Comparison of International Low-Carbon Park Operation and Management Modes

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Abstract. This paper analyses the formation, development and governance of international low-carbon parks, and innovatively summarizes three operation and management modes of international low-carbon parks: "Industrial Symbiosis" operation and management mode, " Industry-City Integration" operation and management mode, and " Informatization-industrialization Integration" operation and management mode. Based on the definition, characteristics, strategies and practices of the three modes, this paper analyses the successful cases of applying the modes, compares the three modes, and summarizes the effectiveness of the cases in terms of sustainable development, as well as the opportunities for experience sharing and cooperation among international low-carbon parks. Finally, the future development trend of international low-carbon parks will be explored and research suggestions will be made based on the above.

Keywords: Comparison of International Low-Carbon Park; Operation and Management Modes

1 Introduction

1.1 Background

1.1.1 Background of dual-carbon strategy. Excessive carbon dioxide emissions have brought about the problem of continuous global warming, posing a serious threat to the ecological security of the planet and the survival of human beings themselves. In December 2015, nearly 200 parties around the world came together to sign the Paris Agreement, which sets the goal of controlling the rise in global average temperature to within 2 degrees Celsius of pre-industrial warming and striving to limit it to within 1.5 degrees Celsius to combat climate change and global warming.

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China has actively responded to the Paris Climate Change Agreement and formulated a "dual-carbon" strategic goal. In March 2021, the Ninth Meeting of the Central Financial and Economic Commission incorporated carbon peak and carbon neutral into the overall layout of the construction of an ecological civilization, and implemented actions to reduce pollution and carbon emissions in key industry sectors.

1.1.2 Background of the establishment of low-carbon parks. Policy background. In October 2021, the State Council issued the Circular on the Action Plan for Peak Carbon by 2030, stating that it would "create a number of energy-saving and low-carbon parks that have reached the international advanced level, build green factories and green industrial parks, push forward the development of recycling in industrial parks, and select 100 cities and parks that are typical and representative to carry out the construction of pilot projects for peak carbon. "

Social background. In 2010, the United Nations Industrial Development Organization (UNIDO) published a guidance document on the construction of low carbon industrial parks.[1] In 2022, the Guidelines for the Construction of Low/Zero Carbon Industrial Parks, led by the China National Institute of Standardization (CNIS) and Vision Energy Limited, were approved for publication, providing guidelines for the establishment and operation of industrial parks with zero carbon as the ultimate goal.

1.2 Purpose and significance

Our country is in the middle and late stages of industrial development, with industry accounting for the highest percentage of gross domestic product, and we are experiencing high levels of emissions, energy consumption and pollution at a stage of rapid industrial development. In addition, economic growth is constrained by the natural environment. The significances of low-carbon transformation of parks are as follows:

Low-carbon transformation of parks can help China's "dual-carbon" strategy. According to the 2020 research data from Tsinghua University's School of the Environment，industrial parks account for nearly 70% of the total industrial energy use, and the carbon emissions from industrial parks account for 31% of the country's total carbon emissions. According to the Rocky Mountain Institute's preliminary estimation, zero-carbon parks will contribute at least 15% of carbon emission reduction to the country's "dual-carbon" strategic goal. Industrial parks are the key space for carbon emissions.

Low-carbon transformation of parks can promote industrial transformation. Industrial parks are an important carrier for industrial development and a core unit for enterprise agglomeration and development. The policy requirements of the "dual-carbon" strategy will promote the green and low-carbon transformation of industries in industrial parks. The low-carbon industrial park integrate the resources and energy between different industries in the comprehensive industrial park, to realize resource complementarity, improve resource utilization and develop a circular industrial chain; low-carbon industrial parks apply green technology, green buildings, green equipment, etc., to lead the reform of the supply side of the industry; low-carbon industrial parks create a smart platform and collect a large amount of data to provide a platform for the industry enterprises to integrate resources and cooperate in the development of the platform.

Low-carbon transformation of parks can accelerate regional economic development. There has been a growing trend towards de-industrialization in developing countries, which creates jobs, increases household incomes and drives gross domestic product (GDP) and positive economic development. The 2030 Agenda for Sustainable Development states that sustainable industrialization and supporting infrastructure play an important role in poverty eradication. Industrial parks are the core force of regional economic development due to the factors including population, industry, energy, resource, innovation, etc. By 2020, the growth rate of the park economy's contribution to the national economy had exceeded 31 per cent.

2 Overview of low-carbon parks

2.1 Definition

Zhang Hongbo et al. (2010) defines industrial park as a new type of industrial park designed and established on the basis of a low-carbon economic development mode that seeks low energy consumption, low pollution, and high production, and follows the principles of low-carbon energy conservation, complementary industrial recycling, and low-carbon economics.[2] Zong Jianfang et al. (2018) define low carbon as a people-centered industrial park that integrates carbon emissions and sustainable development, actively uses clean energy, and has a high utilization rate of resources and energy.[3] This paper summarizes the above viewpoints and defines a low carbon park as an industrial park aiming at reducing carbon dioxide emissions and energy consumption, with the development of a low carbon economy as the core and low carbon operation and management as the means.

2.2 Objectives

2.2.1 Objectives. The ultimate goal of the low carbon park is to develop a "carbon neutral" zero carbon park.

The Rocky Mountain Institute (RMI) report "Zero Carbon Parks: A Carbon Neutral Demonstration from the Park" categorizes typical industrial parks into six types, namely industrial parks, port logistics parks, science and technology innovation parks, industry-city complexes, business parks, and tourist resorts. The parks have different strategic positioning for different functions which are given by Table 1.

Table 1. Zero-carbon strategic positioning of functional parks.

Type of park	Strategic positioning of zero carbon parks
Industrial Park	Industrial clusters and eco-industrial parks that focus on intelligent manufacturing, using clean energy, improving resource utilization, and satisfying the principles of circular economy.
Port Logistics Park	A comprehensive trade service hub and green physical practice base that is open, shared and innovative, aiming at low-carbon transportation and adopting high technologies as management means.
Science and Technology Innovation Park	Independent innovation platform and science and technology innovation demonstration zone that applies zero-carbon technologies with the development objective of high-end science and technology.

Type of park	Strategic positioning of zero carbon parks
Industry-City Complex	An eco-livable district driven by low-carbon industries and applying zero-carbon technologies in energy supply, transportation, and construction.
Business Office Park	A modern green office park featuring zero-carbon integration of transportation and building.
Tourist resort	An eco-tourism zone integrating sustainable design with zero-carbon cultural tourism at its core.

Source: RMI; FOREWARD

3 International low carbon park operation and management modes

3.1 Operation and Management Mode of Industrial Symbiosis

3.1.1 Definition and characteristics.

In this paper, the industrial symbiosis operation and management mode is defined as a low-carbon operation and management mode that relies on industrial ecological chains and industrial symbiosis systems and centers on the development of a circular economy.

Characteristics.

a. Forming an industrial ecological chain that simulates "producer-consumer-decomposer" and realizing the recycling of resources.

b. Forming a stable resource exchange network and constructing an industrial symbiosis system composed of multiple industrial ecological chains.

c. Forming a comprehensive energy system and realizing the gradual utilization of energy.

d. Circularization of parks and development of circular economy.

3.1.2 Operation and management strategies.

a. Introducing chain-supplementing industries to form an industrial ecological chain. Mimicking the symbiotic system in natural ecosystems. For example, power plants that can provide raw materials are "producers", cement factories and chemical plants are "consumers", and waste treatment plants and soil remediation plants are "decomposers" in order to decompose waste and recycle by-products.

b. Formation of industrial symbiosis system and establishment of resource-cycling industrial system. Professor of Tsinghua University School of Environment, pointed out in an exclusive interview with Sustainable Development Economy Guide that the comprehensive utilization of bulk solid wastes due to excess production and the lack of comprehensive utilization of the park economy is the difficulty in the establishment of resource recycling-based industrial system.

c. Equipped with an integrated energy system to achieve energy cascade utilization. Introducing new energy enterprises, increasing the rate of new energy application and adjusting the energy structure. Equipped with an integrated energy system, the integrated energy system is capable of realizing the conversion and integrated application of thermal energy.

3.1.3 Operation and management practices.

In 1989, the world's first eco-industrial park was established in Kalundborg Eco-Industrial Park in Denmark, and the Kalundborg industrial symbiosis mode was followed by other pre-industrialized countries in the world. 1994, the U.S. President's Council on Sustainable Development (PCSD) carried out eco-industrial pilot parks, and built 16 eco-industrial pilot parks by 1996. In 1997, Japan also started the construction of eco-cities using the industrial symbiosis mode, and 26 eco-city pilot parks were built by 2006. 2002, the United Kingdom started the National Industrial Symbiosis Program (NISP), [4] and set up a company specialized in industrial symbiosis to operate and manage eco-city parks in 2005, followed by South Korea in 2003, which is planning the construction of a national eco-park. With the batch establishment of eco-industrial parks in pre-industrialized countries, developing countries such as Brazil and Vietnam are also starting industrial symbiosis projects and parks. Guangxi Guigang National Eco-Industrial Demonstration Park, the first park in China to apply the industrial symbiosis mode, was awarded in 2001. By 2021, 55 national eco-industrial demonstration parks have been established in China.

3.1.4 Successful Case Study. Ulsan Eco-Industrial Park in Korea.

The Ulsan Eco-Industrial Park was once known as the Ulsan National Industrial Park (NIP), which was one of the most environmentally polluted areas in South Korea with heavy industries such as automobiles and chemical and petroleum industries, and in 2004, in order to solve the problem of environmental pollution, the local government promoted the transformation of the NIP into a low-carbon environment and started to build the Ulsan Eco-City.

a. Government policy promotion. In October 2003, the Korean government formulated a national eco-industrial park project plan based on Article 4.2 of the Act on Promotion of Environmentally Friendly Industrial Structures (APEFIS), and in 2004, Ulsan City formulated a plan for the construction of the "Ulsan Eco-City," which aims to establish an industrial eco-chain in the industrial parks, improve the industrial symbiosis system.

b. Natural ecology protection. Concrete riverbanks will be removed and planted wetland riverbanks will be applied; an underground sewage treatment plant will be established to simultaneously discharge water for the Taihe River to improve its water quality.

c. Industrial symbiosis network. Through the establishment of steam and water industry ecological chains, waste metal and by-product recycling industry chains, etc., the park has made it possible to improve the utilization rate of resources and reduce the energy consumption required for necessary industrial production and waste treatment.

3.2 Operation and Management Mode of Industry-City Integration

3.2.1 Definition and characteristics. Definitions:

Industry-City Integration originally refers to the synergistic development of industrial parks and cities, which is a development trend of industrial parks. This paper takes

industry-city integration as a kind of operation and management mode for low-carbon development of industrial parks, absorbing the concept of "green complex of industrial parks", and forming a definition: a low-carbon operation and management mode that introduces industrial parks into urban public service functions such as housing, finance, transportation, commerce, entertainment and recreation, and urban infrastructure construction, with the goal of balancing production, life activities and ecology.

Characteristics:

a. The coordinated development of industrial parks and cities

b. The balanced development of production, living and ecology

c. Integration into the tertiary industry and introduction of urban public service functions

d. he sustainable development of productive service facilities and urban supporting infrastructure construction

e. The formation of a green and low-carbon development-oriented operation system for the intensive development of industry, life, leisure, tourism and supporting facilities.

3.2.2 Operation and management strategies.

a. Extending the industrial chain and developing tertiary industry. The primary and secondary industries provide products for the tertiary industry, and the profitability of the products is accomplished through the perfect service of the tertiary industry, and the products realize the recycling of production and utilization in the industrial park.

b. Building sustainable productive services and urban supporting infrastructure. Constructing green buildings or transforming buildings to be green and low-carbon; establishing perfect living infrastructure and supporting facilities, attracting researchers, engineers and other talents to stay.

c. Developing green mobility and green transport. Green transportation of passenger flow and logistics is carried out within industrial parks to reduce energy consumption and carbon emission during transportation and traffic; a convenient green transportation system between industrial parks and cities is established to objectively strengthen the connection between industrial parks and cities.

3.2.3 Operation and management practices.

In 2016, the National Development and Reform Commission (NDRC) issued the Notice on Supporting the Construction of Industry-City Integration Demonstration Zones in Various Regions, which proposes that industry-city integration demonstration parks should "integrate elements of the city, production, and ecology, and build the demonstration zones into a new type of urban area that is economically developed, socially harmonious, ecologically civilized, and pleasant to live in and work in, and adhere to the four-pronged path of "production, city, people, and culture".

Internationally, developed countries have taken the lead in the establishment of low-carbon cities, such as Copenhagen, Denmark, Polt, the United States, and Tokyo, Japan. As China is in the middle and late stages of industrialization, and the population of our cities is large, at the beginning of low-carbon development, it is not suitable for the

establishment of low-carbon cities like developed countries, and it can only be transformed by making industrial parks low-carbon, and then through the means of industry-city integration, it will gradually develop into a low-carbon city.[5]

3.2.4 Successful Case Study. Suzhou Industrial Park (SIP).

Suzhou Industrial Park (SIP) is a cooperative project between the governments of China and Singapore, and is regarded as "an important window for China's reform and opening up" and "a successful example of international cooperation". The park has formed an industrial system of "2+3+1", i.e., two pillar industries, namely, new generation information technology and equipment manufacturing, three emerging industries, namely, biomedicine, nanotechnology application and artificial intelligence, and high-end modern service industry.

a. Enabling an inclusive carbon trading system. In April 2022, Jiangsu Province released the "14th Five-Year Plan" to address climate change, proposing to promote the construction of a province-wide carbon inclusive system. In November 2022, the nation's first market-based carbon inclusive trading system was launched through the "Suzhou Carbon Intelligent Service Platform", which was developed by Suzhou Industrial Park Carbon Inclusive System.

b. Building low-carbon communities. In 2016, the park issued the first national park-level "Low-Carbon Community Pilot Construction Work Implementation Plan", which focused on low-carbon, ecological and regional integration to create low-carbon community pilots with the park's "industry-city integration" characteristics, and 11 pilot communities have been selected.

c. Developing green finance. SIP has signed contracts with nine banks, including Industrial and Commercial Bank of China (ICBC) and Bank of Suzhou (BOS), on the financial product of "Innovation Points Loan", and has issued credit loans of more than RMB 245.5 million for 27 enterprises to solve the problem of difficult financing for SMEs' entrepreneurship.[6]

d. Adopting green buildings. The park actively promoted green buildings featuring energy conservation and environmental protection, natural lighting, and rainwater collection, and has been awarded the Provincial Building Energy Efficiency and Green Building Demonstration Zone.

e. Implementing of green transportation. The park has improved the public transportation network, popularized electric vehicles, built electric vehicle charging piles, and put in clean energy and new energy vehicles.

3.3 Operation and management mode of informatization-industrialization integration.

3.3.1 Definition and characteristics.

The informatization-industrialization integration operation and management mode is that industrialization and informatization are integrated with each other to promote the transformation of industries into digitalization, intelligence and low-carbonization.[7]

Characteristics:

a. Relying on the Internet platform to implement the "Internet industrial platform + park" mode

b. Utilizing Information technology to realize intelligent manufacturing

c. Digitalization and numerical control of key processes

d. Increased digitization of the industrial chain and supply chain

e. Enhancing system solution capability

3.3.2 Operation and management strategies.

a. Developing integrated based on the industrial Internet platform. Optimize and popularize the industrial Internet platform to improve the efficiency of resource allocation, help industries and enterprises to match production with demands, realize flexible production, optimize the allocation of manufacturing resources and reduce waste.

b. Enhancing the level of key technologies and optimize industrial smart manufacturing. Deepen the application of 5G, artificial intelligence, big data and other technologies to improve the level of intelligent research and development, intelligent testing, etc.

c. Making plans of digital transformation for industries and realize enterprises' digital management. Based on the characteristics of different industries and combined with the industrial ecological position in which they are located, carry out the roadmap for the digital transformation of the industry.

d. Strengthening the digital management of the industrial chain supply chain and improving the level of intelligent management. Build a complete 5G scale network design, construct an Internet big data center, and accelerate the construction of new information infrastructure.

3.3.3 Operation and management practices.

The integration of industrialization and informatization is a major strategic plan made by the CPC Central Committee and the State Council based on China's national conditions and development plans, with the "14th Five-Year Plan" Development Plan for the Deep Integration of Informatization and Industrialization as the policy guideline to analyze the form of development, and to put forward the general requirements and general line. The Plan states that by 2021, the national industrial enterprises will have achieved a CNC rate of 52.1% for key processes, a digitalization penetration rate of 68.1% for operation and management, a 73.0% penetration rate for digital R&D and design tools, more than 700,000 5G base stations, and a total of more than 70 million connections to industrial Internet devices. The plan further puts forward the development goal that by 2025, the national development index of the integration of the two industries will reach 105, the CNC rate of key processes in enterprises will increase by 16 percentage points, the penetration rate of digital R&D and design tools will increase by 12 percentage points, the penetration rate of digitalization of management will increase by 12 percentage points, and the penetration rate of the industrial Internet will reach 45%.

There are also corresponding types of parks abroad, such as science and technology industrial parks, whose low-carbon operation and management modes also reflect the integration of industrialization and informatization. The United Nations Industrial Development Organization (UNIDO) issued a report on "New Generation Science and Technology Parks", proposing a strategic approach to promote inclusive and sustainable industrial development through innovation and technology based on the background of the Fourth Industrial Revolution. Science and technology parks established abroad include export processing zones for high-technology products, high-technology industrial zones, and low-carbon smart parks.

3.3.4 Successful case study. Dongying port economic develop area.

Dongying port economic develop area was established in April 2006, and now forms a petrochemical industry cluster with the port as the leader and the aromatics and propylene industries as the core.

a. Building a dual-carbon digital platform to promote smart parks. The park cooperates with Peking University and China Gas to build the first dual-control energy consumption and dual-carbon digital platform in Shandong Province. In cooperation with Huawei, Beijing Daheng and China Mobile, it is the first time in China to test run the data collection of "Digital Twin + Data Center".

b. Constructing "1+N" Industrial Internet Platform System. "1" is the industrial Internet platform based on the smart park, "N" is more than 10 industry-specific platforms, to build a multi-platform linkage of the operating mode, in order to open up the two sides of the government and enterprises, connecting market resources, and coordinating the coordination of services.

c. Formulating development plans and policy guidance. The park set up a relevant leading group to prepare the Chemical Industry Park Industrial Master Plan and Industrial Development Plan, and implement the digital economy, "Project No. 1" oriented to the development of the digital economy.

4 Comparison of international low-carbon park operation and management modes

4.1 Comparison of characteristics of operation and management modes

In this paper, the operation and management modes of international low-carbon parks are classified into three types: "Industrial Symbiosis" mode, "Industry-City Integration" mode and "Informatization-Industrialization Integration" mode. Table 2 is a comparison of the modes in terms of their core, corresponding zones, types of suitable zones by function and types of zones by industry.

Table 2. Comparison of characteristics of operation and management modes.

Operation and management mode	Industrial Symbiosis	Industry-City Integration	Informatization-industrialization Integration
Core of the mode	Create an ecological industry chain as a means and develop a "circular economy" as the core.	Promote synergistic development of industries and cities to function urban public service for low-carbon development of parks.	Adopt digital and intelligent means to promote low-carbon industrialization of parks.
Corresponding zones	Eco-Industrial Park	Industry-City Green Complex	Low-carbon Smart Park
Types of suitable zones by function	Industrial Park	Industry-City Complex, Business Office Park, Tourist resort	Port Logistics Park, Science and Technology Innovation Park
Types of suitable zones by industry	High-carbon production type	Low-carbon production type, Low-carbon service type	High-carbon production type, High-carbon service type

4.2 Effectiveness and sustainability assessment of success cases

4.2.1 Ulsan Industrial Park, Korea-- Operation and management mode of industrial symbiosis.[8].

Park management: As of 2016, the Ulsan EIP Center received approximately 96 project proposals, of which 77 were funded for further research and development and 34 for operations.

Economy: The total government investment in project research and development (including center operations) is $14.8 million. From this government research fund, the sale of by-products and wastes for recycling purposes generated $65 million/year. in 2016, energy and material savings generated an additional $78.1 million/year.

Environment: Ulsan EIP saved 279,761 tons of oil equivalent; In terms of reductions in waste or by-products, wastewater, 79,357 tons of water and 40,044 tons of by-products and wastes were reused; In terms of reductions in pollutant gases, CO2 emissions were reduced by 665,712 tons and toxic gas emissions, such as sulfur and nitrogen oxides, were reduced by 4,052 tons between 2005 and 2016. In terms of reducing pollutant gases, between 2005 and 2016, carbon dioxide emissions were reduced by 665,712 tons and emissions of toxic gases such as Sulphur oxides and nitrogen oxides by 4,052 tons.

Society: The relationship between the park and neighboring communities has eased as a result of reduced pollution. In addition, private investment of US$245.8 million (as of 2016) for the construction of industrial symbiosis network facilities created 195 new jobs.

4.2.2 Suzhou Industrial Park-- Operation and management mode of industry-city integration.

SIP was selected as one of the first pilot national low-carbon industrial parks, the first national green demonstration park, and the first pilot park for ecological civilization construction.

On September 28, 2022, Professor Zhong Hongwu of the Chinese Academy of Social Sciences led the CSR Cloud to release the report on 2022 Park ESG Development Index. The study takes 402 parks as evaluation samples, constructs the "Park ESG Development Index" around the indicators of three dimensions: ESG system construction, ESG practices, and negative ESG impacts of parks. As Figure 1, The average score of ESG development index of 402 parks is only 32.5, and there are only 6 parks with more than 80 points. As Table 3, Suzhou Industrial Park (SIP), with its relatively complete ESG system construction and ESG practices, scored the highest and ranked first in the ESG Development Index of the parks.

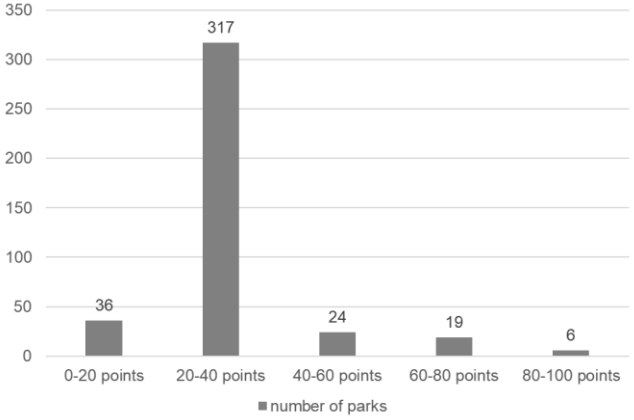

Fig. 1. Distribution of scores for all samples of parks.

Source: Report on 2022 Park ESG Development Index by CSR Cloud

Table 3. 2022 Park ESG List Top 10.

Rank	Name	Score
1	Suzhou Industrial Park	91
2	Changshou Economic & Technological Development Area	86
3	Zizhu High-Tech Industrial Development Park	83
4	Shanghai Chemical Industry Park	82
5	Suzhou National Hi-Tech District	81
6	Tianjin Economic-Technological Development Area	80
7	Hangzhou High-Tech Zone	79
8	Yantai Economic & Technological Development Area	78
9	Chengdu Hi-Tech Industrial Development Zone	77
10	Zhongguancun Science Park	77

Source: Report on 2022 Park ESG Development Index by CSR Cloud

4.2.3 Dongying port economic develop area-- Operation and management mode of informatization-industrialization integration.

Dongying port economic develop area was listed as a green chemical park (founding unit) at the 2019 China Chemical Park Sustainable Development Review, and was selected to be on the 2020 national "Green Chemical Park List" published by the China Petroleum and Chemical Industry Federation by the end of 2020, and was awarded the "National Pilot Demonstration Unit of Intelligent Chemical Park" by the year 2021. In 2021, Dongying port economic develop area will be honored as "National Pilot Demonstration Unit of Intelligent Chemical Park".

Park management: In 2022, the park organized 141 key projects with a total investment of 102.2 billion yuan, and 17 provincial key projects with a total investment of 47 billion yuan, and as of September 2022, 12 of the 16 construction-type projects have been started, with a contribution rate of 43% of the city's investment.

Economy: In 2021, the total industrial output value exceeded 10 billion yuan, with a year-on-year growth rate of 30%. Develop the "four new" economies, including new technologies, new industries, new business forms and new modes, with the total volume of the "four new" economies reaching 2.821 billion yuan in the first half of 2022, and the growth rate of added value at 13.5%, and is expected to increase by more than 100% in the core output value of the digital economy in 2023.

Environment: The total carbon dioxide emissions of Dongying port economic develop area will be reduced by more than 3,000 tons in 2021; carbon dioxide capture technology will be applied in two pilot enterprises, and 250,000 tons of carbon capture will be accomplished in 2022 annually. The energy consumption per unit of industrial added value in the zone drop by more than 10% in 2022 on the basis of a 10.8% drop in 2021.

Society: Dongying port economic develop area through the cloud live online "live with jobs" promotional activities, the organization of chemical, medical and other industries online recruitment, to reach employment intentions of more than a thousand people.

4.3 Experience sharing and opportunities for cooperation among international low-carbon parks

4.3.1 Experience sharing. In 2017, the United Nations Industrial Development Organization, in conjunction with GIZ and the World Bank, released An International Framework for Eco-Industrial Parks and The Eco-Industrial Park Practitioner's Handbook: Implementing the EIP Framework, which gives the World Bank Group, UNIDO, and GIZ the opportunity to implement the framework to establish eco-industrial parks in the countries where they work. In 2019, UNIDO hosted the International Conference on Industrial Parks for Inclusive and Sustainable Industrial Development in Peru, and in the same year published the UNIDO International Industrial Parks Guidelines, which provide a reference for the establishment of a new generation of industrial parks.

The United Nations Industrial Development Organization is also active in providing assistance to Governments in establishing sustainable industrial parks, including ser-

vices such as technical cooperation and policy advisory services. The UNIDO Department of Digitalization, Technology and Innovation (DTI) provides specialized support to UNIDO Member States in addressing the challenges of risk in building a new generation of industrial parks.

In May 2022, the United Nations Conference on Trade and Development (UNCTAD) took the lead in establishing the Global Alliance of Special Economic Zones (GASEZ), whose main functions include: promoting cross-border and cross-sectoral cooperation in trade and investment promotion among special economic zones; improving policies for special economic zones; raising awareness of sustainable development in special economic zones; undertaking projects for sharing exchanges and cooperation among special economic zones.

4.3.2 International cooperation.

China Domestic International Cooperation Park:

The executive meeting of The State Council pointed out that it is necessary to encourage various forms of cooperation with foreign parks to better integrate into the international industrial chain and supply chain. By 2021, 89 international cooperation parks had been established across 13 provinces, according to data released by the Green Development Alliance of state-level economic and technological development Zones. The types of parks are mainly industrial parks, trade and logistics circles, ecological new towns and comprehensive new towns.[9] In the international cooperation Park, science and education projects are one of the characteristics and development impetus of the international cooperation park, which exchanges talents, scientific research, and shares knowledge and technology with the partner countries. For example, the China-Germany (Hefei) International Cooperation Wisdom Park has set up the Volkswagen New energy Vehicle China headquarters and production base for German industries, held China-Germany applied higher education seminars, and introduced about 80 German professors, engineers and other talents. [10]

China Overseas International Cooperation Park:

a. By 2022 China's overseas international cooperation zones have amounted to 201, with 60 zones in operation. However, the degree of low-carbon development is still in the primary stage. In 2022, WRI established an indicator system for low-carbon development of overseas zones, and constructed a low-carbon development index for overseas zones. [11]

b. Green "Belt and Road" Promotes Low-Carbon Development in Overseas Parks. Overseas parks along the "Belt and Road" have the effect of industrial and investment aggregation, absorbing the industrial advantages of various countries, park management experience and a large number of overseas enterprises.

c. Low-carbon development of overseas parks under South-South cooperation to address climate change. In April 2022, the Vientiane Sai Serta Low Carbon Demonstration Zone was established, which is the first low-carbon demonstration zone inaugurated since the launch of China's "Ten Hundred Thousand" South-South Cooperation on Climate Change project. On April 26, 2023, The World Resources Institute (WRI) and the Foreign Cooperation and Exchange Center of the Ministry of Ecology and En-

vironment jointly held a kickoff meeting to promote green and low-carbon action projects in overseas parks under the framework of South-South cooperation to address climate change. [12]

5 Research conclusion and proposals

5.1 Research Conclusion

This article categorizes the operation and management modes of international low-carbon parks into "Industrial Symbiosis", " Industry-City Integration", and " Informatization-Industrialization Integration " modes. These three modes focus on different aspects and core strengths of operational management. The "Industrial Symbiosis" mode focuses on the development of circular economy and the creation of industrial ecological chains and industrial symbiosis systems. The " Industry-City Integration" mode takes the play of urban public service functions as the core, and the main approach is to ensure comprehensive green and low-carbon production and living in the park and surrounding areas. The " Informatization-Industrialization Integration" mode focuses on empowering industrialization through information technology, and promotes the digitization, intelligence, and low-carbon transformation of industries and industrial chains.

These three are only different in focus, but they are not contradictory. Many national level green and low-carbon pilot parks combine two or more operational management modes. For example, as a national level green and low-carbon pilot park, Suzhou Industrial Park is also a national ecological industry demonstration park, industry-city integration demonstration zone, and informatization-industrialization integration demonstration zone, leading in all three aspects of "industrial symbiosis", "two industrialization integration", and "industry city integration".

5.2 Research Proposals

a. Improve the top-level design of international low-carbon parks and take into account the economic and social aspects of "dual-carbon". "Dual-carbon" is an economic term basically, and the realization of the "dual-carbon" goal requires certain policy measures and social governance to guide the realization of the goal. Therefore, it is necessary to take the market as the main force and the government as the auxiliary force. A policy framework system for industrial parks to achieve carbon neutrality should be established, while the subsidy policy and investment and financing mechanism of industrial parks should be optimized.

b. Strengthen the low-carbon indicators in the evaluation index system and improve the ESG assessment system for industrial parks. At present, the domestic government authorities have not formed an environmental benefit assessment system with low-carbon indicators as the main part of the ESG investigation. And although there are third-party organizations that rate domestic zero-carbon parks in terms of ESG, the government has not evaluated low-carbon parks in terms of the ESG system.

c. Strengthen green and intensive development and establish a circular economy system. Improve the land utilization rate and coordinate the intensive development of production and living elements; form a circular industrial chain by complementing and strengthen the chain, organically linking new technologies with intelligent intellectual manufacturing, high-end science and technology and other industries in the industrial park.

d. Stimulate enterprise innovation vitality and provide talent guarantee. Create an innovation and entrepreneurship service platform to provide entrepreneurs with resource-sharing space, which is conducive to the development of a new mode of crowdfunding; cooperate with industrial parks and scientific research institutes, schools and enterprises, and enhance the cultivation of technical personnel; improve the intellectual property protection system, and actively carry out the selection of pilot demonstration parks for intellectual property rights. [13]

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