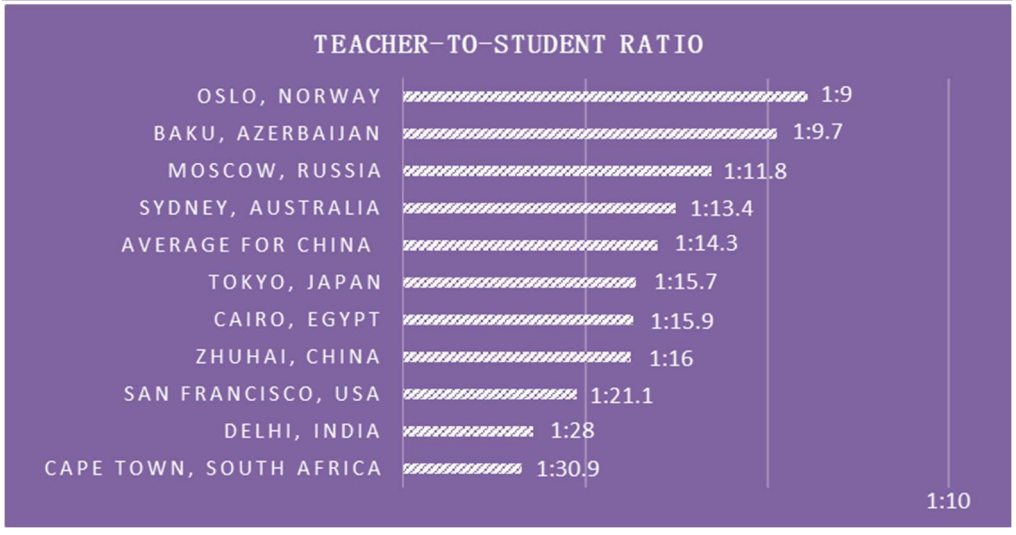


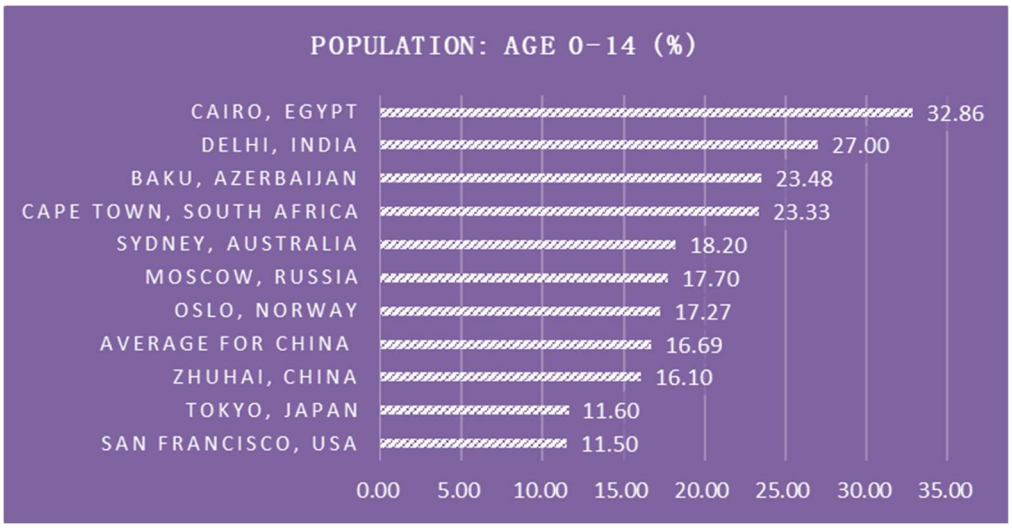
Social Welfare & Livelihood

In terms of social welfare and livelihood indicators, Chinese cities are basically in the middle of the pack when compared to the international cities selected for this report. In terms of road space per capita, Oslo, Norway, which is sparsely populated, comes out ahead. The average for Chinese cities exceeds that of more densely populated cities such as Tokyo and Delhi. In terms of housing affordability, Chinese cities are at about the same level as San Francisco, Tokyo, Delhi and Moscow - with house price pressures higher than in Oslo but significantly lower than in Sydney. In terms of student-teacher ratios in primary and secondary schools, Baku performs well, especially given the city's high proportion of 0-14 year olds. Maintaining a high student-teacher ratio despite a relatively large student population reflects Baku's abundant educational resources, and teacher force. Finally, in addition to Baku, Cairo, Delhi, and Cape Town are cities in the developing world that have a relatively high percentage of adolescents and young adults, signaling the need for more investment in education, health, and medical care to ensure the healthy development of these youngsters, as well as the potential for sustainable growth in these cities in the future.


ROAD AREA (M² PER CAPITA)
OSLO, NORWAY
SYDNEY, AUSTRALIA
ZHUHAI, CHINA
AVERAGE FOR CHINA
DELHI, INDIA
BAKU, AZERBAIJAN
TOKYO, JAPAN
CAIRO, EGYPT
MOSCOW, RUSSIA
112.80
32.45
20.07
15.23
12.82
6.65
6.14
4.29
2.61
0.00
20.00
40.00
60.00
80.00
100.00
120.00


HOUSE-INCOME RATIO (PRICE PER M²/ GDP PER CAPITA)
OSLO, NORWAY
SAN FRANCISCO, USA
ZHUHAI, CHINA
AVERAGE FOR CHINA
TOKYO, JAPAN
DELHI, INDIA
MOSCOW, RUSSIA
SYDNEY, AUSTRALIA
0.06
0.12
0.13
0.13
0.15
0.16
0.17
0.22
0.00
0.05
0.10
0.15
0.20
0.25


TEACHER-TO-STUDENT RATIO
OSLO, NORWAY
BAKU, AZERBAIJAN
MOSCOW, RUSSIA
SYDNEY, AUSTRALIA
AVERAGE FOR CHINA
TOKYO, JAPAN
CAIRO, EGYPT
ZHUHAI, CHINA
SAN FRANCISCO, USA
DELHI, INDIA
CAPE TOWN, SOUTH AFRICA
1:9
1:9.7
1:11.8
1:13.4
1:14.3
1:15.7
1:15.9
1:16
1:21.1
1:28
1:30.9
1:10

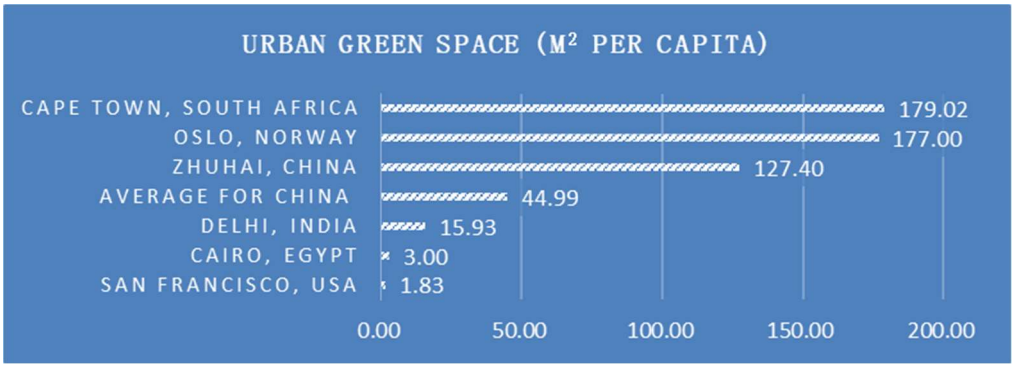


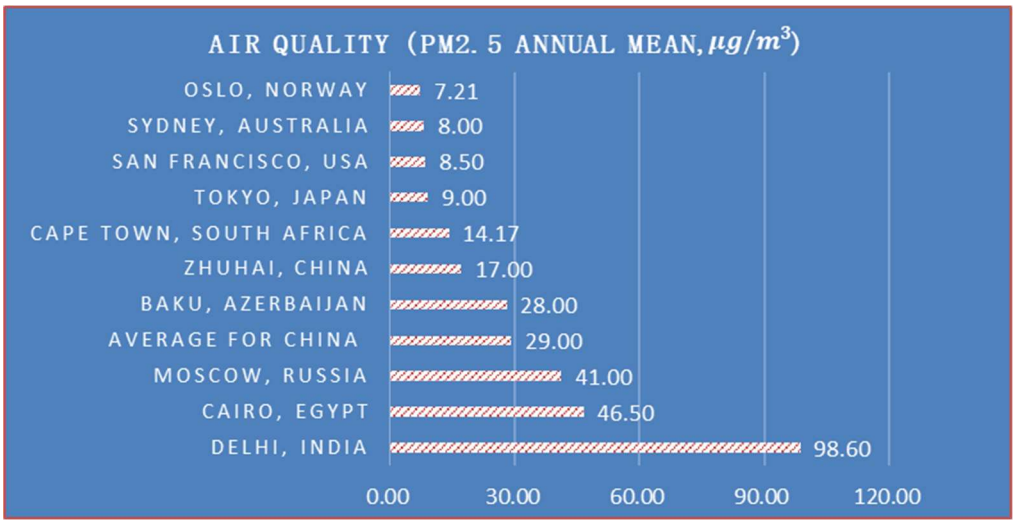
Environmental Resources

In terms of urban green space, Ordos, which tops our 110 Chinese cities with 165 m^2/habitant, and Zhuhai, which ranks first overall, are not far behind the leading international cities. In terms of air quality, although China's national average $PM_{2.5}$ level (29 µg/m^3) still lags behind many cities in developed regions (with pollutant concentrations 3-4 times higher), the air quality of China's cities has been improving steadily compared to 2021 (31 µg/m^3) and 2020 (33 µg/m^3).

Many international cities, such as Baku, Sydney, Oslo, Cape Town, Cairo, and Moscow, have focused their environmental priorities on building parks, public green spaces, and various forms of biodiversity conservation areas to expand public and green spaces within the city and enhance vegetation cover and biodiversity. On top of this, Sydney and Oslo are also actively developing green buildings and infrastructure to increase urban greening while making better use of ecosystem services to help with stormwater management, residential energy efficiency, and mitigating the urban heat island effect. The Oslo BGF Code, which was introduced earlier, is an exemplar initiative where green infrastructure is highly integrated with residential buildings and neighborhood planning. Its detailed rating system naturally promotes the improvement of green infrastructure in residential areas.

In terms of controlling air pollution, most cities take transportation or motor vehicle exhaust as the main target. Measures vary from restricting traffic on motor vehicles, setting stricter emission or fuel consumption standards, to heavily promoting electric vehicles (both private as well as public transportation). In addition, Delhi has introduced specific measures to reduce its particulate matters, such as agricultural stubble burning.



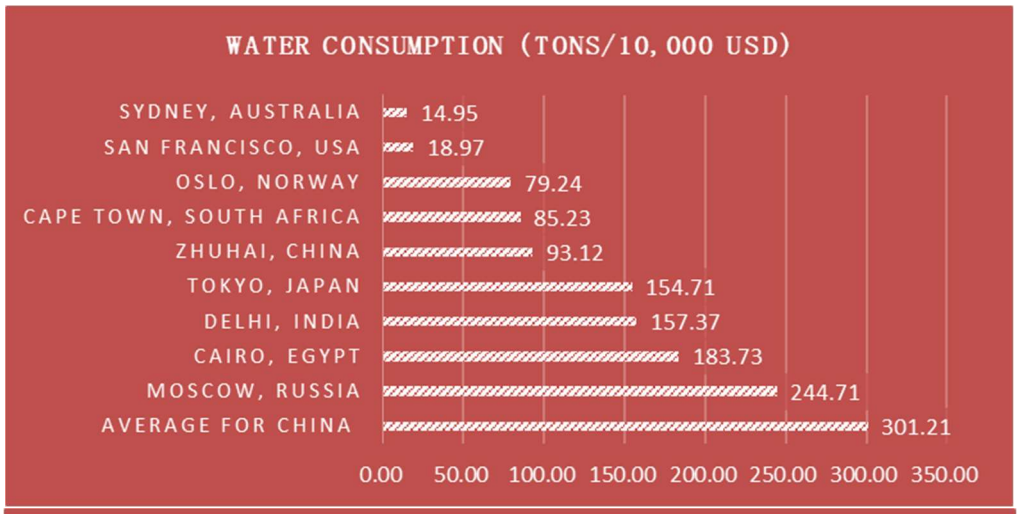


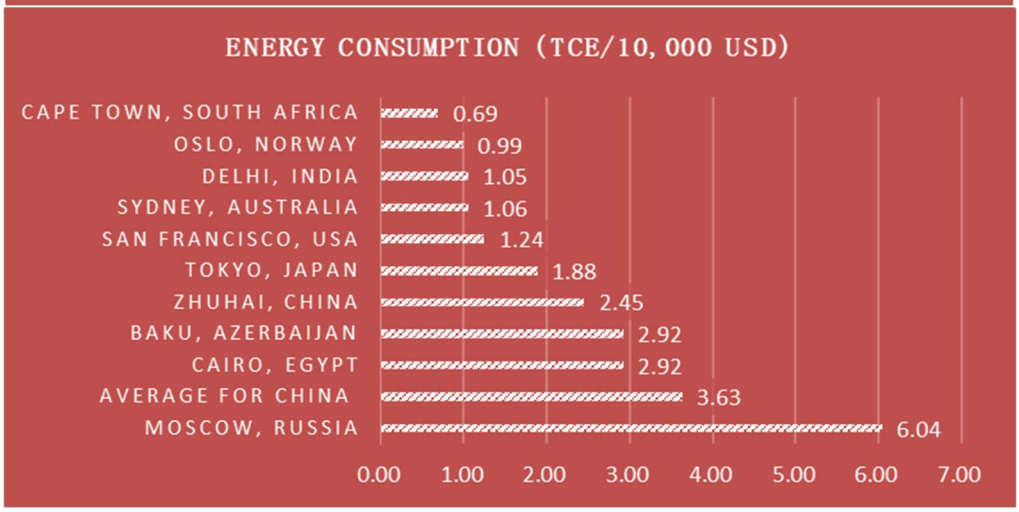
Consumption & Emissions

On the two indicators of consumption and emissions, although Shenzhen, the leading city among the 110 Chinese cities in terms of “energy consumption per unit of GDP” and “water consumption per unit of GDP,” is comparable to the top international cities, the overall level of Chinese cities is still lagging, especially in the area of water consumption.

In terms of sustainable energy management, many international cities have focused on developing renewable energy sources, increasing the share of renewable energy sources, and setting stricter standards for energy consumption in buildings, with municipal buildings leading the way in implementation. A typical example is the Delhi Solar Plan 2024, which provides various concessions and subsidies for rooftop photovoltaic power generation in residential and commercial buildings, including direct discounts on electricity tariffs and large subsidies for installed capacity. Sydney's achievement in 2020 for all municipal buildings in the city to be powered by solar or wind energy. Similarly, San Francisco and Tokyo plan to phase out natural gas from all municipal buildings and replace it with new sources of electricity.

For water conservation, San Francisco's Recycled Water Ordinance details programs to maximize the city's use of recycled water. Oslo and Cape Town, for their part, have implemented a package of water conservation measures in response to freshwater scarcity, including detailed recommendations on residential water use patterns, ongoing public notices on the status of water resources, maintenance of the water supply system to minimize losses, and the development of alternative water resources, all of which are described in detail in the preceding section.





Environmental Management

In terms of environmental management indicators, both Chinese and international comparator cities are largely at or near 100 per cent. Major initiatives by governments have focused on increasing waste recycling rates, reducing the proportion of waste going to landfills, and various reuses of waste as energy fuels and biosolids. Among them, Baku, Tokyo, Oslo and Moscow are utilizing waste-to-energy incineration to reduce their reliance on landfills. In contrast, Cape Town's use of biogas from waste and wastewater to generate electricity further reduces potential air pollution from incineration. In addition, Tokyo, Sydney, and San Francisco have been active in adopting legislation to reduce waste generation, increase waste reuse rates, and increase recycling rates. San Francisco has introduced detailed regulations for the recycling of construction waste as well as the recycling and composting of organic waste.

In summary, this year's report has selected nine international comparison cities that are different from previous years. By comparing the sustainability indicators, we find that although China's 110 cities are no longer leading in their “traditional strengths” of economic development due to the impact of the epidemic, they are making sustained and steady progress in their previous weaknesses, such as “consumption and emissions” and “environmental resources” indicators. It is also clear from the city cases that each city's sustainable development strategy and focus is tailored to its own context and focuses on long-term progress. This also reflects that sustainable development is not an overnight process, and that it does not focus on short-term achievements, but rather on resolute and steady progress.

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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