NEASPEC NORTH-EAST ASIA LOW CARBON CITIES PLATFORM

PEER REVIEW REPORT – GUANGZHOU

Table of Contents

INTRODUCTION 3

Purpose of study and background 3

Review participants 4

Methodology 4

THE STATE OF LOW-CARBON DEVELOPMENT IN GUANGZHOU 6

Official Low Carbon Development Policies 7

Guangzhou's Low Carbon Management System 8

PEER REVIEW 8

Low-carbon Governance – Key Findings in Governance Area 8

Low-carbon Government Structure 8

Low-carbon Development Strategy 9

Sectoral low-carbon development – Key Findings by Sector 10

Energy System 10

Transportation 11

Buildings 12

Waste 13

CONCLUSION 14

ANNEX 1: NAME LIST OF GUANGZHOU WORKSHOP SPEAKERS AND DISCUSSANTS 15

ANNEX 2: GUANGZHOU BACKGROUND REPORT 17

REFERENCES 43

Introduction

Purpose of study and background

This Peer Review report supports the mission of the North-East Asian Subregional Programme for Environmental Cooperation's (NEASPEC) Low-carbon Cities programme. It is designed to promote NEASPEC's goals of enhancing coordinated actions to address subregional environmental challenges, mobilizing mutual support to manage domestic environmental issues in East Asia, and contributing to the implementation of national, regional and global goals for sustainable development. Meanwhile, as the following figure shows, it can facilitate low-carbon policy knowledge sharing and peer learning among peers from government, the private sector and research institutes of different cities.

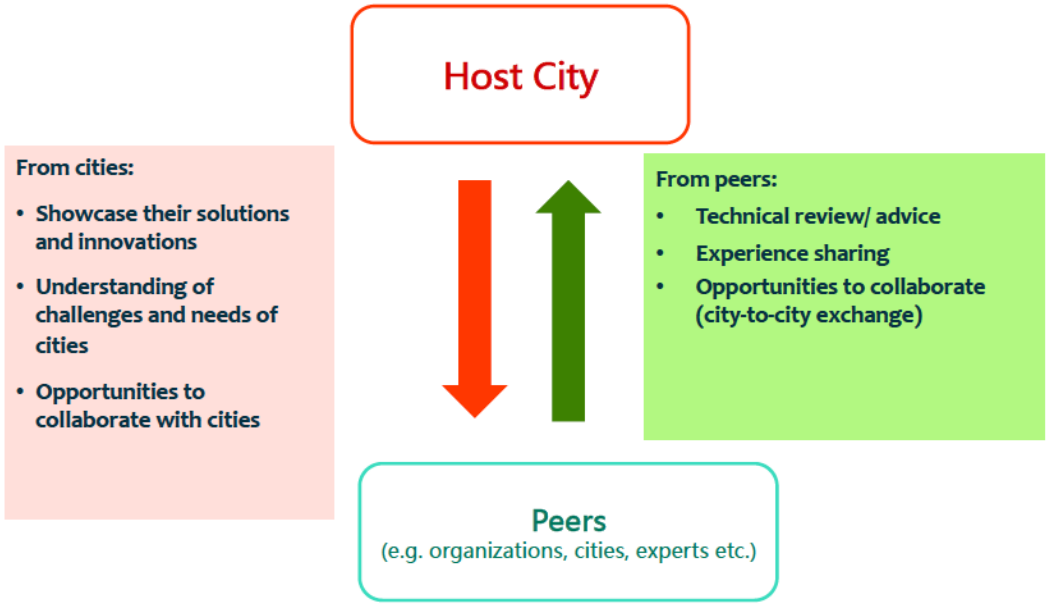

Figure 1. NEA-LCCP Peer Review

The report is a component of innovative Green Development Program's (iGDP) partnership with the NEASPEC Secretariat, under the NEASPEC North-East Asia Low-carbon Cities Platform (NEA-LCCP). In this partnership, iGDP is tasked to develop peer reviews of the characteristics and performance of policies in two Chinese cities, Wuhan and Guangzhou, that belong to China's Low-carbon Pilots program. This report is the second of these two peer review exercises, focusing on the city of Guangzhou, located in southern China.

This peer review report builds on and draws from a peer review methodology workshop held on September 1st and 2nd, 2016 in Seoul, Korea, a methodology report associated with this workshop, a background report on low-carbon policy development in Guangzhou, and a peer review workshop held in Guangzhou on 24-25 January 2019. Throughout these activities, iGDP liaised with Guangzhou public officials

and technical experts to procure information, performed data collection, carried out site visits and interviews, and sought consultation on report progress.

The report includes three main sections: (1) a review of the methodology used to prepare the report, (2) a discussion of the state of low-carbon development in Wuhan, as well as peer review observations about these policies and recommendations for new areas of work going forward, and (3) a concluding summary of the key findings of the peer review exercise.

Review participants

The contributors to this peer review exercise gathered at an International Consultation Workshop on 24-25 January 2019. Titled "Guangzhou's Low-carbon Strategy International Consultation Workshop", the workshop brought together more than 40 participants. Participants including 11 professionals and experts from research institutions in Guangzhou, and 7 from peer Chinese cities and Northeast Asian cities who shared information about low-carbon policymaking and best practices in their respective locales.

The workshop also brought in 23 experts from international and domestic research institutions, including Energy Research Institute, Chinese Academy of Social Sciences, the Korea Environment Institute (KEI), C40, Seoul Energy Corporation, the Institute for Global Environmental Strategies (IGES), ICIEI Asia Secretariat, the National Center for Climate Change Strategy and International Cooperation (NCSC), Incheon Climate & Environment Research Center, and Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ).

Methodology

The production of this peer review of Guangzhou low-carbon strategy consisted of three stages: 1) preparation, 2) consultation, and 3) assessment.

In the preparation stage, a background report on Guangzhou's low-carbon progress was developed. The report provides an overview of Guangzhou's low-carbon strategies and practices, drawing from a multiple sources of data. First, it analyzed a wide range of primary sources (e.g. official government documents and statistical yearbooks), which detail Guangzhou's low-carbon policy planning process and the driving forces behind its low-carbon development. Second, secondary sources were examined, including journal articles and research reports, which provided detailed analysis of Guangzhou's low-carbon development across multiple sectors. The background report also drew on meetings with local experts and officials during site visits, enabling the report to reflect first-hand insights on Guangzhou's low-carbon progress. Drawing on different types of data and information, the background report provides a full picture of Guangzhou's low-carbon development that helps in efforts to track and evaluate Guangzhou's low-carbon performance.

Based on the peer review indicator framework developed by NEA-LCCP, as indicated below:

	Indicators
Background indicators	**General background** (e.g. Population, GDP, Carbon intensity etc.)
Sectoral indicators	**Energy** consumption and CO_2 emissions
	Building Energy Use
	Land Use
	Industry (e.g. industrial structure, energy use etc.)
	Water (e.g. consumption, efficiency etc.)
	Waste (e.g. generation and treatment etc.)
	Public utilities (e.g. street lighting etc.)
	Mobility (e.g. public transportation etc.)
Policy Indicators	**Governance** (e.g. city strategy and targets, coordinating body, evaluation etc.)
	Supporting mechanisms (e.g. legislation, financing, incentives, education and capacity building etc.)

Source: North-East Asia Low-carbon Cities Platform

The background report also identified two groups of factors that influence Guangzhou's low-carbon development policy efforts. The first group is contextual factors: local features of the city that shape and constrain a cities' low-carbon development. These include a city's demographic, geographic and economic features. The second group is strategy-driven factors. These are the factors that can be influenced by Guangzhou's policymakers to directly affect low-carbon performance. They include Guangzhou's economy-wide policies and sector-specific policies. This peer review focuses on the strategy-driven factors shaping Guangzhou's low-carbon development progress.

Table 1 Key Factors in Low-carbon Development

Low-carbon Development	
Contextual factors	**Strategy-driven factors**

• Geographic features
  ○ Climate and weather
  ○ Land area
• Demographic features
  ○ Population size and density
  ○ Urbanization rates
• Economic features
  ○ Economic growth and structure
  ○ Energy consumption and carbon emissions
	• Low-carbon management system
	  ○ Low-carbon governance
	  ○ Low-carbon policy planning
	• Sector-specific strategies
	  ○ Energy sector
	  ○ Transport sector
	  ○ Building sector
	  ○ Waste sector

For the consultation stage, a peer review workshop was held in Guangzhou. The workshop developed an agenda focused on the strategy-driven factors identified in the background report, inviting experts from domestic and international peer cities to evaluate these factors. The workshop was divided into two parts. The first part focused

on progress and prospects of Guangzhou's green and low-carbon development strategy, discussing efforts Guangzhou has made in low-carbon development, as well as opportunities and challenges facing the city's low-carbon development in the context of government restructuring. The second part of workshop focused on the medium- and long-term pathways for urban green and low-carbon development. Particularly, it examined both economic-wide and sector-specific strategies from both Chinese cities and Northeast Asian cities and discussed factors that can shape cities' low-carbon development in the long run.

In the following sections, the inputs of workshop participants on Guangzhou's low-carbon progress are presented, divided into two sections: low-carbon governance and sector-specific strategies. This constitutes the assessment phase the peer review methodology. First, an overview of Guangzhou's low-carbon development will be briefly introduced, drawing on data collection, field visits and consultations prior to the workshop.

The State of Low-carbon Development in Guangzhou

Guangzhou, the capital of Guangdong province, is located in the southern part of the Chinese mainland, on the northern edge of the Pearl River Delta near Hong Kong and Macao. The city is acknowledged as the political, economic, cultural, technological and transportation center of southern China. Guangzhou aims to play a pivotal role as an international business center and transportation hub, science and technology education and cultural center, and ultimately function as a core engine for the development of the Guangdong-Hong Kong-Macao Greater Bay Area.

Guangzhou belongs to the second batch of China's low-carbon pilot cities. In September 2015, China established an "Alliance of Peaking Pioneer Cities" (APPC) at the first Sino-US Climate Leaders Summit. As a member of the APPC, Guangzhou pledged to peak its carbon emissions by 2020.

Driven by increasingly systematic and advanced green and low-carbon policies, Guangzhou has made progress in its green and low-carbon development. In the future, the economic growth of Guangzhou is expected to gradually change from high-speed to medium-high speed growth. The city will likely find it more challenging to reduce energy consumption and carbon emissions per unit of GDP, improve energy efficiency, and increase the share of renewables in its energy mix.

If the average annual GDP growth rate of Guangzhou stays above 7.5 percent, the GDP of Guangzhou will reach 2.8 trillion yuan by 2020. By 2020, the city strives to control the total energy consumption within 62.84 million tons of standard coal, with an average annual growth rate of 2.1 percent. Table 1 below shows progress and prospect for Guangzhou's green and low-carbon development indicators during the 12FYP plan and 13FYP plan.

Table 2 Progress and Prospect on Guangzhou's green and low-carbon development indicators (2010,2017,2020)

Field	Indicators	2010	2017	2020
Economy	GDP, trillion RMB	1.07	2.15	2.8
	GDP per capita	83,494	141,933	180,000
	Industry structure	1.75：37.24：60.85	1.25：31.64：67.11	70% (share of service industry)
Society	Permanent resident population, million	12.7	14.5	15.5
	Disposable income per capita, RMB	30,658 (urban), 12,676 (rural)	55, 400 (urban)，23, 484 (rural)	-
	Urbanization rate, %	83.78	86.06	86.05
Environment	Forest coverage rate, %		42.54	42.5
	PM2.5 concentration, mg/m^3		35	Below 30
	PM10 concentration, mg/m^3		56	-
Energy	Energy consumption (Mtce)	47.76	59.62	62.84
	Share of coal in primary energy consumption, %	32.4	18.4	--
	Energy consumption per unit GDP, tce/10 thousand RMB		0.3168	0.22
	Energy consumption per capita, tce	3.76	4.17	--
Carbon emission	Energy related emissions, Mt CO_2	102.52*	118.45#	~120#
	Carbon emissions per unit of GDP, tCO_2/10 thousand RMB	0.97*	0.63#	0.43#
	Carbon emissions per capita, tCO_2	—	8.12#	-

Source: Guangzhou's Statistical Yearbooks.
* is based on iGDP calculation.
# is based on calculation of Guangzhou Institute of Energy Conversion, Chinese Academy of Sciences.

Official Low Carbon Development Policies

As one of China's low-carbon pilot cities, Guangzhou has issued multiple plans to deal with climate change and promote its low-carbon development. These include the "Outline of Guangzhou's Ecological Civilization Construction Plan," "Guangzhou's 13th Five-Year Plan for Energy Conservation and Carbon Reduction," and "Guangzhou's

Energy Conservation and Environmental Protection Industry Development Plan (2014-2020)".

Guangzhou also conducted a greenhouse gas emission inventory from 2010 to 2016, as well as research on the following topics: carbon emission trading, carbon credits, carbon emission peaking target setting and pathways for carbon peaking. Special funds were established to support energy conservation and to stimulate the development of strategic industries. In 2012, the Guangzhou Carbon Emission Exchange was established, and the city was listed as one of the first batch of pilot cities with a carbon credits system. Guangzhou has also formulated an implementation plan for carbon credit pilots in the building and transportation sectors. In addition, the city constructed the Tianhe Smart City Grand View Ecological Wetland Park as a pilot to implement "sponge city" construction.

Guangzhou's Low Carbon Management System

A leading group for energy conservation, emission reduction and low-carbon economic development was established following the selection of Guangzhou in the second batch of national low-carbon pilot cities. Headed by the mayor, this leading group oversees the city's overall low-carbon development. The office of the leading group is hosted by the Guangzhou Development and Reform Commission (DRC), which also serves as the implementing agency.

Following latest institutional reforms at central level, which the function of Addressing Climate Change was transferred from NDRC to the newly established Ministry of Ecology and Environment (MEE), Guangdong province kicked-off provincial institutional reforms in October 2018. In January 2019, Guangzhou began to launch its institutional reforms at city level. Its institutional arrangements for climate change/low-carbon development now mirror the new national government structure. It established a municipal Bureau of Ecology and Environment (BEE), and the division of climate change and carbon emission management was transferred from the DRC to the BEE. With these changes, low-carbon management will be gradually integrated into environmental protection management.

Peer Review

Low-carbon Governance – Key Findings in Governance Area

Low-carbon Government Structure

Guangzhou has established its low carbon governance system with an implementing body, which was hosted by the Guangzhou DRC. However, after institutional reform, most climate change-related work has transferred from DRC to the newly established Guangzhou's Bureau of Ecology and Environment, which just set a Division of Climate Change to be responsible for city-wide coordinating work on climate change response and GHG's reduction and also to develop plans and policies in this field. Below is the current low-carbon government structure, which is still under development after institutional reform.

Agencies	Responsibilities
A leading group for energy conservation, emission reduction and low-carbon economic development	Coordination, supervision and evaluation of municipal low-carbon management work.
Development and Reform Committee	Coordination of city-wide energy saving and pollutant reduction, and addressing climate change. Taking the leading role in Low-carbon city construction.
Bureau of Ecology and Environment (BEE)	Comprehensive coordination of city-wide climate change. Planning and policy development. Monitoring and evaluation on low-carbon and carbon trading management International cooperation and Capacity buildings.
Bureau of Statistics	Carbon reduction statistics.
Development and Reform Committee (DRC)	Low-carbon energy
Development and Reform Committee	Development and Reform Committee
Bureau of Urban-Rural Development	Low-carbon buildings
Bureau of Industrialization and Informatization	Low-carbon industries
Bureau of Transport	Low-carbon transport
Bureau of Ecology and Environment	Waste management systems

Source: Guangzhou's municipal government website.

Under recent institutional reforms, how to align low-carbon development with environmental protection in Guangzhou remains a challenge. It needs both policymakers and policy researchers making efforts to integrate the objectives, frameworks, supporting policies, and MRV (monitoring, reporting and verification) system of low-carbon development into the administrative systems of environmental protection, to achieve co-benefits of CO_2 reduction and air quality improvement. Otherwise, low-carbon development will receive less attention because air quality improvement will still be the overwhelming priority for municipal government in the upcoming 14th FYP.

Low-carbon Development Strategy

First, Guangzhou needs to set targets that can achieve both air pollution and carbon reductions during the 14th Five-Year Plan. Although Guangzhou has set its carbon emissions peaking target ahead of most Chinese cities, its low-carbon development strategy should focus on the co-benefits of environmental protection and climate change, especially in the context of the recent institutional reforms. Targets should be

tailored to other important policy goals including air quality improvement, carbon emissions reduction, zero-waste efforts and smart cities.

Second, China's multiple low-carbon pilot programs should be integrated under a low-carbon cities framework. Currently, a Chinese city may simultaneously carry out or belong to different of low-carbon pilot projects or national schemes, such as low-carbon cities, low-carbon industrial parks, low-carbon towns, low-carbon communities and so on. Guangzhou can place these different pilot projects under a unified low-carbon city policy system. This will ensure that low-carbon goals and their means of implementation are consistent across different projects.

Third, Guangzhou should develop both medium- and long-term low-carbon development strategies. Guangzhou's development vision is to establish itself as the world's leading economic power as well as taking on a global leadership role for sustainability and livability. Many similar cities throughout the world have put forward medium- and long-term development strategies, some of them containing ambitious strategies intended to carry them all the way through the year 2050, in alignment with the Paris Agreement and global Sustainable Development Goals. Guangzhou should also formulate forward-looking and inspired medium- and long-term strategies in line with global efforts.

Sectoral low-carbon development – Key Findings by Sector

Energy System

The transformation of Guangzhou's energy system will play a key role in achieving low-carbon development goals. Review experts analyzed the current state of Guangzhou's energy transformation, identifying problems and suggesting solutions for the city's energy transformation.

During the 12th Five-Year Plan, the growth rate of Guangzhou's energy consumption slowed down from 8.01 percent in 2010 to 3.31 percent in 2015. During this period, the energy structure gradually shifted from oil and coal- dominant towards clean energy. The share of coal in energy consumption decreased from 32.4 percent in 2010 to 19.8 percent in 2015. Meanwhile, energy efficiency continued to improve, with energy consumption per unit of GDP falling from 0.42 tons of standard coal per 10 thousand yuan in 2010 to 0.33 in 2015.

Guangzhou has formulated a medium- and long-term roadmap for energy transformation. From 2015 to 2020, the city will be focusing on the clean use of coal, a significant reduction in emissions of major pollutants from coal-fired power plants, and accelerating clean and renewable energy development. From 2021 to 2030, the city will endeavor to substitute fossil fuels with alternative energy sources like natural gas, and increase the share of solar and wind power in energy consumption. After 2030, Guangzhou plans for energy consumption to be largely based on green electricity consumption. Reviewers pointed out that the city's energy transformation needs to address four areas of work which include: growth control, structural improvements, efficiency improvements, and smart energy systems.

During the transition process, the primary priority should be given to capping energy

consumption. In “Guangzhou’s 13th Five-Year Plan for Energy Development of Guangzhou 2016-2020”, the city has proposed to control its total energy consumption and develop a working mechanism for the control of its total energy consumption. Guangzhou’s DRC also issued the “2018-2020 Three Year Action Plan for Coal Consumption Reduction and Replacement of Guangzhou” and “13th Five-Year Plan for Guangzhou Energy Conservation and Carbon Reduction”, which set tasks of coal consumption control and reduction. To achieve energy consumption control, the target will be divided into different goals with related measures that align with targets at national, provincial, municipal level and district levels.
energy structure and energy efficiency. Energy structure optimization should focus on increasing the share of natural gas and solar energy and continuously improving energy efficiency. Guangzhou has proposed to reduce its energy consumption per unit of GDP by more than 19.3 percent in 2020 compared with 2015 and further decarbonize its energy production. In the “13th Five-Year Plan for the Energy Development of Guangzhou”, the focus is on natural gas projects but the implementation of these projects has been facing challenges. Continuing issues include the increase in the use of natural gas as it requires improvements in the transmission capacity of natural gas pipeline systems and high natural gas prices in Guangzhou compared to in many other cities. In order to successfully reduce the cost of natural gas use for key industries and big natural gas users, Guangzhou needs to actively cooperate with national and provincial natural gas pipeline deployment operators and promote its own pipeline system reform.

Guangzhou’s energy transformation should also seek to establish a smart energy system. Energy data quality, the energy statistics system and information sharing mechanisms are not well developed in Guangzhou. The city’s legal system for energy use is also weak. As one of the 55 smart energy pilots approved by the National Energy Administration, Guangzhou will set up an energy management demonstration project and auxiliary decision-making platform. This platform will collect municipal energy data and integrate energy development planning, construction management, energy supply and transportation, energy consumption statistics and analysis, oil and gas pipeline protection, and intelligent integrated energy use services. It will also support energy information sharing between government agencies and key energy-using enterprises. This improved system should be leveraged to decarbonize Guangzhou’s energy structure.

Transportation

Due to the seemingly inexorable rise in carbon emissions from the transportation sector, the city leaders have placed on the development of public transportation a top priority. Guangzhou vigorously endeavors to promote subway networks, trams, bus rapid transit and other types of public transport such as waterbuses. When China’s Ministry of Transport reviewed Guangzhou’s public transit pilot program, the aforementioned efforts were considered best practices for maximizing the use of public transit across the country. According to data collected by reviewers and workshop participants, Guangzhou is ahead of other cities in promoting public transportation. More than 60 percent of downtown traveling was done on mechanized public transportation. Average daily traffic amounts to 15 million person-times, most

of which appears in rail transit. Guangzhou has 14 rail transit lines and 399 kilometers' operating mileage, with an average daily passenger volume of nearly 7.7 million. Another characteristic of Guangzhou's green and low-carbon public transportation is the electrification of public transport. Guangzhou has now become the second city in China to fully electrify its buses, with more than 10,000 buses reaching electrification by the end of 2018.

Guangzhou is also developing a non-motorized traffic system. The city has established a greenway system with a length of 3,400 kilometers and well-designed bike lanes. Moreover, Guangzhou is trying to further improve the city's walkability. By dealing with the "last kilometer" problem, the city enables people to take part in urban low-carbon development. While Guangzhou has made great progress in low-carbon transportation, workshop and review experts pointed out some challenges the city still faces. One lies in the management system for the electrification of public transportation. Electrifying public transportation requires different government agencies, such as the transportation bureau, the land use bureau, the planning bureau, and the DRC to break down the barriers between them to coordinate their policymaking. Another challenge to consider is coordinating with the grid. Proper infrastructure for the electrification of transportation depends on good transmission between charging spots, charging stations and the gird. This in turn will depend on careful coordination between Guangzhou's land use and urban planning bureaus.

Buildings

Emissions from buildings are approximately as high as the ones from the transportation sector in Guangzhou. The managers of Guangzhou's building sector have been working on basic data collection that includes energy consumption evaluation, energy consumption auditing, and demonstration projects assessments. So far, this review has developed a complete set of data on energy consumption of nearly thousands of residential buildings on sixteen streets and energy consumption audits for more than two-hundred large public buildings as well as government office buildings. The energy consumption audit includes detailed energy use and energy saving status of these buildings. The energy utilization and energy efficiency status of more than two-hundred residential and public buildings have also been evaluated, providing data that is critical for the low-carbon development of the sector.

Guangzhou has taken a series of measures to save energy in existing buildings. For example, by building a municipal energy consumption and monitoring platform, Guangzhou has developed its technical capacity for setting energy consumption standards and promoting energy transformation. Meanwhile, the city is also actively promoting low-cost but high-energy efficient technologies such as building shading and hydraulic ventilation. Moreover, it has adopted the contract energy management for energy saving in hotels and shopping malls, where energy consumption is relatively high. As of 2018, more than eight million square meters of buildings have been retrofitted for energy saving, which helped reduce the use of 55,400 tons of standard coal and 175,000 tons of emissions.

Guangzhou continues the ongoing efforts to promote energy savings in new building

and green buildings. The city enacted an integrated energy saving system that covers building planning, design, construction and assessment. It has also adopted an energy consumption quota management system, and is gradually promoting the labeling of energy consumption. The large-scale application of renewable energy in the building sector has been promoted, as well as green buildings.

Guangzhou has also developed a variety of low-carbon technologies suitable for its buildings. Fifty kinds of state of the art low-carbon technologies have been analyzed by their investment cooperation period, energy saving efficiency, economic efficiency and ability to be changed out. A low-carbon technology list for the building sector was generated for users.

Despite all-out efforts, Guangzhou's building sector still faces a series of challenges. First, the current system is not well developed. Like most Chinese cities, Guangzhou relies more heavily on the government than on society to promote green and low-carbon buildings. Workshop participants and reviewers suggested that the city need to clarify the responsibilities of all stakeholders, including government agencies, enterprises and the public. Secondly, improvements are also needed in current technical standards. Some existing standards and basic provisions need to be adapted to local conditions as well as the geographical and climatic characteristics of the Guangzhou area.

Third, the lack of sufficient quality of green building is another major concern for Guangzhou. Only a few buildings meet the green building standards. To the above-mentioned issues, the lack of public awareness on green building development remains a big challenge along with the limited amount of basic data in the building sector. The absence of basic data will pose difficulties for Guangzhou to develop plans for the low-carbon development of the building sector. Review experts advised to develop a data platform.

Waste

Review experts recommend that the city needs to pay more attention to the increased generation of waste due to rapid urbanization and economic growth. Guangzhou has begun to focus on energy recovery from landfills and prioritize incineration over landfills. Since 2010, more than 90 percent of the city's waste has gone to landfill sites. Wastes deposited in landfills emit a large amount of methane, a greenhouse gas which highly contribute to global warming. As landfill is regarded as the most prevalent method of waste disposal, biomass-to-energy conversion technologies used to convert captured methane gas into renewable energy must be promoted to shape a sustainable future of Guangzhou.

Currently, 70 to 80 percent of waste in Guangzhou is disposed in landfill, and hence the city is undertaking several projects to convert e methane into electricity. In addition, Guangzhou is speeding up the construction of incineration power plants, which will also help to reduce methane emitted from landfills. Incineration power plants are projected to operationalize sometime between 2020 and 2025, which will in turn become the main avenue for waste disposal in Guangzhou.

Conclusion

Guangzhou has made great progress on low-carbon development with the development of low-carbon governance structure and a series of economic-wide and sector-specific strategies. Its low-carbon performance can be improved in the following areas:

- Align low-carbon development with environment protection. Due to institutional reform, tasks of low-carbon development were transferred to bureau of ecological environment. Attention needs to given to policy alignment that can address both climate change and other environmental problems, such as air quality.
- Develop favorable institutional arrangements to promote the implementation of low-carbon policies in different fields. For example, to increase the share of natural gas use, Guangzhou needs to actively cooperate with national and provincial natural gas pipeline deployment operators and promote its own pipeline system reform. To promote the electrification of transportation, Guangzhou needs to develop a good coordination mechanism to bring good transmission between charging spots, charging stations and the gird.
- Promote the use of low-carbon technologies. As discussed above, low-cost but high-energy efficient technology will facilitate the decarbonization process. For instance, a low-carbon technology list for the building sector was generated for users.
- Develop medium- and long-term low-carbon development strategies. the construction of the Guangdong-Hong Kong-Macao Greater Bay Area will bring uncertainty to Guangzhou's future low-carbon development. The Greater Bay Area will integrate industry, population and land, leading to regional expansion and city clustering. These changes will have a direct impact on the orientation and future trajectory of Guangzhou's economy, industry, and energy systems. This in turn will have to be accommodated in new low-carbon development strategies down the line. Besides, it is uncertain how the new normal economy of low growth will affect Guangzhou's urban economic structure. Guangzhou has entered a phase of economic development, with a major shift from a heavy industry toward service-based economy. As a leading economic center, Guangzhou will want to carefully navigate the structural adjustment of the local economy, while at the same time adjusting to regionalize the economy under plans for the Greater Bay Area. The contribution of investment to GDP in Guangzhou has stayed steady at 40 percent, which suggests that the economy has shifted from an investment-driven to a consumption-driven economy. Recently, Guangzhou has gradually decreased its dependence on tertiary, heavy and export-oriented industries and moved towards the high-tech industry. These changes in capital, the labor force composition, technological and institutional innovation, and other potential driving forces of emissions must be applied to Guangzhou's low-carbon development strategy.

Annex 1: Name List of Guangzhou Workshop Speakers and Discussants

	Opening Remarks
BAI Yu	Guangzhou Institute of Energy Conversion of Chinese Academy of Science
Nobuko KAJIURA	Sustainable Development Officer, United Nations Economic and Social Commission for Asia and the Pacific (ESCAP)
Theme 1	Progress and Prospects of Guangzhou's Green and Low-Carbon Development Strategy
WANG Zhigao	Energy Foundation
LIAO Cuiping	Guangzhou Institute of Energy Conversion of Chinese Academy of Sciences
YANG Li	innovative Green Development Program (iGDP)
YANG Xiu	National Center for Climate Change Strategy and International Cooperation (NCSC)
ZHUANG Guiyang	Institute for Urban and Environmental Studies Chinese Academy of Social Sciences
XIE Pengfei	C40 Cities
LIU Runhui	Institute for Transportation & Development Policy
JIANG Xiangyang	Guangzhou Institute of Building Science Co., Ltd.
WU Hong	Guangzhou Environmental Protection Investment Group Co., Ltd.
CAI Guotian	Guangzhou Institute of Energy Conversion of Chinese Academy of Sciences
Theme 2 Session 1	The Medium- and Long-Term Pathways for Urban Green and Low-Carbon Development, and Supporting Mechanisms
ZHAO Daiqing	Guangzhou Institute of Energy Conversion of Chinese Academy of Sciences
YU Jung Min	Seoul Energy Corporation
CHO Ji Young	Incheon Climate & Environment Research Center
KIM Seonyoung	Gwangju Metropolitan City
WANG Dong	Shenzhen Research Center for Response to Climate Change
HU Xiulian	Energy Research Institute
SHI Zhicheng	China Quality Certification Centre (Guangzhou Branch)
ZENG Xuelan	Guangdong Research Center for Climate Change
JIANG Kejun	Energy Research Institute
Klaus Hoppe	Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ)
JIN Zhen	Institute for Global Environmental Strategies (IGES)

LIN Weiwei	Energy Foundation China
YANG Yun	ICLEI East Asia Secretariat
Theme 2 Session 2	Market-based Mechanisms/Financial Support for Urban Green and Low-Carbon Development
CHEN Meian	innovative Green Development Program
WU Qingyuan	Green Finance Expert
Takuya OZAWA	Tokyo Metropolitan Government City
LIU Jia	Shanghai Information Center
CAI He	Zhejiang Center for Climate Change and Low-carbon Development
LUO Zhigang	Guangzhou Institute of Energy Conversion of Chinese Academy of Sciences
KANG Sang In	Korea Environment Institute
AKAGI Junko	IGES Kitakyushu Urban Center
	Closing Remarks
LIAO Cuiping	Guangzhou Institute of Energy Conversion of Chinese Academy of Science
WANG Zhigao	Energy Foundation China

Annex 2: Guangzhou Background Report

Project Background

Inter-regional low carbon development in Northeast Asia is an important part of the global effort to address climate change. Cities throughout Northeast Asia are promoting low carbon development as a core component of their urban development efforts, with policies that are tailored to local social, economic and political conditions. As a result, the municipal governments of these cities have amassed a great deal of local experience regarding carbon-reducing strategies, measures, and policies. What has been missing is a mechanism for these cities to share experiences and learn from regional best practices.

In 2014, the North-East Asian Sub-Regional Program for Environmental Cooperation (NEASPEC), under the United Nations Economic and Social Commission for Asia and the Pacific, launched the North-East Asia Low Carbon City Platform (NEA-LCCP). NEA-LCCP is designed to support regional low carbon urban development through technical assistance, capacity building, information sharing, and analytical studies. In 2017, at NEASPEC's 21st Senior Officials' Meeting, NEA-LCCP was tasked with two activities – peer reviews and comparative studies – to strengthen knowledge, capacity and networking of experts, agencies and cities in North-East Asia.

Figure 1: North-East Asia Low Carbon City Platform objectives

Peer reviews identify case-study cities, assess their low carbon urban development policies, and promote the sharing of insights among peers. This is done by organizing technical reviews, workshops and field visits by issue-area experts. Comparative studies provide a comprehensive and systematic overview of national approaches to low carbon city development. They identify good practices in specific sectors for information-sharing and promote cooperation on future policy efforts.

Guangzhou is one of the case study cities selected by NEA-LCCP to undergo a peer review study. This background report introduces the key features of the city of Guangzhou that are relevant to low carbon development policy, as well as the city's

key carbon reduction policies. It is designed to provide general information in support of an upcoming peer-review workshop and report.

Guangzhou has been steadily ramping up the ambition of its low carbon policymaking. In September 2010, the Guangzhou municipal government issued *Guidelines on Boosting the Low Carbon Economy*; in February 2011, the Municipal Party Committee and the municipal government held a working meeting on transforming Guangzhou into a low carbon city; and in 2012, Guangzhou was selected for inclusion in the second batch of NDRC's low carbon pilot cities. Since then, it has pursued work on GHG emissions inventories, basic research on emission peaking, carbon reduction roadmaps, and the development of new policies and mechanisms for green and low carbon development. With these efforts, Guangzhou is aligning its local strategic planning and policymaking with the GHG reduction goals of China's national government.

In September 2015, at the first US-China Climate Leaders' Summit, Guangzhou announced that it would strive to peak its carbon emissions by 2020, 10 years ahead of the national CO_2 emission peaking target. As a member of China's Alliance of Pioneer Peaking Cities[1], Guangzhou has collected valuable experiences that can be shared with other NEA-LCCP cities. At the same time, against the backdrop of the "new normal" of China's economy, Guangzhou researchers and policymakers would benefit from the insights of the NEA-LCCP network to refine its strategies in key areas.

This background report provides information about Guangzhou's low carbon strategic measures, policies, and practices. It is not a rigorous evaluation of the city's low carbon performance. Instead, it summarizes the city's social and economic characteristics, urban development strategies and directions, and low carbon policy development. It gives a comprehensive account of policy measures within key areas. The focus is on Guangzhou's urban characteristics, drivers of urban growth, and the strategic measures and policy instruments used by the local government in key areas.

The first part of the report describes Guangzhou's overall characteristics. It identifies the unique features of the city that are relevant to low carbon efforts. The second part of the report describes the city's low carbon development strategies, policies, and practices. It includes discussions of actions in the energy, industry, transportation, buildings and land use sectors, as well as public consumption behavior. Guangzhou's low carbon development management system, strategic measures, and policy instruments, as well as the city's performance against key indicators are also reviewed. The third part provides a brief summary of the main areas of focus of Guangzhou's low carbon development strategy.

[1] Alliance of Pioneer Peaking Cities https://www.wri.org/blog/2016/06/23-chinese-cities-commit-peak-carbon-emissions-2030

1. Overview of Guangzhou

1.1 Overall Characteristics and Geography

Guangzhou has a long history and a rich cultural heritage. The capital of Guangdong Province, Guangzhou is located in the south of mainland China and the middle of Guangdong province, at the northern edge of the Pearl River Delta, adjacent to Hong Kong and Macau. With a history of over 2000 years, it was the starting point of the Silkroad and is now the center of Cantonese culture. For thousands of years, it has been the gateway for China's global engagement and trade activity.

Figure 2: Location of Guangzhou in China

Guangzhou is the third largest city in China after Beijing and Shanghai, covering an area of 7434 km^2. After growing at an average annual rate of 2% for the last three decades, its permanent resident population in 2016 was over 14,043,500. Guangzhou's urban population ratio has been steadily increasing, from 72.6% in 2000 to 86.06% in 2016. Guangzhou's municipal government has jurisdiction over 11 districts.

Guangzhou's geographic location and weather conditions provide a favorable environment for urban development and ecosystem preservation. Located in China and Guangdong's southern edge, it possesses abundant water resources. Guangzhou's subtropical monsoon climate brings it warm weather, heavy rainfall, ample sunlight, only slight temperature differences between night and day, long summers, and short frost seasons. The average temperature across Guangzhou hovers between 21.5℃ ~ 22.2℃, with average annual precipitation of over 1800mm and 150 days of precipitation per year.

Guangzhou is expected to be an important hub along the Belt and Road and play a

central role in the Guangdong-Hong Kong-Macao Greater Bay Area, gradually building itself into an international city on the vanguard of urban development. Guangzhou's municipal party committee and government have proposed to strengthen six city functions and features by 2035 as a part of a city master plan: city leaders are working to develop Guangzhou as National Central City[2], a city with major historical and cultural significance, an international transport hub, and a major trade, communications, and technological and industrial innovation center.

1.2 Demographic Conditions and Trends

The size of Guangzhou's population has been continuously growing, accompanied by a steady rise in the urbanization rate and an increasing median age. Guangzhou's permanent resident population is one of the fastest growing in China. In 2016, Guangzhou's population saw a year-on-year increase of 454.9 thousand residents, taking up 63.22% of the total permanent resident population 14.04 million in Guangdong province and the Pearl River Delta. Its urbanization ratio among permanent residents in 20176 was 86.06%, far exceeding the national average of 57.35%. As the integration of the Pearl River Delta accelerates, Guangzhou's population will continue to grow. It is estimated that by 2020, its permanent resident population will reach 15.50 million; by 2035, that number will be as high as 20 million. The continuous growth of population, the steady increase in urbanization rate, and the gradually increased aging population will pose more challenges to resources allocation, energy consumption, ecological environment, housing and public service infrastructure in the future.

Table 1: Guangzhou's population and demographics from 2010 to 2016.

	2010	2011	2012	2013	2014	2015	2016
Permanent residents (10 thousand)	1270.96	1275.14	1283.89	1292.68	1308.05	1350.11	1404.35
Urbanization ratio (%)	83.78	84.13	85.02	85.27	85.43	85.53	86.06
Percentage of population over 60 (%)	--	--	15.42	16.03	16.75	17.27	17.76

Source: Guangzhou Statistical Yearbook 2017

[2] http://politics.people.com.cn/n1/2017/0221/c1001-29095124.html

1.3 GDP and Industrial Structure

Guangzhou's economy has entered a "new normal" in which economic growth is slowing down while industrial reform deepens. In 2016, Guangzhou's GDP reached 1.98 trillion RMB (298.2 billion USD), a 7% increase from the previous year, boosting the city's competitiveness to a global level. However, there is still a considerable gap between Guangzhou's GDP per capita and that of the most developed cities in the world. In 2016, Guangzhou's GDP per capita was 145,254 RMB (21,868.09 USD), less than half of that of Singapore.

Guangzhou's industrial structure is undergoing a period of adjustment, transformation, and upgrade. In 2016, the growth ratio among the primary, secondary, and tertiary sectors of Guangzhou's economy was 1.22:29.42:69.42, with the tertiary sector contributing nearly 80% of the city's GDP.

Table 2: Guangzhou's economic growth and industrial structure from 2010 to 2016

	2010	2011	2012	2013	2014	2015	2016
GDP (hundred million)	10748	12423	13551	15679	16914	18334	19805
GDP growth rate (%)	13	11.3	10.5	11.6	6.6	8.4	8.2
Structure of the three-sector model	1.75：37.24：60.85	1.65：36.84：61.51	1. 58：34.84：63.58	1.47：34.01：64.52	1.31：33.47：65.22	1.25：31.64：67.11	1.22：29.42：69.42

Source: Guangzhou Statistical Yearbook 2017

The continuously increasing GDP and a more balanced economic structure indicates a relatively stable development trajectory for Guangzhou's economy. Guangzhou is now adjusting its economic growth strategy and long-term trajectory to align itself with next-generation industrial and technological innovations, and China's national strategy for development. During the 12th Five-Year Plan period (2011-2015), the focus of Guangzhou's industrial structure shifted from the heavy chemical industry and service sector to the integrated development of advanced manufacturing and modern services - the so-called "two-wheel drive" phase (2013 - present). In 2015, the growth of emerging strategically-important industries took up more than 10% of the total GDP, with hi-tech contributing to 45% of the total industrial GDP. Strategically-important industries are leading the way forward. Information technology, artificial intelligence, and biomedicine have been speeding up their pace of development.

1.4 Electricity Consumption

As the total amount of energy consumption increases and consumption transitions from coal and petroleum towards electricity and natural gas, energy conservation and emission reduction efforts in the power sector will become a determinant factor in all end-use sectors' CO_2 emissions.

The GDP contributed by the electric and thermal power production and supply industry ranked the fourth largest industry of Guangzhou, next only to auto manufacturing, electronics manufacturing, and petrochemicals, the power industry has become a pillar of the city's economy. In terms of emerging strategically-important industries, the new energy and energy conservation industry is the sixth largest, growing by 33.038 billion RMB in 2015.

Table 3: Coal consumption in electricity and thermal power production and supply percentage of industrial total (2010 - 2016)

	2010	2011	2012	2013	2014	2015	2016
Coal consumption in electricity and thermal power production and supply percentage of industrial total (%)	72.3	74.9	77.5	78.5	81.1	78.8	81.5

Source: Guangzhou Statistical Yearbook 2017

With an electricity self-sufficiency rate of 40%, Guangzhou's local electric power supply cannot meet demand. Of the total electricity consumption, the percentage of electricity transmitted from elsewhere has been continuously increasing. In 2015, the percentage of locally generated electricity only accounted for about 30% of the total electricity consumption. There are 10 coal-fired power plants in Guangzhou. 80% of industrial coal consumption comes from electricity and thermal power plants. At the end of 2014, Guangzhou initiated and successfully implemented the "ultra-clean emission" program targeting coal-fired power plants. Currently, the coal consumption of in-service generator sets across Guangzhou are all over 310 kg/Kwh, requiring greater efforts in coal usage and emission reduction as well as energy structure transformation and upgrading.

1.5 Industry

To date, the industrial sector is the only sector that has achieved CO_2 emission peaking in Guangzhou. In the future, as the work around energy conservation and emission reduction deepens and industrial development gradually slows down, Guangzhou's CO_2 emission will see a steady decline.

In recent years, Guangzhou's industrial development has been slowing down. The percentage of industrial growth in the region's total GDP has dropped from 33.9% in

2010 to 28.6% in 2015. Automotive, electronics, and petrochemicals are the three pillars of Guangzhou's industrial development, taking up 48.25% of total industrial growth. Guangzhou's scarce land resources and diminishing environmental carrying capacity will increasingly constrain the manufacturing industry's development. Guangzhou can no longer depend on an investment-driven, extensive development model.

Guangzhou's manufacturing industry is shedding the old driving forces and taking on new ones. During this transition period, an industry with a clear advantage has yet to be seen, indicating a need to speed up transformation and upgrading. In 2015, the growth of Guangzhou's advanced manufacturing industry took up 54.3% of the total industrial growth of enterprises above a designated size, a significant drop from 64.7% in 2010. Hi-tech manufacturing growth was 11.7%, 16.9% lower than the provincial average.

The optimization of industrial structure and improvement of energy efficiency is an important starting point for Guangzhou's efforts in industrial energy conservation and emission reduction. Another focus of such efforts is to make the industrial energy consumption structure cleaner. Gradually raising the ratio of electricity and natural gas consumption to replace coal and petroleum usage will push forward clean industrial production.

1.6 Building

The building sector is the third largest CO_2 emitter in Guangzhou. Guangzhou has numerous large scale construction projects. In 2015, existing construction projects exceeded 300 million square meters, 50% of which were residential projects. Energy consumption in construction projects accounts for one-third of total city energy use. The rapid development of Guangzhou's third largest industry and the increase of commercial areas will create sustained increases in future energy needs and CO_2 emissions. Going forward, the Public Construction Department will become an important actor in limiting emissions in Guangzhou.

1.7 Transportation

Guangzhou is currently undergoing large scale transportation development. In the future, the number of residents in transit will increase by a large margin. Local shipping is rapidly increasing, while the number of automobiles is also growing steadily. These factors create challenges for the city's transportation needs. The key to achieving Guangzhou's target peak CO_2 levels is managing the city's transit energy consumption and related CO_2 emissions.

Regarding international transportation, Guangzhou has sea, land, and geographic advantages. Baiyun International Airport is one of the three largest international air transit hubs in China; Guangzhou Port is a national coastal hub; Guangzhou railroad

station is among the four biggest passenger transit hubs nationally and the largest in southern China. In short, Guangzhou plays an important role in China's national transport network and is the primary hub in southern China. In 2015, Guangzhou successfully applied to become a nationally recognized model city for transport service. Increasing Guangzhou's comprehensive transport hub's radius and strengthening its integrated capacity is a key component of the city's long-term goals. This is also an opportunity to establish a comprehensive, low carbon, and green transportation system.

The Guangzhou mass transit system includes four types: rapid transit, regular public transit, water buses and taxis. During the 12th Five-Year Plan, Guangzhou successfully applied to become a "national mass transit metropolis." The capacity of Guangzhou's rapid transit system continually increased. From 2010 to 2015 the rapid transit system's total passenger capacity increased from 27% of total mass transit to 43%[3]. The capacity of regular public transit also continually expanded and increased. In 2015, regular public transit accounted for 45% of total mass transit. In addition, the taxi quantity has steadily increased. In 2015, there were 17 cabs per 10,000 people, accounting for 12% of the total mass transit volume. Construction of water bus infrastructure has also improved, accounting for 0.3% of total mass transit volume in 2015.

Table 4: 2015 City Mass Transit System Structure

Category	Rapid Transit	Regular Public Transit	Taxis	Water busses
Proportion of total （%）	43	45	12	0.3

Source: Guangzhou Comprehensive Transportation Development 13th Five Year Plan

Guangzhou continues to promote energy saving and the use of new energy vehicles (NEV). In 2012, Guangzhou was designated a national energy saving and NEV pilot zone. In 2015, Guangzhou produced 14,600 NEVs, with pure electric vehicles accounting for 60% and mixed electric cars (with extended usage) 40%. According to the New Energy Vehicles Work Plan (2017-2020)[4], by the end of 2018, Guangzhou will see the use of more than 100,000 NEVs. By the end of 2020, the city will contain more than 200,000 NEVs. From the beginning of 2017, Guangzhou increased usage of fully

[3] Guangzhou Transportation Development 13th Five Year Plan
http://www.gzjt.gov.cn/gzjt/ghjh/201611/f49bd2182b0e43e1a666cb78bea332c4/files/a269c3e4284e4fc1b3ae81635f71b2fa.pdf

[4] Guangzhou New Energy Vehicles Work Plan (2017-2020)
http://www.gz.gov.cn/gzgov/s2812/201711/3b174f8a3bc543e9ada325e79509b08a.shtml

electric vehicles by 100%.

Guangzhou has implemented a cap control on small and medium-sized passenger car since 2012. Since policy implementation, the number of small and medium-sized passenger cars in the city has increased from 1.694 million of 2012 to 2.063 million of 2018. The average annual growth rate has been decreasing from 19.0% (2008-2012) to 3.2% (2013-2017). The growth of small and medium-sized passenger cars tends to be stable and controllable. During this time period, Guangzhou has been proactively developing public transportation, launched a series of actions to alleviate traffic congestion and develop “national bus city”. These policies have contributed greatly to traffic congestion alleviation and bus priority strategy development.

1.8 Urban Form and Ecological Environment

The Guangzhou city government has made adjustments to district administration and subdivisions to develop the city center. In 2015, Guangzhou’s administrative area increased from 3,843.34 square kilometers to 7,434.4 square kilometers. Guangzhou’s internal city space has developed continuously, expanding outside of original city limits, while construction of its city center reached saturation. According to the Guangzhou Municipal Comprehensive Plan (2011-2020) and the Guangzhou Municipal Comprehensive Plan (2017-2035) Draft Notice, Guangzhou’s development of its city structure has shifted from expansion to optimizing and upgrading. It has transformed from a city based on a single center to a structure that uses the natural measures of “mountain, city, fields, and sea” as the basis for its organization. The Pearl River Delta drainage system’s multicenter approach supports the city’s network structure, and is divided into a “main city, sub-center, outer city, new town, countryside” layout. Guangzhou is strengthening its land use management system and resource exploitation management, defining ecological standards, setting permanent farmland protections, creating boundaries for urban and rural areas, and promoting compact urban spaces.

1.9 Energy Consumption

Guangzhou has scarce traditional fossil fuel energy resources and therefore low energy self-reliance. The city relies on outside sources and imports of coal, oil, natural gas and other fossil fuels. Local energy resources available for use primarily include renewable energy such as water, solar, wind and biomass.

Guangzhou’s energy consumption is continually increasing, though its rate of increase is lower than its rate of GDP growth. During the 12th Five-Year Plan period, energy consumption increased from 47,756,000 tons of standard coal in 2010 to 56,888,900 in 2015, an annual average increase of 3.56%. In the same period, GDP increased by 10.1%. According to the “Guangzhou Energy Development 13th Five-Year Plan”, energy

consumption will be capped by 2020 at no more than 62,840,000 tons, and is forecast to peak before 2050.

Guangzhou's energy consumption structure has undergone some optimization, but the proportion of high-carbon fossil energy consumption represented by oil is still high. Coal consumption, on the hand, has already reached its peak. During the 12th Five-Year Plan period, coal consumption decreased by 4,250,000 tons. Coal as a proportion of energy consumption decreased from 32.4% in 2010 to 19.8% in 2015. Natural gas consumption is steadily increasing, however, from 3% in 2010 to 6% in 2015. By 2020 it will reach 10% of overall consumption. Oil product consumption as a proportion of total energy usage currently exceeds 40%.

Table 5: Guangzhou's Energy Consumption from 2010-2015

	2010	2011	2012	2013	2014	2015
Resource Consumption Amount (10,000 TCE)	4775.60	5013.40	5163.45	5333.57	5496.46	5688.89
Resource Consumption Increase (%)	-	5.0	3.0	3.3	3.1	3.5
Rate of Energy Consumption Decline per 10,000 yuan of GDP	-	4.91	4.94	5.14	3.52	4.52
Total Social Electricity Usage (100 million kw)	625.9	663.5	694.1	710.7	765.9	779.3
Rate of Increase of Electricity Usage (%)	-	6.0	4.6	2.4	7.8	1.76
Coal as a Proportion of Energy Consumption (%)	32.4%	31%	27.7%	26.3%	22.7%	19.8%
Natural Gas as a Proportion of Energy Consumption (%)	3	4	4	5	6	5.8

Source: Guangzhou Resource Development 13th Five Year Plan (2016-2020)

1.10 Carbon Emissions

With the continuous growth of energy consumption, the challenge of greenhouse gas emission reduction faced by Guangzhou is becoming increasingly severe. In 2015, citywide energy consumption reached 56.89 million tons of standard coal, while carbon emissions per 10,000 yuan of GDP were approximately 0.67 tons, a decrease of 30.7% from 2010. The city's GDP in 2015 was 1736.68 billion yuan (in 2010 constant prices) while total CO_2 emissions reached 116 million tons, making per capita CO_2 emissions 8.62 tons.

During the 12th Five-Year Plan period, the main driving force in the decline in carbon

intensity was an increase in energy efficiency and a sharp decline in the proportion of coal consumption. Guangzhou is striving to cap coal emissions by 2020 and decrease carbon emissions per unit of GDP by 23% as compared to 2015. While the reduction of energy consumption in secondary industry has driven a decline in emissions, the industry sector remains the most important contributor of Guangzhou's emissions. With the rapid development of the tertiary industry, its CO_2 emissions have also increased year by year.

2. Guangzhou Low Carbon Development Strategy and Policy Practice

Guangzhou has carried out rigorous planning for low carbon development, taking into account both central and provincial government low carbon pilot requirements and local economic conditions. It has developed a low carbon management system, a comprehensive low carbon strategy, and specific sectoral low carbon measures.

2.1 Low Carbon Development Planning Structure

This planning is based on two national pilot policy directives issued by China's National Development and Reform Commission: "Notice on the Pilot Work on Low Carbon and Low Carbon Provinces and Cities (2010)"[5] and "Notice on Launching the Second Batch of National Low Carbon Provinces Cities Pilot Projects (2012)".[6] It takes into account other relevant urban plans and policies, and factors in social, economic and environmental impacts. The following image displays six steps in Guangzhou's low carbon development planning workflow:

Figure 3: Guangzhou Green Energy Development Method Research[7]

[5] http://www.ndrc.gov.cn/zcfb/zcfbtz/201008/t20100810_365264.html

[6] http://www.ndrc.gov.cn/gzdt/201212/t20121205_517506.html

[7] This illustration is drawn from the technical roadmap adopted by the Guangzhou Academy of Sciences in support of

2.2 Low Carbon Management System Structure

Starting in the 12th Five-Year Plan period, Guangzhou has continuously improved its low carbon management. In 2010, the city government established the Guangzhou Energy Saving, Emission Reduction and Low Carbon Economic Development Leading Small Group (initially named the "Low Carbon Economic Development Leading Small Group").

Located in the Municipal Development and Reform Commission, which serves as a coordinator, the leading group is headed by the Guangzhou mayor and deputy mayor. This body, which contains representatives from nineteen relevant local government bureaus[8], is responsible the development of low carbon strategies, guidelines and policies, and overseeing low carbon pilot projects.

Guangzhou has formulated and released a series of policy guidance documents. These include:

- Guangzhou Energy Conservation and Environmental Protection Industry Development Plan (2014-2020)
- Guangzhou City Ecological Civilization Construction Planning Outline
- Guangzhou Municipal People's Government Guiding Opinions on Developing Low Carbon Economy
- Guangzhou Municipal Committee of the Communist Party of China Implementation Opinions on Promoting Low Carbon Development and Construction of Ecological Cities
- Implementation Plan for the Low Carbon Cities Pilot Project in Guangzhou

Guangzhou is also a participant in five national pilot schemes:

- National Low Carbon Pilot City
- National Renewable Resources Recovery System Construction Pilot City
- National Low Carbon Transportation System Pilot City
- National Kitchen Waste Pilot City for Resource utilization and No Harm treatment
- National Model City for Circular Economies

Guangzhou is gradually improving its low carbon development management and

Guangzhou's low carbon city strategy research.

[8] Its members include representatives from relevant local government bureaus: Municipal Party Committee, Municipal Development and Reform Commission, Economic and Trade Commission, Education Bureau, Science and Technology and Information Technology Bureau, Finance Bureau, State Land and Housing Administration, Environmental Protection Bureau, and Construction Committee. Representatives from the Traffic Committee, Agriculture Bureau, Foreign Trade and Economic Cooperation Bureau, Planning Bureau, Statistics Bureau, Price Bureau, Forestry and Landscape Bureau, Tourism Bureau, Municipal Research Office, and Municipal Finance Office are also a part of the group.

oversight capacity. It has established a greenhouse gas emissions statistics, accounting and assessment system, completed an inspection of the city's greenhouse gas emissions, and carried out verification of greenhouse gas emissions from key enterprises. Guangzhou has also established an energy management center. This management center is now capable of online monitoring of the energy use of key energy-using units and areas in the city, contributing to energy-saving assessments and projects in an integrated fashion.

At the same time, Guangzhou is creating new low carbon development management models. The Guangzhou Carbon Emissions Exchange is carrying out provincial carbon emission information verification, quota issuance and adjustment, and promoting the improvement of institutional mechanisms. Guangzhou is also encouraging public participation as part of Guangdong's first approved general carbon credit system pilot city. As the first pilot in this program, Guangzhou has developed a plan for the construction and transportation sectors to reduce carbon emissions in public transit, buildings, and water and electricity use.

2.3 Key Areas of Low Carbon Development Strategy and Policy Practice

In line with Guangzhou's overall low carbon development strategy, relevant government bureaus have formulated low carbon measures and policies to reduce emissions. This section reviews Guangzhou's low carbon development status, goals and measures adopted in the areas of energy systems, industry, construction, transportation, urban environment and land use. Progress indicators were selected in consideration of the best available data.

2.3.1 Energy System

Current Situation

Guangzhou is almost completely reliant on imports of coal, oil and natural gas. However, Guangzhou has abundant, largely untapped renewable energy resources, including hydropower, wind, and solar. Hydropower is highly developed, while solar, wind and biomass all have excellent potential for further growth. In 2011, the proportion of net energy transfers with other provinces (including autonomous regions and municipalities) was 72%, and the proportion of net imports was 28%.[9] During the 12th Five-Year Plan, Guangzhou's energy consumption increased at an annual average rate of 3.56%, a decrease from the 8.4% growth rate in the 11th Five-

[9] Guangzhou National Circular Economy Demonstration City Implementation Plan
http://www.gzii.gov.cn/sjmw/9.2/201606/cb9a65f7da2841e0b46915a20d7224b1.shtml

year Plan period.[10] In terms of its energy consumption structure (including foreign energy transfers), coal consumption has gradually declined, while oil and natural gas consumption, as well as foreign energy transfers, have increased. Final stage energy consumption in Guangzhou is concentrated in three fields: transportation, industry and construction.

Table 6: Guangzhou Resource Consumption 2011-2015

	Guangzhou Yearly Energy Consumption	**Rate of Increase (%)**
2011	5013.4	5.0%
2012	5163.45	3.0%
2013	5333.57	3.3%
2014	5496.46	3.1%
2015	5688.89	3.5%

Source: Guangzhou Resource Development 13th Five-year Plan (2016-2020)

Low Carbon Indicators

Guangzhou's low carbon energy development can be tracked against four indicators: production value per unit of energy consumption, per capita energy consumption, non-fossil fuels as a proportion of primary energy consumption, and coal use as a proportion of total energy consumption.

Table 7: Changes in energy and low carbon development indicators

Target	**2010**	**2015**
Production value per unit of energy consumption (TCE/10,000 yuan - current year prices)	0.44	0.31
Yearly per capita energy consumption (TCE per capita)	3.76	4.21
Non-fossil fuels as a proportion of primary energy consumption (%)	--	--
Coal as a proportion of total energy consumption	45%	27.5%

Source: Guangzhou Annual Statistics Report

Strategic Measures and Policies

Guangzhou has issued five key energy-related policy documents:

- Guangzhou Municipal People's Government Notice on Renovating High-Pollution Fuel Boilers

[10] Guangzhou 13th Five-Year Plan for Energy Development 2016-2020
http://www.gz.gov.cn/gzgov/s2812/201711/76eb233dd2a141e9840962c35c2a79ca.shtml

- Ultra-Clean Emissions Reconstruction Work Plan
- Guangzhou City Accelerated Natural Gas Promotion and Utilization Work Plan
- Guangzhou Distributed Photovoltaic Power Generation Development Plan
- Guangzhou's 13th Five-Year Plan on Energy Development

These policies are focused on decreasing reliance on fossil fuels and improving energy efficiency. Guangzhou is promoting decarbonization of its energy consumption through decreasing coal use, as well as pushing rapid development of natural gas and renewable energy. Renewable energy development is focused on solar energy use, as well as promoting the development and use of biomass. With regard to energy efficiency, Guangzhou is focused on development of high-efficiency hot-spot cogeneration units and high-efficiency coal-fired power generation technologies; working to quickly eliminate use of outdated technology.

Table 8: Key industries in Guangzhou's energy decarbonization efforts, their primary objectives and related policy measures

Field	Optimization of Energy Structure	Improvements in Energy Efficiency
Primary objectives	Lowering the proportion of coal consumption and transforming power plants from coal to electric; extend and increase use of natural gas and solar energy.	Extend cooperative production on key projects; increase focus on management of high energy demand firms; eliminate and renovate primary resource use facilities.
Policy Measures	Administrative measures ● "Clean Power Emissions": program to transform coal plants to electric power ● By 2020, the city will limit coal consumption in coal-fired power technology to less than 310 g / kWh ● "Gas Turbine Air Pollution Special Emissions Restrictions" a standard for gas turbines ● Decreasing high polluting fuel boiler use ● Expanding the reach of "no coal districts" Economic Incentives ● Financial subsidies (Photovoltaic power generation project construction, elimination of high energy consumption) ● Carbon emissions trading Voluntary Measures ● Pilot Demonstration Program ○ National Circular Economy Model City ○ New Energy Comprehensive Use Demonstration Zone News Model ● Energy Saving and Green Public Awareness Raising	

2.3.2 Industry

Current Situation

Guangzhou is promoting decarbonization in the industry sector (Guangzhou's biggest energy consumer) through industrial upgrading and energy saving measures. In the 12th Five-Year Plan period, Guangzhou increased its focus on removing industrial facilities with outdated modes of production, closing or relocating many high consumption and high polluting industrial firms.

At the same time, it has worked to improve its industrial structure. Guangzhou has developed six key industries: petrochemicals, major equipment, automobile manufacturing, electronic products, textiles and clothing, and food and beverage. These six industries account for 77.7% of industrial value added.[11] In addition, the advanced manufacturing industry developed rapidly. In 2015, the value added of strategic emerging industries accounted for more than 10% of GDP, while the output value of high-tech products accounted for 45% of total industrial output. [12] Production of advanced manufacturing of industrial robots, rail transit equipment, and major equipment has also grown.

Low Carbon Indicators

Progress in Guangzhou's industrial low carbon development can be tracked against three indicators: heavy industry output value as a proportion of industrial output value, total energy consumption per 10,000 yuan of industrial output value, and advanced manufacturing value-added as a proportion of industrial value-added. The following table shows Guangzhou's performance in these three indicators.

Table 9: Graph Changes in industrial low carbon development indicators

Indicator	2010	2015
Heavy Industry Output Value as a Proportion of Total Industry Output	64.63%	63.4%
Energy consumption / 10,000 yuan Industrial Output (TCE/10,000 yuan)	3.02	3.5
Advanced Manufacturing Value Added as a Proportion of Industrial Value Added[13]	64.7%	54.3%

Source: Guangzhou Statistical Yearbook, Guangzhou's 13th Five-Year Plan Advanced Manufacturing Development and Composition (2016-2020)

[11] Guangzhou National Circular Economy Demonstration City Implementation Plan, http://www.gzii.gov.cn/sjmw/9.2/201606/cb9a65f7da2841e0b46915a20d7224b1.shtml

[12] Guangzhou 13th Five-Year Plan for Energy Conservation and Carbon Reduction 2016-2020, http://www.cnemission.com/article/news/ssdt/201705/20170500001278.shtml

[13] Calculation includes five major industries: manufacturing, automobiles, shipping, petrochemicals and steel production

Strategic Measures and Policies

Guangzhou has adopted many strategies and initiatives to promote low carbon industrial development, with a focus on industrial decarbonization and transformation. Guangzhou is deepening energy-saving in high-energy consuming enterprises. At the same time, it is building a circular economy supply chain, extending industrial production chains, and creating a closed loop between projects, businesses and industries. In addition, Guangzhou is focused on promoting industrial transformation and upgrading through the recently released "Guangzhou Industrial Transformation and Upgrading Three-Year Action Implementation Plan 2015-2017", "Strategic Plan on Made in Guangzhou 2025" and "The 13th Five-Year Development Plan for Strategic Emerging Industries in Guangzhou (2016-2020)." Guangzhou is implementing initiatives to make industrial manufacturing high-end and high-tech; while promoting innovation and upgrades in traditional industries such as food and beverage, furniture and home appliances, and electronic products; vigorously developing high-end manufacturing industries such as industrial robots and intelligent equipment, and developing service-oriented manufacturing industries. "Intelligent service" upgrades are drawing on the Internet technologies, big data and other new technologies.

Table 10: Primary objectives and related policy measures in Guangzhou's Industrial Emissions Reductions

Field	Industrial decarbonization		Industrial Model
	Improving Carbon Emissions Efficiency	Improving High Resource Use Efficiency	Improving Product Quality
Primary Objectives	Eliminate outdated production capacity, improve enterprise management for heavy polluting industries	Energy transformation for high energy consumption firms; strengthening key energy-using enterprises (industrial enterprises with annual energy consumption above 5,000 TCE); Creating a circular economy industrial chain	Developing advanced manufacturing; implementing a new round of: technological upgrades, making industrial manufacturing more high end and high tech, industrial innovation activities, green development activities, and six major initiatives from the "four hundred" largest firms

Policy measures	Models of administrative control ● Industrial Transformation and Upgrading Three-year Action Plan ● Clean production audit Economic incentives ● Water, electric, and gas price differentiation policy ● Strategic emerging industry fund ● Financial support (industrial technology transformation and industrial manufacturing upgrading) ● Carbon emissions trading exchange ● Scientific and technological achievements trading subsidies ● Guiding equity investment (for key industrial projects) ● Intellectual property rights financing service Information Measures ● Product energy efficiency record for heavy consumption industries ● Establishing an expanding firm training program directory ● Multi-firm development center ● High-growth SME (privately run) business directory ● Database of the basic industries Voluntary Measures ● Energy efficiency targets for key industries ● Pilot zone program (circular economy industrial park)

2.3.3 Buildings

Current Situation

The buildings sector is Guangzhou's most rapidly growing carbon emitter. During the 12th Five-Year Plan period, Guangzhou upgraded existing facilities, implementing 176 green building evaluation projects, with a construction area of approximately 17.46 million square meters.[14] Urban housing areas have gradually increased, making a decrease in emissions from the buildings industry more vital.

[14] Guangzhou Energy Emissions Reduction 13th Five Year Plan (2016-2020)

http://www.cnemission.com/article/news/ssdt/201705/20170500001278.shtml

Low Carbon Indicators

Guangzhou's buildings industry uses two primary standards to evaluate progress on energy emissions. The first is green buildings as a proportion of annual new buildings, the other is the rate of implementation for urban buildings energy saving code. The chart below displays low carbon emission targets in the construction industry for 2010 and 2015.

Table 11: Guangzhou Construction Industry low carbon development, 2010 and 2015

Indicator	2010	2015
Green Buildings as a Proportion of Annual New Buildings （%）	--	20%
Rate of Implementation for Urban Buildings Energy Saving Code	--	100%

Source: Guangzhou Ecological Civilization Construction Plan Outline (2016-2020)

Strategic Measures and Policies

To promote low carbon buildings, Guangzhou has issued:

- Guangzhou Green Building and Building Energy Conservation Management Regulations
- Guangzhou Green Building Action Implementation Plan
- Guangzhou City Construction Waste Recycling Building Materials Products Promotion and Use Measures

These regulations focus on low carbon policy implementation and formulation. They promote action regarding the management of green and energy efficient buildings. The key goals of this development strategy include:

- Improving Carbon Emission Efficiency: Strengthening efficiency of new buildings, as well as upgrading and managing existing buildings. Upgrading the energy efficiency of high consumption components (lighting equipment, air systems, elevators, etc.), as well as expanding the scope of renewable energy use. This includes the installation and use of renewable energy equipment such as solar powered air conditioners, wind (or hydro) source heat pumps, and solar photovoltaic panels. This plan will monitor, limit, and manage buildings energy consumption.
- Improving Energy Efficiency: By increasing green buildings as a proportion of new construction and combining green building practices characteristic of Guangzhou, this strategy will develop and expand the use of energy-saving and environmentally-friendly building materials. At the same time, it will promote carbon-reducing management practices throughout the entire building life cycle. This includes conserving energy and water, saving materials, and protecting the environment.

Table 12: Guangzhou Construction Emission Reduction Key Industries, Primary Goals and Policy Measures

Industry	Improve Carbon Efficiency	Improve Efficiency of Energy Use
Primary Goals	New and Existing Buildings Energy Upgrades and Management	Promote Green Buildings, Materials and Facilities
Policy Measures	Administrative Control ● New Buildings Energy Standards ● Green Buildings Standards and Evaluation Metrics Economic Incentives ● Contract-based energy use management ● Management of energy consumption limits for large public buildings ● Penalties for exceeding energy use limits ● Industry and Commerce Energy Special Saving Fund Information Measures ● Green Buildings Signage System ● Record keeping system for building consumption ● Labeling system for products made of recycled construction waste ● Energy consumption monitoring platform for public buildings Voluntary Measures ● Encouraging model “green ecology” districts ● Creating a demonstration zone for Southern China green building technology research and integration	

2.3.4 Transportation

Current Situation

Making transportation low carbon is a focus of Guangzhou’s low carbon development goals. Due to infrastructure growth, energy consumption in the transportation sector has rapidly increased. As a national pilot city for improved transit hub systems, Guangzhou has been actively promoting mass public transit. During the 12th Five-year Plan period, public transit increased by 2,685 vehicles and new public transit lines increased by 462. These changes increased public transit passenger capacity by 45%.[15] Citywide public transit as a proportion of motorized transportation has reached 60%.[16]

[15] Guangzhou 13th Five-Year Plan for Comprehensive Transportation Development http://www.gzjt.gov.cn/gzjt/ghjh/201611/f49bd2182b0e43e1a666cb78bea332c4/files/a269c3e4284e4fc1b3ae81635f71b2fa.pdf

[16] Guangzhou 13th Five-Year Plan for Energy Conservation and Carbon Reduction 2016-2020 http://www.cnemission.com/article/news/ssdt/201705/20170500001278.shtml

In addition, as a national pilot city for energy saving and NEVs, by 2015 Guangzhou promoted usage of more than 14,600 NEVs.[17] At the same time, Guangzhou has implemented controls over medium and small scale vehicles to limit the increase of private vehicles.

Low Carbon Indicators

Progress in decarbonizing the transportation sector can be tracked against five indicators:

Table 13: Changes to Guangzhou transportation low carbon development targets (2010 and 2015)

Indicator	2010	2015
City Center Public Transit as a Proportion of Motorized Transit	--	60%
Citywide Public Transit Rate（%）	--	--
Public transportation vehicle quantity per 10,000 residents (standard)	--	--
Rail transit as a proportion of total public transit (%)	--	40%
NEVs quantity	--	14600

Source: Guangzhou Energy Saving and Carbon Reduction 13th Five Year Plan, 2016-2020

Strategic Measures and Policies

Among other policy measures, Guangzhou City has compiled and implemented:

- Pilot Implementation Plan for the Construction of Low Carbon Transportation System in Guangzhou (2012-2014)
- Medium and Long-Term Planning for the Construction of Low Carbon Transportation Systems in Guangzhou (2012-2020)
- Guangzhou's 13th Five-Year Plan on Comprehensive Transportation
- Guangzhou Modern Logistics Development Planning (2012-2020)

These measures provide guidance and support for developing citywide low carbon transport. Low carbon transportation development centers on the three following elements:

- Optimizing City Transit: Constructing a green transportation system, combining all transit methods. Developing modern logistical systems, improving logistics networks and promoting construction of a logistics information platform.

[17] Guangzhou 13th Five-Year Plan for Energy Conservation and Carbon Reduction http://www.cnemission.com/article/news/ssdt/201705/20170500001278.shtml

- Promote Environmental Protection and Energy Saving Transit Tools: Actively promote NEVs, focus on public transit, taxis, and official/VIP vehicles; while simultaneously increasing usage of NEVs in city logistics and by private citizens. Establish a suitable NEV service system, and improve the network of battery charging stations.
- Decarbonization of Basic Transportation Infrastructure: Upgrade public transit stations, freight transit stations, and other high consumption facilities. Establish walkway systems, improve the shared bicycle system and improve the bike transit environment. Invest in green upgrades for ports and maritime shipping. Speed up construction of electric port facilities and improve port machinery. Promote the development of smart transit technology and develop a smart transit service and management platform.

Table 14: Key Areas of Focus, Primary Responsibilities and Policy Measures in Reducing Guangzhou Transit Emissions

Field	City Transit	Energy Saving, Environmental Protection and Transportation Tools	Basic Transportation Facilities
Primary Goals	Integrated Public Transit system	Promote NEVs and Construct Accompanying Service Facilities	Develop walkway systems; develop smart transit; complete low carbon upgrades to high consumption facilities.
Policy Measures	Administrative Measures ● Bus Rapid Transit (BRT) ● Promote use of national V standard vehicle fuel ● Adopt national standard IV oil and diesel fuel, as well as national V standard vehicle fuel ● Institute compact car purchasing limits ● LNC public transit replacement plan Economic Incentives ● Create a subsidy fund (for new energy vehicles) ● Create a traffic energy special fund Information Measure ● Traffic Information Service Software: an “Industry Hotline” Voluntary Measures ● General carbon credit system ● Pilot Demonstrations ■ National Low Carbon Transit Hub System Pilot City ■ National Energy Saving and NEV Model Promotion Pilot City		

Guangzhou Low Carbon Transportation Model Cases

Case 1: Underground spaces in the central core area of Zhujiang New City

Zhujiang New City is Guangzhou's central business district (CBD) for finance, trade, housing, administration and recreation. In this area, Huachenghui, a comprehensive development project for underground spaces, is one of the largest and most complex projects of its kind in the country. Its most distinctive feature is how it combines land, a compact spatial layout and transportation structures to create a three-dimensional transportation system. To support high-density development of the central business district and establish a three-dimensional transportation system integrating above-ground and underground spaces, Huachengji has proposed a multi-level public transportation system with rail transit as the main structure and conventional ground public transit as an auxiliary measure. This system works to build underground, ground and raised systems simultaneously. The central square three-dimensional walking system offers a model for planning and construction modern CBDs in other cities.

Case 2: Guangzhou BRT Express Bus

The Guangzhou BRT system was opened in early 2010. Its innovative operation model of a "dedicated corridor + flexible line" was used to integrate the main BRT line with more than 80 bus lines. Nine-hundred and eighty nice buses have integrated into the BRT system, and the average bus speed has increased from 15km to 18km. The Guangzhou BRT system is the first "Gold Standard" rated BRT system in China. Research indicates that the BRT system reduces emissions by 86,000 tons of carbon dioxide per year in Guangzhou.

Case 3: LPG Clean Energy Vehicle

Since 2003, Guangzhou has promoted the use of LPG (liquefied petroleum gas) clean fuel for taxis and buses throughout the city. As of 2014, Guangzhou has more than 20,000 LPG taxis and more than 10,000 LPG buses. In Guangzhou, use of clean energy vehicles contributes an annual CO_2 reduction of 180,000 tons.

2.3.5 City Environment and Land Use

Current Situation

Following increased consumption of urban land, water, energy and other resources, adjusting Guangzhou's urban environment and land strategy will have an important impact on the city's low carbon development. During the 12th Five-Year Plan period, Guangzhou improved environmental quality by accelerating the construction of urban

environmental facilities, strengthening comprehensive environmental improvement efforts, and improving its urban ecological space. In 2015, annual air quality was rated as “excellent” for 312 days in Guangzhou, accounting for 85.5% of the year. The city's forest coverage rate has increased from 36% to 42.3%. By 2015, the rate of green area construction was 36%, and the green coverage rate was 41.5%.[18]

Low Carbon Indicators

Progress in lowering emissions in this sector can be tracked against ten indicators:

Table 15: Changes in Guangzhou City Environment and Soil Use Indicators

Indicator	2010	2015
Per Capita Public Park Area (square meter)	15.01	16.5
Urban Area Green Space Coverage (%)	35.5%	36%
Forest Coverage (%)	41.4%	42.03%
Per Capita Daily Water Usage (liter)	366.41	253.23
Per Capita Waste Production (ton)	0.28 [19]	0.34
Citywide Waste Water Treatment Rate (%)	85.65% [20]	93.22%
Citywide Solid Waste Harmless Treatment Rate	91.96% [21]	95.24%
Annual Concentration of PM10 （ug/m^3）	-	59
Annual Concentration of PM 2.5	-	39
Proportion of Good Air Quality Days	-	85.5%

Source: Guangzhou Statistical Annual Report, Guangzhou Ecological Civilization Construction Plan Outline (2016-2020)

Strategic Measures and Policies

Guangzhou has successively issued the “Opinions on Comprehensively Promoting Domestic Waste Treatment,” the “Guangzhou Huacheng Greentown Water City Construction Plan,” the “Guangzhou City Interim Measures for Restricting the Management of Excessive Packaging of Goods,” and the “Guangzhou City Construction Waste Recycling Building Materials Promotion and Use” as measures to improve the urban environment. These low carbon action plans focus primary on waste management, forestry carbon sinks and air quality, as detailed below:

[18] Guangzhou Ecological Civilization Construction Planning Outline 2016-2020 http://www.gz.gov.cn/gzgov/s2884/201611/6d8da0f68ba14ee6b75d279061dcf24a.shtml

[19] 2010 data.

[20] 2010 data.

[21] 2010 data.

- Waste management: Strengthen recycling systems for “urban minerals” such as discarded auto parts, electronic products, and plastic packaging; improve resource utilization of urban daily waste. Promote the establishment of specialized sorting centers, renewable resource recycling networks and domestic waste treatment facilities.
- Forestry carbon sinks: Increase the forest carbon credit system, establish a carbon credit calculation and monitoring system and promote development of carbon exchanges; strengthen greenification and beautification of city construction.
- Air quality: control the quantity of air pollution while strengthening control of air pollution emissions in fields including industry, transit, food service, etc.

Table 16: Key Elements of Guangzhou’s Environment and Soil Use Low Carbon Development

Field	Forestry Carbon Sinks	Waste Management	Air Quality
Primary Goals	Improve the carbon sequestration capacity of forestry green space; carbon sinks evaluation, supervision and exchange.	Waste recycling and resource management	Controlling air pollution emission levels; pollution governance.
Policy Measures	Administrative Measures ● Construction Waste Recycling Target System ● Production Responsibility Extension System ● Kitchen waste emission registration, supervision and penalty system ● Automobile air pollution emission standard Economic Incentives ● Sustainable Building Materials Financial Subsidy ● Disposal Permits (air pollution, water pollution, etc.) ● Volatile Organic Carbons (VOCs) Disposal Fee ● Carbon Credit Exchanges Information Measures ● Industrial Resource VOCs Comprehensive Emissions Information Management System ● Forestry Carbon Sink Assessment Monitoring System ● Guangzhou Digital Forestry Platform ● Dust Particle Pollution Information Sharing Platform Voluntary Measures ● General Carbon Credit System ● Pilot Zones ■ Car Component Remanufacturing Pilot		

	■ Recycling System Construction Pilot ■ Household Waste Classification Model City ■ National Kitchen Refuse Utilization and Waste Harmless Treatment Pilot City ■ Green Low Carbon Community

3. Conclusion

Guangzhou is the political, economic, cultural center of southern China. It is also one of China's most economic vibrant cities. In over thirty years of rapid economic development, Guangzhou's per capita GDP has already exceeded 20,000 USD, setting the stage for a new phase of social and economic development. Following rapid increases in total economic output, increases in Guangzhou's energy consumption and carbon emissions pose a tremendous challenge to the city's sustainable development. Guangzhou's transition into a green, low carbon city is facilitating the city's economic and social development, as well as protecting its ecological environment. Guangzhou is China's second nationally approved low carbon pilot city. It has continuously explored paths to achieve a low carbon model, including actively pursuing a greenhouse gas reduction agenda, researching green and low carbon development policies, as well as performing basic research on how to promote low carbon lifestyles.

Guangzhou serves as a national center and pilot city, striving to take the lead in capping total carbon emissions, while also facilitating economic and social development. It is exploring all means of decreasing total carbon emissions. Although Guangzhou's work to promote energy saving and carbon reduction is showing positive results, sustaining such progress presents numerous challenges. Guangzhou has established related systems and comprehensive low carbon management structures, with provisions for measures and policies in all relevant industries. These measures combine traditional administrative command-type policies with market economy incentives, and actively explore information-based policies that utilize data analytics.

Guangzhou's rapid economic development and accompanying increases in energy consumption have created significant pressure on the city's energy structure, as well as its industrial energy saving and low carbon efforts. The rapid increase in transit related emissions also require considerable focus and attention. How to effectively craft policies to support Guangzhou's energy conservation and emission reduction in this sector will become one of the key questions for the city's low carbon development going forward. Effectively coordinating its low carbon efforts, establishing rigorous medium and long term goals, and strengthening market-based mechanisms will also be central challenges. Transportation will soon become the most important sector in Guangzhou's future energy consumption and CO_2 emissions. Future research on reducing carbon emissions in Guangzhou will likely focus heavily on transportation emissions.

References

1. Guangzhou municipal Government. The outline on thirteenth Five-Year Plan for Guangzhou National Economic and Social Development (2016-2020). http://www.hrssgz.gov.cn/zwxxgk/jhzj/zxgh/201607/P020160701347733755621.pdf
2. Guangzhou municipal government. The Thirteenth Five Year Plan for Energy Saving and Carbon Reduction in Guangzhou（2016-2020）. http://www.cnemission.com/article/news/ssdt/201705/20170500001278.shtml. 2017-04-17
3. Guangzhou municipal government. The Thirteenth Five-Year Plan for Energy Development in Guangzhou (2016-2020). http://www.gz.gov.cn/gzgov/s2812/201711/76eb233dd2a141e9840962c35c2a79ca.shtml
4. The Guangzhou municipal government. The Thirteenth Five-Year Plan for Guangzhou's Urban Construction. http://www.gz.gov.cn/gzgov/s2812/201707/48ab63e1b02745cdb0d3cc27be242cc0.shtml
5. Guangzhou Municipal Government. The thirteenth Five Year Plan for Comprehensive Transportation Development in Guangzhou, P58 Green Transportation: Building a High Quality Green Transportation System. http://www.gzjt.gov.cn/gzjt/ghjh/201611/f49bd2182b0e43e1a666cb78bea332c4/files/a269c3e4284e4fc1b3ae81635f71b2fa.pdf
6. Guangzhou municipal government. Outline on Guangzhou's Ecological Civilization Construction Plan（2016-2020）. http://www.gz.gov.cn/gzgov/s2884/201611/6d8da0f68ba14ee6b75d279061dcf24a.shtml
7. The Overall Urban Planning in Guangzhou（2017-2035） http://www.gzlpc.gov.cn/hdjl/zjyj/201802/W020180225000925672953.pdf
8. Guangzhou Municipal Commission of Industry and Information Technology. The Implementation Plan for establishing the national recycling economy demonstration city in Guangzhou. http://www.gzii.gov.cn/sjmw/9.2/201606/cb9a65f7da2841e0b46915a20d7224b1.shtml
9. Sun Wei, Yu Zhuojun, Liao Cuiping. Analysis of the Peak Value of Carbon Emission in Guangzhou. New Energy Development, 2016(06): p 246-252
10. Wang Bo, Zhang Haixia, Zheng Wei. Transportation Carbon Emission Inventory and Emission Reduction Strategies in Guangzhou. Proceedings of China's Urban Transport Planning Annual Conference in 2017. 2017.
11. Guangzhou Institute of energy research, Chinese Academy of Sciences. Research on Green Low Carbon Development Path in Guangzhou. Project Report. 2018.
12. Edited by Green Low Carbon Think Tank Partners. China Urban Low Carbon Development Planning, Peak Values and Case Studies. Science Press. 2018.