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Study on Systematic Solution for Promoting Capacity Building of Low-Carbon Town in APEC Economies

Energy Working Group

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Part 1. Introduction and background

1.1 The globalization background of low-carbon city capacity studies

In 2003, the UK government published the “White Paper on Energy”, themed "Our Energy Future: Creating a Low Carbon ". This white paper noted that the goal of a low-carbon is to achieve greater economic output, create ways and opportunities to achieve a higher living standard and better quality of life, and create new business opportunities and more employment opportunities by developing, applying and exporting advanced technologies through reduced consumption of natural resources and environmental pollution emissions. This white paper has aroused the concern of various governments, as well as the interest of experts and scholars in conducting various in-depth studies, thereby giving rise to the fad of low-carbon economic development.

With the development of low-carbon research practices, the Japanese government promulgated the "Japanese low-carbon social model and its feasibility study" in February 2007, requiring the 2050 CO_2 emissions to represent a 70% reduction from the 1990 level while proposing various low-carbon social models to be chosen.

With the acceleration of the urbanization process, global low-carbon development is increasingly concerned about cities’ development models and development paths. Academia, governments at all levels and international organizations began in 2007 to pay attention to the concept of the "low-carbon city". Although the concept of a low-carbon has been proposed before and has made great progress in construction practices, investigations on building low-carbon city capacity have been rarely reported.

International scholars have developed theoretical upgrades at the levels of the urban ecosystem, symbiotic city, smart growth and sustainable community mainly based on the idea of sustainable development and the recycling and have explored in practice such areas as low-carbon production, low-carbon energy, low-carbon transportation, low-carbon construction, and low-carbon communities. Comparatively, Chinese experts and scholars have been conducting more investigations on low-carbon cities and have emphasized the unique characteristics of China's construction of low-carbon cities and proposed policy recommendations for building low-carbon cities according to local conditions in different areas while learning from the low-carbon city construction experience of developed economies.

Searching in the full-text database of China Knowledge Network using the keyword "low-carbon city" generated a total of 869 papers published in 2008-2013. Based on these research results, we found that Chinese scholars mainly discussed topics such as connotations and features, development models, realization methods, evaluation systems, policy recommendations for low-carbon cities and international low-carbon city development practices. These studies have laid the foundation for effectively enhancing the capacity of the Asia-Pacific Economic Cooperation (APEC) economies in terms of low-carbon cities.

1.2 Background of China's low-carbon city capacity building

China is one of the most important members of the APEC economies; with the development of the concepts and practice of a low-carbon , a low-carbon society and low-carbon cities, China's experts and scholars are paying more attention to construction in low-carbon areas, and “constructing low-carbon city capacity” has become a hot topic in the research and practice of China's urban development. As of 2014, there were 36 pilot low-carbon cities, 286 smart cities and 15 EU-China green and smart cities in China.

1.3 Analysis of the necessity of this research

From the perspective of the development of the APEC economies, the APEC economies must now vigorously develop a low-carbon and build low-carbon cities. On the one hand, most members of the APEC economies are now in a period of rapid economic growth, accelerating urbanization and ever-increasing carbon emissions and industrial restructuring; on the other hand, a low-carbon is likely a new trend in future international economic development. Through implementing activities such as energy savings, emission reductions, clean production, a recycling and low-carbon city construction, low-carbon development has been actively pursued, which not only addresses the current international energy and environmental crises but also provides new opportunities for urban development in the APEC region.

From the perspective of city characteristics, on the one hand, cities play an important role in the economic and social development of the economy and are the key to solving some of the most complex and urgent problems in the world. On the other hand, as production and life centers of the world's population, cities are the main consumers of energy and the main emitters of greenhouse gases.

APEC has successfully held 10 ministerial meetings and 46 working group meetings to promote a variety of initiatives such as energy security, natural gas infrastructure investment and trade, and energy intensity reduction to enhance the exchanges and cooperation among the APEC members in areas such as energy policy, energy demand and supply outlook, energy efficiency, energy market reform, and new energy and renewable energy development. These preliminary works have undoubtedly guided the APEC economies in the capacity building and upgrading of low-carbon cities.

In summary, building smart and low-carbon towns to enhance their capacities is not only an effective way to alleviate the increasingly serious "urban disease" in the APEC region but also an important direction for the construction of the omnidirectional capacity of low-carbon cities in the

APEC region and the necessity of achieving highly efficient, inclusive and sustainable urbanization of the APEC economies.

Part 2. Literature review

2.1 Review of studies on the connotations and characteristics of low carbon cities

2.1.1 Review of studies on the connotations of low-carbon cities

Understanding the connotations of a low-carbon city directly affects the definition of low-carbon cities and construction practice, as well as the development models and evaluation systems.

Fu et al. argued that the requirements of low-carbon cities are to develop a low-carbon in cities, innovate low-carbon technologies, change lifestyles, minimize greenhouse gas emissions, and completely eliminate the past social mode of operation of mass production, high consumption and generation of a large quantity of waste to form an economic system with an optimized structure, recycling utilization and an energy-saving and high-efficiency, as well as healthy, resource-saving and low-carbon, way of life and consumption patterns, ultimately achieving the clean development, efficient development, low-carbon development and sustainable development of cities.

Xin et al. believed that the requirements of low-carbon cities are to implement a low-carbon in cities, including low carbon production and low carbon consumption, so as to establish a resource-saving and environmentally friendly society and construct a healthy and sustainable energy ecosystem.

The Sustainable Development Strategy Group of the Chinese Academy of Sciences also stated that low-carbon cities are to develop a low-carbon using urban space as the carrier, implement green transportation and construction to change the concept of consumer spending, and innovate low-carbon technologies to achieve the maximum reduction in the city’s greenhouse gas emissions.

China's energy and carbon emission research group believed that low-carbon cities refer to cities that adopt a low-carbon as their development model and direction and in which the public adopts a low-carbon life as the ideal behavior characteristics and the urban management adopts a low-carbon society as the model and blueprint for city development. Based on the above-described understanding of low-carbon cities by experts, we conclude that the so-called low-carbon city refers to achieving a low-carbon and a low-carbon social life in the city through technological innovations and changes in lifestyle so that the city's ecological environment is forcefully improved.

Most of the APEC region is in the process of industrialization. Low-carbon city construction in the APEC region should have its own characteristics, rather than resembling the post-industrial era in developed economies. From the interpretations of the connotations by different researchers, the consensus among experts and scholars is as follows.

1. The construction of low-carbon cities in the APEC region should be based on a low-carbon , and high energy utilization efficiency should be achieved on the premise of maintaining appropriate economic growth while maintaining the characteristics of low pollution, low emissions and high efficiency.

2. The areas of low-carbon construction involve the , society, culture and management, while the construction subjects involve the , social organizations, the public, the government, and more; therefore, the construction of a low-carbon city needs to make full use of the holistic role of the city's systems, focusing on low-carbon city planning and mobilizing all factors conducive to the realization of low-carbon economic development.

3. Low-carbon city construction is a multi-objective issue, and how to achieve the win-win situation of objectives such as economic development, ecological environmental protection, and improvement of living standards is the key to low-carbon city construction.

2.1.2 Studies on the characteristics and objectives of low-carbon cities

The essence of a low-carbon city is the harmonious development of man and the environment, and the goal of low-carbon city construction is to achieve economic growth and reduce carbon emissions in the process of urban development. Some scholars believe that one of the important goals of low-carbon city construction is for the carbon source to be smaller than the carbon sink, while others believe that the low-carbon urban development goals are “clean development, efficient development, low-carbon development and sustainable development." The short-term goal is to make the rate of increase of carbon emissions lower than the rate of urban economic growth, and the long-term goal is to achieve a reduction in total carbon emissions.

In contrast to the absolute decoupling of the development goals of developed economies in the post-industrial era, the low-carbon city construction in the APEC region should first strive to achieve relative decoupling of development goals. To achieve low-carbon economic restructuring, the construction of a low-carbon city should have two meanings: first, the proportion of carbon emissions corresponding to energy consumption declines steadily, i.e., a clean energy structure is achieved, which depends not only on natural resources but also on capital and technical capacity; second, the energy consumption per unit of output declines steadily, i.e., energy efficiency continues to improve.

2.2 Studies on the evaluation index system of low-carbon city construction

2.2.1 Studies on the principles of establishing an evaluation index system for low-carbon cities

By collating the principles of establishing an evaluation index system for low-carbon cities, we noted that the principles of scientificness, systematicness, comparability, operability and dynamicness have been unanimously endorsed by the majority of experts and scholars. Among them, in studying China's low-carbon city development of the Pearl River Delta Region, some scholars have proposed six principles for constructing the evaluation index system, i.e., scientificness, comprehensiveness, representativeness, comparability, dynamicness and feasibility. According to the driving force-state-response (DSR) model proposed by the United Economys Commission on Sustainable Development, the following principles should be considered in constructing the index system: (1) the indicators are concise and representative; (2) the indicators are accessible and comparable among different economies (economies); (3) the selection of indicators is linked to policy objectives; and (4) socio-economic indicators are compatible with environmental ones.

2.2.2 The construction of China's low-carbon city evaluation index system

(1) The comprehensive evaluation index system of a low-carbon city by the Chinese Academy of Social Sciences

In March 2011, the Chinese Academy of Social Sciences published a new standard system for evaluating low-carbon cities, which included 12 relative indicators in four categories (low-carbon productivity, low-carbon consumption, low-carbon resources and low-carbon policies)，as Table.1 shown.

Table 1. Standardization System of Evaluating Low-Carbon City by CASS

Cover the category	Involved in environment field	Index
Low carbon productivity Low carbon consumption Low carbon resources Low carbon policy	Low carbon productivity	Carbon emissions index of per industrial production value
		Index of per industrial Energy consumption
	Low carbon consumption	Per capita energy consumption
		Family per capita energy consumption
	Low carbon resources	Ratio of zero carbon energy in primary energy
		Forest coverage
		CO_2 emission coefficient of per Energy consumption
	Low carbon policy	Development plan of Low-Carbon
		Establish mechanism of monitoring, statistics and regulation
		The public cognition degree of Low-Carbon
		Measure up to the building energy consumption index
		The incentive measures of non-commercial energy

(2) The construction of a low-carbon city evaluation index system from the perspective of sustainable development

From the perspective of sustainable development, the methods used were the main index method and the composite index method. In general, the low-carbon city evaluation index system was constructed from three aspects (, society and environment) to describe five support systems of a low-carbon city, for which 23 indicators were used and divided into two major categories (target type and constraint type). The evaluation index of the low-carbon development level was divided into two levels by analyzing the key factors of low-carbon city construction, which included five level-1 indicators, including economic development, social progress, resource carrying, environmental protection and quality of life, and each level-1 indicator contained six level-2 indicators. In the case of the composite index method, a comprehensive evaluation model of an urban low-carbon needs to be established that evaluates the comprehensive development of the urban low-carbon using various indicators with regard to , technology, energy consumption, society and the environment, as Table.2 shown.

(3) The construction of a low-carbon city evaluation index system from urban energy consumption and emission components

Some experts have proposed that a comprehensive evaluation index system for a low-carbon city should include four indicators, i.e., carbon productivity, low-carbon energy structure, life consumption and low-carbon policy. If the four indicators of a city lead economically and even reach the intereconomical level, then the city is deemed a low-carbon city. The “relevant factors” of low-carbon city construction include eight aspects, i.e., economic growth, industrial structure, energy structure, energy efficiency, transport systems, consumption patterns, carbon sink development and institutional environment.

Table 2. Comprehensive Evaluation Indicator System of low-carbon development in Chinese city

First index	Proportion	Second index	Components index	Proportion
Index of economic transformation	60	Strength index of carbon	Strength of carbon emissions per gdp	45
		per capita carbon emission index	Per capita carbon emissions	15
Index of social transformation	10	Index of consumption structure	The proportion of low-carbon consumption about urban residents	5
		Index of employment contribution	Unit carbon emissions to provide the number of jobs	5
Index of equipment transformation	15	Index of Low-carbon building	The density of energy consumption about building	8
		Index of Low-carbon traffic	The preference of bus travel and the efficiency of public transport	7
low carbon Index of resource	10	Index of Low-carbon energy	Ratio of non-fossil energy	6
		Index of forest carbon sink	Forest coverage	4
Low carbon Index of environment	5	Index of Water Environment	Emission intensity of GOD	3
		Index of atmospheric environment	Emission intensity of SO_2	2

Many experts and scholars have investigated the evaluation index system of urban planning for low carbon cities from the perspectives of carbon reduction and carbon sequestration; regarding carbon reduction, they mainly emphasized the industrial carbon emissions mechanism and the traffic and building carbon emissions mechanism. The index system and weight were determined through the expert consultation method and the analytic hierarchy process based on the city's emissions mechanism and the main impact factors.

Regarding the city's low-carbon development plan, plans involving low carbon sources, low carbon flow and increased carbon sequestration have been proposed, in which the urban low-carbon development planning index system was divided into two levels: the four-macro-target level and the specific area indicator level. The four macro targets mainly included carbon emissions per unit energy consumption, carbon emissions per unit output, carbon emissions per capita, etc., while 19 specific area indicators were constructed from five areas (energy, industry, transportation, building and green space). The construction of a low-carbon city evaluation index system from the carbon source and carbon sink perspective mainly included four level-2 indicators (industrial low-carbon index, traffic low-carbon index, building low-carbon index and land carbon sink index) and 28 corresponding level-3 indicators. In the evaluation method, the ways to set the weights of the indicators and the evaluation model were presented, and ultimately, the urban low-carbon comprehensive index was established.

2.3 Studies on low-carbon city development models and construction approaches

2.3.1 Low-carbon urban development planning

Low-carbon urban development planning combines low-carbon ideas and technologies with urban development planning and spatial planning under certain social and economic development conditions that enable institutional arrangements regarding urban space and development timing. For example, the first eight chapters of the New York City Master Plan (2008-2030) all contain the relevant content and measures for "carbon reduction". However, the theoretical system and the planning and construction of China's low-carbon cities remain in the exploratory stage. Low-carbon city construction should have a relatively clear road map of construction planning, and the development direction and development model of the entire city should be grasped through the low-carbon city development plan.

At present, the construction of a low-carbon city from the perspective of urban planning has also attracted much attention from many researchers. These researchers highlighted that urban planning is the application platform for various "low carbon" ideas, theories and technologies, mainly reflected in policy topics such as land use and transportation planning, and reflects the outcome of public participation while also reflecting "low carbon" technology integration applications and creative ideas. Low-carbon urban development planning should produce provisions for the direction of both urban spatial planning and urban and rural land use planning.

2.3.2 Low-carbon urban development model

Most of the APEC region's low-carbon and low-carbon city construction are still in their infancy, and the exploration of low-carbon development paths with unique characteristics must make full use of the successful experience of developed economies. Among them, the five low-carbon urban development practice models of the C40 cities are particularly worth learning from: low-carbon urban energy (low-carbon base); the promotion of recycling industries and low-carbon production methods (low-carbon structure); the promotion of land use through urban spatial planning to shape low-carbon urban forms (low-carbon form); the construction of green transportation infrastructure and improvements in low-carbon technology application capability from the perspective of carbon sources (low-carbon support); and the promotion of low-carbon ideas to guide the behavior of the residents (low-carbon behavior).

China's current pilot low-carbon cities can be divided into three types:

First, local trials, e.g., Beijing and Shanghai, two mega cities. In practice, it is very difficult to implement full-scale city-wide development, and it is necessary to resort to exploring the construction of local low-carbon demonstration areas.

Second, the characteristic industry type, e.g., the construction of "China’s Power Valley" and "Solar City" proposed by Baoding City and the Turpan New Energy Demonstration Base in Xinjiang, among others.

Third, the systematic planning type, e.g., Jilin City, the old northeastern heavy industry city as the first low-carbon economic case study pilot city by the Economical Development and Reform Commission, and the reconstruction of Guangyuan City of Sichuan Province after the "5.12" earthquake.

2.3.3 Low-carbon town construction approaches

Viewing low-carbon city construction from the perspective of carbon sinks, forests are the largest carbon storage reservoir on earth and the most economical carbon sequestrator. The forestry carbon sink refers to the process, activity or mechanism of the forestry ecosystem in reducing the concentration of carbon dioxide in the atmosphere. Therefore, forests are an important way to achieve a low-carbon city and must be considered in the process of urbanization.

From the perspective of energy systems, low-carbon urban construction measures include the adjustment of industrial structure and energy structure to improve energy efficiency, save energy and reduce carbon emissions based on the material flow of the urban system. In addition, the development of a low-carbon and the construction of low-carbon cities also require strengthened financial support for the low-carbon and active development of the carbon financial market. The development of carbon finance is not only conducive to the reduction of emission reduction costs, the promotion of clean energy development and the expansion of financial innovations in China but also beneficial to promoting the transformation of the APEC regional toward a low-carbon .

Regarding low-carbon city construction approaches, we summarize the implementation methods and the C40 cities’ approach to low-carbon city construction as follows: (1) commercial development, i.e., the commercialization of low-carbon technologies and services by enterprises so that customers, businesses and cities all benefit through the driving interests; (2) policy guidance, in which low-carbon city construction is ensured through the development of policies and planning or laws, standards, norms, and so on in a given field; (3) community driving, in which residents are mobilized to participate in community-based low-carbon community building; and (4) project transplantation, in which coordieconomy and cooperation among intereconomical cities are conducted through the CDM clean mechanism, and carbon emission reduction projects are successfully introduced.

2.4 Studies on policy recommendations for low-carbon city construction

2.4.1 The role of government in the construction of low-carbon cities

(1) The government should become the main driver of low-carbon city construction and policy providers. Government-led force is mainly reflected in the institutional arrangements of low-carbon urban governance. It is necessary for China's cities to establish a complete institutional system, including the target system, action plans, and

incentive mechanisms, as well as the corresponding regulations and standards, at the government level so that the transformation to low carbon can be achieved.

(2) The government should take into account the low-carbon city concept and development in the overall city planning and make "urbanization and low-carbonization" the new direction and target in urban construction.

(3) In low-carbon city construction, the government should establish a systemic governance structure to form three-party complementary cooperation among the government, market (business) and citizens. While playing the leading role in the construction of low-carbon cities, the government must coordinate broad participation by various parties in society, including enterprises, NGOs and citizens.

(4) While encouraging trials of low-carbon cities and low-carbon communities, the government should accelerate the development of the relevant standards for low-carbon cities, low-carbon communities, low-carbon buildings and low-carbon transportation.

2.4.2 Policy options for low-carbon city development

The APEC region is vast, with varying geographical locations and climate conditions and enormous differences in industrial structure and the level of economic development among cities from different areas; therefore, it is necessary to set reasonable goals and measures for coordieconomy policies according to local conditions. The construction of low-carbon cities should comprehensively consider various urban objectives as much as possible to make full use of the role of policy synergies, e.g., while reducing energy consumption and carbon emissions and preventing and mitigating disasters, it should also consider synergies such as the creation of employment opportunities, the promotion of social equity, ecological protection and the sustainable use of resources.

Table 3. Governance In the three subjects and four fields

	Industrial production	Transportation	Architectural usage	Utilization and development of new energy sources	Carbon Sink, Carbon car capture
Government	Circular and industrial policy based on government management	Compact low carbon city based on government management	Building low carbon policy based on government management	New energy incentives based on government management	Construction of green land and carbon car capture based on government management
Enterprise	Low carbon production mode based on enterprise innovation	Low carbon type automobile manufacturing based on the enterprise production	Use low carbon buildings based on the enterprise manage	new energy development and utilization based on the enterprise innovation	Carbon capture technology based on the enterprise's technology development
Social	Low carbon consumption patterns based on the Citizen behavior	Low carbon way to travel based on the Citizen behavior	Low carbon living mode based on the Citizen behavior	New energy consumption patterns based on the Citizen behavior	Carbon sequestration policy based on the Citizen behavior

The start-up and development of low-carbon cities need to rely more on reforms at the institutional level, with forceful policy arrangements and policy implementation, and cannot do so without the participation of the government, enterprises and the public. The promotion measures and strategies for low-carbon urban development in Shanghai are shown in Table 3.

2.5 Studies on smart and low-carbon town capacity building

2.5.1 Practices and basic models of smart and low-carbon towns

(1) Major application practices abroad

Currently, there are more than 1,200 smart town projects and more than 1,500 low-carbon towns in implementation. With the application of information technology, the trend of the "intelligentization of low-carbon towns and low-carbonization of smart towns" is becoming increasingly more obvious. Many cities have conducted meaningful explorations in the practice of organic integration and interaction between intelligentization and low carbonization, as Table.4 shown.

Table 4. Main areas of smart low-carbon city development intereconomically

	Transportation	Living	Building	Municipal administration	Others
Singapore "Smart Garden"	ITMS reduces carbon emissions caused by congestion and saves the cost about $40 million	One Map and MyTransport.SG services improve the living efficiency of the resident.	Intelligent building with zero consumption, Multifunctionally external wall, Setup for light guide and sensor,	Rework process after secondary sewage treatment: Multi-functional sharing and utilization of Integrated water infrastructure and municipal facilities	Garbage power generation and utilization of biomass energy.
Amstdam "The European model"	Energy Dock project uses clean energy to charge the tanker and cargo ship .Through the link between mobile terminal and shore power station ,it can charge automatically.	Geuzenveld and WestOrange Intelligent energy-saving technology project; SmartMeter and Energy feedback display device; New energy management system;	Intelligent building project analyze the building energy use date, promoting the power system run more effectively.	Climate street project: automatically control illumieconomy of Energy Saving street lamp, solar energy garbage box	
Seoul "Ubiquitous City"	Intelligent transportation system, "Smart Seoul map"	Smart work center near-by workplace, "Seoul open data Plaza", Low energy consumption electronic information ecological display screen in	BRP, The recycling of new energy and renewable energy , the roof of high-property heat preservation material, regularly	monitoring and reminding the road, pipeline, emergency and other information with intelligent sensing equipment and network, providing nearly a	Intelligent environmental system can monitor the eco-environment index, and automatically send information to provide

		public places, distance education、medical treatment、tax affairs, Intelligent room on energy consumption control.	publish data on energy consumption of large buildings.	hundred online municipal services	real-time information for energy conservation and emission reduction and environmental protection.
Dubuc "The first smart city"	In order to better plan the traffic routes and improve the scheduling efficiency of public transport system, Dubuc uses radio frequency identification technology to track bus routes operation .	Set intelligent water meter , gas meter, water meter, NC,to prevent public facilities and residential waste water leakage,To achieve 6.6% water-saving.		Integrated detection platform for sustainable development of the city's water, electricity, gas, transportation, public services and other resources connects the data for the detection, transmission, analysis and display	
Tokyo "Advocater of Low-carbon wisdom "	ITS new plan has greatly improved the traffic jam and 40% carbon emissions.	Use energy from waste incineration, the heat energy contained in waste water and energy in other forms, to greatly reduce the environmental burden and to improve the utilization of energy	Lay down a criterion of Building Energy Saving Technology, advocate Energy Saving residence, use Energy Saving equipment; Intelligent analysis by compatibility system, Effective configuration management for power	Low power control system is widely used in city, temperature, pressure, humidity and rainfall for detection and analysis of information	Promote the use of solar energy, solar energy and geothermal energy

			control and consumption.		
Stockholm "Green capital of Europe"	Intelligent toll collection system has reduced road traffic emissions by 8%-14% and other greenhouse gas emissions by 40%.	Intelligent disposal system of domestic Waste: Classification of electronic trash recycling as required	The construction of Intelligent and informationization, the development with low carbon and efficiency		Increase the use of low carbon fuels; recycling system
London "Model of future city"	Intelligent transportation system: Each train is equipped with GPS, to the control room and passengers to provide the corresponding information.	The informative living service: full coverage of free WIFI, Fully digital restaurant operations; Urban network data center, the sharing and application of intelligent database gradually open	Architecture powered by hydrogen fuel cells makes the huge building energy consumption is only 1% for the use of of the ordinary fuel supply.	intelligent municipal facilities of Low carbon, the LED smart lights with iPad controlling ; the digital recycling bins of solar battery supply electrical energy; green recyclable tiles.	zero carbon community of Beddington through intelligent technology to make thermoelectric consumption than other ordinary communities decreased by more than 45%

(2) China's major application practices

China is in the initial and exploratory stage of constructing smart and low-carbon towns; based on existing trials, China has made some achievements in the process, as Figure.1 shown. Among them, some cities with better basic conditions, such as Shenzhen, Guangzhou and Hangzhou, have achieved significant results in the construction of smart and low-carbon towns and become the vanguard and leader in the development of smart and low-carbon towns in China, as Table.5 shown.

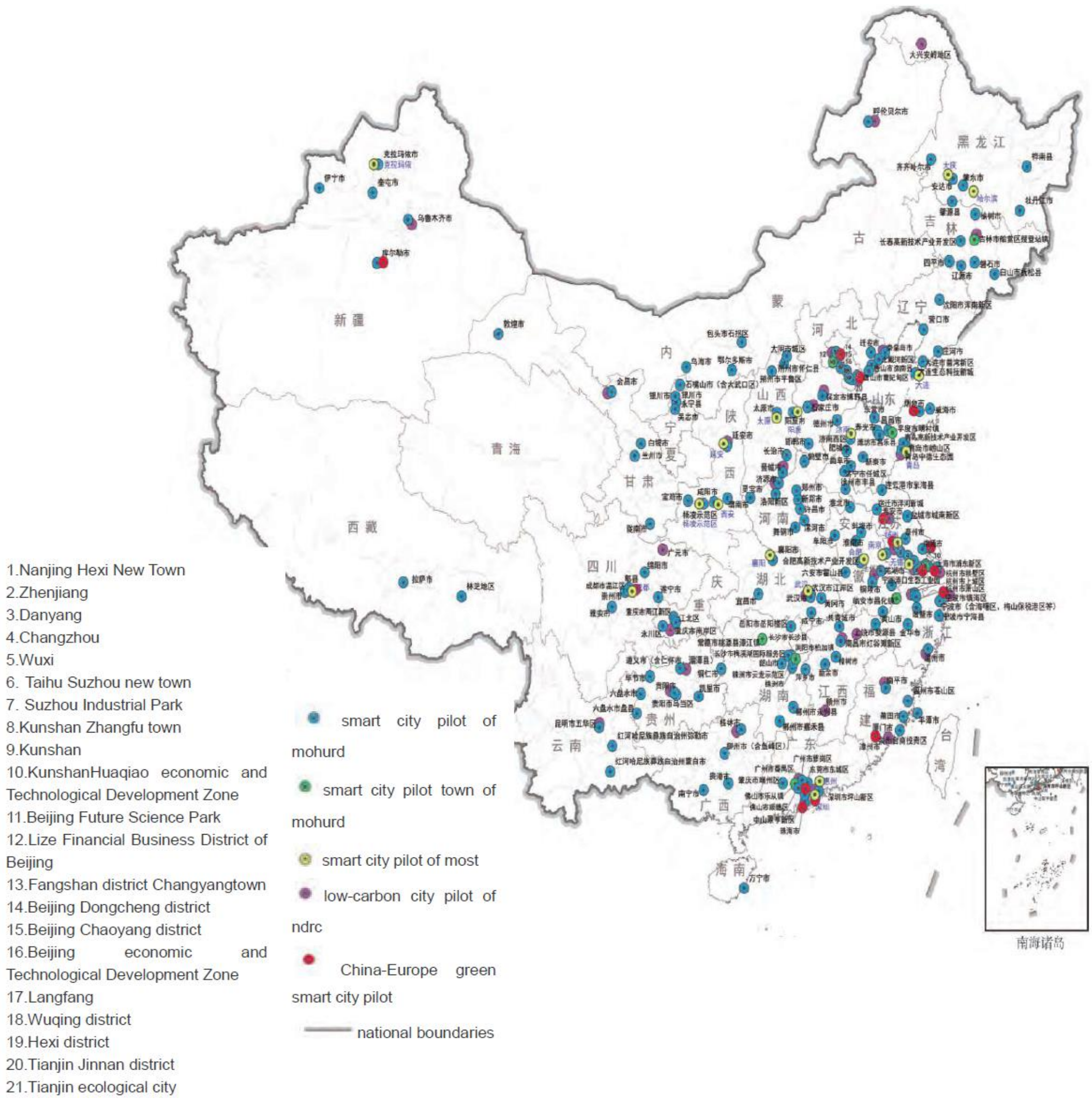


Figure 1. Low-carbon town activeness in China till 2015

Table 5. Main areas of smart low-carbon city development

City	Transportation	Living	Building	Municipal administration	Others
Shenzhen	The largest cities of application of new energy vehicles in the field of global public traffic:" Intelligent transportation network", Intelligent hub service system, the Electronic Bus Stop Board	Distance education, telemedicine , Trip-detection, Intelligent information network, Micro climate optimization, et al.	Low-power design, Large-scale utilization of renewable energy, structure physique system energy efficiency reconstruction of existin g buildings , et al.	Environmental monitoring, climatic forecasting, government affairs openness, emergency command, and other fields have achieved efficient integration services, of management information and resources	China's first carbon trading platform, has realized the 635 companies in industrial added 10000 yuan in carbon intensity decreased by 33.5% and carbon emissions decreased by 11.7%, the industrial added value growth of 42.6%
Hangzhou	Intelligent transportation infrastructure projects sets up parking guidance system and road information acquisition terminal by monitoring, contacting and scheduling people, vehicles and road	Information monitoring service for community elderly, community's security monitoring services, electronic health records service, home-school information interaction and network teaching, electronic comprehensively travel service platform, etc	The demand and the use of management system of Intelligent office building energy, building health records, intelligent environmental protection and energy saving renovation of unsafe buildings.	Wisdom urban management system, the quality of surface water environment automatically detect, intelligent regulatory environmental pollution	To promote e-commerce, instant messaging, such as the Internet and Internet , actively develop solar photovoltaic, biomass energy, new energy vehicles and other low carbon industry cluster of high-tech content

Shanghai	The wisdom of the public transportation system of intelligent transportation and information real-time query is constantly improving	Using intelligent means to improve health care, food safety monitoring, etc.	Energy audit of large commercial building; intelligent control and transformation of low carbon on building energy consumption	Internet faster, more convenient electronic government; with camera, micro base station LED Street powered with solar energy	Promote the effective use of renewable energy; promote the functional facilities, communications hub, the next generation of the Internet, radio management and other special construction
Wuhan	Intelligent transportation of network full coverage	Intelligent life service; intelligent logistics can achieve the product' full life cycle of the fine management; intelligent electronic medical records can achieve hospital electronic medical record sharing	Low carbon intelligent community and building: the existing building which intelligent low carbon transformation can achieve new residential building of the central city saving 65% energy.	Intelligent grid, optoelectronic interactive sensing network, network infrastructure, cloud platforms and public data centers, etc.	Low carbon innovation industry of wisdom and technology application: solar LED, geothermal heat pumps, water heat pump and soil source heat pump intelligent, other intelligent technology of heating and refrigeration
Beijing	Having built the scheduling command, traffic management, traffic monitoring, bus service and monitoring, cargo transportation, electronic toll	High-definition interactive digital TV network upgrades, The construction of wireless Internet and broadband wireless private network,	Application of automatic frequency converter, water metering systems, intelligent light control,	Information city operate monitoring platform and management system to achieve systematic regulation of the air pollution, traffic	Hydrology and water quality monitoring, water testing and environmental quality monitoring and

	collection, traffic information service and so on more than 80 intelligent application system	WIFI, etc. A complete coverage of the wireless network	heat recovery unit, fresh air system, intelligent home control system, automatic protection, security systems, etc	congestion, all kinds of carbon emissions, reducing carbon emissions by nearly 30%	pollution sources monitoring, carbon monoxide monitoring, etc
Guangzhou	One-stop intelligent transportation solutions, real-time traffic monitoring, car information integration services	Intelligent logistics, intelligent food traceability, intelligent medical, smart pay, intelligent safety regulation, smartly social security, etc	The transformation and construction of intelligent information and the development of high efficiency and low carbon	Intelligent power grid, municipal water distribution network platform, urban pipe network monitoring information platform	WeChat smart community
Ningbo	Buses wireless communication system, intelligent scheduling information, urban traffic induced services, intelligent traffic cloud, wisdom road comprehensive management system, etc	City information network, wireless network, basic information sharing; wisdom medical collaboration platform, public health service platform	building energy-saving standard,the renewable application of energy construction, the development of low carbon architectural technology, the low carbon design of whole life	The government cloud computing center, the underlying database and major database such as credit information	The system of Buildings and infrastructure effectively integrate with the spatial layout of the city
Nanjing	Intelligent traffic management systems and intelligent rail solutions		Resident health information electronic file	The modern intelligent power grid	

(3) The basic models of smart and low-carbon towns

Although there is no universally accepted definition of a smart and low-carbon town, many cities and towns have nonetheless explored and put the concepts into practice in urban construction by actively making good use of modern information technology tools based on their own development needs. By summing up the construction experience and the relevant studies of the construction of smart and low-carbon towns at home and abroad, we can group the basic models of smart and low-carbon towns into three categories, with a total of ten development models from three perspectives (the focus area, the participating players and the construction applications) , as Figure.2 shown.

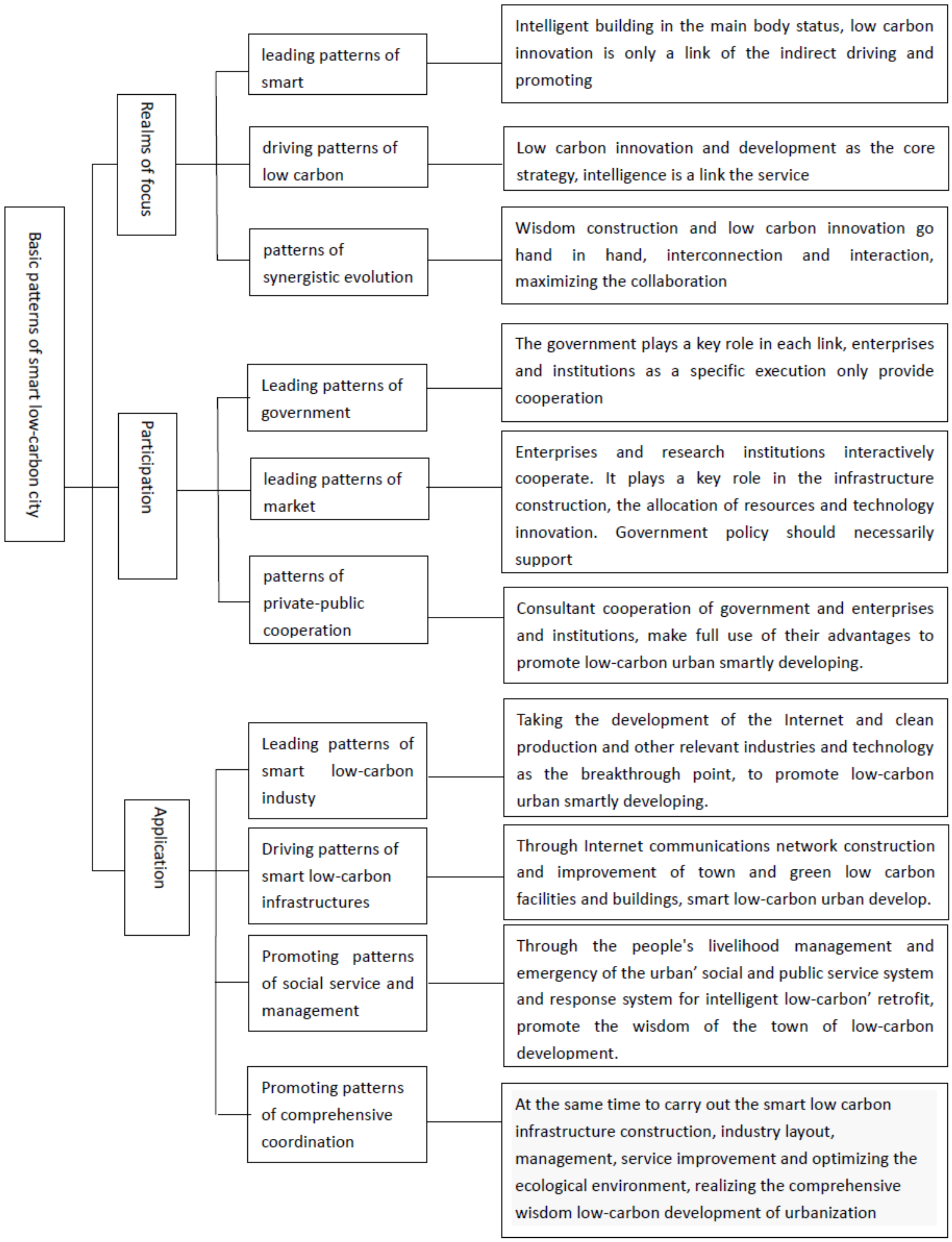


Figure 2. Basic patterns of smart low-carbon city

2.5.2 Studies on the policies of smart and low-carbon towns

(1) Major intereconomical policies

To construct smart and low-carbon towns, many economical and local governments have introduced relevant policies, plans and strategies to provide policy support and create the institutional environment. As Table.6 shown, in Europe, strategies and policy frameworks for the development and construction of smart and low-carbon towns have rather completely covered the entire EU, including urban agglomeration and each city level. In Asia, Singapore, Japan and Korea have adopted a series of development policies and action plans consistent with their economical conditions to provide a wide range of policy support for the construction of the economies' smart and low-carbon towns. In the United Kingdom, the relevant policy guidelines for research and practice planning have been systematically and comprehensively formulated and formed an effective institutional environment with long-term binding. In the United States, the federal government, state government and county and city governments have developed various relevant policies, bills and action plans from different levels and angles to promote the development of smart and low-carbon towns in multiple aspects. In addition, Japan, Korea, Malaysia, Russia, Singapore, Thailand, the United States and other economies have also proposed their own economical strategies, action plans and policy frameworks in terms of energy-saving, emission-reducing, green low-carbon, and intelligent innovation according to their economical characteristics and advantages, as Table.7 shown.

Table 6. Policies and programs for smart low-carbon city development

Japan	"New Energy Strategy", "21st Century Environmental Economical Strategy", "Tokyo Climate Change Strategy - Basic Policy of Low Carbon Tokyo Ten-Year Plan", "Low Carbon Technology Plan", "Low Carbon Social Action Plan" , "Action Plan for Expanding Utilization of Solar Power", "Green and Social Transformation", "U-Japan Plan", "I-Japan Strategy 2015", Japan's Low Carbon Social Situation in 2050, "Smart City Plan" and so on.
Korea	"Humanitarianism in the Digital Age: IT839 Strategy", "Overall Planning for Low Carbon and Green Growth", "U-Korea" Policy, "Ubiquitous City" Program and "Smart Seoul2015".
Malaysia	"Economical Environmental Policy", "Economical Green Technology Policy", "Economical Climate Change Policy", Multimedia Super Corridor, Iskandar Development Plan, etc.
Russia	"2010-2015 and the federal energy efficiency of the federal special plan", "2010-2015 and 2020, a new generation of nuclear energy technology", "2020 years ago, the use of renewable energy to improve the efficiency of power policy focus on economical policy."
Singapore	IT2000 "Smart Island Program", "Smarter Economy 2015" Program (IN2015), "Wisdom State 2025" Plan, etc.
Thailand	"Wisdom Thailand" development strategy, "ICT2020" economical ICT development framework
United States	The Low Carbon Act, the American Recovery and Reinvestment Act, the Economical Information Infrastructure (NII), and the Global Information Infrastructure (GII) program.
Brazil	Low-carbon agriculture program, the "resilience" of urban sustainable development, the Brazilian smart city development plan.
Britain	At the economical level, the Climate Change Act, the UK Low Carbon Transformation Strategy, the UK Renewable Energy Strategy, the Low Carbon Strategic Vision, the Low Carbon Transportation Strategy and the Digital Britain Program, Levels: London Energy Strategy, Action Plan for the Mayor's Response to Climate Change, Climate Change Action Plan, and the London Climate Change Agency.
Europe	City level: "SMARTIP Project", "Fireball Collaborative Action", "Life2.0" and so on; the city level: the European level: "European 2020 Strategy", "Information Society" Plan, "Internet Strategy Research Roadmap" The "lighthouse projects" in Copenhagen, and the "Smart City Action Plan" in Amsterdam.
India	The Economical Action Plan on Climate Change, the Five-Year Plan on New Energy and Renewable Energy, and the Economical Plan on Megagraj.

Table 7. Main policies and programs for smart low-carbon city development in China

Emphasis point	Major policies and programmes
Intelligence	**Policy:**”2006-2020 Economical Information Development Strategies”, "The several opinions of the State Council on promoting the information consumption to expand domestic demand"(No 32 Document in 2013 of the State Council), "The related work notice of accelerately implement the information Huimin project ", "’12th Five-Year’ The strategically cooperative agreement of intelligent city’s construction ", " Technical manual of Intelligent city cloud information platform’s pilot", " Technical offense of Intelligent city cloud information platform’s pilot”, “the Interim Measures of economical intelligent city’s pilot ", "Index system of economical Intelligent City’s (District, town) pilot (Trial) ", and" The opinion on promoting the healthy development of intelligent city "etc. **Solution:** Chinese intelligent city’s construction and strategically advanced research, the two batch of" economical mainly projects on ‘863’ smart city “, three intereconomically intelligent city’s pilot, pilot of economically smart tourism city and significantly information-based application project of gold card, other engineering research and construction project etc.
Low-carbon	**Policy:** “The Economical programme for Eco-Environmental Conservation”, " The construction index of ecological County, city, province (Trial)", "The work notice of developing low carbon and low carbon city’s pilot " (No 1587 in 2010 of Economical Development and Reform Commission of Climate Change]), " The implement opinion on demonstration work of the green key small towns’ pilot ", " Demonstration work notice about developing the first batch of green low carbon key small town’s pilot ", "About promoting the development of new energy vehicles and the management of energy contract" etc. **Solution:** The demonstration and application project of "Ten City 1000" energy-saving and new energy vehicle, The application and demonstration city’s plan of "Ten City million cover" semiconductor lighting, ” The implementation scheme of Building application of renewable energy demonstration city ", two batch of green low carbon key small towns pilot.
Comprehensiveness	The party's eighteenth Economical Congress report, "the CPC Central Committee on deepening reform of the overall number of major issues" and the "People's Republic of China economical economic and social development in the Twelfth Five Year Plan", "economically new urbanization plan (2014-2020)".

(2) China's major policies

China has been taking more proactive actions to promote the development of new cities and build modern smart and low-carbon towns using intelligent technology tools. The “Economical New Urbanization Program (2014-2020)”, released in March 2014, clearly defined green low-carbon cities and smart cities as key construction targets, providing a maneuverable concept for the organic interaction and deep integration of smart and low-carbon features in China's future urban development. At the same time, the relevant state ministries and research institutions provide scientific support and create the institutional and policy environment for China's smart and low-carbon town construction from various perspectives.

Almost all provinces and sub-provincial cities in China have proposed related concepts for the intelligentization and low carbonization of development and construction in their respective “Twelfth Five-year” Economical Economic And Social Development Plans, and in some regions, the relevant industrial planning, infrastructure construction planning and strategic cooperation framework agreement on the development of smart and low-carbon towns were also released to conduct top-level design and detailed planning on the regions’ overall concepts and sub-areas of the development of smart and low-carbon towns. Especially in mega-cities such as Beijing, Shanghai and Shenzhen, a variety of legal policies, planning programs, action plans and implementation outlines have been proposed to provide policy support for the construction of a smart and low-carbon city, as Table.8 shown.

Table 8. Regional and urban policies and plans in major smart low-carbon cities in China

Major city	Major policy and planning
Beijing	“Design Standard of Green Buildings”, “Rule of Beijing on the Prevention and Control of Atmospheric Pollution”, " Action plan of Beijing technical innovation (2013-2017)", "Beijing City Economical Economic and social development in the Twelfth Five Year Plan", "low carbon city development program", "Beijing’ urban informatization and the planning of mainly informational infrastructure construction ", " The improved plan of Beijing informational infrastructure (2009-2012)", " Action plan of smart Beijing " etc.
Shanghai	“The twelfth ‘Five-year’ plan of economical and social development of Shanghai municipality”,” Action Plan of Shanghai Municipality for Building Smart City”,” Action Scheme of Shanghai Municipality for Cloud Computing”, ”Regulation of Shanghai Municipality for E-commerce”, ”Action Scheme of Shanghai Municipality for Cloud Computing”, “The long-term plan of science and technology development of Shanghai municipality ”
Ningbo	“Strategic Co-operation Frame Agreement of construction pilot for commonly promoting the deeply essential amalgamation integration of information technology and industrialization and smart city”, “The decision of smart city construction of Ningbo municipality government and Ningbo Municipal Communist Party Committee”, ”Action Scheme of speedy building the smart city (2011-2015)”, ”Action plan of speedy building the smart city in 2012”.
Shenzhen	“The agreement of economically designated low-carbon Eco-Demonstration city’, " The reform and development plan of the Pearl River Delta region (2008-2020)", “The long-term plan of low carbon development of Shenzhen municipality(2011-2020) ”,”The rule on construction Energy Conservation of Shenzhen Special Economic Zone”, “The policy of new energy industry development of Shenzhen municipality”, ”The rule on construction Energy Conservation of Shenzhen Special Economic Zone”, “Design Standard of Green Buildings of Shenzhen municipality”, ”The rule on emission reduction and utilization of buildings of Shenzhen municipality”, ”Action Scheme of Shenzhen Municipality for ecological civilization construction”, “ The regulation of renewable energy utilization ”, ”Action Scheme for bulling capital of Green Building”, ”General Scheme of Shenzhen Municipality for synthetically reform”, ”General planning of Shenzhen Municipality(2007-2020)”, “General planning of economical innovative city

	Of Shenzhen Municipality (2008-2020)", "The twelfth 'Five-year' plan of economical and social development of Shanghai municipality", "The construction plan of smart Shenzhen (2013-2015)", "The planning outline of smart Shenzhen (2011-2020)" etc.
Guangzhou	" The reform and development plan of the Pearl River Delta region (2008-2020)", "The twelfth 'Five-year' plan of economical and social development of Guangzhou municipality ", "General planning of economical innovative city of Shenzhen Municipality (2011-2015)", " The implement opinion in strategic Building smart Guangzhou into A economical Central City ", " The implement opinion on building smart Guangzhou", "Strategic planning of nansha smart island construction of Shenzhen Municipality", "Action Scheme of Guangzhou Municipality for Cloud Computing (2011-2015)" etc.
Wuhan	"Digital wuhan", " Light city plan Wuhan ", "General planning and design scheme of buliding smart city of Wuhan Municipality", "The twelfth 'Five-year' plan of economical and social development of Wuhan municipality " etc.
Hangzhou	" The development planning of " 12th Five-Year "low carbon city of Hangzhou Municipality ", "The construction plan of smart Shenzhen(2013-2015)" " The implement opinion on pilot construction pilot of Hangzhou low-carbon transport system", "General planning of buliding smart city of Wuhan Municipality", "General construction planning of smart Wuhan".

2.6 Comments and discussion

2.6.1 General comments

The number of studies related to smart and low-carbon towns has rapidly increased and the research field enlarged while the content was growing more in-depth; the investigated regions are mainly located in China, the United States, and Europe, and the related evaluation method models and index systems have become increasingly more diversified as the applications gradually entered the stages of planning, pilot trial and demonstration while the policy support was gradually improved. Still, there are some shortcomings:

(1) The basic concepts and definitions are not clear. Although some scholars have investigated smart and low-carbon towns and conducted studies on conceptual frameworks, there is still no accepted definition or uniform norm and standard.

(2) A universal authoritative quantitative evaluation index system is lacking. At present, there are almost no quantitative criteria for smart and low-carbon towns, and the field remains blank. The existent related quantitative studies have been mainly focused on macroscopic discourse, quantitative thinking and frameworks, and the indicators are not sufficiently dynamic and elastic. Although there are plenty of index systems, they lack internal organic links, and a more comprehensive and complete, universal and authoritative evaluation index system is not yet available.

(3) Systematic and cross-disciplinary investigations are inadequate. Current studies have been mainly in the fields of management science, computer science and ecology and rarely performed through interdisciplinary and systemic analyses, which makes it difficult to apply some suitable concepts and modeling techniques from engineering, economics and geography to smart and low-carbon towns and restricts further in-depth research.

(4) Studies on the development mechanism and model optimization have not yet been initiated. The research focus of smart and low-carbon

towns remains on aspects such as technology application, measurement and evaluation and construction methods, while the analysis and identification of important internal mechanisms and development-related principles, such as the dynamic mechanisms, evolution mechanisms, dynamic change patterns, adaptive modes and evaluation, construction paths and optimization control, remain lacking, and even if there are a few studies, they are mostly qualitative ones. Key issues among major influencing factors in the development of smart and low-carbon towns, such as interaction coupling, interactive evolution, coordieconomy and adaptation channels and typical development models, have not been addressed yet.

2.6.2 Development direction

(1) Clearly, defining basic concepts and connotations. Based on a full grasp and understanding of the existing research, the basic characteristics, concept and nature of smart and low-carbon towns should be comprehensively investigated to form a comprehensive and complete definition of a smart and low-carbon city that is clear, with rich connotations, distinctive features and appropriate extensions.

(2) Strengthening cross-disciplinary integration studies. Through studying and borrowing theories and methods from geography, urban planning, ecology, economics, engineering, management science and other fields, the concepts related to smart and low-carbon towns should be

analyzed and empirically tested from multiple perspectives, and the occurrence and development mechanisms, evolution mechanisms and interactive coupling processes should be fully investigated to continuously enrich the conceptual system of smart and low-carbon city research.

(3) Establishing a theoretical and methodological research system that is suitable for smart and low-carbon towns in the APEC region. The unique nature of the environment in the developing APEC region and the start-up stage of the academic community in the study of smart and low-carbon towns make it especially important to develop a theoretical and methodological research system for smart and low-carbon towns that is suitable for the APEC region. Investigations on problems such as the basic connotations, the dynamic mechanisms of development and evolution, construction models and paths and the optimization and control of smart and low-carbon towns from more comprehensive and complete, more novel and systemic and more realistic perspectives will have significant implications for the establishment of a reasonable and maneuverable measurement and evaluation research model and method index system, as well as the level and trend of the development of smart and low-carbon towns.

(4) Focusing on empirical studies on the development of smart and low-carbon towns. It is encouraged to adopt studies using data from continuous time periods and tracking design and to focus on typical cities

with different levels, scales, sizes and characteristics to conduct empirical studies and summarize the dynamic mechanism of the development and evolution of smart and low-carbon towns, main construction models, optimization and regulation paths and maneuverable policy norms and standards under multi-scenario and multi-factor influences.

Part 3. Summary and research on government documents about LCTs in China

3.1 Policy perspectives of China's low-carbon city construction

3.1.1 Economical low-carbon city pilot policy

The Economical Development and Reform Commission of the People's Republic of China (NDRC) initiated the construction of pilot low-carbon provinces and cities in July 2010, and Tianjin, Chongqing, Shenzhen, Xiamen, Hangzhou, Nanchang, Guiyang, and Baoding were selected as the low-carbon pilot cities. In December 2012, 27 cities, including Beijing, Shanghai, and Shijiazhuang, were designed as the second batch of economical low-carbon pilot cities. In terms of low-carbon development planning, statistical analyses and management systems for greenhouse gas emission data, low-carbon industrial systems, low-carbon lifestyles, supporting policies, greenhouse gas emission target responsibility systems, etc., policy requirements have been proposed for the pilot cities. In June 2011, the Ministry of Housing and Urban-Rural Development (MHURD) issued the Evaluation index for the construction of pilot green low-carbon small cities and towns to help evaluate the construction of green low-carbon small towns.

In promoting low-carbon city construction, China has emphasized intereconomical cooperation with economies advanced in low-carbon development and has actively carried out the construction of intereconomical demonstration projects of low-carbon cities. The NDRC, the Ministry of Science and Technology, and the MHURD cooperated with the United Kingdom (UK), the United States, Germany, and other European and American economies to conduct pilot demonstrations on low-carbon city construction.

In 2009, under the China-UK Joint Statement on Climate Change, the NDRC cooperated with the UK Strategic Program Foundation and assigned Nanchang City as the "low-carbon city pilot project". Together with the UK Research Council, the Ministry of Science and Technology launched the “Sino-UK low-carbon city development” dialogue mechanism, with the cities of Nanchang, Guangzhou, Shanghai, and Nanyang as the low-carbon development pilot cities.

In 2013, in collaboration with the United States Department of Energy, the MHURD assigned six cities, including Langfang City, as the China-US low-carbon eco-pilot cities. In 2014, the MHURD cooperated with the German Federal Ministry of Transport, Construction and Urban Development (BMVBS) and launched the "Sino-German Low-carbon Eco-city Cooperation Project", in which the cities of Yixing and Haimen of Jiangsu Province, Yantai of Shandong Province, Urumqi of Xinjiang, and Zhangjiakou of Hebei Province were chosen as the first batch of pilot demonstration cities. The MHURD also launched the "China-EU Low-carbon Eco-city Cooperation Project", in which Zhuhai and Luoyang were assigned as the comprehensive pilot cities, and other cities, such as Changzhou and Hefei, were chosen as special project pilot cities in 2015.

3.1.2 Low-carbon city construction promoting policies by local governments

Since Baoding City first introduced the Guideline on the construction of a low-carbon city of Baoding Municipal Government (draft) in 2008, some Chinese cities have issued a series of government documents or schemes on low-carbon city construction and proposed policies and actions on low-carbon development，as Table.9 shown. In addition, China's low-carbon pilot cities have developed various low-carbon city pilot programs based on their respective socio-economic characteristics. To ensure the implementation of government documents, plans and programs for low-carbon city construction, these cities have developed appropriate policy measures on a variety of aspects such as organization and management, statistical accounting and evaluation systems, target responsibility systems, industrial policies, fiscal and tax policies, low-carbon development special funds, government procurement, and carbon emission trading trials. In some cities, in addition to developing urban low-carbon development plans or government documents, they also initiated the development of local policies, regulations, and rules. For example, Shenzhen City has promulgated and implemented a series of rules and regulations related to urban low-carbon development beginning in 2010， as Table.10 shown.

Table 9. Local policy document of China's low carbon city construction

City	Policy documents and planning	Issue time
Baoding	Opinions of Baoding municipal government on the construction of low carbon city (for Trial Implementation)	December 2008
	Baoding municipal government on the construction of low carbon city guidance	October 2010
Hangzhou	Decision of Hangzhou Municipal People's Government of Hangzhou Municipal Committee of the Communist Party of China on the construction of low carbon city	December 2009
	Low carbon city development plan of Hangzhou city in 12th Five-Year	December 2011
Xiamen	Overall planning outline of low carbon city in Xiamen	March 2010
Jilin	Low carbon development plan of Jilin City	March 2010
Kunming	Kunming Municipal Committee of the Communist Party of China Kunming Municipal People's Government on the construction of low carbon Kunming views	June 2010
Guiyang	Guiyang low carbon development action plan (outline) (2010~2020)	July 2010
Jiangmen	Strategic planning for the development of low carbon city in Jiangmen city (2010~2020)	July 2011
Wuxi	Construction planning of low carbon city in Wuxi city in 12th Five-Year	November 2011
Nanchang	Development planning of low carbon city in Nanchang	November 2011
Shenzhen	Long term planning of low carbon development in Shenzhen city (2011~2020)	February 2012
Guangyuan	Low carbon development plan of Guangyuan city in 12th Five-Year	April 2012
Shijiazhuang	Shijiazhuang low carbon development "12th Five-Year" planning	May 2012
Zhenjiang	Opinions of the people's Government of Zhenjiang Municipality on accelerating the construction of low carbon cities	December 2012
Tianjin	Tianjin city to deal with climate change and low carbon development "12th Five-Year" planning	January 2013
Ganzhou	Decision on the construction of low carbon city in	September 2013

	Ganzhou	
	Ganzhou Municipal People's Government on the construction of low carbon city views	April 2014
Suzhou	Low carbon development plan of Suzhou City	February 2014
Qingdao	Low carbon development plan of Qingdao city (2014~2020)	September 2014
Guangzhou	Planning outline of low carbon city construction in Guangzhou City	Unknown

Table 10. Part of the policy related to low carbon development introduced by Shenzhen city

Field	Rules and regulations	The implementation of the time
Carbon trading	Carbon emissions trading management provisional regulations Of Shenzhen city	2014
Appraisal system	appraisal system of ecological civilization construction of Shenzhen city (try out)	2014
Government procurement	Government procurement catalogue of circular of Shenzhen city	2014
Transportation	New energy automobile application and implementation plan of Shenzhen city (2013-2015)	2014
	Advance eliminate incentive compensation plan of Consists car of Shenzhen city (2013-2015)	2013
	Motor vehicle exhaust pollution control regulations of Shenzhen special economic zones	2012
	New energy vehicles public charging station siting guidelines	2010
	Energy saving and new energy vehicle demonstration promote pilot implementation plan of Shenzhen city	2010
Building	The green building to promote of Shenzhen city	2013
	Public key cities for the construction energy conservation transformation construction special fund management procedures of Shenzhen city	2013
	Five new building energy efficiency assessment interim measures of Shenzhen city	2011
Atmosphere	Atmospheric environmental quality improvement perks of Shenzhen city	2013
	Atmospheric environmental quality improvement plan of Shenzhen city	2013
Energy conservation	Contract energy management financial reward fund management interim measures of Shenzhen city	2011
City planning	Green urban planning and design guideline of Shenzhen city	2010

3.1.3 Low-carbon development policies in urban areas

In the field of production, the relevant policies have been mainly related to the assessment and audit of energy-saving industrial fixed asset investment projects, industrial energy-saving and emission reduction, and the elimieconomy of backward production capacity.

In the field of construction, the relevant policies have been mainly related to public building energy-saving, energy-saving renovations of existing residential buildings, promoting green buildings and applying renewable energy to construction, i.e., developing relevant standards, norms and labeling systems focused on energy-saving in construction.

In the transportation sector, guiding policies on the construction of low-carbon transportation systems have been introduced and the construction of pilot cities with low-carbon transportation systems has been carried out. In the field of urban living, energy-saving and emission reduction action plans have been issued to the public, and policy measures such as “Project of benefiting the public with energy-saving products” have been implemented.

These policy measures prompted the development of low-carbon industries, promoted green buildings and low-carbon transportation, and advocated low-carbon lifestyles through administrative, technical, economic, publicity, and education measures in key areas such as industry, construction, transportation, and daily life to control greenhouse gas emissions.

3.2 Policy characteristics of China's low-carbon city construction

3.2.1 Policy evolution

In 1990, the Chinese government set up some relevant institutions to address climate change. China set up the Economical Climate Change Countermeasure Coordieconomy Team in 1998 and the Economical Climate Change Countermeasure Coordieconomy Leadership Team in 2007. In 2007, the NDRC sponsored and formulated the Economical Climate Change Countermeasure Program, and since 2008, the Annual Report on China's Policy and Action on Climate Change has been published annually. Given that cities are the largest producers of greenhouse gas emissions, urban low-carbon development has become the focus of the policy response to climate change. The launch of low-carbon pilot cities in 2010 indicated that the promotion of urban low-carbon development has formally been listed on the economical policy agenda. One of the main tasks of the low-carbon pilot cities was to formulate supporting policies to support low-carbon green development, to innovate institutional mechanisms conducive to low-carbon development, and to provide the basis for the economy’s policy decisions through policy tests.

3.2.2 Policy innovation paths

China's low-carbon city development practice is still in the exploratory stage, and the state tried to form a path using the policy "pilot demonstration-the accumulation of experience, promotion and expansion", which promoted policy innovation in urban low-carbon development. This low-carbon pilot city policy was essentially a methodology policy for the formation of policy decision-making strategies. There was no mature experience in low-carbon city construction in China, and the formation of a policy system required continuous practice, feedback, and adjustments, which enabled a policy system to be gradually accomplished through a gradual development process.

This type of policy innovation path is found using policy innovation practices and subsequently institutionalizing the successful policy measures through policy experiments in pilot cities by relying on continuous learning and drawing lessons from past experiences and investigations so that more mature policy arrangements can be gradually formed; i.e., low-carbon pilot works are first implemented in some cities, and once the cities establish certain practical experiences and policy innovations, the experiences and innovations are gradually extended to other parts of the economy. Policy learning and transplantation are important features of this policy innovation and diffusion process. In recent years, the NDRC and the MHURD have constructed low-carbon pilot cities (towns), demonstration projects, and intereconomical cooperations, which have played an important role in exploring the models and policy systems of China's low-carbon city construction with Chinese characteristics.

3.2.3 Policy decision levels

China's urban low-carbon development policy has a significant government-led top-down feature. Currently, low-carbon city development is being guided by the economy's policies on a macroscopic level and gradually extends to and refines policy design at the city's mid-scopic level and the micro-policy level of specific areas of operation.

In terms of the level of public policies, policy decisions generally cover three levels: economical, local, and departmental. At the economical level, macroscopic guiding policies are formulated; at the local level, planning and implementation programs (i.e., policies on how to implement policies) are created; and at the departmental level, specific implementation policies are developed.

First, the state proposes the economical programs and policies to combat climate change based on the stage of economic development and economical conditions, clarifies the goals and key areas of greenhouse gas emission reduction, and puts forward directional and principle-based policies for urban low-carbon development by promoting and implementing the construction of pilot low-carbon cities.

Second, each city introduces urban low-carbon development plans and formulates appropriate policy options based on its understanding of a low-carbon city and the tasks of a low-carbon pilot city.

Third, relevant departments implement each of the tasks to achieve the goal of controlling greenhouse gas emissions in key areas such as low-carbon industries, buildings, transportation, and lifestyle using appropriate policy tools and adopting certain policy instruments.

3.2.4 Types of policy development

First, regarding basic policies, the state proposes “we should integrate the concept and the principle of ecological civilization into the entire process of urbanization and take the road toward new urbanization that is intensive, intelligent, green, and low carbon.” Moreover, it puts forward the policy directions and requirements of urban low-carbon development through policy documents implementing low-carbon pilot cities.

Second, in terms of substantive policies, low-carbon pilot cities develop plans or government documents for low-carbon development and propose development goals, main tasks and policy safeguards for low-carbon cities.

Third, in terms of strategic policies, low-carbon policy directions in key areas such as industry, construction, transportation, and consumer spending have been clarified, and there have already been some policy measures regarding industrial energy-saving and emission reduction, green building, low-carbon transportation, etc., whereas some specific policy actions are being gradually implemented.

Fourth, in terms of rules and procedural policies, currently, administrative means, i.e., control-type policy tools, have been heavily used; however, the use of other policy instruments and tools are gradually acknowledged by all parties and are constantly enriched and improved.

3.3 China's low-carbon city policy problems

3.3.1 Urban low-carbon development policy system has not yet been formed

First, low-carbon city construction at the economical level is lacking systematic policy guidance. The state policies on low-carbon city construction are mostly macro-level policies, with unspecific and unclear content. The specific rules and procedures for implementing these policies are also lacking and far from being specifically implemented as the development practice for the entire city; however, the effect of implementation is still to be observed. In addition, policy measures for low-carbon development in each area of the cities are rather fragmented and do not support each other.

Second, various state departments have put forward some policies in the related fields such as industry, transportation, construction, and consumption and formulated policy documents and regulations such as the

Action Plan on Climate Change in Industry (2012-2020), Green Building Action Plan, Guidance on speeding up the green, recycling and low-carbon transport development and Energy-saving and emission reduction action plan; however, the implementation of these policies in the construction of low-carbon cities requires the convergence of implementation rules and relevant supporting policies by the local government.

3.3.2 Urban low-carbon development policy structure is irrational

Although many cities in the economy have proposed the development of low-carbon city construction, their understanding of low-carbon cities is still, to some extent, deviated and biased in terms of policy structure.

One of the cases is the many cities whose only purpose is to build their brand image and that lack solid actions and policy innovation incentives for the control of greenhouse gas emissions. In contrast, other cities are considering the construction of low-carbon cities from the perspective of industrial development and the construction of a new city. The former case forms the so-called "carbon-interest city", which is characterized by the development of low-carbon industries, whereas the latter case gives rise to a variety of new city construction projects in the name of a “low-carbon (eco) city”. In both cases, the policy focus of low-carbon city construction has been on the city's industrial areas and construction sectors, without adequate attention to other areas and sectors of urban development. From the perspective of policy formulation and implementation, policies on low-carbon industrial development are more real, while those on the other aspects are rather unsubstantiated.

3.3.3 Policy means for urban low-carbon development are too simple

Administrative order is the most important policy means for low-carbon city development in China, and there are only a few economic incentive policies that are based on market mechanisms. Various types of policy instruments that promote urban low-carbon development are not fully utilized. Even the commonly used orders, i.e., the control-style policies, are present in the form of government documents, mostly temporary ones, whereas policy tools related to low-carbon development, such as laws, regulations, standards, and norms, are incomplete. Furthermore, the long-term effectiveness of these policies still has significant room for improvement. Economic incentive policy tools are rarely applied, and financial subsidies are the staple incentives; however, there is a lack of effective policy tools such as carbon trading, carbon taxes, carbon financing, and low-carbon procurement. Even for commonly used government subsidies and tax relief policies, there are also problems with application areas and applicable sectors being too narrow and application forms being too simple. The public participation policies are nothing but propaganda and persuasion and lack specific measures to encourage low-carbon consumption by residents.

3.3.4 The efforts for the implementation of urban low-carbon development are inadequate

(1) At present, evaluation or assessment mechanisms for low-carbon city construction have not been established, and the effectiveness of policy implementation lacks an institutional guarantee. There are neither binding targets in the construction of low-carbon cities in China nor measurement and assessment index systems; thus, the low-carbon pilot cities lack policy innovation and external pressure for effective implementation.

(2) The management system of greenhouse gas emissions is not complete. At present, low-carbon pilot cities have set up the relevant institutions, but the city-level greenhouse gas emissions accounting systems, greenhouse gas emissions target responsibility systems, and low-carbon city construction evaluation indicators have not been established.

(3) The investment and incentives for low-carbon development are insufficient. Compared with the investment by developed economies in urban environmental control, China lacks long-term and stable capital investment mechanisms that are adapted to urban low-carbon development.

(4) The support areas and links to government financial investments are too simple. Most of the government subsidies go to the city's production areas and investment sectors, e.g., the development of

low-carbon industries and the procurement of low-carbon environmental protection facilities and equipment, whereas there is little support for low-carbon living consumption areas and operation sectors in the city.

3.4 Summary and policy recommendations

Using China's policy research as an example, it is recommended that the low-carbon city support policy of the Asia-Pacific Economic Cooperation (APEC) region should be improved in the following aspects:

(1) Improving the management system and strengthening the macroscopic guidance on low-carbon city construction. On the basis of drawing lessons from the relevant policies and measures of low-carbon city construction in developed regions and summarizing the experience of the construction of China's pilot cities, the management system for low-carbon city construction should be improved at the economical level and policies related to the standards, norms, assessment and evaluation of low-carbon city construction should be developed to give the necessary specific guidance on low-carbon city planning and construction.

(2) Strengthening policy coordieconomy and establishing an urban low-carbon development policy system. The establishment and improvement of an urban low-carbon development policy system are indispensable to promoting low-carbon urbanization development models. Urban low-carbon development involves many areas, and it is difficult for isolated sector policies or a single policy to achieve the overall goal of

low-carbon cities. Only by establishing low-carbon policy systems that have complete levels and sound mechanisms and are mutually supportive will a joint policy force be able to be formed and the low-carbon transformation of urban development be achieved.

(3) Innovating policy mechanisms and designing and utilizing various low-carbon policy tools. Low-carbon city construction involves complex interest relations, and we should learn from the policy experience of developed economies and comprehensively utilize various types of policy tools, such as command-control, economic incentives, and social participation, by using a variety of policy mechanisms, such as administrative means, market instruments, and social means, through scientific policy design to prompt diverse actors, including the government, enterprises and the public, to act together.

(4) Choosing appropriate policy combieconomys timely according to the actual development of the city. The APEC economies have vast differences in geographical locations and development conditions and are in different stages of the development and construction of low-carbon cities. Each region should flexibly choose and innovatively use various policy combieconomys based on its own characteristics and phased targets to introduce corresponding policy measures step-by-step in a planned manner.

Part 4. Modeling method research towards capacity buidling of LCTs

4.1 Assessment models of carbon emissions for green eco-city low-carbon planning, construction, and management

4.1.1 Significance of the assessment model

The APEC region low-carbon urbanization development models have been identified as the economical development policy. However, while promoting green eco-city planning and construction, investigations on enhancing scientific decision-making in urban planning are still lacking. To incorporate low-carbon urbanization objectives into the statutory decision-making process for urban planning and management, it is necessary to have scientific and quantitative measures to assess carbon emissions that arise from the planning programs and management decisions.

At present, studies in this field mainly focus on greenhouse gas emission inventory and assessment methods at the overall and macroscopic economical, provincial and city levels, whereas theoretical research and practices on carbon emission assessment at the urban planning level are severely lacking, which makes it difficult to measure the effectiveness of green eco-city planning and construction management on coping with climate change. Since the implementation of green eco-cities mainly requires the implementation of statutory detailed planning, it is necessary to establish carbon emission assessment methods that are suitable for the detailed planning of green eco-cities, promote "emission reduction-oriented" management mechanisms at the mid-scopic urban space scale, and reflect the demonstration role of green eco-cities in the implementation of carbon emission reduction by analyzing the carbon reduction benefits of relevant component indicators.

In this section, by analyzing the main carbon emission/elimieconomy departments in green eco-cities, the carbon emission assessment model of green eco-cities is proposed and the carbon emission assessment methods and data collection sources of each panel are collated.

4.1.2 Evaluation model and evaluation index system of carbon emissions in green ecology demonstration areas

(1) Carbon emission assessment model in green ecological demonstration areas

Carbon emissions on the spatial scale of green eco-cities are mainly from departments such as construction, transportation, industry, water resources, waste, and road facilities. Because the economic activities of green eco-cities are dominated by tertiary industry and there are few carbon emissions from industrial production, the most important carbon emissions sectors are construction and transportation, water resources, waste disposal, road lighting and other municipal facilities related to construction and management. It is necessary to consider carbon removal by urban green spaces and carbon mitigation due to the replacement of conventional energy sources with alternative energy sources when developing a carbon emission assessment model. Therefore, it is recommended to establish an urban carbon emission assessment model framework as shown in Figure. 3.

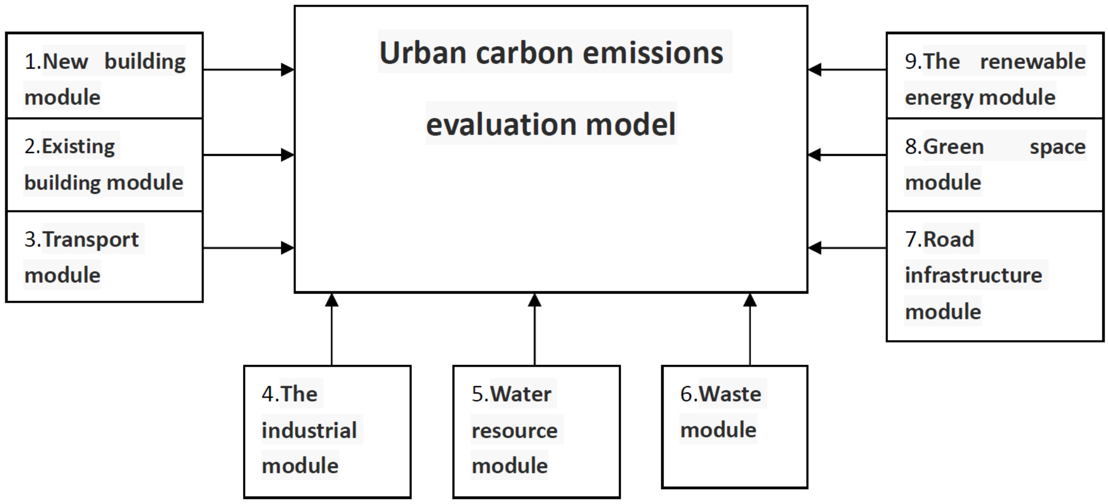


Figure 3. Recommended framework for an urban carbon emission assessment model

It is also recommended to use Equation (1) to improve the estimation method and analyze the activities and carbon emission characteristics of each panel. In addition, it is also advised to calculate the carbon emissions of each panel through the amount of activity, the intensity of energy consumption, and the emission factors and to calculate the total urban carbon emissions and the proportion of carbon emissions of each panel in the total emissions. In the green eco-city carbon emission assessment model formula, the net emissions value is obtained by subtracting the carbon removal amount from the amount of carbon emissions detailed in the green eco-city planning.

$$C = \sum_i A_{di} e_i + W e_w - A_g e_g \qquad (1)$$

In Equation (1): C is the annual net carbon emissions of green ecological urban detailed planning(t CO_2e per year);A_{di} is the active carbon emissions of the i, expressing in energy consumption (i=1,···,6; 1 is a new building; 2 is a existing building; 3 is transportation; 4 is industry; 5 is the water resource; 6 is road infrastructure), according to different energy types: power consumption(kwh per year), gas consumption(Nm^3 per year), gasoline and diesel consumption(L per year), standard coal consumption of energy consumption(tce per year), etc. e_i is active carbon emission coefficient of energy consumption of i. W is quantity of waste covering(m^3). e_w is carbon emission coefficient of waste covering(t CO_2 e m^3 per year). A_g is the areas of green in urban(hm^2); e_g is carbon removal coefficient (t CO_2 e m^3 per hm^2 per year).

The carbon footprint at the detailed planning level comes mainly from the above-mentioned six aspects of energy consumption, plus the greenhouse gas methane (which can be converted to a carbon dioxide equivalent and is generated from landfills) and green land. The status and planning scale of these eight types of activities can be obtained from the current situation maps, planning map legends, texts, and special planning of the detailed control planning. After the annual carbon emissions of each category are estimated, the sum of all categories is the total carbon emission value in the planning area. Renewable energy can be treated as a panel that is independently measured to be used to assess the efficiency of renewable uses in urban construction, transportation, municipal, and other activities. The energy consumption of different amounts of activity, the emission factors of different levels of energy consumption, and the emission factors of waste as parameters are analyzed and collated through the investigation and reference of relevant literature（Table.11）and are further used as the emission/removal coefficient of the evaluation model

Table 11. Green ecological city planning：Activity and reference factor

Carbon plate	Activity	The date source/ Collection methods	Reference emission factor data sources
1.New buildings 2.Existed building	Construction area of : ·Energy consumption per unit building area ·Building energy structure	·Regulatory detailed plan ·To build a detailed plan ·The economical energy statistics yearbook ·Department of research ·Refer to the research literature ·Building energy efficiency |Energy special planning ·Green building special planning ·Urban energy consumption quota ·Building user survey	All kinds of fossil energy emission factor ： ·The IPCC and the economical list of greenhouse gases ·Economical list of greenhouse gases ·Development and reform commission issued the grid emission factor ·Other official energy data
3.The traffic	·Traffic and transportation share rate ·Transportation capacity and the average trip distance ·Transportation fuel structure ·Energy consumption per unit trip distance	·Regulatory detailed plan ·The economical energy consumption statistical yearbook ·Department of research ·Refer to the research literature ·Traffic planning special planning ·Transportation research	Different fuel emission factor ·Official release energy data
4.Industrial	·Different industries/Industrial added value of the industry ·Unit energy consumption of	·Enterprises can use research ·Department of research ·The economical energy statistics yearbook	Industrial emission factor： ·The ipcc and the economical list of greenhouse gases

	industrial production ·Can be used in industry structure	·The state | city statistical yearbook	·Official release energy data
5.The water resources （The water supply |Sewage treatment ）	·Resident population and per capita water consumption ·Public building area and unit comprehensive water use ·Sewage treatment	·Regulatory detailed planning water/municipal sewage treatment special planning ·The local situation of urban water research literature ·Relevant standard specification	Water treatment (water / wastewater treatment) can use emission factor： ·Official release energy data ·Water supply company, municipal water supply, sewage treatment company related research of energy consumption ·Water supply and drainage process energy consumption related research literature
6.Waste	·Residential population and per capita living garbage output ·Employment and garbage output per capita ·Landfill volume ratio	·Regulatory detailed plan ·Sanitation special planning ·Local related research literature of the city	Energy emission factor and landfill emission factor ： ·The IPCC and economical emissions listing research ·The sanitation department investigation ·Landfill research literature ·Waste composting research literature
7.Road infrastructure	·Road at all levels and all levels of road lamp span length ·Road lamp energy consumption	·Regulatory detailed plan ·Lighting special planning ·City road lighting design standards	Energy emission factor ： ·China regional power grid baseline emission factor

		·Research department (municipal government, electric power company) ·Refer to the research literature	
8.Green space	·All kinds of green space area ·All kinds of green space percentage of trees	·Regulatory detailed plan ·Landscape planning and design ·Research department (garden department) ·Refer to the research literature ·The relevant design standards	Urban trees carbon elimieconomy factor： ·Research department (garden department) ·Refer to the research literature

(2) Carbon emission assessment index system for green ecological demonstration areas

Based on the spatial characteristics of green eco-cities, the following recommendations are put forward for the development of carbon emission assessment index systems:

(1) Total carbon emissions. By applying a common carbon emission assessment method, total urban carbon emissions are comparable; therefore, it is recommended to use total carbon emissions as one of the indicators for measuring urban carbon emissions.

(2) Per capita emissions. The definition of urban "per capita" includes urban resident and employment populations. Given that (A) the spatial scale of an urban area is smaller than that of a city as a whole; (B) smaller urban districts have a lower level of independence in their economic activities and industries; and (C) the differences in the residence/job ratios in different urban areas may be significant, it is difficult to establish a meaningful and comparable "per capita" basis value. Therefore, it is not recommended to use per capita emissions as an indicator for urban carbon emissions. If an urban district itself has a large spatial scale and the internal economic employment and proportion of the population reach an equilibrium, then the indicator of per capita gross domestic product (GDP) carbon emissions can be considered as one of the indicators.

(3) Unit GDP emissions. Since urban areas have a relatively small spatial scale, it is difficult to estimate their GDP value and thus obtain a meaningful and comparable GDP value; therefore, it is not recommended to use unit GDP emissions as a major indicator in assessing the carbon emissions of an urban area. If the urban area has a rather complete spatial scale and economic size, e.g., a new town, then carbon unit GDP emissions can be considered as one of the indicators.

(4) Unit construction land area emissions and unit construction area emissions. Because green ecological demonstration areas use detailed control planning as the basis of the assessment, as a city planning and construction management system, the main management and control base values are construction land and construction area; therefore, it is recommended to use "unit construction land area" and "unit construction area" (which can be subdivided into unit residential construction area and public building area or different types of buildings) as the basic and major indicators for the assessment and comparison of urban carbon emissions. It is recommended to use the following three main categories for the assessment:

1) Annual total carbon emissions;

2) Annual total carbon emissions per unit of construction land; and

3) Annual total carbon emissions per unit of construction area.

If the scope of the urban space reaches a certain level, to the scale of a town, and the internal economic employment and proportion of the population are relatively concentrated in the exchanges and transactions within the scope, the indicator of per capita GDP carbon emissions can also be considered as one of the indicators.

4.1.3 Summary

The planning and construction of green eco-cities should incorporate low-carbon urbanization goals into statutory urban planning and management decision-making while striving to establish scientific and quantitative evaluation methods for carbon emissions that result from planning and management decision-making. In this paper, we analyzed and collated the relevant theoretical research and planning practices in recent years in this field and sorted out the connotations of carbon emission assessment methods that are suitable for overall planning to establish a planning carbon emission assessment model suitable for the APEC region green eco-city spatial scale, which can be used to calculate the activities and emissions of carbon emission and the activities and emissions of carbon removal that are related to detailed planning.

4.2 Studies on the evaluation index system of low-carbon city construction in less developed APEC regions

4.2.1 Challenges faced by low-carbon city construction in less developed APEC regions

(1) Rapid economic growth has caused a substantial increase in energy consumption in production areas. In 2007, GDP growth in less developed regions reached 14.2%, which exceeded that of developed regions for the first time in history and remained higher for more than five consecutive years. The development of less developed areas cannot be separated from coal and oil-based fossil fuel resources, and to maintain rapid growth and large-scale industrial production under a high-carbon energy structure, a large quantity of greenhouse gas emissions is bound to be produced.

(2) Rapid population aggregation has led to ever increasing total greenhouse gas emissions in consumption areas. In the past five years, urbanization in less developed areas has accelerated, with an average annual urbanization rate of 2.1%, which is approximately twice as high as that in developed areas. In less developed areas, a new urban population of more than 6 million has been generated each year, and the cities with this increased population will produce approximately 42 million tons of greenhouse gas emissions annually based on the current consumption levels of coal, electricity, and gas by urban residents.

(3) The general public has a misunderstanding of the low-carbon city development concept. The public has an inadequate understanding of the level and model of low-carbon city construction and even misunderstand the direction of low-carbon city construction, which they feel simply emphasizes the absolute reduction of carbon emissions; this results in

timid development of energy consuming industries by less developed areas in the urban construction process.

4.2.2 The establishment of an evaluation index system for low-carbon city construction in less developed APEC regions

In this section, we use analytic hierarchy processes (AHP) to elaborate the overall design ideas for an evaluation index system for low-carbon city construction in less developed APEC regions and put forward the principles of index selection for a low-carbon city construction evaluation system.

(1) General design ideas

The Driving forces, Pressures, States, Impacts and Responses (DPSIR) model is an important methodology that is widely used by the Organisation for Economic Co-operation and Development (OECD) to evaluate the harmonious development between man and nature. In this study, we employed the DPSIR model to establish a set of multi-dimensional comprehensive evaluation index systems based on five aspects, i.e., driving forces, pressures, states, influences, and responses. The general design ideas are as follows:

First, the evaluation index of low-carbon city construction is set as the goal level, purporting to combine the multiple indicators at each level into a "total score".

Second, the rules level is established from the driving forces, pressures, states, influences, and responses. Based on these factors, the factor level is constructed, in which the driving forces are broken down into social productivity driving factors and residents' consumption driving factors, the pressures into ecological pressure factors and environmental pressure factors, the states into energy consumption state factors and greenhouse gas emission state factors, the influences into air influence factors and climate and temperature influence factors, and the responses into government response factors and public response factors.

Then, the index level is constructed based on the specific manifestation of each factor, and ultimately, an index system consisting of the goal level, rules level, factor level and index level is formed.

(2) Determieconomy of the index system

Based on the design ideas of the index system and the index selection principles of scientificness, systematicness, comparability, simplicity, and maneuverability, the evaluation index system for low-carbon city construction in less developed APEC regions is established, as shown in Table 12.

Table 12. Low carbon city construction level evaluation index system of the less developed areas in China

The target layer	Rule layer	Factors layer	Index layer	Index of the unit
Less developed areas of low carbon city construction level evaluation index	Driving force	Driving force factors of production	Economic growth(D1)	%
			GDP per capita	Yuan per person
			Urbanization rate	%
		Driving consumption	Per capita consumption expenditure	Yuan per person
			Per capita electricity consumption life	kw.h per person
	pressure	Energy consumption stress factors	Energy intensity	Tons of standard coal per million
			Unit energy consumption of industrial production	Tons of standard coal per million
		Greenhouse gas emissions stress factors	Per capita carbon emissions	Ton per person
			All carbon dioxide emissions	Ton per km^2
			Sulfur dioxide emissions per capita	Ton per person
			Both sulfur dioxide emissions	Ton per km^2
	state	Production status factors	Per capita green area	m^2 per person
			Forest coverage rate	%
		State environmental factors	Industrial effluents	%
			Industrial waste water discharge success rate	%
	impact	Factors affecting the air	Air quality falls below days all the year round	no
			The annual average air pollution index	dimensionless
		Climate temperature influence factors	The annual average temperature change rate	%
			Climate change index	dimensionless
	The response	The government response	Environmental protection investment accounted for the	%

		factorThe response factor	proportion of fiscal expenditure	
			Enterprise energy conservation and emissions reduction monitoring coverage	%
		The response factor	Can use solar energy, geothermal energy, or biogas family accounted for	%
			Energy-saving home appliances usage	%

4.2.3 Research implications

Compared with developed areas, less developed areas in the APEC regions need to maximize emission reduction and energy conservation while maintaining high growth, thereby assuming the dual tasks of “catching up" and “transforming” not only to catch up with developed regions but also to adjust their industrial structure and energy structure, which face tough challenges. In this section, the evaluation index system for low-carbon city construction in less developed APEC regions is constructed and the implications are as follows:

(1) At present, less developed areas of the APEC are characterized by high growth (high driving force), and the pressure on resources and the environment in these cities will only increase. Since “low carbon” cannot be achieved at the expense of economic development and people's quality of life, we must consider "carbon neutral" ways to ensure low-carbon city construction. The government can focus on supporting a group of carbon

emission trading markets in the less developed areas to vigorously promote green financing and green credit and present preferential policies in these markets to prompt enterprises in less developed areas to actively participate in emission offsetting mechanisms. The government should also formulate measures to strictly protect carbon sink resources such as forests, grasslands, and wetlands to allow them to fully participate in carbon sequestration.

(2) The construction of low-carbon cities in less developed APEC regions is essentially a multi-objective decision-making problem, i.e., to improve the ecological environment and reduce the impact of human activities on nature while maintaining social and economic development. This requires the relevant government departments to conduct overall planning for low-carbon city construction decision-making and fully consider the advantages of urban location and the ecological status quo so as to strive to develop low-carbon industrial systems suitable for the local conditions while taking into account environmental protection and achieving the harmonious coexistence between man and nature.

(3) Less developed APEC regions are generally more isolated, and the public in these areas have limited knowledge on the true meaning of the concept of low-carbon lifestyles and the relationship between daily consumption behaviors and emission reduction. Therefore, we should strive to strengthen advocacy on the awareness and knowledge of

low-carbon ideas to foster the atmosphere of saving electricity and water, using clean energy, improving energy efficiency and reducing greenhouse gas emissions. At the same time, we should also introduce a series of economic measures, such as energy-saving subsidies and environmental protection incentives, to encourage the public to live a low-carbon lifestyle in all aspects of their daily life such as clothing, food, housing, and travel.

Part 5. Case study on developing pattern of capacity building of LCTs

5.1 Case study of low-carbon town planning: follow-up development of the Urban Best Practices Area of the Shanghai World Expo

5.1.1 Background of the planning and scope of the carbon emission assessment

Follow-up development of the Urban Best Practices Area of the Shanghai World Expo has resulted in one of the main reservation areas of the Shanghai World Expo. It encompasses a complex that integrates offices, culture and art, conferences and exhibitions, business catering, entertainment and recreation, hotels and apartments, and open spaces. It is located in the northern part of the Shanghai World Expo Park on the north bank of the Huangpu River and has a controlled detailed planning area of 15.08 hm^2 (Figures 4 & 5), a floor area ratio of 1.67, and a total building area of 240,000 m^2. The planning data and the design plan are shown in Figure 6.

The data on carbon-emitting activities in this case study were mainly used to explain their application in the project. These data were adjusted case study data; the actual planning and construction data should be based on public information issued by government departments.

Figure 4. The Shanghai world expo scope of further development
Image Source: Shanghai municipal planning and land resources administration, 2012

Figure 5. The urban best practices area range of regulatory detailed planning
Image Source: Shanghai municipal planning and land resources administration, 2013

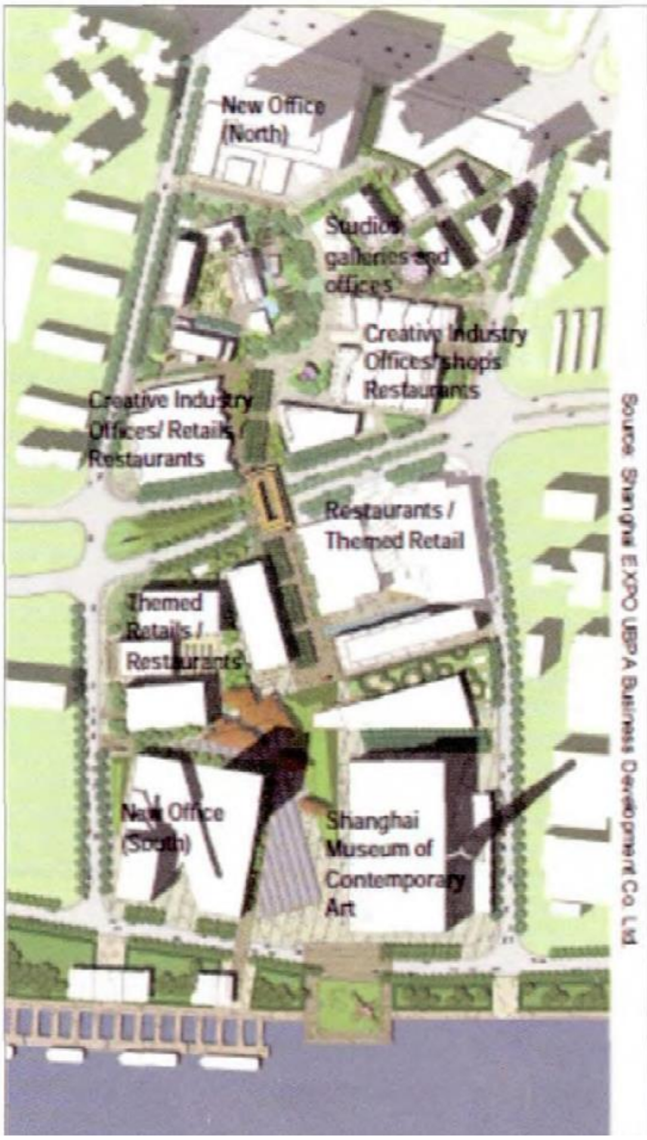


Figure 6. The Shanghai world expo urban best practices area subsequent planning

5.1.2 Detailed planning: method for assessing carbon emissions

The carbon emissions of the follow-up development of the Urban Best Practices Area of the Shanghai World Expo were assessed based on controlled detailed planning and detailed construction planning in which the carbon emissions of various activities within the red line surrounding the Urban Best Practices Area were assessed by collating the relevant planning data, such as the energy efficiency of the existing buildings, the current use of renewable energy, the green space landscape design, and supporting municipal facilities. Focusing on the relevant sources of carbon emissions in the plan, we established a framework for assessing carbon emissions in the follow-up development of the Urban Best Practices Area of the Shanghai World Expo. The main sources of emissions in the Urban Best Practices Area included construction, transportation, water resources, and waste; carbon was removed by green spaces and mitigated primarily through the use of renewable energy sources.

The carbon emission scenarios for the follow-up development of the Urban Best Practices Area of the Shanghai World Expo were divided into a baseline scenario and a low-carbon scenario. Since the end of 2014, the existing buildings and landscape of the site have been reused, and new buildings are expected to be completed in approximately 2017. The two scenarios and construction indicators for carbon emission assessment were as follows:

(1) The baseline scenario: This scenario was implemented under statutory and mandatory management control conditions based on the conventional development model without introducing additional low-carbon policy objectives and measures.

(2) The low-carbon scenario: On top of the basic statutory requirements, the current low-carbon construction policy objectives and the recommended means of the state and Shanghai City were added. In the

low-carbon scenario, the carbon emissions were calculated based on the low-carbon index system of the Urban Best Practices Area after the appropriate low-carbon technical measures were adopted. In Table 13, the indicators for the baseline and low-carbon scenarios are depicted, and the relevant low-carbon construction indicators for construction, transportation, water resources, waste, green space, and renewable energy are provided. The data for the main activities in the baseline scenario of the follow-up development of the Urban Best Practices Area of the Shanghai World Expo are shown in Table 14.

Table 13. The scenario of carbon emission assessment in Shanghai World Expo urban best practice area (%)

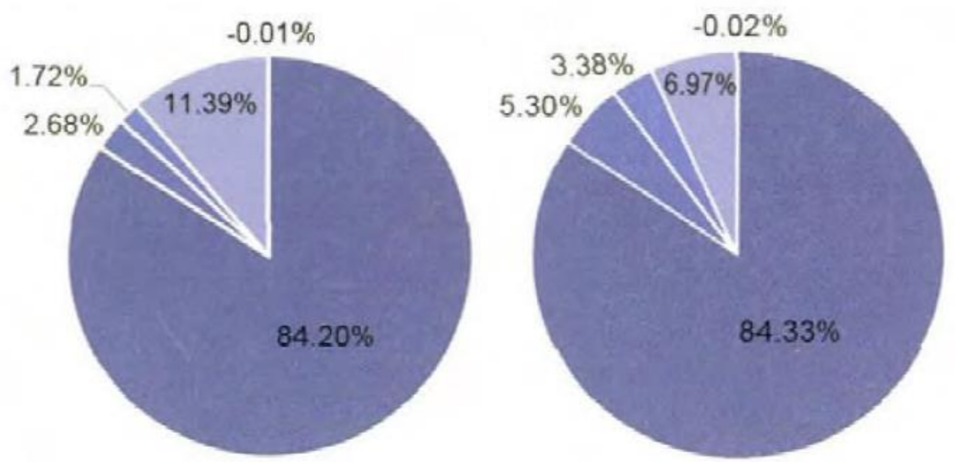
Emission block		Scenario		Baseline scenario	Low carbon scenario
1	Cities and towns	Efficiently saving energy	New building	50	60
			Renovated buildings	50	55
			Preserved buildings	50	50
2	Transportation	The rate of transit trip		50	47
3	Water resource	Utilization ratio of unconventional water resource		/	15
4	Waste	Garbage minimization		/	25
		The proportion of waste resources recovery		/	60
5	Green space	Forestation efficiency		38	40
6	Renewable energy	Renewable energy utilization ratio		/	22

Table 14. The main activity of scenario of carbon emission assessment in urban best practice area

<table>
<tr><td>Carbon emission</td><td colspan="2">Active amount</td></tr>
<tr><td>1.New building</td><td colspan="2">New building area:105950 m^2</td></tr>
<tr><td rowspan="9">2.Existing building</td><td colspan="2">Existing building area:107438 m^2</td></tr>
<tr><td colspan="2">Energy consumption per building area(kWh per m^2 per year):</td></tr>
<tr><td rowspan="2">*New building</td><td>Office:180</td></tr>
<tr><td>Commerce:180</td></tr>
<tr><td rowspan="2">*Existing building</td><td>Office:140</td></tr>
<tr><td>Commerce:220</td></tr>
<tr><td rowspan="2">*Preserved building</td><td>Office:140</td></tr>
<tr><td>Commerce:220</td></tr>
<tr><td>Energy structure</td><td>Electricity:100%</td></tr>
<tr><td rowspan="6">3.Transportation</td><td colspan="2">Trips: 10620 thousand people</td></tr>
<tr><td colspan="2">Transit trip ratio: 47%</td></tr>
<tr><td colspan="2">Average trip distance: 9.7 km per person every time</td></tr>
<tr><td rowspan="3">Energy consumption per kilometer
per people (KJ per person)</td><td>Rail transit: 322.4</td></tr>
<tr><td>Routine bus system: 714.0</td></tr>
<tr><td>Taxi: 2795.1</td></tr>
<tr><td rowspan="3">4.Water resources</td><td colspan="2">Feed water flow: 774 thousand m^3 per year</td></tr>
<tr><td colspan="2">Discharge of sewage: 97 thousand m^3 per year</td></tr>
<tr><td colspan="2">Energy consumption coefficient of feedwater ratio: 0.4 kWh/m^3</td></tr>
<tr><td rowspan="2">5.Waste</td><td colspan="2">Domestic waste output: 3974t</td></tr>
<tr><td colspan="2">The quantity of solid waste to landfill site: 3974t</td></tr>
<tr><td rowspan="2">6.Green space</td><td colspan="2">Green area: 2.96 hm^2</td></tr>
<tr><td colspan="2">Forestation efficiency: 38%</td></tr>
</table>

5.1.3 Carbon emission assessment conclusions and indicators

Assessments of the carbon emissions in the follow-up development of the Urban Best Practices Area of the Shanghai World Expo (the baseline scenario and the low-carbon scenario) were presented through carbon emission assessment indicators.



Building: 84.2% vs. 84.33%   The traffic 2.68% vs. 5.3%

The water resources 1.72% vs. 3.38%   Waste: 11.39% vs. 6.97%

Green space: -0.01% vs. -0.02

Figure 7. Benchmark scene points plate carbon emissions (Left) vs. Low carbon scenario plate carbon emissions (Right)

Based on the above-described assessments, data collation, and analysis of carbon emissions, the total carbon emissions of the follow-up development of the Urban Best Practices Area of the Shanghai World Expo in the baseline and low-carbon scenarios were approximately 36,371 tCO2e/year and 17,679 tCO2e/year, respectively, which represents a 51% reduction in carbon emissions. By decomposing the sources of carbon emissions in the Urban Best Practices Area, the carbon emission assessment indicators for each source were obtained; the relevant estimates

Table 15. The index system of carbon emissions of each block in Shanghai World Expo urban best practice area

Block	The index of carbon emissions	Unit	Baseline scenario	Low-carbon scenario
Cities and towns	Total emission amount of buildings	tCO_2e per year	30625	14909
	Emission amount of per building	$kgCO_2e/m^2$ per year	128	63
Transportation	Total emission amount of transportation	tCO_2e per year	1040	982
	Per trip distance	$kgCO_2e/km$ per year	0.014	0.014
Water resource	Total emission amount of water resource	$t\ CO_2e$ per year	367	342
	Water resource emission amount of per built-up area	$t\ CO_2e/hm^2$ per year	15	14.4
Waste	Total emission amount of waste	$t\ CO_2e$ per year	4173	1252
	Emission amount of per built-up area	$t\ CO_2e/hm^2$ per year	99	30
Green space	Total carbon removal amount of green space	$t\ CO_2e$ per year	3.44	3.62
	Carbon removal amount of per green space	$t\ CO_2e/hm^2$ per year	1.16	1.22
Renewable energy	Total carbon alleviation amount of renewable energy	$t\ CO_2e$ per year	/	6005
	Renewable energy on carbon alleviation amount of per built-up area	$t\ CO_2e/hm^2$ per year	/	142

and comparison results are shown in Figure 7. These results show that construction accounted for the largest share of the total carbon emissions and exceeded 84% in both scenarios. This assessment result reflects the fact that the study area was located in the center of an urban development whose main economic activity was in the service industry; therefore, the main sources of carbon emissions was energy consumption due to construction. The carbon emission evaluation index system for each source is shown in Table 15.

5.2 Case study of the application of the evaluation index system to low-carbon cities in underdeveloped areas: Guiyang

Guiyang, a typical underdeveloped area in China and one of China's important selected low-carbon pilot cities, has been promoting low-carbon city construction since 2008.

5.2.1 Data collection and standards

The original data were from the "Guiyang Statistical Yearbook," the "Guizhou Statistical Yearbook," the "China City Statistical Yearbook," the "China Meteorological Yearbook," and the "China Environment Statistical Yearbook" for the period from 2009 through 2013. Because the dimensions of the original data were not consistent, the original data were normalized to avoid excessive error in the calculation results. Because the indicators listed in Table 12 all had positive values, the mean method, in which the average of each index sequence was calculated and then each original data point was divided by the average, was adopted in the normalization process. This resulted in 115 normalized values that were also positive, as shown in Table 16.

5.2.2 Calculation of each index's weight

The entropy method is a method for determining the weight of each index that is particularly suitable for systems derived from multiple indexes, such as the one used in this study. With fj, pj, and uj defined as the weight, entropy, and value, respectively, of the jth index, k as the number of indexes, and m as the year (where the year 2008 is the first year, i.e., m = 1, and so on), Equations (2) and (3) are

$$f_j = \frac{1 - p_j}{\sum_{j=1}^{k}(1 - p_j)} \tag{2}$$

Among Equation (2):

$$p_j = -k\sum_{i=1}^{m}\left[\left\{\frac{\mu_{ij}}{\sum_{i=1}^{m}\mu_{ij}}\right\}.\ln\left\{\frac{\mu_{ij}}{\sum_{i=1}^{m}\mu_{ij}}\right\}\right] \tag{3}$$

Equations (2) and (3) is the eq for calculating index weight.

$$\text{Evaluation results}=\sum_{j=g}^{n}\left(f_{i\ j}\cdot\mu_{i\ j}\right) \qquad i=1,2,3,4,5 \tag{4}$$

When g=1 and h=5, g=6 and h=11, g=12 and h=15, g=16 and h=19, g=20 and h=23, Driving force , pressure, state, influence, response can be separately calculated, see Table 17.

Table 16. Standardization data of evaluation index of Guiyang low carbon city construction:2008-2012

Year	D_1	D_2	D_3	D_4	D_5	P_1	P_2	P_3	P_4	P_5	P_6	S_1	S_2	S_3	S_4	I_1	I_2	I_3	I_4	R_1	R_2	R_3	R_4
2008	1.246	0.762	0.805	0.777	0.698	0.894	0.814	0.904	0.760	0.819	0.916	0.742	0.982	0.748	0.685	1.185	1.224	0.829	1.326	0.854	0.565	0.888	0.665
2009	0.911	0.981	0.882	0.818	0.729	1.123	0.995	0.941	0.868	0.841	0.944	0.767	0.990	0.794	0.798	1.094	1.011	0.959	1.145	0.907	0.784	0.931	0.726
2010	0.892	1.055	0.934	1.042	0.804	1.197	1.267	1.038	0.923	0.985	0.927	0.895	0.995	0.930	0.847	1.057	0.962	1.359	1.028	0.947	0.862	1.079	0.989
2011	1.017	1.231	1.007	1.122	1.175	0.944	0.941	1.078	0.977	1.062	1.083	1.274	1.003	1.066	1.016	0.929	0.913	0.863	0.840	1.053	1.264	1.093	1.159
2012	1.193	1.290	1.109	1.209	1.292	0.744	0.830	0.904	1.286	1.197	1.111	1.314	1.009	1.212	1.493	0.891	0.877	0.782	0.827	1.209	1.395	1.251	1.263

Table 17. The evaluation results: 2008-2012

Year	Evaluation index	Driving force	Pressure	State	Influence	Response
2008	0.797	0.424	0.308	0.533	0.361	0.509
2009	0.746	0.479	0.379	0.494	0.431	0.583
2010	0.988	0.536	0.395	0.625	0.399	0.621
2011	1.210	0.551	0.421	0.762	0.326	0.644
2012	1.365	0.588	0.466	0.898	0.311	0.656

5.2.3 Results and analysis of the assessment

After integrating the data listed in Table 16 using Equation (4) with $g = 1$ and $h = 23$, evaluation indicators for 2008-2012 were obtained; they are shown in Table 17.

5.2.4 Results and Discussion

In terms of the driving force, pressure, status, influence, response, and evaluation indicators for 2008-2012 (Figure 11), the low-carbon city construction in Guiyang showed the following characteristics:

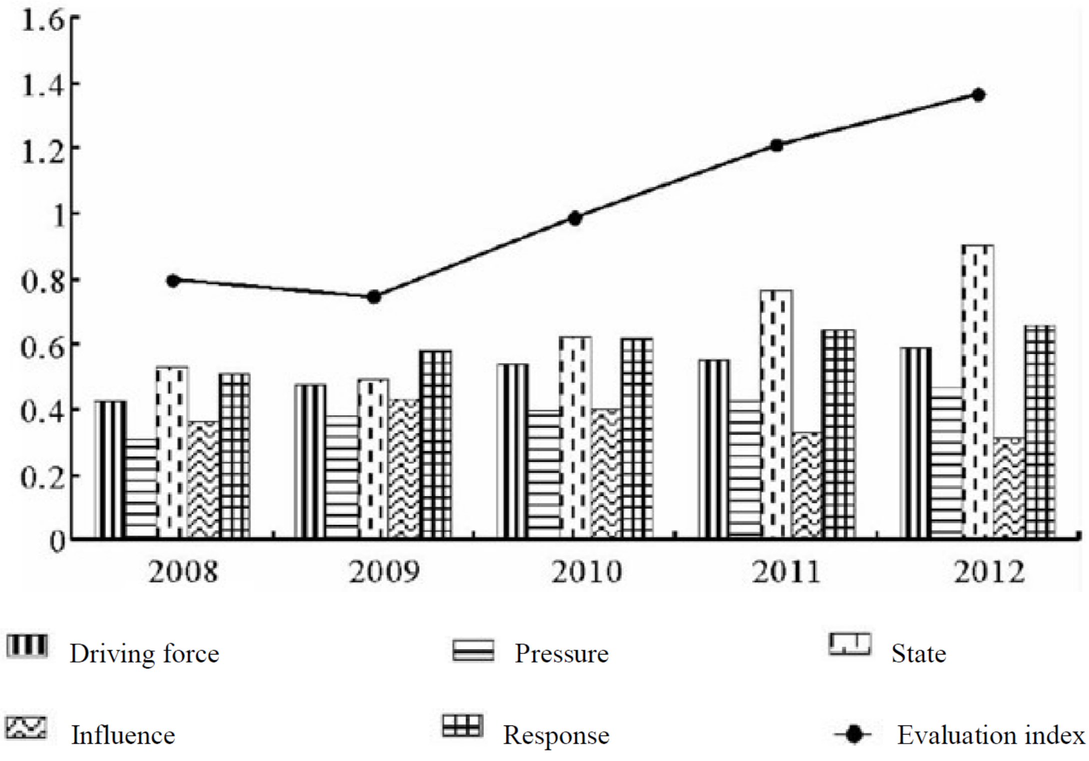


Figure 11. Driving force, Pressure, State, Influence, Response, Evaluation index:2008-2012

(1) The overall level of low-carbon city construction exhibited an upward trend. The total score, i.e., the evaluation indicator, shows that the evaluation indicators for the years 2008, 2009, 2010, 2011, and 2012 were

0.797, 0.746, 0.988, 1.21, and 1.365, respectively, with the overall value continuously increasing, and the evaluation indicators obtained in this study also revealed that “the higher the value was, the higher the level of low-carbon city construction was.” In recent years, Guiyang has not only been among the frontrunners in terms of social and economic development in China but also made significant achievements in optimizing industry and energy structures, especially in low-carbon urban construction, and has become a model of success for low-carbon city construction in China’s less-developed areas.

(2) The socio-economic driving force has been increasing year by year. The driving force continuously increased from 0.424 in 2008 to 0.588 in 2012, which indicates that social production and consumption drove the city's rapid development. According to the data in the “2013 China Statistical Yearbook,” the growth rate of the annual GDP of Guiyang from 2008 through 2013 was ranked second economically, and according to the “Report on the Competitiveness of Global Cities (2011-2012)” published by the Chinese Academy of Social Sciences, the growth rate of the comprehensive competitiveness of the region was ranked fourth in the economy.

(3) The value of the urban low-carbon pressure has been increasing. The pressure increased from 0.308 in 2008 to 0.466 in 2012, which indicates that the pressure of the greenhouse gas emissions caused by

economic growth, urban population growth, high consumption of coal, electricity and gas, etc., was increasing. In 2008, the per capita carbon emitted only 7.52 t/person in Guiyang; however, this value has increased to 10.27 t/person and 14.56 t/person in 2010 and 2012, respectively, which exerted an enormous pressure on Guiyang due to its low-carbon development.

(4) The development of the urban ecological environment has exhibited a good trend and has laid a solid foundation for the construction of low-carbon cities. The status decreased first and then increased; although the value decreased from 2008 to 2009, it has been increasing dramatically, from 0.494 to 0.898, ever since, which indicates that the urban ecological environment has been continuously improving. This is because, on the one hand, Guiyang has unique forest resources; it has the best forest coverage in China. According to the intereconomical standard that 1 hm^2 of forest can absorb 13 tCO_2 annually, Guiyang's forest resources can absorb 434 tCO_2 every year, which provides an excellent platform for carbon neutrality. On the other hand, in recent years, Guiyang has vigorously remediated industrial wastewater and waste gases, which strongly promotes the construction of a low-carbon city.

(5) The negative influences of air quality and climate temperature have been weakening. Although the negative influences strengthened in 2008 and 2009, they have gradually weakened from 0.431 to 0.311 since

2009, which indicates that the influence of human activities in the "human-nature dynamic balance mechanism" was decreasing in this region, which promotes low-carbon city construction.

(6) The responses of government departments and the public to the construction of low-carbon cities have become more and more active. The value of these responses continuously increased from 0.509 in 2008 to 0.656 in 2012 because on the one hand, the government provided policy support by developing relevant financial support while widely implementing monitoring of enterprises' energy-saving and emission reduction activities; on the other hand, the public responded actively and consciously practiced a low-carbon lifestyle.

5.3 Case of eco-city construction and comprehensive management: Yantai City

5.3.1 Evaluation of the comprehensive development capacity of the eco-city Yantai

(1) Evaluation index

By combining China's eco-city evaluation indicators and the natural and social status of Yantai City, representative indicators were selected for a scientific evaluation and comprehensive investigation of the structure, function, status, development strength, and trend of three social, economic, and natural subsystems of the city, and a pressure-state-response (PSR) index system that reflects the basic situation and the direction of the city's development direction (Table 18) and standard, current and planned values of each indicator (Table 19) were established. In addition to the selection of 22 indicators for economical eco-city construction, taking into account the characteristics of a coastal city, three indicators, i.e., the seawater intrusion area, the fishery eco-aquaculture area, and the marine environmental functional area compliance rate, were added; considering the actual prominent conflicts between the population, resources, , and environment of Yantai City, eight indicators, i.e., the improvement rate of soil and water loss, the registered unban unemployment rate, the average life expectancy, the proportion of high-tech industrial output in the output of designed-size enterprises, the ratio of environmental protection investment to the GDP, the ratio of science, technology, and education expenditures to the GDP, the number of people who had completed technical secondary or higher education per ten thousand people, and the popularity of high school, were added to comprehensively assess the comprehensive development capacity of Yantai City until 2020.

Table 18. Yantai eco-city evaluation

<table>
<tr><th>1st level indicator</th><th>2nd level indicator</th><th>3nd level indicator</th><th>4th level indicator</th></tr>
<tr><td rowspan="6">Synthesis development ability of eco-city</td><td rowspan="6">System pressure</td><td rowspan="2">Population pressure</td><td>Ratio of urban unemployment</td></tr>
<tr><td>Average life expectancy</td></tr>
<tr><td rowspan="4">Society pressure</td><td>Urbanization level</td></tr>
<tr><td>GDP per capita</td></tr>
<tr><td>Engle’s coefficient</td></tr>
<tr><td>Ratio of high-tech</td></tr>
</table>

			industrial output to qualified industry
		Resource pressure	Surfur dioxide emission intensity
			Public urban space per person
			Ratio of the invasion
			Ratio of the invasion
			Ratio of recycle of straws
	System state	Environment quality	Ratio of environment satisfaction of tourism site
			Ratio of qualified urban drinking water supply
			Ecological fisher area
			Ratio of environment satisfaction of sea
		Ecology quality	Green coverage urban built-up area
			Ratio of protected area to total area
			Forest coverage
			Ratio of soil erosion control
		Living quality	Average annual income per urban resident
			Ratio of public participation in environment
			Average annual revenue per capita
			Average annual income per farmer
	System response	Environment response	Ratio of qualified emission of

			industrial pollution source
			Ratio of city heating
			Ratio of qualified noise environment
			Ratio of treatment of municipal solid wastes
			Energy consumption per GDP unit
		Ecology response	GDP ratio of service industry
			Ratio of environmental investment to GDP
		Human response	Ratio of technology and education investment to GDP
			Ratio of people's satisfied with their environment
			People graduated from technical and high school and above per 10000 people
			Ratio of high school graduate

Table 19. The Yantai eco-city evaluation values, references and resources

Indicators	Standard value	2005	2010	2015	2020
*Ratio of urban unemployment(%)	<1[1)]	3.3[18)]	3[13)]	2[13)]	1[13)]
*Average life expectancy(age)	80[2)]	72[12)]	76	80	85
Urbanization level(%)	≥55[3)]	46[12)]	50[17)]	55[17)]	60[17)]
GDP per capita(10 thousand yuan)	≥3.3[4)]	3.1[18)]	4.1[13)]	6[13)]	8[13)]

Engle's coefficient	<0.4[3]	0.38[20]	0.35	0.3	0.3
*Ratio of high-tech industrial output to qualified industry(%)	≥35[5]	28.6[18]	31[12]	35[12]	40[12]
Sulfur dioxide emission intensity(kg per 10 thousand yuan)	<5[3]	5.6[18]	5[16]	4[16]	3[16]
Public urban space per person(m^2)	≥11[3]	12.7[18]	15[13]	20[13]	25[13]
*Ratio of the invasion(%)	<1[5]	3.6[12]	3[13]	2[13]	1[13]
Ratio of recycle of straws(%)	100[6]	63.5[12]	80[13]	90[13]	100[13]
Ratio of environment satisfaction of tourism site(%)	100[3]	85[12]	95[12]	100[12]	100[12]
Ratio of qualified urban drinking water supply(%)	100[7]	100[18]	100[13]	100[13]	100[13]
*Ecological fishery area(10 thousand mu)	≥80[5]	60[12]	75[12]	85[12]	95[12]
*Ratio of environment satisfaction of sea(%)	100[8]	100[12]	100[13]	100[13]	100[13]
Green coverage in urban built-up area(%)	≥45[9]	39.3[18]	42[13]	45[13]	50[13]
Ratio of protected area to total area(%)	≥17[3]	11.5[12]	15[13]	18[13]	22[13]
Forest coverage(%)	≥40[10]	25[18]	30[13]	35[13]	40[13]
*Ratio of soil erosion control(%)	≥90[5]	74.2[12]	87[12]	95[12]	100[12]
Average annual income per urban resident(yuan)	≥24000[4]	12452[18]	19100[17]	24000[17]	30000[17]
Ratio of public participation in	≥85[3]	50.4[12]	70	85	100

environment(%)					
Average annual revenue per capita(yuan)	≥5000[4]	1345[18]	3000[15]	5000[15]	7000[15]
Average annual income per farmer(yuan)	≥11000[4]	5437[18]	7800[13]	9000[13]	11000[13]
Ratio of qualified emission of industrial pollution source(%)	100[7]	100[18]	100[13]	100[13]	100[13]
Ratio of city heating	≥80[3]	52.5[18]	65[12]	75[12]	85[12]
Ratio of qualified noise environment	≥95[3]	76.13[18]	80[13]	90[13]	100[13]
Ratio of treatment of municipal solid wastes	100[7]	94.3[18]	100[12]	100[12]	100[12]
Energy consumption per GDP unit(t per 10 thousand yuan)	<0.9[11]	0.95[18]	0.9[12]	0.75[12]	0.5[12]
GDP ratio of service industry(%)	≥45[4]	30.9[18]	45[12]	50[12]	55[12]
*Ratio of environmental investment to GDP(%)	≥3[2]	2[18]	2.5[13]	3[13]	3[13]
*Ratio of technology and education investment to GDP(%)	≥6[11]	1[18]	4[14]	6[14]	8[14]
Ratio of peoples' satisfied with their environment(%)	≥95[8]	86.7[19]	90	95	98
*People graduated from technical and high school and above per 10000 people(people)	≥3000[6]	990[18]	2000	3000	4000
*Ratio of high school graduate(%)	≥90[5]	88.7[18]	90	92	95

Notes: * indix based on the new index of Yantai. According to: 1) Unemployment rate near the intereconomical cities of the best year; 2) Reference to the advanced level of foreign cities； 3) Construction indicators of economical ecological city； 4) Indicators of economically developed areas in economical eco-city； 5) Extrapolated values； 6) Construction indicators of economical ecological county； 7) Intereconomical standard； 8) Extrapolated values according to the ecologically provincial construction plan of Shandong province； 9) Status value of Shenzhen； 10) Construction indicators of hilly area of economical ecological city； 11) Extrapolated values according to status value of developed economies； 12) “Construction plan of Yantai eco-city”； 13) “Environmental protection and construction plan of Yantai city”； 14) Yantai "Eleventh Five-Year Plan"； 15) “Main expected indicators of the Tenth Five-Year Plan of economical economic and social development”； 16) “Comprehensive prevention plan of sulfur dioxide pollution in Yantai city”； 17) “Ideas and suggestions on speeding up the process of urbanization of Yantai city”； 18) “Yantai statistical yearbook”； 19) “Annual report on environmental management and integrated remediation of economical cities”； 20) Economical bureau of statistics.

(2) Evaluation method

In our case study, the polygon indicator method was employed in the assessment. In this method, it is assumed that there are n indicators (with standardized values). The upper bound of each indicator is used as the radius of a centered n-gon, and the lines connecting each indicator value form an irregular centered n-gon. The vertices of this irregular centered n-gon form an end-to-end entire array of the n indicators, which ensures that the n indicators form (n-1)!/2 different irregular centered n-gons. The integrated index is defined as the ratio of the mean area of all the irregular polygons to the area of the centered polygons. The indicator values were normalized using the hyperbolic normalization function; the normalization formula for the ith indicator is given in Equation (5). The calculation of the integrated indices of the entire array of polygons is shown in Equation (6).

$$S_i = \frac{(Ui-Li)(Xi-Ti)}{(Ui+Li-2Ti)Xi+UiTi+LiTi-2UiLi} \tag{5}$$

Among eq: U is the upper limit of the index X, L is the lower limit of the index X, T is the critical value of the index X

$$S = \frac{\sum_{i\neq j}^{i,j}(Si+1)(Sj+1)}{2\cdot n\cdot(n-1)} \tag{6}$$

Among eq: S is comprehensive index value, S is single index value.

The entire-array-polygon method uses a four-level classification method in which the comprehensive development of an ecological city is graded using four levels: “poor” (S<0.25), “fair” (0.25<S<0.5), “good” (0.5<S<0.75), and “excellent” (S>0.75). The entire-array-polygon indicator method used in this study had both single indicators and integrated indicators, both geometric visual diagrams and analytic values, and both static indicators and dynamic indicators; compared with the traditional simple weight method, the subjective determieconomy of weight coefficients by an expert is unnecessary, and therefore, the subjective randomness is decreased.

Next, the indicators were normalized using the entire-array-polygon method, and three aspects of the ecological construction in Yantai were evaluated (system pressure, system status, and system response). This was followed by a comprehensive evaluation. The results of the evaluation are as follows:

(1) System pressure: From 2005 to 2020, the system pressure index for Yantai City quickly improved from “fair” to “excellent.” Figures 12 & 15 show that the system pressure development index increased from 0.26 in 2005 to 0.31 in 2010. The improvement in indicators such as the sulfur dioxide emission intensity, the straw recovery rate, and the Engel coefficient has played a leading role, whereas some indicators, such as the per-capita GDP, the ratio of the high-tech industrial output to the output of designed-size enterprises, and the per-capita urban public green area, needed to be improved. In the “Yantai Eco-city Construction Plan,” it was estimated that the system pressure development index reached 0.31 in 2015 and 0.75 in 2020, when the level of comprehensive development is expected to change from “excellent” to “good” and that indicators such as the per-capita GDP and the proportion of high-tech industrial output in the output of designed-size enterprises are expected to improve significantly while still lagging 25% behind the standard value because of the small per-capita urban public green area, the high registered urban unemployment rate, and the low level of urbanization.

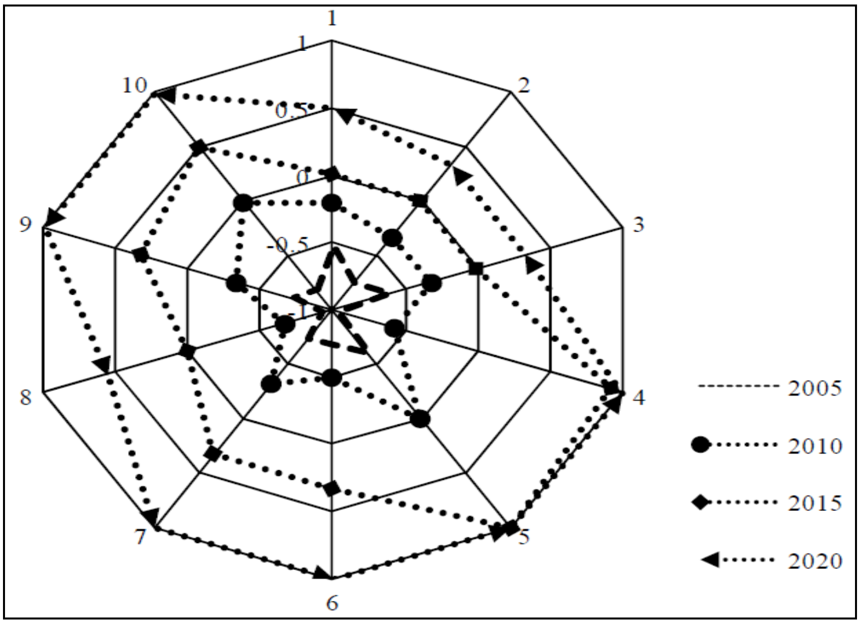


Figure 12. Synthesis evaluation of system pressure of Yantai eco-city

1. Ratio of urban unemployment；2. Average life expectancy；3. Urbanization level；4. per capita；5. Engle's coefficient；6. Ratio of high-tech industrial output to qualified industry；7. Sulfur dioxide emission intensity；8. Public urban space per person；9. Ratio of the invasion；10. Ratio of recycle of straws

(2) System status: From 2005 to 2020, the system status index of Yantai City is expected to rapidly improve from "fair" to "excellent." Figures 13 & 15 show that as the system status development index increased from 0.3 in 2005 to 0.4 in 2010, environmental management achieved initial success, indicators such as ecological construction continuously made progress, and the rates at which the centralized drinking water quality, the marine environment functional area, etc. progressed toward the standards all reached the planned values, whereas various quality of life indicators have not yet improved, and other lagging indicators, such as the fishery eco-aquaculture area, the green coverage

rate of the urban built-up area, and the forest coverage rate, have been hindering improvement in the system status. The “Ecological City Construction Plan of Yantai City” predicted that the system status development index would increase to 0.6 by 2015 and to 0.92 by 2020, when the level of comprehensive development is expected to change from “good” to “excellent,” albeit with an 8% difference from the standard value, which is mainly due to large gaps in the planned values of the following three indicators: the fishery eco-aquaculture area, the annual per-capita income, and the ratio of protected area to the land area.

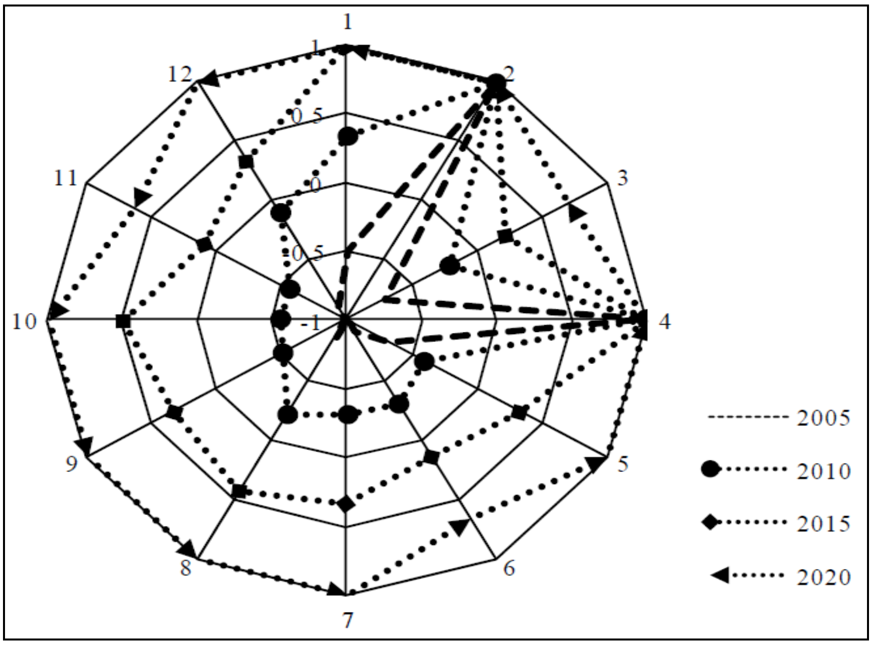


Figure 13. Synthesis evaluation of system state of Yantai eco-city

1. Ratio of environment satisfaction of tourism site; 2. Ratio of qualified urban drinking water supply; 3. Ecological fishery area; 4. Ratio of environment satisfaction of sea; 5. Green coverage in urban built-up area; 6. Ratio of protected area to total area; 7. Forest coverage; 8. Ratio of soil erosion control; 9. Average annual income per urban resident; 10. Ratio of public participation in

environment; 11. Average annual revenue per capita; 12. Average annual income per farmer

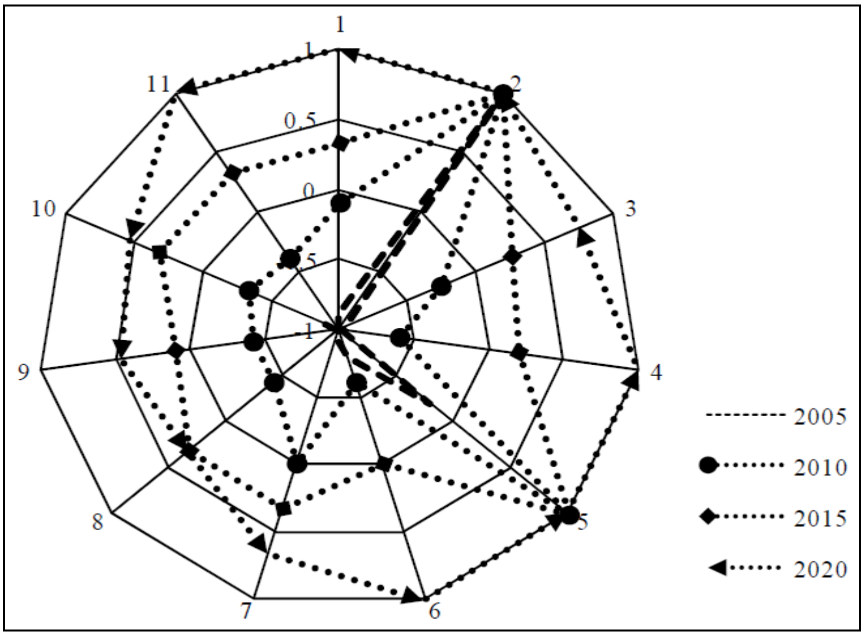


Figure 14. Synthesis evaluation of system response of Yantai eco-city

1.Ratio of qualified emission of industrial pollution source; 2. Ratio of city heating ; 3. Ratio of qualified noise environment; 4. Ratio of treatment of municipal solid wastes; 5. Energy consumption per GDP unit; 6. GDP ratio of service industry; 7. Ratio of environmental investment to GDP; 8. Ratio of technology and education investment to GDP; 9. Ratio of peoples' satisfied with their environment; 10. People graduated from technical and high school and above per 10000 people; 11. Ratio of high school graduate.

(3) System response: From 2005 to 2020, the system response index for Yantai City has been rapidly improving from "fair" to "excellent." Figures 14 & 15 show that the system response development index increased from 0.27 in 2005 to 0.35 in 2010, which was mainly due to the dominant roles of the rate of harmless treatment of urban domestic waste and the proportion of the tertiary industry in the GDP, whereas the rates at

which the noise compliance area, the energy consumption per unit GDP, and the public's satisfaction with the environment remained poor despite improvements.

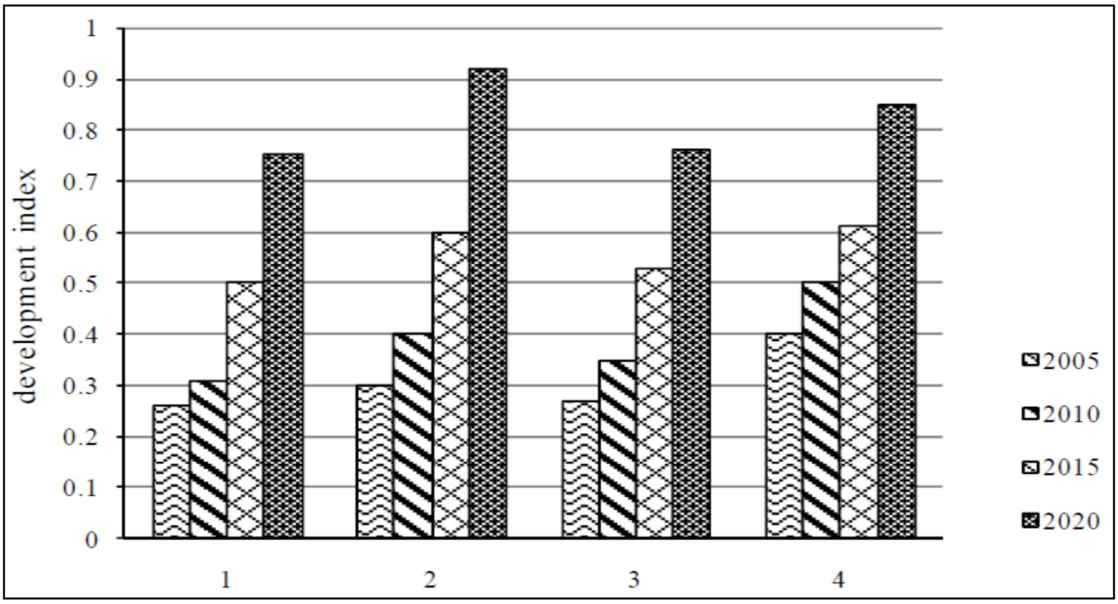


Figure 15. Synthesis development ability evaluation of Yantai eco-city

1. System pressure；2. System state；3 System response；4 Synthesis development

The "Ecological City Construction Plan for Yantai City" predicted that the system response development index would increase to 0.53 by 2015 and to 0.76 by 2020, when the level of comprehensive development is expected to change from "good" to "excellent" despite being 24% from the standard values, mainly because the values of some indicators, such as public satisfaction with the environment, the education rate of the urban population, and the ratio of the investment in environmental protection to the GDP, need to be improved.

(4) Comprehensive development capacity of an eco-city: An analysis of the comprehensive development capacity of Yantai in 2005 and 2010 (Figure 15) showed that the comprehensive development index increased from 0.4 to 0.5 and that the level of comprehensive development changed from “fair” to “good.” Although at the planned baseline, the system pressure was high, the economic development foundation was weak, the starting point for social development was low, environmental debt was abundant, and most of the indicators were far from the economical standards, various system response indicators for Yantai City improved significantly due to the vigorous development of cleaner production methods and a recycling-based , strict control of pollutant emissions, and improvements in harmless disposal as part of its eco-city construction, whereas the system pressure and response indicators still need to be improved, especially indicators such as the per-capita urban public green area and GDP, the rate at which the noise compliance area approaches the standards, and the energy consumption per unit GDP, which all differ by 75% from the planned values and need special attention. The “Ecological City Construction Plan for Yantai City” predicted that the system response development index will increase to 0.61 by 2017 and to 0.85 by 2020 when the level of comprehensive development changes from “good” to “excellent” and that only three of the system status indicators will be unable to reach their standard values, whereas some indicators of system

pressure and system response will be significantly different from the standard values, which will cause the eco-city comprehensive development index of Yantai to lag behind its ideal value by 15%, mainly due to the lack of eco-aquaculture area, the low ratio of protected area to land area, and other lagging indicators, such as the registered urban unemployment rate, the population’s life expectancy, and the ratio of environmental protection investment to the GDP.

5.3.2 Management countermeasures for ecological construction in Yantai City

Based on the evaluation results and the trend analysis, the “Eco-city Construction Plan for Yantai City” predicted that the comprehensive development capacity will gradually improve to the “excellent” level by 2020, which is 15% below the planned value due mainly to slow economic development, the low level of pollution prevention and control, poor living conditions, poor awareness of public participation, and the need for improvement of the coastal environment. To realize the goal of constructing an eco-city in Yantai quickly and efficiently, the following measures are proposed:

(1) Develop the recycling to coordinate the relationship between economic development and environmental protection. We need to establish a recycling system with the core goals of reducing, recycling, and reusing materials by fostering backbone industry chains of a recycling

and establishing a complete and new system for comprehensively utilizing resources to improve the industrial structure; we should also control the scope of mariculture and change the method of aquaculture from extensive to intensive to develop environmentally friendly and highly efficient eco-aquaculture. We should highlight the “ecological” characteristics of agricultural production, strengthen the construction of the farmland forest network, develop agricultural tourism resources, promote the virtuous circle of agricultural ecosystems, and pursue the unification of economic and ecological efficiency.

(2) Improve the city’s ecological restoration function. We need to speed up the improvement of urban sewage and waste disposal facilities, improve the centralized control of and treatment capacity for pollution, establish and improve the city’s ecological controls by primarily using an ecological landscape, and form a stable landscape pattern with natural patches connected by roads and rivers at all levels to protect the biodiversity while enhancing green coverage and rationally designing urban public green space to improve the green space functionality.

(3) Improve the public awareness of and participation in ecological civilization. We should provide publicity and education on ecological civilization to the public with a focus on ecological city construction planning, ecological early-warning education, recycling-based social constructs, ecological civilization, etc., though multi-tool and multi-media

approaches and, by making use of various theme days and tourism festivals, promote eco-city construction with widespread public participation.

(4) Strengthen water resource protection and improve and maintain the coastal ecological environment. First, we should establish water resource protection areas and water conservation forests, maximize control of soil and water loss, and reduce water source pollution due to production and living activities. Second, we should improve the utilization of water resources by applying water-saving measures, such as reusing reclaimed water and replacing some freshwater with seawater. Third, we need to construct underground reservoirs and coastal shelterbelts to collect and store groundwater to block seawater intrusions. Fourth, we should implement controls on the total amount of pollutants emitted and gradually establish a good coastal ecological environment.

5.4 Analyses of typical low-carbon cities in China

(1) Tianjin Sino-Singapore Eco-City. Tianjin Sino-Singapore Ecological City is 45 km from the center of Tianjin City. It is the first eco-city in the world to be developed and constructed by cooperative economies. It does not use farmland and is built completely on saline land; it has a planned permanent population of 350,000 by 2020 and a construction land population density of 14,000 persons/km^2; the proportion of renewable energy used by the city will reach 20% in 2020,

and the utilization rate of non-traditional water sources will exceed 50%. In September 2008, the construction of Tianjin Sino-Singapore Eco-City officially began; the current built-up area is 652 hm^2, the total construction area is 6.59 million m^2, and the current construction land to comprehensive floor area ratio is 1. Additionally, numerous road networks have been completed, including 55 km of motor vehicle road and 51.36 km of a slow transport system along the main road. The proportions of green buildings and green travel are 100% and 90%, respectively. In 2011, the fiscal revenue of the city was over 2 billion yuan, and the entire start-up area exhibits a new model of green low-carbon development (Figures 16 & 17).

Figure 16. Perspective of Sino-Singapore Tianjin Eco-city

Figure 17. Construction of Sino-Singapore Tianjin Eco-city

(2) Caofeidian Eco-city. Located in the barren saline land of Caofeidian New District in the southern coastal area of Tangshan City, Hebei Province, 80 km from the main urban area of Tangshan, Caofeidian Eco-city has a planning area of 74.3km^2, on which full coverage with green buildings is planned. Currently, approximately 15 km^2 of land construction has been completed, and the city is constructing large-scale infrastructure and public service facilities in a total construction area of approximately 300,000m^2 with a cumulative total investment of approximately 1.695 billion yuan. There are 85 km of external and municipal roads with a total

investment of 6.3 billion yuan; 13 km of gas pipeline has been laid, and the designed municipal central heating pipe network is 25 km long. In terms of industry, the so-called “five major industries,” i.e., the low-carbon environmental protection industry, the coastal tourism industry, the life culture industry, the intereconomical education industry, and the medical and health industry, are the top priority for development (Figures 18, 19, & 20).

Figure 18. Perspective of Caofeidian Eco-city

Figure 19. Wind-force and solar energy road in Caofeidian Eco-city

Figure 20. First green housing project in Caofeidian Eco-city

(3) Taihu New Town. This town is located in the south of Wuxi City in southern China, nearly 6 km from the old city in the north; it has a total land area of approximately 150 km2 and a planned construction area of 95 km^2. Taihu New Town has a planned resident population of approximately

1 million and approximately 500,000 planned jobs. Its main functions are positioned in administrative and business centers, science and education creativity centers, and leisure and residence centers in Wuxi (Figure 21). The public service facilities constructed and under construction include a civic center, a grand theater, and various functional projects, such as primary and secondary schools and commercial centers. A total of 20 million m^2 of green low-carbon buildings has been erected (Figure 22).

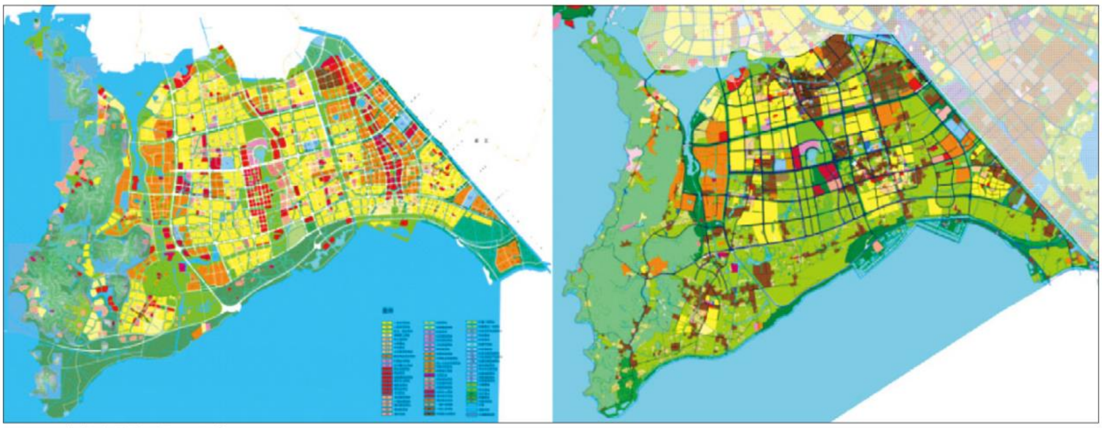


Figure 21. Planning and current situation of Taihu New Town

Figure 22. Construction of Taihu New Town

(4) Shenzhen Pingshan New District. Located in the eastern part of Shenzhen City with an area of approximately 168 km^2, this district accommodated a population of approximately 0.6 million in 2010, and the planned construction area for 2020 is 65.51 km^2 (Figure 23). Since the establishment of the new district, the public transport capacity and service coverage have steadily increased, and pedestrian roads, bus lanes, bicycle lanes, and other slow traffic systems have been continuously improved. Four primary industries, i.e., new-energy vehicles, electronic information, bio-medicine, and equipment manufacturing, have been established. New buildings have been constructed 100% in accordance with green building standards, and a total of approximately 1.31 million m^2 of green buildings has been built. A multi-level, diverse park green system with “economy park-city park-community park” as its main structure has been constructed based on the adjustment requirements of the basic ecological control line of Shenzhen City (Figure 24).

Figure 23. Planning of Pingshan New District in Shenzhen

Figure 24. Low impact treatment of river basins and green building construction in Pingshan New District

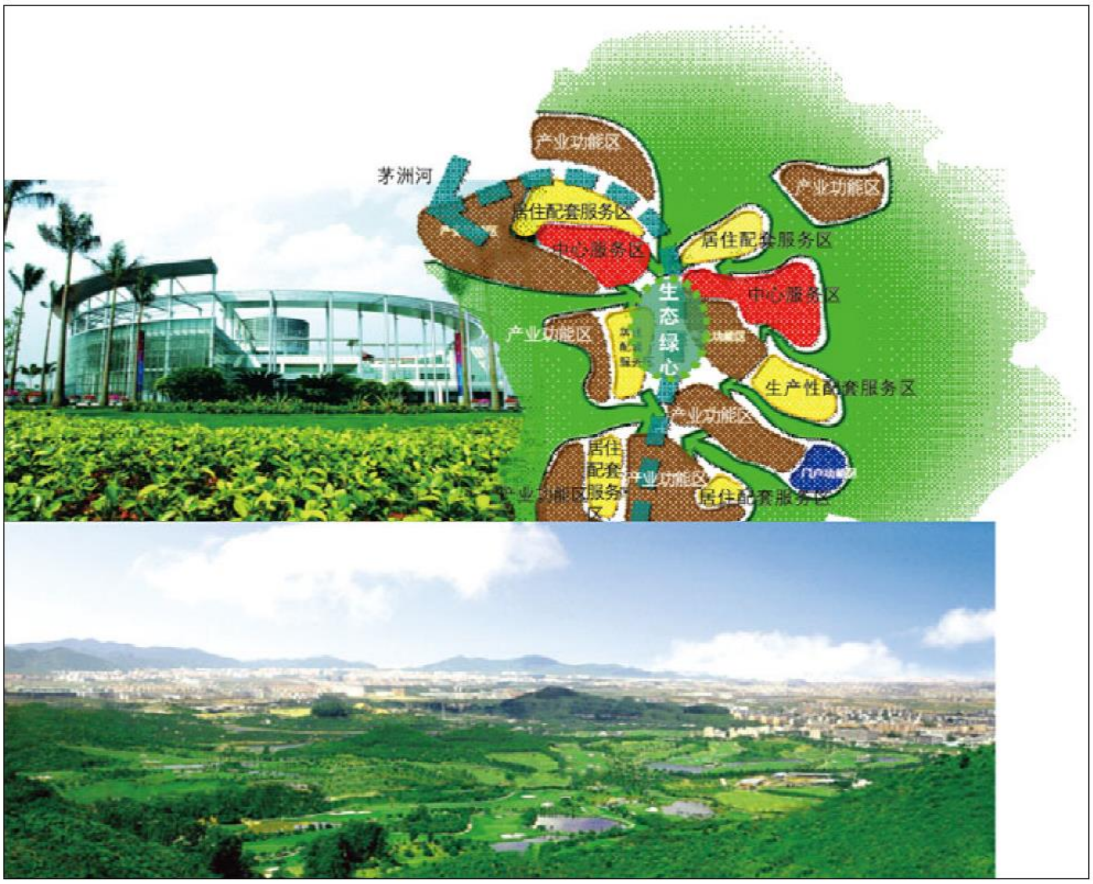


Figure 25. Guangming New District in Shenzhen

(5) Shenzhen Guangming New District. With a total area of 156.1 km^2, this new district was established in 2007 based on Guangming Street and Gongming Street. Currently, it has a population of approximately 800,000, including 42,000 permanent residents. The built-up area of Guangming New District has reached 48.61 km^2, and the unused land area is approximately 27 km^2, including 5,850.50 hm^2 of urban construction. The road framework, especially the slow traffic system, has been realized, which has strengthened the industrial agglomeration and supporting capacity, and facilities for utilizing rainwater and waste disposal have been significantly improved. A total of 81 building projects with a construction

area of 376 million m^2 have been constructed in accordance with more-than-one-star green building standards (Figure 25).

Part 6. Study on developing pattern in LCTs in China

6.1 Analysis of the current carbon emissions of Chinese cities

In accordance with the carbon management life cycle, the significant sources of carbon emissions in China's urbanization process can be summarized as follows:

(1) Urban construction bubble

During the urbanization process, alongside large population influxes in cities, large-scale infrastructure, including municipal facilities such as transportation, housing, electricity, telecommunications, water, sanitation and sewage, solid waste collection and treatment, gas pipelines, and other public facilities for education and healthcare, must be constructed. According to the United Economys Development Programme, the proportion of urban infrastructure invested in developing economies should account for 9%–15% of the investment in fixed assets and 3%–5% of the GDP. A World Bank survey showed that public infrastructure investment generally accounts for 2%–8% of the GDP. In China's urbanization process in the new century, transport investment alone accounted for 7%–9% of the GDP, and urban real estate investment accounted for 8%–10% of the GDP. This mega-scale investment has prompted the construction of large-scale urban infrastructure and has exceeded the actual demand to a certain extent, which has caused urban construction bubbles.

First, the land area under urban construction expanded rapidly. The urban expansion coefficient is calculated by dividing the increment in the urban built-up area by the increment in the urban (resident) population. Its value for cities in China over a 12-year period (2000-2011) was 1.87, which is much higher than its intereconomical value (1.12). The excessive expansion of the urban land area caused a large number of idle, abandoned, and occupied areas and areas with diverted uses and led to the loss of a large area of arable agricultural land. Moreover, the amount of wasted land in urban construction projects has been excessive; the floor area ratio of industrial projects was only 0.3 to 0.6 for China but generally over 1.0 for other economies. In addition, low-density urban development has increased the demand for urban infrastructure.

Second, the forward-looking construction has been excessive. Public buildings, luxury buildings, conference halls, museums, government office buildings, and iconic buildings are ubiquitous. The per-capita public construction area is 35.7% of the per-capita floor area in China, which is 5.5-14.9 percentage points higher than it is in developed economies overall. Skyscrapers are luxury buildings that are soaring frenziedly in China, which makes China the world's most active high-rise building market. Regarding residential buildings, in 2011, China's urban per-capita residential area was 32.7 m^2, which exceeded the 29.3 m^2 level reflected by the statistics of the United Economys for mid- and high-income economies, and China completed its 2020 construction target ahead of schedule; in large cities, China's per capita living area was 17-20 m^2, which approached the level of cities in developed economies; the total housing has also reached 1.02 units per household of permanent residents.

Third, the transport infrastructure is too advanced and unbalanced. Generally, transportation determines the urban density and the extent of urban expansion and has an impact over a long period of economic and social development. Moderately forward-looking transportation construction is reasonable, but a large number of transport facilities projects that were originally part of the mid- and long-term plans have been completed substantially ahead of schedule; for example, the 85,000 km expressway that was originally scheduled for 2020 was completed ahead of schedule in 2011; in the Yangtze River Delta region, there are nine airports per 100,000 square kilometers, which is greater than the six airports per 100,000 square kilometers in the United States; this is also the case for port construction; in some places, the designed port throughput drastically surpasses the actual volume. Although China's land area is approximately equal to that of the United States, the area suitable for human habitation is smaller in China, which results in an even higher density of actual transport facilities. The energy consumption varies with the different transportation facilities, and for the same transport capacity, the land used by railways is only approximately one third that used by expressways; therefore, the excessive construction of expressways not only uses a great deal of land resources but also increases the energy consumption of the operation. The energy consumption of intercity railways is only 3/5 that of buses and 1/6 that of private vehicles, but, relatively speaking, the construction of China's intercity railway is lagging far behind. Since the construction of a large number of expressways, airports, and ports, there has been a serious shortage of passenger and cargo traffic. In 2011, the passenger throughput of the top 20 airports in China accounted for 54% of the economy's throughput (industry concentration ratio), and 160 small and medium-sized airports accounted for only 1/4 of the economical passenger throughput and 1/10 of the cargo and mail throughput; the concentration ratios of the port throughput of 15 designed-size coastal ports decreased 19.2%, from 89.3% in 1990 to 70.1% in 2011. Moreover, the construction of a large number of expressways, urban fast lanes, and urban ring roads pushed the city to expand toward the suburbs, extending travel distances and increasing travel frequency.

(2) Driving industries that consume significant amounts of energy by urban construction

The construction of urban infrastructure requires a great deal of resources, including consumable items such as cement and steel, which stimulates the development of the upstream industries that consume significant amounts of energy, such as ferrous metals, nonferrous metals, petrochemical coking, chemical raw materials, mineral products, and chemical fiber, and is essential from the perspective of urban construction. However, the unreasonable or excessive advance of urban construction, e.g., luxury public buildings, intercity high-speed rail and air networks, expressways within densely populated urban areas, and redundant inter-city rapid transport systems for passengers, have artificially exaggerated the demand for upstream industries that consume significant amounts of energy. Taking an expressway as an example, in addition to the need for a great deal of land, constructing a 1 km expressway requires 1,000 tons of steel, 9,000 tons of cement, and 1,000 tons of asphalt. Therefore, over the past decade, the construction of expressways alone has consumed a tremendous amount of resources and energy, and this type of over-construction has not only resulted in a significant waste of resources but also led to excessive heavy and chemical industrialization, which is responsible for the energy consumption of the secondary industry remaining high and stubbornly accounts for approximately 73% of China’s total energy consumption, whereas Japan’s industrial energy consumption accounted for only 62.5% at most in its period of high-speed growth.

(3) The impact of urban construction on residents' lifestyles

Although urbanization improves economic efficiency, it often changes both consumers’ needs and families’ lifestyles. As rural populations are concentrated into cities, they not only are provided with shelter and work but also have their behavior influenced by traffic and information communication, thereby adopting lifestyles that have urban characteristics. Changes in consumers' demand and behavioral patterns also affect household energy-use patterns and are an important driver of the increased carbon emissions associated with the energy consumption involved in urbanization, whereas different lifestyle choices in turn affect the level of urban carbon emissions. In the course of China's urban construction process, suburban low-density residential villas have been extensively developed and housing area has been continuously increasing; the average household housing area of new residential construction increased from 90.6 m^2 in 1999 to 103 m^2 in 2011, prompting consumers to seek large residences, thereby leading to increasing household electricity usage. With the continuous separation between residential location and work location, a large "pendulum" population has been created; the construction of giant residential communities, ever-widening urban roads and ever-decreasing sidewalks and bicycle lanes have all rendered travel increasingly inconvenient, thus increasing the pressure on traffic, lengthening travel distances and causing significant added carbon emissions from traffic. A survey in Nanjing has shown that the traffic-related carbon emissions of residents living in new residential areas increased by 41% over the emissions of residents living in the central urban areas. Meanwhile, with improved living standards, private vehicle ownership has continuously increased. In 2013, private vehicle ownership in China surpassed 100 million. People have become more dependent on private vehicles for travel, and both travel frequency and travel distance involving private vehicles increased. In Beijing, for example, the travel distance of private vehicles was 15,000 km, 3-5 times the driving distance of private vehicles in other intereconomical metropolises such as Tokyo, London and New York. All of the above factors have induced people (either consciously or unconsciously) to move closer to a lifestyle of high energy consumption. Once that lifestyle is created, high levels of energy consumption and carbon emissions are locked in.

6.2 The development model of eco-low-carbon city support policies

The Chinese government is taking the initiative to implement high-quality, low-carbon and social justice-based urbanization and has proposed numerous preferential policies to promote the development of low-carbon eco-cities, including the following:

(1) Encouraging the application of renewable energy construction and directly providing subsidies to users.

(2) Providing 50-80 million yuan in support to each renewable energy demonstration city.

(3) Implementing energy-saving renovation and monitoring in large-scale public buildings and providing renovation subsidies.

(4) Given that the green buildings are the basic components of low-carbon eco-cities, the state financial department provided direct construction subsidies of 45 yuan/m^2 for two-star green buildings and 80 yuan/m^2 for three-star green buildings.

(5) Green building scale promotion subsidies have been provided in which once a city has 3 million m^2 of green buildings, it received a subsidy of 50 million yuan.

(6) Implementing a green small-town plan in which small towns that have satisfied green standards have received a one-time subsidy of 10-20 million yuan.

(7) Providing eco-city demonstration subsidies in which demonstration projects that satisfy state standards (and that have a demonstration effect) have received subsidies of 50 million-80 million yuan. Because of these preferential policies, China's low-carbon eco-city projects have increased dramatically on an annual basis. In recent years, the low-carbon eco-city has become the new model and target of urban development economywide, inspiring unprecedented enthusiasm (Figures 26 & 27).

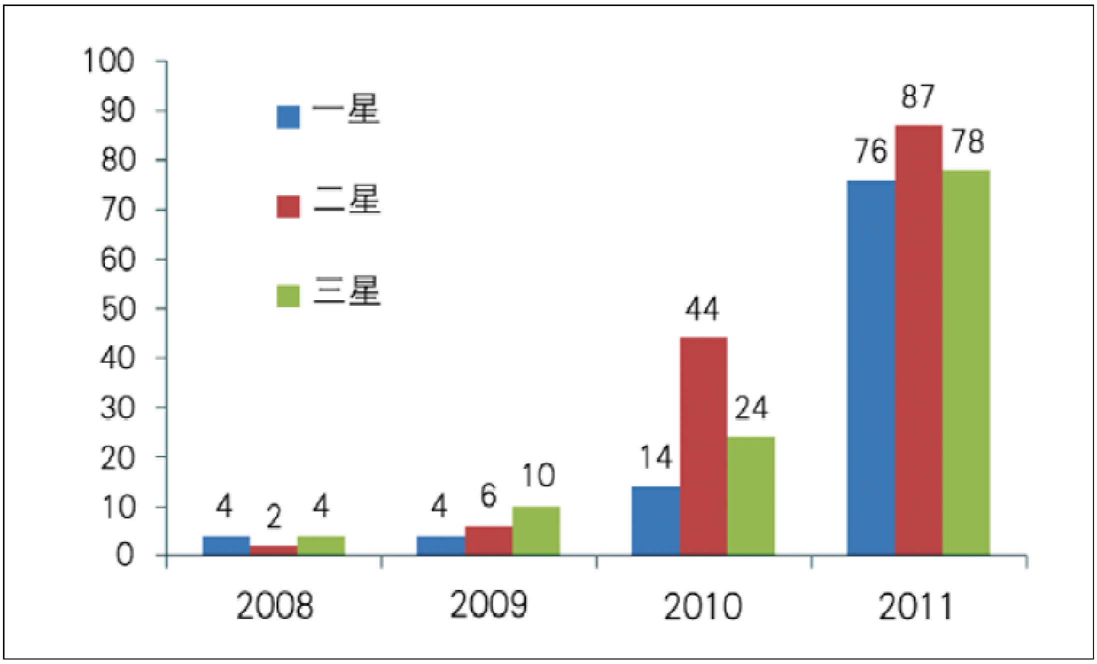


Figure 26. Granted number of Green Building Evaluation Label indifferent years

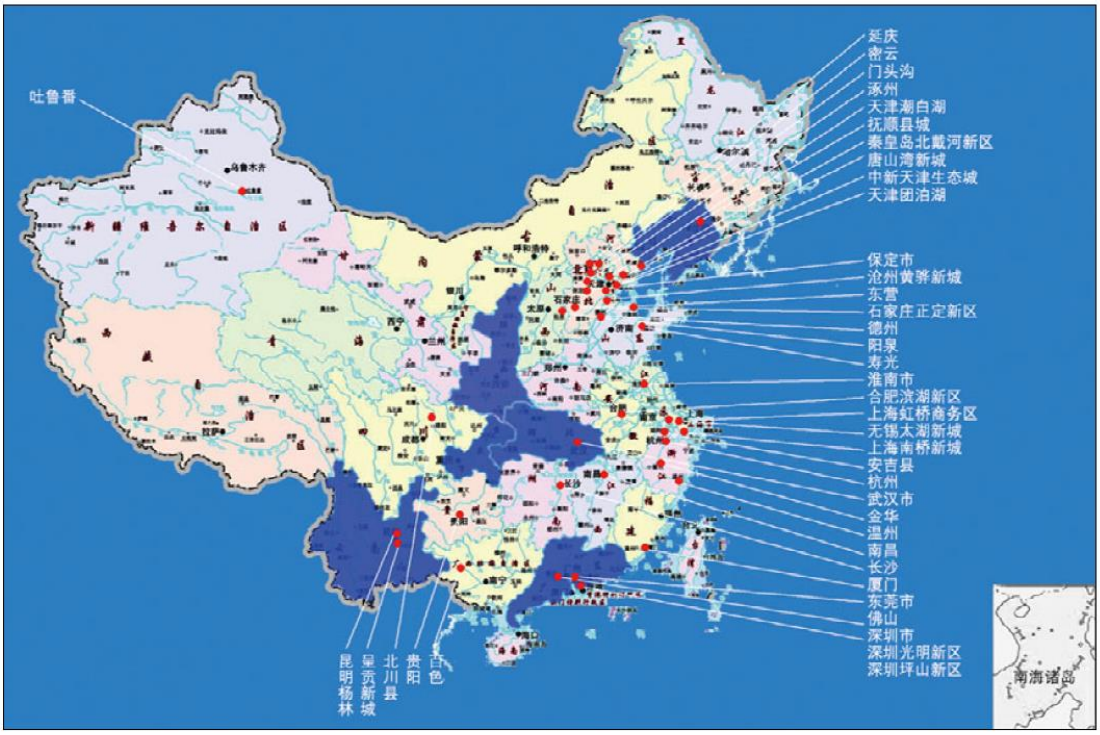


Figure 27. Distribution of the construction of China's low carbon eco-cities in recent years

The status of China's low-carbon eco-city planning and construction is described as follows:

(1) A low-carbon eco-city planning and construction system has been established, including guidelines for the overall planning of urban new districts, so that eco-city pilot projects can be coordinated and guided.

(2) The index system and implementation guidelines for the low-carbon eco-city have been developed according to local conditions to strengthen guidance and control over the process of eco-city planning and implementation.

(3) Low-impact development, renewable energy applications, green buildings, low-carbon transportation and other low-carbon ecological key technologies have been introduced in various pilot programs.

(4) Eco-city planning management methods and mechanisms have been investigated, and the first local eco-city laws and regulations have been promulgated.

6.3 A development model of the low-carbon eco-city management strategy

The city is a complex mega-system. Planning and constructing a low-carbon eco-city requires the adoption of a systematic scientific thinking and systematic research that enables the development of plans and schemes for promotion and implementation. It is especially important to understand the phased and long-term nature of the task so that it is possible not only to create cooperative relationships between the overall and the local and between large and small systems but also to orchestrate overall planning and implementation strategies. These aspects are difficult to include when constructing common, traditional industrial cities.

(1) Progressiveness: a solid push forward that involves the ecological transformation of existing urban structures.

China's city contest systems, including garden cities, water-saving cities, China Habitat Awards, and historical and cultural cities, have existed for many years, establishing a solid foundation for the ecological upgrade of existing cities.

Various reasonable, legitimate and long-standing selection systems used by standard-achieving cities can be used by existing cities as systematic performance steps in the direction of ecological transformation and sustainable development. The cities that satisfy monitoring, affirmation and acceptance requirements will receive the China Habitat Award. Based on that foundation, a grading standard that certifies eco-city transformation can be proposed.

(2) Systematicness: a systematic assessment, evaluation indicators and a systematic index system are to be established for evaluating and examining whether development has achieved its goals, thus both ensuring a solid push forward towards the creation of an eco-city and avoiding "fake construction" . These indicators can be assessed and amended, providing feedback to solidly promote eco-city construction.

(3) Diversity: China has complex terrains and a vast territory, both of which determine the diversity of low-carbon eco-city development models.

In South China, methods such as shade and three-dimensional greening can be used to reduce buildings’ energy consumption, whereas traffic energy consumption can be reduced by improving green traffic measures such as bike lanes. These are the primary methods of planning and control for southern low-carbon eco-cities.

In the cold northern regions, a winter heating metering system for buildings should be implemented not only to promote the use of solar energy and geothermal energy to replace traditional fuels but also to mobilize owners’ enthusiasm for improving their building envelope. In western areas suffering from water scarcity, saving and recycling water should be one of the eco-city’s basic characteristics.

Various eco-city planning models should be implemented according to the geographical and geologic conditions, climatic conditions and resource endowments in different regions, new eco-homes should be constructed in a scientific and rational manner, and to the greatest extent possible, new eco-towns should be built on barren non-farming land to effectively protect China's eighteen billion mu of valuable farming land resources.

The key strategic technologies related to the key breakthroughs of low-carbon eco-city development are as follows (Figure 28):

Figure 28. Key fields of eco-city development

1. Green Transportation; 2. Space layout and land use; 3. Low carbon culture; 4. Industrial upgrading and transformation; 5. Resource energy saving cycle; 6. Green buildings; 7. Ecological protection and construction

(1) The compact mixed land-use model

The compact mixed land-use model is a prerequisite for all eco-cities, in which land use is both compact and functionally mixed. The compact mixed land-use model arranges urban space according to green traffic so that both landscape diversity and very good accessibility can be realized. These elements should be promoted in the compact mixed land-use model (Figures 29 & 30).

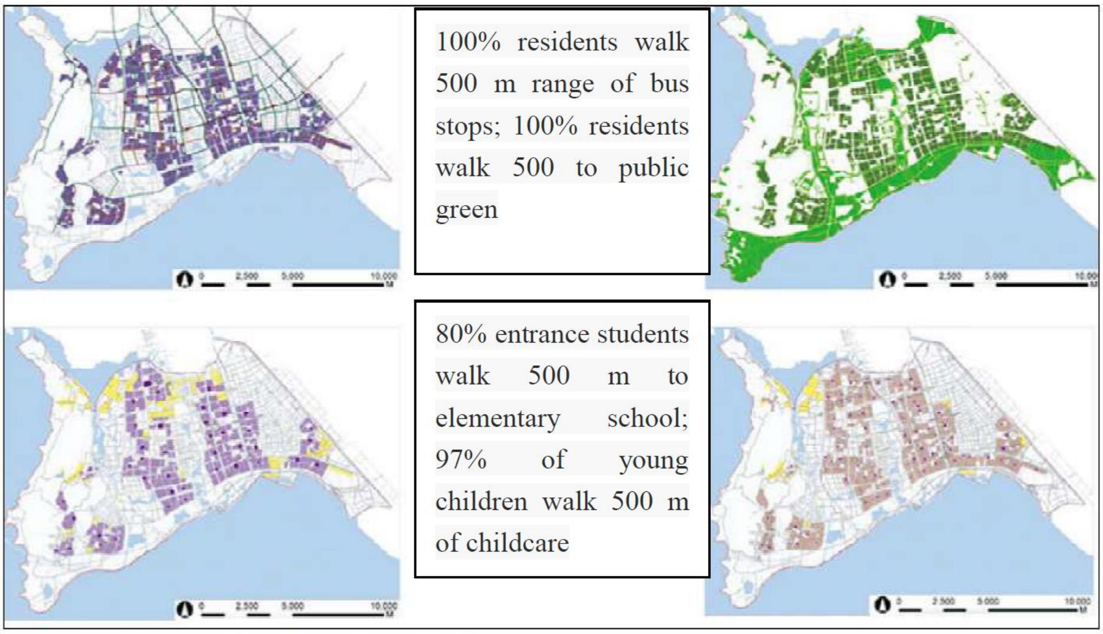


Figure 29. Compact mixed land use of Taihu New Town in Wuxi

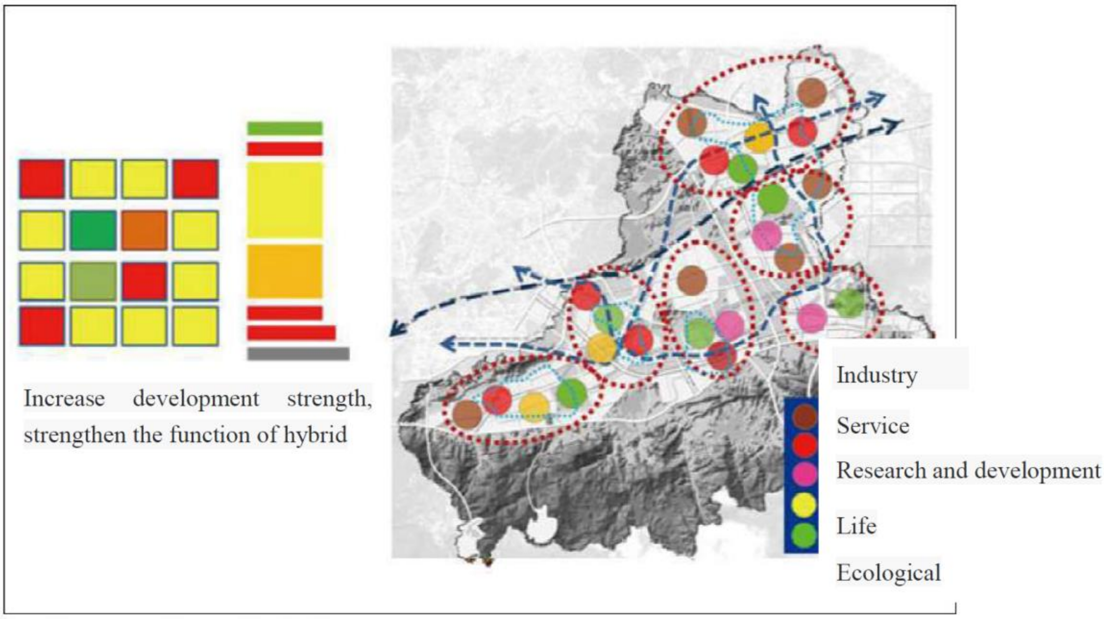


Figure 30. Compact mixed land use mode

The compact mixed land-use model emphasizes functional integration, traffic-guided development, a compact and intensive spatial layout, and improved land use efficiency, which is the first threshold condition to be achieved by the eco-city. In this land-use model, the mix of individual buildings' use functions and the mixed layout of cities' sublet functions should also be innovative. By controlling floor area ratio, a compact-type city is created that achieves the eco-city's goal of taking good care of nature and water (Figure 31).

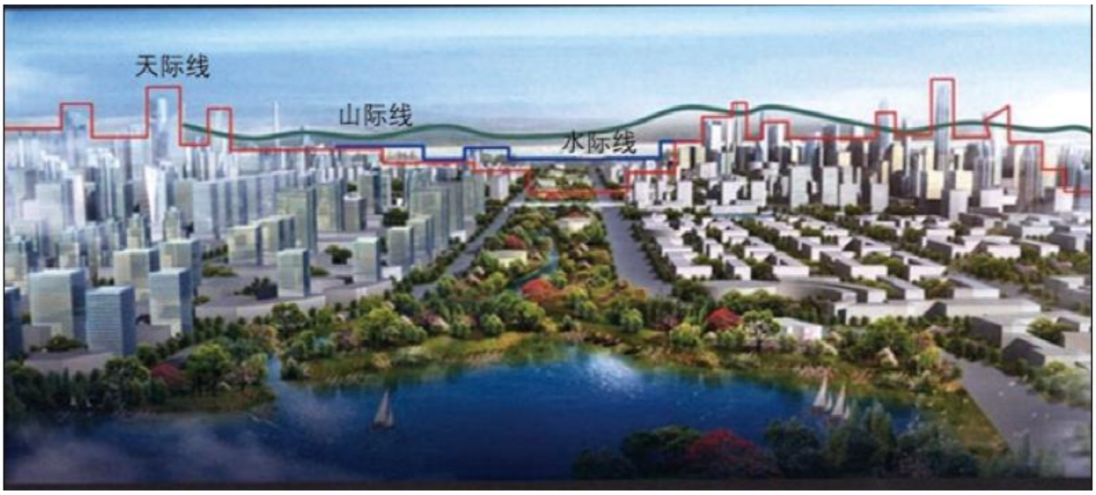


Figure 31. Floor area ratio control: compact city

Figure 32. Energy planning and resource utilization of Sino-Singapore Tianjin Eco-city

(2) Resource conservation and recycling

Another key technology for the construction of the low-carbon eco-city is to satisfy the requirement that the proportion of renewable energy be more than 20%, the non-traditional water use rate be more than 50% and the per capita integrated water consumption be less than 320 liters/person-day. Planners must pay attention to learning energy problems that they have not previously encountered; energy planning is very important new planning in low-carbon eco-city construction and should be integrated into urban space and architectural forms so that buildings become energy generators. In eco-cities economywide, resources and water recycling have become core issues. Unlike traditional cities' practice of frequently "breaking open the belly," eco-cities generally use common pipe trenches. Moreover, drainage, electricity, communications, and garbage pipelines are installed only once and concentrated in a single trench, resulting not only in ease of repair but also in the lack of a need to re-dig the trench, thus avoiding the waste of additional energy and materials. Consequently, the eco-city must simultaneously implement comprehensive rainwater utilization technology (Figure 32 & 33).

Programming guidelines	Implementation progress
■Renewable energy utilization and greater than or equal to 20% (with average of built-up areas). ■The new building renewable energy utilization is above 15%. ■65% new building must perform the energy-saving standards.	■Renewable energy construction buidlings as 3.56 million square meters, buildings about 160,000 square meters of ground source heat pump, including Civic Center, Landsea experimental school of green streets, bridges and other projects. ■Construction of sewage source heat pump is about 400,000 square meters, including Perception Expo, Taikeyuan 530 buildings, too, such as science and Technology Exchange Center.

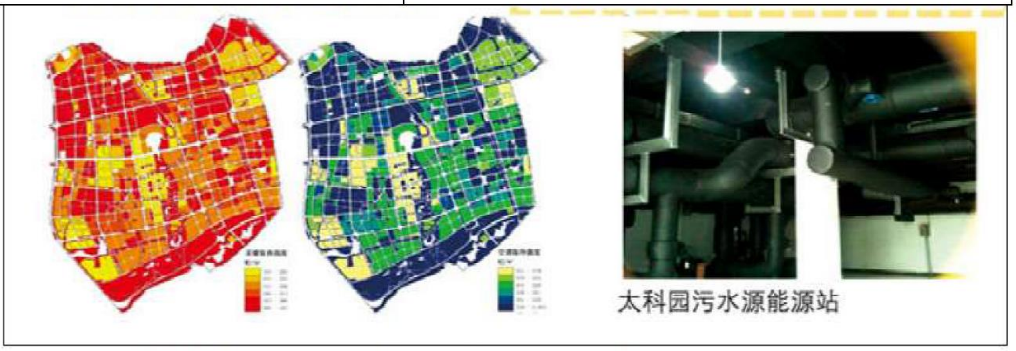


Figure 33. Energy planning and implementation progress of Taihu New Town in Wuxi

(3) Scaling up green buildings

Green buildings are the most basic ecological elements of an eco-city. Regardless of whether a large community, a single green building, or enterprise buildings are contemplated, the strategy in this regard should be led by the government and promoted in multiple fields. First, the government should require that all new buildings that have received government investment or subsidies fully implement green building standards. Second, new social public buildings and commercial buildings should be encouraged to implement green building standards. Third, project demonstrations of local green buildings should be conducted. Fourth, one-time decoration of green buildings should be encouraged in which all buildings’ interior decorations are completed at the same time, rendering it unnecessary for owners to redecorate their buildings in a manner that causes waste in building materials. Fifth, green buildings should be implemented in industrial functional areas and industrial buildings. In this way, green building systems can be promoted and achieved both systematically and comprehensively (Figures 34 & 35).

Figure 34. Pipeline installation and rainwater utilization in Guangming New Distract in Shenzhen

Figure 35. Large public buildings and green neighborhoods

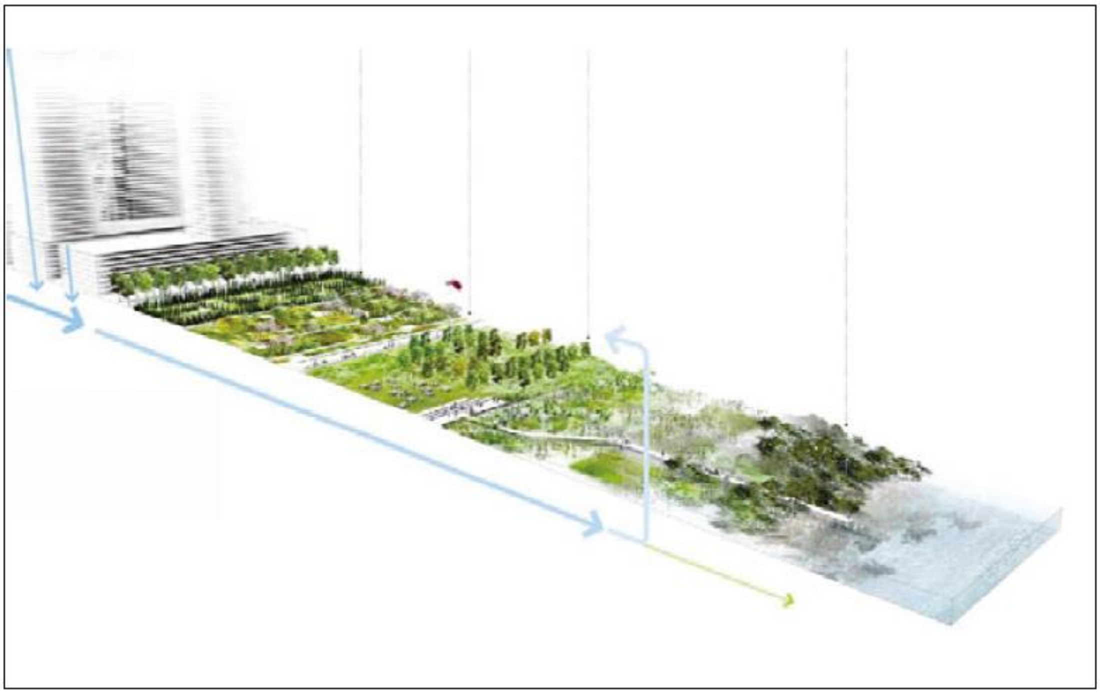
(4) Maintaining biodiversity

To retain original ecological areas and nature patches along lakes, rivers, mountains and forests, we should both prioritize and guarantee green park land use and satisfy the demand for ecological diversity and humane landscape by creating greening ecosystems through reliance on major regional water systems. The new technology that can be adopted involves vigorously promoting the low-impact development model in which stormwater runoff and primary stormwater pollution can be controlled by decentralized and small-scale source control mechanisms and techniques, thus largely reducing flood control pressure, controlling non-point source pollution (especially urban water pollution), and improving the overall water ecological environment. Although these facilities require only very small investment, they can achieve substantial ecological benefits through careful design and management. We should take full advantage of the benefits of integrated river basin control, starting from the sources to systematically, comprehensively and intensively promote the low-impact development and construction model (buildings, communities, roads, municipal systems, rivers, etc.), thus achieving comprehensive efficiency (Figures 36).

Green buildings

Greening and eco-system

Low impact development



Technologies of low impact development

Figure 36. Advanced systems and technologies for achieving efficiency

(5) Constructing a green traffic system

Green traffic system prioritizes the development of slow traffic systems while enabling the integration of slow traffic systems into rail and regular bus transportation, ultimately giving rise to both a transportation system in which green traffic accounts for more than 65% and the realization of a win-win situation for public transportation and green transport (bicycle traffic, pedestrian traffic). Simultaneously, there has been special emphasis on the use of the TOD concept in the planning and design of the ecological metro group. Rigorous land planning and control are applied to subway stations' exits, thus bringing added land value through accessibility and compensation for investment in rail transportation through land transfer. Large-volume public ground transportation should be designed at the transits of rail transport systems to closely integrate public transportation into bicycle lanes and greenways, thus forming a perfect combieconomy of the rail transit system, the ground bus system and slow traffic systems to achieve both compactness and savings. The TOD's objectives include optimizing traffic accessibility, improving public finances, increasing social employment, advocating the high-density use of land, achieving energy savings and emissions reduction, etc. (Figures 37 & 38).

Figure 37. Establishment of green transportation system

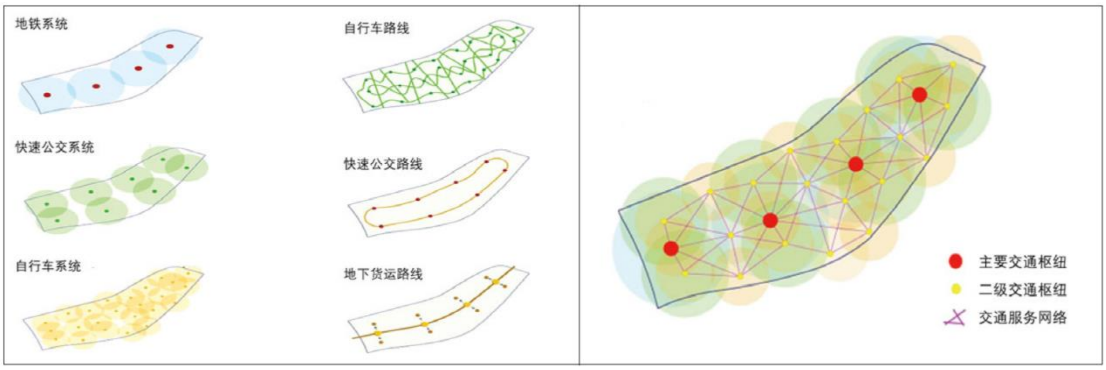


Figure 38. Slow transportation and its connection with public transportation

The premise of green traffic is a high-density road network structure. Kunming Chenggong New City is a very prominent example of this phenomenon: as a low-carbon eco-city, the original road network structure (whose design was based on conceptual planning) was later adjusted to a high-density road network structure in which spaces for bicycles and pedestrians were doubled (Figure 39).

Figure 39. Chenggong New Town before and after planning

(6) Rejecting industrial projects with high energy consumption and high emissions

To build competitive industries, we must pay attention to industrial cultivation for an ecological city. To nurture eco-city industries, we should not only create enough jobs but also ensure that those jobs are in line with the development of China's emerging advantageous industries. More importantly, we should ensure the intercross and comprehensive development of the service industry, information industry, creative industry and modern agriculture. Meanwhile, we should learn from the experience of Japan’s eco-cities, in which an eco-town’s enterprises can use each other's waste materials to form a circular chain of industrial .

On the one hand, many Chinese cities need to build a satellite city or new district or new town. On the other hand, they need to promote the transformation and renovation of the old city, thus requiring two new urban development models: one to construct new eco-cities and the other to transform existing cities and towns into low-carbon eco-cities. This approach requires pilot and demonstration programs, constantly summarizing experience and active and steady forward progress. Meanwhile, it is necessary not only to engage in innovation and the promotion of key technologies for eco-cities but also to achieve technology localization. Large scale eco-city planning and construction is conducive to extensive intereconomical scientific and technological cooperation, which deepens China's opening-up model. The depth and breadth of this new intereconomical cooperation are far greater than ever; moreover, they are untroubled by trade protectionism. Therefore, the government is unswervingly promoting the development of the low-carbon eco-city to promote cities' urban, economic and civilization transformation.

6.4 China's low-carbon urbanization development model

(1) Obtaining a correct understanding of urbanization

Urbanization is not the same as urban construction, nor does it "round up" people and bring them to cities. The primary substance of urbanization is not the increase in the number of towns and the expansion of their scale; thus, we cannot use the ratio of urban population to economical total population as the indicator to measure urbanization levels. Urbanization is a comprehensive and systematic process in which changes in society, the , production, life, and ideas are the most important; accordingly, we must fully understand that the essence of urbanization is the urbanization of people. Only by keeping in mind the ultimate goal of "improving people's quality of life" are we able to avoid the emergence of the so-called “city-making” phenomenon that emphasizes only changes in physical space and environment while people compete to invest in projects, acquire land and build houses.

(2) Adhering to cities’ compact development

First, we must scientifically plan the urban population. When predicting urban population size, we should comprehensively take into account factors such as the natural growth and mechanical growth of the population, population inflows and outflows, the carrying capacity of resources, and development potential. Only by accurately grasping the size of the population of urban planning are we able to curb the excessive construction of the city. Otherwise, as urban planning population exceeds the size a location can accommodate, it will inevitably occupy too much land, cause the excessive loss of arable land resources, and exaggerate the demand for both urban infrastructure and various types of public facilities, leading to excessive resource and energy consumption that drives the excessive development of upstream high energy-consuming industries and generates wasteful carbon emissions.

Second, city construction should be compact. Only by realizing compact city development can we reduce the input of resources from the source of urban construction, reduce the accumulation of "carbon stock," and provide the possibility for later-stage efficient operation. Because new cities usually have a long maturity period, the scale of new cities should not be too large. Because industry provides the city's foundation, new cities should gradually advance based on local conditions related to old cities' industries. In constructing new cities, we should avoid chaotic construction because the disorderly development of space is not conducive to population concentration and it is impossible for fragmented industrial distribution to achieve the effect of economic agglomeration. The construction of industrial parks should be organically combined with urban space expansion to avoid the phenomenon in which people live in the city but work in the suburbs or new cities, thus avoiding the development of a "pendulum population" of residents who are employed in the city but housed in the suburbs. Only by building cities into "people-oriented" livable cities from the urban planning level and achieving mixed functions—i.e., achieving the integration of residential, work, and business functions to shorten travel distance and reduce traffic pressure—is it possible to fundamentally reduce demand for and dependence on private vehicles, thus decreasing traffic energy consumption and carbon emissions while maintaining quality of life. Moreover, the compact development of cities can increase density, thus improving cities' public transport access rate and lowering energy consumption. Compact development also helps business and service industries prosper and create more jobs; overall, the service sector is relatively low-carbon.

(3) Measuring the rationality of urban construction using full life-cycle efficiency

To avoid an urban construction bubble, urban construction should be moderate and reasonable, which is key to ensuring highly efficient, intensive and low-carbon cities. According to life-cycle thinking, the rationality of urban construction can be measured based on the following aspects:

First, the facilities should have an adequate service life with low maintenance costs. Second, the utilization rate and use frequency should be high. Third, costs should be taken into account when implementing energy-saving high technologies.

(4) Integrating the concept of residents' low-carbon lifestyle into urban planning and construction

China's promotion of energy saving and emissions reduction has long focused on production processes and technological innovations. However, all production is for the purpose of consumption; in terms of consumption, the big differences among different cities’ carbon emissions levels are caused by residents’ different lifestyles, whereas urban physical attributes such as density, spatial distribution, public service supply, economic base and unique social factors often affect residents' choice of lifestyles and then determine the level of urban per capita carbon emissions. Therefore, it is necessary to create the conditions for consumers to establish a low-carbon lifestyle in urban planning and construction to establish the most extensive public foundation for low-carbon city construction.

First, the residential sublet scale can be appropriately reduced. This reduction will not only increase the interaction among the residents and strengthen the sense of neighborhood in the living space but also help disperse various functional spaces near the living space to form a mixed layout of residential space and other various functional spaces, including office, small-scale industries, various service facilities, etc., to facilitate residents’ travel, employment and daily life.

Second, house sizes should be controlled. Housing comfort does not necessarily positively correlate with house size, and the inefficient use of space created by inappropriately large sizes or large but not useful houses not only wastes land resources but also increases the power consumption of home appliances, resulting in further waste. The scale-down of family size is an important trend worldwide; with smaller-sized families, the number of families increases, leading to increased housing demand and the consumption of more land, resources, etc. Smaller households have lower energy efficiency, leading to increased carbon emissions caused by energy consumption. China's land resources are limited, and its resources suitable for human habitation are even more limited. To achieve the goal of "adequate shelter for all," it is necessary to control the per capita residential area standard, e.g., to avoid exceeding the standard of 29.3 m^2 per capita in middle- and high-income economies that is demonstrated by United Economys statistics. If the average size of an urban household in China is 2.9, it is appropriate to have a residential area of approximately 90 m^2, which is equivalent to the average area of new houses in Japan (91.3 m^2).

Third, priority should be given to the development of public transportation. Prioritizing the development of urban public transportation is an important way to reduce energy consumption, environmental pollution and land use, making it convenient for residents to travel. Developed economies' experiences show that when people become accustomed to traveling in private vehicles, it is difficult for them to switch back to public transportation. In the US, the automobile-driven, sprawling urban development model has made people dependent on cars to travel, leading to household per capita carbon emissions from travel that are much higher than that in other European and American economies. Given China's huge population, if China's urban road design is oriented toward the demand of motor vehicles and the ownership and use intensity of private vehicles are not controlled, then regardless of how roads are to be expanded and how many over-crosses and subways are to be built, it will remain impossible to meet travel needs and control traffic jams. Therefore, the implementation of demand management strategies and the prioritization of both public transportation and the humanistic design of pedestrian sidewalks and bike lanes in urban planning and construction will create more convenient travel conditions for residents. In addition to convenience and accessibility, it certainly remains necessary to provide quality services that prompt the residents to prefer public transportation.

Part 7. Conclusions

In this study, we conducted a systematic investigation of low-carbon towns' construction capacity at five levels: a literature review, policy research, an assessment model, case studies and demonstrations of China's low-carbon city construction. The research contents of this report have implications for the construction of low-carbon cities and towns in the APEC region. The driving force of low-carbon towns' capacity building in the APEC regions can be summarized at the following four levels. It is necessary to understand how to take full advantage of the driving paths at these four levels, to enhance the comprehensive building capacity of low-carbon cities and towns in the APEC economies and to avoid the detours taken by China while learning from the successful experience of developed areas so that integrated building-capacity programs of low-carbon cities and towns can be developed according to local conditions.

7.1 Low-carbon, innovation-driven paths at the government level

At the government level, we should develop low-carbon innovation-driven strategies and improve low-carbon innovation policies so that policy support and legal protection can be provided for the new type of urbanization.

First, we should develop a low-carbon innovation-driven strategy and development planning to determine the direction and paths of innovation development, low-carbon development, and green development of new types of urbanization based on a macro, strategic and global vision. The state government, local governments and local governments' functional departments must not only attach great importance to the green development of low-carbon and new types of urbanization but also pay attention to low-carbon, energy-saving and emission reduction in industrial planning, policy choices, institutional arrangements, etc.

Second, we should develop various incentive policies for low-carbon technological innovations, establish low-carbon innovation funds and increase government funding for low-carbon innovation, establish government seed funds and guide social capital and social forces into low-carbon technology innovations that not only provide policy support and public services for low-carbon technological innovations but also lower the social costs of low-carbon technological innovations.

Third, we should strengthen infrastructure construction and public service supply for low-carbon innovation and encourage enterprises, universities, research institutes and others to jointly construct public low-carbon science and technology service platforms, low-carbon science and technology innovation key laboratories, low-carbon science and technology research and development centers, etc., to transform governmental functions and establish intellectual property protections that provide the necessary services and legal protection for enterprises and research institutes engaged in low-carbon technology innovations.

7.2 Low-carbon, innovation-driven paths at the enterprise level

At the enterprise level, we should allow enterprises to assume the subject status in low-carbon technology innovation to improve their independent low-carbon innovation capability and establish a low-carbon corporate image. In the new urbanization, enterprises are not only urban and regional economic development task forces but also key players in technological innovation. To realize the low-carbon, green and sustainable development of the new urbanization, enterprises should be encouraged and guided to actively reduce the development of traditionally high-energy consumption industries and the production of high-carbon products, take the initiative to engage in enterprise transformation and product upgrades, strengthen technological innovation (especially low-carbon, ecological, and green innovation), and achieve improvement in enterprise competitiveness through low-carbon technological innovation and breakthroughs.

First, enterprises should improve their ability to achieve low-carbon, independent innovation and pay more attention to independent innovation based on introducing, learning, copying, imitating, etc., to transform the traditional foundry production model and enhance their own technological strength and innovation capability, especially in the energy-saving and emission-reducing field of low-carbon technology, more effectively improving their technological competitiveness and innovation capability.

Second, we should actively respond to market demands (especially from the green low-carbon products market), select low-carbon and energy-saving technologies and products for innovation breakthroughs, establish low-carbon technology innovation systems with enterprises as the mainstay and the integration of production, learning and research pertaining to emerging and low-carbon markets, jointly conduct low-carbon technology research and development projects with universities and scientific institutes and establish a long-term mechanism of urban low-carbon innovation cooperation.

Third, we should use low-carbon technology innovation as a driving force and low-carbon product marketing and low-carbon management innovation as a strategy to build a low-carbon corporate image, create low-carbon product brands, improve enterprises' competitiveness in low-carbon markets and promote the low-carbon innovation and low-carbon development of the new urbanization.

7.3 Low-carbon innovation-driven paths at the level of research institutes

At the research institute level, we should encourage basic research on low-carbon knowledge and low-carbon scientific and technological innovation, increase funding and establish an alliance of production, learning and research for low-carbon innovation.

First, research institutes are encouraged to engage in basic studies of low-carbon knowledge, low-carbon theory, low-carbon science and technology, etc., to establish a theoretical foundation for low-carbon technological innovation, promote the integration both of basic research and applied research and of low-carbon technology innovation theory and low-carbon technology innovation practice. In terms of infrastructure, equipment condition, and research funding, we should increase financial input to improve research institutes' low-carbon theoretical innovation, low-carbon scientific and technological innovation and low-carbon science and technology service capabilities.

Second, we should establish an alliance of production, learning and research for low-carbon innovation and encourage universities, research institutes and enterprises to work closely to develop low-carbon technologies and products, promote low-carbon technology transformation and application, cultivate new low-carbon industries, and provide technical and industrial support for low-carbon development of the new type of urbanization, e.g., joint studies and cooperative innovation in fields such as carbon capture and carbon sequestration technologies, alternative technology, reduction technology, recycling technology, green consumer technology, ecological restoration technology, etc. Research institutes are encouraged to transfer low-carbon scientific achievements to enterprises and are supported in starting up low-carbon scientific and technological enterprises.

Third, universities and research institutes are encouraged to improve their personnel training and innovation team building in the field of low-carbon technology, thus strengthening training of their personnel in the fields of low-carbon technology and low-carbon development and cultivating high-quality workers who specialize in low-carbon technology, low-carbon innovation, low-carbon management, low-carbon marketing, etc., for enterprises and society alike.

7.4 Low-carbon, innovation-driven paths at the social and public level

At the social organization and public levels, we should foster low-carbon innovation service organizations, encourage public participation, build or make space for low-carbon innovation and create a social and cultural environment for low-carbon innovation. This is necessary to strengthen the construction of social organizations to cultivate intermediary organizations for low-carbon innovative science and technology that responds to the needs of the new urbanization and low-carbon innovation services, providing not only the necessary technology, information, laws, marketing, promotion, etc., for low-carbon innovation but also the technological transformation and industrial development related to low-carbon innovation. We should promote low-carbon innovation cooperation in production, learning and research by relying on the intermediary role of social organizations; strengthening social organizations' institutional innovation and building of talented teams; establishing a communication mechanism among the government, enterprises and science and technology-oriented social organizations; and establishing an information-service and resource-sharing mechanism for low-carbon science and technology innovation. However, we should also encourage and attract the public not only to actively participate in low-carbon innovation and the new urbanization but also to either build or make space appropriate to the new urbanization and low-carbon development through co-building and sharing, urban and rural co-ordieconomy, and coordinated innovation. It is necessary both to take full advantage of the public's pioneering spirit related to low-carbon innovation and to fully mobilize the vitality of social innovation to encourage public innovation oriented toward low carbon, energy savings and environmental protection while actively cultivating the green low-carbon consumption culture and consumption concepts of low carbon, saving energy and saving resources so that the public takes the initiative to select green low-carbon products and create a cultural atmosphere and social environment of low-carbon innovation and low-carbon consumption. We should also strengthen promotional and publicity activities regarding low-carbon knowledge, low-carbon technology, low-carbon innovation, low-carbon life, etc., guiding public opinion about low-carbon innovation so that urban low-carbon consumption and urban ecological civilization become mainstream values. We should encourage the public to actively participate in urban greening, beautifying construction, afforestation, planting flowers and grasses, increasing carbon sinks, reducing carbon emissions, and jointly building a new low-carbon urban system that is ecological, livable and consistent with APEC characteristics, thus enhancing the comprehensive capacity of the APEC economies to build low-carbon cities and towns.

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