

# Comparative Study on the Development Path of Zero-Carbon Parks in China and Abroad: An Analysis of Institutional and Technical Governance Based on the Six-Dimensional Framework

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**Abstract.** Against the backdrop of the critical stage of global climate governance and countries racing towards the carbon neutrality goal, industrial parks, as important spatial units for carbon emissions concentration and industrial agglomeration, are becoming a key breakthrough point for green transformation. This paper focuses on the "zero-carbon park", an important policy tool and practice paradigm in global climate action, systematically compares the differences in standard systems, policy tools, and practice models at home and abroad, and reveals the underlying institutional roots and governance logic. By constructing a six-dimensional comparative analysis framework covering "standards, policies, paths, techno-economics, digital governance, and future trends", the study finds that there is a typical distinction between "market-driven" and "strategy-driven" in the construction of zero-carbon parks in China and abroad. China has achieved efficient progress by virtue of its institutional advantages and industrial foundation, but also faces challenges such as insufficient market mechanisms and standard docking. The study holds that China's experience can provide useful reference for the world, especially for developing countries, and suggests promoting mutual recognition of standards at the institutional level, strengthening the construction of digital governance capabilities, and enhancing the sustainability of transformation.

**Keywords:** Zero-carbon Park; industrial symbiosis; policy tools; digital governance; Comparative analysis.

## 1. Introduction

### 1.1. Research background and questions

Since China proposed the "carbon peak and carbon neutrality" strategic goals in 2020, green and low-carbon development has become critical for reshaping national development paradigms and international competitive advantages. Concurrently, United Nations Climate Change Conferences (e.g., COP26, COP30) have strengthened global emission reduction responsibilities, prompting systemic transformations in energy, industry, and technology worldwide. Industrial parks, with concentrated energy consumption, close industrial synergy, and strong policy controllability, have emerged as key entry points for regional emission reduction and industrial structure optimization. Globally, "zero-carbon parks"—integrating green infrastructure, clean energy systems, and digital governance tools—are developing rapidly: cases like Denmark's Kalundborg and the UK's Humber represent developed countries' exploration in industrial symbiosis and technological evolution, while China advances localized paths exemplified by Suzhou Industrial Park and Ordos Zero-Carbon Park, demonstrating effective system implementation and policy synergy under national strategic guidance. Existing research lacks systematic cross-country comparisons of zero-carbon parks; this study focuses on differential trajectories between China and international models, quantifies gaps in standards, policies, and implementation models under global carbon neutrality goals, identifies institutional drivers of these gaps, and extracts China's practical experience for developing countries.

## 1.2. Literature review

Existing research on zero-carbon parks focuses on three main areas: First, park-level carbon accounting and carbon neutrality path simulation, emphasizing technical paths and energy substitution, such as discussions in Ge Leijiao, Li Jingjing, Li Changlu, et al.'s [1] "Review of Optimization Technologies for Integrated Energy Systems in Zero-carbon Parks". However, such research remains largely theoretical with few practical cases, lacking replicable engineering paths, and neglects factors like multi-energy system scheduling, low-carbon technology costs, and user behavior. Second, case study model exploration analyzes construction processes, effectiveness, and bottlenecks of typical parks, as in Chen Yanbo, Zhang Ning, Li Jiaqi, et al.'s [2] "Review and Prospect of Zero-carbon Park Research", but suffers from deficiencies in unified quantitative evaluation systems and limited discussion of dynamic feedback issues like economic feasibility [3]. Third, policy toolkit analysis for green transformation, such as Song Zhuoran, Cheng Mengzeng, Niu Wei, et al.'s [4] discussion in "Key Technologies and Development Trends of Optimal Planning for Zero-carbon Parks in the Context of the Energy Internet", covers technical dimensions like multi-energy complementarity but lacks research on multi-technology coordination mechanisms and integration of soft factors like policies, restricting a comprehensive understanding of sustainable operation mechanisms [5]. These gaps provide the entry point for this study: exploring similarities, differences, and evolution mechanisms of zero-carbon park paths under diverse institutional and policy logics through cross-border comparison.

## 1.3. Research significance and innovation

The academic and practical significance of this research is mainly reflected in three aspects: At the theoretical level, a six-dimensional comparative analysis framework covering "standards, policies, paths, techno-economics, digital governance, and future trends" has been constructed, breaking through the limitation of existing research focusing on a single dimension. At the variable level, "digital governance" has been incorporated into the core variable system for the first time, and its key role in resource optimization and allocation, carbon emission monitoring, and governance feedback mechanisms has been systematically analyzed. At the practical level, based on cases of various parks in China, a development model with local characteristics and its replicable value for developing countries have been summarized.

## 1.4. Research framework and thesis structure

This paper adopts the method of comparative research and case analysis, focusing on the three main lines of "standard-policy-path", and combining the six-dimensional analysis framework to conduct a systematic analysis. The structure of the full text is as follows:

Chapter 2 introduces the core concepts and theoretical foundations, and constructs an analysis framework; Chapter 3 compares the differences in standard systems, policy tools and practice paths between Chinese and foreign zero-carbon parks; Chapter 4 discusses the deep mechanisms behind the differences, such as the political and economic system, development stage and industrial structure. Chapter 5 summarizes the research findings, puts forward multi-level policy suggestions, and points out future research directions.

## 2. Theoretical basis and analytical framework

### 2.1. Definition of core concepts

A zero-carbon park refers to an industrial agglomeration area that achieves annual net zero carbon emissions through means such as clean energy substitution, energy efficiency optimization, carbon capture and offsetting. Its core features include carbon management throughout the life cycle, system-level collaborative governance, and clear carbon boundary setting. Industrial symbiosis, originating from the theory of ecological industry, refers to the construction of a resource recycling network

through the exchange of by-products and energy sharing among enterprises to improve overall resource efficiency and environmental performance. In park governance, digital twin uses technologies such as the Internet of Things and artificial intelligence to build a mapping system between the virtual and physical parks, enabling real-time collection, dynamic simulation, and optimized decision-making of carbon emission data [6].

## 2.2. Relevant theoretical basis

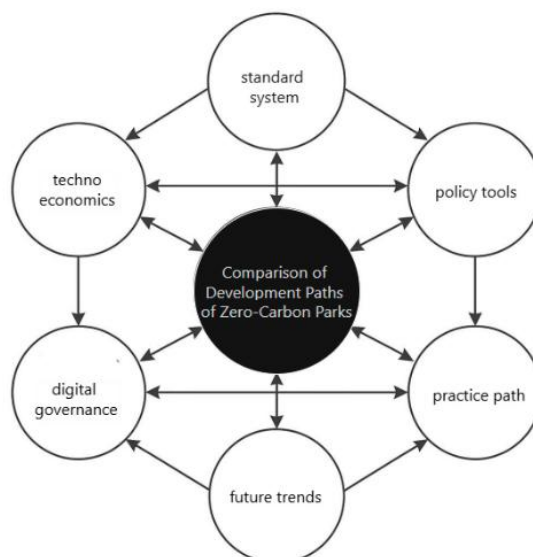
**Institutional economics:** emphasizes the shaping role of institutional arrangements in economic behavior. In the construction of zero-carbon parks, the property rights structure, policy implementation mechanisms and governance models of different countries have a decisive impact on the development path of the park.

**Policy Instruments Theory:** Policy tools are divided into regulatory (such as standards, prohibitions), incentives (such as subsidies, taxes) and information (such as information disclosure and evaluation systems). This theory can be used to compare the combination of tools, implementation efficiency and effects adopted by countries in the promotion of zero-carbon parks.

**Technological Paradigm Shift:** Proposed by Freeman et al., it emphasizes that under specific historical conditions, new technology-institutional configuration becomes dominant. In the context of zero-carbon parks, the collaborative evolution of green energy systems, digital technologies, and institutional innovation constitutes a new technological paradigm.

## 2.3. Six-dimensional comparative analysis framework

To systematically reveal differences in the development paths of Chinese and foreign zero-carbon parks, this paper constructs a six-dimensional analysis framework covering: standard systems (analyzing formulation mechanisms, boundary definitions, and carbon accounting requirements); policy tools (comparing types, implementation mechanisms, and incentive logic); practical paths (sorting out construction modes and evolution logic of typical parks); technical economics (examining economic feasibility and deployment modes of key low-carbon technologies); digital governance (analyzing roles of data infrastructure and digital platforms); and future trends (predicting integration directions and international alignment possibilities). These dimensions are nested and dynamically linked, with standards providing a basis for policy tools, practice paths constrained by technical economy, digital governance supporting standards and policies, and future trends reflecting synergistic potential of all dimensions. Six-dimensional comparative analysis framework as shown in the figure 1.



**Fig 1.** Six-Dimensional Comparative Analysis Framework for the Development Path of Zero-Carbon Parks.

### 3. Comparison of Chinese and foreign zero-carbon park paths: standards, policies and practices

#### 3.1. Comparison of standard systems

Internationally, zero-carbon park standards show diversification and specialization, represented by the UK PAS 2060, ISO 14064 series, and EU Green Deal Industrial Plan, focusing on self-declaration, third-party verification, "market verifiability" and transparency. Developed countries adopt a "carbon footprint-emission reduction plan-offset" model, with standards led by non-governmental organizations or industry associations, reflecting strong market orientation.

In contrast, China lacks a unified authoritative standard system, mainly relying on "group standards" or "guidelines" from local pilots and research institutions. Although the Ministry of Industry and Information Technology's "Green Park Evaluation Requirements"[7] proposes quantitative indicators, ambiguities remain in carbon neutrality boundaries and accounting methods. China's standard evolution features "policy first, standard follow-up" with promotion mainly through administrative means. The specific comparison is shown in Table 1.

**Table 1.** Comparison of zero-carbon park standard systems between China and foreign countries.

Comparison table of zero-carbon park standard systems in China and abroad		
Comparative dimensions	European and American standard system	Chinese standard system
Representative standard	PAS 2060, ISO 14064 series, EU Green The Green Deal Industrial Plan	Ministry of Industry and Information Technology Green Park Evaluation Guidelines and Local Group Standards
Standard-setting bodies	Non-governmental organizations and industry associations	Government-led, pilot demonstration is the mainstay
Accounting method	"Carbon footprint - emission reduction plan - offset" three steps	Quantitative indicators are not uniform, and carbon boundaries are blurred
Standard authority	High, in line with international standards	low, fragmented and lacking unified authority
Verification mechanism	Third-party verification, market verifiability	Administrative means promoted, with limited third-party participation
transparency	High	Lower

#### 3.2. Comparison of policy tools

European and American countries generally adopt the combination of "market-oriented + informatization" policy tools. For example, the EU's "Industrial Symbiosis Program" incentivizes enterprises to carry out green transformation through carbon trading markets, green taxation and innovation funds. The government plays the role of a platform to promote knowledge sharing and enterprise collaboration. Digital tools, such as carbon emission databases and park online monitoring platforms, have become important support for policy implementation.

China has a strong "strategic-oriented" policy style. The central government has guided local governments to compete to set up zero-carbon parks through the "dual carbon" goal, and most of the policy tools are direct incentives such as financial subsidies, land incentives, and pilot demonstrations. At the same time, the dual linkage of "local-enterprise" has become the core implementation mechanism, emphasizing the combination of "goal-oriented + process assessment". The comparison of specific policy tool combinations is shown in Table 2.

**Table 2.** Comparison of Policy Tool Combinations for Zero-Carbon Parks Between China and Foreign Countries.

Comparison of policy tool combinations of Chinese and foreign zero-carbon parks		
Policy tool types	European and American countries	China
Incentive means	Carbon trading market, green taxation, innovation fund	Financial subsidies, land concessions, and pilot demonstrations
Government role	Platform role, promoting knowledge sharing and enterprise collaboration	Direct promotion, goal-oriented + process assessment
Digital support	Carbon emission database, online monitoring platform	Industrial Internet and smart park platform
Policy implementation mechanism	Market-oriented mechanism is the main focus, and information is open and transparent	Strategically oriented, administrative-led

**3.3. Comparison of practice paths**

Practically, European and American parks mostly adopt a "bottom-up" approach, emphasizing independent enterprise exploration and industrial network evolution. Denmark’s Kalundborg, for example, built its industrial symbiosis system on long-term inter-enterprise trust and economic mutual benefit, with the government providing limited support in supporting facilities, showing a "gradual evolution - cluster strengthening" characteristic.

Chinese parks emphasize "top-down" deployment. Suzhou Industrial Park, guided by the government’s clear carbon peaking roadmap and indicator system, adjusts energy structure and implements key projects. Ordos Zero Carbon Park integrates wind-solar resources with hydrogen energy and energy storage systems to create a highly integrated energy network, reflecting the path of "policy promotion, platform integration, and technology empowerment". The specific differences in the typical park practice paths are shown in Table 3.

**Table 3.** Comparison of Practice Paths of Typical Zero-Carbon Parks.

Comparison of the practice paths of typical zero-carbon parks		
Path characteristics	Cases from European and American countries (e.g., Kalenborg, Denmark)	China Cases (e.g. Suzhou Industrial Park, Ordos Zero Carbon Park)
Path pattern	From the bottom up, enterprises independently explore and evolve the network	From the top down, government planning and policy driven
Industrial synergy	Industrial symbiosis based on long-term trust between enterprises	The government coordinates and integrates energy and industrial resources
Development speed	Steady and gradual, the path is stable	Rapid progress, policy-driven resource concentration
Technical application	Focus on the optimization of existing industrial processes and green upgrading	The side reinfrastructure drive is highly integrated with the energy system
Government support	There is limited support for the construction of supporting facilities	Comprehensive policy, funding, and platform support

**3.4. Comparison of technical economy**

Significant differences exist in technology selection, cost structure, and financial support for zero-carbon park construction between Chinese and foreign parks, re-flecting path differentiation rooted in development stages and institutional back-grounds [8].

Developed country parks prefer mature, high-efficiency, and intelligent technologies like BEMS, distributed PV-storage integration, and AI-optimized energy scheduling, with high initial investment but stable lifecycle benefits—e.g., Germany’s EUREF campus smart microgrid achieved break-even within 5 years [9].

Chinese parks focus on initial cost control and localized equipment, favoring low-threshold single green technologies (e.g., high-efficiency heat pumps, PV roofs) and relying on subsidies to reduce costs, such as Shenzhen’s BIPV project cutting investment pressure by ~30% via municipal subsidies [10]. Europe and America use market incentives like carbon taxes, while China relies more on special funds, with domestic parks gradually shifting from "policy-driven" to "market-guided" amid improved green tools.

#### 4. Deep Mechanisms of Path Differences

The divergent development paths of Chinese and foreign zero-carbon parks stem from distinct institutional logics: China embeds such parks in national strategic top-level design, enabling rapid resource deployment and implementation through "policy-platform-project" chains driven by the "dual carbon" goal, as seen in Ordos’ government-led "wind-solar-hydrogen-storage integration"[11]; in contrast, European and American countries rely on market self-organization and inter-enterprise col-labo-ration, exemplified by Denmark’s Kalundborg industrial symbiosis system formed through long-term commercial trust. Development stages and industrial struc-tures further shape these differences: developed countries with high tertiary industry and low-carbon energy focus on green upgrading of traditional zones (e.g., the UK Hum-ber’s hydrogen and carbon capture cluster), while China, in mid-late industriali-zation with energy-intensive industries, uses parks for "industrial cluster + energy system" reconstruction to convert energy advantages into low-carbon competitiveness. Tech-nical paradigms and digital governance capabilities also differ: China leverages indus-trial Internet and smart platforms for emission monitoring and optimization, as in Su-zhou Industrial Park’s "source-grid-load-storage" scheduling[12]; European and American countries rely on mature data supervision and transparency mechanisms like EU ETS’s third-party audits, with China emphasizing "platform governance" for ef-fi-ciency and others focusing on "rule embedding" for compliance, reflecting adapta-bility to respective environments. The differences in institutional logic and technical governance capabilities between Chinese and Western zero-carbon parks are shown in Table 4.

**Table 4.** Comparison of Institutional Logic and Technical Governance Capabilities of Zero-Carbon Parks Between China and Foreign Countries.

Comparison of institutional logic and technical governance capabilities of Chinese and foreign zero-carbon parks		
dimension	China Zero Carbon Park	European and American zero-carbon parks
Institutional logic	National strategy leading, three-level government linkage, policy-platform-project chain	The market is self-organizing, and the enterprise network is collaborative, based on trust mechanisms
Development stage and industrial structure	In the middle and late stages of industrialization, heavy industry and energy-intensive industries are the mainstay	In developed countries, the tertiary industry is dominant and the low-carbon energy foundation is good
Technical path	Highly integrated energy networks and industrial Internet applications	Relies on mature market mechanisms and third-party audits for high transparency
Digital governance focus	platform governance, dynamic monitoring, and data-driven administrative efficiency improvement	Rule embedding, compliance supervision, information authenticity and market supervision
Promote advantages	Efficient resource integration and strengthen government mobilization capabilities	Stabilize the resilience of the system and adjust the ability to independently adjust for a long time
Challenges	Fragmented standards, financial dependence, and insufficient market mechanisms	The speed of advancement is slow and depends on the spontaneity of enterprises

## 5. Conclusions and policy recommendations

### 5.1. Key findings and Policy Recommendations

Through a six-dimensional comparative framework ("stand-ards-policy-path-technical economy-digital governance-future trends") and cross-border practice comparisons, key findings show institutional differences de-ter-mine path models: China achieves efficient deployment via "top-down" government leadership, while Europe and America pursue enterprise-led gradual transformation through market mechanisms. Standard systems and policy tools differ—European and American standards are independent and internationally integrated with mar-ket-oriented policies, while China faces standard fragmentation, relying more on fiscal investment and administrative assessment. China’s "data-driven governance" via smart platforms offers strengths in emission supervision and resource optimization, with its "policy traction + platform empowerment" model providing reference for Global South countries. Based on these findings, policy recommendations include: establishing a unified authoritative standard system aligned with international standards like ISO and PAS; optimizing policy tools by introducing market-oriented mechanisms (e.g., carbon trading, green taxation) while maintaining financial support [13]; strengthening digital infrastructure through a unified carbon monitoring platform and cross-entity data sharing; and promoting international experience export via platforms like the "Belt and Road", participating in international standard formulation, and ex-ploring a "pub-lic-private cooperation + technical assistance + capacity building" model for developing countries. The summary of policy optimization suggestions for China's zero-carbon parks is shown in Table 5.

**Table 5.** Summary of Policy Optimization Suggestions for China's Zero-Carbon Parks.

Summary of policy optimization suggestions for China's zero-carbon parks	
direction	Specific recommendations
Standard system construction	Unify authoritative standards, align with international standards, and promote third-party verification
Optimize policy tools	Introduce market-oriented mechanisms, improve performance evaluation, and promote green collaboration between parks
Digital infrastructure strengthened	Build a unified monitoring platform to promote cross-subject data sharing and ensure network security and privacy
International experience output	Combine the "Belt and Road" to export overall solutions, participate in the formulation of international standards, and support developing countries

### 5.2. Research Limitations and Future Prospects

Despite constructing a systematic analysis framework and comparing multiple cases, this study has limitations: limited case coverage excluding Global South models in regions like Latin America and Southeast Asia; macro-level description of digital governance lacking micro-mechanism empirical data; and unvalidated causal rela-tion-ships between policy tools and performance requiring quantitative verification.

Future research directions include: building a park-level carbon performance da-tabase to deepen policy-effectiveness empirical analysis; conducting multi-country field surveys to compare zero-carbon governance logics across development stages; and focusing on digital platform governance mechanisms to study interactions between algorithmic decision-making and institutional regulation.

## References

- [1] Ge Leijiao, Li Jingjing, Li Changlu, et al. Power System Technology, 48(05), 1821-1835, 2024.
- [2] Chen Yanbo, Zhang Ning, Li Jiaqi, et al. Proceedings of the CSEE, 44(14), 5496-5517, 2024.
- [3] China Industrial Internet Research Institute. Report on the Economic Development of China's Industrial Internet Industry, 2024.
- [4] Song Zhuoran, Cheng Mengzeng, Niu Wei, et al. Electric Power Construction, 43(12), 15-26, 2022.

- [5] Khan, M. I., Hussain, S., & Ullah, I. *Sustainable Cities and Society*, 107, 106798, 2024.
- [6] Li, H., & Zhang, Y. *IEEE Transactions on Industrial Informatics*, 21(3), 1924–1934, 2025.
- [7] Ministry of Industry and Information Technology of the People's Republic of China. Evaluation requirements for green industrial parks, (n.d.).
- [8] Mandal, S., & Chakraborty, S. *Journal of Cleaner Production*, 438, 139943, 2024.
- [9] Nguyen, T. T., Tran, D. T., & Le, T. T. *Energy Policy*, 187, 113543, 2024.
- [10] Al-Sulaiman, F. A., & Al-Rashed, A. A. *Renewable Energy*, 191, 432–443, 2024.
- [11] State Council. Notice of the State Council on Printing and Distributing the Action Plan for Carbon Peaking before 2030, 2021a.
- [12] State Council. "Opinions of the Central Committee of the Communist Party of China and the State Council on Complete, Accurate and Comprehensive Implementation of the New Development Concept to Do a Good Job in Carbon Peak and Carbon Neutrality", 2021b.
- [13] State Council Information Office. White Paper on China's Policies and Actions to Combat Climate Change, 2021.