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Low-Carbon Development Dilemmas and Differentiated Pathways for Non-Core Cities in China's Chengdu–Chongqing Economic Zone: A Case Study of Nanchong

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ABSTRACT

China's dual-carbon strategy calls for all cities to formulate carbon peaking action plans, yet the academic literature overwhelmingly focuses on megacities and core economic centers, leaving the low-carbon transition challenges facing non-core, underdeveloped cities underexplored. This paper addresses this gap by examining Nanchong, a populous yet economically peripheral prefecture-level city in the Chengdu–Chongqing Economic Zone (CCEZ), as an in-depth case study. Drawing on Gerschenkron's latecomer advantage theory and the comparative advantage framework, and using publicly available statistical data, government policy documents, and secondary literature, we construct a systematic comparison between Nanchong and the CCEZ's twin core cities (Chengdu and Chongqing) across six analytical dimensions: economic structure, carbon emission profile, energy endowment, industrial innovation capacity, green finance accessibility, and human capital. Our analysis reveals that non-core cities face a distinctive "low-carbon development trilemma" — the simultaneous pressure to industrialize, urbanize, and decarbonize — which core cities have largely resolved sequentially. However, we identify four differentiated low-carbon pathways available to Nanchong that leverage its latecomer status: (1) leapfrogging through new-energy commercial vehicle manufacturing; (2) exploiting natural gas resource endowments for a transitional "grey-to-blue-to-green" hydrogen strategy; (3) green upgrading of the traditional silk industry chain through eco-certification and cultural branding; and (4) utilizing near-zero-carbon industrial park pilots as institutional innovation platforms. We argue that non-core cities need not replicate the carbon-intensive industrialization trajectory of core cities but can pursue "curve-bending" strategies that compress the time between economic take-off and emission peaking. The findings carry implications for similar non-core cities across China's western urban agglomerations and for developing-country cities more broadly.

KEYWORDS

Non-core city; Low-carbon development; Chengdu–Chongqing Economic Zone; Nanchong; Latecomer advantage; Carbon peaking; Differentiated pathways

1. INTRODUCTION

Climate change mitigation has become a central concern of urban governance worldwide. China, as the world's largest carbon emitter, pledged to peak CO_2 emissions before 2030 and achieve carbon neutrality by 2060. To operationalize these goals, the central government established a "1+N" policy framework — the most comprehensive carbon reduction framework in the world, with clearly defined timetables and action plans. Within this framework, the "1" stands for the guiding principles and top-level design, while the "N" includes sectoral and regional implementation plans [2]. The national Action Plan for Carbon Dioxide Peaking Before 2030 explicitly instructs that "work related to peaking carbon dioxide emissions must be carried out in a vigorous, orderly and effective manner by setting explicit targets and tasks for different regions, fields and industries [6]." Crucially, the Plan warns against "one size fitting all" approaches to electricity consumption restriction and industrial production restriction, and against campaign-style carbon mitigation [6].

This principle of differentiated action is particularly salient for non-core cities within China's major urban agglomerations. Decarbonization has increasingly become a major policy direction globally, deeply intertwined with urban socio-economic development. However, the connection between decarbonization and urban livability remains underexplored, which is particularly consequential for non-core cities, because limited resources, institutional constraints, and weaker economic structures in these smaller cities mean that decarbonization often places extra restrictions on their socio-economic progress [5]. Urban agglomerations formed by megacities currently contribute roughly 78% of China's GDP and 72% of China's carbon emissions, which will further increase to 90% and 83% respectively by 2030 [6]. Yet the vast majority of cities within these agglomerations are non-core cities that contribute relatively little to aggregate emissions but face disproportionate challenges in balancing growth and decarbonization.

The Chengdu–Chongqing Economic Zone (CCEZ) is a case in point. As a key region in western China and the upper reaches of the Yangtze River, the CCEZ not only holds significant economic development potential but also has an important ecological status [4]. The economic zone has established industrial clusters in electronic information, equipment manufacturing, advanced materials, and consumer goods, each valued at more than CNY 1 trillion [3] Yet its internal spatial inequality is stark: at both city and county scales, high carbon emission areas are mainly distributed in Chengdu and Chongqing, while low carbon emission areas are concentrated in the marginal cities of the CCEZ [2].

Nanchong exemplifies the non-core city predicament. It is a prefecture-level city located in the northeast of Sichuan Province, covering approximately 12,500 square kilometers, serving as a central hub in the CCEZ, and as of the end of 2024, its resident population stands at about 5.49 million, making it the second-largest city in Sichuan by population [2]. Despite its demographic weight, Nanchong has consistently ranked among the lowest-performing cities in the CCEZ on indices of green industry development, eco-efficiency, and urbanization. Dazhou and Nanchong had the lowest green industry (GI) levels among all the cities in the Chengdu–Chongqing region [3]. Among the bottom five cities in eco-efficiency growth rate were Nanchong (−30.13%) and Dazhou (−47.99%) [4]. At the same time, Nanchong was identified as a coldspot area in terms of carbon emissions, while hotspot areas were concentrated in Chengdu, Deyang, and the main urban area of Chongqing [1].

This paradox — low emissions not from successful decarbonization but from underdevelopment — raises a critical question: How can non-core cities like Nanchong achieve low-carbon development without sacrificing the economic growth they urgently need? The existing literature provides limited guidance. Research on low-carbon city pilot policies shows that such policies can significantly promote high-quality economic development, but the effects are relatively greater in the eastern region, non-resource-based cities, and megacities [9]. Large cities typically possess more advanced infrastructure, better industrial support systems, and stronger capacities for technological factor agglomeration, providing a superior institutional foundation for the effective implementation of low-carbon policies [8]. Non-core cities, by contrast, face what we term the "low-carbon development trilemma" — the simultaneous pressure to industrialize, urbanize, and decarbonize.

This paper addresses the gap by conducting an in-depth qualitative case study of Nanchong, systematically comparing it with the CCEZ's core cities across six dimensions, and identifying differentiated low-carbon pathways that leverage Nanchong's latecomer advantages. The theoretical contribution lies in applying Gerschenkron's latecomer advantage theory (1962) — originally developed for national-level industrialization — to the city-level low-carbon transition context, and in articulating the concept of "curve-bending" strategies that compress the temporal gap between economic growth and emission peaking.

2. THEORETICAL FRAMEWORK

2.1. The Low-Carbon Development Trilemma for Non-Core Cities

Core cities in Chinese urban agglomerations, such as Chengdu and Chongqing, have generally followed a sequential development model: rapid industrialization first, followed by tertiarization, and only then systematic decarbonization. Their current low-carbon transitions are supported by large service-sector shares, high-tech industry clusters, deep capital markets, and abundant human capital. Peaked cities usually have controlled carbon intensities at a low level, with more improved production and energy structures toward light industries or service sectors (such as Shenzhen and Chengdu) and clean energy (Suining and Nanchong) [5].

Non-core cities, by contrast, must pursue all three objectives — industrialization, urbanization, and decarbonization — simultaneously, under tighter resource constraints and weaker institutional capacities. This creates three interlocking tensions. First, the growth–emission tension: non-core cities need industrial expansion to generate employment and fiscal revenue, but traditional industrial growth is inherently carbon-intensive. Second, the urbanization–emission tension: urbanization often results in higher CO_2 emissions due to demand for steel and cement as well as rising consumption levels [6]. Third, the policy–capacity tension: non-core cities must implement the same national carbon peaking mandates as core cities but with far fewer financial, technological, and institutional resources.

2.2. Latecomer Advantage Theory

Alexander Gerschenkron (1962) argued that economically backward countries possess distinctive advantages in industrialization precisely because of their backwardness. On the basis of summarizing the catch-up experience of Germany, Italy and other countries, Gerschenkron first proposed the concept of latecomer advantage, pointing out that "a country with a relatively backward economy during the industrialization period has its industrialization process and characteristics that are significantly different from those of advanced countries [2]." The higher the degree of relative backwardness, the faster the subsequent growth rate, because these countries have a "latecomer advantage" that benefits from being left behind [2].

The American sociologist M. Levy later concretized this theory. Levy summarized latecomer advantages into five points: latecomers have a richer understanding of modernization; they can adopt mature plans, technologies, and organizational structures from first-movers; they can skip some necessary development stages; they can make predictions about their own modernization prospects; and first-developing countries can provide help in capital and technology [2].

We apply this framework to the city-level low-carbon transition as follows. Non-core cities like Nanchong are "latecomers" relative to Chengdu and Chongqing. Their backwardness in traditional industrialization is simultaneously an advantage: they carry less legacy carbon-intensive infrastructure, face lower sunk costs in fossil-fuel-dependent industries, and can directly adopt the latest clean technologies without the need for costly retrofitting. Latecomer advantage refers to the ability of developing countries to increase their knowledge factor in a cost-effective manner by learning, importing, assimilating, and using knowledge and technology that already exist [1]. In the low-carbon context, this translates into the ability to "leapfrog" carbon-intensive development stages altogether.

2.3. Comparative Advantage and Differentiated Pathways

Ricardo's theory of comparative advantage, when applied at the city level within an urban agglomeration, suggests that cities should specialize in activities where they hold relative cost or resource advantages. A system-of-cities model incorporating internal urban structures and a highdimensional theory of factor-driven comparative advantage predicts that larger cities will be skill-abundant and specialize in skill-intensive activities [7]. By implication, non-core cities with different factor endowments — natural resources, lower labor costs, available land, and specific industrial traditions — should pursue differentiated development pathways rather than imitating core cities.

For Nanchong, we argue that the relevant comparative advantages include: abundant natural gas reserves (enabling hydrogen economy development), an established silk-and-textile industrial chain (enabling green upgrading), a nascent but rapidly growing new-energy commercial vehicle cluster (enabling industrial leapfrogging), and relatively low carbon lock-in (enabling near-zero-carbon park experimentation). The integration of latecomer advantage theory with comparative advantage theory provides the analytical foundation for identifying Nanchong's differentiated low-carbon pathways.

3. STUDY AREA AND METHODOLOGY

3.1. Study Area: Nanchong in the CCEZ

Nanchong's urban core is composed of three districts — Shunqing, Gaoping, and Jialing — that collectively drive the city's administrative, industrial, commercial, and cultural functions, encompassing a combined area of approximately 2,527 km² [2]. Its rural administrative divisions comprise five counties — Nanbu, Yingshan, Peng'an, Yilong, and Xichong — and the county-level city of Langzhong, which together form the prefecture's agrarian periphery [2].

The city has experienced significant demographic and economic change. By 2024, the urban resident population had risen to 2,949,000, with the overall urbanization rate reaching 53.73%, a significant rise from the 39.1% recorded in 2010 [2]. However, by the end of 2024, the resident population had decreased to 5,489,000, reflecting a net reduction of 22,000 from the prior year, primarily due to out-migration [2]. This out-migration pattern is characteristic of non-core cities in the CCEZ, where Chengdu and Chongqing exert powerful siphon effects on talent and capital.

In terms of carbon emissions, Nanchong has been categorized as a hydropower-rich city, and emissions could peak in hydropower-rich cities such as Chengdu and Nanchong [5]. A recent study classified Nanchong as potentially having already peaked or being near-peak in carbon emissions. However, this seemingly favorable status is at least partly attributable to the city's relatively low level of industrialization rather than to successful decarbonization policies.

3.2. Methodology

This study employs a qualitative single-case study design with embedded units (Yin, 2018), combining three analytical approaches.

Comparative benchmarking analysis. We systematically compare Nanchong with the CCEZ's core cities (Chengdu and Chongqing) and with selected peer non-core cities (Suining, Guang'an, Mianyang) across six dimensions: (1) economic structure and GDP composition; (2) carbon emission profile; (3) energy endowment and consumption structure; (4) industrial innovation capacity (R&D spending, patent output, high-tech enterprise count); (5) green finance accessibility; and (6) human capital (educational attainment, population inflows/outflows). Data are drawn from publicly available statistical yearbooks, government statistical communiqués, and the Carbon Emission Accounts and Datasets (CEADs).

Policy document analysis. We conduct a systematic analysis of Nanchong's Carbon Peaking Implementation Plan (issued January 2024), its Hydrogen Energy Industry Development Plan (2024–2035), its 14th Five-Year Plan for Silk and Textile Industry, and the associated sub-plans for green manufacturing, energy conservation, and transport. These are compared with the corresponding national and Sichuan provincial plans to identify policy gaps and local innovations.

Secondary literature synthesis. We synthesize findings from recent empirical studies on carbon emissions, green development, eco-efficiency, and urbanization–environment coupling in the CCEZ, positioning Nanchong within the broader regional evidence base.

3.3. Data Sources

All data are publicly available. The principal sources include: the Nanchong Statistical Yearbook (2009–2023), Sichuan Statistical Yearbook, China City Statistical Yearbook, Nanchong's annual Statistical Communiqué of National Economic and Social Development (2020–2024), CEADs city-level carbon emission data, the National Intellectual Property Administration (CNIPA) for patent data, the Ministry of Industry and Information Technology's lists of national green factories and green industrial parks, and government policy documents published on the Nanchong Municipal Government website.

4. COMPARATIVE ANALYSIS: NANCHONG VERSUS CORE CITIES

4.1. Economic Structure

The CCEZ exhibits extreme economic polarization. Chengdu and Chongqing collectively account for over 60% of the zone's total GDP, with service-sector shares exceeding 55% and 52% respectively. Nanchong, by contrast, had a GDP of approximately ¥286.17 billion in 2024, with primary, secondary, and tertiary industry contributions of roughly 16.5%, 27.2%, and 56.3%. While the tertiary sector share appears comparable to the core cities, this is partly inflated by traditional services (retail, transport, government) rather than by the high-value-added producer services and digital economy that characterize Chengdu's tertiary sector.

The industrial structure also differs markedly. Nanchong's pillar industries — automobile and auto-parts, oil-and-gas chemical processing, silk-and-textile, food and beverage processing, and building materials — represent a mix of traditional resource-based and emerging manufacturing sectors. The Sichuan Nanchong Economic Development Zone is a provincial-level economic development zone, targeting four industrial chains: petroleum and natural gas chemical engineering, fine chemical engineering, new materials and new energy, extending development into downstream industries to build a low-carbon park and a circular economy park [7].

4.2. Carbon Emission Profile

At both city and county scales, high carbon emission areas and counties are mainly distributed in Chengdu and Chongqing, while the low carbon emission areas are concentrated in the marginal cities of the CCEZ and the counties with low levels of industrialization around the Sichuan Basin [2]. In 2000, there were 52 counties classified as LL-type (low–low spatial autocorrelation), mainly distributed in cities such as Ya'an, Leshan, and Nanchong, while 35 counties were classified as HH-type, mainly distributed in Chengdu, Deyang, and Chongqing [1]. Over the subsequent two decades, higher carbon emission areas increased in Deyang city and Nanchong city [1], suggesting that Nanchong's emissions were rising from a low base as industrialization progressed.

This pattern reveals a fundamental asymmetry: core cities are decarbonizing from a high emissions base, while non-core cities like Nanchong are still on the ascending limb of their emission trajectories. The policy implications are profound — Nanchong cannot simply adopt the same "post-peak mitigation" strategies that work for Chengdu.

4.3. Energy Endowment

Nanchong possesses a distinctive energy endowment that differentiates it from both the core cities and many peer non-core cities. Located in the heart of the Sichuan Basin, the city sits atop significant natural gas reserves, with the Longgang and Yuanba ultra-large gas fields in its vicinity. It also benefits from substantial hydropower capacity (installed capacity of 113.89 MW). Peaked cities usually have controlled carbon intensities at a low level, with more improved production and energy structures toward clean energy (Suining and Nanchong) [1]. This clean energy endowment is a critical comparative advantage: while many non-core cities in northern and central China remain heavily dependent on coal, Nanchong has structural access to lower-carbon energy sources.

4.4. Industrial Innovation Capacity

The innovation gap between Nanchong and the core cities is substantial. Chengdu hosts over 12,000 high-tech enterprises, numerous national-level research institutes, and two "Double First-Class" universities. Nanchong, while home to several regional universities, has far fewer R&D resources. In the regression coefficients for the level of economic development, only three cities — Guangyuan, Bazhong, and Nanchong — show negative effects on the coupling coordination between new urbanization and ecological welfare performance [5]. The spatial distribution of the regression coefficient for green technological innovation displays evident polarization, with Chengdu at the core showing a positive effect, while peripheral areas show mixed or negative effects [5].

However, Nanchong has shown emerging momentum in specific innovation niches. In 2024, the city's high-tech manufacturing value-added grew rapidly, led by a surge in computer, communications, and electronic equipment manufacturing. The key question is whether such nascent innovation clusters can be scaled sufficiently to drive a broader low-carbon industrial transformation.

4.5. Green Finance Accessibility

Core cities benefit from deeper capital markets, more green bond issuances, and greater access to national carbon trading pilot revenues. Nanchong, as a lower-tier city, faces structural disadvantages in green finance. However, recent national policies — including the establishment of the Chengdu–Chongqing Green Finance Reform Pilot Zone — have begun to create new channels for non-core cities to access green capital. Nanchong's Carbon Peaking Implementation Plan explicitly calls for leveraging green bonds, green credit, and climate investment funds.

4.6. Human Capital

Between 2010 and 2020, Nanchong's population experienced an average annual growth rate of −1.16%, declining from 6,278,622 to 5,607,565, largely driven by rural-to-urban migration outflows to larger economic centers [2]. This talent drain is perhaps the most serious structural obstacle to Nanchong's low-carbon transition. Nanchong's urbanization level score (0.152) placed it among the bottom five cities in the CCEZ [4]. Without sufficient skilled workers, engineers, and researchers, the city's capacity to absorb and deploy clean technologies is constrained.

4.7. Summary of Comparative Analysis

Table 1. Comparative profile: Nanchong versus CCEZ core cities

Dimension	Chengdu (Core)	Chongqing (Core)	Nanchong (Non-Core)
GDP (2024, ¥ billion)	~2,270	~3,010	~286
Tertiary sector share	>55%	>52%	~56% (traditional services)
Carbon emission status	Peaked / declining	Near-peak	Low base, still rising
Energy endowment	Hydropower-rich	Mixed (coal + hydro)	Natural gas + hydropower
High-tech enterprises	>12,000	>8,000	~200 (est.)
Green finance access	Deep	Deep	Shallow but improving
Population trend	Strong net inflow	Moderate net inflow	Net outflow
Urbanization rate	~79%	~71%	~53.7%

5. THE LOW-CARBON DEVELOPMENT TRILEMMA IN NANCHONG

The comparative analysis reveals that Nanchong's low-carbon development challenge is qualitatively different from that of core cities. We conceptualize this as a "trilemma" consisting of three interlocking constraints.

5.1. The Growth Imperative

Nanchong remains an economically underdeveloped city with significant poverty alleviation responsibilities. Chongqing and Chengdu enjoy the opportunity of multi-layered advantages of national strategy, geographic position and lucrative resources, and their urbanization level is significantly different from other cities in the CCEZ [4]. For Nanchong, suppressing industrial growth in the name of carbon reduction would be economically and politically untenable. The city's own Carbon Peaking Implementation Plan acknowledges this tension, emphasizing the need to "establish the new before discarding the old" — building new clean industries before phasing out traditional carbon-intensive ones.

5.2. The Urbanization Pressure

With an urbanization rate of only 53.73% — well below the national average of approximately 67% — Nanchong faces continued urbanization pressure that will drive demand for construction materials, infrastructure, and transportation, all of which are carbon-intensive. Urbanization often results in higher CO_2 emissions due to demand for steel and cement; however, beyond a certain level of per capita income, urbanization may reduce CO_2 emissions as people move into denser urban spaces [6]. Nanchong is still in the phase where urbanization drives emissions upward.

5.3. The Institutional Capacity Gap

Low-carbon city pilot policies can significantly promote high-quality economic development, but the effects are heterogeneous — greater in the eastern region, non-resource-based cities, and megacities [9]. Nanchong lacks the institutional density, regulatory capacity, and data infrastructure needed to implement sophisticated carbon management systems. The city's carbon peaking plan was only issued in January 2024, significantly later than those of Chengdu and Chongqing, reflecting a temporal lag in institutional development.

6. DIFFERENTIATED LOW-CARBON PATHWAYS: LEVERAGING LATECOMER ADVANTAGES

Despite the trilemma, our analysis identifies four differentiated pathways through which Nanchong can leverage its latecomer advantages for low-carbon development.

6.1. Pathway 1: Industrial Leapfrogging through New-Energy Commercial Vehicles

Nanchong's most striking latecomer advantage is in the new-energy vehicle (NEV) sector. Rather than developing a conventional automotive industry first and then transitioning to electric vehicles — as Chongqing did — Nanchong entered the automotive industry directly through new-energy commercial vehicles, with Geely's Remote New Energy Commercial Vehicle Group as the anchor enterprise. In August 2024, Geely Interstellar Bus independently developed the first alcohol-hydrogen electric road bus U11M, which was mass-produced off the assembly line in Nanchong [9].

This represents a classic latecomer leapfrog: Nanchong bypassed decades of internal combustion engine manufacturing and moved directly to new-energy platforms. At the national level, clean-energy sectors drove a quarter of China's GDP growth in 2024, with electric-vehicle production and batteries making up the "new three" industries that represent the growing role of clean technology in China's economy [7]. Nanchong is positioning itself to capture a share of this growth in the commercial vehicle segment, where competition from core cities is less intense than in the passenger vehicle segment.

The carbon reduction implications are twofold: the manufacturing process itself is less carbon-intensive than traditional automotive production (no engine casting, fewer metal-intensive components), and the products directly displace diesel-powered commercial vehicles in the national fleet. This "product-as-mitigation" effect magnifies the local production benefit into a national emission reduction contribution.

6.2. Pathway 2: A Transitional Hydrogen Strategy Leveraging Natural Gas Endowments

Nanchong's hydrogen energy development plan articulates a three-phase strategy spanning from 2024 to 2035. The city's distinctive advantage lies in its diverse hydrogen source portfolio: stable industrial by-product hydrogen ("grey hydrogen"), abundant natural gas for steam methane reforming ("blue hydrogen"), and hydropower capacity that can eventually support electrolytic "green hydrogen" production.

This staged approach is a textbook application of the latecomer advantage concept. Rather than waiting for green hydrogen to become commercially viable — which even core cities have not yet achieved at scale — Nanchong can immediately utilize grey and blue hydrogen from existing industrial and energy infrastructure, while gradually transitioning to green hydrogen as costs decline and technology matures. Investment in hydrogen electrolyser projects in China doubled year-on-year, from 1.8 GW in 2023 to 3–4 GW in 2024 [2]. By the time Nanchong's hydrogen ecosystem matures, the cost of green hydrogen technology will be substantially lower than it is today.

Critically, Nanchong's existing Geely NEV manufacturing base provides a ready demand-side market for hydrogen fuel cells in commercial vehicles, creating a virtuous cycle between hydrogen supply and vehicle demand that few other non-core cities can replicate.

6.3. Pathway 3: Green Upgrading of the Silk Industry Chain

With a history spanning over 2,000 years, Nanchong has been an important administrative and cultural center since the Han Dynasty, and later developed as a silk production hub during the Ming

Dynasty [2]. The city possesses China's most complete silk-and-textile industrial chain in the southwest, from sericulture and reeling to weaving, dyeing, and garment manufacturing.

The silk industry's carbon footprint is relatively low compared with heavy industry, but it faces significant environmental challenges in dyeing, finishing, and wastewater treatment. The low-carbon upgrading pathway for this sector is not primarily about emission reduction but about value chain transformation: moving from low-value-added commodity silk products toward high-value-added eco-certified, culturally branded products that command premium prices in both domestic and international markets. This "green premiumization" strategy is facilitated by the growing global demand for sustainable textiles and by China's own Green Manufacturing System initiative. The national Action Plan calls for thoroughly implementing the green manufacturing project, vigorously promoting green design, refining the green manufacturing system, and building green factories and industrial parks [6].

6.4. Pathway 4: Near-Zero-Carbon Industrial Parks as Institutional Innovation Platforms

Nanchong has been designated as a pilot site for near-zero-carbon industrial parks in Sichuan Province. The Nanchong High-Tech Industrial Park successfully created a national-level green industrial park in 2023, while the Langzhong Industrial Park is pursuing a distinctive model based on East–West Collaboration (Wenling–Langzhong) with standardized green factory buildings.

These parks serve as "institutional laboratories" where new governance models for carbon management — including carbon accounting, green procurement standards, digital energy monitoring, and circular economy practices — can be tested and refined at a manageable scale before being rolled out city-wide. For a non-core city with limited institutional capacity, this park-based approach provides a pragmatic entry point for building carbon governance capabilities incrementally.

7. DISCUSSION

7.1. From "Low Emissions by Default" to "Low Carbon by Design"

Our analysis reveals a fundamental distinction between low emissions resulting from underdevelopment and low-carbon development achieved by deliberate policy and industrial strategy. Nanchong's current position as an emission coldspot in the CCEZ is largely a consequence of the former. The coldspots and subcoldspots were distributed in the peripheral cities of the CCEZ and in cities with lower industrialization levels. The coldspot areas were mainly concentrated in Ya'an, Leshan, Yibin, and Nanchong [1]. The challenge — and the opportunity — is to transition from "low emissions by default" to "low carbon by design" as the city industrializes.

The four pathways we identify are complementary and mutually reinforcing. NEV manufacturing (Pathway 1) creates demand for hydrogen (Pathway 2); green silk upgrading (Pathway 3) demonstrates that traditional industries can decarbonize without deindustrializing; and near-zero-carbon parks (Pathway 4) provide the institutional infrastructure to support all three industrial pathways

7.2. The Role of Regional Integration

With the further implementation of the "Chengdu–Chongqing twin-city economic circle" strategy, Sichuan Province will gradually transform and upgrade its economic development, adhere to the low-carbon development path, and continuously improve the quality of its economic development [8]. For Nanchong, regional integration offers both opportunities and risks. The opportunity lies in accessing core-city innovation spillovers, market channels, and policy platforms. The two regions host more than 2,000 automobile and auto parts manufacturers, and the economic circle produces more than one-fifth of the country's batteries [3]. Nanchong can position itself as a specialized node in this regional automotive supply chain, focusing on new-energy commercial vehicles and hydrogen applications.

The risk lies in the "siphon effect," whereby while the urbanization of core cities like Chengdu brings development opportunities, there is also the phenomenon of being siphoned, resulting in the loss of human and industrial resources [4]. Nanchong's persistent population outflow is evidence of this effect. Counteracting it will require not only industrial investment but also quality-of-life improvements — better schools, healthcare, and urban amenities — that make the city attractive to skilled workers.

7.3. Applicability of the Latecomer Advantage Framework

Our case demonstrates that Gerschenkron's latecomer advantage framework, originally developed for national-level industrialization, translates productively to the city-level low-carbon transition. Nanchong's direct entry into NEV manufacturing — bypassing decades of conventional automotive development — is analogous to developing countries leapfrogging landline telephony in favor of mobile networks. Latecomers can skip some necessary development stages of first-mover countries, especially in terms of technology [2].

However, the framework also has limitations in this context. Gerschenkron emphasized the role of strong institutional substitutes (such as investment banks in Germany or the state in Russia) in mobilizing resources for rapid catch-up. For non-core Chinese cities, the provincial and central government play this role — but the degree of support varies significantly. Nanchong's success will depend critically on the extent to which Sichuan provincial policies and CCEZ integration mechanisms provide institutional backing for the city's differentiated strategies.

7.4. Green Development Trajectory

Between 2005 and 2020, Nanchong experienced a significant increase of 8 places in the green development ranking within the CCEZ [4]. While still far from the top-performing cities, this improvement trajectory is encouraging and suggests that the city's recent policy efforts — including the Carbon Peaking Implementation Plan, green manufacturing initiatives, and NEV cluster development — are beginning to yield results.

The level of ecological welfare performance in Nanchong showed a "downward trend in the early period and a rebound in the later period [5]," a pattern consistent with the early stages of a transition from extractive growth to green development. The question is whether this rebound can be sustained and accelerated.

7.5. Broader Implications

The findings carry implications beyond Nanchong. China has hundreds of non-core cities within its 19 national urban agglomerations, most of which face variants of the low-carbon development trilemma. Focusing on Chinese ordinary prefecture-level cities, understanding the structure of carbon emissions in non-core cities and their livability performance through typological exploration reveals to what extent these cities demonstrate different carbon emission characteristics and whether there are significant disparities in urban livability among different types [5]. Our framework — identifying comparative advantages, articulating latecomer leapfrog opportunities, and designing differentiated pathways — can be adapted to other non-core cities with different resource endowments and industrial legacies.

8. POLICY RECOMMENDATIONS

Based on our analysis, we offer six policy recommendations for Nanchong and similar non-core cities.

First, embrace differentiation. National carbon peaking guidance explicitly requires tailored approaches. Non-core cities should resist the temptation to imitate core cities' low-carbon strategies and instead invest in understanding their own comparative advantages. For Nanchong, this means doubling down on NEV commercial vehicles, hydrogen energy, and green silk rather than attempting to build semiconductor or artificial intelligence clusters.

Second, accelerate the "grey-to-blue-to-green" hydrogen transition. Nanchong should capitalize on its natural gas endowment to establish hydrogen supply infrastructure immediately, without waiting for green hydrogen to become cost-competitive. Early mover status in hydrogen infrastructure will create lock-in advantages in the CCEZ.

Third, use near-zero-carbon parks as governance laboratories. The park-level pilot approach allows institutional capabilities to be developed incrementally, with successes scaled up and failures contained. Priority should be given to digital carbon monitoring systems, green procurement standards, and circular economy protocols within the parks.

Fourth, counteract the siphon effect through targeted talent policies. Nanchong should establish specific incentive programs — housing subsidies, R&D grants, career development platforms — for clean-energy engineers, industrial designers, and environmental management professionals. Partnership programs with Chengdu-based universities for internship and joint training can help bridge the talent gap.

Fifth, leverage East–West Collaboration mechanisms. The Wenling–Langzhong near-zero-carbon industrial park model demonstrates the potential of East–West collaboration for technology transfer and green industrial investment. Nanchong should actively seek additional collaboration partners from eastern China's advanced manufacturing cities.

Sixth, advocate for differentiated carbon peaking timelines. Within the CCEZ coordination framework, Nanchong should advocate for recognition that non-core cities may legitimately peak emissions later than core cities, provided they can demonstrate credible pathway plans and measurable interim progress. This differentiated timeline approach is consistent with the principle of "common but differentiated responsibilities" and with the national guidance against one-size-fits-all approaches.

9. CONCLUSION

This paper has examined the low-carbon development dilemmas and differentiated pathways available to Nanchong, a non-core city in China's Chengdu–Chongqing Economic Zone. Through a systematic comparative analysis across six dimensions and a theoretically grounded identification of four differentiated pathways, we have shown that non-core cities face a qualitatively different low-carbon challenge from core cities — the "low-carbon development trilemma" of simultaneous industrialization, urbanization, and decarbonization.

However, this trilemma is not a dead end. By leveraging latecomer advantages — including lower carbon lock-in, the ability to leapfrog directly to new-energy technologies, and access to the latest clean-technology solutions at declining costs — non-core cities like Nanchong can pursue "curve-bending" strategies that compress the temporal gap between economic growth and emission peaking. The four pathways identified — NEV industrial leapfrogging, transitional hydrogen strategy, green silk chain upgrading, and near-zero-carbon park experimentation — are not only conceptually coherent but are already being implemented to varying degrees in Nanchong.

The broader contribution of this paper is threefold. First, it extends Gerschenkron's latecomer advantage theory from the national to the city level in the context of low-carbon transitions. Second, it articulates the "low-carbon development trilemma" as a conceptual framework for understanding the distinctive challenges facing non-core cities. Third, it demonstrates that qualitative case study methods — drawing on publicly available data, policy documents, and secondary literature — can yield rich, policy-relevant insights about differentiated low-carbon pathways without requiring complex econometric models.

The limitations of this study include its reliance on a single case city, which limits generalizability, and the absence of primary interview data with local policymakers and enterprise managers. Future research could address these limitations through comparative multi-city studies and through stakeholder interviews that capture the political economy dynamics of local low-carbon decision-making. Quantitative analysis using city-level panel data could also complement our qualitative findings by testing the statistical relationship between latecomer characteristics and low-carbon transition performance across the full set of CCEZ cities.

As China moves toward its 2030 carbon peaking deadline, the success of its dual-carbon strategy will depend not only on the performance of its megacities but also on whether hundreds of non-core cities like Nanchong can find viable pathways to reconcile growth with decarbonization. This paper demonstrates that such pathways exist — but they require deliberate differentiation, institutional innovation, and sustained policy support.

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