Low Carbon Society Scenario Towards 2030

GuangZhou

A win-win strategy for climate change and sustainable development of regional economy

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Preface

Global warming is an important issue affecting human survival and development. Cities account for more than half of the world's population, consume 75% of the world's energy output, and emit around 70% of global greenhouse gases (GHGs). It is therefore essential to consider low-carbon development at the urban level from a long-term perspective when facing the urgent and continuous challenge of climate change. As fossil fuels are the main carbon source of cities, the question of how to control CO2 emissions from energy activities is crucial in order to fight climate change at the urban level. However, the existing studies focus more on global and national scenarios and less on urban scenarios from a long-term standpoint. We take Guangzhou as a case study to demonstrate the calculation of current carbon emissions and prediction of future emissions at the city level using the Extended Snapshot Tool (ExSS) developed by Kyoto University, Japan, in order to design a quantitative future scenario for a low-carbon society.

This study proposes a low-carbon city scenario–namely, a win-win strategy of carbon emission mitigation and economic development–for Guangzhou City towards 2030. The results provide a reference for the policy-making process to achieve low-carbon development by showing the potential of individual countermeasures. It is our hope that this research report will provide a direction among stakeholders for further intensive discussions and preparation of the roadmap for Guangzhou Green City development.

This brochure was prepared mainly by Kyoto University researchers and the Guangzhou Institute of Energy Conversion, Chinese Academy of Sciences (GIEC, CAS) in collaboration with NIES, Japan. We wish to express our gratitude to Professor Hu Xiulian and Professor Jiang Kejun of the Energy Research Institute, National Development and Reform Commission (ERI, NDRC) for their valuable information and comments.

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Executive Summary

This study proposes a low-carbon city scenario–namely, a win-win strategy of carbon emission mitigation and economic development–for Guangzhou City towards 2030. The term low-carbon city refers to urban development patterns and social development approaches based on a low-carbon economy and green lifestyles and behaviours of the citizens. A city can realize the reduction of carbon emissions through changes in economic development patterns, consumption behaviours, lifestyle concepts, and technological innovations. However, this requires a blueprint for the construction of a low-carbon society at the government and management level. Against such a background, the objective of this study is to seek a possible future vision of Guangzhou as a low-carbon city by means of a scenario approach using quantitative modelling.

The Extended Snapshot Tool (ExSS) was applied as a tool for quantification of the future development of Guangzhou in 2030. This tool projects consistent and quantitative socio-economic variables, energy demand, GHG emissions, and diffusion of mitigation options in order to achieve an emission target or assess the potential for emission reduction by various countermeasures..

Table ES1. Summary of main variables

Variable	Unit	2005	2030BAU	2030CM	2030BAU /2005	2030CM /2005	2030CM /2030BAU
Population	million	9.6	13.1	13.1	1.37	1.37	1.00
Household	million	2.9	4.8	4.8	1.66	1.66	1.00
GDP	billion RMB	506	2,501	2,501	4.94	4.94	1.00
Primary industry		13	28	22	2.19	1.70	0.78
Secondary industry		204	868	681	4.26	3.34	0.78
Tertiary industry		289	1,605	1,798	5.55	6.22	1.12
Passenger transport demand	billion passenger-km	173	232	231	1.34	1.34	1.00
Freight transport demand	billion ton-km	273	1,155	863	4.23	3.16	0.75
Final energy demand	million tce	34	115	74	3.37	2.17	0.64
CO_2 emissions	million tCO_2	98	336	165	3.43	1.69	0.49
CO_2 intensity	$kgCO_2$/RMB	0.19	0.13	0.07	0.69	0.34	0.49
Per captia CO_2 emissions	tCO_2	10	26	13	2.51	1.23	0.49

Table ES1 shows the projected results of main variables including socio-economic variables, energy demand, and CO_2 emissions. Future socio-economic development is based on recent trends and official targets of economic development. Projected CO_2 emissions in Guangzhou in 2030 will be 336 $MtCO_2$ under the 2030 Business as Usual (BAU) scenario, a 243% increase from the 2005 level. Under the 2030 Countermeasures (CM) scenario, emissions in 2030 can be reduced by 170 $MtCO_2$ to 165 $MtCO_2$, a 51% decrease from the BAU level (see Figure ES1). CO_2 emissions from industry account for the largest share of total emissions under both the 2030 BAU and 2030 CM scenarios, despite a shift in the industrial structure to commercial and service industries. Improving the energy efficiency of the industrial sector is therefore crucial for the development of Guangzhou as a low-carbon city, as well as energy efficiency improvement and fuel switching in the power supply sector.

The results obtained in this study provide a reference for the policy-making process towards the achievement of low-carbon development by showing the potential of individual countermeasures. Using the quantitative results presented here, it will be possible to discuss choices of countermeasures and priority options based on scientific and technological analysis.

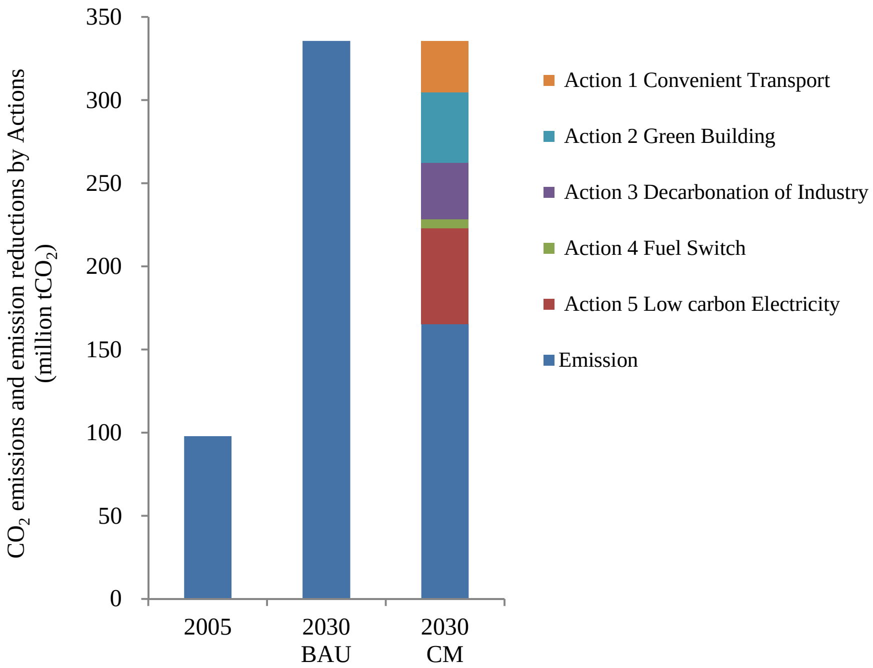


Figure ES1. Summary of GHG emission and emission reduction by Actions

1. Concept and Development of Low-Carbon City

1.1 Background of low-carbon city development

With the dawn of the 21st century, issues of energy security and global warming due to anthropogenic GHG emissions have aroused wide public concern. According to research by meteorological institutions, the average global land surface temperature has risen by about 0.74°C within the past 100 years. It is predicted that the global land surface temperature will rise by 1.1°C to 6.4°C by the end of the 21st century. With the warming climate, extreme weather conditions have been occurring more frequently, causing a succession of natural disasters. These natural disasters may cause large population migrations and threaten the economic and political stability of various countries.

Among all of the possible actions to tackle this problem, the concept of low-carbon development, which aims to reduce the human “footprint”, is receiving greater recognition around the world and has become a goal of the new era. A low-carbon economy is defined as an economy in which resource consumption and environmental impacts are reduced while achieving higher economic profits. Based on this principle, the concept of low carbon is being rapidly disseminated at all levels of society, reflecting the urgent need to promote green lifestyles and to develop a management model for a low-carbon society,

More than half of the world’s population currently lives in urban areas, which account for only 20% of the global land area, and 70% of the world’s population is projected to live in cities by 2050. Production, consumption, living activities, and associated energy consumption will mainly take place in these cities. Cities will therefore become increasingly important for human progress in general, and climate change mitigation in particular. One study has shown that the economic activities carried out within urban areas account for 75% of global energy consumption and almost 80% of the world’s GHG emissions. Cities have become not only the major source of GHG emissions, but also places vulnerable to the effects of climate change. Cites are therefore key players in solving the issue of climate change, one of the most complicated and urgent problems facing the world.

The development strategies of cities, especially the emerging “factory cities”, have become the focus of global low-carbon development in order to tackle climate change and shifting development priorities. Academia, international organizations, and governments have consequently been paying increasing attention to the concept of low-carbon cities..

1.2 The concept and basic component of a low carbon city

The term *low-carbon city* refers to urban development patterns and social development approaches based on a low-carbon economy and green lifestyles and behaviours of the citizens. This requires a blueprint for the construction of a low-carbon society at the government and management level. A city can realize the reduction of carbon emissions through changes in economic development patterns, consumption behaviours, lifestyle concepts, and technological innovations. A low-carbon city is constructed from various components such as a low-carbon economy, low-carbon transport, low-carbon buildings, a low-carbon built environment, low-carbon communities, and low-carbon families. With the combination of city-specific development goals and constraints, a low-carbon strategy should be promoted step by step.

1.3 Low-carbon city development in China

As a developing country, China is in an era of fast urbanization and its total GHG emissions are increasing. At the same time, as a responsible country, China has shown a positive attitude on the international stage, announcing before the COP15 meeting in Copenhagen its goal of reducing GHG emissions per unit GDP by 40 to 45% of 2005 levels by 2020.

Since the reform and opening up of China, its economy has grown rapidly. Due to technological limits and development methods, however, issues of low efficiency and high pollution are concealed behind the flourishing economy. Higher demand for housing, transport, and electricity are causing increases in both energy consumption and GHG emissions, and the conflict between economic development and natural resources has become increasingly prominent. How to solve the problem of a highly carbon-dependent economy and highly energy-intensive development has become one of the greatest challenges for China. Low-carbon development is no doubt a new pathway for sustainable urban development. A number of plans for low-carbon “experimental cities” are gradually being developed. Currently, Shanghai, Baoding, Guiyang and some other cities are considering the construction of low-carbon cities.

2. Guangzhou and Its Potential as a Low−Carbon City

2.1 Overview of Guangzhou

Guangzhou, the capital of Guangdong Province, is located in the northern part of the Pearl River Delta in southern China, not far from Hong Kong and Macau. The city has 10 districts and two satellite cities in a total area of 7,434.4 square kilometres. It had a residential population of 10.3 million in 2010 and has maintained an average annual growth rate of 2% over the past 30 years. Guangzhou is the third-largest city in China, after Beijing and Shanghai.

Economy:

As the centre of politics, economy, culture, technology, and transport in southern China, Guangzhou is an open city on the coast and a pilot area of national comprehensive reform. It is also one of the most economically active cities in the country. In 2009, Guangzhou's GDP reached 9,138 billion RMB, accounting for 2.7% of the country's total GDP. Tertiary industry has become the focus of economic growth.

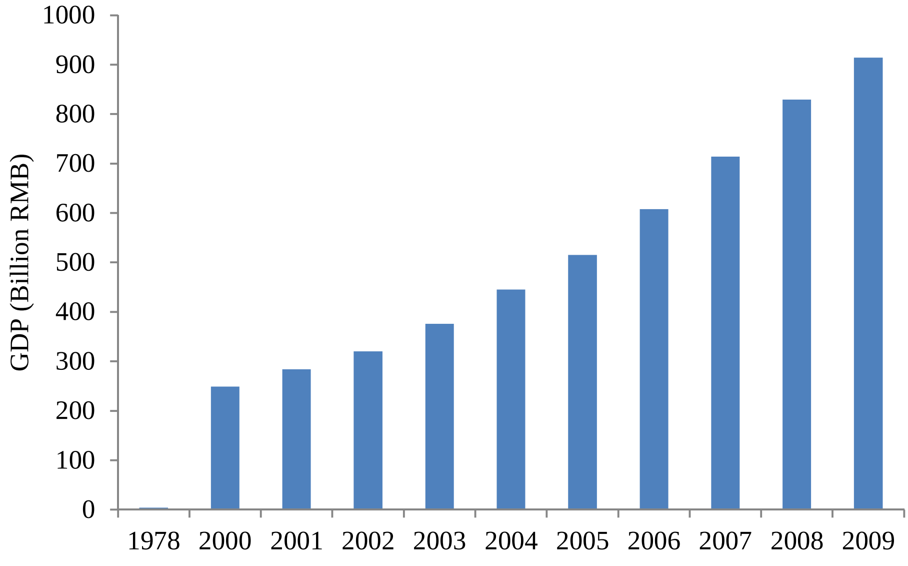


Fig. 1: Guangzhou GDP between 1978-2009 (at current prices)
(Data Source: Guangzhou Statistical Yearbook)

Energy:

Guangzhou's energy consumption per GDP is 40% lower than China's overall level because of the reformation of its industrial structure and improved energy efficiency. It is in the leading position in China in terms of energy efficiency. However, the increase in total energy demand has not been effectively curbed due to rapid overall economic growth. In 2009, its final energy consumption was 54.5 million tons of coal equivalent (TCE), a 12.2% increase compared with 2008. Guangzhou's increasing rate of resource consumption exceeds that of China overall. Coal and oil respectively account for 16% and 32% of energy consumption, LPG and natural gas for 4%, and electricity for 40%. The excessive use of coal and oil has resulted in great pressure on the environment.

Industry:

Guangzhou is an important and comprehensive industrial centre in the country. Through its years of development, the city has formed an open and modern industrial structure, with the development of a variety of products, integrated assembly lines, and a capacity for R&D to achieve product innovation. Guangzhou has 34 of the 40 categories of industry in China. Guangzhou's industrial added value accounts for more than one-third that of the whole city. The automotive manufacturing, electronics, communications, and petrochemical industries hold a share of one-third of all industries located there.

Construction:

Urbanization has been accelerating in line with the steady economic growth. The construction industry has developed rapidly and maintained long-term prosperity. The average housing floor space per capita increased from 13.1 m^2 to 20.4 m^2 between 2000 and 2009, and the total area of public buildings has increased to 1.2 billion m^2. Electrification of buildings has diffused widely, as is also the case for construction equipment and household electric appliances.

Transport:

Transport is a basic infrastructure for economic development. Guangzhou's transport industry has experienced strong growth in recent years. The city had 9,089 km of highways, 1,468 km of railways, 855 km of inland waterways, and 1.1 million km of civil aviation routes in 2009. The total volume of passenger transport is 145.4 billion passenger-kilometres, and that of freight transport is about 217.6 billion freight ton-kilometres. Investments in high-speed railways, subways, and other rail transit systems have increased, although the integration of various transport modes is still insufficient and energy-intensive road transport still holds a large share.

2.2 Co-benefits of transforming Guangzhou into a low-carbon city

Besides mitigation of climate change and contribution to the national goal of GHG emission reduction as a leading city in the country's advancement, the development of Guangzhou as a low-carbon city has a variety of co-benefits, as follows.

- The development of a low-carbon city can mitigate increases in energy demand. With the increasing prices of energy and other resources, the city has been suffering from energy and resource shortages. The stabilization of energy demand is crucial for the development of a city like Guangzhou.
- The development of a low-carbon city enhances the competitiveness of industries. With the increasing pressure to reduce global GHG emissions and the introduction of carbon pricing, the improvement of energy efficiency and the development and utilization of renewable resources have become increasingly important for industries in Guangzhou. By promoting its transformation into a low-carbon city, Guangzhou can strengthen its competitiveness and promote new sources of economic growth.
- The development of a low-carbon city can also reduce local air pollution. Coal and oil currently account for about 70% of the total energy supply, while LPG and natural gas hold a share of around 5% and renewable energy less than 1%. The combustion of conventional fossil fuels is the major source of SO_2, NO_x, and other air pollutant emissions.

The objective of this study is to seek a possible future vision of Guangzhou as a low-carbon city by a scenario approach using quantitative modelling. This report is an output of purely academic research activity and does not present any authorized or official policy decisions.

3. Scenario Analysis of Guangzhou as a Low-Carbon Society

In this study, the Extended Snapshot Tool (ExSS) was applied for quantification of the future development of Guangzhou in 2030. ExSS was developed by Kyoto University and NIES, Japan. This tool projects consistent and quantitative socio-economic variables, energy demand, GHG emissions, and diffusion of mitigation options in order to achieve an emission target. We also aim to develop a suitable methodology for low-carbon society research for Chinese cities, so that other cities can benefit from it.

The year 2005 was selected as the base year. Since more low-carbon technologies will become matured and available in the decade after 2020, 2030 was selected as the target year for the low-carbon society scenarios. Two different types of development scenarios were established: 2030 BAU (Business as Usual) and 2030 CM (Counter Measures). Due to the difficulty of obtaining data, some of the data used in this study had to be estimated by the research team, and thus the study may involve a certain degree of subjectivity.

Table 1. Quantitative socio-economic assumptions in 2030

Indicator	Assumption in 2030（data in 2005）	Trends between 2005 and 2030
Population	13.1 Million (9.6 Million)	Growth rate at 1.2% per annum based on “The Eleventh Five-Year Plan of Guangzhou National Economy and Social Development”
Demographic composition	age 0-14:13.5%(14.8%) age 15-64:71%(77.6%) age 65 and over: 15.5%(7.6%)	Birth and death rates are declined
Urbanization rate	95% (82.4%)	Urbanization increases
Average number of persons per house-hold	Urban: 2.6 (3.2) Rural: 3.0 (3.6)	Significant decrease in average size of household
GDP	2501 Billion RMB (506 RMB)	Growth rate at 7% per annum, and will focus on the development of tertiary industry, especially in the CM scenario

The data source of 2005: Guangzhou Statistical Yearbook 2006; the 1% population sample survey bulletin of Guangzhou in 2005

3.1 Socio-economic assumptions for Guangzhou in 2030

Based on the current socio-economic development of Guangzhou, the city's future economic development in 2030 was projected. This subsection presents the depicted future picture of the economy, society, commercial activity, industry, and transport in Guangzhou in 2030. A summary of the future socio-economic assumptions is shown in Table 1.

Demographics:

Based on Guangzhou's population history from 1978 to 2009 and the trends in its rates of birth, death, immigration, and emigration, it is expected that the city's population will reach 13.1 million in 2030, the number of households will rise to 5 million, and the average household size will decrease from 3.2 persons to 2.6.

Economy:

Considering the current trend of economic growth in Guangzhou and its future development plan, the average annual growth rate of real GDP is assumed to be 6.7% from 2005 to 2030. The real GDP of Guangzhou in 2030 is estimated to be approximately 2.5 trillion RMB

Industry:

ExSS applies input-output analysis in order to determine the future industrial structure. Based on the input-output tables for Guangdong Province in 2005 and assumptions of future changes in the demand structure, the projected industrial outputs are 98 billion RMB for primary industry, 5,391 billion for secondary industry, and 4,645 billion for tertiary industry. The respective shares of the three industries are 1:53:46. Although their output is increasing in terms of absolute value, the shares of primary and secondary industries will continue to follow a declining trend while tertiary industry is expected to contribute more to Guangzhou's economy in the future.

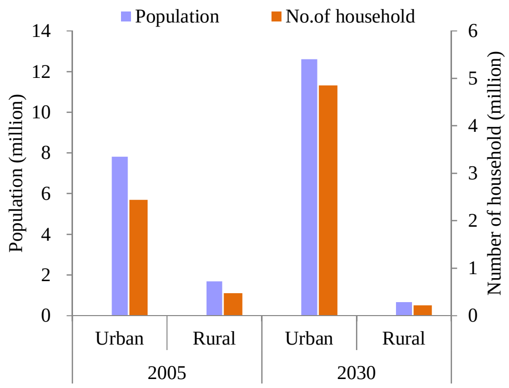


Fig. 2 Projection of population and household number in 2030

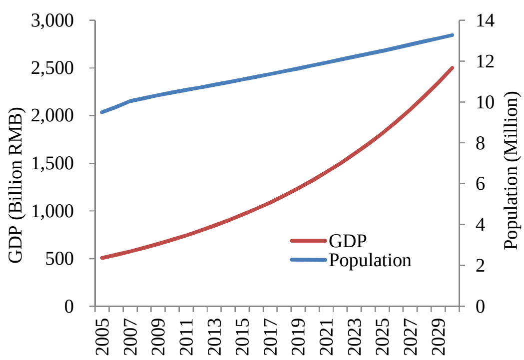


Fig. 3 Projection of population and GDP growth by 2030

Transport:

With the ongoing development of the economy, the share of vehicular and air transport will continue to increase. Based on the future population and trends in transport from 1978 to 2009, passenger transport demand is expected to increase from 173 billion passenger-kilometres (2005) to 236 billion passenger-kilometres (2030). At the same time, due to the growth of manufacturing industries, corresponding freight transport demand will also increase and reach 1,155 billion ton-kilometres in 2030 (Figure 5).

Under the 2030 BAU scenario, as a result of the continuation of the current trend, passenger transport demand in Guangzhou City will further increase and more frequent traffic congestion will be caused. Under the 2030 CM scenario, on the other hand, the share of private vehicles will be reduced by 20% compared with the BAU scenario. Instead, the share of bus and rail transport will increase by 15%, and that of transport by bicycles and walking will increase by 5%. Freight demand will continue to increase due to the growth of manufacturing industries.

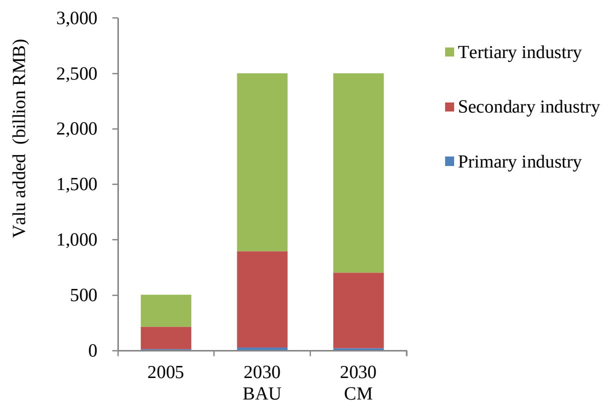
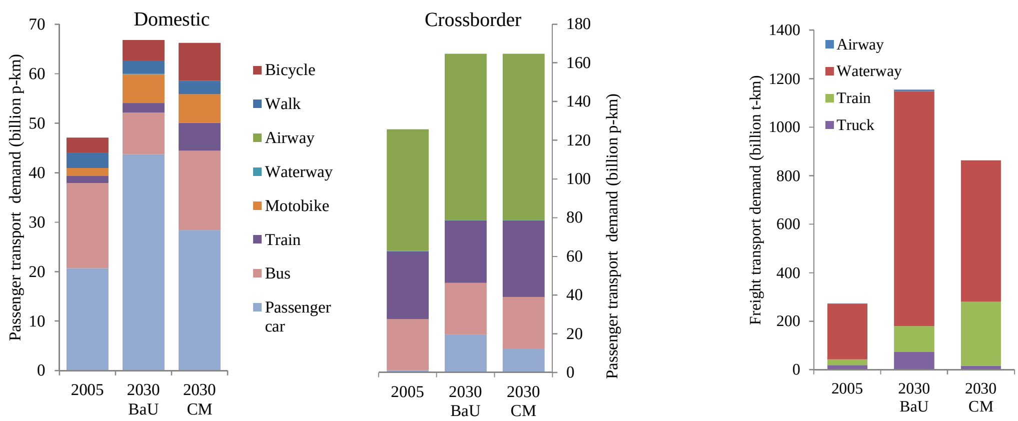


Fig. 4 Projected value added by industries



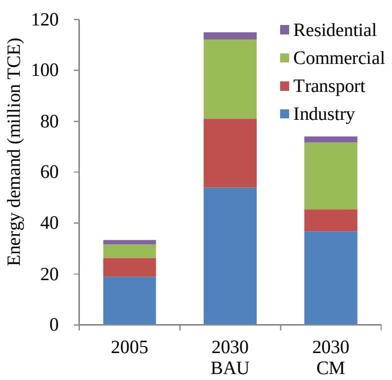
(a) Passenger (b) Freight

Fig. 5 Projected transport demand in the scenarios

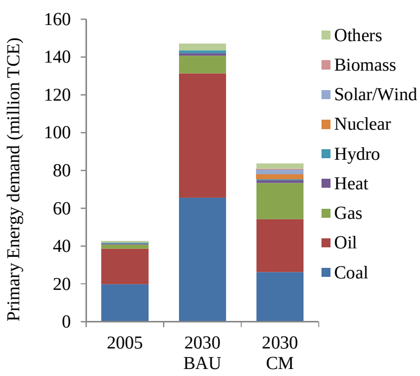
3.2 Energy demand and GHG emissions in 2030

Final energy demand, primary energy supply, and corresponding GHG emissions in 2030 were projected by a bottom-up type energy demand and supply model in ExSS. Final energy demand under the 2030 BAU scenario will be 115 million TCE, a 3.4-fold increase compared with 2005. Under the CM scenario, on the other hand, final energy demand will be 74 million TCE, a 36% reduction from the BAU level. As can be seen in Figure 6(a), the industrial sector has the largest share of energy demand under both the BAU and CM scenarios, accounting for more than half of total final energy demand. Under the CM scenario, however, since low-carbon measures are introduced to industry, the shares of the commercial and residential sectors will increase. Figure 6(b) shows how the energy system of Guangzhou will rely more on coal and oil under the 2030 BAU scenario. In contrast, under the 2030 CM scenario, the primary energy supply is projected to be reduced by 44% compared with the BAU scenario, while the share of renewable energy will significantly increase. Projected CO_2 emissions in Guangzhou will be 336 $MtCO_2$ under the 2030 BAU scenario. Under the 2030 CM scenario, on the other hand, the projected emissions are 165 $MtCO_2$, a reduction of 170 $MtCO_2$ from the BAU level. CO_2 emissions from industry will account for the largest share of total emissions in 2030 under both the BAU and CM scenarios, despite the shift in the industrial structure to commercial and service industries. Improving the energy efficiency of the industrial sector is therefore crucial for the development of Guangzhou as a low-carbon city.

The contributions of each countermeasure to reduce CO_2 emissions are shown in Figure 8. The industrial sector shows high potential for mitigation because of its already large emissions.



(a) Final energy demand



(b) Primary energy supply

Fig. 6 Projected final energy demand and primary energy supply in 2030

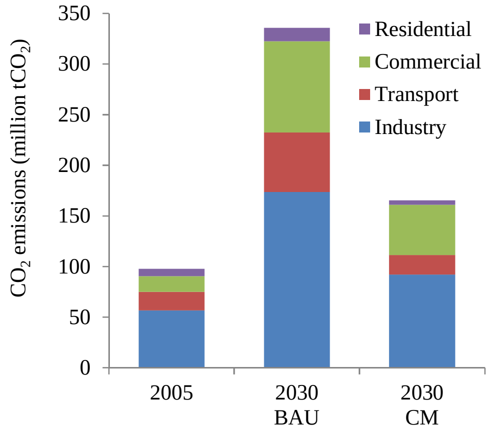


Fig. 7 Projected CO_2 emission in 2030

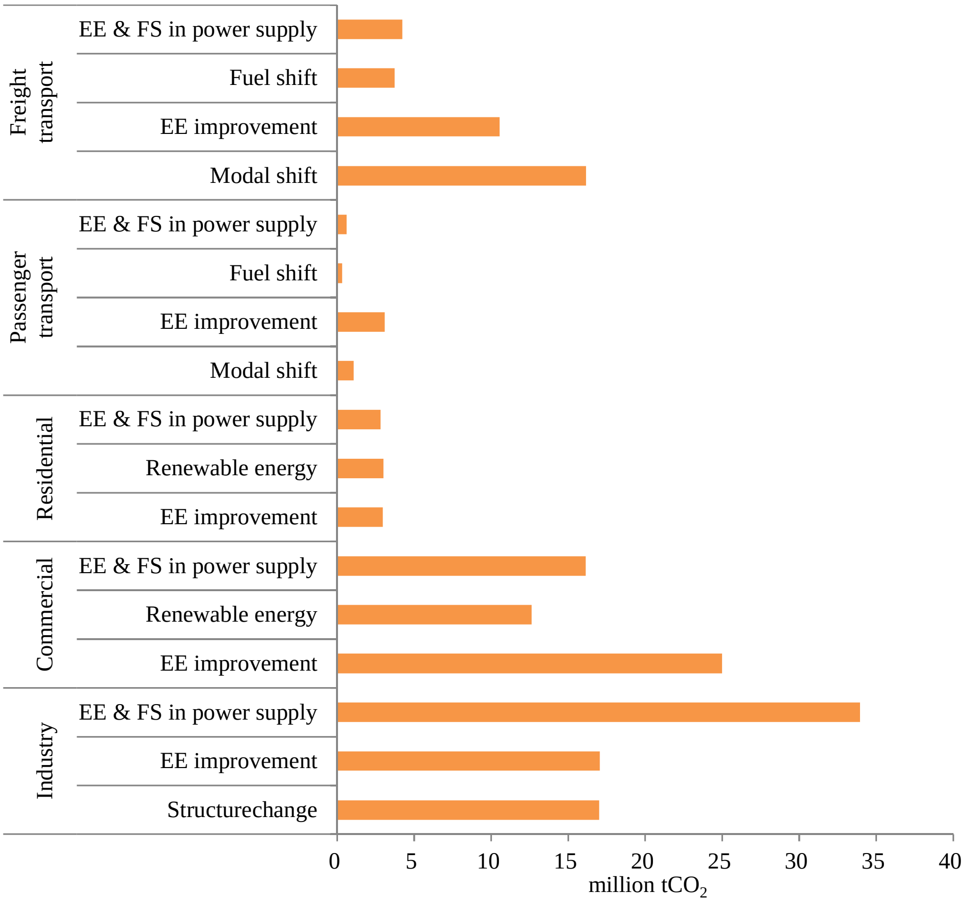


Fig. 8 Contributions of each countermeasure to reduce CO_2 emission

4. Actions for Guangzhou Low-carbon Social development

The preceding section outlines a set of low-carbon measures that achieve a 55% reduction of CO_2 emissions from the 2030 BAU level. This section proposes five actions corresponding to these measures (Figure 9).

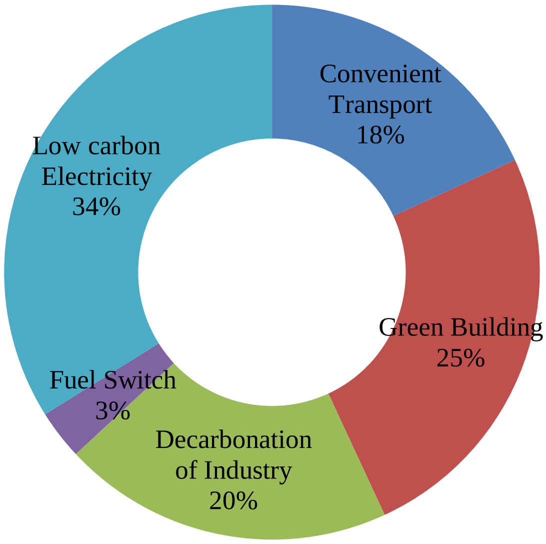


Fig. 9 Share of CO_2 emission reduction by “Five Actions”

Table 2 GHG emission reduction actions

No.	Action name	Measures
Action 1	Convenient Transport	Modal shift of passenger transport
		Efficiency improvement of passenger transport
		Modal shift of freight transport
		Efficiency improvement of freight transport
Action 2	Green Building	Efficiency improvement of office equipment
		Distributed renewable energy utilization of commercial sector
		Efficiency improvement of household appliances
		Distributed renewable energy utilization of household sector
Action 3	Decarbonation of Industry	Energy efficiency improvement
		Industrial restructuring
Action 4	Fuel Switch	Industry
		Commercial
		Residential
		Passenger transport
		Freight transport
Action 5	Low-carbon Electricity	Efficiency improvement of power plants
		Fuel switch of electricity generation

Action 1: Convenient transport

This action comprises efficiency improvement of vehicles and a modal shift from private vehicles to public transport. It requires new traffic management systems. The CO_2 emission reduction from this action contributes to 18% of the total reduction. For the passenger transport sector, under the 2030 CM scenario, in order to mitigate CO_2 emissions and develop a convenient transport system, countermeasures for such a modal shift are introduced. In addition, an approximately 60% energy efficiency improvement of vehicles is assumed. In the freight transport sector, we have assumed that the share of road transport will be reduced by 27% compared with the BAU scenario in 2030, while the shares of rail and maritime transport will increase by 22% and 5%, respectively. We have also assumed that the efficiency of freight transport will improve by about 60% through improvements in engine efficiency and strengthening of freight management.

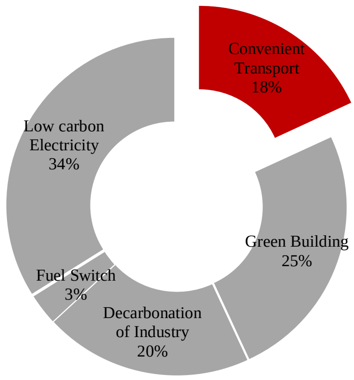
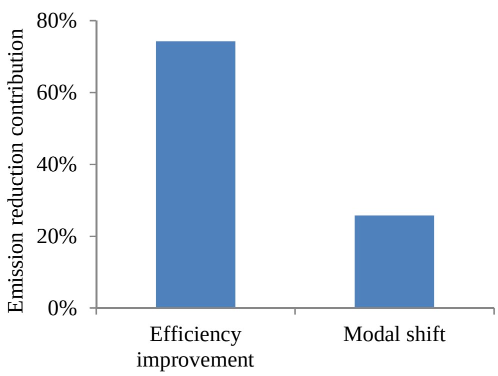
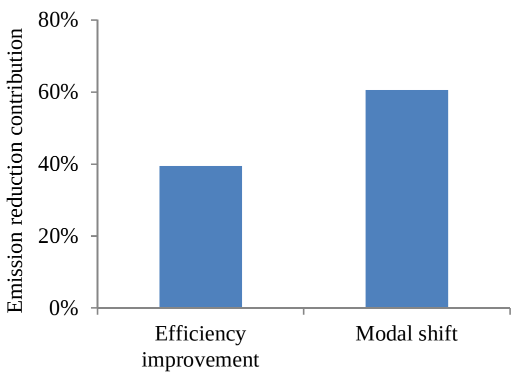


Fig. 10 Contribution of CO_2 minigation by Action 1

In order to develop convenient transport, it is necessary to optimize the transport structure. This means giving priority to the development of urban public transport, speeding up bus rapid transit and rail transit construction, and accelerating the development of rail and maritime transport to promote the coordinated development of various modes of transport. At the same time, it is necessary to promote alternative fuels and new energy vehicles and to strengthen the organization and management of transport, in order to improve the efficiency of the integrated transport system.



a. Passenger transport



b. Freight transport

Fig. 11 Analysis of CO_2 emission reduction in transport sector

Action 2: Green building

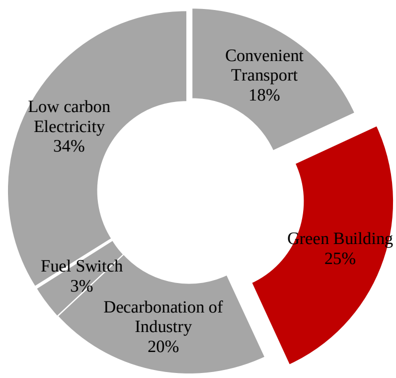
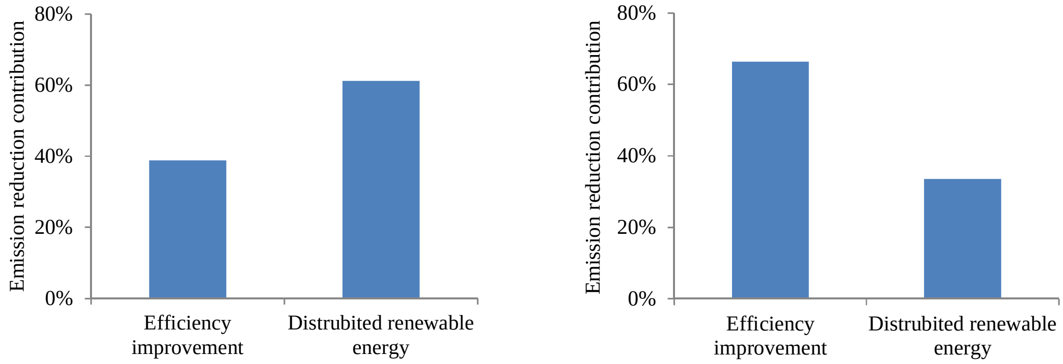


Fig. 12 Contribution of CO_2 minigation by Action 2

This action focuses on measures for efficiency improvement and renewable energy utilization in the residential and commercial sectors. The CO_2 emission reduction achieved by this action contributes to 25% of the total. Accompanying economic growth, people's expectations of living and working conditions are increasing. Electrical equipment will become more widely disseminated with growth in per capita income and population and will consume more energy if efficiency is not improved. For the residential sector, under the 2030 CM scenario it is assumed that the efficiency of household appliances will be improved by about 60% compared with the BAU scenario through technological innovations. For the commercial sector, under the CM scenario we have assumed that the energy efficiency of office equipment will also be improved and that the share of distributed renewable energy will increase. Consequently, a 45% CO_2 emission reduction is achieved compared with the BAU scenario.

In order to realize the measures in this action, a set of policies is required such as (1) subsidies for introducing distributed renewable energy systems (photovoltaic and wind energy), (2) low-interest loans for investments in energy-efficient buildings and renewable energy, and (3) environmental performance standards for and evaluation of houses and buildings.



a. Residential sector

b. Commercial sector

Fig.13 Analysis of CO_2 emission reduction in building sector

Action 3: Decarbonation of industry

Industry is presently the sector with the largest energy consumption and GHG emissions in Guangzhou. The decarbonation of industry comprises two main measures: improvement of the energy efficiency of industries, and industrial restructuring. This action contributes 20% of the total CO_2 emission reduction.

The measures for improvement of the energy efficiency of industries include the following:

- Optimization and innovation of industrial technologies, equipment, and processes
- Improvement of device-level energy efficiency
- Accelerated transformation of large-scale equipment
- Strengthening of energy management

The measures for industrial restructuring are as follows:

- Elimination of outdated production facilities
- Enhancement of the scale of industries
- Conversion of investments from energy-intensive industries to tertiary industries

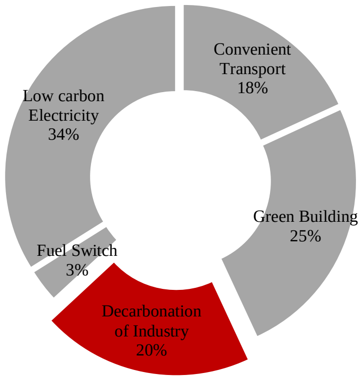


Fig. 14 Contribution of CO_2 minigation by Action 3

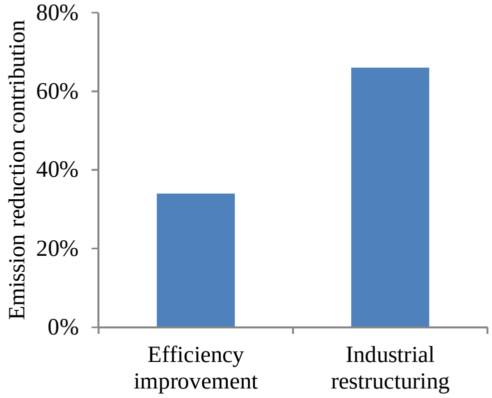


Fig. 15 Analysis of CO_2 emission reduction in industry sector

Action 4: Fuel switch

Fuel switch aims to change the fuel structure of the industrial, construction, and transport sectors. It is expected to achieve 3% of the total CO_2 emission reduction. This action will also contribute to national energy security by diversification of energy sources. Fuel switch here means shifting from carbon-intensive fuels to less-intensive fuels. For example, under the 2030 CM scenario, there is a movement towards the replacement of coal and oil by natural gas, electricity, and new and renewable energies. In the industrial sector, the shares of natural gas and electricity are assumed to increase by 5% and 10%, respectively, compared with the BAU scenario. In the building sector (residential and commercial), the shares of natural gas and electricity increase by 10% and 20%, respectively, as they replace oil products. In the transport sector, the share of natural gas and biofuel increases by 20% as a replacement for petroleum.

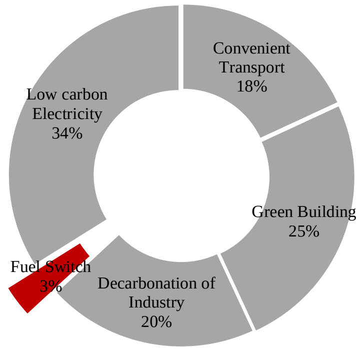


Fig. 16 Potential of CO_2 minigation by Action 4

Action 5: Low-carbon Electricity

Power supply is a major source of GHG emissions. Under the CM scenario, 34% of the total GHG emission reduction can be achieved through the action of introducing low-carbon electricity. This action comprises improvement of the efficiency of power plants and fuel switching for electricity generation. The countermeasures for improvement of the efficiency of power plants are improvement of energy efficiency, expansion of installed capacity, and reduction of transmission and distribution losses. We have assumed that the efficiency of coal-fired power plants will improve from 35% under the BAU scenario to 39% under the CM scenario, that the efficiency of oil-fired power plants will increase to 45%, and that the efficiency of gas-fired power plants will increase to 50%. Incentives for switching the fuel used for electricity generation are also necessary. The share of high-carbon-intensity energy, especially coal, should be reduced and instead, the shares of natural gas, nuclear power, and hydroelectric power should be increased. The projected shares of various fuels in the power sector are shown in Figure 18

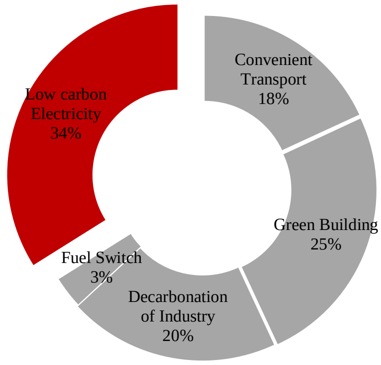


Fig. 17 Potential of CO_2 minigation by Action 5

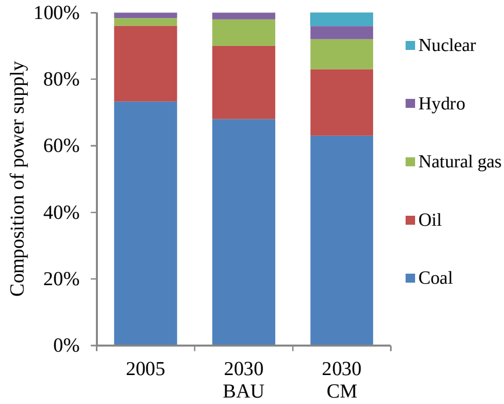


Fig. 18 Structure of energy consumption in power sector

Appendix: The Methodology for Guangzhou Low-carbon society Analysis

1. A procedure to create LCS scenarios

In order to create a local low-carbon society scenario, we developed a method based on the idea of "back casting", which sets a desirable goal first, and then seek the way to achieve it. Figure A1 shows overview of the method.

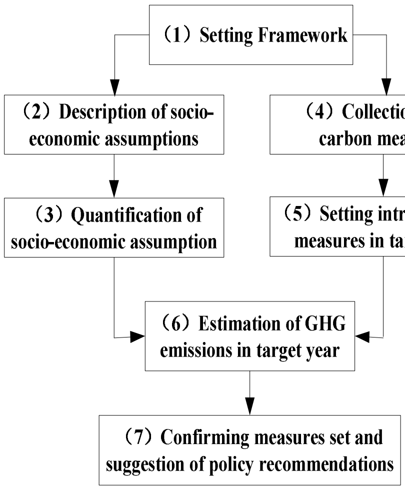


Fig. A1 Procedure to create LCS scenarios

(1) Setting framework

Framework of a LCS scenario includes target area, base year, target year, environment target, and number of scenarios. The target year should be far enough to realize required change, and near enough to image the vision. In this study, we set the 2030 as the target year of Guangzhou. As an environmental target, we targeted CO_2 from energy use because it will be a main source of GHG emissions from Guangzhou.

(2) Assumptions of socio-economic situations

Before conducting quantitative estimation, qualitative future image should be description. It is an image of lifestyle, economy and industry, land use and so on.

(3) Quantification of socio-economic assumptions

To estimate Snapshot based on future image, values of exogenous variables and parameters are set. ExSS calculates socio-economic indices of the target year such as population, GDP, output by industry, transport demand, and so on.

(4) Collection of low-carbon measures

To collect counter measures which are thought to be available in the target year. For example, high energy-efficiency devices, transport structure change, use of renewable energy and energy saving behavior. Technical data is required to estimate their effect to reduce GHG emissions. One of the main input data is IO table. In this study, the first level of industry divided into five sectors in this model, including industrial sector, commercial sector, residential sector, passenger transport sector and freight transport sector. Then the five sectors subdivided into 18 sectors in the second level, which correspond to the I/O table of Guangdong Province (table A1)

(5) Setting introduction of counter measures

Technological parameters related to energy demand and CO_2 emissions are defined. Since there can be various portfolios of the measures, one must choose appropriate criteria. For example, cost minimization, acceptance to the stakeholders, or probability of technological development.

(6) Estimation of GHG emission in the target year

Based on socio-economic indices and assumption of measures' introduction, GHG emissions are calculated.

(7) Proposal of policies

Propose policy set to introduce the measure defined. ExSS can calculate emission reduction of each counter measure. Therefore, it can show reduction potential of measure which especially needs local policy. It can also identify measures which have high reduction potential and important.

2. Quantitative projection tool "Extended Snapshot Tool"

Extended Snapshot Tool (ExSS) is a comprehensive estimation tool for socio-economic indicators and environmental load emissions designed for a backcasting study. Figure A2 shows the structure of the Extended Snapshot Tool; seven blocks with input parameters, exogenous variables and variables between modules. ExSS is a system of simultaneous equations. Given a set of exogenous variables and parameters, solution is uniquely defined. In this simulation model, only CO_2 emission from energy consumption is calculated, even though, ExSS can be used to estimate other GHG and environmental loads such as air quality.

In many LCS scenarios, exogenously fixed population data are used. Population is decided by demand from outside of the region, labor participation ratio, demographic composition and relationship of commuting with outside of the region. To determine output of industries, input-output approach is applied. For future estimation, assumption of export value is especially important if the target region is thought to (or, desired to) develop led by particular industry, such as automotive manufacturing or sightseeing. Passenger transport demand is estimated from the population and freight transport demand whereby it is a function of output by manufacturing industries. Floor area of commerce is determined from output of tertiary industries. Other than driving force, activity level of each sector, energy demand by fuels determined with three parameters. One is energy service demand per driving force, energy efficiency and fuel share. Diffusion of counter measures changes the value of these parameters, and GHG emissions.

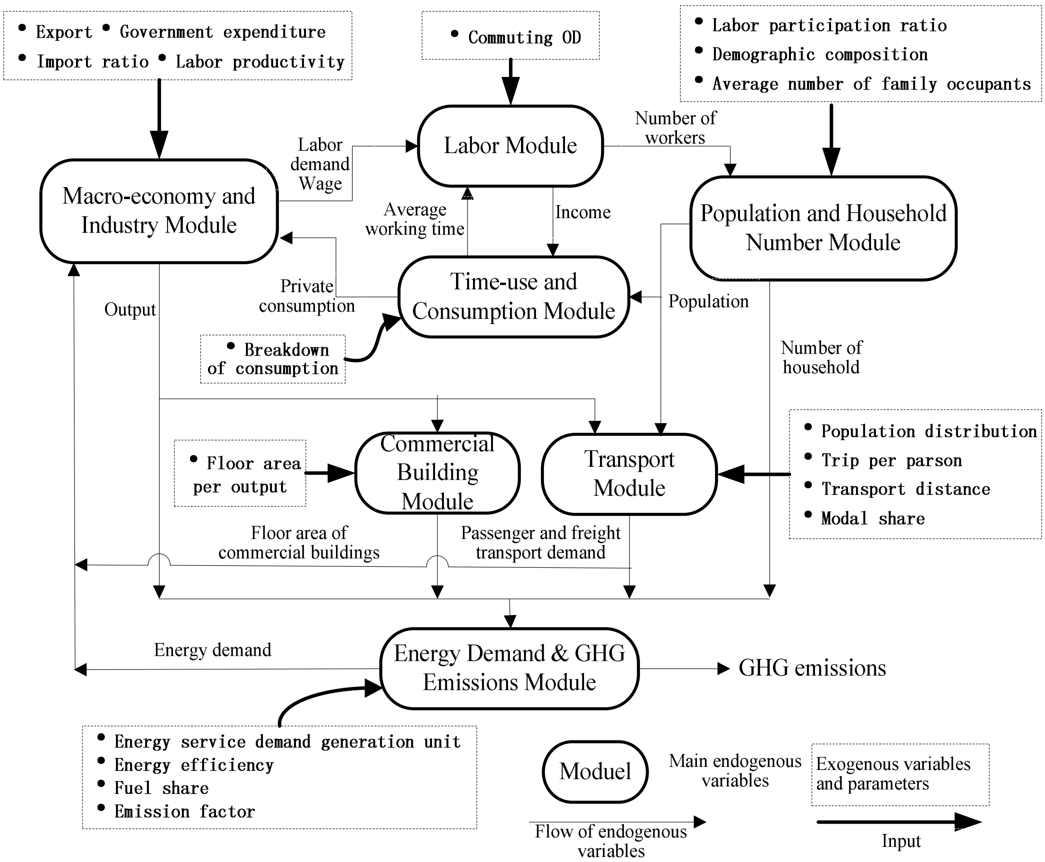


Fig. A2 Overview of calculation system of Extended snapshot Tool

Table A1. Industrial classification and its correspondence

Industry sector of 2002 IO table (42 sectors) in the original input-output table [18]	Sector after aggregation in this study (18 sectors)
Agriculture	Agriculture
Coal mining	Mining
Crude petroleum and natural gas	
Metallic ores	
Non-metallic ores	
Foods and tobacco	Food, Beverages and Tobacco
Textile products	Textile Products and Apparel
Wearing apparel and other textile products	
Timber, wooden products and furniture	Timber, Wooden Products and Furniture
Pulp, paper products and printing	Pulp, Paper Products and Printing
Petroleum refinery products	Petroleum Refinery, Coke and Nuclear Fuel
Chemical products	Chemical Industries
Non-metallic products	Non-metallic Mineral Products
Pig iron and crude steel	Metal Refinery and Metal Products
Steel products	
Industrial machinery	Machinery and Equipments
Transportation equipment	
Electronic computing equipment and accessory equipment	
Communication equipment	
Applied electronic equipment and electric measuring instrument	
Miscellaneous manufacturing products	Other Manufacture Industries
Reuse and recycling	Recycling Industries
Electricity and heat supply	Electricity, Heat and Water Supply
Gas supply	
Water supply	
Construction	Construction
Freight forwarding and storage	Transportation Related
Postal	
Information service and software	
Wholesale and retail industry	Wholesale and Retai
Lodging, eating and drinking places	Other Services
Financial and insureance	
Real estate	
Leasing and business services	
Travel business	
Research	
Technical services	
Other public services	
Education	
Medical service and social security	
Amusement and recreational services	
Public administration	

References:

[1] Xin Zhangping, Zhang Yintai. Low-carbon economics and low-carbon city, Urban Studies, 2008, 15(4): 98-102.

[2] Fujino, J., Ehara, T., Matsuoka, Y., et al. Back-casting analysis for 70% emission reduction in Japan by 2050. Climate Policy 8, 108-124 supplement.

[3] Gomi, K., Shimada, K., Matsuoka, Y. A low-carbon scenario creation method for a local-scale economy and its application in Kyoto city. Energy Policy, 2009.

[4] Li Xueling. The international trends of Low-carbon economics and strategy for China. Guangdong Economics, 2010, (5): 26-28.

[5] Feng Ying, Yang Chunlin. Low-carbon city is a new mechanism to improve the urban environment and development. Global Technology Economic Outlook, 2010, 25(3): 20-26.

[6] Japan Low-carbon Society scenario team, 2008. Japan Scenarios and Actions towards Low-Carbon Societies (LCSs).

[7] Vietnam Low-carbon Society scenario team. Sustainable Low-Carbon development towards 2030 in Vietnam.

[8] Guangzhou Bureau of Statistics, Guangzhou Investigation Team of National Bureau. Guangzhou Statistical Yearbook 2006. Beijing: China Statistics Press, 2006.

[9] Guangzhou Bureau of Statistics, Guangzhou Investigation Team of National Bureau. Guangzhou Statistical Yearbook 2010. Beijing: China Statistics Press, 2010.

[10] Guangzhou Bureau of Statistics, Guangzhou Investigation Team of National Bureau. Statistical Bulletin of Guangzhou National Economy and Social Development 2009. 2010,3. http://www.gzstats.gov.cn/tjgb/qstjgb/201004/t20100409_20933.htm

[11] National Bureau of Statistics of China. Main Data of the Fifth National Population Census. http://www.stats.gov.cn/tjsj/ndsj/renkoupucha/2000pucha/pucha.htm

[12] Guangzhou Bureau of Statistics. The 1% population sample survey bulletin of Guangzhou in 2005. http://www.gzstats.gov.cn/tjgb/glpcgb/200903/t20090306_5225.htm

[13] Guangdong Bureau of Statistics. Guangdong Statistical Yearbook 2006. Beijing: China Statistics Press, 2006.

[14] The Office of the National Coordination Committee on Climate Change serves, Energy Research Institute National Development and Reform Commission. The People’s Republic of China National Greenhouse Gas Inventory. Beijing: China Environment Press, 2007.

[15] Intergovernmental Panel on Climate Change. 2006 IPCC Guidelines for National Greenhouse Gas Inventories, the Institute for Global Environmental Strategies for the IPCC, 2006.

[16] Guangzhou Municipal Development & Reform Commission. The Eleventh Five-Year Plan of Guangzhou National Economy and Social Development. http://www.gd.gov.cn/ govpub/ fzgh/ sywgy/0200607030001.htm.

[17] Guangzhou Institute of Energy Conversion. The New Energy Development Plan of Guangzhou City (2008-2020), 2008.

[18] National bureau of statistics, national economic accounting department. China input-output tables (2007), Extended input-output table of 2005 in Guangdong province, 2009.

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