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Innovation practice in engineering management of the Shenzhen International Low-Carbon City

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Keywords low-carbon city, low-carbon design, city-industry integration, low-carbon development, low-carbon management

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1 Introduction

Shenzhen is a pioneer city in China's reform and development. The city has entered a post-industrialization stage and created the "Shenzhen Miracle" in the development of cities around the world after nearly 40 years of rapid development. In 2010, Shenzhen became one of the first low-carbon pilot cities in China. Since then, the city has taken the lead in explorations in many aspects, including developing low-carbon industries, building low-carbon cities, and advocating low-carbon life. Furthermore, the city has developed a duplicable and promotable sustainable development model for super-large cities.

Xiamen, Nanchang, Guiyang, Baoding, Hangzhou, Tianjin, and Chongqing are among the first batch of low-carbon pilot cities along with Shenzhen. Most cities, such as Sino-Singapore Tianjin Eco-city, Guian New District of Guiyang City, and Liangjiang New District of Chongqing

City, opt to build new towns on undeveloped land as a demonstration of low-carbon urban construction. Conversely, as a highly developed city, Shenzhen explores the mode of low-carbon development transformation through the renewal and upgrade of stock space.

Pingdi Subdistrict is located in Longgang District, Shenzhen City. As an industrialized urban area with a relatively low level of development, it has undeveloped land, low-density industrial areas and high-density residential areas, good ecological forestland, polluted rivers, emerging industries, and a large number of traditional backward industries. This complex construction condition provides a possibility for conducting centralized research and development, integrated applications, and a comprehensive demonstration of low-carbon technologies. To this end, the research team of the Harbin Institute of Technology Shenzhen Graduate School and the Next Generation Fund from the Netherlands suggested that Pingdi Subdistrict could be built into an international eco-city. Since then, this idea has continued to attract attention from leaders of related ministries, Guangdong Province, and Shenzhen City, as well as experts at home and abroad. Finally, at the end of 2011, the National Development and Reform Commission named this project the Shenzhen International Low-Carbon City.

The China-Europe Urbanization Partnership Summit was held in Brussels, Belgium, in May 2012. Xu Qin, who was the mayor of Shenzhen City at that time, proposed to cooperate with the EU to plan for and build the Shenzhen International Low-Carbon City and present a flagship project for sustainable urbanization cooperation between China and Europe. In August of the same year, Shenzhen launched the Core Area Project of the Shenzhen International Low-Carbon City, which covered a total planned area of 53 km² and a total investment of approximately 10.37 billion yuan. The project mainly studied the possibilities of reduced total carbon emissions while maintaining the vitality of regional development. Furthermore, it explored the country's low-carbon development, presented a replicable and promotable model, and provided

Received April 1, 2019

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an important strategic fulcrum for China's participation in international negotiations on climatic change.

2 Low-carbon practices by the Shenzhen International Low-Carbon City

2.1 Project positioning and construction mode

The Shenzhen International Low-Carbon City Project bears the orientation to integrate international guidance with local features, integrate urban development with industry development, and combine resource development with ecological civilization. As such, it aims to build "Four Zones and One Highland," namely, national low-carbon development pilot zone, national pioneering zone for addressing climatic change, national demonstration zone for low-carbon industries, and leading zone for international low-carbon cooperation, and a strategic highland for China's low-carbon development.

The project adheres to a multiplanning synergy under the constraints of carbon targets. A top-level design research will be comprehensively implemented considering the constraints of carbon emission targets. A "multiplanning synergy" planning system that includes overall development, industrial, spatial, and resource planning, and indicator system research is innovatively established. The country's first low-carbon industry access list and guidelines for low-carbon control of construction land are developed.

At the same time, the SMART planning strategy is proposed under the premise of sustainability based on a detailed ecological background diagnosis. This strategy includes comprehensive considerations of carbon sink networks, microclimate optimization, green buildings, low-carbon municipal administration, and low-carbon transportation.

The development model of the Shenzhen International Low-Carbon City applies a bottom-up practice path. A 1 km² start-up area was set up as the "research and

development" stage of the low-carbon development model. Furthermore, a 5 km² expansion area was set up as the "trial stage" of low-carbon brand building. Through these areas, the full output and promotion of 53 km² will be finally achieved.

To guide the construction and implementation of the international low-carbon city, its construction and management organization were based on relevant policies and referred to research on low-carbon cities locally and abroad. An indicator system that includes the general development, energy utilization, industrial development, livelihood, consumption, resource environment, and policy supervision of the low-carbon city, was developed. At the same time, the government also compiled an industry access list for the international low-carbon city. The list defines the types of encouraged industry, restricted development, and prohibited industry and provides guidance for the introduction and development of low-carbon industries.

2.2 Construction of "Green Workshop"

The Shenzhen International Low-Carbon City adopts a "half-step" rolling development model. The start-up area utilizes relatively less capital and a short construction period. Furthermore, it uses light-weight structures, existing renovated buildings, and open spaces, such that the area presents a small but comprehensive model image. Among them, the "Green Workshop—Shenzhen International Low-Carbon City Convention and Exhibition Center" is the core of the 1 km² start-up area. The main functions include low-carbon technology exhibition and transaction, low-carbon international conferences, the Shenzhen International Low-Carbon City exhibition hall, energy and resource information monitoring center, auxiliary supporting functional housings, various micro-municipal administrations, micro-energy, micro-transportation demonstration, ecological plank road systems, and ecological parks and revetments. The Green Workshop was completed in 183 days and serves as a venue for



Fig. 1 Effect drawing of Green Workshop

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international conferences. It aims to build a low-carbon lifestyle experience base rapidly and become a “window” for the international low-carbon city project to attract foreign investment.

The Green Workshop relies on the advanced low-carbon concept, local integrated low-carbon technology, and three-dimensional low-carbon atmosphere building. It also integrates multiple functions, such as business activities, conference exchanges, special celebrations, and leisure and entertainment. Moreover, the Green Workshop is committed to building an experience base with a low-carbon city lifestyle mode. The project respects the natural background and applies 10 technical systems and 97 technical strategies that are adapted to the local and southern Chinese climate. In this manner, the building performance can exceed the three-star standard requirements for national green buildings. The energy consumption level can be reduced by 50% compared with the traditional exhibition center. Thus, the demonstration effect of an annual average carbon reduction of more than 1000 tons can be achieved. The main building of the Green Workshop is divided into exhibition, conference, and trading halls and supporting facilities. It is a structural steel construction that creates a large space during design. Then, segmentation and transformation were performed according to specific needs that can enhance the flexibility of its functions. The Green Workshop is the venue for the Shenzhen International Low-Carbon City Forum. The project can transform the front porches and outdoor platforms in the conference hall into several conference rooms and lounges for flexibility in meeting the needs of a

large number of conferences. Its outdoor space is fully integrated with the natural background, which becomes an open space for daily rest and activities of the surrounding residents.

2.3 Construction of a low-carbon industrial cluster

The Shenzhen International Low-Carbon City will selectively promote the project implementation by using the “Three Steps” strategy. By 2025, the Start-up Zone of 1 km² is expected to be fully completed; the Expansion Zone of 5 km² will reach a considerably scale; and the Whole Region of 53 km² will achieve a leap-forward development. The Shenzhen International Low-Carbon City will always adhere to the strategy of four major low carbon, adhere to the concept of “High-end Leading, Innovation Driving,” and take the major project as an important starting point for the development of low-carbon cities. Moreover, the mechanism of innovation to high-end low-carbon R&D resources will be introduced, a low-carbon industrial cluster will be formed by drawing upon experience gained on key points, urban construction and operation mode will comprehensively innovate.

Since its startup and construction, the Shenzhen International Low-Carbon City has started with the planning and construction of comprehensive systems, such as clean energy, construction of low-impact municipal infrastructure, purely electric public transportation, and green buildings. To achieve these objectives, the elimination of enterprises with low output value and strong pollution has been increased, and low-carbon industries



Fig. 2 Quick-start construction process of Green Workshop
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were developed. Furthermore, a number of strategic emerging industries, such as energy conservation and environment protection, new energy and new materials, and high-end quality projects that focus on future industries, such as aerospace and life health have been successfully introduced. In recent years, 44 high-tech enterprises above the state-designated scale have been introduced. These enterprises, such as AeroJones Aviation, Space Institute of Southern China, Distributed Energy Resource Projects, Sino-US Low-Carbon Building and Community Innovation Experimental Center, reached a total output value of 27.403 billion yuan.

Adherence to the city-industry integration and focusing on improving the infrastructure conditions of the area have been observed. The opportunity of a low-carbon city and intensive development of urban railway stations have been combined to build public infrastructure and innovate urban construction and operation mode. In addition, development concepts, such as city-industry integration and three-dimensional city, have been combined to build a high-density and low-carbon community. At the same time, historical and cultural villages have been protected and integrated with the Dingshan River ecological corridor to form a largely dense-sparse urban spatial form. The Shenzhen International Low-Carbon City has completed a total of 30 infrastructure service projects, which were approved with a total investment of approximately 13.6 billion yuan. The project has covered the construction of educational and medical service facilities; infrastructure construction projects, such as highway construction and river improvement based on the Dingshan River; and construction of park and green spaces, such as the Country Park of the Shenzhen International Low-Carbon City.

3 Effect of low carbon development

Before the construction of the Shenzhen International Low-Carbon City in 2011, the average energy consumption and carbon emission intensity of the Pingdi Sub-district were approximately two times that of the average level of Shenzhen. When it produces 10000 yuan of GDP, approximately 2.21 tons of standard coal are consumed. And the number was equivalent to the national average level of the year. In addition, the gross regional production of land per unit area of the Shenzhen International Low-Carbon City was 1/5 that of the average level of Shenzhen.

Upon the beginning of the Shenzhen International Low-Carbon City project in 2012, it organically integrated social and economic development, green and low-carbon transformation, and urban planning and construction. Furthermore, it adhered to quality leading, planning guidance, project promotion, and the concept of human-oriented, and extensively cooperated with developed countries and regions to explore an effective path for high-end and low-carbon leapfrog development in rela-

tively backward regions. The gross regional production, total industrial output value, and fixed-asset investment of Pingdi Subdistrict achieved a rapid growth. Its gross regional production increased from 4.28 billion yuan in 2011 to 10.925 billion yuan in 2017, with an average annual growth rate of 16.9%; its total industrial output value increased from 11.5 billion yuan in 2011 to 32.744 billion yuan in 2017, with an average annual growth rate of 19.05%; and its social fixed-asset investment increased from 1.91 billion yuan in 2011 to 7.752 billion yuan in 2017, with an average annual growth rate of 26.3%. From 2011 to 2017, its carbon emission intensity decreased by 54.20%. Pingdi has initially embarked on a quality development path with low environmental cost, low resource consumption, and positive economic benefits.

Through green transformation, the stocking plants of the Start-up Zone reconstruct 270000 m² of parks, and the Expansion Zone arranges for 300000 m² of innovation parks. The community collective and private economy are full of vitality, residents' dividend is increased by 30% on average, and the plant rent doubles from the original 7 yuan or 8 yuan per square meter.

The Shenzhen International Low-Carbon City will vigorously promote the application of clean energy. By the end of 2018, the planned solar installation area of 16421 m² was achieved, and the annual power generation is expected to reach 408 million kWh. The electricity consumption per 10000 yuan of GDP dropped from 2325.07 kWh in 2011 to 1482.80 kWh in 2017, with an average annual decrease of 7.22%. In addition, the water consumption per 10000 yuan of GDP dropped from 59.22 tons in 2011 to 24.80 tons in 2017, with an average annual decrease of 13.5%. With the needs of construction of the Shenzhen International Low-Carbon City and the entry of a large number of enterprises, the total carbon emission was relatively stable; it increased from 57.21 tons in 2011 to 57.45 tons in 2017, with a growth rate that is considerably lower than the average level in Shenzhen. The carbon emission intensity shows a significantly downward trend, that is, from 2.326 tons/10000 yuan in 2011 to 0.657 tons/10000 yuan in 2017 (estimated value), with an average annual decrease of 18.99% and indicates a decrease of 71.75% in 2017 compared with that in 2011.

Upon the completion of the first phase of the Start-up Zone of the Shenzhen International Low-Carbon City, the Green Workshop, which is an open exhibition center without walls and gates, has become a place for daily relaxation and recreation of the surrounding residents. The Green Workshop has greatly improved the happiness index of the local residents. The government procurement service introduced the research institute named the Shenzhen Institute of Building Research Co., Ltd. The institute will monitor and evaluate the actual operational performance of the low-carbon technology used in the Start-up Zone using the innovation model Design + Operate + Transfer. A continuous tracking service of the entire process of design,



Fig. 3 Pictures of activities in the Shenzhen International Low-Carbon City
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construction, and operation will be implemented to provide a low-carbon technology list for the development and construction of the Expansion Zone and the Whole Region.

During the past five years of operation, the Shenzhen International Low-Carbon City has ushered distinguished guests from 129 countries and regions, as well as 26 provinces (cities) for visit and exchange. It has held various activities for more than 120 times. More than 150000 people have participated in low-carbon science popularization activities, of which more than 90000 are primary and secondary school students. Thus, the Shenzhen International Low-Carbon City is a window for promoting the concept of green and low-carbon technologies in Shenzhen to the entire country and shows the world of China's advocacy of low-carbon emission.

4 Review and outlook

The development and construction history of the Shenzhen International Low-Carbon City show that this project has achieved sustainable development through green leading, international benchmarking, smart innovation, and inclusive sharing. The project has relied on the improvement of endogenous power and integration of technology and market without dividend policy.

The Shenzhen International Low-Carbon City reverses the traditional development model of “Seven Accesses and Site Leveling”. It initially builds a soft and hard infrastructure system, including low-carbon energy supply network, carbon emission management network, sponge

city base, and low-carbon transportation network, to reduce carbon emissions. This system is used as a platform to gather innovation resources and low-carbon technology applications.

The Shenzhen International Low-Carbon City pays attention to reducing carbon emission intensity while developing the economy to challenge GDP growth and the traditional concept that remains inconsistent in coping with climate issues. As a result, it provides one new environment. With the international language of “carbon emissions,” it performs all-round exchanges and cooperation in economy, technology, and culture to promote the opportunities and new atmosphere for economic development through the improvement of the ecological environment of late-developing regions.

The original issues are clarified, and a “new normal” of low carbon is defined. An ecological background diagnosis of the Shenzhen International Low-Carbon City is actively performed, and the current status of the carbon emissions of the project is mastered through analysis of existing enterprises. On this basis, an indicator system is created for the Shenzhen International Low-Carbon City, which comprehensively grasp its development and construction. A catalog of low-carbon industry orientation is compiled, and access standards are clarified. In addition, carbon emission assessment methods are formulated for construction projects, and a public platform for carbon emission monitoring is established. Furthermore, corporate carbon emissions are monitored, managed, supervised, and assessed.

The first phase of the construction of the Shenzhen International Low-Carbon City adheres to the principle of

“1 + 2 + N,” which breaks the construction mode of the conventional “Management Committee” and builds a platform for the mutual improvement of government resources at city, district, and subdistrict levels. Furthermore, it promotes the joint participation of the government social markets, where each side works to diversify and promote the construction of the Shenzhen International Low-Carbon City.

Under the guidance of the low-carbon indicator system, the Shenzhen International Low-Carbon City should strictly implement the top-level strategy of “Multiple Plans Merging into One Area” in future construction. It should also rapidly improve the existing service facilities level; control the optimization of spaces, such as area style; and continue to strengthen the adjustment and optimization of the industrial structure. Under the development trend of specialization, segmentation, and industrial chain of low-carbon industry, the project should deepen resource integration and gradually form a low-carbon industrial ecosystem.

At the same time, the construction management level should be further improved. In addition, the low-carbon indicator system should be implemented from the source, and low-carbon emission and environmental protection

should be ensured during the construction and operation of industrial projects. A carbon emission management platform should also be established to realize the dynamic monitoring of carbon emissions in the Shenzhen International Low-Carbon City. This step is an important starting point for the continuous implementation of carbon emission reduction in the construction of the Shenzhen International Low-Carbon City. After completion, this aspect is also one of the capacity building steps for docking the Shenzhen and national carbon emission permit trading markets.

Planning and constructing the Shenzhen International Low-Carbon City is practical for the Shenzhen Special Economic Zone for the implementation of central decision making and green and low-carbon development. This project is also a useful exploration for strengthening green and low-carbon international cooperation, gathering green and low-carbon resources in a wide scope, and promoting quality new urbanization. The successful construction and operation of the Shenzhen International Low-Carbon City will enable the relatively backward areas to achieve high-end and low-carbon leapfrog development and provide reference and example for other relatively backward areas in Shenzhen and similar areas throughout China.