China Sustainable Cities Report 2016:

Measuring Ecological Input and Human Development

This research paper should be referenced as: UNDP (2016). China Sustainable Cities Report 2016: Measuring Ecological Input and Human Development. United Nations Development Programme in China, Beijing, China.

This research paper is published in English and Chinese. UNDP China has strived to ensure the consistency between the two versions of the paper. The English version should prevail in case of any ambiguity or conflict in terms of the two versions.

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UNDP China welcomes comments on the research paper via email to Ms. Samantha Anderson (samantha.anderson@undp.org).

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FOREWORD

Empowered lives.
Resilient nations.

Foreword

This October in Quito, Ecuador, the UN Conference on Human Settlements, Habitat III was held. This was the first major global conference under the 2030 Agenda for Sustainable Development, during which the participants in this conference adopted the New Urban Agenda, a framework that will guide sustainable urban development around the world for the next 20 years. The New Urban Agenda calls for cities to be safer, resilient and more sustainable, to lower carbon emissions and become cleaner and greener, and to be more inclusive, provide equal opportunities for all and fully respect the rights of migrants and refugees regardless of their status.

China has undergone a major philosophical shift in its approach to urbanization since the last Habitat conference in 1996 when the focus for the development of Chinese cities was rapid growth with little consideration of quality or long-term consequences. This focus on rapid growth was understandable and has had major positive impacts on poverty reduction. China has benefitted from policies that promoted basic education and healthcare from 1949, and then beginning in the Reform and Opening-up period, from fast economic growth.

We can see the impact of these policies in the China Sustainable Cities Index presented in this report. All of China's major cities score highly on UNDP's Human Development Index, which measures health, education and income. Each one of the 35 cities included in the report scores above the 'high' cut-off of 0.7 on the HDI scale, and 15 score above the very high cut-off of 0.8. This continual investment in health, education and economic growth means that major Chinese cities have reached the same level of development as developed countries globally.

However, this high level of human development has come at the expense of environmental well-being, and China is now at the point where environmental problems are threatening to undermine important gains in social development. This too is reflected in the China Sustainable Cities Index. The Ecological Input Index average has increased from 2015, meaning that overall the 35 cities included in the report are consuming more resources and producing more pollution.

Some cities have taken steps to improve by shifting to cleaner energy, investing in cleaner transportation, putting in policies to limit sprawl, and improving waste management. These efforts now need to be scaled up, not only to China's major cities, but also to the smaller cities that will see the most significant growth over the next few years.

Now at the start of this new development era, China's internal planning documents have become entirely compatible with the global development agenda. The policies outlined in the 13th Five-year Plan, the New-type Urbanisation Plan, the Urban Climate Change Adaptation Plan, local air quality plans, etc. reflect a shift to human-centred and green development that will guide the transition to sustainable urbanization in the New Normal period. The rebalancing effort towards quality growth provides the framework that local officials need to change the way cities are developed so that they can support human development within ecological limits. Along with China's own planning frameworks, global frameworks such as the Sustainable Development Goals, the New Urban Agenda and UNDP's Global Sustainable Cities Strategy can also provide guidance for long-term, healthy and balanced development that will ensure that China's cities are inclusive, safe, resilient and sustainable.

UNDP China is proud to be partnering with Tongji University and the Xinhua News Agency Think Tank on this report. I would like to extend my sincere thanks and warmest congratulations to all the authors for their outstanding work and to the many colleagues in the United Nations System who provided valuable insights and assistance.

Agi Veres
Country Director
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瞭望东方 周刊 Oriental Outlook

Foreword

What is an “eco-city”?

An eco-city can be defined as a compact human settlement where society, economy, cultures and nature develop in coordination, where materials, energy, technologies, and information are efficiently used, where the potential of humanity and nature are fully tapped, where the residents lead physically and mentally healthy lives while the ecosystem achieves a virtuous circle.

In a broad sense, the idea of eco-cities is a new cultural perspective based on renewed insights into humanity’s relationship with nature. The idea represents new social relationships based on ecological principles and allows society, economy and nature to develop in coordination. It also refers to new lifestyles and production patterns that achieve sustainable development through the reasonable use of natural resources. In a narrow sense, eco-cities are efficient, harmonious, healthy and sustainable human settlements planned in accordance with ecological principles.

Building a beautiful country and achieving green, circular, and low-carbon development was a target first put forward in the *Report to the Eighteenth National Congress of the Communist Party of China*. Promoting ecological progress as one of the five key progresses in China’s development plan has become a new national strategy. Today, booming urbanisation serves as part of the driving force behind socioeconomic development in China. Against this background, an emphasis on building eco-cities has great practical and historic significance.

After rapid development over the past three decades, China has stepped into the New Normal where well-rounded urbanisation could not be possible without a focus on ecological progress as a fundamental issue actively integrated in all aspects and processes of economic, political, cultural, and social development.

“These days, driving an electric scooter is like driving a plane – you drive through ‘clouds’!” This is an online comment joking about the smog in North China. Data from UN-Habitat show that over 300 cities in China are suffering from water shortage or severe shortage. How can a city be proud when its dwellers are craving for fresh air and clean water, the two factors indispensable to humanity’s survival?

Admittedly, “development” and “exploitation” were once the theme at the very beginning of urbanisation when understanding of the process was limited. Instead, “ecology” and “restoration” have taken over and become buzz words in the field recently, representing a promising shift with raised awareness to avoid unsustainable practices in urban development.

The ultimate goal of urban construction and development is to provide city dwellers with healthier, happier and better lives. Development disregarding this goal will fail to ensure quality livelihood. Cities should adopt a people-oriented development view which highlights the goal in both urban planning and governance.

Naturally, the ideals of eco-cities include high livability. To complete the building of a moderately prosperous society, urban development should take a green path. Unchecked urban sprawl running counter to the rules of nature brings short-sighted benefits only. On the other hand, long-term benefits of quality air, water, ecosystems, natural environments, and transport are often considered neglectable or expendable as they are not “realistic” or “significant” enough. Thus, environmental deterioration, traffic congestion, and other “urban diseases” are plaguing first-, second- and third-tier cities in China. Myopic practice that pursuits short-term benefits at the expense of long-term ones will result in major backlashes in urban development.

Cities must hold fast to ecological progress. Cities suffering from urban diseases should make painstaking efforts in restoration so that future development will not follow the same old path. One of the urgent tasks is to avoid the pandemic of urban diseases. City administrators should balance short-term benefits and long-term ones, especially on fundamental issues. Drawbacks in urban ecological progress should be addressed with perseverance. As pollution control and ecological construction cannot be completed over a short period, cities are faced with an uphill battle to achieve better environmental governance. Governments should not only play a firm leading role but also advocate increasing social participation, multi-stakeholder co-governance, and enhanced public awareness. Raised public awareness of ecological construction and a new lifestyle based on it is a characteristic of modern civilised societies.

To tackle air pollution, the Chinese government has formulated a series of policies to address smog and improve air quality. The urgent task is to control PM 2.5 concentration through various measures including industrial upgrading, fuel coal reduction, traffic restrictions, enhanced management, joint pollution control, governance by law, etc. To address water shortages, China has identified water security strategies of “water resource-based urban development” and “prioritized water saving, balanced special distribution, systematic management, and coordination between government and market.” In other words, urban development should be subject to the capacity of water resources; sponge cities that hold, clean and drain water should be built to minimise negative impact of urban development on natural environments.

Traffic congestion is also one of the critical urban diseases. “An-hour driving can take you from France to Germany and another hour from Germany to Poland. Here in Beijing, an hour driving takes you from some place in Chaoyang District to another place in the District, and after another hour you are still stuck in the District.” City builders and administrators should reflect on this thought-provoking joke on the Internet. Undoubtedly, public transport is one of the effective solutions to congestion. Step-by-step measures need to be taken to accelerate construction of a transport network that is fast, accessible, efficient and safe, with high capacity at low cost. Urban congestion can only be alleviated when high-capacity public transport and low-capacity private transport complement each other. Policies to build modern transport networks and prioritise transport integration should go beyond the talk.

Urban ecosystems are a mark of development quality that cities should prioritise. Only when the ideals of eco-cities are adopted can well-rounded development be promoted through new approaches and targets. The progress of new urbanisation will be a matter of time if extensive resource exploitation shifts to intensive use of ecological capacity which urges cities to prioritise green, circular, and low-carbon economic patterns and take the lead to form resource-saving and environmentally friendly industrial structures, growth patterns and consumption habits. Harbouring such hopes, we present the China Sustainable Cities Report 2016 to push forward quality evaluation of urban development by reviewing not only the strengths but also the weaknesses of cities and listing ecological infrastructure, human habitats, and ecological capacity building as indicators of urban ecological progress.

President Xi Jinping described relations between natural environments and economic development vividly by saying “we need not only mountains of gold [high economic growth] but also green mountains [good natural environments] and we would choose the latter over the former. In fact, green mountains are golden.” As a guideline for urbanisation, this outlined benefits and welfare that ecological progress can bring to the people. Greater environmental protection of cities means greater urban development under the New Normal. Prioritised environmental protection along with green development might generate benefits greater than expected for urban environments. This, as a highlight of new urbanisation, is in line with the long-term interests of the Chinese people.

At this historic new start point, new urbanisation should go beyond and rediscover cities.

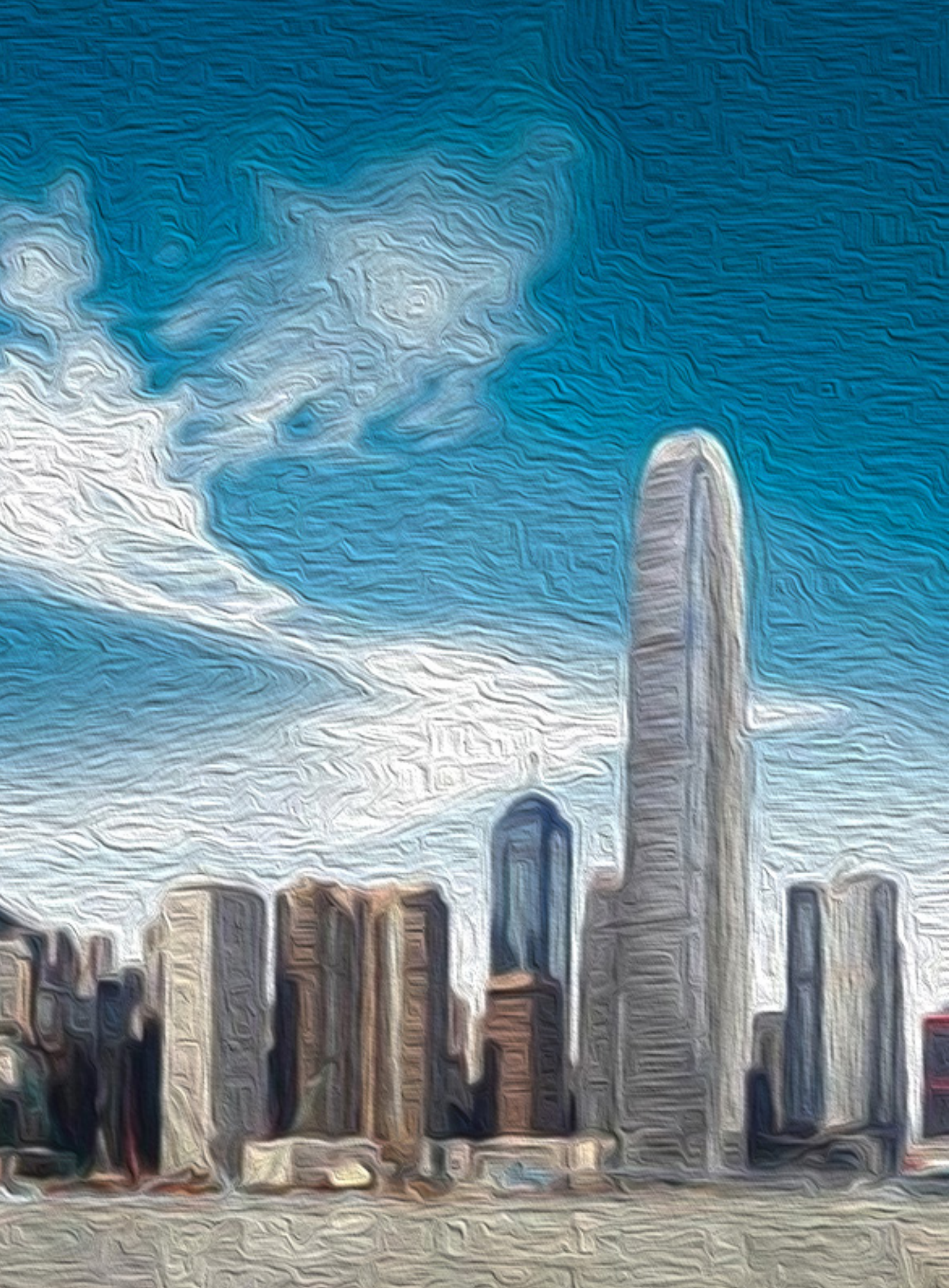
Looking at cities from a civilisational perspective beyond regions, we can see that they are crown jewels of modern civilisations. Fine, liveable eco-cities, in turn, fuel the constant progress of civilisation while unsustainable cities put an end to the progress.

Looking at urban sustainability from a long-term perspective beyond utilitarianism, we can see that cities should guard against herd phenomenon and overemphasis on size of development. Take a long-term perspective and a greater vista can be gained; China embracing the new development phase should be persevering, patient and confident in the shift to green and sustainable eco-cities.

Looking at eco-cities in a perspective beyond national boundaries, we can see reasons to believe that the exploration and innovation of China can benefit the world. Good planning, development and construction of Chinese cities will contribute to human civilisation. This report upholds the principles of green development, circular economy, low-carbon lifestyles, and livelihood and livability. With core targets and extensional targets, the report establishes a unique, valid and integrated evaluation system for eco-cities, providing valuable reference for urban development in China. I look forward to wider international recognition of this report through the work of United Nations Development Programme to share the green ideals that China advocates in new urbanisation. This is a meaningful cause for both humanity and the world. *November 2011*

Ji Bin

Editor-in-Chief, Outlook Weekly Agency of Xinhua News Agency



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ACKNOWLEDGEMENTS

Thank you to Nicholas Rosellini, Resident Coordinator of the United Nations in China, Agi Veres, Country Director of the UNDP China Office, and Ji Bin, President and Editor-in-chief of Oriental Outlook Magazine, Xinhua News Agency for their continued support, inputs and guidance for the project. Thank you to the lead authors at Tongji University, Zhu Dajia, He Fang and Huo Jiazhen for their outstanding work and to the research and writing team at Tongji University, including Zhang Zongyi, Xu Jie, Du Juan, Hu Jing, Liu Guoping, Zhang Chao, Chen Haiyun, Peng Jing, Tan Wu, Guan Lihua, Li Wenying, Wang Yixin, Teng Xiuxiu and Zhang Simin. Thank you to the research and writing team at UNDP including Samantha Anderson, Wu Qiong, Mao Sihan, Zhou Shuwen, Angelina Bishman and Anita Zhang. Patrick Haverman, Deputy Country Director of UNDP China Office has been critical in keeping the project moving forward. We also acknowledge Christophe Bahuet of UNDP Indonesia for his support in initiating the project. Zhang Wei of UNDP and Zhao Yue of Oriental Outlook Magazine initiated this collaboration and continue to guide the project at every step. We gratefully acknowledge UNDP's Private Sector Advisory Board for providing the funding for this project initiative.

Thank you to Jin Feng of Outlook Magazine, to Wang Qiguang, Xing Jing, Liu Liu, Bai Wei, Gu Jiayun of Oriental Outlook Magazine and to Meng Jun of UNDP for general support. Thank you to Liao Siqi and liu Xuan for the beautiful report design and layout. Thank you to Siemens Cites Center of Competence Asia for their inputs and provision of additional data. Thank you to the peer reviewers, Agi Veres, Carsten Germer, Gu Qing and Leah Bell of the UNDP China Office, Joseph D'Cruz and Taimur Kilji of UNDP Asia-Pacific Regional Office, Zhang Zhenshan of UNHabitat and Nan Zhou, Wei Feng and Brian Heimberg of the University of California, Berkeley for their insights and feedback for their insights and feedback. All errors remain our own. We sincerely hope that this report will help advance sustainable urbanisation in China.

EXECUTIVE SUMMARY

The next 15 years will be a critical period for the world to fully commit to its goals for sustainable development. China, both by virtue of its size, and its astounding development history, is one of the world's key leaders in the sustainability transformation. These achievements now need to be supported by protecting and restoring China's damaged ecosystems. One of the critical areas where human development and environmental protection come together is in the realm of sustainable urbanisation. The China Sustainable Cities Report assesses the shift to sustainability of China's directly-administered municipalities and provincial capitals by applying 2 indices- the Urban Human Development Index and Urban Ecological Input Index-made up of 12 indicators to these cities. Cities are categorised into 4 quadrants: high human development, low ecological input (sustainable); high human development, high ecological input (less sustainable); low human development, low ecological input (less sustainable); and, low human development, high ecological input (unsustainable).

Overall, all 35 cities exceed the high (0.7) or very high (0.8) cut-off points on UNDP's Human Development Index. 20 cities fell below the average ecological input of all 35 cities (0.44) while 15 exceeded the average. Of the 35 cities evaluated in the report, Beijing, Hangzhou, Tianjin, Qingdao, Dalian, Shenyang, Changsha, and Jinan have been able to achieve high human development while also having a lower impact than average on the environment. Average ecological input has deteriorated since last year's report, rising from 0.316 to 0.44. However, this may be due to changes in data collection and the authors await the results of next year's evaluation before commenting on trends.

As Chinese cities are centres of industry, industrial optimisation through the development of tertiary industry, pollution control, circular economy strategies and a rapid increase in renewable energy and energy efficiency all need to be promoted – this is unlike developed country cities, where residential resource consumption or pollution from, for example, private transportation, is a bigger issue. However, as China begins the shift to a more mixed or service-based economy, it is critical that cities not continue the environmentally, economically and socially unsustainable land use and transportation patterns that have characterised so much of the urban development over the past 70 years. Many high-level global and national-level policies such as the New Urban Agenda and China's New-type Urbanisation Plan provide better frameworks for urban development. Now it is necessary to implement those frameworks on the ground.

This report also includes three case studies on good sustainability practices linked to the indicators included in the Index. The case studies from Foshan, Guangdong and Guangzhou, Guangdong look at specific policies related to vocational education and solid waste management respectively. The case from Wulong County, Chongqing, shows how the environmental protection policies instituted originally to support the tourism industry have become a driving force behind a wide range of economic development activities.

Sustainable Development Goal 11 is to make cities inclusive, safe, resilient and sustainable by 2030. The Report emphasizes the importance of considering both human development and environmental impacts concurrently. An integrated approach that looks at urban development as a system will ensure that Chinese cities are at the forefront of the global transition to a more sustainable future.

Contents

PART ONE THEORETICAL FOUNDATION

CHAPTER ONE: INTRODUCTION

1.1 Sustainable urban development and the 2030 Development Agenda

In October, 2016, the world came together at the Third United Nations Conference on Housing and Sustainable Urban Development (Habitat III) to adopt the "New Urban Agenda". The New Urban Agenda forms a framework to guide sustainable urbanisation over the next 20 years. This follows a year of intensive international negotiations in 2015 that culminated in the core agreements of the 2030 Development Agenda: the Sustainable Development Goals (SDGs), the Financing for Development Agenda, and the Sendai Disaster Risk Reduction Framework as well as the Paris Agreement on climate change. As each of these agreements was negotiated and signed, a common theme was reiterated: the goals of these agreements can only be realised through implementation at the local level. Since the world is now majority urban, it is widely recognised, as Ban Ki-moon said in the lead-up to the Rio +20 Sustainable Development Summit, "Our struggle for global sustainability will be lost or won in cities."[1]

The cornerstone of the 2030 sustainable development agenda are the Sustainable Development Goals. These 17 goals and 169 targets show the scale and ambition of this new global agenda. The SDGs take into account a more complex environment for development focusing on interlinkages for sustainability and issues of inequality. They also address areas that received less attention in the Millennium Development Goals such as cities and climate change. Cities are clearly an important focus of the 2030 Agenda, explicitly referenced in Goal 11 of the Sustainable Development Goals, *Make cities inclusive, safe, resilient and sustainable*.[2] Many of the other goals are also linked to urban development.

1. For Ban Ki-moon's full speech, see http://www.un.org/press/en/2012/sgsm14249.doc.htm
2. See all the United Nations Sustainable Development Goals http://www.un.org/sustainabledevelopment/sustainable-development-goals/

Goal 11: Make cities inclusive, safe, resilient and sustainable

Each Sustainable Development Goal is broken down into more specific targets. SDG 11's targets are as follows:

- By 2030, ensure access for all to adequate, safe and affordable housing and basic services and upgrade slums
- By 2030, provide access to safe, affordable, accessible and sustainable transport systems for all, improving road safety, notably by expanding public transport, with special attention to the needs of those in vulnerable situations, women, children, persons with disabilities and older persons
- By 2030, enhance inclusive and sustainable urbanisation and capacity for participatory, integrated and sustainable human settlement planning and management in all countries
- Strengthen efforts to protect and safeguard the world's cultural and natural heritage
- By 2030, significantly reduce the number of deaths and the number of people affected and substantially decrease the direct economic losses relative to global gross domestic product caused by disasters, including water-related disasters, with a focus on protecting the poor and people in vulnerable situations
- By 2030, reduce the adverse per capita environmental impact of cities, including by paying special attention to air quality and municipal and other waste management
- By 2030, provide universal access to safe, inclusive and accessible, green and public spaces, in particular for women and children, older persons and persons with disabilities
- Support positive economic, social and environmental links between urban, peri-urban and rural areas by strengthening national and regional development planning
- By 2020, substantially increase the number of cities and human settlements adopting and implementing integrated policies and plans towards inclusion, resource efficiency, mitigation and adaptation to climate change, resilience to disasters, and develop and implement, in line with the Sendai Framework for Disaster Risk Reduction 2015-2030, holistic disaster risk management at all levels
- Support least developed countries, including through financial and technical assistance, in building sustainable and resilient buildings utilizing local materials

1.1.1 The SDGs, the Thirteenth Five Year Plan and Chinese urban policy

The next 15 years mark a critical period for China to fully commit to its goals for sustainable development. How China chooses to transform its model of development and what characterizes its consumption patterns will be key to determining the extent that China can successfully pursue development within the context of an urban ecological environment. As it stands, the Chinese government's development goals include accelerating the creation of a resource-saving and environment-friendly society, improving the level of ecological civilization and enhancing its capacity to engage in sustainable development.[3]

In September 2015, Chinese President Xi Jinping delivered a speech entitled "Towards Win-Win Partnership For Sustainable Development"[4] at the United Nations Sustainable Development Summit, where he pledged China's full commitment to implementing the 2030 Development Agenda in order to advance the cause of global development. President Xi articulated this vision with confidence, recalling China's decade-long contributions to global development and its expansive engagement in diverse activities and reforms to develop an 'ecological civilization'.

From 2000 to 2015, China made significant headway in fulfilling the United Nations' Millennium Development Goals (MDGs), and did so within the context of its own sizeable socioeconomic development.[5] In September, 2016, China released its National Plan for implementing the SGDs aligned with its own development priorities such as eradicating absolute poverty by 2020.[6]

While the new SDG agenda is intended to be universal– in that it seeks to embody a universally held notion of progress towards building a sustainable space for all humans to thrive on the planet– it also recognizes that each country faces specific challenges to achieving sustainable development. Indeed, each country will set different goals and targets that reflect different degrees of challenge and ambition.[7] Accordingly, even though China's path towards sustainable development should be based on overarching goals shared by the international community, the government has made clear that it will tailor its development objectives to national conditions.[8]

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3. See the United Nations Environment Programme, (2016). Green is Gold: The Strategy and Actions of China's Ecological Civilization for a review of China's ecocivilization approach to environmental protection. Available at: http://web.unep.org/greeneconomy/sites/unep.org.greeneconomy/files/publications/greenisgold_en_20160519.pdf
4. For Xi's full speech see https://sustainabledevelopment.un.org/content/documents/20548china.pdf
5. See http://www.cn.undp.org/content/china/en/home/library/mdg/mdgs-report-2015-.html for a report on China's implementation of the MDGs.
6. See http://english.gov.cn/premier/news/2016/09/20/content_281475446661058.htm
7. For a discussion of countries' differentiated responsibilities, see Osborn et al (2016). Universal Sustainable Devleopment Goals: Understanding the Transformational Challenge for Developed Countries: Report of a Study by Stakeholder Forum. Available at: https://sustainabledevelopment.un.org/content/documents/1684SF_-_SDG_Universality_Report_-_May_2015.pdf
8. Yi, W. (2012). Chinese Academy of Sciences, Institute of Policy and Management: China's Sustainable Development in the Shifting Global Context. Available at: http://english.cbcsd.org.cn/SDtrends/20160325/86084.shtml

We can trace four critical moments in recent years where China outlined a framework for sustainable development within its national context that will be crucial for the transition to sustainability for Chinese cities.

First, at the 18th National Congress of the Communist Party of China (CPC), party officials formally adopted a "scientific outlook on development", which called for development and reform within China's economic, political, cultural, social and ecological spheres.[9] This complemented the UN's own vision of global sustainable development, which similarly advocates for development in the economic, social, environmental and governance realms. During the fifth plenary session, the CPC Central Committee also underlined the importance of innovation, coordinated development, green development and open development, where development initiatives amongst different countries should strive to produce sustainable and mutually beneficial results. Overall, such a convening, especially at the top level, exemplified China's commitment to integrating a global development strategy within its own framework of development: pursuing sustainable development with Chinese characteristics.

Second, when issuing its thirteenth Five-Year Plan earlier this year, the CPC articulated its vision to uphold the principles of innovation, increased coordination and openness, and green development. The plan provides a framework for building a "moderately well-off society" and reflects increasing emphasis on quality growth- that is, balancing economic growth with environmental protection and inclusive development. The 13th Five Year Plan sets multiple binding targets for enhancing resource conservation and management, intensifying environment protection, strengthening ecological protection and restoration, pollution reduction, coping with climate change, green financing and green industries. It calls for infrastructure improvement in transportation, energy, and water, new urbanization, rural and urban linkages, and coordinated regional development. Improving social security and enhancing innovation through education are also key components of the plan.[10]

Third, in 2014 China adopted the *National New-type Urbanisation Plan (2014-2020)*[11] which sets out a 'human-centred' model of urban planning in order to address current problems in China's urban environment–slow industrial upgrading, a depletion of resources, a deterioration of the environment and social inequality and marginalisation. Conversely, China's new model of urbanization is predicated upon efficiency, inclusivity and sustainability.[12] More explicitly, it seeks to make all cities ecologically sustainable while making vast improvements in the availability of public services.

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9. China Daily, 2016. Scientific Outlook on Development. Available at: http://www.chinadaily.com.cn/china/cpc2011/2010-09/08/content_12474310.htm
10. China's 13th Five-Year Plan (Chinese) is available at http://news.xinhuanet.com/politics/2016lh/2016-03/17/c_1118366322.htm; an overview of the Plan is available at: http://www.cn.undp.org/content/china/en/home/library/south-south-cooperation/13th-five-year-plan--what-to-expect-from-china.html
11. The Plan is available here (in Chinese): http://www.gov.cn/zhengce/2014-03/16/content_2640075.htm
12. World Bank; Development Research Center of the State Council, the People's Republic of China. 2014. Urban China: Toward Efficient, Inclusive, and Sustainable Urbanization. Available at: https://openknowledge.worldbank.org/handle/10986/18865

Fourth, in February 2016, the CPC issued its *Urban Action Plan on Climate Change Adaptation,*[13] which serves as a programmatic subcomponent to its more overarching "National Climate Change Adaption Strategy".[14] In it, specific activities relevant to achieving national sustainable development and promoting the development of an ecological civilization are delineated. The program stipulates that China's urban planning must take into full account the primacy of factors associated with climate change and work towards improving the environmental governance of cities. More specifically, the program proposes that, by 2020, 30 pilots for climate change adaptation will have been built, with exemplary urban green buildings promoted in 50 percent of all cities.[15] Overall, the plan highlights China's heightened awareness of the importance of adapting its urban spaces to climate change.

Finally, in 2015, the central government held a high level urban planning conference for the first time in 37 years. The Central Urban Work Conference along with the Central Economic Work Conference, took place in Beijing from Dec. 18 to Dec. 21, to set guidelines on strengthening urban planning, construction and management. President Xi Jinping and Premier Li Keqiang both addressed the conference and the central government set out the "Five Integrations"[16] programme to guide urban development as follows: First, to co-ordinate space, scale, and industry, improving the overall situation; Second, to incorporate planning, construction, and management, improving the overall system; third, to link reform to technology and culture as a three-wheel vehicle, to improve sustainability; fourth, to integrate production, living conditions, and ecological development, to improve liveability; and, fifth, to co-ordinate the government, society, and the public, to improve social initiative.

The conference identified safety, Party leadership, improved awareness of urban planning, reform of urban management institutions, innovation of urban work mechanisms, and improved training for city leaders in professional planning, construction, and management skills. The government aims to largely finish renovation of shantytowns, underdeveloped areas and dilapidated housing by 2020. More measures will be taken to upgrade city clusters in the eastern region, and to foster city clusters and key regional cities in the central and western regions.

13. The Urban Climate Change Adaptation Action Plan (Chinese) is available at: http://www.sdpc.gov.cn/zcfb/zcfbtz/201602/t20160216_774721.html
14. For more information on China's climate commitments, see OECD (2016). China's Climate Change Combat. Available at: http://www.oecd.org/environment/china-climate-change-combat.htm and The National Development and Reform Commission (2015). China's Policies and Actions on Climate Change. Available at: http://www.cma.gov.cn/en2014/climate/featutes/201511/P020151120633951236905.pdf
15. China Business Council for Sustainable Development (2016). Available at: http://english.cbcsd.org.cn/SDtrends/20160325/86084.shtml
16. For more information on the Five Integrations (五个统筹), see (in Chinese) http://news.xinhuanet.com/politics/2015-12/22/c_1117545528.htm

1.2 Performance evaluation and the decoupling of human development and ecological input

1.2.1 The two-hemisphere theory and decoupling theory

Evaluation is a very important part of urban sustainable development management. It can both help recognise the current status of where a city is on the path towards sustainability and identify optimal improvement paths for a transition to sustainability.

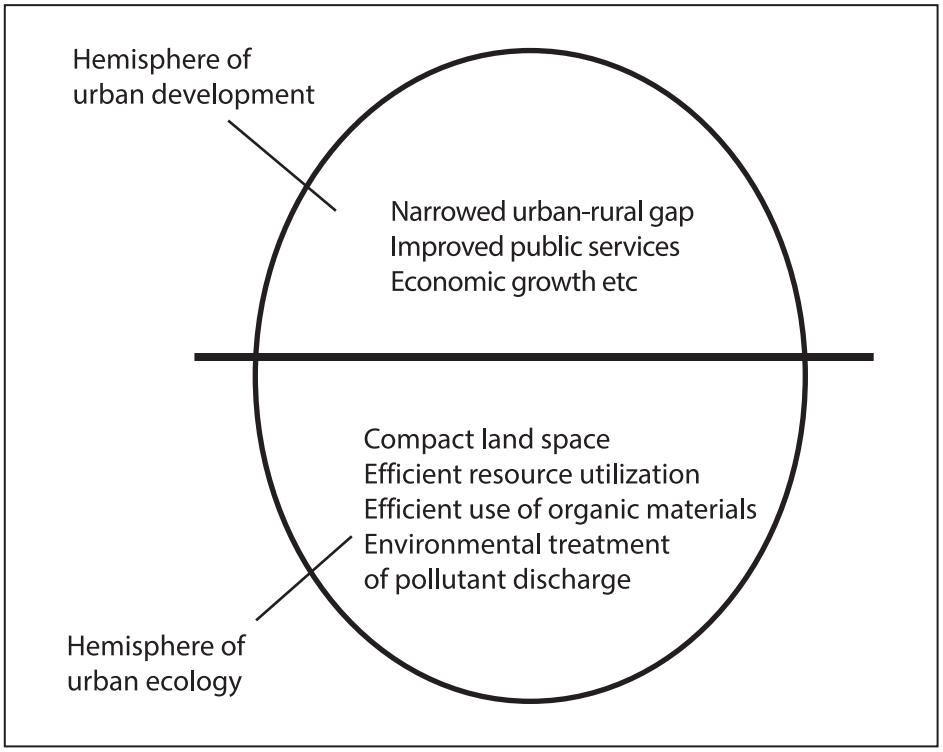
Chinese cities are currently focused on developing their economies and societies at the cost of excessive resource consumption and environmental pollution. This report combines Ecological Input (EI) and Human Development (HD) into the same framework to establish an assessment model that, based on the research methodology developed by Zhu Dajian (2008),[17] evaluates sustainable urban development in a way that takes into account the scientific validity, measurability and data availability of the indicators as well as the simplicity and clarity of ecological footprint and Human Development Index evaluation methods. On the one hand, the China Sustainable Cities Index (CSCI) makes up for a lack of consideration of economic and social development in urban environmental protection; on the other hand, it also considers the pressures that human development exert on urban environments.

The China Sustainable Cities Index is composed of two indices: the Urban Human Development Index (UHDI) and Urban Ecological Input Index (UEII). The Urban Human Development Index applies the United Nations Development Programme's (UNDP) Human Development Index (HDI) at the city level. The HDI was developed by UNDP to assess development through a human capacity lens and has been applied to countries globally since 1990.[18] It measures development in three categories: a long and healthy life, being knowledgeable and have a decent standard of living. The Urban Ecological Input Index is made up of three resource consumption indicators and six pollution output indicators to measure the environmental health of a city. These indicators are selected because they reflect areas over which local governments have policy influence (as opposed to, for example, an indicator of air quality which may be affected by inputs beyond the jurisdiction of a municipality) and have also been identified as targets for improvement in the 12th and 13th Five-year Plans.

The level of urban sustainable development can be determined by evaluating whether human flourishing is taking place within ecological limits. This is illustrated by allocating indicators into two hemispheres- urban development and urban ecology- as outlined in Figure 1-1.

17. Zhu Dajian, Meng Weihua & Xu Ping, Contribution of economic growth to welfare in China from 1980 to 2005. Economic Management in Proceedings of the Sixth Academic Annual Meeting of Social Sciences in Shanghai. 2008: 9-21.
18. For more information on the development and application of the HDI, see http://hdr.undp.org/en/content/human-development-index-hdi

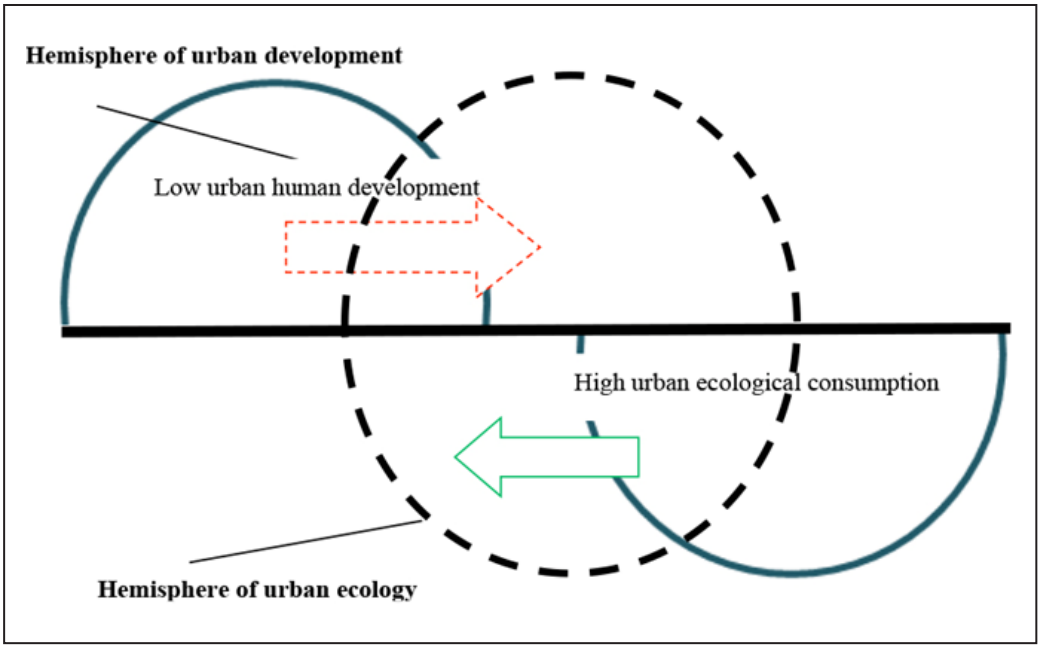
Figure 1-1 Two hemispheres of urban development



The economic and social systems of a city including GDP, life expectancy and education are allocated to the upper hemisphere, the development hemisphere, and urban environmental systems are allocated to the lower hemisphere, the ecological hemisphere. The sustainable development achievements of a city can be measured by to what extent the two hemispheres match. For any city, its population, resources and environmental carrying capacity is limited. There does exist an ecological threshold. The hemisphere of urban development is restricted by the carrying capacity of the hemisphere of urban ecology and the land, energy, water and materials that are consumed as human development is improved cannot exceed the carrying capacity of the urban ecological environment. As shown in Figure 1-1, the goal of urban sustainable development is that economy and welfare in the hemisphere of urban development are highly developed, while environmental and resource consumption in the hemisphere of urban ecology remain within the scope of urban ecological carrying capacity. In other words, the development hemisphere and the ecological hemisphere have achieved "decoupling", which means that the growth of the economy and welfare is not subject to increases in ecological input.

According to the "decoupling" theory, there are three categories in the relationship between the human development hemisphere and the ecological hemisphere: coupled (matched), relatively de-coupled and absolutely de-coupled. When expansion of the human development hemisphere keeps pace or even outpaces the growth of the ecological hemisphere, economic growth relies on the overconsumption of natural resources, resulting

Figure 1-2 Alignment of the two hemispheres



in serious environmental damage. In this case, the two hemispheres are closely coupled and ecological efficiency is low, making this an unsustainable development mode. When expansion of the ecological hemisphere is slower than the growth of the human development hemisphere, "relative decoupling" is realised and greater economic and human development is achieved with less resource and environmental input. "Absolute decoupling" refers to continuous economic and welfare growth under the precondition that resource consumption and environmental pollution are not increased and may even decrease, representing a high level of sustainable development.

In practice, the hemisphere of urban development and the hemisphere of urban ecology are usually staggered, with either urban development excessively consuming ecological resources and exceeding the environmental carrying capacity of a city or the economy, society and welfare of a city is less-developed, as illustrated in Figure 1-2. The two dashed half-circles represent highly matched urban development and urban ecology hemispheres, which is an ideal status for urban sustainable development, while the two solid line half-circles stand for actual status. During the process of development towards sustainability, cities need to take multiple measures to boost economic growth and human welfare on the one hand, as directed by the dashed arrow, and on the other hand, reduce consumption of ecological resources as indicated by the solid line arrow, so that the human development hemisphere and the ecological hemisphere can be re-matched.

An evaluation model based on two hemispheres that examines to what degree the urban development hemisphere and the urban ecological hemisphere are staggered plays a role in policy guidance for urban sustainable development.[19]

The China Sustainable Cities Index can show city administrators where their city is relative to other cities with regards to ecological input and human development and identify areas for improvement. However, the most important comparison for any city is not with other cities, but with their own past performance. Cities can learn from the experience of other cities, but in the end must take action that is appropriate to their own specific situation. An appropriate assessment system can help a city formulate and adjust its sustainable development strategies within the constraints of its environmental carrying capacity and identify priority fields and optimal paths for achieving sustainability within its local context.

19. For an expanded discussion of the theoretical underpinnings of the conceptual model of the CSCI, see Zhu Dajian et.al. 中国城市可持续发展绿皮书（2015-2016 中国 35 个大中城市可持续发展评估）, forthcoming.

CHAPTER TWO: DATA SOURCES AND ASSESSMENT METHODOLOGY

2.1 Index methodology and collection and treatment of data

The indices are the Urban Ecological Input Index (UEII) and Urban Human Development Index (UHDI). The indicators are comprised of nine ecological input indicators and three human development indicators.

The Urban Ecological Input Index (UEII) includes two sub-indices: the Urban Resource Consumption Index (URCI) and Urban Pollutant Discharge Index (UPDI). The URCI is made up of 3 indicators: water consumption, land consumption and energy consumption. The UPDI is made up of 3 indicators of 2 sub-indicators each: urban water pollutant indicator (COD + Ammonia Nitrogen); urban air pollutant indicator (Sulfur dioxide + Nitrogen oxide); and, urban solid waste indicator (industrial waste + domestic garbage).

The Urban Human Development Index (UHDI) consists of three indicators, namely the life expectancy indicator (LEI), education indicator (EI) and income indicator (II). The education indicator is comprised of 2 sub-indicators: mean years of schooling + expected years of schooling.

Data is derived primarily from the 2015 Statistical Yearbook of Chinese Cities and the China Statistical Yearbook on the Environment 2015.

See Appendix 1 for more information on the data sources and methodology.

(1) Urban Ecological Input Index Methodology

Urban ecological input in this report refers to land, energy and water consumed and pollutants discharged during urban development under a given population, technical level and economic size within a set time period. The Urban Ecological Input Index (UEII) is the result of the arithmetical average of the Resource Consumption Index (URCI) and Urban Pollutant Discharge Index (UPDI).

UEII is equal to the arithmetical average of URCI and UPDI:

$$UEII = \frac{1}{2}(URCI + UPDI) \quad (1.1)$$

Among them, $$URCI = \frac{1}{3}(UWCI + ULRI + UECI) \quad (1.2)$$

$$UPDI = \frac{1}{3}(UWPI + UAPI + USWI) \quad (1.3)$$

$$= \frac{1}{6}(UWP_{COD} + UWP_{N-NH_4} + UAP_{SO_2} + UAP_{NO_X} + USW_{Ind} + USW_{Hh}) \quad (1.4)$$

The value of UEII ranges from 0 to 1. The closer to 0 the value is, the lower the urban ecological input is and the fewer resources such as water, land, energy and materials are consumed and the less wastewater, emissions (waste gas) and solid waste are discharged during urban development. The closer to 1, the higher the urban ecological input is and the more water, land, energy and materials are consumed and more wastewater, emissions (waste gas) and solid waste are discharged.

(2) Urban Human Development Index Methodology

The Urban Human Development Index (UHDI) is based on the same methodology as the UNDP Human Development Index (HDI). HDI was first released by the United Nations Development Programme (UNDP) in its *Human Development Report – 1990* and is intended to measure average achievement in key dimensions of human development in different countries across the world. The HDI measures the general achievement of a country in the three basic aspects of human development: life expectancy, knowledge and standard of living. It is a comprehensive index composed of three basic indicators: life expectancy measured by life expectancy at birth, degree of education that is measured by the mean years of schooling (MYS)[20] and expected years of schooling (EYS)[21] and standard of living measured by per capita national income (GNI) (PPP in USD).[22] In 2010, the methodology used to calculate the HDI was revised and the UHDI following this methodology. This Report combines the choice of parameters in HDI calculations by UNDP from 2010 and 2014 and comes up with the following calculation method for the application of the Human Development Index to Chinese cities.[23]

Human Development Index (HDI) is geometric mean of life expectancy indicator (LEI), education indicator (EI) and income indicator (II):

$$HDI = \sqrt[3]{LEI \times EI \times II} \tag{1.5}$$

Among them,

$$LEI = \frac{LE - 20}{85 - 20} \tag{1.6}$$

$$EI = \frac{MYSI + EYSI}{2} \tag{1.7}$$

20. "School education years" refers to education years of people aged above 25.
21. "Expected education years" refers to years of education that a 5-year-old child will receive in his/her lifetime.
22. RMB PPP adopted in this Report is 4.1862, based on estimation of RMB PPP in World Economic Outlook Report, IMF. http://www.imf.org/external/pubs/ft/weo/2013/01/weodata/index.aspx.
23. Selection of parameters for the Human Development Index is the result of adjustment based on the 2010 edition. When the maximum value of related indicators in 2013 is higher than the 2010 edition, the value needs to be replaced by the extreme observed in 2013. For instance, for life expectancy, Japan's 83.6 years in 2013 is used; per capita income adjusted for PPP is Qatar's income of USD 119,029 in 2013; basic income level necessary for survival adopts the lowest value of 100 for 2014 HDI calculations.

MYSI is the mean years of schooling index,

EYSI is expected years of schooling index,

$$MYSI = \frac{MYS - 0}{15 - 0} \quad (1.8)$$

$$EYSI = \frac{EYS - 0}{18 - 0} \quad (1.9)$$

$$II = \frac{\ln(GNI_{pc}) - \ln 100}{\ln 75000 - \ln 100} \quad (1.10)$$

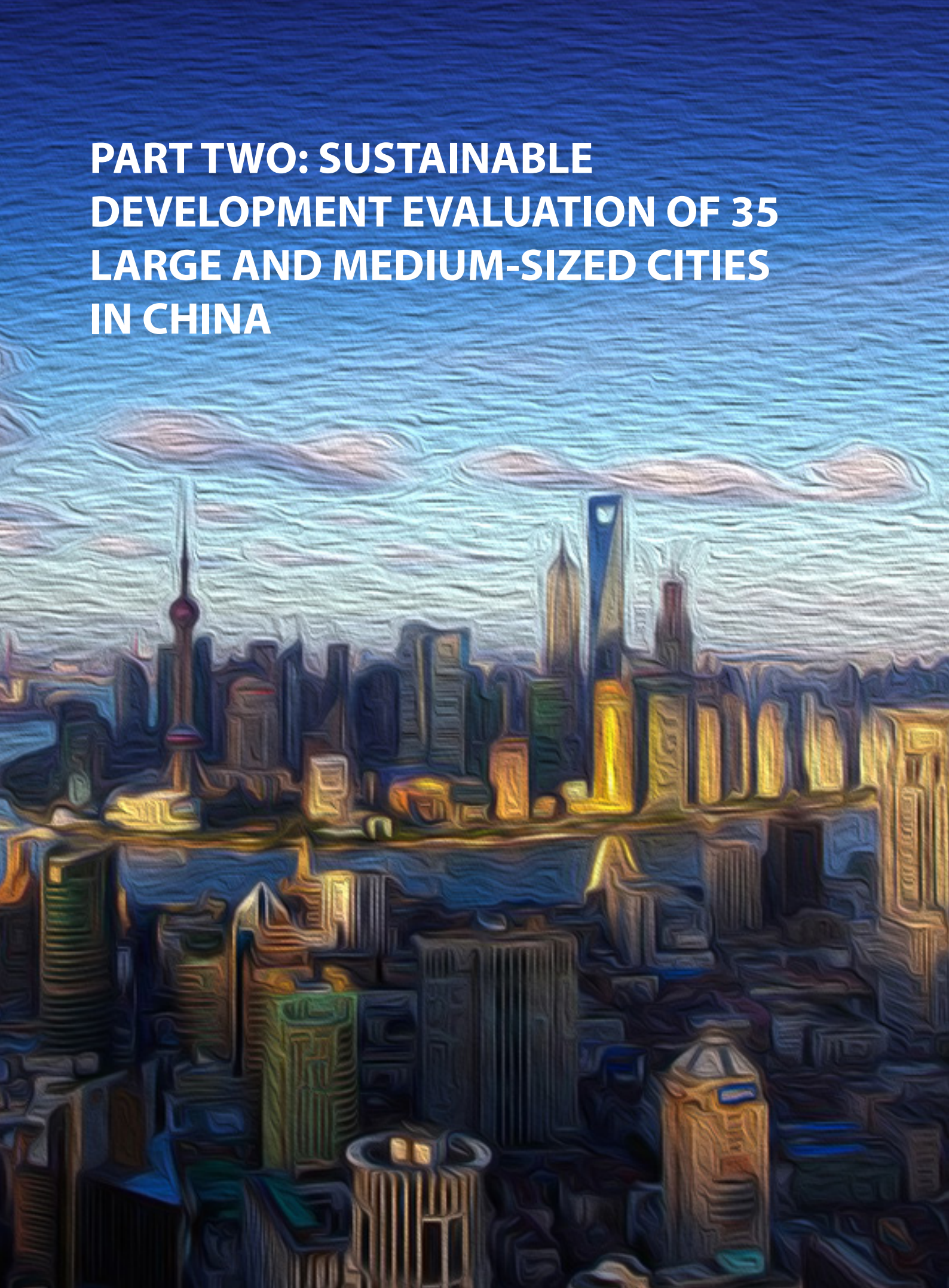
The HDI value ranges from 0 to 1. The closer to 1 the value is, the higher the human development level. In 2014, globally UNDP adopted 0.55, 0.7, 0.8 as the cut-off points for low (below 0.55), medium, high and very high (above 0.8) human development.

Table 2-1 List of sustainable development indicators for 35 large and medium-sized cities in China

Indicator		Human Development Index				Urban Ecological Input Index								
						Resource consumption index			Pollutant discharge index					
City		Per capita GDP (international dollar/person)	Per capita life expectancy (Year)	Per capita education year	Expected education year	Per capita building area (m^2/person)	Per capita standard coal (tce/person)	Per capita water supply (t)	Per capita COD emission (kg/person)	Ammonia nitrogen emission (kg/person)	Sulfur dioxide emission (kg/person)	Nitrogen oxide emission (kg/person)	Industrial solid waste production (t/person)	Domestic garbage disposal (t/person)
1	Beijing	28525	81.81	11.5	14.37	64.42	3.17	84.78	4.1	0.65	3.66	3.65	0.47	0.34
2	Shanghai	27776	82.29	10.58	14.26	64.44	4.57	130.79	7.76	1.7	7.76	10.2	0.79	0.31
3	Guangzhou	36650	81.34	10.55	15.4	79.13	4.2	153.24	9.75	1.45	4.85	4	0.38	0.33
4	Shenzhen	42646	79.7	10.7	13.6	82.57	6.08	152.27	10.02	1.63	0.52	1.41	0.1	0.5
5	Hangzhou	29614	81.56	9.88	14.22	55.67	4.97	74.42	7.74	1.31	9.11	6.97	0.81	0.37
6	Nanjing	30679	82.17	10.82	14.56	89.34	5.99	148.98	9.75	1.71	12.86	12.66	2.13	0.32
7	Tianjin	30019	81.08	10.2	14.25	48.65	5.37	53.57	7.17	1.26	13.79	14.93	1.14	0.14
8	Chengdu	19974	78.2	9.75	13.15	41.86	4.92	64.55	7.77	0.93	3.85	3.28	0.31	0.3
9	Wuhan	27956	80.27	10.9	13.9	53.49	7.19	126.46	9.43	1.27	8.73	8.28	1.36	0.25
10	Qingdao	27535	80.98	9.66	13.52	54.28	2.23	51.57	3.75	0.65	10.07	6.76	0.96	0.11
11	Ningbo	28059	81.24	8.91	14.36	39.56	5.36	64.15	5.56	1.34	15.36	20.82	1.53	0.41
12	Xiamen	24770	80.04	10.07	15.77	79	4.1	109.86	6.83	1.44	4.28	2.47	0.27	0.37
13	Chongqing	13650	77.78	7.89	13.25	41.15	2.57	37.73	8.89	1.3	17.61	7.96	1.03	0.21
14	Dalian	31362	81.41	9.92	14.02	56.87	3	56.31	10.76	1.55	15.91	13.94	0.81	0.17
15	Shenyang	24493	80.01	11.5	15.47	56.21	1.87	69.11	2.73	1.57	16.75	10.04	0.98	0.32
16	Changsha	30718	76.24	10.21	14	45.96	5.86	76.03	8.79	1.15	3.1	1.99	0.15	0.28
17	Xi'an	18198	75.73	9.52	12.97	51	3.09	58.78	9.47	1.39	10.71	5.04	0.29	0.36
18	Zhengzhou	20822	78.4	10.32	12.8	44.08	3.71	36.43	3.62	0.9	11.16	12.56	1.49	0.2

19	Jinan	23407	78.45	10.02	13.87	54.46	6.66	48.89	4.83	0.75	13.81	9.74	1.45	0.13
20	Taiyuan	16837	78.5	10.76	13.51	76.76	7.07	79.25	2.89	0.77	27.75	23.2	5.7	0.4
21	Changchun	20223	79	9.85	13.43	62.29	1.91	35.24	5.78	1.13	8.42	12.94	0.77	0.16
22	Kunming	16042	77.5	9.29	14.24	61.42	3.8	61.15	3.19	0.78	10.01	6.83	3.25	0.21
23	Hefei	19309	76.6	9.84	13.95	52.36	1.94	52.55	6.93	0.86	5.87	8.1	1.3	0.13
24	Harbin	15368	78.71	9.73	12.81	40.42	5.38	37.94	9.16	1.4	12.1	10.98	0.69	0.14
25	Fuzhou	19967	75.92	9.49	13.94	34.19	4.17	43.71	9.52	1.3	7.76	9.63	1.05	0.14
26	Haikou	14247	79.78	10.26	13.22	69.07	2.73	96.3	3.51	1.7	0.81	0.09	0.02	0.33
27	Nanchang	20075	77.6	9.95	12.79	50	3.15	84.41	9.28	1.28	7.19	3.16	0.37	0.11
28	Shijiazhuang	13969	76.34	9.66	12.52	24.87	4.92	17.99	3.64	0.61	16.16	15.6	1.41	0.14
29	Hohhot	27374	74.44	10.04	13.1	75.89	9.42	49.09	11.31	1.17	33.39	34.38	3.73	0.24
30	Urumqi	20091	72	10.68	12.73	116.71	7.32	84.58	4.65	1.41	22.17	26.55	2.73	0.39
31	Nanning	12353	76.21	9.4	13.52	70.6	2.51	99.46	20.08	2.19	10.11	9.5	0.89	0.22
32	Lanzhou	15624	73.5	10.31	13.5	60.3	5.84	66.93	10.72	2.15	20.19	18.79	1.74	0.26
33	Guiyang	15695	74.75	9.35	13.46	70.24	7.74	61.8	8.17	1.14	23.51	6.58	2.41	0.26
34	Yinchuan	18811	77.6	9.84	12.9	70.76	10.97	46.14	8.48	2.52	34.76	33.4	3.1	0.21
35	Xining	13340	74.48	9.16	12.8	39.29	10	66.79	14.33	1.77	32.75	21.54	2.37	0.41

PART TWO: SUSTAINABLE DEVELOPMENT EVALUATION OF 35 LARGE AND MEDIUM-SIZED CITIES IN CHINA



CHAPTER THREE: THE URBAN ECOLOGICAL INPUT INDEX

3.1 Ecological Input Index ranking of 35 large and medium-sized Chinese cities

3.1.1 Ranking by Urban Ecological Input Index

Using the methodology introduced in the last chapter, a quantitative analysis of resource consumption, pollutant discharge and comprehensive ecological input of 35 large and medium-sized cities in China was conducted, ranking each city by the Urban Ecological Input Index and the sub-indices Resource Consumption Index and Pollutant Discharge Index (Table 3-1). A lower score on the Urban Ecological Input Index means less resource consumption and pollutant discharge and the city ranks higher in the Ecological Input Index.

Table 3-1 UEII and indicators ranking of 35 large and medium-sized cities in China

Inder / City	Ecological Input Index (UEII)		Resource Consumption Index (URCI)		Pollution Discharge Index (UPDI)	
	Score	Rank	Score	Rank	Score	Rank
Qingdao	0.277	1	0.33	7	0.23	1
Shijiazhuang	0.286	2	0.26	1	0.31	10
Hefei	0.293	3	0.32	6	0.26	5
Changchun	0.307	4	0.31	3	0.30	9
Zhengzhou	0.316	5	0.32	4	0.31	11
Fuzhou	0.323	6	0.32	5	0.33	14
Chongqing	0.330	7	0.28	2	0.38	22
Chengdu	0.339	8	0.41	12	0.27	6
Nanchang	0.341	9	0.42	15	0.26	4
Beijing	0.352	10	0.46	18	0.24	2
Harbin	0.354	11	0.36	8	0.35	17
Xi'an	0.371	12	0.37	9	0.37	21
Changsha	0.373	13	0.47	20	0.27	7
Haikou	0.373	14	0.49	21	0.26	3
Kunming	0.374	15	0.42	16	0.32	13
Jinan	0.377	16	0.46	17	0.29	8
Shenyang	0.379	17	0.37	10	0.39	24
Tianjin	0.390	18	0.42	14	0.36	19
Dalian	0.396	19	0.38	11	0.42	25
Hangzhou	0.413	20	0.47	19	0.35	18
Xiamen	0.452	21	0.59	26	0.32	12
Ningbo	0.453	22	0.42	13	0.49	28
Shanghai	0.499	23	0.61	28	0.39	23

Nanning	0.500	24	0.49	22	0.51	29
Wuhan	0.507	25	0.65	30	0.37	20
Guiyang	0.508	26	0.57	25	0.44	26
Guangzhou	0.514	27	0.69	32	0.34	16
Lanzhou	0.526	28	0.50	23	0.56	30
Shenzhen	0.545	29	0.75	34	0.34	15
Taiyuan	0.613	30	0.61	27	0.62	32
Nanjing	0.624	31	0.76	35	0.49	27
Xining	0.632	32	0.56	24	0.70	34
Hohhot	0.648	33	0.61	29	0.69	33
Urumqi	0.658	34	0.74	33	0.58	31
Yinchuan	0.681	35	0.64	31	0.73	35

As can be seen from Table 3-1, the Ecological Input Index score ranges from 0.277 to 0.681 in 35 large and medium-sized cities, with an average of 0.44. The resource consumption index score range is 0.26 ~ 0.76, with a mean of 0.48. The Pollution Emission Index score interval is 0.22 ~ 0.73, with a mean of 0.40. Overall, ecological input scores have increased since last year with resource consumption seeing the largest jump. In the 2015 Report (2013 data) the UEII average was 0.316, the URCI was 0.284 and the UPDI was 0.349. (although changes in data collection methods may account for some of the difference).

Regarding the overall ranking, cities that have a more sustainable ecological input ranking (that is they have low ecological input) such as Shijiazhuang and Harbin also have relatively low per capita GDP, ranking among the bottom ten of the 35 cities, so that low ecological input may simply reflect lower levels of development. Some cities rank well however because they have taken proactive steps to control consumption and pollution. For example, in 2009, Hefei was chosen as one of 26 cities to demonstrate the use of renewable energy in buildings and won national subsidies to carry out further development. It also provides incentives for electric vehicles and was the first city to run a bus line entirely serviced by electric buses. Around 80 percent of the city's decorative lights use LED bulbs. The road lighting has been replaced with high-efficiency sodium high-pressure lights.[24]

Cities with high ecological inputs generally fall into two categories: one is made up of the cities centred around the wealthy major industrial areas of the Pearl River Delta such as Guangzhou and Shenzhen, or the Yangtze River Delta such as Shanghai, Nanjing, and Ningbo. For example, Nanjing has been developing rapidly in recent years, and investment in the 2014 Nanjing Youth Olympic Games increased resource consumption. The other group consists of the western cities with economies highly dependent on resource extraction and inefficient

24. See Meza, E. (2015). Trinia to develop 300 MW distributed PV project in Hefei City. Available at: http://www.pv-magazine.com/news/details/beitrag/trina-to-develop-300-mw-distributed-pv-project-in-hefei-city_100019266/#axzz4Oe8CdAz4 and ADB: Environmental Monitoring Report (2010). PRC: Anhui Hefei Urban Environment Improvement Project. Available at: https://www.adb.org/sites/default/files/project-document/63220/36595-01-prc-emr-01.pdf

coal boilers for heating in the winter such as Hohhot, Xining, Urumqi and Yinchuan. For example, coal mining is a major industry in Yinchuan and during the year 2014, local coal production facilitated a growth rate of up to 66 percent.[25]

3.2 Analysis of ecological input sub-indicators of 35 cities in China

(1) Ranking by resource consumption indicators

The quantitative analysis of resource consumption of the 35 cities, and results and ranking of three indicators, namely urban water resource consumption, land resource consumption and energy consumption, are shown in Table 3-2.

Table 3-2 Ranking of 35 large and medium-sized cities in China by Resource Consumption Index and sub-indicators

City	Resource Consumption Index (URCI)		Water Consumption Index (UWCI)		Land Resources Consumption Index (ULRI)		Energy Consumption Index (UECI)	
	Score	Rank	Score	Rank	Score	Rank	Score	Rank
Shijiazhuang	0.26	1	0.12	1	0.21	1	0.45	19
Chongqing	0.28	2	0.25	4	0.35	6	0.23	6
Changchun	0.31	3	0.23	2	0.53	22	0.17	2
Zhengzhou	0.32	4	0.24	3	0.38	8	0.34	12
Fuzhou	0.32	5	0.29	6	0.29	2	0.38	15
Hefei	0.32	6	0.34	11	0.45	13	0.18	3
Qingdao	0.33	7	0.34	10	0.47	15	0.20	4
Harbin	0.36	8	0.25	5	0.35	5	0.49	23
Xi'an	0.37	9	0.38	14	0.44	12	0.28	9
Shenyang	0.37	10	0.45	21	0.48	18	0.17	1
Dalian	0.38	11	0.37	13	0.49	19	0.27	8
Chengdu	0.41	12	0.42	18	0.36	7	0.45	18
Ningbo	0.42	13	0.42	17	0.34	4	0.49	21
Tianjin	0.42	14	0.35	12	0.42	10	0.49	22
Nanchang	0.42	15	0.55	25	0.43	11	0.29	10
Kunming	0.42	16	0.40	15	0.53	21	0.35	13
Jinan	0.46	17	0.32	8	0.47	16	0.61	28
Beijing	0.46	18	0.55	27	0.55	23	0.29	11
Hangzhou	0.47	19	0.49	22	0.48	17	0.45	20
Changsha	0.47	20	0.50	23	0.39	9	0.53	25
Haikou	0.49	21	0.63	28	0.59	25	0.25	7
Nanning	0.49	22	0.65	29	0.60	27	0.23	5
Lanzhou	0.50	23	0.44	20	0.52	20	0.53	24
Xining	0.56	24	0.44	19	0.34	3	0.91	34
Guiyang	0.57	25	0.40	16	0.60	26	0.71	32

25. See the Guardian (2016).The Coal Boom Choking China. Available at: https://www.theguardian.com/environment/ng-interactive/2015/jun/05/carbon-bomb-the-coal-boom-choking-china

Xiamen	0.59	26	0.72	30	0.68	31	0.37	14
Taiyuan	0.61	27	0.52	24	0.66	30	0.64	29
Shanghai	0.61	28	0.85	32	0.55	24	0.42	17
Hohhot	0.61	29	0.32	9	0.65	29	0.86	33
Yinchuan	0.64	30	0.30	7	0.61	28	1.00	35
Wuhan	0.65	31	0.83	31	0.46	14	0.66	30
Guangzhou	0.69	32	1.00	35	0.68	32	0.38	16
Urumqi	0.74	33	0.55	26	1.00	35	0.67	31
Shenzhen	0.75	34	0.99	34	0.71	33	0.55	27
Nanjing	0.76	35	0.97	33	0.77	34	0.55	26

The range in scores of the 35 cities for the Resource Consumption Index is 0.26 ~ 0.76, with a mean of 0.48. This is an increase over the average value of 0.284 last year. For the sub-indices, the range for the Water Resource Consumption Index is 0.012 ~ 1.000, with a mean of 0.482; the range for the Land Resource Consumption Index is 0.21 ~ 1.000, with a mean of 0.509 and the range for the Energy Consumption Index is 0.17 ~ 1.000 with an average of 0.45.

The ten cities with the lowest resource consumption are Shijiazhuang, Chongqing, Changchun, Zhengzhou, Fuzhou, Hefei, Qingdao, Harbin, Xi'an and Shenyang. Ranking 11 to 25 are the cities of Dalian, Chengdu, Ningbo, Tianjin, Nanchang, Kunming, Jinan, Beijing, Hangzhou, Changsha, Haikou, Nanning, Lanzhou, Xining, and Guiyang. The largest resource consumers are Xiamen, Taiyuan, Shanghai, Hohhot, Yinchuan, Wuhan, Guangzhou, Urumqi, Shenzhen and Nanjing.

1) Classification by water resource consumption indicator

More than 300 out of 667 cities surveyed by the Ministry of Housing and Rural-Urban Development in China face water shortages with a total annual shortfall of 5.8 billion cubic meters and China has resorted to large-scale engineering projects to divert water from south to north China.[26] Cities such as Shanghai and Tianjin are dealing with ground subsidence due to overpumping of ground water. In coastal cities, subsidence exposes aquifers to greater risks of salinization.

Urban leakage wastes about 20 percent of piped water. Industrial recycling is officially 85.7 percent comparable to 85 percent for developed countries.

The cities with the lowest water consumption are Shijiazhuang, Changchun, Zhengzhou, Chongqing, Harbin, Fuzhou, Yinchuan, Jinan, Hohhot and Qingdao. The average water consumption index of these 10 cities is 0.266, and the average water supply per capita is 40.4.

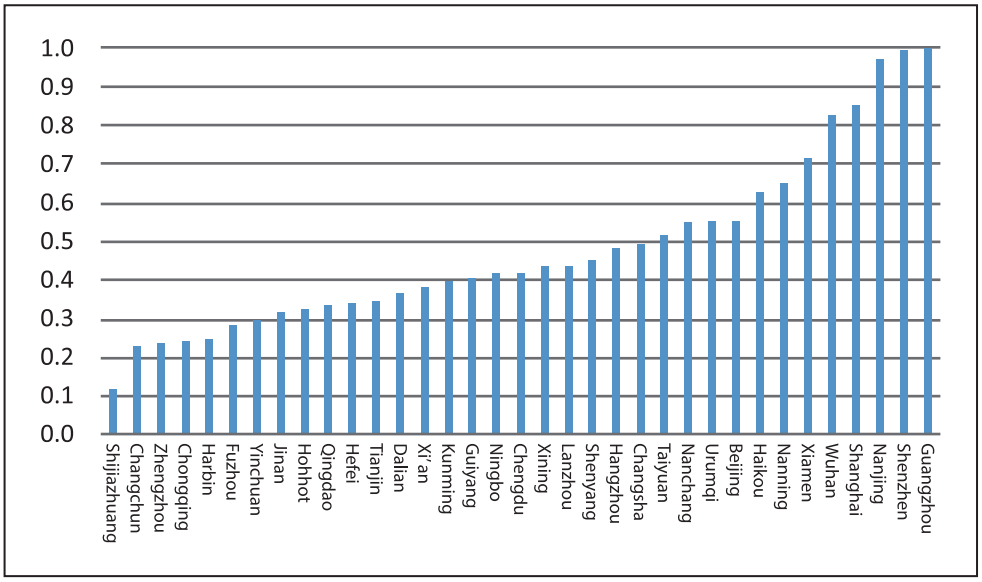
Shijiazhuang, Zhengzhou and Changchun are cities that experience serious water shortage for geographical reasons. All these governments have strict water-saving policies in place and

26. See http://www.ce.cn/xwzx/gnsz/gdxw/201405/26/t20140526_2875876.shtml

water prices in these cities are considerably higher than those cities with abundant water resources such as Hangzhou.[27] However, these cities still sometimes fail to meet residents' daily water requirement.

Although Chongqing is a city with enough water resources but with a high population it is also faces water shortages dues to lack of water facilities and aging facilities; seasonal water shortages, mainly caused by the climatic conditions and environmental pollution.[28]

Figure 3-1 Classification of 35 large and medium-sized cities in China by water consumption



The five cities with the highest water consumption indicator score are Wuhan, Shanghai, Nanjing, Shenzhen and Guangzhou (Figure 3-1). The average water consumption indicator of these 5 cities is 0.928 and average per capita water consumption is 142.3t. These cities are all wealthy cities in warm areas with government policy focused on reducing water pollution rather than water use. Although Guangzhou has reduced its water consumption per capita by 40 percent over the past ten years, its performance is still ranked last.

Zhejiang province has adopted water plans to reduce water pollution and improving water utilization efficiency, especially for agricultural water consumption.[29] Zhejiang cities therefore are lower consumers than other Yangtze Delta cities. Hangzhou saw the biggest change in ranking from 35th in 2015 (2013 data) to 17th in 2016 (2014 data). The price of water in Hangzhou was the lowest of the 35 cities in 2013- CNY1.85 per cubic meter. The Hangzhou government began instituting policies to lower water usage and adopted the Hangzhou

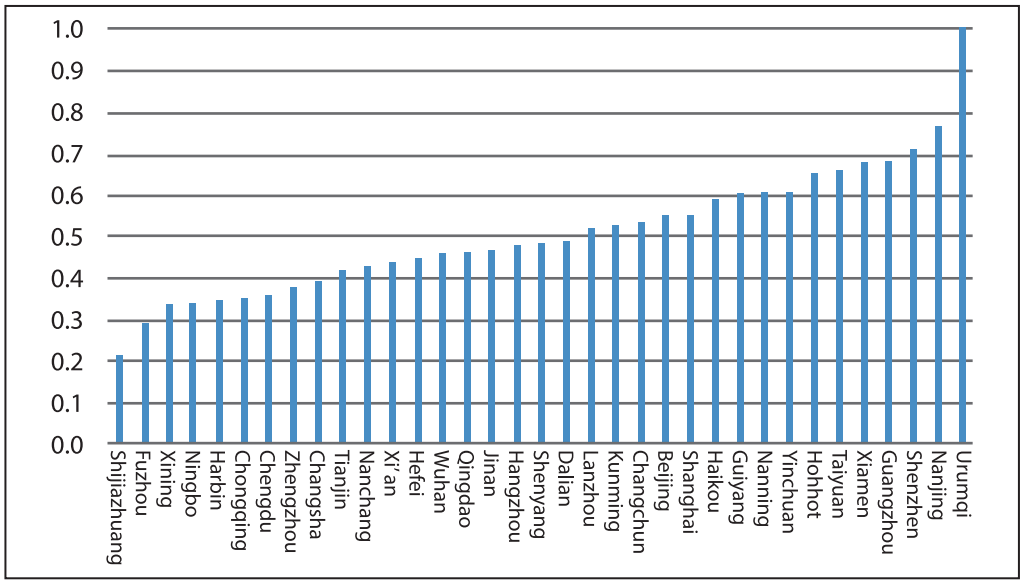
27. See Shijiazhuang's water saving law. Available at (in Chinese): http://www.sjzsl.gov.cn/col/1291081959286/2014/02/27/1393462546849.html; Regulations of Zhengzhou municipality on water conservation. Available at (in Chinese): http://public.zhengzhou.gov.cn/05CAB/58457.jhtml; Information on Changchun's water regime is covered in the Regulations of Jilin Province on Water Conservation. Available at (in Chinese): http://www.ccsl.gov.cn/slj/2/15/2014/07/i958.shtml
28. See http://cq.qq.com/a/20110515/000079_1.htm
29. See http://www.121jk.cn/news/renzhengbiaozhun/show44881_5.html

Water-saving Three-Year-Plan 2014-2016[30] which includes measures such as improving outdated water supply systems and reducing leakage, promoting water recycling and rain collection projects, improving water efficiency for agriculture and metering all households by 2020. A downward trend is likely to continue as the water price was increased to CNY 2.95 per cubic metre as of January 2015.[31] Both Ningbo's twelfth five year plan and thirteenth five year plan identify water saving and energy saving plans.[32]

2) Classification by land resource consumption indicator

Urban land supply is limited. Nearly all land in the south-eastern coastal cities is built up and land use intensity in some cities has exceeded the international warning level of 30 percent. Shenzhen, for example, is at 50 percent.[33] Average per capita construction area is 132.2sq. m. above the national planning standard of 120 sq. m. (lowered to 100 sq.m. in the new urbanisation plan) and the world average of 83.[34] At the same time, Chinese cities are starting to sprawl on their peripheries, due to local governments' reliance on land development for income, resulting in low-density, high-carbon land use patterns and the unnecessary urbanization of rural land.[35] The 13th Five-year Plan has set a target of a 20 percent reduction in built-up land area per unit of GDP.

Figure 3-2 Classification of 35 large and medium-sized cities in China by land consumption



30. Hangzhou Municipal Government Action Plan for Water Savings 2014-2016. Available at (in Chinese):<http://hznews.hangzhou.com.cn/xinzheng/swwj/content/2014-05/26/content_5298886.htm>
31. See Regulations of Hangzhou Municipality on the administration of urban water supply. Available at (in Chinese): <http://www.hzwgc.com/pre/articleContent.do?docid=36545F29AC1E1E1A6FBFDB106741309D
32. From <http://district.ce.cn/zt/zlk/bg/201206/11/t20120611_23397601_4.shtml>
33. Pearl River Delta Global Planning Project Analysis Report, Shenzhen Urban Planning and Land Resource Research Center.《珠江三角洲全域规划》分析报告，深圳市规划国土发展研究中心。
34. Ministry of Land Resources Data cited in MLR Data. Source from news article available at http://news.xinhuanet.com/house/hf/2014-02-20/c_119419389.htm
35. Axel Baeumler, et. al. Sustainable Low-carbon City Development in China. World Bank, 2012, pp. xl-xli

Overall, the large cities are consuming more land than in previous years, but still fall below the national average. The lowest land consuming cities are Shijiazhuang, Fuzhou, Xining, Ningbo, Harbin, Chongqing, Chengdu, Zhengzhou, Changsha and Tianjin with an average index score of 0.343, and average per capita area of 40 square meters. Shijiazhuang and Fuzhou have a per capita area of only 24.87 square meters and 34.19 square meters, far below the 35 cities average per capita area of 59.35 square meters built area.

Guiyang, Nanning, Yinchuan, Hohhot, Taiyuan, Xiamen, Guangzhou, Shenzhen, Nanjing and Urumqi consume the most land with an average indicator score of 0.697 with an average per capita built-up area of 81.1 square meters. The per capita built-up area of Urumqi, Nanjing and Shenzhen is 116.71 m^2, 89.34 m^2 and 82.57 m^2 respectively, which is far higher than the average of 59.35 M2 for all the cities, and the intensive use of land is relatively low. In recent years Beijing and Shanghai have been restricting land supply especially for residential land use.[36] Guangzhou and Shenzhen, although they continue to expand, are however, realizing the importance of land use efficiency, and they are making policies to improve this issue through urban planning.[37]

Several western cities rank high in the land resource consumption indicator. However, if we look at their absolute amount of urban built area, none is higher than the average level of all 35 cities. For Taiyuan and Yinchuan, their urban built area is only 70 percent and 50 percent of the average. However, they perform badly on a per capita basis with inefficient use of land relative to their smaller populations.

3) Classification by energy consumption indicator

Energy demand is high and supplies are tight. An overreliance on coal has severely impacted air quality. The overall use of renewables and energy efficiency is generally low and some Chinese cities experience hardship due to lack of energy supplies. However, China has committed to an absolute energy cap of 5 billion tons of standard coal by 2020 and pledged to increase non-fossil fuel energy sources to 20 percent by 2030 as part of its international climate change commitments.

The margin of difference in the energy consumption indicator shows that the gap in energy consumption between the 35 cities is wide. The eight best-performing cities in terms of low energy consumption are Shenyang, Changchun, Hefei, Qingdao, Nanning, Chongqing, Haikou,

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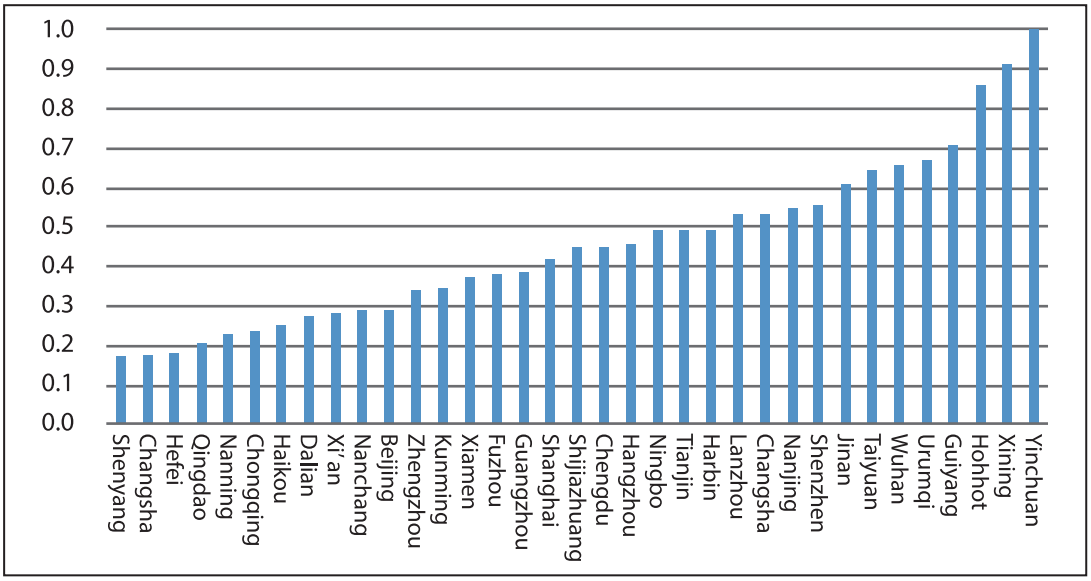
36. See the Beijing 12th Five-year Plan period Land Resources Protection, Development and Utilization Plan. Available at (in Chinese): <http://zhengwu.beijing.gov.cn/ghxx/sewgh/t1203400.htm> and Beijng's Land Use Master Plan（2006-2020.）. Available at (in Chinese): <http://wenku.baidu.com/link?url=DBaVF5yq_wHiGxMrbBlVppiatz2EmUC2C01Q_MbZkMB21tjRdKJyHKM1mlkB1spIFboN8QHa645ykHpQVkWolWHYbpkzZQK35vR0hVzVl4y>；See Shanghai's Land Use Master Plan（2010-2030）Available at (in Chinese): <http://wenku.baidu.com/link?url=nyz0pXxlJKcvBFOx2LSTgFNliXaDOs68-Supy6YjB-HRKhHCPesiYyacvwJaor-3R28RUikhGjDYcEbVLD5_glnYvWBNcn7FVftE5mNJakO>

37. See Guangzhou's Land Use Master Plan（2010-2030）Available at (in Chinese): <http://www.laho.gov.cn/ywpd/tdgl/zwxx/tdlyztgh/201312/t20131216_383071.htm> ; See Shenzhen's City Master Plan. Available at (in Chinese): http://www.szpl.gov.cn/xxgk/csgh/csztgh/201009/t20100929_60694.htm and Shenzhen's Land Use Master Plan（2010-2030）Available at (in Chinese): http://www.szpl.gov.cn/xxgk/ghjh/td/201303/P020130326414200155682.pdf

Dalian, Xi'an and Nanchang with a per capita consumption of standard coal of less than 4 tons, below the average value of the 35 cities at 4.96.

Even though Dalian is a centre of the oil refining and petrochemical industry, it has been promoting non-fossil fuel energy production in recent years. 34.9 percent of the city's total power generation came from nuclear power in 2014.[38] As well, Dalian consumed 1,010 million kwh wind power in 2014 and as of 2015, there were two 220-kilowatt wind power stations and eight 66-kilowatt wind power stations in Dalian, with a total capacity of 462.15 MW, accounting for 6.19 percent of the total capacity of the Dalian power grid.[39] Therefore Dalian is likely to continue to perform well on this indicator.

Figure 3-3 Classification of 35 large and medium-sized cities in China by energy consumption



The top 4 energy consuming cities are Yinchuan, Xining, Hohhot and Guiyang (Figure 3-3). The per capita consumption of standard coal in Xining and Yinchuan are 10.00t and 10.97t respectively. Energy consumption is correlated with the predominant industries of a city and their consumption levels. For instance, as one of the major industrial bases in China, Taiyuan is supported by such pillar industries as energy, metallurgy, machinery and chemicals. Yinchuan is in a coal mining area and uses coal as its main source of heating energy. Yinchuan is the highest energy user due to both abundant supply and poor quality coal.

Nanjing improved over last year. 63 percent of Nanjing's energy is consumed by secondary industry, mainly in the construction materials, steel, electricity and petrochemical industries.[40] Without being able to reduce the energy consumption in these four heavy

38. See Liaoning Pronvical Government Analysis on the production and consumption of industrial energy above the scale of 2014 in Dalian City, Liaoning Province. Available at (in Chinese): http://www.lnic.cn/rdtj/mrjj/2015/06/146636.shtml
39. See http://www.in-en.com/article/html/energy-2232965.shtml
40. See Nanjing Municipal Bureau of Statistics Energy Consumption Report. Available at (in Chinese): <http://www.zgjssw.gov.cn/shixianchuanzhen/nanjing/201411/t1864370.shtml>

industries, Nanjing has adjust its energy consumption structure by using cleaner energy and improving energy efficiency.[41 42]

3.2 Ranking and classification by pollutant discharge indicators

(1) Ranking by pollutant discharge indicators

A quantitative analysis of pollutant discharge of the 35 cities was conducted, and the results and ranking of the three indicators, namely urban water pollutant discharge, air pollutant emission and solid waste discharge are shown in Table 3-3.

Table 3-3 Ranking of 35 large and medium-sized cities in China by pollutant discharge index and sub-indicators

Indicator / City	Pollution Discharge Index (UPDI)		Water Pollution Index (UWPI)		Air Pollution Index (UAPI)		Solid Waste Index (USWI)	
	Score	Rank	Score	Rank	City	Score	Rank	Score
Qingdao	0.23	1	0.24	5	0.24	12	0.19	2
Beijing	0.24	2	0.23	3	0.11	6	0.38	20
Haikou	0.26	3	0.42	15	0.01	1	0.33	16
Nanchang	0.26	4	0.49	22	0.15	8	0.14	1
Hefei	0.26	5	0.34	8	0.20	9	0.24	8
Chengdu	0.27	6	0.38	10	0.10	5	0.33	14
Changsha	0.27	7	0.45	18	0.07	3	0.29	11
Jinan	0.29	8	0.27	7	0.34	20	0.26	9
Changchun	0.30	9	0.37	9	0.31	18	0.23	4
Shijiazhuang	0.31	10	0.21	1	0.46	28	0.26	10
Zhengzhou	0.31	11	0.27	6	0.34	21	0.33	15
Xiamen	0.32	12	0.46	20	0.10	4	0.39	22
Kunming	0.32	13	0.23	4	0.24	13	0.50	28
Fuzhou	0.33	14	0.49	24	0.25	15	0.23	5
Shenzhen	0.33	15	0.48	19	0.03	2	0.51	30
Guangzhou	0.34	16	0.53	28	0.13	7	0.36	17
Harbin	0.35	17	0.51	25	0.33	19	0.20	3
Hangzhou	0.35	18	0.39	12	0.23	11	0.44	25
Tianjin	0.36	19	0.43	16	0.42	25	0.24	6
Wuhan	0.37	20	0.49	23	0.25	14	0.37	18
Xi'an	0.37	21	0.51	26	0.23	10	0.39	21
Chongqing	0.38	22	0.48	21	0.37	22	0.30	13
Shanghai	0.39	23	0.53	29	0.26	16	0.38	19
Shenyang	0.39	24	0.38	11	0.39	24	0.41	23
Dalian	0.42	25	0.58	30	0.43	26	0.24	7

41. See <http://www.njnews.gov.cn/html/publish/tjj/2014/11/24/7708.html>
42. From Nanjing "Twelfth Five-Year" Energy-saving Plan. Available at (in Chinese): http://www.nanjing.gov.cn/xxgk/szf/201304/t20130420_1178477.html; the Nanjing Government's Research on the Energy Problem in the Sustainable Development of the Nanjing Economy http://www.nanjing.gov.cn/xxgk/bm/tjj/201411/t20141124_3063190.html and the Nanjing Government's Environmental Report 2013 http://www.njhb.gov.cn/43462/43464/201406/t20140604_2884912.html and 2015 http://www.njhb.gov.cn/43462/43464/201606/P020160604379598118347.pdf

Guiyang	0.44	26	0.43	17	0.43	27	0.47	26
Nanjing	0.49	27	0.58	31	0.37	23	0.51	29
Ningbo	0.49	28	0.41	14	0.52	29	0.54	31
Nanning	0.51	29	0.93	35	0.28	17	0.30	12
Lanzhou	0.56	30	0.69	32	0.56	30	0.41	24
Urumqi	0.58	31	0.40	13	0.71	31	0.63	34
Taiyuan	0.62	32	0.22	2	0.74	32	0.90	35
Hohhot	0.69	33	0.51	27	0.98	34	0.57	32
Xining	0.70	34	0.71	33	0.78	33	0.62	33
Yinchuan	0.73	35	0.71	34	0.99	35	0.48	27

The range in scores for the pollutant discharge index of the 35 cities is 0.23 ~ 0.73 and the average value is 0.395. Scores for the water pollutant discharge indicator range from 0.21 ~ 0.93 and the average value is 0.45. The air pollutant emission indicator range is 0.01-0.99 and the average value is 0.352, slightly lower than last year's 0.364. The solid waste discharge indicator ranges from 0.14-0.9 and the average value is 0.382.

The ten cities with the lowest Urban Pollutant Discharge Index score are Qingdao, Beijing, Haikou, Nanchang, Hefei, Chengdu, Changsha, Jinan, Changchun, Shijiazhuang and Zhengzhou. Cities ranking between 11th and 25th are Xiamen, Kunming, Fuzhou, Shenzhen, Guangzhou, Harbin, Hangzhou, Tianjin, Wuhan, Xi'an, Chongqing, Shanghai, and Shenyang. The top ten cities with the highest pollution emissions are Dalian, Guiyang, Nanjing, Ningbo, Nanning, Lanzhou, Urumqi, Taiyuan, Hohhot, Xining and Yinchuan.

It is important to remember that these indicators show emissions produced by the city, not necessarily how heavily the city is impacted by emissions which may originate elsewhere.

(2) Classification by pollutant discharge indicators

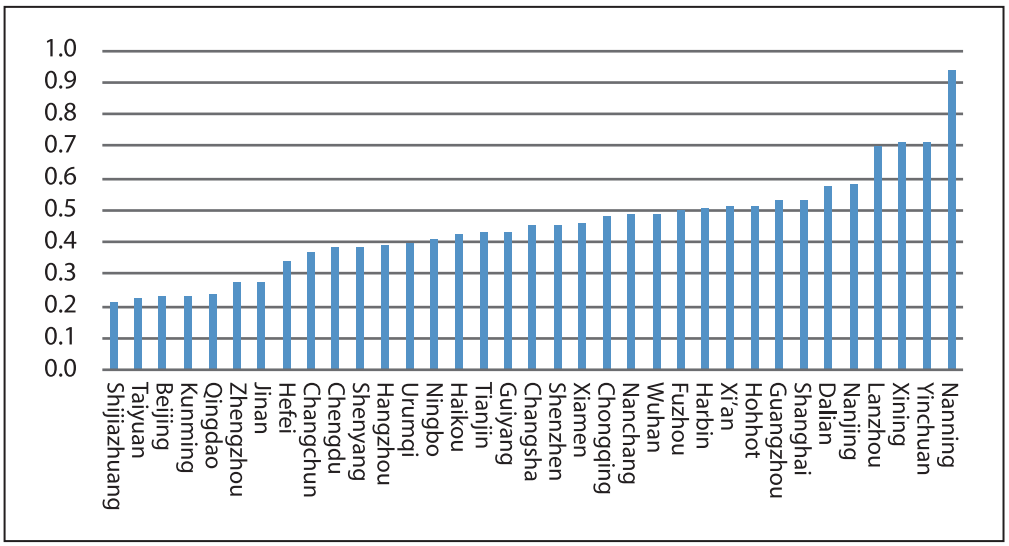
The classification of the 35 cities by the water pollutant discharge indicator, air pollutant emission indicator and solid waste discharge indicator are shown in Figure 3-4, Figure 3-5 and Figure 3-6 respectively.

1) Water pollutant discharge indicator

97.1 percent of urban centralized drinking water reaches national standards. However, 61.3 percent of underground water is categorized as poor and very poor contaminated with urban sewage, domestic and industrial waste, fertilizers and pesticides. Water pollution accounts for around 50 percent of negative pollution events affecting the environment.[43]

43. From the Bulletin of the Chinese Communique on the Environment 2015, http://www.zhb.gov.cn/gkml/hbb/qt/201606/W020160602413860519309.pdf

Figure 3-4 Classification of 35 large and medium-sized cities in China by water pollution



The five cities with the lowest water pollution discharge indicators are Shijiazhuang, Taiyuan, Beijing, Kunming and Qingdao (Figure 3-4). The top five cities are Nanjing, Lanzhou, Xining, Yinchuan, and Nanning.

In spite of performing relatively well on the Resource Consumption Index, Dalian, as China's largest oil refining and processing city and an important base for chemical and petrochemical products processing and production, does not perform as well on pollution discharge. The Northeast Environmental Protection Supervision Centre spot checked Dalian's inner city water quality and found serious water pollution problem: "water was black and stinky".[44] The Northeast Environmental Protection Supervision Centre also spot checked 17 industrial enterprises. Seven had excessive emissions and other environmental violations. 82 out of 144 key water pollutant discharge companies have not submitted legally required reports. The China National Petroleum Corporation Dalian branch has reported multiple water pollutant issues such as oil spills, but supervision has not improved. Urban wastewater reuse rate was only 11.2 percent, far below national requirements and there are still roads crossing, residential households, and cultivated land within the reservoir - water source protection area.[45]

Lanzhou also suffers from poor planning and environmental oversight with regards to water pollution. Major chemical and industrial enterprises such as aluminum production sites are located at the upper reaches of the Yellow River in Xigu. Meanwhile, water supply lines are extremely close to these polluting sites and their petro and chemical lines. Industrial accidents, such as a Benzene leakage incident in 2014 which polluted the domestic water supply of the inner city are almost inevitable.[46]

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44. See <http://china.caixin.com/2015-10-27/100867256.html>
45. See <http://www.cepnews.com.cn/news/500553>
46. See Bulletin of the State of Environment of Lanzhou in 2014. http://tjj.lanzhou.gov.cn/tjgb_1222/201506/t20150608_409749.htm

Urumqi, however, scores quite well on the water pollution index at number 13. The city has enforced strong regulations on industrial and domestic polluted water emissions in recent years, and accordingly receives good results on its UWPI indicator.[47]

2) Air pollutant emission indicator

Air pollution may now be the leading cause of premature death in China and has become a major policy focus.[48] 78.4 percent of 338 prefecture-above cities did not meet national Grade II in 2015, lower than World Health Organisation air quality standards. 77.5 percent of 338 prefecture-above cities did not meet national Grade II standards for PM2.5. 194 out of 480 cities surveyed experience acid rain, which accounts for 14 percent of total rainfall.[49] However, nationally, air quality has steadily improved since the 1990s and targeted air quality improvement plans with significant funding are being implemented.[50] The Airborne Pollution Prevention and Control Action Plan (2013-17) issued by the State Council in 2013 targets the Beijing-Tianjin Hebei region, the Yangtze River Delta and the Pearl River Delta. The Action Plan outlines ten measures for reducing air pollution including decreasing coal consumption to below 65 percent in the three target areas by 2017, increasing renewables, increasing public transportation and clean energy vehicles, eliminating old vehicles, small coal boilers and illegal industries and improving industrial processes.[51]

The air pollutant emissions indicator differs greatly among the 35 cities. The first eight cities ranked below 0.2 on the air pollution emissions indicator and the average of the group was 0.0875 with only minor differences between them. The middle 16 cities scored between 0.200 ~ 0.400 on the Grade II air pollution emission indicators with a group average of 0.289, again with only small differences between them. The next nine cities range between 0.400 ~ 0.750 with a group average group of 0.56. Differences between these cities is larger and the final two cities, Hohhot and Yinchuan see a big jump with scores higher than 0.9.

Ranked No. 1, Haikou's air pollution emissions are only 0.90kg / person, almost 76 times less than the last ranking city Yinchuan with air pollution emissions at 68.16kg / person. Yinchuan's high levels of air pollution and its high consumption of energy are directly linked, due to winter heating, and the industrial structure of the city. Wind and dust in the spring also impact Yinchuan's air quality which makes ecological management in this area very important.

Other western cities also score poorly, but are beginning to take steps to address their air quality and emissions. Urumqi was once labelled the National Most Polluted City. It was

47. See http://news.cnr.cn/native/city/20141221/t20141221_517169961.shtml
48. See the China National Human Development Report 2013. Available at: http://www.cn.undp.org/content/dam/china/docs/Publications/UNDP-CH_2013%20NHDR_EN.pdf
49. From the Bulletin of the Chinese Communique on the Environment 2015, http://www.zhb.gov.cn/gkml/hbb/qt/201606/W020160602413860519309.pdf
50. The national reports are available on the Ministry of Environmental Protection website at http://wfs.mep.gov.cn/dq/kqzl/201208/t20120827_235262.htm.
51. See the Ministry of Environmental Protection http://english.mep.gov.cn/News_service/infocus/201309/t20130924_260707.htm

heavily dependent on coal for industrial production and domestic heating. Located in a basin which prevents air pollution from dispersing, Urumqi has high absolute amounts of SO2 and nitrogen oxide emissions. However, these total emissions are still 15 percent lower than the average level of the 35 cities. The UAPI indicator ranks Urumqi at 31, mainly because the city's lower population makes this per capita indicator relatively higher than its absolute amount.

Since 2012, Urumqi has launched a huge anti-pollution campaign called "From Coal to Gas", and is providing CNY 12.1 billion to adjust the energy structure for heating. Within two years, Urumqi replaced more than 17 thousand scattered coal-fired boilers with 960 gas-fired boilers, transferred 55 polluting factories and finally became the first "Gasified" city in China.[52] Both SO2 and nitrogen oxide emissions have been decreasing since 2012, thanks to the city's ambitious environmental protection plans. Urumqi's From Coal to Gas Campaign won the Ministry of Housing and Urban-Rural Development's China Habitat Environment Model Award in 2014 for its efforts in air quality improvement.

Hohhot's municipal government has also launched a "From Coal to Gas" campaign to replace coal-fired boilers with gas-fired boilers. Heating plants and electric power plants are also required to install desulfurization devices. The city has also upgraded vehicle emission standards and developed public transportation with clean energy.

However, the city's emission performance on all pollution indicators, except nitrogen oxide, increased from 2013 to 2014. The municipal government has analysed the situation and notes the following issues with the implementation of their anti-pollution strategies: the lagging desulfurization of power plants because many heating plants failed to install the devices in time; heavy-polluting industrial companies have failed to invest in clean technologies to lower emissions as it is still voluntary to do so; and lack of cooperation and coordination between municipal government departments on environmental protection and monitoring.[53]

Lanzhou launched a program similar to "From Coal to Gas" even earlier in 1998, called the "Blue sky campaign", to deal with industrial pollutants, coal-generating pollution and automobile tailpipe gas. Its impact on air pollution has been slow but effective over the last five years. SO2 emissions decreased 3 percent in 2013, and 7 percent in 2014.[54] Annual SO2 emissions is 10 percent lower than the average of 35 cities. Nitrogen oxide also decreased 16 percent in 2014. Finally in 2014, Lanzhou rid itself of the title "The monthly or annually worst air polluted city" by increasing the number of days of "good", "medium" air quality to 313.[55]

However, Lanzhou is still one of the most polluted and energy inefficient cities in China. High heating fees forces low income households and shanty town areas to use coal-fired boilers

52. See http://finance.chinanews.com/ny/2014/01-10/5724345.shtml
53. See http://www.hhhtnews.com/2014/1225/1825944.shtml
54. http://www.lzbs.com.cn/xwpl/gz/2014-06/05/content_3615553.htm
55. Ibid

during winter and industrial emissions, which account for 80 percent of total emissions, have yet to be upgraded.[56]

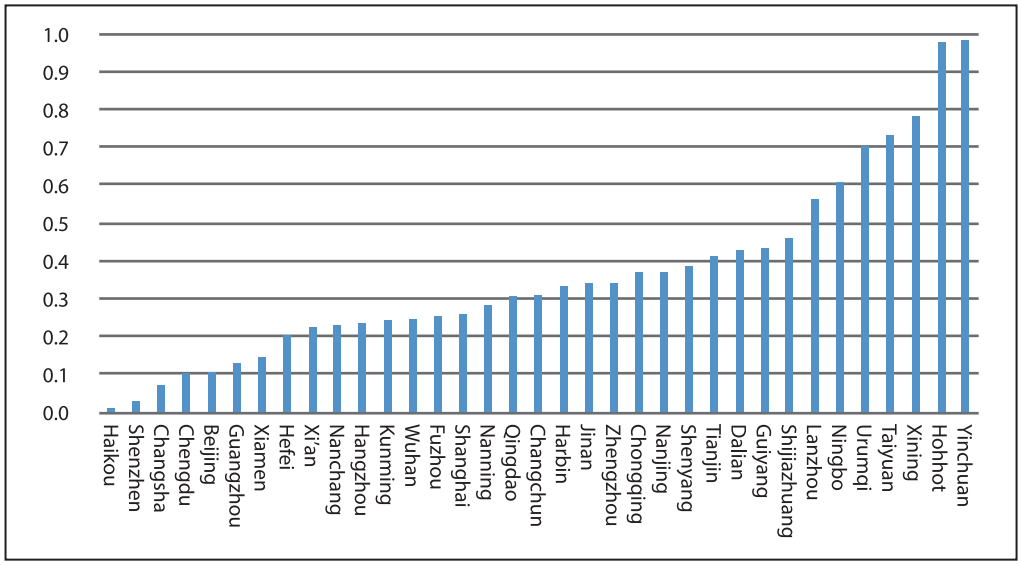
Beijing ranks fifth in the air pollutant indicator, while nearby cities such as Tianjin, Shijiazhuang rank in the bottom fifteen. This reflects the implementation of recent policies under the Jing-Jin-Yi Air Pollution Control Plan[57] where factories were moved out of Beijing to Hebei and Tianjin. Other policies implemented in Beijing include increasing pollution discharge charges, improving oil quality and rural subsidies for replacing coal. Other policies such as the desulphurization and retrofitting of coal plants will improve air quality throughout the region.[58]

Shanghai also is implementing new penalties for emissions violations. Fines for undocumented discharges have been raised from CNY 10,000~100,000 to 50,000 ~ 500,000 on a daily continuing basis until the discharge is stopped.[59] Shanghai is also controlling coal consumption at a steady 58 million tons. Coal has dropped to 40 percent of Shanghai's primary energy source, with increases in natural gas, renewables and nuclear power.[60]

Shenzhen scores very well on the air pollution indicator. Its economy is moving away from manufacturing and toward a service economy. The four pillar industries in Shenzhen are finance, logistics, culture, and the high-tech industry.[61] Unlike other Chinese cities where industry dominates pollution inputs, Shenzhen shows more similarities to developed country cities. The major contributor to air pollution is from vehicles at approximately 70 percent of emissions.[62]

56. http://gansu.gansudaily.com.cn/system/2010/11/23/011782864.shtml
57. See the Ministry of the Environment's "Beijing, Tianjin, Hebei and surrounding areas to implement air pollution control action plan and implementation details." Available at (in Chinese): http://www.mep.gov.cn/gkml/hbb/bwj/201309/W020130918412886411956.pdf
58. See the Ministry of the Environment's Notice on Printing and Distributing the Plan for Terminating Air Pollution in Key Industries of Beijing, Tianjin and Hebei and Its Adjacent Areas. Available at (in Chinese): http://www.zhb.gov.cn/gkml/hbb/bwj/201407/t20140729_280610.htm
59. See the Regulations of Shanghai Municipality on the Prevention and Control of Atmospheric Pollution 2014. Available at (in Chinese): http://www.mep.gov.cn/home/ztbd/rdzl/dqst/mbzrs/201504/P020150422604164302284.pdf
60. Twelfth Five - Year Plan for Environmental Protection and Ecological Construction in Shanghai Available at (in Chinese):http://www.shanghai.gov.cn/nw2/nw2314/nw2319/nw12344/u26aw50076.html
61. See the Statistical Communique on Shenzhen's Economic and Social Development in 2014. Available at (in Chinese): http://www.sztj.gov.cn/xxgk/tjsj/tjgb/201504/t20150424_2862885.htm
62. See http://wb.sznews.com/html/2015-08/07/content_3302736.htm

Figure 3-5 Classification of 35 large and medium-sized cities in China by air pollutant emissions



3) Solid waste discharge indicator

192 million tons of domestic garbage was collected in Chinese cities in 2015[63] (out of a total of 1 billion tons for the whole country), increasing at a rate of 8.38 percent each year. 63.9 percent goes to landfills, 33.9 percent is incinerated and the rest is composted. Industrial solid waste in medium and large cities totalled 1.92 billion tons in 2015.[64] Many towns do not have proper disposal facilities and among 600 large and medium cities, two-thirds experience problems with build-up of waste.

The ten cities ranking at the top, that is, having the least amount of per capita solid waste discharge are Nanchang, Qingdao, Harbin, Changchun, Fuzhou, Tianjin, Dalian, Hefei, Jinan and Shijiazhuang. The three cities ranking last are Xining, Urumqi and Taiyuan, at 0.62, 0.63 and 0.9 respectively, far higher than other cities.

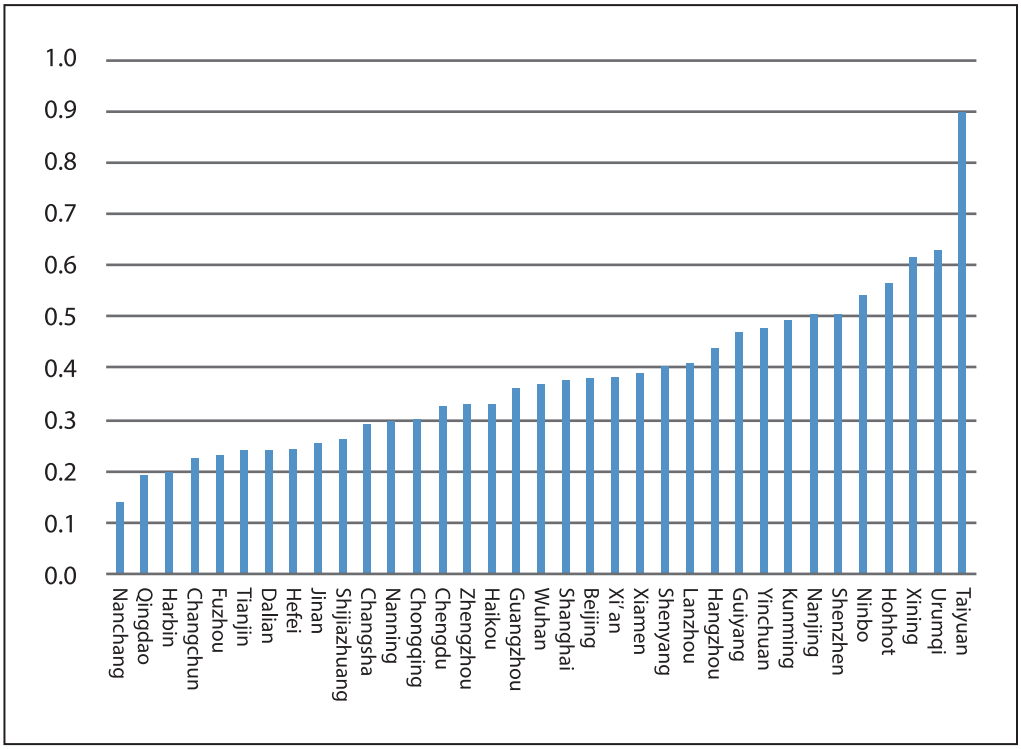
The ten cities that rank poorly can be divided into two categories. The first consists of eastern developed cities such as Shenzhen, Nanjing and Ningbo where developed industries contribute to excessive solid waste discharge. Shenzhen's waste is largely comprised of industrial waste, medical waste, construction waste and household garbage. Shenzhen still lacks disposal capacity such as garbage incineration, and good waste management practices. The city produces tens of thousands of tons each year, but only has actual treatment capacity of 10,000 tons.[65] Guangzhou, however, although its solid waste continues to increase, has

63. Bulletin of the Chinese Communique on the Environment 2015, http://www.zhb.gov.cn/gkml/hbb/qt/201606/W020160602413860519309.pdf
64. See the Ministry of Environment's Large and Medium Sized Cities Solid Waste Pollution Prevention and Control. http://www.zhb.gov.cn/xxgk/hjyw/201512/t20151208_318612.shtml
65. From http://news.xinhuanet.com/local/2014-06/24/c_1111286509.htm

instituted a comprehensive waste management system that includes waste separation, recycling, composting and waste-to-energy incineration (see Section 3, Guangzhou case study).

The other is represented by Taiyuan, Urumqi, Xining, Yinchuan and other central and western cities, which have low recycling rates, large quantities of waste from mining operations as well as inefficient industrial production which results in higher levels of solid waste.

Figure 3-6 Classification of 35 large and medium-sized cities in China by solid waste discharge



CHAPTER FOUR: THE URBAN HUMAN DEVELOPMENT INDEX

4.1 Ranking of 35 large and medium-sized Chinese cities by the Human Development Index

4.1.1 Ranking by Urban Human Development Index

The Human Development Index is used to assess the human welfare aspect of sustainable development. Data on per capita life expectancy (LEI), per capita education years (EI) and per capita GDP (II) of 35 large and medium-sized cities in China is collected from the China Statistical Yearbook 2015, the statistical yearbooks of the cities and regional statistical yearbooks. The three indicators were geometrically averaged to obtain the rankings of each of the 35 large and medium cities in China. The results are shown in Table 4-1.

Table 4-1 HDI and its sub-indicators of 35 large and medium-sized cities in China

City	HDI		LEI		EI		II	
	Score	Rank	Score	Rank	Score	Rank	Score	Rank
Guangzhou	0.869	1	0.944	6	0.779	3	0.892	2
Beijing	0.860	2	0.951	3	0.783	2	0.854	8
Nanjing	0.859	3	0.956	2	0.765	5	0.865	5
Shenyang	0.854	4	0.923	12	0.813	1	0.831	15
Shenzhen	0.851	5	0.918	14	0.734	9	0.915	1
Shanghai	0.848	6	0.958	1	0.749	7	0.850	11
Tianjin	0.841	7	0.940	8	0.736	8	0.862	6
Xiamen	0.841	8	0.924	11	0.774	4	0.833	14
Wuhan	0.839	9	0.927	10	0.749	6	0.851	10
Dalian	0.839	10	0.945	5	0.720	13	0.868	3
Hangzhou	0.839	11	0.947	4	0.724	12	0.860	7
Ningbo	0.823	12	0.942	7	0.696	25	0.851	9
Qingdao	0.822	13	0.938	9	0.698	24	0.849	12
Changsha	0.817	14	0.865	27	0.729	11	0.865	4
Jinan	0.811	15	0.899	18	0.719	14	0.824	16
Taiyuan	0.800	16	0.900	17	0.734	10	0.774	26
Changchun	0.799	17	0.908	15	0.701	21	0.802	18
Zhengzhou	0.797	18	0.898	19	0.699	22	0.806	17
Hohhot	0.792	19	0.838	33	0.699	23	0.848	13
Hefei	0.791	20	0.871	25	0.716	16	0.795	23
Chengdu	0.791	21	0.895	20	0.690	26	0.800	21
Haikou	0.788	22	0.920	13	0.709	18	0.749	31
Nanchang	0.787	23	0.886	22	0.687	28	0.801	20
Fuzhou	0.785	24	0.860	29	0.703	20	0.800	22

Yinchuan	0.784	25	0.886	22	0.686	29	0.791	24
Kunming	0.782	26	0.885	24	0.705	19	0.767	27
Harbin	0.776	27	0.903	16	0.680	31	0.761	30
Xi'an	0.770	28	0.857	30	0.678	32	0.786	25
Urumqi	0.769	29	0.800	35	0.710	17	0.801	19
Lanzhou	0.767	30	0.823	34	0.719	15	0.763	29
Guiyang	0.761	31	0.842	31	0.686	30	0.764	28
Nanning	0.757	32	0.865	28	0.689	27	0.728	35
Shijiazhuang	0.757	33	0.867	26	0.670	33	0.746	32
Chongqing	0.747	34	0.889	21	0.631	35	0.743	33
Xining	0.743	35	0.838	32	0.661	34	0.739	34

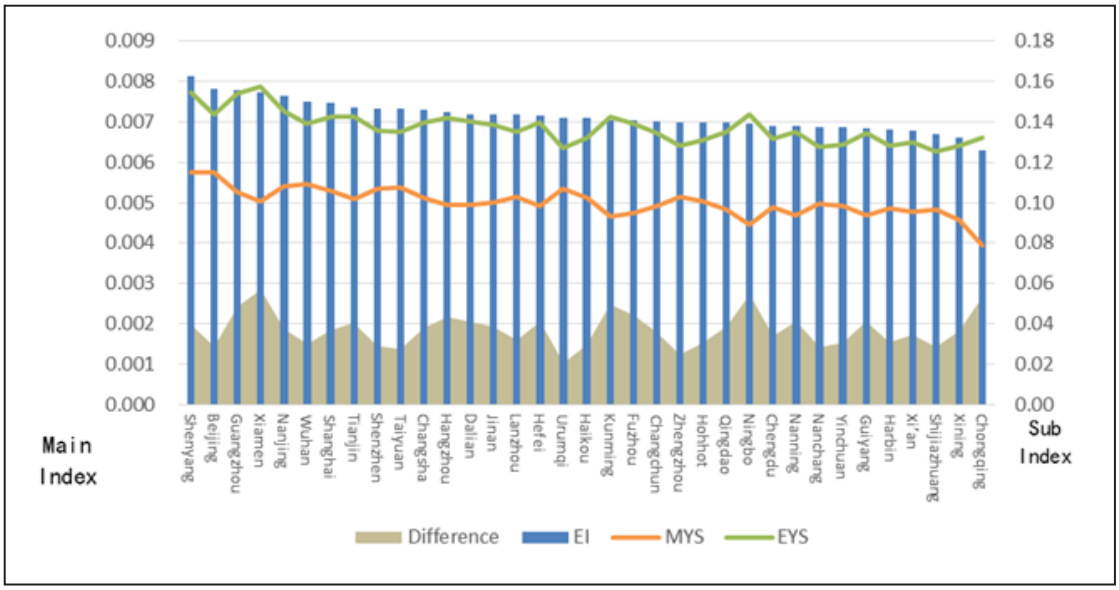
Overall, the cities perform well on the Human Development Index. China's national ranking reached 0.727 in 2014, ranking 90th among the 188 countries surveyed.[66] The 35 cities in this report all score higher than the national average, with the lowest ranking city, Xining, coming in at 0.743. A score above 0.700 is already considered high human development. In 2014, globally UNDP adopted 0.55, 0.7, and 0.8 as the cut-off points for low (below 0.55), medium, high and very high (above 0.8) human development.[67]

As noted in the China National Human Development Report 2016,[68] attention paid to social policies such as public and maternal health and universal basic education after the founding of the People's Republic of China in 1949 resulted in China having higher life expectance and education levels than other low-income countries. Life expectancy rose from 35 in 1949 to 67.9 in 1987, and enrollment of school-aged children rose from 20 percent in 1949 to 95.9 percent in 1978. Life expectancy and educational attainments have risen even further in the reform and opening up period, while income has risen most dramatically. Now that China has achieved middle-income country status with per capita GDP reaching US $7,575 in 2014, health and education indicators continue to outpace its income status. Life expectancy reached 74.8 in 2010. Universal nine-year compulsory education was instituted in 1986 with the adoption of the Compulsory Education Law. By 2011, net primary enrollment rates were over 99 percent for both boys and girls and illiteracy among young and middle-aged citizens fell to 1.08 percent.

In the China Sustainable Cities Index, the top 5 cities ranked by HDI are Guangzhou, Beijing, Nanjing, Shenyang and Shenzhen. Guangzhou, Beijing and Nanjing all demonstrate relatively balanced human development with all three indicators ranking highly. Shenyang and Shenzhen are more skewed, with Shenyang ranking first in education raising its overall HDI and Shenzhen scoring highly in income but less so in life expectancy and education.

66. See the 2016 National Human Development Report (NHDR) for a discussion of China's national ranking as well as a breakdown by province. http://www.cn.undp.org/content/china/en/home/library/human_development/china-human-development-report-2016.html
67. See http://hdr.undp.org/sites/default/files/hdr2015_technical_notes.pdf and http://hdr.undp.org/en/content/why-were-fixed-cut-points-define-human-development-groups-reintroduced-2014-hdr for a description and justification of the cut-off points.
68. Ibid

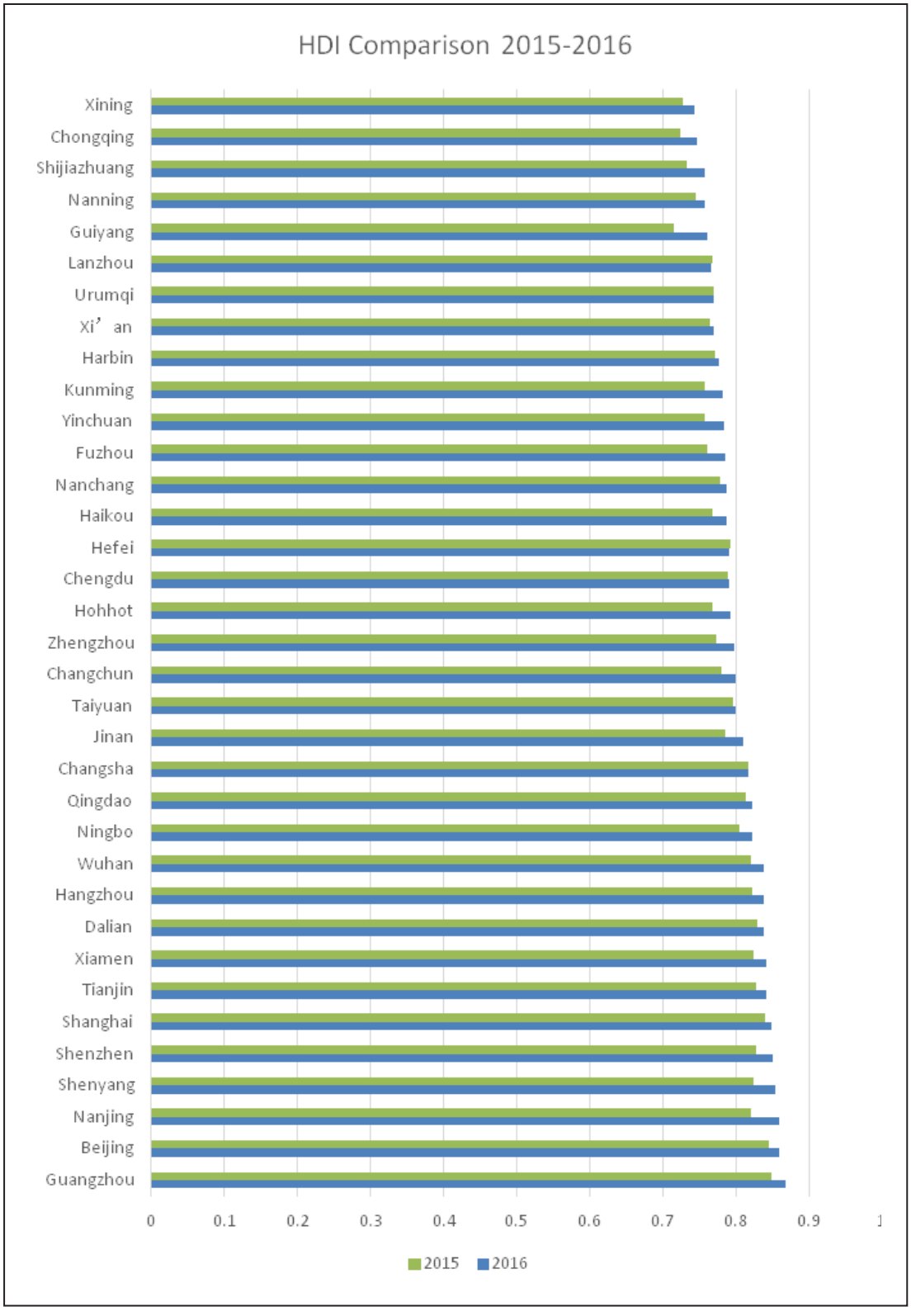
Figure 4-1 35 China large and medium-sized cities HDI and sub-indicators



Overall, there is an upward trend in urban HDI. The average value of all 35 cities' HDI has jumped from 0.789 to 0.804 from the 2015 Report to the 2016 Report, a 2 percent increase. Changsha, Chengdu, Hefei, Urumqi, and Lanzhou's HDI remains basically unchanged, while all other cities saw their HDI increase. The top 3 cities, Guiyang, Nanjing and Shenyang had their their HDI values increase by 6 percent, 5 percent, and 4 percent respectively.

The largest gains were made in income which saw jumps of between 7 percent (Nanjing) and 15 percent (Haikou), with most cities seeing an increase of 12-13 percent. Life expectancy and educational attainment however, has dropped in many cities. Whether this is due to absolute reductions or is a result of increased rural migration is as yet unclear and more research needs to be done.

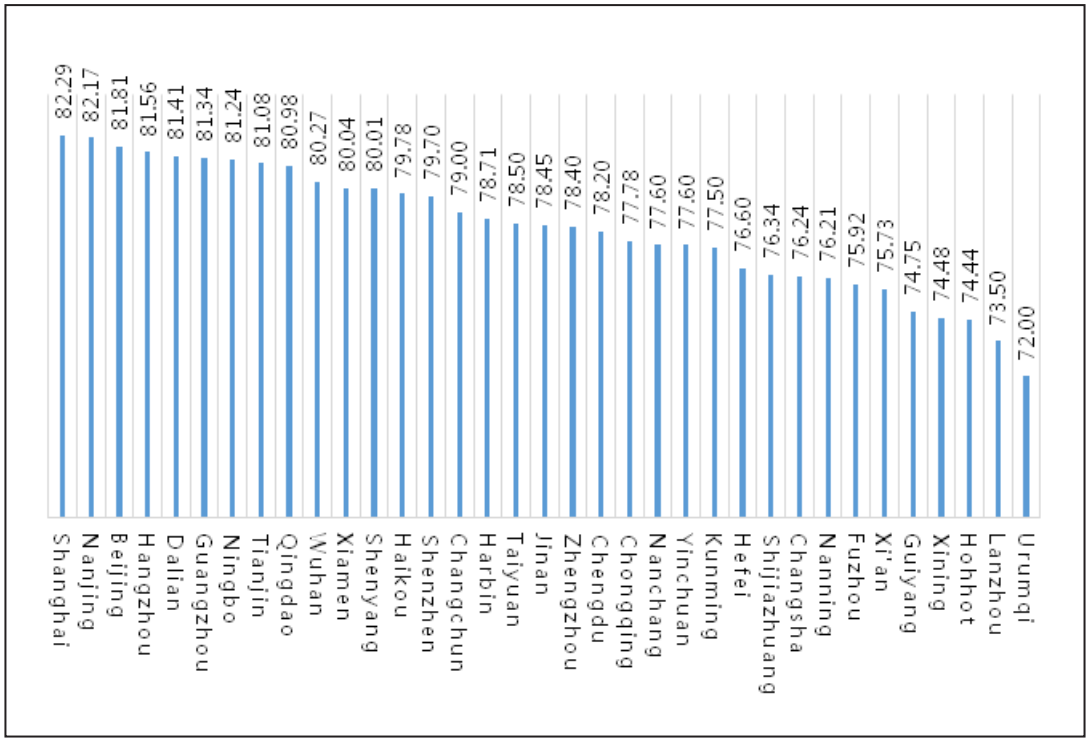
Figure 4-2 HDI comparison 2015-2016



1) Life expectancy

There is still quite a significant discrepancy between the 35 cities on the measure of per capita life expectancy. The average life expectancy of the 35 cities in the Index is 78.33 years, higher than the national average life expectancy (about 74.8 years, and the world average of 70 years). Shanghai ranks first with an average per capita life expectancy of 82.29 years, followed by Nanjing at 82.17, Beijing at 81.81, Hangzhou at 81.56 and Dalian at 81.41 years. There are 7 other cities with life expectancies above 80 years. Urumqi, Lanzhou and Hohhot ranked last, with an average life expectancy of 72 years, 73.5 years, and 74.44 years respectively. The gap of 10.29 years between the lowest ranked city, Urumqi, and the highest, Shanghai, demonstrates the considerable differences between the developed eastern seaboard and the still-developing north-west. Average life expectancy is influenced by factors such as the level of economic development, medical conditions, quality of education, population status, environmental quality, population structure and geographical location. Rural areas and smaller cities have a harder time retaining high-quality medical personnel, and China's medical insurance system which requires up-front payment that is later reimbursed can limit access to medical services for lower income individuals.[69] The level of economic development is highly correlated with life expectancy, although some cities such as Shenzhen with extremely high incomes do not have correlative health outcomes suggesting that the city needs to invest more in improving access to high quality health care.

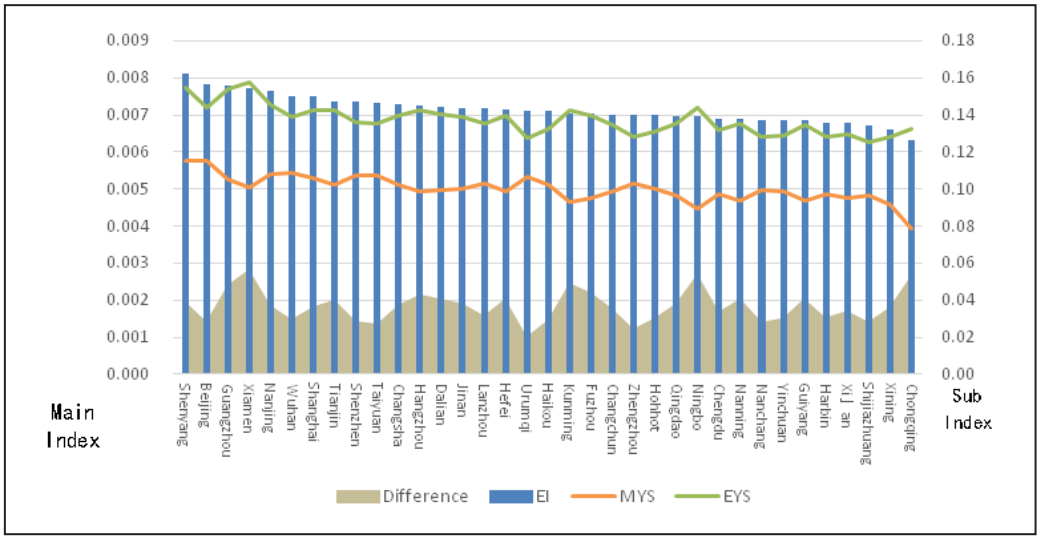
Figure 4-3 Life expectancy of 35 large and medium-sized cities in China



69. See 2016 NHDR, p.35. op.cit.

2) Education

Figure 4-4 35 China's large and medium - sized cities distribution of education years



As can be seen from Table 4-4, the per capita years of schooling vary by city. Shenyang, Beijing, Guangzhou, Xiamen, Nanjing, Wuhan and Shanghai all score highly on mean years of schooling (MYS) and expected years of schooling (EYS).[70] Chongqing scores last with its population only receiving an average of 7.89 years of schooling. This likely reflects the fact that Chongqing still incorporates a large rural population and a large migrant population that still have poorer education outcomes than urban regions.[71] However, expected years of schooling are higher at 13.25 years and the State Council has made rural education reform a priority, issuing a circular on in July 2016. Nationally, China's education outcomes are continuing to improve. 93 percent of the population has receiving 9-year compulsory education in 2015. While only 15.83 percent of the working age population (20-59) had graduated from high school in 2014, enrollment in high school and post-secondary education has increased significantly. Gross senior high school rates have increased to 87 percent in 2015.[72]

Although there are still significant challenges to extending years of schooling, in many cities, 12 years of education has become the norm. Currently, students must write an exam to access high school (10th, 11th and 12th years of schooling) and there are various other limitations depending on the jurisdiction such as tuition fees and residency requirements. Some cities have been active in reducing disparities between its rural and urban areas and expanding educational options to keep children in school longer (see Section 3, case study on

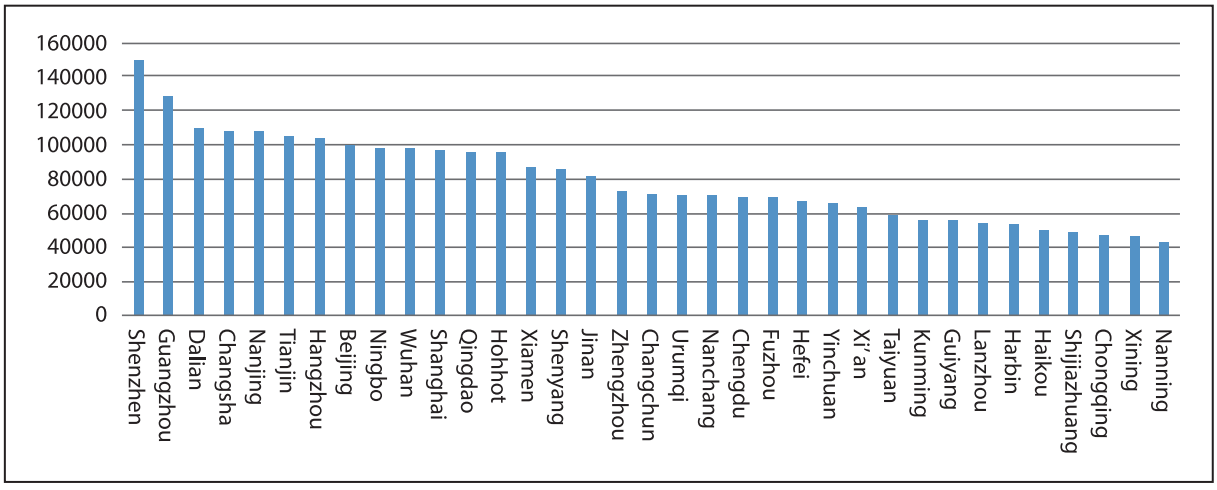
70. The education indicator (EI) is the geometric average of the mean years of schooling indicator (MYSI) and expected school education indicator (EYSI). MYS is the actual number of years of education attained by persons aged 25 years and over. EYS years is the number of years a 5-year-old child will be educated throughout his or her lifetime.
71. See UNESCO's Rural-Urban Migration and Children's Access to Education: China in Comparative Perspective Background Paper for the Education for All Global Monitoring Report 2015 for more information on China's rural-urban education gap at http://unesdoc.unesco.org/images/0023/002324/232466e.pdf
72. See NHDR 2016 p.26.

Foshan). Shenyang ranks first in the education indicator (this report reflects 2014 data), rising from fourth in 2012, and second in 2013, thanks to its focus on improving basic education through urban and rural integration. In 2013, Shenyang announced a CNY 1.88 billion investment over three years to ensure access to quality education for all through improved infrastructure as well as teaching quality.[73] It is also aiming to increase higher education enrollment rates and continuing education enrollment rates.[74]

Higher education resources are not evenly distributed. In the late 1990s, China implemented Project 985 and Project 211 which promote the development of certain Chinese universities into world-class institutes by providing them with significant financial support. However, these investments were not evenly distributed. 31 of the 44 "985 Engineering" colleges and universities are in the east, 6 in the central region and 7 in the west. 76 of the 122 "211 Project" institutions are in the eastern region, 17 in the central and 29 in the western regions. Eastern cities, Beijing in particular, have far more elite higher education institutes than central or western cities and this is reflected in the Index. Beijing has very rich educational resources, with nearly a hundred colleges and universities located in the city, and many highly educated graduates choosing to stay in Beijing after graduation. Longer per capita years of education also highlights Beijing as a political and cultural centre of the overall positioning. While Beijing outperforms other cities in terms of current years of schooling, other high performing cities such as Guangzhou, Xiamen, Shenyang, and Nanjing are all outpacing Beijing in terms of expected years of schooling.

3) Income

Figure 4-5 GDP per capita of 35 large and medium-sized cities in China



73. See http://epaper.gmw.cn/gmrb/html/2012-12/23/nw.D110000gmrb_20121223_5-02.htm
74. Outline of the Medium and Long - term Education Reform and Development Plan of Shenyang (2010-2020). Available at: http://124.95.131.124:8080/zwgk/open/publicshow/showColumnTreeByRootAction.do?method=show&showType=&columnId=13055&articleId=1019138&articleCode=210100004D10120150013

As shown in Figure 4-5, the per capita GDP of Shenzhen, Guangzhou, Dalian, Changsha, Nanjing, Tianjin and Hangzhou have all exceeded CNY100, 000. The GDP per capita in Shenzhen is CNY 149,495. The last ten cities all have less than half the GDP per capita of Shenzhen. Gaps in per capita GDP between the 35 cities are larger than the other indicators.

The top cities are the administrative and economic centres of the developed coastal provinces or regions. The differences in the industrial structure of these cities are important reasons for differences in per capita output level. Coastal cities and regional economic centres have common characteristics, including having been the focus of the first wave of economic reform including the establishment of special economic zones and favourable tax regimes, and benefitting from investment and industrial transfer from Hong Kong and Taiwan. Economic opportunities have attracted human capital and talent, and benefit from rich educational resources. After decades of development, these cities have begun to adjust their industrial structure, and focus on the development of higher economic value-added tertiary industries, resulting in higher per capita GDP.

Shenzhen ranks first in per capita GDP. Shenzhen was China's first special economic zone and has seen an astonishing transformation from a small fishing village in 1980 to a megacity of 10 million people today. Shenzhen developed as a gateway to Hong Kong, and now has extended its reach globally as the world's third largest container port. Having taken the lead in manufacturing-driven growth for several decades, Shenzhen is now spearheading the shift to an innovation and quality based economic strategy. Shenzhen leads the country in R & D investment, patents, venture capital and other indicators of innovation-based economic development.[75]

It is worth noting that Changsha ranks fourth even though it is located in the central region of China. In 2008, Changsha set out to build the "China Construction Machinery Capital" in 2011 and proposed to create "the world's largest equipment manufacturing base." The Changsha Institute of Intelligent Manufacturing Research established a research, financing and service platform as well as a business incubator to foster the growth of 'intelligent manufacturing'. In 2014, equipment manufacturing enterprises in Changsha increased by 46 from 723 to 769 and by more than two hundred in 2015. A long-term focus and strong investment in the field of equipment manufacturing has brought Changsha into the top 5 cities ranked by per capita GDP.[76]

75. See http://english.sz.gov.cn/gi/ and http://english.sz.gov.cn/economy/201608/t20160830_4377815.htm for more details.
76. See http://mt.sohu.com/20160819/n464970065.shtml

CHAPTER FIVE: FOUR-QUADRANT CLASSIFICATION

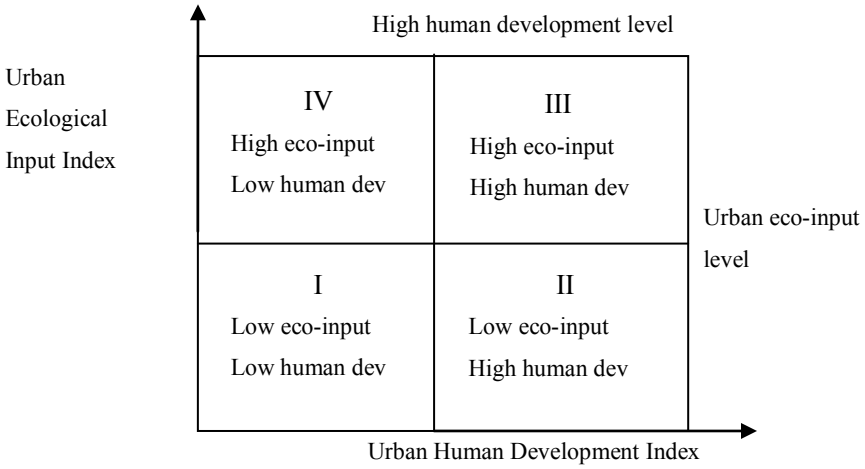
5.1 Four-quadrant classification of the 35 cities 35

This report uses two dimensions, urban human development and urban ecological input, to measure the sustainable development of 35 large and medium-sized cities in China.

Urban sustainable development takes into consideration the limits to both size and resource utilisation of a city as well as the development of urban social welfare within a certain period of time. When using urban sustainable development sub-indices, we consider both the threshold of urban ecological input and the benchmark of urban human development.

The results of the analysis are displayed in a scatterplot with the X-axis showing the UHDI and the Y-axis the UEII. The coordinates represent the relative position of human development and ecological input and indicates the status of the sustainable development of each city.

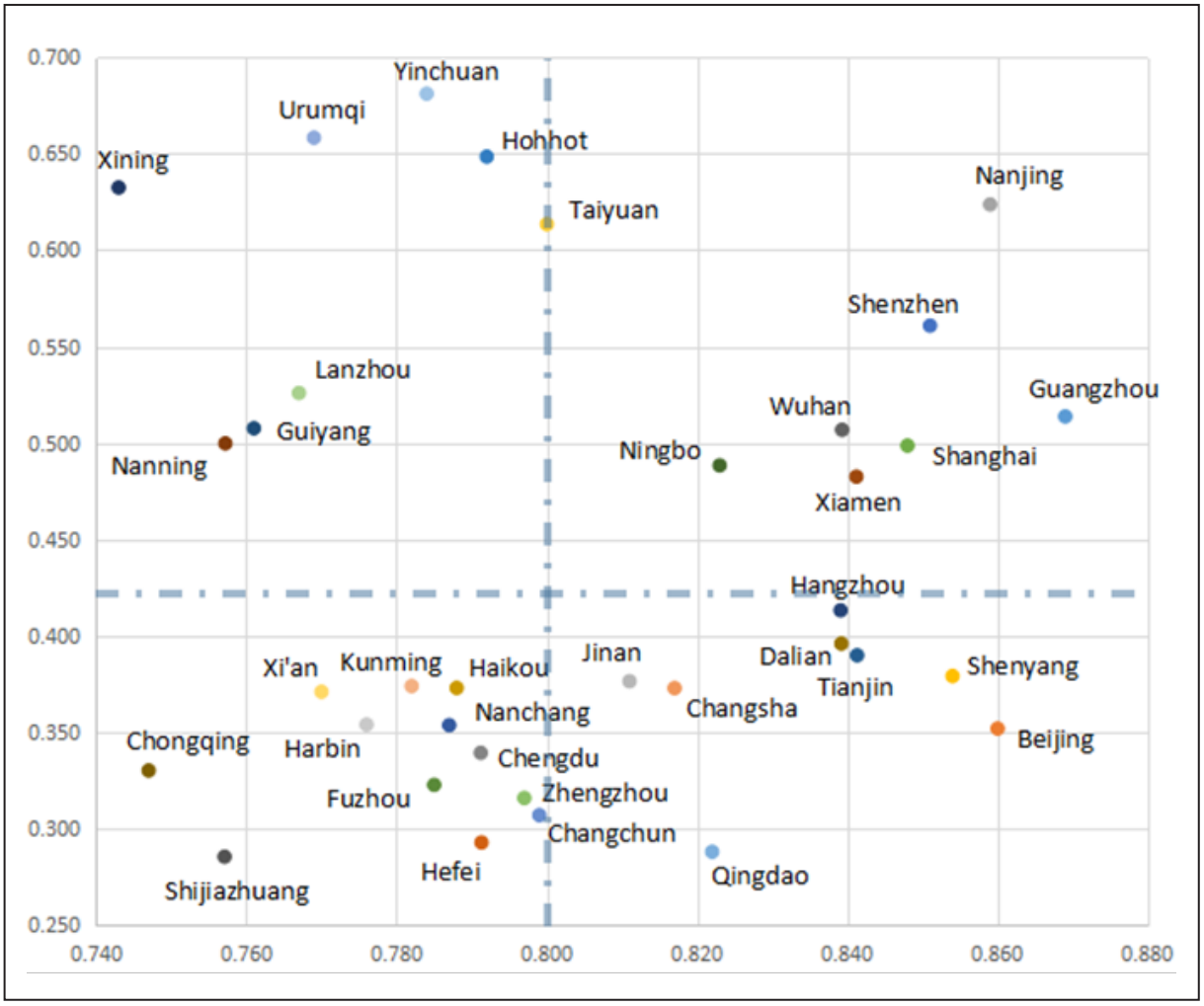
Figure 5-1 Categories of urban sustainable development in China



We can use this Four Quadrant Classification Model to evaluate the sustainable development of Chinese cities and measure the ratio between ecological input and human development in each city's development. Section I represents low ecological input and low human development, section II low ecological input and high human development, section III high ecological input and high human development and section IV high ecological input and low human development (Figure 5-1).

The report fixes the average urban ecological input level (line y=0.44) and very high human development level (line x=0.80) as reference lines for setting the two-axis and four-quadrant diagram (Figure 5-2).

Figure 5-2 Two-axis and four-quadrant diagram of 35 large and medium-sized cities in China



Cities in Quadrant II are the most sustainable, characterised by relatively low ecological input and high human development output. Cities in Quadrant I and III are less sustainable, characterised by low input and low output or high input and high output. Cities in Quadrant IV are unsustainable, characterised by high input but low output. This classification is summarised in Table 5-1.

Table 5-1 Classification of sustainable development of 35 large and medium-sized cities in China

Quadrant	City	Feature of input/output	Sustainable development level
II	Beijing, Hangzhou, Tianjin, Qingdao, Dalian, Shenyang, Changsha, Jinan	Low input, high output	Sustainable development
I	Chengdu, Chongqing, Xi'an, Zhengzhou, Harbin, Changchun, Kunming, Hefei, Fuzhou, Haikou, Nanchang, Shijiazhuang	Low input, low output	Less sustainable development
III	Shanghai, Guangzhou, Shenzhen, Nanjing, Wuhan, Ningbo, Xiamen,	High input, high output	
IV	Taiyuan, Hohhot, Urumqi, Nanning, Lanzhou, Guiyang, Yinchuan, Xining,	High input, low output	Unsustainable development

Overall ecological input has increased since the 2015 evaluation (based on 2013 data). The average ecological output of the cities rose from 0.316 to 0.440. Only one city, Jinan, moved into the very high human development category.

Cities in Quadrant I make up 34.29 percent of the total. Cities in Quadrant II, 20 percent, Quadrant 3 22.86 percent and Quadrant 4, 22.86 percent. The cities in Quadrant I which are characterised by low input and low output need to consider how they can increase their human development while maintaining or only slightly increasing their ecological input. As the majority of cities fall into this category, and human development indicators are on an upward trajectory, these cities are likely to be able to achieve a sustainable transition. Quadrant II can adopt a continual optimization approach to maintain their current status. Quadrant III cities have achieved high human development, but need to implement more low-carbon and pollution control policies. Each city can examine which resource consumption or pollution discharge indicators they perform particularly poorly on to prioritise interventions. Quadrant IV cities are facing the greatest challenges in needing to both improve their environmental conditions and human development status. Some cities have already begun to take positive steps to lower their ecological footprints but may need more support than other cities.

CHAPTER SIX: SUSTAINABLE DEVELOPMENT PATHS

China adopted sustainable development as a national strategy in 1996. It has made major achievements in human development and its major cities are at the forefront of that achievement. Nevertheless, many complex challenges still remain, including unsustainable resource consumption and pollution, inequality, persistent rural-urban gaps and industrial restructuring. While every city is unique and needs to develop a path to a sustainable transition based on its own demographic and geographic conditions, economic development status, infrastructure and community-based assets, there are some general principles that all cities can look to guide future sustainable development.

6.1 Sustainable development frameworks

6.1.1 The New Urban Agenda

The New Urban Agenda[77] was adopted on October 20 in Quito at the third Conference on Human Settlements, Habitat III. It provides an overarching framework for the development of cities over the next 20 years and commits to a vision of cities that are: "just, safe, healthy, accessible, affordable, resilient, and sustainable".

The New Urban Agenda outlines commitments in three main areas:

Social Inclusion and Ending Poverty - this includes recognising the importance of land tenure, cultural and natural heritage and access to public space

Sustainable and Inclusive Urban Prosperity - this includes access to knowledge, skills, and education, and opportunities for investment, innovation and entrepreneurship for sustainable economic development

Environmentally Sustainable and Resilient Urban Development - this includes more efficient resource consumption, pollution reduction, energy efficiency, green and resilient infrastructure both in slums and the rest of the city, improved urban planning to help cities become more resilient

The Agenda identifies the following policy areas to support implementation:

Building the Urban Governance Structure - this refers to supporting capacity development, reliable financing and management mechanisms for local government, coordination among and between levels of government, and public participation in decision-making

77. The full text is available at: https://habitat3.org/the-new-urban-agenda

Planning and Managing Urban Spatial Development - mixed use development, quality public space, accessible transportation systems, water management and food security are all identified as relevant issues

Means of Implementation- includes capacity development, cooperation, mobilization of financial resources, and political and legal frameworks

In broad terms, the priorities of the New Urban Agenda are already reflected in the policy and planning documents that is guiding China's new-type urbanisation. The challenge now is to take these broad principles and implement them in an integrated way at the local level.

6.1.2 UNDP's sustainable urbanisation strategy

At Habitat III, UNDP also released its global strategy for sustainable urbanisation.[78] Many of the issue areas raised are relevant to Chinese cities. These include:

Transportation and mobility systems - robust public and non-motorized transportation systems can not only decrease emissions and improve air quality, they can also reduce inequality by ensuring that everyone has access to the city, not just those with cars. Valuable urban land can be used for purposes other than highways and parking. China's central government has committed to building 7000 km of urban rail by 2020 and many cities are also expanding their bus systems. The next step will be to improve street connectivity which will require rethinking megablock and gated community development and building overly large highways. Pedestrian and bicyclist safety, off-street parking, traffic calming, and connectivity between different transportation modes all need more attention. The relationship between congestion and the distance between housing and employment is another area many cities may need to consider.

Energy systems - shifting from highly-polluting fossil fuel energy systems to low-carbon and renewable energy sources is an imperative for the entire world to stave off catastrophic climate change. The co-benefits in improved air quality and therefore improved health make this shift one that can have immediate local benefits as well. Chinese cities have already begun to improve the efficiency of their power facilities and are beginning to reduce coal use. Cities can also promote demand-side management through green building strategies that include retrofits for older buildings. Continued industrial transformation and regional coordination will also be necessary to ensure that polluting factories are not simply exported elsewhere but that emissions are in fact controlled.

Waste and wastewater management - advanced technologies such as waste-to-energy incinerators, kitchen waste composting facilities, sanitary landfills, and sewage treatment

78. The full text is available at: http://www.undp.org/content/undp/en/home/librarypage/poverty-reduction/sustainable-urbanization-strategy.html

are being adopted in Chinese cities. Guangzhou is leading in the field of waste management, but even cities that do not have the ability to invest in state-of-the art waste management facilities can explore community based waste separation, recycling and composting alternatives as well as ecosystem based sewage and stormwater treatment. Buildings can be equipped with rainwater capture and water recycling facilities.

Compact cities - dense, transit oriented development are lower-emission, and encourage the protection of surrounding agricultural and natural land. Cities such as Beijing and Shanghai have already started to limit greenfield development. Others need to rationally evaluate the need for expansion of new towns and residential developments. Many master plans are in place that if implemented will result in massive oversupply of housing and commercial buildings. Planning needs to be an iterative process that is continually revisited to ensure that construction only happens in light of market demand. The central government has begun to examine the current system of municipal financing which encourages land sales and therefore irrational sprawl. Establishing a new diversified reliable funding system for municipal governments will be imperative to realizing the green transformation of Chinese cities.

Public space - high quality, accessible and safe public space that is diverse in size and type can help decrease inequality and increase social integration, as well as often providing ecosystem services if the public space is also green space. Cultural and natural heritage should be protected and integrated into public space. Many Chinese cities have overbuilt large squares that have been created without people in mind and as such are underutilised. Smaller spaces often serve the needs of the community more effectively. Good public space design is essential and the building of public spaces is also a good opportunity to engage in participatory design processes.

Migrants - cities throughout the developing world struggle to integrate migrants as rapid urbanisation can often overwhelm the ability of receiving cities to absorb new residents. The next five years in China will see significant equalization of access to social services and welfare benefits between rural and urban populations and a decrease in household registration (hukou) based discrimination. Many cities such as Guangzhou and Chengdu have already eliminated household registration in the area under their jurisdiction and smaller cities such as Foshan have ensured that key social service systems such as education are accessible to all irrespective of household registration status. Other cities can look to these experiences and speed up household registration reform.

Job creation - Cities can support local economic development by creating employment opportunities that build on the comparative advantages and unique qualities of their localities. Innovation and entrepreneurship can be supported through education systems and access to financing. While manufacturing and heavy industry will continue to be a critical component of China's economy, technological transformation can make these industries more sustainable. Many cities are now in the process of developing more robust service economies. A sustainable transition will include many social and ecological function-based services, all of which offer opportunities for increased employment.

Open and participatory governance systems - citizens deserve to be able to participate in decision-making that affects their lives. Governments need to be more transparent with the public and also support data sharing and collaboration between government departments for more effective and efficient public service delivery. Policy design and service delivery cannot and should not be the responsibility of government alone but needs to happen in a coordinated system that links government, enterprises, civil society organisations and the public.

6.2 Conclusion

Urbanisation in China has taken the traditional path of increased ecological inputs resulting in increased human development. However, the world is now at a crisis point and increased ecological inputs are beginning to undermine human development. We now require two types of decoupling: that of economic growth from ecological input and that of quality of life from economic growth. Production and consumption in cities in the future must be resource-conservative and environmentally-friendly. The second is the decoupling of quality of life and economic growth, or in other words, improving quality of life while economic growth is controlled and per capita capital stock is stabilised. These two decouplings point out the essential difference between sustainable urban development targeted at social welfare growth and traditional development paths aimed at economic growth.[79]

The world has never seen anything like China's economic transformation over the past thirty years. As China now begins to shift away from a singular focus on rapid economic development, the rebalancing that is beginning to happen under the New Normal is a very supportive environment for Chinese cities to make the transition to a more sustainable future. We can anticipate as extraordinary a transformation over the next thirty years, but one this time that supports human flourishing within ecological limits.

79. Zhu Dajian, China's Development 3.0: Green Development under Eco-civilization—Ten Viewpoints about Deepening the Study of Eco-civilization. Economic Management in Proceedings of the Seventh Academic Annual Meeting of Social Sciences in Shanghai (2009), 1-12 (in Chinese).

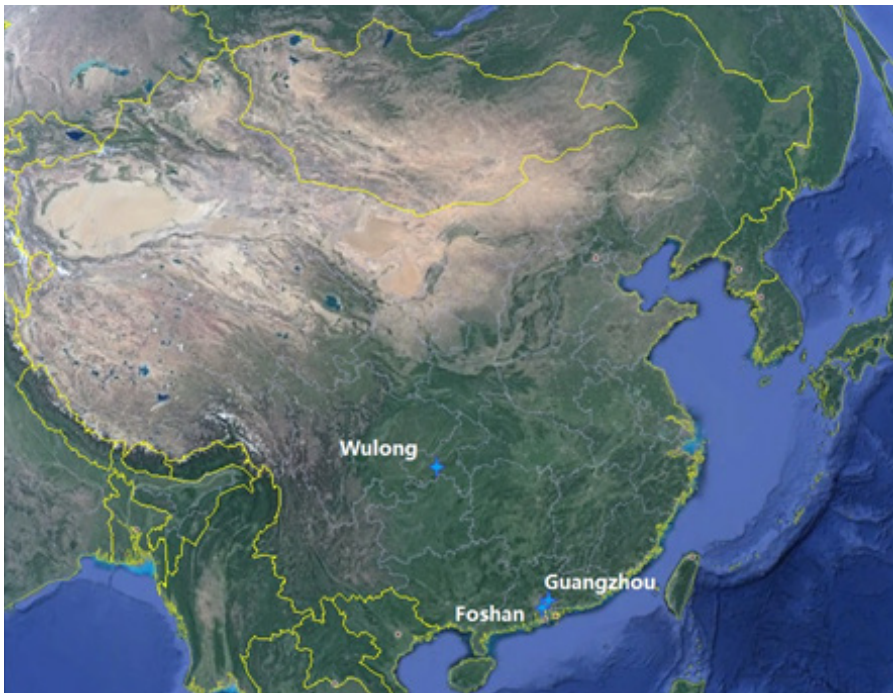
PART THREE SPECIAL TOPICS

CASE STUDIES: GOOD PRACTISES IN CHINESE CITIES

Good urban sustainability practices are contributions to the environmental, social and economic sustainability of cities and communities. UNDP and its partners use case studies to recognise and enhance awareness of good practices in sustainable city development in China and to help share and transfer knowledge, expertise and experience through networking and peer-to-peer learning. Case studies are used in this report to illustrate how the principles that underlie the China Sustainable Cities Index are being applied in Chinese cities and communities. Case studies help raise awareness among policy-makers and the public of practical, implementable solutions to sustainable development challenges and acknowledge the efforts of local decision-makers and communities in implementing sustainable approaches to development. In addition, although the Index is currently only applied to provincial capitals and directly-administered municipalities, second and third tier cities are also actively engaged in transitions to sustainability and have good lessons to share.

The case studies from Foshan, Guangdong and Guangzhou, Guangdong look at specific policies related to vocational education and solid waste management respectively. As a critical component of human development, education is one of the 3 indicators that make up the Human Development Index. Foshan's vocational education system has contributed to economic development in the city, but has also helped reduce inequalities by ensuring that all children has access to 12 years of schooling and that education suitable to a wide range of capabilities and interests is available to all. Guangzhou's ranking on the solid waste discharge indicator is in the middle range of the index. However, the case study shows how Guangzhou has leveraged its solid waste management strategy to improve city governance, increase community engagement, improve recycling rates and use waste as a resource both for clean energy and fertilizer. The case from Wulong County, Chongqing, shows how the environmental protection policies instituted originally to support the tourism industry has become a driving force behind a wide range of economic development activities. All three cases show the integrated nature of sustainable development approaches, how actions taken in one area has important co-benefits in other areas, and how a strong vision can help drive sustainability actions across multiple sectors and by a diverse range of actors.

Figure 7-1 Wulong, Guangzhou and Foshan



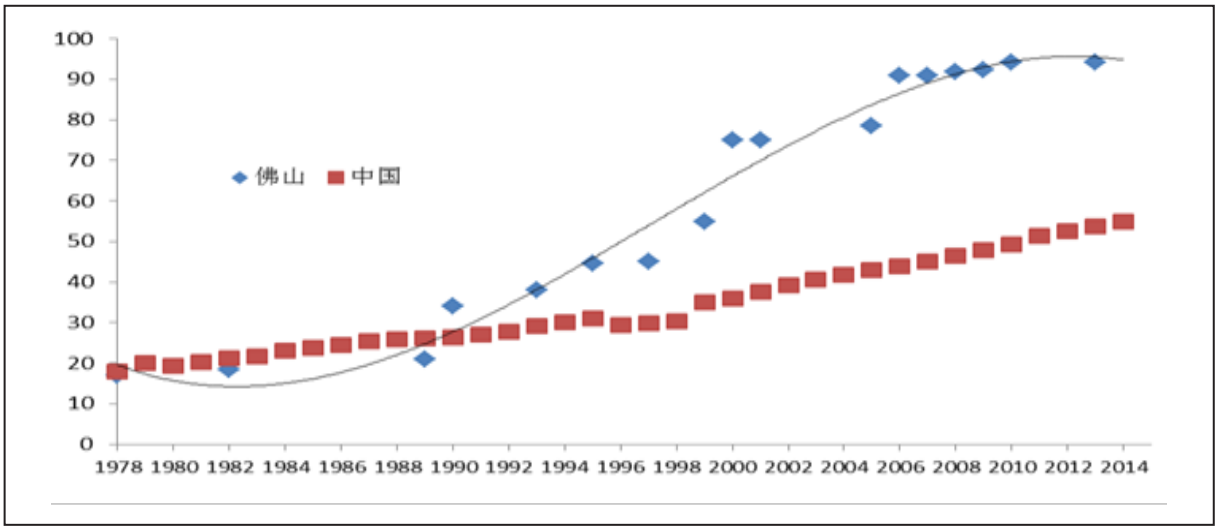
Education for all: the vocational school system

FOSHAN, GUANGDONG

Introduction

Foshan is a prefectural-level city located in the hinterland of the Pearl River Delta, close to Guangzhou with an area of 3,875 sq km, and resident population of more than 8 million. It reached a 50% urbanisation rate in 1994 and 94.1% in 2013.

Figure 8-1: Foshan after reform and opening up and China's urbanization rate



The 2010 Asian Games, hosted by Guangzhou, were a major catalyst for pollution control and restoration in the Pearl River Delta. Foshan addressed pollution in major industries including plastic, metal and ceramics, and improved wastewater treatment to restore the Fenjiang River. Energy saving and emission reduction were facilitated and levels of urban greening increased.

Foshan has been well-known as a handicraft manufacturing centre dating back to the Tang Dynasty. It was well-positioned to take advantage of the reform and opening up period and after 30 years of rapid economic growth, Foshan is the 3rd most prosperous city in Guangdong after Guangzhou and Shenzhen with a GDP of CNY 7603.28 billion in 2014. Manufacturing was initially focused on low value-added products. By 2000, however, Foshan was facing serious competition due to rising labour and energy costs and the rise of other emerging markets. Foshan then began to take steps to accelerate the transformation and upgrading of traditional manufacturing industries and cultivate strategic emerging industries. Foshan has emphasized innovation in social governance as well, abolishing the division between rural and urban household registration (hukou) in July, 2004 and has equalized public services between urban and rural areas. It is also relatively easy to obtain a Foshan hukou. Migrants only need three years of stable employment with a legal and stable residential address (renting contract) or a record of three years of paying social security or certificate of property purchase. Unemployment is low at only 1.95%, well below the provincial rate of 4%. Basic medical insurance rates are 98%.

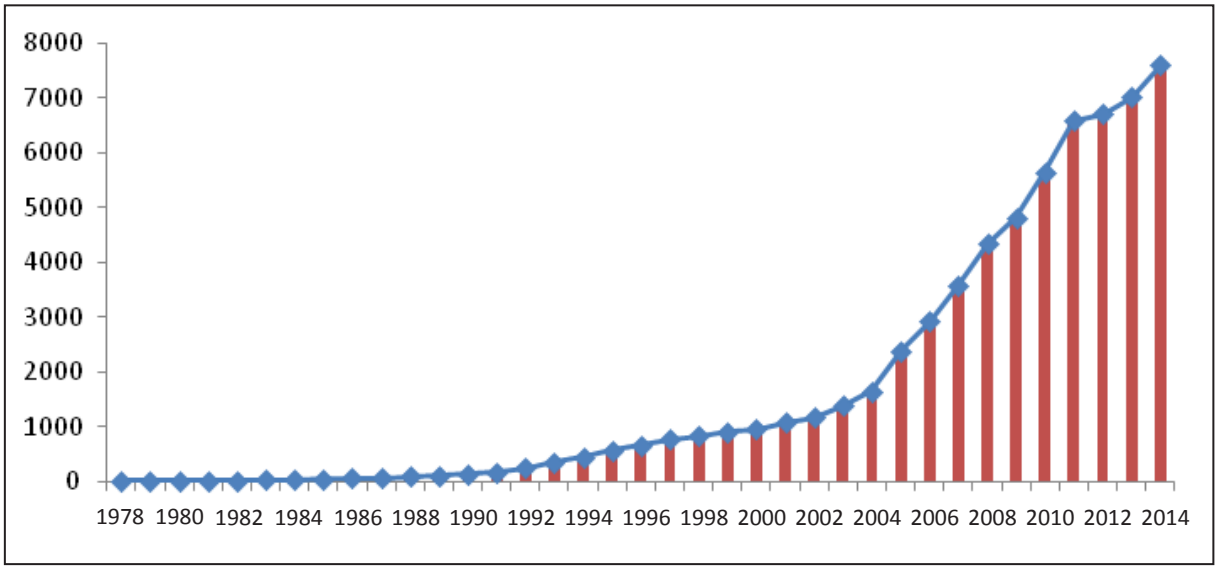


Figure 8-2 Foshan GDP growth since the reform and opening up

Vocational education system

It is in this context that Foshan has developed its vocation education system. Vocational schools were an important part of the education system from 1949, with an emphasis on agriculture, teaching and health in the early years. After the national education reforms in

1980, the vocational system in Foshan expanded. In particular, because of the increase in township enterprises, many vocational schools were opened by township governments. By 1988, there were 53 municipal vocational schools and 40 township schools and the ratio of vocational high school students to academic high school students was 59:41. In 2016, numbers had declined somewhat as rising incomes are correlated with rising educational aspirations. Currently, there are 41 vocational schools with 120 thousand students enrolled, and 61 academic high schools. 25,000 students enter the vocational school system each year compared with 39,000 on a traditional academic track.

Schools may be run by the provincial, municipal or district governments or by associations such as the China Democratic League. The majority of high schools are run by district governments with the municipal government providing funding and subsidising tuition. The municipal Education Bureau may set other requirements such as the requirement that teachers spend 6 months out of every five years working in an enterprise in the teacher's area of specialisation. The Bureau will also work with schools to develop new specialisations, such as e-commerce, as the market requires and invest in needed equipment based on market and industry collaboration needs.

There is a national education quality evaluation system in place with evaluation standards incrementally increased each year. Evaluation is mainly the responsibility of the province. Schools can be designated as national or provincial model schools- an awarding mechanism that motivates schools to improve quality. The municipality sets certain requirements for course content, core courses, number of courses required and pass standards, but individual schools have the freedom to develop the specific content of specialised courses in partnership with industry. How a school develops is often dependent on its specific location and the kinds of businesses located nearby.

Schools recruit students prior to the city-wide high school entrance examinations through presentations at middle schools, workshops, media, booklets, etc. After the entrance examinations, students apply to a school of interest to them. There are student intakes in the fall and spring, with fall students generally entering more competitive specialisations. There are core courses in Chinese, English, math and physical education with other courses relevant to the student's area of specialisation. The schools generally attract the majority of their students from the district in which they are located with about 30 percent of students coming from elsewhere in the city. The schools will have a minimum score for entrance and different majors have different minimum requirements. All vocational schools have lower minimum entrance requirements than academic high schools. This and the fact that they are free makes the vocations schools much more accessible than academic high schools.

Nevertheless, vocational schools still are not considered as prestigious as academic high schools and students still feel pressure from parents to prioritise an academic track. The municipality has conducted media outreach to publicise the advantages of accessing the vocational education system and that students should be free to pursue career paths that suit their talents and interests. As well, students graduating from vocational high schools now

have more opportunities for higher education. Some with high marks are recruited directly into vocational colleges where they can earn bachelor degrees and others are able to sit the Gaokao or university entrance exam. Overall, approximately one third of vocational high school students went on to tertiary education in 2015. Education bureau officials and high school administrators all note that increased opportunities for accessing tertiary education have improved the attitude of many parents towards vocational education. They also note that in any case, most vocational students did not have good enough exam results to enter academic high schools. As well, many students come from families that are business owners and they see vocational school as a way for them to gain the practical skills they need to help with the family business.

Industry collaboration

In the early 2000s, Foshan industries first experienced labour shortages, particularly for senior technicians and skilled workers. Concerned that this could undermine Foshan's economic development, in 2004 the Foshan government eliminated tuition for vocational schools as a way to attract more students. They empowered local schools to collaborate with industry and each school chooses a focus depending on the industrial structure of their district and the kinds of relationships they have been able to develop.

Small enterprise, big cooperation

One programme running in most vocational schools throughout the city is called "Small enterprise, big cooperation" (小微企，大合作). There are approximately 380 thousand small enterprises in Foshan which generate CNY 45 billion in GDP, 60 percent of the tax income and 80 percent of the employment. The Foshan government supports small enterprises to cooperate with industry associations, vocational schools and experts to form a school-enterprise platform. Each programme consists of 1 teaching supervisor coordinating with an enterprise manager, 8-10 teachers, 25-30 students and 1-2 experts.

For example, the Nanhai Information Technology School is a high school located in Nanhai District currently has about 4200 students and offers a wide range of courses from early childhood education to automobile repair. The "Small enterprise, big cooperation" programme has become a particular focus at Nanhai IT School as many of the businesses located near the school are small and medium-sized enterprises. Some projects involve developing websites or doing computer maintenance, but the major focus of the cooperation programme takes place as part of a logistics class. The class has approximately 50 students who are divided up into four 12/15-person groups to work on one project. The groups take turns by week within one month. Students take theoretical classes in factories every morning, and practice on site in the afternoon. The school recruits businesses within a 30 minute drive of the campus and sets up a project team made up of a project director from the school, the general manager of the enterprise and the director of career development (school administration), students and teachers. If necessary, they will hire outside industry experts. Most projects have a focus on technical improvements, material control improvements, or improved storage.

In some cases, the project will take place at a larger enterprise that has good systems in place. In these cases, the students will implement the enterprises' systems as a learning opportunity. For smaller enterprises that lack knowledge and human resources, the partnership functions more as a consultancy. The project team designs a plan in consultation with the enterprise. The enterprise decides how much of the plan it wishes to implement and provides implementation funds. The students led by the teacher then implement the plan. Students are paid for work done at the business according to national regulations at about 50 percent the rate of an entry level worker. This makes the course a popular one with students. The school so far has received very high satisfaction ratings from the enterprises with over 95 percent providing offers of employment to students involved in the project. Students do not always accept, as they can generally choose from a range of employment opportunities. As well, the teachers at Nanhai estimate that almost all their male students return to work in their family businesses after graduation.

The school sees the "Small enterprise, big cooperation" programme as beneficial on many fronts. It improves the quality of students, moving them from an 'operations' mindset to a 'solution' mindset as well as expanding their experience. It give the teachers an opportunity to develop their industry expertise and the school to develop into a logistics training base. It improves the quality of the enterprises, given them much needed support and access to expertise.

Apprenticeship programme

Another type of industry cooperation is modelled on Germany's apprenticeship system. The Chencun Vocational and Technical School located in the Shunde District has set up cooperation with several large enterprises close to the school. They describe this as a model where enterprises enter the school rather than students enter the enterprises. The school offers specialisations in machining technology, mechanical applications, E – commerce, logistics service and management, computer animation and game production, pre - school education and hotel management. The school has a 2.5 + 0.5 system, whereby the students are based in the school for 2.5 years and for their last (sixth) semester relocate to a company. Classes are taught by both full-time teachers and by practitioners who engage in one-on-one mentoring as well.

One of their major partnerships is with the Keda Clean Energy Company. Keda has set up its own training system with five levels from high school through to doctorates. They partner with Chencun School to teach students technical skills for assembly line production. They have donated equipment to the school for students to learn on and supply personnel who come to the school to teach relevant pratical and theoretical courses. These employees take on the role of master in a master-apprentice relationship with the students. In the fourth and fifth semesters, those students who have successfully completed the Keda training course, then relocate to the company. There are four areas of concentration each with 30-50 students. After the completion of the apprenticeship all students are offered a position at the company. The company feels that the programme not only supplies them with entry-

level skilled workers, but improves the skills of their employees who teach those skills and enhances their corporate culture.

Chencun School also encourages the development of innovative thinking in its students. All students, even those in non-technical specializations, are required to take a course in innovation with a focus on new product creation. The students have won multiple competitions and have successfully applied for 198 patents for their products which include stationary bike-based power generator, arch processers, wireless refrigerator etc.

Foshan Lighting Company, a joint venture with the German company Osram, also cooperates with several vocational high schools as well as with Foshan Polytechnics College. They had entered the market in 1995, but had trouble finding skilled workers. With considerable experience with the German vocational education system, they set up the first industry-school dual vocational training programme in 1996 with Foshan Huacai Technical High School. They have a dedicated training centre at their factory. By 2002, as their production in China increased, they expanded in Liuyang, Hunan province and replicated the system with the Hunan Petrochemical Technical School. They recruit about 60-80 people a year through this system split evenly between Foshan and Liuyang.

Their training needs have been increasing with automation as workers need more skills to operate this equipment. For students recruited into this programme, in their first year of study when they are under the age of 16, they remain at school and take courses that have been jointly developed with the company. In the second year, they spend 70 -80 percent of their time in the enterprise, approximately 14 weeks per semester in the enterprise and 6-7 weeks at school. In the third year, the students spend 8-10 weeks in school and the rest of the time at the enterprise. The company does not, however, put students immediately to work. They have classrooms and workshops in their training centre where the students complete their education taught by the full-time teachers of the training centre all of whom worked in the areas they have taught for many years. They are also matched with skilled workers for one-on-one mentorship and cycle through different departments at the enterprise to see which area suits their skills and interests. Although conceivably if they has a student who could not complete the programme or could not find a suitable area of work, they would not hire them, currently they hire 100 percent of graduates from the programme and this has become Osram's main recruiting channel.

The training centre also provides on-going training for its workers offering 58 courses a year of between 4 hours and two days. Osram’s training programme has been so successful that the training centre is applying to become a public training centre to provide skills training for other companies. With the dominance of Foshan’s economy by small and medium-sized enterprises, most companies do not have the capacity or are not willing to invest in training to the same extend that Osram has. The director of the training centre, Mr. Xia Jin sees a cross-enterprise training centre as being able to plug a gap in the training requirements of Foshan businesses.

SME apprenticeship collaboration

Nanhai Yanbu Vocational Technical School has been collaborating with small and medium enterprises since for over 15 years. The school is located in Yanbu Township, an area with more than 300 women's underwear enterprises. The school therefore has a strong fashion and design specialization with many of the students designs that have been put into production put on display. One of the companies holds a design competition each year with a prize of CNY 50,000. The school also collaborates with the Guangdong Zipper Association. Guangdong produces three-fifths of zippers nationally and although the industry is small, most of the technicians in the industry come from this school.

Market-driven specialisations

Huacai Technical Vocational School is one of 5 vocational high schools in Foshan designated as national model schools. While Huacai hosts industry training centres for the automobile industry, it also focuses on maintaining cutting-edge programmes in emerging industries. 15 years ago it was the only high school in the city to offer an advertising programme. Since then it has developed programmes in graphic design, interior design, urban design, e-commerce, online security, and gaming. It has set up shops in auto detailing, graphic and website design and e-commerce across the street from the school where students work on one month rotations supervised by teachers to gain work experience. The employment rate of graduates is 99 percent, usually at higher than average salaries.

Box 1: Huacai Graduates

Huang Ziliang graduated with a specialisation in advertising in 2002. Huacai was the only school to offer this specialization. At the time, the school also had very low tuition so there was really no other choice for him. Huang has now developed the "Foshan New-town Art Village", an art and design incubation space, where Huacai students are welcome to come and work and use the space to exhibit their creations. Huacai students also participated in the design of the space.

Wu Zhichang graduated in 2002 in car repair, and has started several businesses since graduation. Huacai had cheap tuition at the time and trained kids from rural backgrounds in industries where they could get a good job. But more importantly, Wu felt that the school also provided students with a strong ethical basis for their development and taught them how to behave in the right way to make their way in the world.

James Zhao now works in Zhongguancun in Beijing and Silicon Valley in the USA for a venture capital firm focused on the high-tech industry. He previously worked as the marketing director for Xiaomi in the States. He believes that Huacai Vocational School not only gives students a chance to learn what they are interested in, but is able to see what the industry trends are, providing a platform for students to develop in-demand

skills. Vocational education also gives students enough time to experiment unlike academic high schools where time is taken up with rigorous training for the Gaokao. It was at Huacai that he gained the skills and had the time to launch his first start-up when he was 16, an on-line platform that gathered information about discounts and coupons in one place for subscribers.

Li Jianzheng specialises in computer networks and now operates a new-media based cultural communications company. While at Huacai he started an e-commerce company. After graduating from high school, he attended the Guangdong Newsoft Institute, but felt he was already far beyond the university students there as he'd already been effectively working in his field for the three years he spent at Huacai.

Higher education

Industry-school collaboration continues at the tertiary level. Foshan has seven vocational colleges. Foshan Vocational Technical College was given a CNY 1.18 billion investment by the city to relocate to the San Shui Industrial Park. Having the college there was seen as an amenity for the industrial park and of benefit to both the college and the companies in the park. The college has 33 majors, and 60 percent of the student graduate with an engineering degree in various specialities. Graduate employment rates are all over 97 percent.

The college collaborates with a number of large companies located in Foshan, many of which have established specialised centres at the college including Kuka, Changan Ford Automotive Service College, Haier Logistics Management Institute, AIKANG Photovoltaic Technology Institute, and the Sanshui Synthetic Rapid Manufacturing Institute. The college has state of the art robotics and other equipment donated by companies for training purposes.

Conclusion: Access for all

The vocational education system in Foshan is being developed in close collaboration with industry to support industry needs for skilled workers. Because the schools have the flexibility to coordinate with the businesses in their districts, the needs of many types of businesses are met and the schools can adapt to emerging markets and student interests. The system supports economic development and access to high quality jobs. All schools report almost universal employment after graduation with the Dean of the Foshan Vocational Technical College maintaining that demand far exceeds the ability of the college to graduate skilled workers. Entrepreneurship and innovation is encouraged. At the same time, the vocational system has ensured that 12 years of education is largely universal in Foshan, exceeding the national mandatory nine years of schooling. Inequalities are reduced, with migrant children having the same access to education as local children. With a large variety of programmes, students have a range of choices to suit their interests and capabilities.

Thank you to: The Foshan Education Bureau especially MAO Yongtian, Party Secretary and XU Xuyan, Deputy Director; the Foshan Education Bureau Vocational Education and Adult Education Section, especially WEN Yuehua, Chief, LIN Feng, Deputy Director, and HE Aihua, staff; SU Shunbin, Director of Human Research Management, Keda Clean Energy Co.Ltd; the teachers and students of Foshan Politechnic College especially XU Yubo, Deputy Secretary of the Party, and YUAN Yiye, Principal; the teachers and students of Foshan Shunde Chencun Vocational & Technical School especially LIN Jiaxiang, Principal and YUAN Jiyu, Vice Principal; the teachers and students of Yanbu Vocational and Technical School especially HUA Qunqing, Vice Principal; the teachers and students of Foshan Huacai Vocational and Technical School especially SHAO Yandong, Principal, and Graduates: James Zhao, WU Zhichang, LI Jianzheng, HUANG Ziliang; YAN Shaoqing; the students and teachers of Nanhai School for Information and Technology especially OU Minyi, principal; and XIA Jin, Director of Training for Osram China Lighting Ltd. Data and figures supplied by the Foshan Education Bureau.

Tourism+N: Green and equitable economic development through sustainable tourism

WULONG COUNTY, CHONGQING

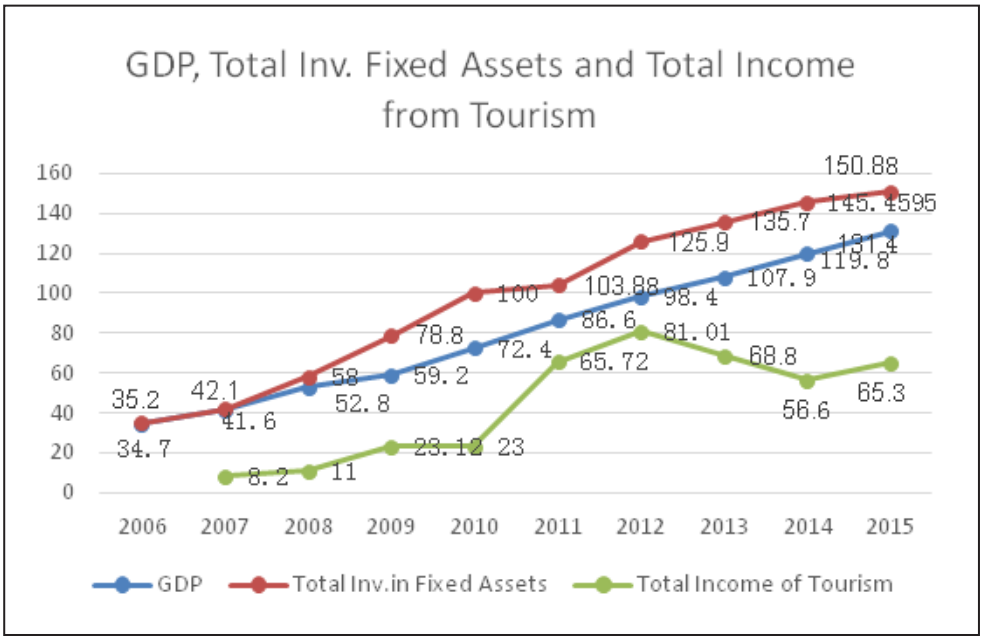
The development of the tourism industry in Wulong has become a catalyst for environmental protection, green economic development and poverty reduction. The government has titled their strategy Tourism+N: the combination of tourism with ecocivilization, agriculture, industry, sports and all other aspects of development within the county.

Introduction

Wulong is a county-level subdivision of Chongqing Municipality, in South-Central China located in the southwest of Chongqing, with 26 towns and 186 villages and a registered population of 410,000 people.

The economy of Wulong has grown rapidly over the past ten years. GDP in 2015 is almost double that of 2010 and this growth is reflected in significant success in poverty alleviation. Since 2005, disposable income per capita has increased from approximately CNY 4500 to CNY 16,311 in 2015. However, there is still a significant urban-rural gap: disposable income for town people is CNY 27, 000, but for villages only 9,572. The urbanisation rate in the county is 39.3%.The population under the national poverty line has declined by 56% from 125,000 in in 2005 to 55,000 in 2015. The poverty rate is 18.7% as of 2015.

Figure 8-3 Economic impact of tourism in Wulong



Tourism attractions and development

Wulong is the location of the Wulong Karst National Geology Park as well as part of the South China Karst formation, a UNESCO World Heritage Site since 2007. This landscape covers four provinces, and the Heritage Site is spread over 7 clusters in Guizhou, Yunnan, Guangxi and Chongqing.[80] Wulong's rich tourism resources attracted more than 21 million visitors in 2015 generating CNY 6.5 billion in income directly related to tourism. Along with being part of the World Heritage Site, these destinations have also been designated Chinese AAAAA-rated Tourist Attractions and a National Tourist Holiday Area, the only one in Chongqing. Building on this success, the municipality of Chongqing designated Wulong as a key ecotourism county and the United Nations Development Programme China Office recognised Wulong's Tourism+N as a good sustainability practice in 2015. Dr. He Ping, the Wulong Party Secretary, believes that national and international recognition of Wulong's success in integrating economic development and environmental protection will ensure that this approach is maintained long-term.

Furong Cave

Wulong began developing its tourism industry more than 20 years ago with the landmark discovery of the Furong Cave in 1993. This 2,700 metre-long limestone cave is the only cave in China included in a World Heritage Designation (as part of the South China Karst World Heritage Site) and was opened to tourism on May 1, 1994. The county then developed other attractions such as Xiannvshan (Fairy Mountain) and the Karst Sky Bridges.

80. For a complete description of the heritage site see: http://whc.unesco.org/en/list/1248

Cultural attractions

The county also hired Zhang Yimou's company Impression Wonders Arts Development Co., Ltd. to design the Impressions of Wulong (Yinxiang Wulong) sound and light show. Some of the set pieces (for example, of the workers who used to haul boats and barges up the mountain rivers) are similar to those used by Zhang Yimou in the Beijing Olympic opening ceremony, and the songs sung in this set piece have been declared an intangible cultural asset. There are 335 shows a year and in 2015, the show brought in revenue of CNY 4.5 million. More importantly, it keeps tourists in the area overnight.

Future development

The county intends to develop future sites at Baima Shan (White Horse Mountain) over the next five years, as well as develop more cultural and boutique tourist experiences. This includes a planned CNY 4.5 billion investment into seven village tours that will be used to improve living conditions and accessibility to the villages. The expectation is that long-term the villagers will be able to support themselves off of tourism revenue. The county has already begun to promote cultural events such as an annual music festival, and recent beer and kite festivals.

Other future development plans include attracting more foreign tourists, developing hot springs attractions, temples and amusement parks. Up to this point, the focus has been strongly on developing natural tourism assets but the county considers cultural tourism will be a critical future focus.

Enabling environment for sustainable tourism and environmental protection

The county government has created a strong enabling environment for the development of a sustainable tourism industry. It provides tax benefits for tourist businesses and utilities such as water and electricity are provided at reduced rates for hotels than for industry. It provides free training for village tour businesses (3000 people per year). The government also believes that running facilities themselves is preferable to outsourcing. Early on they had experimented with hiring experienced companies from outside the county, but in the end felt that local residents care more about Wulong and capacity can be built. Training has been an important component of tourist development with extensive training provided for all employees of tourist facilities on customer service and environmental protection. This has also been extended to local businesses and ordinary people.

The government has adopted a veto (一票否决) performance evaluation (on which promotions and raises are based) for local officials. Performance evaluation is very strict- for example, if more than 2 wild animals are killed or more than an accumulated 100 mu (6.7 Hectares) of forest are lost to forest fires in one year, all members of the Forest Bureau will have a performance rating of zero. As well, the Environment Bureau has the right to award up to five points to other bureaus' performance ratings for environmental protection.

Employment and economic benefits

Local employment and economic development is considered a critical component of a sustainable tourism strategy, to ensure that local people benefit from tourism development.[81]

In Wulong, tourism directly employs 71,000 people out of a registered population of 410,000 and 350,000 long-term residents (i.e. people who have not migrated permanently elsewhere). 21 million visits in 2015 generated CNY 6.5 billion in direct tourism income, not including the indirect income generated such as small business.

The major tourism sites are managed by the Karst Tourism Group Ltd., a county-owned enterprise that took over the site management from a private Chongqing company in 2007. The government felt that the private company was not prioritising environmental protection and decided to take back control to ensure the alignment of environmental and economic priorities. The company employs 1300 people, all of them local. The company also works with smaller businesses such as hotels and restaurants to do training on environmental protection and advertising for tourist attractions.

Holiday accommodation

While there are a limited number of hotels available within the Fairy Mountain protected area, most of the tourism services such as hotels, restaurants, transportation and a tourist service centre are located in Fairy Mountain township on the outskirts of the protected area. As well, there have been several holiday home developments near the town as a tourism model of longer term holiday stays rather than short-term sightseeing is being promoted. So far, 25,000 holiday homes have been built and approximately 20,000 sold as of 2016. New starts are being limited until the current stock is sold out. The county provides design guidelines limiting height to 1100-1500 metres for holiday homes, and no tall buildings are allowed near any of the tourist sites. The county sees this model of integrated tourism and real estate development as critical to the long-term economic development of the area and has garnered interest from other counties who have come on study tours to learn from them.

Another popular form of accommodation is village homestays (see box) which account for roughly half of all tourist accommodation in the county. 410 new homestay businesses with 8,000 beds were launched in 2015. As of 2014 there were 31,556 beds available in homestay businesses. In 2015, homestays accommodated 3.5 million visitors and generated CNY 380,000,000 in income largely to rural, previously impoverished families. The government provides a CNY 500 subsidy for each new homestay bed and bonuses of CNY 10,000, 20,000 and 30,000 to homestays that earn 3, 4 and 5 stars respectively. The Tourism Bureau promotes all kinds of accommodation to meet different needs. These and other small businesses.

81. See the UN WTO definition of sustainable tourism at http://sdt.unwto.org/content/about-us-5

Box 2: Homestay

Ran Xiaoming is a member of the Tujia minority and lives in Longbaotang Village. He is the owner-operator of the Precious Tang Villa Homestay, the first homestay in Longbaotang opened fifteen years ago. He says his business developed naturally, starting from when friends from the city would come for meals and to stay. Because they kept coming, they felt they should contribute to his costs. His homestay business was born.

The village used to be very poor. The land is mountainous and of poor quality with a lot of rain so crop production was low. Mr. Ran noted that villagers could support their families for about half a year off the land, but would have to go to urban areas to find temporary work in factories or construction to make up the difference. Young people still migrate to find work in the low season, but most people will return to the village for tourist season.

Other villagers were nervous about the investment needs to make their houses more welcoming for visitors so for many years Precious Tang Villa was the only homestay in the village. Eventually, Mr. Ran's success convinced his neighbours and more homestay businesses opened about 7 or 8 years ago. There are 300 households and about 800 people in the village. Half of the 300 households are now operating summer homestays. There are 8 villages in their township area and 6 now rely primarily on tourism for their income. Two villages still grow crops, but even they are prospering because they sell fruit and vegetables to the homestay businesses to supply guests. Prices have risen as the economy has improved.

Marginal cropland has been returned to forest, which makes the area more appealing for tourists. No-one needs to cut trees for energy anymore as was the habit in the 1970s as electricity and oil are available for light and heating. Villagers are actively involved in forest protection including one villager who is paid to patrol the mountain on the lookout for fires. Mr. Ran noted that the government's policies on forest protection, bans on campfires and bans on hunting have been generally accepted as people realise the long-term benefits through increased tourism.

"We now have enough money to send our kids to school and send our old people to doctors." Many households have been able to afford to buy cars. He estimates that households are able to earn an average of CNY 10,000 from the summer tourism season. They host approximately 600 long-staying guests each season, with more daily visitors who come just to eat. Average charges are 120-150 per day per person for a short stay and CNY 2000 including food and lodging per month per person. The majority of their guests are from Chongqing. They mainly rely on word of mouth and drop-ins and little formal advertising is done.

The village collects garbage and delivers it themselves to the collection points in town. Villagers also have developed a village agreement (村规民约) regarding maintaining public areas and environmental protection. For example, they have developed safe wastewater disposal methods to keep it out of local ponds and streams. The homestay businesses have also agreed to invest around CNY 200,000 in the coming year to grow flowers and make the village more beautiful to attract more tourists. Tourists are vocal with suggestions when things are not up to standard. The villagers respond as well as they can such as collecting garbage along the road even when it is not their responsibility, or improving the quality of their accommodation with better food, furniture or more hot water. But some things like unsafe traffic conditions is outside of their control.

The government has also helped by providing transportation, roads electricity and subsidies to homestay businesses that meet certain standards. They enforce construction standards, homestay quality standards including food and water safety and limit construction in the village.

Tourism-compatible industries

While tourism is the major focus of economic development in Wulong, there are four other industry clusters including automobiles and machine manufacturing in the Baima Mountain area, a planned new materials industrial park in Changba, machine manufacturing in Pingqiao Township, and agricultural products in Yajiang Township. High pollution and high energy consuming factories have been banned in the central and eastern parts of the county. Large animal husbandry facilities are being phased out with 10 already shut down and 12 more targeted to be moved out of the tourist areas by 2017. Limited, low-polluting industry is allowed in the south-west part of the county.

The county actively supports the development of small businesses that support tourism such as small-scale agriculture which is often integrated with homestay businesses. For example, the Forest Bureau supports the “Under the forest canopy economy” which currently covers 120,000 acres and produces an income of CNY 330 million for 11,500 households. Major economic activities include raising chickens and goats and cultivating Chinese medicinal herbs as well as tourist homestays. The Chongqing Forest Bureau gives a ‘Forest People” award to outstanding forest homestays. So far 28 businesses have received CNY 50,000 since 2014.

E-commerce agriculture and agro tourism are becoming important areas for small business development. Because of its mountainous location and poor weather conditions, it has never been a very productive agricultural area, but has had success in promoting unique agricultural products including vegetables, grass-eating animals, fruit trees, high mountain tea, and cold water fish.

U-pick businesses are popular with tourists and can be lucrative. The Agricultural Bureau notes that while average incomes for fruit farmers is CNY 4,000-5,000 per year, some can earn up to CNY 40,000-50,000 per year by marketing U-pick to tourists. Fruit orchards have expanded to Popular U-pick products include: “zhuoyao” dates, “yangjiao” dates, “wenfu” sweet tomatos, and “xiannv” crispy peaches. Prices may be 3-5 times higher for U-pick than for local purchases.

The county has also been promoting organic food with vegetables such as radishes, peppers and cabbages, "Zhuyao" dates and Baima Mountain honey receiving national recognition. About 30-40% of the 200,000 goats raised in the mountains are certified organic. While organic and conventional agricultural products used to be exported to Hong Kong and overseas, local demand and prices have risen along with tourism, so now it is more profitable to sell locally. However, some businesses to take advantage of e-commerce platforms to market specialty products such as honey, or other local products. For example, a disabled villager in Heshun Town started an online business selling smoked pork, wild fruit (e.g. wild kiwi fruits), vacuum sealed packs of free range chicken etc. His revenue was CNY 2 million in 2015.

The county has seen an expansion of villages in high mountain areas after having been abandoned for years due to the development of the lucrative high mountain tea industry. Families can earn CNY 40-50,000 annual income and the county plans to expand the current 50,000 acres of tea plantations to 100,000.

Box 3: Li Family Mutton Village Restaurant

Mutton stew is a popular local speciality. Mr. Li is the 5th generation of his family to run a mutton restaurant based on a recipe passed down through his family. His family ran a small shop in his village near Fairy Mountain, until he moved to the county seat of Wulong in 1995.

At that time, he only had one small restaurant operating in rented space with 4-5 employees and 6-7 tables. His main restaurant in the county seat now has more than 20 tables, 17-18 staff, and Mr. Li just opened a branch in the Township of Fairy Mountain. He owns both properties and has also recently opened a local food shop attached to his town restaurant. It sells his restaurant’s mutton products and the rest of the merchandise are food products from other local businesses. He estimates half his customers are local and half are tourists.

Mr. Li does not advertise himself, but notes that the agriculture bureau and the business bureau have done some promotion for him.

Environmental Protection

Environmental protection is integrated into the management and development of the tourist sites and is a guiding principle for industrial, urban and rural development as well as infrastructure investment.

Tourism facilities

The Karst Tourism Group operates on the principle of 'protect first, then develop'. According to the Karst Tourism Group general manager Huang Daosheng, the critical approach to their work is to maximise planning time to ensure that there is minimal disruption from tourism activities and to develop step-by-step to avoid overdevelopment. When they developed Fairy Mountain and the Karst Bridges sites, the tourism facilities were designed to be integrated with the natural environment. Buildings within the sites are minimised to only necessary facilities such as toilets and garbage collection and natural materials are used as much as possible. While there are some hotels located in the larger Fairy Mountain park, the majority of offices and major service facilities are located outside of the main sites. There used to be road access to Furong Cave, but parking has now been moved away from the site, and the company has made a CNY 150 million investment in cable car access and site restoration.

Tourists are encouraged to use the electric buses and trams available from the service centre in Xiannv town and between key sites to minimise emissions and the need for parking. Each site will only accept a certain number of visitors per day and each special event, such as festivals, limit the number of attendees.

Forest Management

Forest management has changed considerably over the past twenty years as ecotourism development and environmental protection became guiding principles for forest management. The forest coverage rate has increased considerably since 2003 from 32.7% to 59.2% in 2013. Coverage is expected to increase to 65% by 2020. This has partly come about due to rising incomes and alternative energy sources which has reduced demand for charcoal, as well as the most restrictive and enforced logging regime in Chongqing. Local people are licenced to cut 1-3 trees per year while a few companies are licenced to log 1000-2000 cubic metres for a total of 50,000 cubic metres per year. Licences are only approved by the Forest Bureau Director.

The National government provide 5 or 8 years subsidy to local farmers planting economic forests or ecological forests respectively. Since 2000, around 200,000 acres of arable land have been reforested and the county follows the national Green for Grain Project, which targets arable land with a slope of over 250 for reforestation.

The Bureau monitors invasive species and diseased trees replacing them with mixed indigenous plantings. The Bureau also monitors the forest for fires and hunting, engaging in ongoing education with the public.

Pollution Control

Efforts are also being made to improve the physical environment with solid waste collection points extended to 96 villages as of 2016 and wastewater treatment plants established in every village with a population of over 2000 people. Wastewater treatment coverage is higher in Wulong than other counties in Chongqing, with 22 treatment plants already in existence and 4 more being built. By the end of 2016 all villages will be covered, as are the towns and tourist centres.

The Environment Bureau, in addition to expanding solid waste and wastewater treatment services throughout the county, also works on localised pollution control efforts. For example, every year 20-30 restaurants are subsidized to control emissions and improve oil disposal. They implement an on-line monitoring system and random inspections of large enterprises for pollution put in place by the Chongqing government. The run a tourist hotline for pollution complaints and run training sessions for tour guides to help them promote environmental protection to tourists. They enforce noise and dust control on construction sites and gas spill collection at petrol stations.

Renewable Energy

The county has effectively halted all use of coal for electricity generation and has been closing one coal mine every year. The goal is to have only one coal mine producing 300,000 tons of coal in the whole county. There are currently three large power stations and 350 microhydro stations. There are plans for a new hydro station to be developed at Baima mountain. They have been developed to be compatible with tourism- for example, the hydropower station finished in 2004 next to the Furong Cave has all its generation facilities hidden inside a mountain. The county has one wind power station under operation, 2 under construction and are testing four sites for new wind power stations. Some farmers use off-grid renewables such as solar or biogas.

While the county has focused on renewable energy to this point, there is strong interest in developing fracking resources in the west of the county. The government feels that they can minimise the negative impact on the environment as the holes are small and they have been receiving technical training from Sinopec on fracking and environmental management. They have a restoration plan in place for after the resources are exploited.

As with other environmentally-friendly practices in the county, renewable energy is also a major economic driver. It is one of the three prongs of the economic development strategy of the local 13th Five-year Plan along with the development of the new materials industrial park and the development of the Baima Mountain tourist area. As demand for clean sources of energy continues to grow, Wulong is in a good position to supply them to the rest of Chongqing.

Conclusion: A unified vison of environmental protection and economic development

Wulong has been extremely successful in using tourism as a catalyst force for economic development that benefits a wide range of local people and is symbiotically entwined with environmental protection. A strongly unified vision of environmental protection as a critical component of poverty alleviation and economic benefit drives development in the county. As Wulong moves into the next phase of its development, with the eradication of poverty, opening up new areas for tourism, and greater accessibility to the rest of the world with the construction of an airport next to Fairy Mountain and a highspeed train from Chongqing (eventually part of a longer line linking Xiamen to Jiangjiajie), this dedication must be continually renewed so as not to undermine the impressive gains the county has made.

Thank you to: Wulong Party Secretary Dr. HE Ping; Wulong County Magistrate JIA Jianguo; Wulong County Vice-magistrate, HE Lin; Wulong County Public Relations Bureau Director MA Qike, and staff Chen Ping; Wulong County Environmental Protection Bureau Director, DENG Tao; LI Pengcheng, deputy director of Wulong County Tourism Bureau; Deputy Director of the Wulong County Council RAN Chongxiao; Deputy Director of the Wulong County Forestry Bureau LIAO Shuyun; Wulong County Development and Reform Commission staff member WU Fubing; General manager of the Karst Wulong Tourism Group Company HUANG Daosheng; Mr. LI of Li Mutton Family Restaurant; Wulong County Dragon Fairy Township Bao Tang Bao Tang villa farmhouse, RAN Xiaoming. Data and figures supplied by Wulong County Government.

Integrated Solid Waste Management

GUANGZHOU, GUANGDONG

Introduction

Guangzhou is China's third largest city after Shanghai and Beijing with a population of 16 million. As a major centre of the Pearl River Delta manufacturing area, it continues to experience rapid economic growth at 8 percent in 2015. Hosting the Asian Games in 2010 encouraged Guangzhou to take measures to improve its environment, including shutting down or moving 5000 factories, investing in clean energy, gasoline standards, protecting the over 1000km of waterways in the municipality and addressing soil pollution.

One area of particular concentration has been solid waste management. The mayor Chen Jianhua has made waste separation, sorting and processing his signature issue. The city processes approximately 22,600 tons of solid waste a day for a population of 16 million people. 6,000 tons are recycled (a 30 percent recycling rate for villages and suburban areas and 36-37 percent rate for core urban areas), with the remaining 15,800 tons going to landfill or incinerators.

The overall strategy of the waste management system is to reduce waste through the front-end sorting, transfer, and final treatment, and build up a comprehensive sorting-transfer-treatment network. The city has established a multi-layer mechanism: sort in households, collection in communities/villages, transfer by street (jiedao) or township committee, and treatment by districts. Each village has one collection spot, and each township has one transfer station. Additionally, the city has adopted a market-based public-private-people partnership to improve recycling rates.

Front-end waste sorting

Measure 1. Specification of time and areas for waste disposal

To sort and reduce solid waste, Guangzhou started specifying time and designated areas for disposing of kitchen waste in every community. Residents can bring their garbage to specific disposal spots in the morning or evening. In Xinlong Community for instance, the timed spots open between 7am and 9am, and 6pm and 8pm. Bins are placed before the scheduled time, and removed at the end of the period. 24-hour disposal spots are also open in every community, but are normally located further from residential buildings in comparison with the timed disposal spots, to encourage residents to put waste out at the designated time.

Measure 2. Door-to-door collection

While the Guangzhou Municipal Government sets standards for waste sorting in households, at the community level, each community is encouraged to have their own plan for collecting and sorting waste. Ouzhuang Community,[82] for instance, introduced a '92 Recycling' app while Xinlong Community[83] utilises its block focal points to connect residents and waste collectors.

Ouzhuang Community is the first community to introduce an 'internet + waste sorting' model for its waste management. '92 Recycling' is an app developed by the Guangzhou Lvchuang Technology and Information Limited Company, an e-commerce enterprise. The residents use the app to make appointments with collectors of recyclables, and receive door-to-door pick-up service. 45 collectors in Huanggang Jiedao have registered on the app. Users earn points after each deal, which can be used as coupons for goods in the 92 online mall. As of October 2016, 800 out of around 1000 residents from Ouzhuang have registered on the app. There are 180 deals per month on average.

Xinlong Community took a different approach, which highlights the role of traditional block focal points. Residents from Xinlong who need assistance call the block focal points. At its community centre, the contact information of all waste management related personnel is published on a billboard and their Wechat account and phone number information is also available.

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82. Ouzhuang Community is administered by the Huanggang Jiedao, which covers 4.3 km2.
83. Xinlong Community is the oldest community in Guangzhou. It has 1700 households.

In addition, all street committee offices have a bin for hazardous waste that is monitored by staff to make sure it is only being used for waste that cannot be disposed of in any other way.

Measure 3. Infrastructure investment

'Details are important.' says by Chen Xiaolong, the director of the Office for Waste Sorting, City Management Bureau of Yuexiu District. Guangzhou made major investments in infrastructure to shape the environment to encourage front-end waste sorting. In communities, lounges for street cleaners were built, which are spacious, and installed with tea corners as well as sofas. These spaces ensure that cleaners get proper breaks, improving working conditions and demonstrating respect for their work. At the cross of Yuehua Road and Jixiang Road, close to the offices of the municipal government, 24-hour disposal spots have turned into attractions. Trash bins are enclosed within nicely designed wooden fences, and decorated with potted plants. This strategy is also being applied to spots in communities.

Sanitation workers' tools have also been improved for more efficient front-end sorting. In Central Park (中央公园) for instance, each large trash bin is equipped with a small hanging bucket. Cleaners can easily sort out plastic waste as they sweep up leaves. The leaves then go directly into the on-site grinder. The processed leaves are reused as fertiliser back in the park. Some are given to the residents for home planting as part of the city's waste education activities. At a waste transfer station, workers are equipped with customised semi-automatic sorters for kitchen waste. Scrapers pick up trash bins, and pour the kitchen waste onto the sorters' operating desk. Workers remove plastic bags, bottles, and so on, so the food waste can be transferred to the kitchen waste plant for treatment. The customised sorters allow workers to complete the whole process in under five minutes. A recent competition held by the district saw the winner complete sorting in one minute. Sorters are also equipped with biological bacteria sprayers to efficiently reduce unpleasant smells.

Measure 4. Public education

Public education has three targets: community residents, school students/teachers, and government staff. The fourth Saturday of every month is the All-people Waste Sorting Action Day of Guangzhou. The district governments work with communities to do education about recycling and waste sorting. Street Committees organise activities to promote waste sorting including prize challenges, dancing, singing, short plays, and so forth. Community members also learn about any fines for improper waste disposal. As well, every year on July 10 the city hosts a conference with participation from the municipal and district governments, community representatives and schools. In 2014, over 10,000 people visited garbage facilities across the city. The city has also leveraged the influence of the media to promote examples of garbage sorting and recycling. The city's incinerators and landfills have environmental education centres that explain the waste stream and what the facilities do. The incinerators also post real time data on emissions at the facility gates and on the internet.

For school students/teachers, the Bureau of Education has set up evaluation standards for waste sorting education. In 2014, the Bureau set up standards for selecting model schools.

Now, all primary schools and middle schools have had their own waste sorting education base to help students have a better understanding of the benefit of practising waste sorting. From 2015, requirements for waste sorting education were extended to preschools. In over 100 preschools, Guangzhou launched the 'Hands-in-Hands' initiative, in which children become the promoters, practitioners and supervisors of waste sorting in their families. Children are encouraged to bring two used milk boxes every week. Schools also distribute fertiliser processed from kitchen waste to students.

Government employees are required to be models of waste sorting. Model units' evaluation standards have also been set up by the Guangzhou Municipal Government. Cameras were installed to monitor the behaviour of government employees within office areas. The performance evaluation of individuals is now linked with waste sorting as well.

Measure 5. Institutionalisation

The Guangzhou Municipal Government set up the Office for Solid Waste Management in 2010, the first in the country. Guangzhou also was the first to issue a Regulation on Waste Sorting (tentative) (广州垃圾分类管理暂行规定), which has been submitted to the Guangzhou People's Congress for legalisation. Having a legal and institutional basis for waste management highlights the long-term commitment to better waste management of the municipality.

Waste transfer network

Aside from the measures to improve sorting rates at the front end, Guangzhou also reformed its waste transfer network. In the past, transferring waste from communities to treatment facilities was the responsibility of the Bureau for City Management. City Supply and Marketing Cooperatives were in charge of waste sorting and treatment. The Bureau for City Management paid the City Supply and Marketing Cooperatives CNY 100 /ton-CNY 175 /ton was for waste treatment, and CNY 75 /ton was compensation for ecological damage.

After reform, the City Supply and Marketing Cooperatives took over the entire waste transfer network in Guangzhou. As waste sorting is now largely completed before transfer, the City Supply and Marketing Cooperative were able to become self-funding through recyclables or biological fertiliser products.

Final treatment

Guangzhou has a range of waste management facilities including one landfill (five are now closed), 2 waste-to-energy incinerators, recycling facilities and 1 kitchen waste plant. Six industrial parks for recycling are under construction as are 3 incinerators.

The landfills have largely reached capacity and incinerators are becoming the end treatment facility of choice. The first waste-to-energy incinerator uses Japanese technology and the second Danish technology. The next 5 will also use Danish technology and standards for

emissions are as high as Europe. All large cities in China have high standards for incinerators, but Guangzhou's are the highest. The energy produced by each incinerator is fed directly into the grid and generates 210 million kw/year, enough to provide energy to 7-8,000 households.

The kitchen waste facility was built as part of a public-private partnership with the Golden Way Biology Technology Company. The government invested CNY 40 million in land development and the company invested CNY 80 million in equipment. Through 8~10 hours of fermentation using aerobic organism processing, kitchen waste is turned into organic fertiliser and fodder. Each machine can process 5 tons/day/time, and can work twice a day. The factory has the capacity to process 200 tons of wastes a day or 17.3 thousand tons/year. The fertilizer is currently being used in Chengdu, Hulunbeier for land recovery.

The city has also implemented intensive public engagement around its incinerator development. Guangzhou's main landfills were reaching capacity in 2012- one already had garbage piled up to 70 metres. Incinerators were seen as an appropriate solution; however, the public had been opposed to incinerators when proposed in 2008. The city set up a public opinion committee that included those opposed to the incinerators and netizens as well as people living close to the areas where the plants would be installed. They sent members of the committee to Japan, Macao and Taiwan to visit existing incinerator plants. This helped assuage concerns regarding the health impact of incinerators as well as concerns about the impact of plants on neighbours. Five of the six planned incinerators are now under construction and the city eventually plans to have one incinerator in every district.

Conclusion: Partnerships for waste management

A critical facet of the success of Guangzhou's waste management is its market-based collaborative public-private-people partnership. The government is responsible for the system and policy design and coordination of different societal actors, the private sector for operations, and citizens participate in sorting and solution design.

In front-end sorting, Guangzhou introduced market mechanisms to sort out reusable waste. Different types of waste including glasses, bottles, e-waste and used wood are tagged with different prices. Guangzhou Supply and Marketing Cooperatives, Guangzhou Zaishengbao Glass Treatment Limited Company, etc. participate in collection. Residents and street cleaners receive subsidies.

With these market mechanisms in place, it encourages private companies such as 92 Recycling to develop easy tools for waste collection, and stimulate the participation of residents, especially younger generations. The smart phone app simplifies the process of sorting in each household, and also make the process more interesting and rewarding to residents. Government helps to promote these kinds of applications. The company gains through the increase of users and traffic. For final treatment, the Guangzhou government invites private companies to bid to operate its waste recycling facilities. The government develops the land, and private company invests in equipment. Profits from recycling and

production are returned to private companies and the government fulfils its public service requirements.

The public is also engaged in decision-making. As there is no unified strategy, each community can develop its own approach to household waste collection. Residents participate in the formulation of their community's approach as well as in the implementation through each household's own waste management practices.

This integrated management system for addressing solid waste is not only improving the urban environment and using environmentally-friendly treatment systems but is also supporting economic development and community engagement as well as contributing to improved city governance mechanisms.

Thank you to: XIE Shaodan, Vice-mayor, Guangzhou Municipal Government; GU Shiyang, Deputy Secretary-general, Guangzhou Municpal Government; the Guangzhou City Management Committee especially WEI Weihan, Party Secretary, XU Jianyun, Deputy Director, LIN Shaohong, Deputy General Engineer, and YU Shangfeng, Head of the Facility Construction Management Division; TANG Jianhui, Chief of the Guangzhou City Administration Committee Waste Recycling Section; XIAO Wen, Manager and Senior Engineer, Guangzhou Municipal Solid Waste Management Centre; CHEN Xiaolong, Director of the Office for Waste Sorting, City Administrative Bureau of Yuexiu District, Guangzhou City; GUO Guangsheng, General Manager Assistant, Guangdong Goldenway Blossom Bio-tech Co., Ltd.; the resident committees of Ouzhuang Community and Xinlong Community. Data and figures supplied by the Guangzhou Municipal Government.

APPENDIX

The indices are the Urban Ecological Input Index (UEII) and Urban Human Development Index (UHDI). The indicators are comprised of nine ecological input indicators and three human development indicators. Data is derived primarily from the 2015 Statistical Yearbook of Chinese Cities and the China Statistical Yearbook on the Environment 2015.

1. Urban Ecological Input Index (UEII) and indicator treatment

The Urban Ecological Input Index (UEII) includes two sub-indices: the Urban Resource Consumption Index (URCI) and Urban Pollutant Discharge Index (UPDI). UEII is calculated using the arithmetic average of URCI and UPDI.

$$UEII = \frac{1}{2}(URCI+UPDI) \quad (2.1)$$

(1) Urban Resource Consumption Index (URCI)

The Urban Resource Consumption Index (URCI) consists of three indicators: the urban water resource consumption indicator (UWCI), urban land resource consumption indicator (ULRI) and urban energy consumption indicator (UECI).

The data sources and calculation methodology of each indicator are as follows.

$$URCI=\frac{1}{3}(UWCI+ULRI+UECI) \quad (2.2)$$

The urban water resource consumption indicator (UWCI): the indicator is measured by per capita water supply and data is directly derived from the 2015 Statistical Yearbook of Chinese Cities.

The urban land resource consumption indicator (ULRI): the indicator is measured by per capita built area and calculated by dividing built area by permanent population.[84] Data on built area is derived from the *2015 Statistical Yearbook of Chinese Cities* and that on permanent population from the *2015 Statistical Yearbook of Chinese Cities* and local statistical yearbooks published by each city, such as the 2015 Statistical Yearbook of Shanghai.

The urban energy consumption indicator (UECI): the indicator is measured by per capita standard coal and calculated by dividing the annual comprehensive energy consumption of each city by permanent population. The 2014 comprehensive energy consumption of most cities is covered by the 2015 local statistical yearbooks. Some cities have no data on annual comprehensive energy consumption but do have data on consumption by industry and by

84. Permanent population refers to the population that has lived in a place for more than six months and is registered to live there.

energy variety, primary energy such as raw coal, crude oil and natural gas and secondary energy such as clean coal, other washed coal and briquettes. These are converted to standard coal based on the General Principles for Calculation of the Comprehensive Energy Consumption (National Standard GB/T 2589—2008 of the People's Republic of China). For instance, 1kg raw coal is equivalent to 0.7143 standard coal, 1kg crude oil to 1.4286 standard coal, 1 cubic metre of natural gas to 1.33kg standard coal and 1kg cleaned coal to 0.9000 standard coal. For cities that have neither data on annual comprehensive energy consumption nor that on consumption by industry and by energy variety, we multiply the energy consumption per unit GDP released in the statistical communiqué on national economic and social development or the annual government work report by GDP of the city. The statistical calibre of permanent population is consistent as before.

(2) Urban Pollutant Discharge Index (UPDI)

Multiple pollutants including water pollutants, air pollutants and solid waste are the results of many of the processes of production and consumption in cities. The amount of discharge of pollutants is determined by multiple factors such as the industrial structure of a city, its technical level, consumption structure and level, and inputs into environmental protection. Once a certain economic output level is reached, minimising the production and discharge of pollutants and improving environmental performance are important dimensions of urban sustainable development.

In this report, the Urban Pollutant Discharge Index (UPDI) consists of three indicators, the urban water pollutant indicator (UWPI), urban air pollutant indicator (UAPI) and urban solid waste indicator (USWI). Indicator inputs are selected based on data availability and policy importance. UWPI is measured by COD and ammonia nitrogen levels in water, UAPI by sulfur dioxide and nitrogen oxide emissions and USWI by industrial solid waste and domestic garbage.

The 12th Five-year Plan for national economic and social development set specific total discharge control targets for the above-mentioned four types of water pollutants and air pollutants. Therefore, reducing discharge of the four types of major pollutants is not only crucial to improving urban environments, but also a factor that must be considered when urban environment management policies and sustainable development policies are formulated in China. The two types of solid waste indicators respectively correspond to discharge in production and domestic waste production, reflecting the size of material flowthrough of the urban economic system.

To get the indicator of per capita discharge, we divide the sum of the six types of pollutants by the permanent population of each city; urban pollutant discharge index (UPDI) is constructed from the dimensionless arithmetic average of the indicators:

$$UPDI = \frac{1}{6}(UWP_{COD} + UWP_{N-NH_4} + UAP_{SO_2} + UAP_{NO_X} + USW_{Ind} + USW_{Hh}) \quad (2.3)$$

UWP_{COD}, $UWP_{N\text{-}NH_4}$, UAP_{SO_2}, UAP_{NO_X}, USW_{Ind} and USW_{Hh} respectively refer to the value after non-dimensional treatment of per capita COD discharge, per capita ammonia nitrogen discharge, per capita sulfur dioxide emission, per capita nitrogen oxide emission, per capita industrial solid waste production and per capita domestic garbage disposal.

Table A-1 Calculation and data sources of UEII sub-indicators

Indicator	Unit	Formula	Data Sources
UWCI	Per capita water supply (ton/person)	The total urban water supply divided by residential population, note 1	*China Statistical Yearbook of Cities*
ULRI	Per capita built - up area (m^2/person)	City area built-up area divided by residential population	*China Statistical Yearbook of Cities*
UECI	Per capita consumption of coal equivalent (ton of coal equivalent/person)	The annual combined energy consumption of the city divided by residential population	*Local Statistical Yearbook 2015*, note 2
UWPI	Per capita COD (kg/person)	Total emission of COD divided by residential population	*China Statistical Yearbook on the Environment 2015*, note 3
	Per capita Ammonia Nitrogen (kg/person)	Total emission of Ammonia Nitrogen divided by the residential population	
UAPI	Per capita SO_2 (kg/person)	Total emission of SO_2 divided by the residential population	*China Statistical Yearbook on the Environment 2015*
	Per capita Nitrogen Oxide (kg/person)	Total emission of Nitrogen Oxide divided by residential population	
USWI	Per capita industrial solid waste (ton/person)	Industrial solid waste divided residential population	*China Statistical Yearbook on the Environment 2015*
	Per capita domestic solid waste (ton/person)	Domestic solid waste divided by residential population	*Local Statistical Yearbook 2015*, note 4

Note 1: Resident population data are from each city's "Statistical Yearbook 2015."

Note 2: In this study, most of the 35 large and medium cities' comprehensive energy consumption data come directly from the cities' 2015 statistical yearbook. If there is no such data in the yearbook, the index is calculated by multiplying the energy consumption per unit GDP of that year (from the 2015 statistical yearbook) by the gross domestic product (GDP) of the year.

Note 3: Data for water pollutants, air pollutants and industrial solid waste discharge/ production are derived from the China Statistical Yearbook on the Environment 2015 as a total and the data of individual cities are calculated by pollutant emissions of GDP per unit area multiplied by the city's 2014 GDP. Data for domestic garbage disposal come from the 2015 Report on the State of Environment or the 2015 statistical yearbook of each city.

Note 4: Data on urban domestic solid waste can be found in the entry on "Urban Appearance and Environmental Sanitation" under "Urban Public Utilities" in the 2015 local statistical yearbooks. If there is no data in the local statistical yearbook, the report uses data from the urban environment development bulletin, or data from the provincial statistical yearbook. The 2014 National Economic and Social Development of Urban Statistics Bulletin only has garbage treatment rates. For cities where data is unavailable, the domestic solid waste treatment rate is used instead, or the previous year's data is used.

2. Urban Human Development Index (UHDI) and indicator treatment

The Urban Human Development Index (HDI) uses the calculations and formulas of the United Nations Human Development Report 2015.[85] The Urban Human Development Index (UHDI) consists of three indicators, namely the urban life expectancy indicator (LEI), education indicator (EI) and income indicator (II). Data source and calculation explanation are shown as follows.

$$HDI = \sqrt[3]{LEI \times EI \times II} \tag{2.4}$$

(1) Life Expectancy Indicator (LEI)

The life expectancy indicator (LEI) is measured by per capita life expectancy. In this book, the Life Expectancy Indicator (LEI) of cities is derived by normalizing the life expectancy of 35 large and medium-sized cities into formula (2.5). In equation (2.5), constants 85 and 20 are the maximum and minimum life expectancy values, respectively, set by the United Nations Human Development Report 2015. Urban life expectancy cannot be obtained from statistical yearbooks so per capita life expectancy in 2014 is mostly obtained online via data released by local statistical bureaus and centres for disease control and prevention. For cities where no relevant authority releases life expectancy, data is obtained from 2015 per capita life expectancy targets proposed in local 12th "Five-year" Plan on Development of Social Undertaking, 12th "Five-year" Plan on Development and Reform of Social Undertaking or the 12th "Five-year" Plan. For a few cities where no data can be attained via these channels, statistics from the latest news coverage is adopted.

85. UN 2015 Human Development Report HDI Calculation Explanation http://hdr.undp.org/sites/default/files/hdr2015_technical_notes.pdf

$$LEI = \frac{LE - 20}{85 - 20} \tag{2.5}$$

(2) Education indicator (EI)

The education indicator (EI) is the geometric average of the school education indicator MYSI and expected school education indicator EYSI. It is mainly affected by two variables, namely per capita education years and expected education years. Per capita education years is the actual number of years of education for persons aged 25 years and over. Expected education years is the number of years a 5-year-old child will be educated throughout his or her lifetime.

Most cities do not have direct data for per capita education years (MYS) and expected education years (EYS). According to the principle of availability and rationality, this report uses the following methods for MYS and EYS conversion.

$$\text{Per capita education years} = \Sigma P_i E_i / P \tag{2.6}$$

P_i refers to population with i types of education and E_i refers to the education year coefficient of population with types of education. This report adopts a coefficient of 16 for education above junior college, 12 for senior high school, 9 for junior high school, 6 for primary school and 0 for no education. i follows the Chinese education system and P refers to the total population of the group. P_i and E_i come from the report on the sixth population census of each city.

Data on expected education years are attained by the sum of the net enrollment rate of each grade in degree education.

$$\text{Expected education years} = \lambda_i\text{Primary school}\times 6 + \lambda_i\text{Junior high school}\times 3 + \lambda_i\text{Senior high school}\times 3 + \lambda_i\text{College}\times 4 \tag{2.7}$$

λ_i refers to net enrollment rate of each grade and scope of is 1st to 16th grade (excluding kindergarten and postgraduate-above education). However, due to lack of accuracy of the net enrollment rate, the gross enrollment rate is used instead for approximate calculation.

The gross enrollment rate for each stage of degree education is mainly obtained from the Statistical Bulletin on the Development of Education, 12th Five-year Plan on Development of Education, Mid and Long-term Plan on Development of Education, Statistical Bulletin on National Economic and Social Development and Mid and Long-term Plan on Education Reform and Development in each city.

The constants 0, 15, and 18 are the minimum, maximum, and expected maximum years of schooling set for the United Nations Human Development Report 2015, respectively.

$$MYSI = \frac{MYS - 0}{15 - 0} \tag{2.8}$$

$$EYSI = \frac{EYS - 0}{18 - 0} \tag{2.9}$$

(3) Income indicator (II)

The income indicator (II) is measured by per capita GDP (PPP).[86] The conversion factor of the CNY against the Geary-Khamis Dollar dollar is 3.5055.[87] Substituting the converted GDPpc into the formula (2.11) gives the city's income index (II). Per capita GDP_{pc} in 2014 is derived from the 2015 statistical yearbook of each city and then converted to USD PPP.

Equation (2.11) uses a logarithmic approach to normalizing income indicators, where the constants 100 and 75000 are the minimum and maximum per capita domestic income set in the United Nations Human Development Report 2015.

$$II = \frac{\ln(GNI_{pc}) - \ln(100)}{\ln(75000) - \ln(100)} \tag{2.10}$$

86. In the United Nations Human Development Report 2015, the income index is calculated from per capita national income (GNIpc) based on the PPP. China's urban statistics generally use gross domestic product (GDP) as the main indicator of economic development. Historically in China, the difference between per capita GDP and per capita GNI is less than 2%. (Yu Fangdong, Yang Hongjun & Xie Mingming, International position of Chinese per capita GDP and per capita GDI being steadily improved. China Information News, May 18, 2011. http://www.zgxxb.com.cn/xwzx/201105180007.shtml.) Therefore, using PPP of per capita GDP to replace per capita GNI to calculate the income index will have little influence over the reliability of data calculations.

87. In line with the HDI calculation rules of the United Nations Human Development Report 2015, this book uses the 2011 PPP conversion factor of 3.5055. The data are based on estimates from the World Economic Outlook report of the World Economic Outlook (WEO), which is available at http://www.imf.org/external/pubs /ft/weo/2016/01/weodata/index.aspx.

List of Figures

List of Tables

List of Boxes