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ORIGINAL RESEARCH

China's special economic zones: from traditional labor-intensive industries to eco-industrial park development

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Abstract

Special economic zones (SEZs) development plays a significant role in China`s economic and industrial growth. However, rapid industrialization and increasing number of industrial parks has significantly intensified environmental pollution issues. These facts resulted in an urgent need for effective coordination between further economic growth, industrial expansion, and search for solutions to environmental issues. One of the most effective approaches to implement these concerns is to develop eco-industrial parks (EIPs). The research applied methods: the dialectical method for analyzing models of various SEZ types creation and operation; historical and logical analysis methods for examining the historical stages and processes for SEZ development; comparative analysis methods for studying the prerequisites to modernize and transform certain SEZ types into EIPs; structural analysis methods to evaluate economic performance indicators and identify the structure of EIPs. The primary goal for EIP concept development has been to balance between intensive industrial growth and environmental issues resolution. The EIPs creation can be considered as one of the key instruments in implementing the sustainable development policies, aiming to integrate environmentally friendly technologies into production, reduce CO_2 emissions, and promote efficient resource use. The EIPs operational mechanism is built on circular economy principles, fundamentally modifying production and consumption models within China`s economy. EIPs serve as a key mechanism for transitioning China's economy from extensive to intensive growth model. To achieve sustainable development goals and coordinate the relationship between economic expansion and environmental protection issues, China has been implementing programs for more than two decades aimed at gradually transforming national development zones, ETZs and HTZs into EIPs. The economic performance indicators of EIPs highlight their role as the leading economic and industrial centers in China, driving substantial economic growth due to innovation, sustainability, and international cooperation.

***Keywords**:* China, special economic zones, economic development, Eco-Industrial Parks, environmental technologies, circular economy, sustainable development, innovation.

Introduction

Special economic zones (SEZs) establishment processes in China were initiated in 1979, alongside the government's economic reforms. Over the past 35 years, SEZs have played a significant role in the country's economic development and rapid industrialization. SEZs can be considered as a key instrument of state policy, fulfilling multiple strategic functions:

- SEZs have been used as a tool for industrial development, aiming to drive the country's industrial expansion and technological development;
- SEZs serve as a key instrument of investment policy, aiming to attract foreign capital and stimulate economic growth;
- SEZs have functioned as a regional policy tool, facilitating industrial development in specific areas of the country while solving employment issues.

The first SEZs, in the form of Development Zones (DZs), primarily specialized in labour-intensive production due to the availability of extremely cheap labour at the time. These zones consumed large amounts of resources, promoted rapid industrial capacity expansion, and contributed to extensive economic growth in China. Hundreds of industrial parks were established, serving as hubs for concentrated industrial production. However, this led to severe environmental pollution, particularly air pollution, and high carbon dioxide (CO_2) emissions, especially in major industrial centres. By the 2000s, amidst escalating environmental chal-

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lenges, the need to transition from an extensive growth model to an intensive growth model became evident. China initiated the development of Eco-Industrial Parks (EIPs) within the framework of existing National Economic and Technological Development Zones (ETZs) and National High-Tech Zones (HTZs). The emergence of EIPs reflects a shift in China's economic development strategy. The primary goal behind the EIP concept development was to establish a balance between rapid industrial growth and environmental issues solution. The EIPs creation can serve as a key tool in sustainable development policies implementation. One of the most effective mechanisms for coordinating sustainable economic policies has been the implementation of circular economy principles, including the establishment of Eco-Industrial Parks. EIPs enhance the economic, environmental, and social efficiency of enterprises. The Eco-Industrial Parks have become a central element of China's modern industrial strategy, which seeks to combine intensive industrial development with the advancement of green technologies, minimize environmental impact, and improve resource efficiency. As of 2022 China had already established 109 EIPs.

Literature Review

In scientific literature, numerous scholars have conducted research over different time periods on the mechanisms of Special Economic Zones (SEZs) and their impact on the economy of the host country. Various studies have analysed both positive and negative effects of transnationalization and foreign capital inflows, particularly in developing countries, as these investments have had diverse economic consequences. Global researchers have shown significant interest in China`s experience with establishing different types of SEZs and their role in the country's industrial development. A distinct area of research focuses on the development of Eco-Industrial Parks (EIPs) in China and their role in sustainable development policies. The main thematic areas of research by both domestic and foreign scholars can be outlined as follows:

1) The establishment of SEZs in China and their use as a tool for industrial, investment, and regional policies, as well as their role in economic and industrial development, have been explored in the works of S. Zhang (Zhang, 2019), X. Chen (Chen, 2019), D. Marjanac (Marjanac, 2021), M. Wu, C. Liu, J. Huoang (Wu et al., 2021), X. Lin, C. Yan, K. Zhang (Lin et al., 2022), F. Lu, W. Sun, J. Wu (Lu Fangwen et al., 2022), etc;

2) The creation and development of Eco-Industrial Parks in China as a new model for ecological and innovative development, the transformation of existing industrial clusters into EIPs, and the formation of circular economy models and green production within EIPs have been studied in the works of H. Hong, A. Gaspararatos (Hong, Gaspararatos, 2020); T. Wang, M. Zhang, C.H. Springer, C. Yang (Wang et al., 2021); R. Bleischwitz, M. Yang, B. Huang, X. XU, J. Zhou, W. McDowall (Bleischwitz et al., 2022), A. Coussa (Coussa, 2024), etc;

3) The environmental and economic effects of Eco-Industrial Parks in China, their role in environmental conservation, and their contribution to the implementation of sustainable development policies have been discussed in the research of B. Huang, G. Yong, J. Zhao, T. Domenech, Z. Liu, S.F. Chiu (Huang et al., 2019), K. Cao, l. Jin, Y. Zhu, Z. Ne, H. Li (Cao et al., 2022), X. Liu, J. Zhang, T. Liu, X. Zhang (Liu et al., 2022), Z. Tingting, X. Jiaping, L. Ling, X. Jiqing (Tingting et al., 2024), etc;

4) The statistical and analytical data on the functioning of SEZs in China can be found in the reports and databases of UNCTAD, the World Bank, as well as in databases Ministry of Commerce of the People's Republic of China, Ministry of Science and Technology of the People's Republic of China, Websites of SEZs.

At the same time, many aspects of the impact of SEZs and EIPs — such as their temporal, spatial, economic, and environmental effects — on China's economic development, as well as the applicability of China's experience to other developing economies, remain open for further research.

Methods

In conducting this study, the authors used the following research methods: a) dialectical analysis was used to analyze the models for establishing various types of special economic zones (SEZs) (to understand how development zones can be transformed into Eco-Industrial Parks (EIPs), and explore the EIPs operational mechanisms based on circular economy principles, as well as to analyze interactions between various factors such as the geographic concentration of EIPs, their sectoral specialization, resource distribution and circulation, government policies, and social and economic outcomes); b) historical and logical analysis (used to analyze the stages and processes of SEZ creation); c) comparative analysis (used to study the processes of prerequisites formation to modernize and transform the certain types of SEZs into Eco-Industrial Parks); d) structural analysis (used to analyze economic performance indicators and identify the structure of Eco-

Industrial Parks, as well as to determine EIP development trends and assess their role in sustainable development policies implementation); e) systematic approach and empirical research methods (comparison, analysis, and synthesis) to identify the individual components of the object under study and establish cause-and-effect relationships.

Results

Since China initiated its economic reforms and the "open door" policy in 1978, the country has achieved remarkable progress in its economic development, becoming one of the largest economies in the world. A significant role in this phenomenal economic growth has been played by the numerous Special Economic Zones (SEZs). The establishment of SEZs, the first of which emerged nearly 40 years ago, is regarded as one of the most critical factors in China's integration into the global economy. Today, SEZs account for 22 % of China's GDP, 45 % of total foreign direct investment (FDI), and 60 % of the country's exports (The World Bank, database).

As of 2022, China has established numerous 2543 SEZs across the country (Liu Xiao et al., 2022). In 1984, the State Council of China approved the establishment of the first 14 SEZs in the eastern coastal regions, focusing primarily on industrial projects (although the earliest SEZs — Shenzhen, Zhuhai, Xiamen, and Guangdong — had been operating de facto since 1979). The combination of SEZs being supplied with cheap labour from rural areas, essential production resources, and a favourable regime for foreign investments created conditions for scaling up industrial production. From this period onward, China started the large-scale implementation of the SEZ concept, using them as tools for industrial, investment, and regional policies (Marjanac, 2021). The role of SEZs in China's regional development, aimed at smoothing out existing imbalances, is extremely important (Cranea et al., 2018). Since their creation in China, Special Economic Zones (SEZs) have been primarily focused on key objectives such as developing industrial production, particularly manufacturing sector, promoting cutting-edge technologies, generating employment opportunities, fostering human capital development, and attracting foreign investors with all necessary investments to support these processes. It is necessary to separately highlight the importance of zones for the technological development of the country and the introduction of innovations into industrial production (Yeung in et al., 2009). SEZs have played a major role in developing human resources, improving labor productivity and building China's modern human resource potential Lu Fangwen et al., 2022). SEZs are now established in various regions of China, leveraging demographic potential and accessibility to global markets (making them more attractive for foreign investments), administrative centres, seaports, and other strategic advantages. Each SEZ is designed for specific sectors and employs unique approaches to fostering global competitiveness, offering a distinct "value proposition" (UNCTAD,2019).

The key functions that special economic zones (SEZs) were required to fulfill for the national economy include the following:

- Attracting additional financial resources, particularly foreign investments, to accelerate economic growth both at the national level and within specific regions;
- The progressive role of SEZs in driving China's rapid industrialization at the end of the last millennium and fostering extensive diversification of production;
- Developing key sectors of the manufacturing industry to facilitate the transition from labor-intensive specialization to capital-intensive production, and eventually to the emergence of high-tech industries and research centers equipped with modern technologies;
- Promoting export-oriented industries to enhance China's competitive potential and facilitate the country's expansion into international markets;
- Developing domestic research and innovation, establishing research centers, and consequently, developing a highly skilled workforce and creating advanced production facilities;
- Establishing new economic activity centers to ensure balanced development across different regions;
- Implementing a regional development model to promote economic growth, particularly in industry, tourism, and trade.

In China, numerous types of SEZs can be identified (Table 1). The evolution of SEZs in China has taken place in stages, reflecting the country's primary goals and economic development priorities (Zhang, 2019; Chen, 2019). During the initial phase, following the introduction of the "open door" policy, the Chinese government aimed to accelerate industrialization through the attraction of foreign capital. SEZs became a key tool in achieving this goal by providing preferential conditions for foreign investors and stimulating the creation of new production capacities. The next step involved the industrialization of specific regions. The

transition to more complex manufacturing took place within industrial parks and clusters, with a focus on processing final products. Subsequently, the Chinese government shifted its focus to fostering high-value-added production. SEZs became hubs for the development of high-tech industries based on cutting-edge innovations and research (Zeng, 2010; Yeung, 2009). (Examples include SEZs such as Shenzhen, Zhuhai, Xiamen, Hainan (Lin et al, 2022)). The practical results showed that the SEZ's program (2000–2017) significantly promoted the green technology innovation of enterprises. The number of green patents in SEZ's has increased by 17 % (Liu Xiao et al., 2022). A progressive advancement followed with the establishment of eco-industrial parks, designed to adhere to strict environmental standards and principles of a circular economy. Even today, China's practice of establishing eco-industrial parks serves as a model and an example for other countries to follow.

Table 1. Key types of SEZs in China and their strategic focus

Types of economic zones	Targeted focus and periods of establishment
Special Economic Zones (SEZs)	Attracting foreign capital, creating jobs, developing underperforming regions, and promoting export-oriented, labour-intensive industries — Shenzhen, Zhuhai, Xiamen, Guangdong (established in 1979). Over time, a gradual shift occurred toward capital-intensive and technologically advanced production, with examples such as Hainan (1988) and the Pudong New Area in Shanghai (1989).
Development Zones (DZs)	Varying by status (provincial, regional, national), level of autonomy, and territorial size, often created for large-scale investment projects. Facilitating industrialization of specific regions. Initiated in the 1990s. By 2006, 1,568 DZs were operational, serving as a foundation for further development into ETZs and FTZs.
National Economic and Technological Development Zones (ETZs)	These are government-designated areas in China where state development programs are used to encourage foreign investment inflows, promote industrial production (focusing on transition from labor-intensive specialization to capital-intensive production), and encourage cutting-edge technologies development and implementation. ETZs serve as the foundation for the specialized industrial clusters development. The first ETZs were established in 1984 across 14 coastal cities, including Shanghai, Tianjin, Dalian, Qingdao, and Shenzhen. By 1992, 35 ETZs existed, growing to 70 by 2010.
National High-Tech Zones (HTZs):	The establishment of HTZs focuses on high technologies and innovations, the development of green technologies, and the creation of concentrated scientific potential for the commercialization of research and development. These zones aim to facilitate the design, production, and export of advanced technological products and innovations. The first HTZ, Zhongguancun (Beijing), established in 1988. By 2010, 54 HTZs were in operation.
Free Trade Zones (FTZs):	The primary goal of their establishment is to promote international trade and related business activities. Specialization: duty-free zones, export processing, foreign trade, logistics, warehousing, and infrastructure development. One of the first zones, Waigaoqiao, was established in Shanghai in 1992. By 2010, 15 FTZs operated across 13 coastal cities.
Export Processing Zones (EPZs)	EPZs started to be established to promote industrial export production and attract foreign investment. Typically, EPZs involve designated areas within Special Economic Zones (SEZs) designed to facilitate goods production for export. The first EPZ in China was established in 1980 in Shenzhen. One of the largest EPZs was the Waigaoqiao EPZ in Shanghai. Today, China has over 50 EPZs, primarily located in major industrial centers. By 2010, there were 61 EPZs in China (44 in coastal areas and 17 inland).
Industrial Parks	Concentration of industrial activity, creating technologically advanced production facilities, and forming industrial clusters.
Eco-Industrial Parks (EIPs)	EIPs embody China's national development strategy, focusing on environmental conservation and zero-waste production development. The core principles of EIPs are to develop eco-friendly industries and integrate circular economy practices. The first EIP in China was considered to be Suzhou Industrial Park, which started developing in the late 1990s, introducing the closed-loop production concept. The title of China's first national demonstration eco-industrial park was granted to Guangxi Guigang National Demonstration Eco-Industrial (Sugar) Park, established in 2001.
Note — compiled by the authors according to databases of UNCTAD, the World Bank, FDI-China, Websites of SEZs	

After establishing labour-intensive industries within SEZs, the Chinese government laid the foundation for developing capital-intensive and high-tech production. To achieve this, the government implemented a differentiated policy for foreign direct investments (FDIs), offering incentives and preferences to attract FDI into high-tech and innovation-driven industries. This policy became the cornerstone for the establishment of

National Economic and Technological Development Zones (ETZs) and National High-Tech Zones (HTZs). While many of the measures for foreign investors in ETZs and HTZs mirror those in SEZs, ETZs introduced a division between manufacturing and non-manufacturing enterprises, with a tax rate of 15 % for the former and 30 % for the latter (China's Ministry of Commerce, 2024). FDI activities within HTZs are focused on knowledge-intensive projects and exports.

To encourage research and development (R&D) activities within ETZs and HTZs and facilitate their integration into production, as well as to stimulate export-oriented activities (where at least 70 % of production must be exported), China has introduced a preferential tax rate of 15 %. Additionally, this preferential period can be extended for three more years for the companies engaged in advanced technologies development and implementation. To further incentivize reinvestment, China introduced tax refunds for reinvested capital. If profits are reinvested in the enterprise within five years, 40 % of the tax is refunded; if reinvestment targets high-tech or export-oriented enterprises, 100 % of the tax is refunded. Through these measures, the Chinese government successfully specialized ETZs and HTZs for attracting FDI into export-oriented, capital-intensive production (ETZs) and export-driven, high-tech enterprises (HTZs). In contrast, SEZs encouraged FDI more broadly (Kuznietsova, 2024).

Traditional models of industrial parks in China serve as areas of concentrated industrial activity and key drivers of the country's economic development. Industrial parks account for 60 % of China's industrial output, 70 % of energy consumption, and 72 % of greenhouse gas emissions (Bleischwitz et al., 2022). Despite China's impressive achievements through the establishment of industrial parks, rapid industrialization has also brought significant environmental challenges. With growing attention to climate change, ecological issues have become a major concern. Key problems include severe water, air, and soil pollution, as well as large volumes of industrial waste. To preserve the environment and implement sustainable development goals, China is undertaking large-scale efforts to transform industrial clusters established within DZs, ETZs, and HTZs into eco-industrial parks.

In 2001, the Chinese government implemented a large-scale program to establish Eco-Industrial Parks, emphasizing the adoption of resource-efficient and environmentally friendly technologies. This initiative paved the way for the China's gradual transition from extensive to intensive economic growth model. That same year, the construction of China's first national demonstration eco-industrial park — the Guangxi Guigang National Demonstration Eco-industrial (Sugar) Park — was approved (Zhang Ling et al., 2010). The transformation and conversion of Development Zones (DZs) into Eco-Industrial Parks (EIPs) typically occur through specific UpGrade processes in production technologies within individual zones, following this sequence (Cao Kairui et al., 2022): 1) provincial development zones undergo UpGrade processes to achieve the status of national development zones; 2) national development zones, through economic development initiatives, can be transformed into either: a) National Economic and Technological Development Zones (ETZs), or b) National High-Tech Zones (HTZs); 3) modernization and transformation of ETZs and HTZs into Eco-Industrial Parks (EIPs).

The modernization and transformation processes of ETZs and HTZs into EIPs differ significantly due to distinct industrial focus of each zone type, their technological levels, the readiness of enterprises to implement EIP principles, and the varying types of industrial clustering within the zones. The primary characteristic of HTZs is the development of knowledge-intensive and high-tech industries, with a focus on scientific and technological innovations, including information technology, nanotechnology, biotechnology, and more. For this reason, the trends in activities, operational principles, financial preferences and subsidies for National High-Tech Zones (HTZs) were monitored by China's Ministry of Science and Technology, ensuring alignment with the country's overall economic and technological development strategy. In contrast to HTZs, the goals for the National Economic and Technological Development Zones (ETZs) establishment were different. They focus on industrial development based on contemporary technologies within specific regions, emphasizing processing or extractive industries depending on the region's resources (this transition typically involves transitioning from labor-intensive to capital-intensive industries) while actively attracting foreign investors. ETZs actively implement export-oriented programs. Based on ETZs core functions, their activities are monitored by the Ministry of Commerce of China. This Ministry is responsible for shaping ETZ policies while considering China's positioning in primary global commodity markets. The operating mechanism of EIPs is much broader, based on the principles of a circular economy. EIPs encompass a wide range of industries, emphasizing the development of environmentally sustainable technologies. Key industries include electronics, electrical engineering, machinery manufacturing, automotive production, chemical production, energy, healthcare, and food and textile industries.

At the current stage of economic development, both in China and globally, eco-industrial parks represent the highest level of evolution among special economic zones, particularly industrial parks. The concept of EIPs is based on the principles of circular economy and integration of environmentally friendly green technologies into industrial production, complying with sustainable development goals (Coussa, 2024). Primary goal of Eco-Industrial Park is to connect various enterprises through logistics or energy flow transfers, creating a symbiotic combination of industries that share resources and exchange by-products (Wang Tiantian et al., 2021). In this system, by-products or waste from one facility can become raw materials, resources, or energy sources for another. EIP should imitate a "natural system" within the park and establish a "producer-consumer-decomposer" cycle within the industrial ecosystem. Aiming to establish a high-tech, highly efficient, and environmentally friendly park, EIP can also implement closed-loop material cycles, multi-level energy utilization, and waste minimization (Mathews et al., 2018). Depending on the level of production activities diversification, EIPs are divided into three main groups: integrated (with entities/operations from several industries sectors); sectoral (with a dominant industrial sector): venous (dominant industrial sector is waste reuse and recycle) (Hong, Gasparatos, 2020).

The operations of EIPs are based on the principle of "reduce, reuse, and recycle", which encompasses three core components: 1) reduction principle: focuses on minimizing the sources of economic activity by reducing consumption of materials, raw resources, and energy required to meet production and consumption demands through the adoption of advanced technologies; 2) reuse principle: focuses on both production and consumption sectors; 3) recycling principle: requires that products can be turned into usable resources instead of unnecessary waste (Cao Kairui et al., 2022).

The above principles integration into operations represents the practical implementation of the circular economy concept and leads (as a result of EIPs activities), to more efficient use of natural resources and the solution of various environmental issues. Among the top priorities are reducing environmental pollution levels and lowering greenhouse gas emissions. Based on 15 years of research data, it has been established that EIPs significantly reduce the intensity of carbon dioxide (CO_2) and sulphur dioxide (SO_2) emissions; EIPs have been found to reduce sulphur dioxide emissions by 27.8 % and carbon dioxide emissions by 11.2 %. This indicates that the establishment of EIPs can contribute to sustainable development with low carbon emissions (Cao Kairui et al., 2022).

China's current policy on Eco-Industrial Parks creation demonstrates the country's commitment to integrate environmental approaches into industrial growth**. The key features of China's Eco-Industrial Parks include:**

- **Circular Economy: reuse of resources and waste.**
- **Green Energy: utilization of renewable energy sources.**
- **Industrial Symbiosis: resource sharing among enterprises.**
- **International Cooperation: joint projects with other countries (e.g., Germany, Singapore).**

The circular economy (closed-loop economy) represents a system of interconnected enterprises and complementary structures (operating within the framework of EIPs), organized into a unified production system based on closed technological cycles. This approach ensures the complete utilization of raw materials and waste within the system. These systems are built on compatible technological processes and adhere to clearly defined environmental standards and requirements (Liu Changhao, Cote, 2017).

The key objectives of implementing the circular economy, as outlined in China's 14th Five-Year Economic Development Plan, aim to establish the most advanced resource recycling system and enhance resource efficiency. These objectives include (Bleischwitz et al., 2022):

- Achieving a 20 % increase in resource use efficiency compared to 2020;
- Reducing water resource consumption by 13.5 % and energy resource — by 16 % per unit of GDP;
- Achieving waste recycling targets, including 86 % for agricultural residues (e.g., crop stems), 60 % for municipal solid waste, and construction debris;
- Expanding the resource recycling sector to a production value of 5 trillion yuan (approximately $770 billion USD);
- Deepening the development of agricultural circular economy systems and creating closed-loop agricultural production models etc.

The state program for defining environmental requirements and standards for the formation of Eco-Industrial Parks (EIPs) includes a two-tiered procedure: 1) Initial Approval: state authorities issue approval for the creation of the park; 2) Certification Process: the park undergoes certification to verify compliance with established standards and is granted the status of a National Demonstration Eco-Industrial Park (ND-

EIP). Currently, the total number of eco-industrial parks includes both approved EIPs since 2001 and those that have undergone the certification process and received the status of ND-EIPs. In 2022, the total number of (approved and certified) EIPs was 109, of which 79 had the status of ND-EIPs. The first certified ND-EIP was established in 2008, and by the end of that year, there were 2 ND-EIPs (number of approved — 29 EIPs). By 2019, the number of ND-EIPs has already reached 55, and the number of Eco-Industrial Parks at the approval stage (actually at the development stage) was 52. The most significant growth in EIP development occurred between 2008 and 2015, during which the total number of EIPs increased 3.5 times, from 30 to 106 (for example, the Twelfth Five-Year Plan (2011–2015) for China's development included the establishment of 55 EIPs) (Hong, Gasparatos, 2020).

Since EIPs were primarily established based on industrial parks, it is important to note their concentration in economically developed regions of China, particularly in provinces where environmental issues had significantly escalated, necessitating a shift in the government's approach to further economic growth. The transformation of high-tech zones into eco-industrial parks should contribute to increasing ecological productivity (Tingting et al, 2024). Many industrial park locations were characterized by high levels of CO2 emissions and urgently required measures to improve the ecological situation. The concentration of EIPs remains in the industrially advanced provinces, with Jiangsu standing out with 25 EIPs, followed by Shanghai with 9, Shandong with 8, and Zhejiang with 7. However, over the past decade, a trend toward more even distribution of EIPs across China has emerged (Hong, Gasparatos, 2020). Table 2 presents a list of 10 prominent EIPs along with their primary areas of specialization.

Table 2. The largest EIPs in China and their focus sectors

№	EIPs focus sectors
1	**China-Singapore Suzhou Industrial Park** (SIP) — Jiangsu Province **Features**: a joint project between China and Singapore, focused on clean energy and water resource management. It incorporates advanced wastewater treatment technologies and industrial symbiosis practices.
2	**Tianjin Economic-Technological Development Area** (TEDA) — Tianjin **Features**: one of China's first Eco-Industrial Parks, emphasizing industrial waste recycling and resource utilization. The development of renewable energy and emission reduction.
3	**Qingdao Sino-German Ecopark —** Shandong Province **Features**: joint initiative of China and Germany. Utilization of renewable energy sources (solar, wind). Promotion of environmentally friendly construction and sustainable urban planning.
4	**Yixing Environmental Science and Technology Industrial Park —** Jiangsu Province **Features**: specialization in environmental protection technologies, with a primary focus on water treatment and pollution control.
5	**Hangzhou Circular Economy Industrial Park —** Zhejiang Province **Features**: implementation of industrial symbiosis models, waste recycling, and resource reuse. Emphasis on energy efficiency and low-carbon processes.
6	**Guiyang Eco-Industrial Park —** Guizhou Province **Features**: integration of eco-friendly practices into industrial development. Deployment of clean production technologies. Conservation of biodiversity in surrounding areas.
7	**Zhuhai Eco-Industrial Park —** Guangdong Province **Features**: integration of renewable energy into industrial production. Air and water pollution control measures. Development of "smart" manufacturing facilities.
8	**Baotou Rare Earth High-Tech Industrial Development Zone —** Inner Mongolia **Features**: a hub for sustainable mining and processing of rare earth metals. Strict resource management controls.
9	**Chengdu High-Tech Industrial Development Zone —** Sichuan Province **Features**: high-tech manufacturing with environmentally conscious approaches. Application of advanced electronic waste recycling technologies. Focus on ecological innovations and research.
10	**Fuzhou Circular Economy Demonstration Park —** Fujian Province **Features**: implementation of circular economy principles, including waste recycling and material reuse. Integration of green logistics systems.
Note — compiled by the authors according to databases of FDI-China; China Services Info: Industrial Park; Websites of SEZs	

The case of three largest EIPs in China (China-Singapore Suzhou Industrial Park (SIP), Tianjin Economic-Technological Development Area (TEDA), and Qingdao Sino-German Ecopark) and the main indicators of their economic activity are analyzed in detail below.

China-Singapore Suzhou Industrial Park (SIP). Annual GDP exceeds RMB 300 billion, significantly contributing to Suzhou's overall economic development. Land Area covers 288 square kilometres, with over 60 % dedicated to environmentally friendly and high-tech industries. Foreign Direct Investment

(FDI) surpasses USD 40 billion, with more than 5,000 foreign enterprises operating in the park, including Fortune 500 companies such as Bosch, Siemens, and Johnson & Johnson. Industrial Output: annual industrial output exceeds RMB 500 billion. Specializations: key sectors include electronics, biotechnology, automotive manufacturing, and information technology. Export volume: annual exports exceed USD 100 billion**,** making SIP one of China's largest export hubs. High-tech products and services dominate the trade portfolio.

The park has created over 800,000 jobs across various sectors. A high concentration of skilled labour is achieved through partnerships with educational institutions and programs aimed at attracting highly qualified specialists. To promote innovation and research, the park has established and now operates over 30 research institutes and 3,000 high-tech enterprises. Annual investments in research and development exceed 5 % of the Park's GDP**,** fostering continuous innovation (Suzhou Industrial Park, 2024).

Sustainable Development and Environmental Initiatives: SIP is recognized as a model of eco-industrial development. It has implemented advanced waste recycling systems, wastewater treatment, and renewable energy usage. The green coverage exceeds 45 %, with substantial investments directed toward sustainable urban infrastructure development.

The Tianjin Economic-Technological Development Area (TEDA) is one of China's most significant economic and industrial zones, driving growth in manufacturing, technology, and international business. TEDA's annual GDP exceeds RMB 400 billion **(**approximately USD 58 billion**)**, contributing significantly to the overall economic development of Tianjin. TEDA covers an area of about 119 square kilometres**,** with well-developed infrastructure supporting industrial, commercial, and residential needs. The industrial output value of TEDA surpasses RMB 600 billion annually. In the high-tech sector, aviation manufacturing and nanomaterials production stand out as key industries. TEDA's industrial base is primarily composed of knowledge-intensive and capital-intensive industries, such as electronics, electrical engineering, electronic technologies, petrochemicals, and machinery manufacturing. TEDA offers a diverse economic structure with a well-balanced mix of traditional industries and emerging sectors.

TEDA has attracted over USD 30 billion in foreign direct investment. The zone hosts more than 5,000 foreign enterprises**,** including leading international corporations like Siemens, GE, Johnson & Johnson, and Volkswagen. TEDA appeals to investors through supportive policies, efficient infrastructure, and its proximity to key trade routes. TEDA employs over 600,000 workers across various industries. The workforce is highly educated, with a significant portion of the population holding higher education degrees and technical training, as core sectors like IT, finance, and advanced manufacturing require skilled and professional personnel.

TEDA is a key trade hub for Tianjin, with an annual export volume exceeding USD 70 billion**.** Its well-developed logistics and transportation infrastructure ensure efficient trade operations. The zone supports a wide range of export activities, including high-quality products such as machinery, electronics, chemicals, and industrial equipment. TEDA is also a major centre for innovation, hosting numerous research institutes and high-tech enterprises. Investments in research and development exceed 5 % of GDP**,** focusing on artificial intelligence, robotics, biomedicine, and environmental technologies (TEDA, 2024).

Sustainable development and environmental initiatives: TEDA's activities are based on the principles and approaches of sustainable development programs. This includes the implementation of safe green technologies, resource conservation and energy efficiency programs (with a strong focus on renewable energy sources), as well as initiatives to combat environmental pollution by reducing industrial CO_2 emissions.

Qingdao Sino-German EcoPark. The EcoPark makes a significant contribution to Qingdao's economic development by focusing on innovation and sustainable industrial practices. The annual GDP of the Qingdao Sino-German EcoPark exceeds RMB 20 billion (approximately USD 2.9 billion**).** Industrial production in the EcoPark surpasses RMB 50 billion annually. Key industries: primary industries include intelligent manufacturing, new energy, environmental technologies, and high-tech sectors such as biomedicine and robotics. The Qingdao Sino-German EcoPark features advanced infrastructure, and its convenient location near Qingdao Port enables efficient trade both domestically and internationally. The park has a well-developed export economy, with an annual export volume exceeding RMB 10 billion. Major export categories include machinery, high-quality electronic components, and environmental technologies.

The EcoPark has attracted over USD 5 billion in foreign direct investment and provides employment for more than 30,000 workers, with an emphasis on a skilled workforce. The park collaborates with leading German corporations such as Bosch, Siemens, Thyssenkrupp, and others, engaging in joint projects in sustainable technologies and advanced manufacturing. Kingdao Xinyo-German Ecopark encourages cooperation between Chinese and German companies, universities and research institutes, which promotes knowl-

edge exchange, joint research projects and technological transfers aimed at developing environmentally sustainable industries. The EcoPark invests a substantial portion of its GDP in innovation and technological development. Over 10 % of GDP is allocated annually to research and development, with a focus on advancements in artificial intelligence, production automation, energy efficiency, and environmental solutions (Qingdao Sino-German Ecopark, 2024).

Sustainable development and environmental initiatives: Qingdao Sino-German Eco-Park actively implements sustainable development with a focus on environmentally safe technologies. It implements programs aimed at reducing industrial CO emissions, waste management, and efficient water use. Additionally, renewable energy initiatives are being widely implemented, including solar energy and industrial waste conversion into an energy source.

Thus, the EIPs reviewed are prime examples of successfully integrating sustainable development and advanced technologies into manufacturing and business. Through significant investments in green technologies and international partnerships, EIPs contribute to sustainable economic growth and innovation, creating a competitive environment for businesses.

The certification of Eco-Industrial Parks (EIPs) in China involves a stringent process requiring compliance with specific sustainable development and environmental standards. Since the constitution of China establishes a three-tier administrative division, a similar three-level system is applied in setting requirements for environmental standards and assessing their impact on the economy and the environment. At both the national and local levels, the primary focus is on reducing CO_2 emissions into the atmosphere, improving water resource management system, and implementing energy-saving programs, particularly the development of renewable energy sources (Huang Beijia et al., 2019). In 2015, the Ministry of Environmental Protection (MEP) introduced a new standard for National Demonstration Eco-Industrial Parks (HJ/T274-2015). Since 2016, new environmental standards for EIPs have been enforced in China to achieve high environmental performance and enhance competitiveness at both domestic and international levels. The economic impact assessment of these standards demonstrates both preliminary improvements in environmental performance and enhanced economic competitiveness of EIPs. However, due to the strict requirements of the Green Manufacturing Standard System, there are certain issues (technical, technological, organizational, and, in many cases, primarily financial) in transforming industrial zones and individual enterprises into fully operational EIPs.

The environmental requirements for EIPs, as defined by standardization procedures established, are based on three main programs: Green Manufacturing Standard System Construction Guide (2016), Industrial Green Development Plan (2016–2020), and Green Factory Evaluation General Rules (GB/T 132-2018). In 2020, based on above documents, the Chinese government adopted the program "Accelerating the Establishment of Green Production and Consumption Regulations and Policy System", which outlines the main directions and priorities for environmental technologies implementation in production processes.

Among the key organizations responsible for certification at the national level, the following should be highlighted: 1) **National Development and Reform Commission (NDRC)**, which plays a crucial role in setting standards and defining development directions for eco-industrial parks. The **NDRC** oversees the supervision and certification of sustainable industrial parks; 2) **Ministry of Ecology and Environment (MEE)**, which is responsible for certifying eco-industrial parks based on established environmental protection requirements, pollution reduction measures, and sustainable development principles; 3) **China Association of Circular Economy (CACE)**, which promotes circular economy principles and provides certification services for parks that meet ecological standards. Additionally, numerous independent organizations accredited by the government conduct certification of eco-industrial parks based on established sustainability criteria. At the regional and local levels, government authorities collaborate with industrial parks to ensure compliance with regional environmental policies and sustainable development goals (Huang Beijia et al., 2019). Thus, the certification of eco-industrial parks in China is a multi-layered process involving national, regional, and local organizations, as well as independent certification bodies. This policy focuses on integrating environmentally friendly technologies into production, promoting efficient resources uses, and in general supporting sustainable development policy. EIPs successfully integrate economic growth with environmental responsibility through the adoption of green technologies and sustainable practices (Table 3).

Table 3. EIPs' Performance Efficiency

Objectives of EIPs	Result of EIPs' activities
Environmental Efficiency: Emission reduction Efficient use of water and energy	Reduction of greenhouse gas emissions and pollutants through the implementation of cleaner production methods, energy-efficient technologies, and sustainable waste management practices. Significant improvements in water conservation and energy efficiency, leading to reduced overall resource consumption per unit of production.
Circular Economy and Waste Management: Increase in recycling rates Efficient resource utilization	EIPs have achieved higher waste recycling and resource reuse rates, minimizing landfill waste. Implementation of systems for more efficient use of secondary materials reduces waste and ensures a sustainable approach to production processes.
Technological Development and Innovation: Implementation of green technologies Research and development	EIPs have successfully integrated innovative solutions in renewable energy, water purification, pollution reduction, and other environmental areas. Significant efforts are dedicated to developing eco-friendly solutions that contribute to sustainable development.
Economic and Social Impact: Attracting investments Regional development Job creation	Enterprises within EIPs attract both domestic and international investments, focusing on sustainable development. EIPs contribute to job creation in the green industrial sector, emphasizing environmentally responsible production.
Improvement of Government Policy in Management and Monitoring	Certified EIPs adhere to stricter environmental standards, ensuring greater transparency, accountability, and regulatory compliance. Enhanced collaboration between government agencies, businesses, and local communities promotes sustainable development.
Alignment with Global Sustainable Development Goals	Among the primary goals of EIPs complying with sustainable development goals are environmental conservation (by reducing overall consumption and production costs), mitigation of negative climatic change effects (by implementing green production standards), and in general promotion of environmental responsibility at both the state and individual enterprise levels.

Note — compiled by the authors based on the databases of the World Bank; China Services Info: Industrial Park; Websites of EIPs

Thus, EIPs in China demonstrate positive results in reducing environmental impact, stimulating sustainable economic growth, and fostering technological advancements. These parks play a pivotal role in achieving the country's environmental and socio-economic goals, contributing to a more sustainable future.

Conclusions

At the initial stage of the open-door policy, the government of the People's Republic of China (PRC) sought to accelerate the industrialization of the economy by attracting foreign capital. Special Economic Zones (SEZs) became a key instrument in achieving this goal, providing preferential conditions for foreign investors and stimulating the creation of new production capacities. Currently, China has developed multiple types of SEZs. The evolution of SEZs in China has proceeded in stages, reflecting the primary goals and priorities of the country's economic development. The transformation of SEZ types illustrates China's shift from specializing in labor-intensive manufacturing to more complex production processes within industrial parks. Over time, the Chinese government shifted its focus toward promoting high-value-added production, and SEZs became hubs for the development of high-tech industries. A progressive step in this transition was the establishment of eco-industrial parks, based on strict environmental standards and principles of the circular economy.

The Chinese government actively promotes the creation and development of Eco-Industrial Parks (EIPs) through the implementation of comprehensive policies, financial incentives, and the encouragement of sustainable technologies. China has integrated the concept of ecological civilization into its national strategy, which focuses on sustainable development and environmental conservation. This strategy is practically implemented through the establishment of eco-industrial parks.

To achieve sustainable development goals and ensure coordination between economic expansion and environmental protection, China has been implementing programs for over two decades to gradually transform National Development Zones, National Economic and Technological Development Zones (ETZs), and National High-Tech Zones (HTZs) into Eco-Industrial Parks. The models for transforming economic devel-

opment zones into EIPs, as outlined in this study, constitute a central element of China's modern economic strategy. This strategy aims to integrate intensive industrial development with the advancement of green technologies, achieving high environmental efficiency while reducing the burden on the environment. Since the early 2000s, EIP development programs have been incorporated into China's five-year economic plans, demonstrating a phased, strategic, and justified approach to this process. China's national policy defines economic development goals and directions, promoting the reduction of environmental pollution, improvement of energy efficiency in production, implementation of circular economy principles, and the green development of industrial parks. Eco-industrial parks play a central role in these processes, contributing to sustainable economic development. They also serve as a key instrument for transitioning China's economy from an extensive to an intensive growth model. The emergence of EIPs signifies a shift in China's economic development trajectory, manifesting in a combination of continued active industrial growth, a focus on high-tech industries, and environmental conservation policies. A key mechanism for integrating these directions is the implementation of circular economy principles, including the establishment of EIPs.

The foundation of EIP operations lies in the implementation of a closed-loop economic strategy. The principles and mechanisms of the circular economy within EIPs are aimed at minimizing waste, promoting reuse, recycling materials and waste, utilizing all types of resources efficiently, restoring resources, and establishing sustainable interconnections along production-consumption processes between individual enterprises within EIPs. EIP development programs place significant emphasis on introducing green and clean technologies to enhance energy efficiency, including multi-level energy utilization, the creation of closed energy cycles, and the use of renewable energy sources. EIPs serve as hubs for high-tech industries, as demonstrated by the case studies of three parks: China-Singapore Suzhou Industrial Park (SIP), Tianjin Economic-Technological Development Area (TEDA), and Qingdao Sino-German Ecopark.

Thus, the primary functions of EIPs include: a) Combining the development of the circular economy with enhanced market competitiveness through the use of innovative technologies; b) Facilitating fundamental transformations in industrial production and consumption models within China's economy; c) Supporting the transition toward intensive economic growth.

The Chinese government provides substantial financial incentives for Eco-Industrial Parks in the form of grants and subsidies for projects that promote sustainable development, particularly those focused on waste recycling and green technology advancement. EIPs benefit from tax incentives and preferential loan conditions for enterprises implementing environmental initiatives. On the other hand, EIP standards emphasize improved environmental management, with comprehensive ecological indicators defining the framework for sustainable operations. Strict environmental requirements for EIP establishment, along with an existing certification system, aim to balance ecological responsibility with intensive economic growth based on circular economy principles and green standards. China's experience in establishing EIP standards and performance indicators can serve as a model for other countries seeking to develop industrial benchmarks aligned with sustainable development goals.

The economic performance of EIPs reflects their role as leading economic and industrial centers in China, significantly contributing to economic growth through innovation, sustainability, and international cooperation. Observing China's experience in EIP development demonstrates their effectiveness in social, economic, and environmental aspects, underscoring the importance of promoting such industrial zones on a global scale.

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