

# Henan Carbon Neutrality Planning Research

## Executive Summary

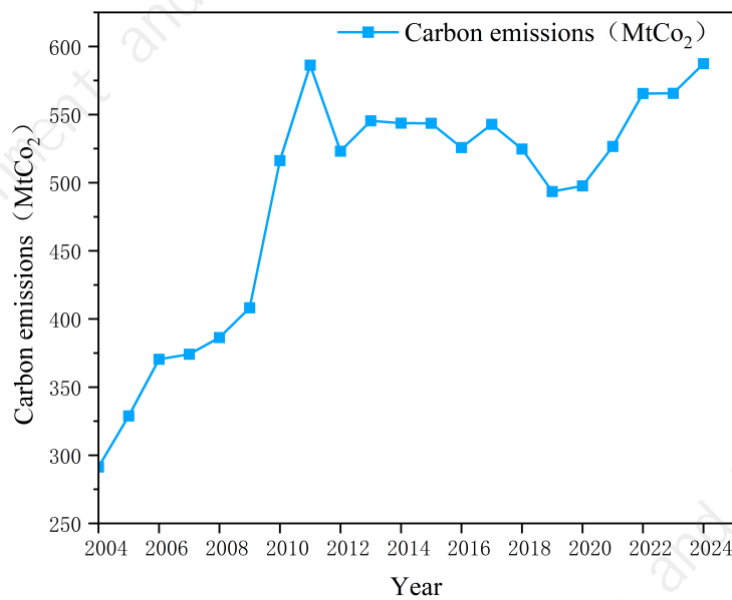
### 1. Current economic development and emission-reduction foundations

As a core province under the national strategy for ecological conservation and high-quality development in the Yellow River Basin, and as a pivotal hub of the Central Plains Economic Region, Henan Province holds both the characteristics of a major agricultural province and a heavily industrialized economy. Its carbon neutrality transition carries important demonstrative value for achieving China's dual-carbon goals. Henan covers a total area of 167,000 square kilometers and had a permanent population of 97.85 million in 2024, with an urbanization rate of 59.22 percent. The province recorded a GDP of RMB 6358.99 billion, and its industrial structure has been optimized to a ratio of 8.6:38.3:53.1 across the primary, secondary, and tertiary sectors. However, Henan's energy mix has remained coal-oriented, with fossil energy accounting for 74.4 percent in 2024. Its industrial structure is dominated by energy-intensive sectors that contribute more than 80 percent of industrial CO<sub>2</sub> emissions. Energy-related CO<sub>2</sub> emissions are projected to peak at approximately 591 Mt around 2028. The pathway toward carbon neutrality, therefore, requires balancing economic growth with ecological constraints, presenting a demanding yet clearly defined transition agenda.

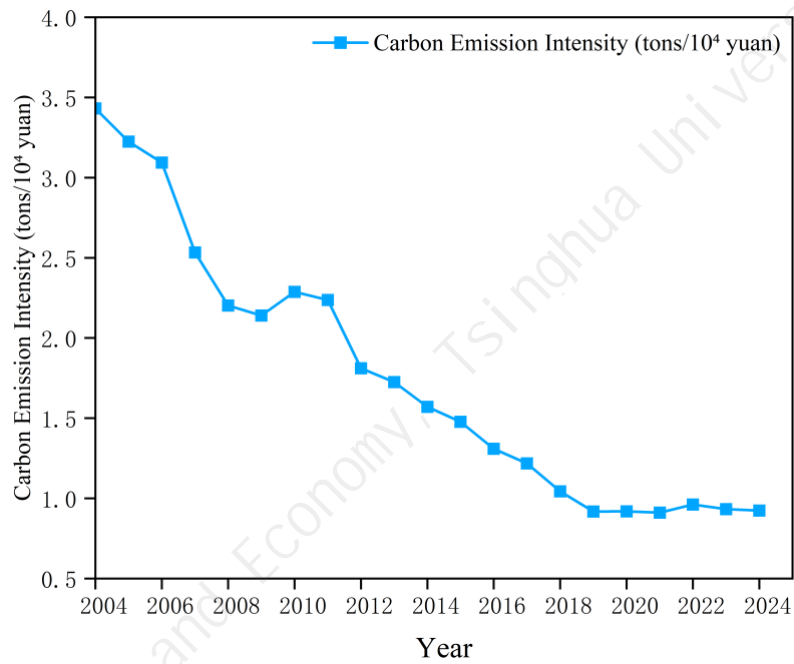
Henan Province possesses a distinctive endowment of renewable energy resources. Solar energy potential exhibits a spatial pattern of higher resources in the north and lower in the south, with maximum photovoltaic generation reaching approximately 4 MWh per square kilometer in cities such as Nanyang and Anyang. Wind resources are stronger in the east and weaker in the west, with annual maximum generation exceeding 70 million MWh in areas such as Zhoukou and Nanyang. The province is also rich in biomass resources and geothermal energy. In terms of energy consumption, the secondary industry accounts for 55.7 percent of electricity use, and coal-fired power

generation remains the dominant source of electricity supply, indicating that the transformation of the energy structure still faces considerable challenges.

Henan's total carbon emissions increased continuously from 2004 to 2012, then entered a fluctuating plateau. In 2024, total emissions reached approximately 587.31 Mt (Fig. 1). Overall, the province's carbon emission intensity first increased and then began a sustained decline (Fig. 2). By 2024, Henan's emission intensity had been significantly reduced compared with the year 2004, reflecting notable progress in shifting from energy-intensive growth toward a greener and low-carbon development model.

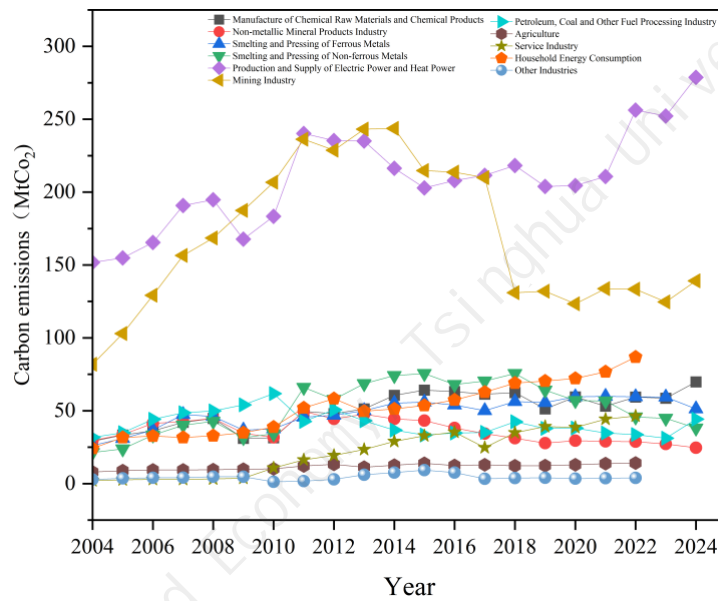


**Fig. 1 CO<sub>2</sub> Emissions in Henan Province from 2004 to 2024.**



**Fig. 2 Henan Province CO<sub>2</sub> emission intensity distribution from 2004 to 2024.**

A sector-level assessment shows that the power and heat production sector (Fig. 3) constitutes the largest source of CO<sub>2</sub> emissions. This predominance results from Henan's coal-oriented energy structure in which coal-fired generation has remained the primary source of electricity for many years. Although the installation of wind and solar power has expanded rapidly, coal-fired units still provide essential baseload and system flexibility, and cannot be easily replaced in the short term. Over time, emissions from the power and heat sector rose steadily from 2000 to 2010, driven by rapid economic expansion and increasing electricity demand. After 2010, policies such as the retirement of small coal-fired units helped reduce emission intensity, although total emissions have remained high. The industrial sector is the second-largest source of CO<sub>2</sub> emissions and exhibits clear internal structural characteristics. The non-metallic mineral industry (which includes cement and glass production) and the ferrous metals industry contribute a large share of industrial CO<sub>2</sub> emissions. Between 2004 and 2024, most industrial subsectors experienced rising CO<sub>2</sub> emissions, reflecting the broader trends of industrialization and urbanization in the province.



**Fig. 3 Spatial distribution of CO<sub>2</sub> emissions across cities in Henan Province.**

Marked differences also exist across cities. Industrial cities in central and northern Henan, including Zhengzhou, Luoyang, and Anyang, report the highest emission levels. In contrast, agricultural cities in southern Henan, such as Xinyang and Nanyang, exhibit significantly lower emission intensities. The province's total carbon sink increased steadily from 2004 to 2024, although the growth rate has gradually slowed. In 2024, Henan's carbon sink reached 277.58 Mt, with southern cities such as Nanyang and Xinyang contributing large percent of the provincial total, forming a spatial pattern characterized by higher sinks in the south and lower sinks in the north.

Henan Province's carbon balance ratio exhibited an overall declining trend during 2004–2024 and has remained in a state of carbon imbalance. Since 2020, the carbon balance ratio has gradually stabilized, indicating that the province's carbon control and mitigation measures have begun to take effect. Improvements in the energy structure and strengthened ecological conservation have jointly driven the carbon balance into a new phase of relatively stable dynamic equilibrium. At the city level, the carbon balance shows a clear gradient pattern. Cities such as Zhengzhou, Kaifeng, and Luoyang experienced relatively severe carbon imbalances, while Nanyang, Xinyang, and

Sanmenxia exhibited moderate levels of carbon imbalance.

Henan's low-carbon transition faces several key challenges. Firstly, the province's energy consumption structure remains heavily coal-oriented, resulting in sustained long-term pressure on emissions reduction. Secondly, the province has a strong heavy and chemical industrial base, with a high concentration of high-emission industries. Thirdly, regional development is uneven, leading to significant disparities in low-carbon transition capacity. Forth, the consumption-side emissions increased rapidly, while the shift toward low-carbon lifestyles has lagged behind. Lastly, the province's carbon sinks are highly volatile, and the overall carbon balance has remained in a long-term deficit.

## **2. Target Setting**

Based on Henan's pathway toward carbon peaking and carbon neutrality, targets are formulated through a comprehensive assessment of the province's economic development level, energy-resource endowment, and industrial structure. The approach strengthens the objectives for reducing carbon intensity, clarifies the trajectory for total emissions control, continuously optimizes the energy structure, and promotes green and low-carbon transitions in key industries. At the same time, it leverages market mechanisms to enhance policy effectiveness. On this foundation, the targets are divided into three stages: the near term before 2030 and the medium term from 2031 to 2035. This phased strategy ensures a progressive realization of carbon peaking and carbon neutrality, with emission-reduction goals that are scientifically grounded, reasonable, and practically achievable.

The analysis in this study is conducted using a recursive dynamic, multi-sector, multi-region computable general equilibrium model, namely the C-REM 4.0 version. The model characterizes the economic and energy systems of 30 provinces in China across 20 production sectors and incorporates multiple alternative energy technologies through production function formulations. By comparing a reference scenario with a carbon neutrality scenario, the model evaluates Henan's economic development

trajectory under the carbon neutrality target. The reference scenario represents the baseline pathway. Before 2030, the emission-reduction intensity follows China's commitments made at the 2015 Paris Climate Conference. After 2030, the scenario assumes that the same reduction effort continues. The carbon neutrality scenario reflects the policy stringency required for China to achieve its 2060 carbon neutrality goal. Henan's emission trajectory is aligned with China's representative carbon neutrality pathway under the 2 °C target, namely the Tsinghua-CMA pathway<sup>1</sup>. This pathway integrates the temperature-control objective of the Paris Agreement with China's current CO<sub>2</sub> emission status and mitigation policies, and produces a national CO<sub>2</sub> trajectory with relatively acceptable economic costs. Under this pathway, China reaches its CO<sub>2</sub> emissions peak around 2028 to 2029, and reduces emissions from energy combustion and industrial processes to approximately 0.9 billion tons by 2060, with emissions from energy combustion alone decreasing to roughly 0.8 billion tons.

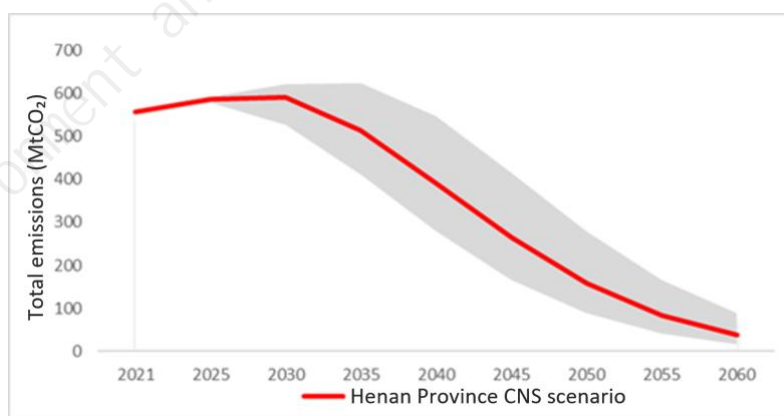
Building on the national scenario assumptions and drawing on existing research, the national emission pathway is further allocated to individual provinces. For Henan, assumptions are made regarding short-term emission trends and economic development trajectories, taking into account the province's development stage, resource endowment, strategic positioning, and ecological conditions. Adjustments are also made based on performance during the 13th Five-Year Plan period. On this basis, the annual average CO<sub>2</sub> intensity reduction rate for Henan under the carbon neutrality scenario is derived, as shown in Table 1.

**Table 1. Annual CO<sub>2</sub> intensity reduction rates for Henan Province under the carbon neutrality target (% per year).**

Period	Near term	Medium term	Long term				
Year	2025 to 2030	2031 to 2035	2036 to 2040	2041 to 2045	2046 to 2050	2051 to 2055	2056 to 2060
Reduction Rate (%)	4.6	6.4	8.3	10.3	12.4	14.6	16.5

<sup>1</sup> Zhang D, Huang X D, Zhong J T, et al., 2023. A representative CO<sub>2</sub> emissions pathway for China toward carbon neutrality under the Paris Agreement's 2°C target[J]. *Advances in Climate Change Research*, 14(6): 941-951.

Henan's total CO<sub>2</sub> emission targets are shown in Fig. 4. Under the carbon neutrality scenario, emissions from fossil fuel combustion and industrial processes are projected to peak around 2028 at approximately 591 Mt, followed by a steady decline. A marked reduction is expected between 2035 and 2040, and emissions fall to 39 Mt by 2060. Henan's carbon sink reached 47.05 Mt in 2020 and has shown continuous growth, although the rate of increase has gradually slowed. Given this trend, the province is expected to offset its future energy-related CO<sub>2</sub> emissions with carbon sequestration from forests and cropland, ultimately enabling the achievement of carbon neutrality.



**Fig. 4 Total CO<sub>2</sub> Emissions in Henan Province from 2021 to 2060.**

Under the carbon neutrality scenario, the share of high-carbon industries in Henan declines sharply, indicating a fundamental shift in the economic structure. Other major sectors are also progressively achieving green and low-carbon development. Total primary energy consumption shows a steady downward trend, reaching 290 Mt in 2060, which is about 9 percent lower than the 318 Mt recorded in 2030. In terms of energy intensity, Henan's energy consumption per unit of GDP decreases year by year under the carbon neutrality scenario. The annual reduction rate reaches 3 percent in 2030 and increases to 4 percent by 2060. Structurally, the share of fossil energy in Henan's future energy mix continues to decline, and the overall energy structure transitions toward cleaner and lower-carbon forms. The share of coal consumption drops significantly

from 52 percent in 2030 to 9 percent in 2060. Both natural gas and oil consumption peak around 2035 and then gradually fall to 3 percent and 4 percent, respectively, by 2060. Primary electricity consumption increases steadily, rising from 19 percent in 2030 and surpassing 50 percent by 2050. By 2060, electricity accounts for as much as 84 percent of total primary energy consumption.

Based on the model results, the following targets are proposed for Henan Province across different time periods. (1) Near term (before 2030): Energy-related CO<sub>2</sub> emissions peak around 2028 at approximately 591 Mt. By 2030, CO<sub>2</sub> emissions per unit of GDP fall by 45 percent compared with 2020, and non-fossil energy reaches a 50 percent share of total energy consumption. All key industries achieve emission peaking on schedule. (2) Medium term (2031–2035): By 2035, total CO<sub>2</sub> emissions decline by 13 percent from the peak level, reaching 514 Mt. Primary energy consumption peaks and begins to decrease steadily. The share of coal falls below 40 percent. Technologies such as CCUS and hydrogen are deployed at scale.

### **3. Emission-reduction pathways and measures for key sectors**

This section focuses on the low-carbon transition of energy-intensive industries and emerging sectors. As a major national energy base and an important industrial province, Henan hosts several key energy-intensive sectors, including coal mining and processing, chemical raw materials and chemical product manufacturing, non-metallic mineral production, ferrous metal smelting and rolling, non-ferrous metal smelting and rolling, and the production and supply of power and heat. These industries form the backbone of regional economic growth, yet they also represent the primary sources of energy consumption and CO<sub>2</sub> emissions. Their decarbonization progress will directly influence the province's achievement of its dual-carbon goals and the overall quality of industrial development. Due to the long-established resource-driven and heavy-industry-oriented structure, the six major energy-intensive sectors continue to face multiple constraints. These include strong path dependence in conventional production processes, high costs associated with low-carbon technology research and deployment,

and insufficient availability of clean energy to support large-scale transformation. At the same time, emerging technology industries serve as the core engine for industrial upgrading in the Central Plains Economic Region and represent a critical growth pole for Henan's low-carbon transition. Benefiting from rapid technological iteration and inherently low emission intensity, these industries are becoming an increasingly important driver of the deep integration between carbon-neutral development and high-quality economic growth. Among them, the new energy vehicle industry is the central platform for transport electrification, while the electronic information industry underpins the coordinated development of the digital and green economies. Both sectors are experiencing strong expansion, and through supply-chain linkages, they are also accelerating the green transition of upstream and downstream industries, forming new strategic pillars for optimizing Henan's industrial structure.

**Coal mining and washing industry:** Henan is one of China's major coal-producing provinces and an important national coal base. While coal resources remain relatively abundant, reserve resources available for future development are limited, and basic reserves have been declining rapidly. The industry is now undergoing a critical transition from traditional scale expansion toward high-quality, green, and sustainable development. Under the dual-carbon goals, the sector's focus has shifted from expanding production to optimizing existing capacity and improving efficiency. In 2024, Henan's raw coal output accounted for 2.18 percent of the national total, ranking among the leading provinces. Since the beginning of the 14th Five-Year Plan period, national requirements related to energy security and green low-carbon development have continued to strengthen. In response, Henan's coal industry has accelerated its transformation toward safer, more efficient, greener, and smarter operations, and the structural optimization of the coal mining and washing industry has achieved notable progress. However, the sector faces several challenges in its low-carbon transition. These include strong path dependence in industrial restructuring, limited economic feasibility of key emission-reduction technologies, and difficulties in coordinating relevant environmental policies. The main strategies for addressing these issues include

promoting systemic industrial restructuring, improving technology-economy incentive mechanisms, and strengthening policy coordination frameworks.

**Chemical raw materials and chemical product manufacturing:** Henan is a major chemical production base in central China. Leveraging abundant local resources such as coal and salt deposits, the province has developed an industrial system dominated by coal-based chemical production and salt chemistry. The industry exhibits strong clustering effects with wide sectoral coverage, and more than 1,300 chemical enterprises above a designated size operate in the province. The total output value of the chemical sector has reached RMB 400 billion. However, structural overcapacity in basic chemical feedstocks and tightening resource and environmental constraints have become increasingly prominent. The sector is undergoing a critical transition from scale expansion toward high-end, green, and fine-chemistry development. Both the carbon emission intensity and energy consumption levels of Henan's chemical industry exceed the national industrial average, resulting in considerable pressure to reduce emissions. The main challenges for low-carbon transformation include pronounced technological bottlenecks and issues related to energy use and cost. Key measures include strengthening technological innovation, accelerating digital transformation within the chemical sector, and improving energy and cost management.

**Non-metallic mineral products industry:** The non-metallic mineral products industry is an important component of Henan's industrial economy and includes several major subsectors such as cement, glass, ceramics, and refractories. In recent years, the sector has steadily expanded by leveraging the province's abundant non-metallic mineral resources, including limestone, quartz sand, and clay, which has strengthened overall industrial competitiveness. The main challenges for low-carbon transformation in this industry include structural and scale-related constraints, gaps in technological application and innovation, insufficient regional coordination and policy alignment, and limitations imposed by resource and energy structures. Key strategies to address these issues include optimizing the industrial structure to balance scale and low-carbon

development, enhancing technological drivers to overcome innovation and application bottlenecks, improving regional coordination to increase policy effectiveness, and promoting low-carbon use of energy and resources.

**Ferrous metal smelting and rolling industry:** This industry is one of the core pillars of Henan's industrial system. Supported by advantageous transportation links and a solid industrial foundation, the sector has expanded steadily in recent years, with continuous optimization of production capacity and pronounced regional clustering effects. Since 2017, the industry has entered a period of structural adjustment. Although carbon emissions remain at a high level, the previous growth trend has been curbed. The goal of controlling total emissions has achieved initial success, and emissions in some cities have begun to decline, marking the transition into a more challenging phase of low-carbon transformation. The main challenges for decarbonization include strong structural dependence within the industry, high costs associated with promoting green technologies, insufficient mechanisms for regional industrial coordination, and limited market and policy support. Key strategies include regulating production capacity, upgrading industrial processes, and providing targeted support for enterprises to facilitate low-carbon development; strengthening research and innovation systems for low-carbon technologies to reinforce the technical foundation for industrial transformation; establishing cross-city low-carbon industrial alliances to promote coordinated sectoral transition; and advancing green finance and deepening the carbon market mechanism.

**Non-ferrous metal smelting and rolling industry:** As one of China's core provinces in the non-ferrous metals sector, Henan has leveraged its resource endowment and industrial foundation to develop an industrial structure dominated by aluminum smelting and rolling, supported by coordinated development in lead, zinc, and copper smelting and processing. The industry has long ranked among the largest nationwide in terms of production scale. From the perspective of emission reduction, Henan is one of the most important provinces for carbon mitigation in the non-ferrous metal smelting

and processing sector. It ranks second nationally and accounts for 21 percent of the country's total emission-reduction potential in this field. The key challenges for low-carbon transformation include heavy reliance on fossil energy in high-energy-consuming processes, a relatively weak foundation for emission reduction, limited scale and standardization in the recycled metal industry, and gaps between low-carbon technology development and industrial application. Primary strategies include promoting a greener energy structure to reduce dependence on fossil fuels and strengthening the recycled metal industry system to enhance resource circulation and reuse.

**Power and heat production and supply industry:** As the primary source of carbon emissions in Henan, this sector has maintained steady growth in recent years and ranks among the largest nationwide. Its low-carbon transition is therefore critical to the overall emission-reduction outcomes of the province. With the advancement of energy-structure adjustment policies, renewable energy development in Henan has accelerated significantly, although dependence on coal-fired power remains relatively high. The sector currently shows a pattern of increasing total output alongside gradual structural optimization. Looking ahead, rising pressure to reduce emissions will drive a faster shift toward cleaner and smarter energy systems. Key challenges for low-carbon transformation include insufficient momentum for a green shift in the energy structure, technical bottlenecks in renewable energy integration and energy storage, and continued growth in total carbon emissions. Primary strategies include accelerating the optimization and upgrading of coal-fired power plants, developing a new-type power system, and strengthening mechanisms for energy-efficiency improvement and carbon-emission management.

To achieve the above targets, the major tasks of Henan Province's low-carbon development in the coming period can be summarized into six core priorities, which together constitute a key action framework for reaching carbon peaking and advancing toward carbon neutrality. Firstly, the development of a clean, low-carbon, secure, and

efficient modern energy system should be accelerated by taking the low-carbon transformation of the energy system as the central thread. Secondly, energy-intensive industries should realize deep emissions reductions by implementing differentiated, sector-specific low-carbon transition pathways. Thirdly, the technological foundation for deep decarbonization should be consolidated by strengthening research, development, and large-scale deployment of key low-carbon technologies. Fourthly, the government should promote the optimization and upgrading of the industrial structure and foster new drivers of low-carbon growth. Fifthly, the endogenous momentum of the low-carbon transition should be enhanced by improving market-based emissions reduction mechanisms and policy coordination frameworks. Lastly, the regional and societal transitions should be coordinated to ensure that low-carbon development proceeds in tandem with livelihood protection and social stability.

#### **4. Policy recommendations**

To ensure that Henan Province achieves carbon peaking before 2030, makes decisive progress toward high-quality energy development by 2035, and ultimately reaches carbon neutrality by 2060, it is essential to establish a comprehensive and coherent policy framework tailored to its characteristics as a major energy producer and industrial hub. This framework should be grounded in administrative guidance, driven by market-based mechanisms, supported by financial and technological instruments, and reinforced by broad societal participation. The core challenge lies in breaking the long-standing path dependence of energy-intensive industries and the heavy reliance on fossil fuels embedded in the provincial energy structure, thereby transforming the low-carbon transition from an externally imposed constraint into an endogenous development.

From a policy design perspective, greater emphasis should be placed on strengthening price signals and market incentives. This includes deepening reforms of energy pricing and carbon pricing mechanisms, strictly implementing differentiated and tiered electricity tariffs for energy-intensive sectors, and directly linking energy costs

to energy efficiency performance and carbon intensity. Such measures are critical for creating effective incentives that reward high-efficiency firms while exerting pressure on lagging ones. At the same time, building on participation in the national emissions trading system, Henan should gradually expand the coverage of its carbon market and promote coordinated management of carbon emission allowances and energy-use rights. By reinforcing expectations regarding future carbon prices, firms can be encouraged to internalize long-term carbon costs in their investment decisions and proactively deploy low-carbon technologies, thereby reducing the risk of stranded high-carbon assets.

Fiscal and financial policies play a pivotal role in supporting the low-carbon transition. Public finance should be more strategically oriented toward key low-carbon infrastructure and priority technologies, including large-scale renewable energy deployment, flexibility retrofits of coal-fired power plants, and the research, demonstration, and commercialization of frontier technologies such as hydrogen energy and energy storage. In parallel, the development of a comprehensive green finance system—through innovative green credit instruments, green and carbon-neutral bonds, and other climate-aligned financial products—can help channel capital toward projects and enterprises with high energy efficiency and low emissions. Expanding the use of public–private partnerships (PPP) and environment-oriented development (EOD) models can further mobilize social capital and enhance the scale and sustainability of low-carbon investment.

Effective implementation requires robust institutional coordination and accountability mechanisms. This entails establishing high-level coordination bodies and inter-departmental platforms to ensure policy coherence across energy, industrial, environmental, and fiscal domains. Binding targets—such as reductions in carbon intensity and increases in the share of non-fossil energy—should be systematically disaggregated across cities and sectors, with differentiated assessment criteria reflecting heterogeneous development stages and functional roles. Such an approach can improve

both the precision and fairness of policy enforcement while strengthening incentives for local governments to pursue green transformation.

Finally, long-term success depends on strengthening technological innovation and human capital. Building high-level low-carbon innovation platforms and enhancing industry–university–research collaboration are essential for accelerating breakthroughs in key technologies and facilitating their large-scale deployment. At the same time, more proactive talent attraction and training policies are needed to improve both governmental governance capacity and firms' technological capabilities, thereby providing sustained intellectual and technical support for Henan's low-carbon transition and high-quality energy development.