China Council for International Cooperation on Environment and Development

SPECIAL POLICY REPORT

Low-Carbon Transition of Traditional Energy Regions of China

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China Council for International Cooperation on Environment and Development (CCICED)

Low-Carbon Transition of Traditional Energy Regions of China: A Case Study of the Coal Triangle Region

Special Policy Study

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Special Research Project Members

Co-Leads:*

- Jinnan WANG, Academician of the Chinese Academy of Engineering; Honorary President of the Chinese Academy of Environmental Planning, Ministry of Ecology and Environment.
- Wenbin LYU, Director of Energy Research Institute, National Development and Reform Commission.
- Pete Harrison, Executive Vice President of Environmental Defense Fund.
- Helen Mountford, President and CEO, Climate Works Foundation.

Deputy Co-Leads:*

- Hu QIN, Vice President and Chief Representative of the Beijing Office, EDF.
- Xiaohua ZHANG, Chief Representative, ClimateWorks Foundation Beijing Representative Office.

Special Policy Study Members:*

- Ziwen RUAN, Assistant Researcher, Chinese Academy for Environmental Planning, Ministry of Ecology and Environment.
- Bofeng CAI, Researcher, Chinese Academy for Environmental Planning, Ministry of Ecology and Environment.
- Kejun JIANG, Professor, Hong Kong University of Science and Technology (Guangzhou).
- Zhiyu TIAN, Researcher, Institute of Energy Research, National Development and Reform Commission.
- Lu WANG, Assistant Researcher, Institute of Energy Research, National Development and Reform Commission.
- Ying CHEN, Researcher, Institute of Ecological Civilization, Chinese Academy of Social Sciences.
- Jianjun TU, China Director, Agora Energy Transition.
- Lin YANG, General Manager, CECEP Standard & Certification Technology Co., Ltd.
- Lyujun CHEN, Professor, School of Environment, Tsinghua University.
- Jinping TIAN, Researcher, School of Environment, Tsinghua University.
- Ji GAO, Senior Policy Advisor, Beijing Representative Office, EDF.
- Haili HUAN, Director of China Energy Transition, Beijing Representative Office, Environmental Defense Fund.
- Xiaomei LI, Deputy Director of the Power Program, Beijing Representative Office, Environmental Defense Fund.
- Yiwei GAN, Manager of Regional Energy Transition, Beijing Representative Office, Environmental Defense Fund.

- Yi CHEN, Director of Clean Energy Transition Program, ClimateWorks Foundation.
- Qiuxia WANG, Director of Strategic Planning, Program, ClimateWorks Foundation.
- Lei SUN, Director of the Innovation Research Center, Green Finance Department, CECEP Standard & Certification Technology Co., Ltd.
- Fang LUO, Senior Project Manager, Green Finance Department, CECEP Standard & Certification Technology Co., Ltd.
- Mou WANG, Researcher, Institute of Ecological Civilization, Chinese Academy of Social Sciences.
- Ren MIAO, General Manager of Beijing Guohong Xinneng Consulting Co., Ltd.
- Lianna GAO, Deputy General Manager of Beijing Guohong Xinneng Consulting Co., Ltd.
- Sha CHEN, Professor, College of Environmental Science and Engineering, Beijing University of Technology.
- Xing LI, Assistant to the Director of the Environmental Ecology Division, School of Environment, Tsinghua University.
- Xiaojun CHEN, Senior Engineer, Chinese Academy for Environmental Planning, Ministry of Ecology and Environment.
- Yunhao ZHAO, Director of the EOD Innovation Center, Chinese Academy for Environmental Planning, Ministry of Ecology and Environment.
- Jing LU, Deputy Director of the EOD Innovation Center, Chinese Academy for Environmental Planning, Ministry of Ecology and Environment.
- Zhikai WANG, Senior Engineer of the EOD Innovation Center, Chinese Academy for Environmental Planning, Ministry of Ecology and Environment.
- Hongkun ZANG, Assistant Researcher, Chinese Academy for Environmental Planning, Ministry of Ecology and Environment.
- Zhou YANG, Deputy Director of the China Local Energy Transition Program, Agora Energy Transition.
- Wenbo ZHAO, Manager of China Industrial Program, Agora Energy Transition.
- Daiyang ZHANG, Consultant of China Local Energy Transition Program, Agora Energy Transition.

Research Support Team:

- Qigong XU, President, Chinese Academy for Environmental Planning, Ministry of Ecology and Environment.
- Gang YAN, Director, South China Institute of Environmental Sciences, Ministry of Ecology and Environment.
- Zhong LI, Deputy Director, Institute of Energy Research, National Development and Reform Commission.
- Yuan LIAO, Deputy Secretary-General, Climate Finance and Investment Committee, Chinese Society for Environmental Sciences.

- Zhang CHENG, President, Shanxi Energy Research Association.
- Wenke HAN, Senior Advisor, Institute of Energy Research, National Development and Reform Commission.
- Xiulian HU, Researcher, Institute of Energy Research, National Development and Reform Commission.
- Jing GUO, President, International Institute of Green Development under the Belt and Road Initiative.
- Tao BIE, Former Director, Department of Policies, Laws and Regulations, Ministry of Ecology and Environment.
- Qiang LIU, China Program Director, Children's Investment Fund Foundation.
- Béla Galgóczi, Senior Researcher, European Trade Union Institute.
- Patricia Espinosa, Former Executive Secretary, United Nations Framework Convention on Climate Change.
- Fuqiang YANG, Senior Advisor, Climate Change and Energy Transition Program, Institute of Energy, Peking University.
- Sonia Medina, Executive Director, Climate Change Department, Children's Investment Fund Foundation.
- Fabby Tumiwa, Executive Director, Institute for Essential Services Reform (Indonesia).
- David Elzinga, Principal Energy Specialist, Asian Development Bank (ADB).

Coordinators:

Chinese Coordinator:

- Bofeng CAI, Researcher, Chinese Academy for Environmental Planning, Ministry of Ecology and Environment.
- Zhiyu TIAN, Senior Researcher, Energy Research Institute, National Development and Reform Commission.

External Coordinator:

- Ji GAO, Senior Policy Advisor, Beijing Representative Office, EDF.
- Yi CHEN, Director of Clean Energy Transition Program, ClimateWorks Foundation.

** The co-leaders and members of this SPS serve in their personal capacities. The views and opinions expressed in this SPS report are those of the individual experts participating in the SPS Team and do not represent those of their organizations and CCICED.*

Executive Summary

To achieve the dual objectives of carbon peaking and carbon neutrality, with particular reference to the nationally determined contribution announced by President Xi Jinping at the UN Climate Change Summit on September 24, 2025, it is necessary to advance the early peaking and orderly phase-down of coal consumption. This process, while ensuring energy security and supporting regional sustainable economic development, constitutes a critical pathway for optimizing China's energy structure and facilitating the low-carbon transition. At the same time, the global climate governance landscape is marked by growing uncertainties, as climate policy rollbacks in some countries add further complexity to the energy transition process. In this context, China's firm pursuit of its carbon peaking and carbon neutrality strategy is not only essential for fulfilling its responsibilities as a major country and contributing to the global climate agenda, but also a fundamental requirement for driving the profound transformation of the domestic energy system toward green, secure, and efficient development.

As a key strategic region for traditional energy development in China, the Coal Triangle Region encompasses four resource-rich provinces—Shanxi, Inner Mongolia, Shaanxi, and Ningxia—and ranks among the country's major coal-producing areas. The systematic green and low-carbon transformation of the region's energy structure and socio-economic development is not only closely linked to China's energy transition and the achievement of its carbon peaking and carbon neutrality goals but also serves as an important example for global climate change mitigation efforts. This report examines the green and low-carbon transition pathways and practical experiences of the Coal Triangle Region, aiming to provide insights for promoting sustainable regional development, facilitating coordinated management of traditional energy sectors, and contributing Chinese solutions to the global energy transition.

1. Research Methods and Focus

This report is based on the CEAP-CP-3.0 model developed by the research team. It combines quantitative simulation, qualitative analysis, and field research to systematically examine the green and low-carbon transition pathways of the Coal Triangle Region. Through current-state assessments, policy analysis, and model scenario construction, it focuses on the potential to optimize the energy structure, industrial evolution trends, and their systemic socioeconomic impacts under different transition pathways, striving to ensure that the conclusions are both scientific and actionable. Furthermore, it extensively reviews national and local policy documents, industrial statistics, and transition cases from typical regions internationally to provide a solid policy foundation and practical reference for the research.

In terms of the project's research priorities, the research team systematically reviews the current industrial structure, energy mix, and economic development status of the Coal Triangle Region, clarifying its strategic positioning and emission reduction responsibilities in achieving the national "Dual-Carbon" targets. In this regard, it focuses on clean upgrading pathways for traditional energy industries and the development orientation of green emerging industries, proposing development indicators for zero-carbon trade demonstration zones and a systematic funding guarantee mechanism to support regional transition. Particular attention is paid to just transition issues, such as employment resettlement and sustainable regional economic development, to ensure socio-economic sustainability. Finally, through comparison with and lessons drawn from international transition experiences, the study summarizes a policy system and implementation pathway suitable for the Coal Triangle Region, provides solutions for the low-carbon transition in China's traditional energy areas and offers decision-making supports for optimizing national energy layout and promoting regional coordinated development.

2. Key Findings and Conclusions

Against the backdrop of both the global energy transition and China's, this report systematically analyses the current status, challenges, and carbon peak pathways of the green and low-carbon transitions in the Coal Triangle Region. It identifies industrial transformation directions and emerging growth drivers, explores development models for zero-carbon industrial parks, estimates funding requirements, and proposes just transition policy recommendations informed by international experience. The key findings and conclusions of this report are as follows:

(1) The energy transition in the Coal Triangle Region is of great significance and faces multiple challenges. In 2024, the region produced 3.45 billion tonnes of coal, accounting for 78.6% of China's total output and approximately 37.3% of global production; its carbon emissions represent 6.4% of the global total. At the same time, the region is endowed with abundant renewable energy resources, with substantial potential for wind and solar power installations. The combined wind and solar power generation potential could account for up to 25% of the national total, indicating a strong capacity for green and low-carbon development. On the other hand, the region faces a salient challenge in balancing economic stability and the energy transition. The region heavily relies on coal-based industries, which include coal mining, coal power, and coal chemical sectors. These account for 15%–35% of the industrial value added in each sub-region. While supporting economic growth and ensuring national energy, this reliance has also led to a "lock-in effect" and path dependency, constraining industrial diversification and undermining the sustainability of the regional socio-economy. Moreover, high dependence on coal-based industries subjects the Coal Triangle Region to multiple environmental challenges, including mining-induced subsidence, water scarcity, air pollution, and solid waste disposal. The high costs associated with the development, demonstration, and application of zero-carbon technologies hinder technological substitution and emission reduction efforts. Key areas, such as the share of non-coal power generation, green retrofits in traditional heavy industries, and the upgrading of clean production technologies, lag behind. Compared to other regions in China, the Coal Triangle Region exhibits greater vulnerability when confronting rapid energy transition, industrial restructuring, ecological and environmental protection, and economic development pressures.

(2) Under the guidance of the "Dual-Carbon" targets, the development of fossil energy in the Coal Triangle Region must align with China's overall energy transition trend, requiring the establishment of a coal phase-down roadmap consistent with emission reduction goals. Model simulations of the emission reduction pathways for the Coal Triangle region indicate that, with policy efforts, its carbon emissions are expected to peak between 2026 and 2029, at around 2.51 billion–2.7 billion tonnes. By 2060, residual emissions of 15 million–275 million tonnes may still remain, which will need to be offset through ecological carbon sinks and external negative-carbon technologies. By accelerating the optimization of its energy structure, this implies that raw coal output is expected to peak in 2026/2027, followed by a slow decline over approximately 3 to 4 years at an annual rate of about 1%–2%. Between the emissions peak and 2035, coal production in the region needs to decrease by 2.5%–3% annually, with significant reductions in coal use and emissions from transport, buildings, steel, and chemicals in addition to the power sector. From 2035 to 2060, coal consumption must fall rapidly, with electricity mainly supplied by wind, solar, and other green energy sources. By 2060, about 680 million tonnes of coal may still be produced, serving as "last-resort backup" and "strategic reserves" to safeguard national energy security and the operation of key industries. Compared to other regions in China, this region faces an exceptionally challenging task in reducing coal consumption. From an industry perspective, coal-fired power and coal chemicals industries are the primary drivers of rising coal consumption in the Coal Triangle region, making it urgent to advance technological breakthroughs and system optimization to achieve proactive emission reductions and deep decarbonization in key coal-consuming industries.

(3) Building on its existing industrial base and abundant green power resources, the Coal Triangle Region should systematically plan both deep decarbonization of existing industries and the development of alternative sectors. The core of industrial transformation lies in the orderly phase-out of coal-based industries, together with technological substitution and system optimization of high-carbon segments. In the short term, coal power and coal chemicals will remain major consumers of coal, though the region is already showing a dual trend of capacity expansion and green transition. Decarbonization of key sectors will advance in stages: between 2025 and 2035, demonstration projects on green hydrogen, carbon capture, utilization and storage (CCUS), and hydrogen-based metallurgy should be launched, followed by large-scale deployment after 2035. By 2060, CCUS is expected to capture 0.3 billion–0.5 billion tonnes annually, with green hydrogen accounting for over 90% of hydrogen supply. On the renewable side, wind and solar installed capacity is projected to reach 590 GW by 2030 and 2,180 GW by 2060, supported by storage, smart grids, and green hydrogen facilities, thereby achieving integrated wind-solar-storage-hydrogen development. Renewable power generation will account for more than 85%, while coal-fired power will gradually shift toward peak-shaving functions and be coupled with CCUS. The study proposes a "technology-driven tertiary–secondary integration" industrial pathway through a dual-track strategy: from 2025 to 2035, emphasis should be placed on low-carbon retrofits in traditional industries to steadily reduce the share of secondary industry in energy consumption; from 2035 to 2060, the region should accelerate the transformation and upgrading of its industrial structure and boost the tertiary industry share to over 60%, forming a virtuous cycle of "coal exit–new sector cultivation–value creation." A green manufacturing and service industries supported by renewables, hydrogen-based manufacturing, and carbon removal clusters will be systematically established, realizing a comprehensive shift from "black dependence" to "green dominance."

(4) Regional coordination mechanisms are essential to advance green electricity and green hydrogen, thereby reshaping the resource endowment of the Coal Triangle Region. With abundant wind and solar resources, it serves as a core area of China's large-scale "desert, Gobi, and wasteland" renewable bases. Its vast land, low population density, and low costs make it highly suitable for wind and solar deployment, energy storage, and integrated generation–grid–load–storage projects. At the same time, traditional industry upgrades—particularly modern coal chemicals—and national strategies such as "Eastern Data, Western Computing" are increasing green power demand and creating diverse technology application scenarios. The report estimates the region's total wind and solar potential at 14.5 billion kW of capacity (27% of China's total) and 23.7 trillion kWh of generation (25% of the national total). By 2060, regional hydrogen demand is expected to exceed 40 million tonnes, with coal chemicals as the main consumer. As green hydrogen costs decline, its share could surpass 90%, reaching about 37 million tonnes annually and providing vital support for coal-based industry deep decarbonization. The rise of green electricity and green hydrogen will reshape the regional resource base, and their optimized development will also support the sustainable phase-out of coal consumption, but requires stronger collaboration, both internally, by enhancing industrial cooperation, grid interconnection, ecological co-protection, and knowledge sharing, and externally, by promoting industrial transfer, supply chain collaboration, and systematic optimization of industries and emissions.

(5) Leveraging the construction of Zero-Carbon Industrial Parks and Zero-Carbon Trade Demonstration Zones as key initiatives, this effort explores the systematic integration of green technologies, standards, and policy mechanisms. Among the 169 provincial-level and above industrial parks in the Coal Triangle Region, over 60% (104 parks) are dominated by resource-dependent industries such as coal mining, coal chemicals, coal power, metallurgy, and chemicals, as well as energy equipment manufacturing. These parks collectively emit 636 million tonnes of CO_2, accounting for about 33% of regional emissions, with a carbon intensity of 0.94 tonnes per 1,000 USD (hereafter, $ denotes USD) of output. Notably, three major coal chemical demonstration zones—Yulin, Ordos, and Ningdong—emitted 174 million tonnes in 2023, comprising 27% of park emissions with a carbon intensity of 2.37 tonnes per $1,000, far exceeding the national average and highlighting urgent decarbonization needs. Developing Zero-Carbon Industrial Parks has thus become a systemic endeavour involving renewable integration, green industrial transition, spatial optimization, energy restructuring, and institutional innovation. As a core production base for energy-intensive products, the Coal Triangle Region plays a decisive role in carbon-intensive sectors like energy and coal chemicals, significantly influencing product life cycle carbon footprints. The Coal Triangle Region's abundant green power resources and the development prospects for related green hydrogen, green methanol, and green ammonia, will help reduce indirect emissions from purchased electricity and heat within industrial parks, as well as emissions across the supply chain, product use, and end-of-life stages. By accelerating the establishment of Zero-Carbon Industrial Parks and Zero-Carbon Trade Demonstration Zone in the Coal Triangle Region, and exploring green technologies, standard certifications, and policy frameworks to facilitate the production, circulation, and trade of zero-carbon products, the region will provide a critical model for the low-carbon and zero-carbon transformation of national industrial and supply chains.

(6) Over the next 5 years, the Coal Triangle Region will face large-scale funding needs and multiple challenges for its transition, requiring full mobilization of private capital and accelerated innovation in fiscal and financial policy tools. Between 2025 and 2030, the total funding demand for coal-based industry transformation and upgrading, including coal-fired power plant retrofits, new renewable energy investments, ecological restoration of retired coal mines, and technological upgrading of downstream industries, is projected at about $254 billion. Provinces in the region have established initial financial support systems, but investment and financing still face three problems. First, capital supply and demand are mismatched, as private high-tech enterprises struggle to obtain financing while some government funds remain idle. Second, policy coordination is insufficient, with inconsistent standards for green credit and bonds and complex approval procedures that limit financial institutions and enterprises. Third, risk-sharing mechanisms are lacking, since current credit enhancement and insurance cannot cover technological and market uncertainties, and risk-reward allocation among government, financial institutions, and private capital is inadequate. The key to promoting green and low-carbon transition in the Coal Triangle Region is to leverage fiscal transfers to stabilize social costs, fill fiscal gaps, and prevent systemic risks, while establishing regional green development funds to generate commercial returns from viable projects and mobilize private capital.

(7) Emphasizing a just transition, the goal is to achieve coordinated progress in social welfare, industrial revitalization, and the "Dual-Carbon" targets. The GDP and per capita GDP of the four provinces in the Coal Triangle Region rank in the lower-middle range nationally. The region's green and low-carbon transition faces the challenge of balancing economic growth with carbon reduction. Its highly concentrated economic structure and heavy reliance on coal-based industries increase vulnerability when confronted with rapid energy transition, industrial restructuring, and economic development pressures. The report estimates the impact of industrial upgrading and structural adjustment on employment. Industrial upgrading is expected to reduce the coal industry's contribution to industrial GDP from 20.3% to about 4%, and total coal-based employment from 4.5 million in 2024 (accounting for 8% of the region's total employment) to 0.5 million in 2060 (accounting for merely 1% of the region's total employment in that year. As emerging industries, such as green hydrogen and green transportation, are still in the early development stage, their short-term capacity to absorb employment is limited and cannot fully offset job losses from coal-based industries. In the long term, total employment in the new energy sector is expected to increase from 330,000 today to 1.4 million by 2060, with approximately 1,400 of the newly created jobs each year suitable for women. It must be acknowledged that even with large-scale development of new energy, fully absorbing the large legacy workforce from the coal industry will be challenging. Constrained by skill transition barriers, the regional labor market will face long-term structural pressure. At the same time, industrial upgrading places greater demands on local education and training systems. Coupled with the unprecedented scale of China's employment transition, this underscores the urgency and complexity of skills re-training and social security system development.

(8) Drawing on international experiences in traditional energy transitions, it is crucial to systematically advance the formulation and implementation of China's transition policies. Both policy guidance and market dynamics are core drivers of the energy transition. Drawing upon the challenges and lessons encountered by Germany, Poland, and the UK provide valuable insights for advancing the transition of the coal triangle region: Germany incurred high costs due to an unclear path toward ending coal use; Poland's single compensation mechanism failed to achieve true re-employment and industrial continuity; and the UK's neglect of just transition led to long-term socio-economic difficulties in mining regions. These cases highlight that successful transitions require a coordinated and clear exit schedule, systematic industrial and employment support, and embedded mechanisms for fairness throughout the process. The European Union's experience in diversified transition pathways also provides an important reference for China's relevant practices. International experience indicates that successful transitions must involve coordinated planning of clear phase-out schedules, the establishment of systemic industrial and employment support systems, and the full integration of just transition mechanisms throughout the transition process. Compared with international counterparts, the Coal Triangle Region currently has a more single-structured industrial base and a significantly lower share of the service sector, so it faces higher systemic transition risks. The lack of systematic planning for regional industrial development and energy transition goals may trigger prolonged regional economic decline. Therefore, national-level coordinated planning is needed to establish phased exit pathways, supported by fiscal, industrial, and social security measures to effectively mitigate transition impacts. Innovation in financial and policy instruments is key to enabling a just transition and achieving sustainable regional development.

3. Key Policy Recommendations

The report recommends that, under the national carbon peaking and carbon neutrality goals, a new energy security strategy be pursued to innovatively coordinate regional energy supply and emission reduction through policy mechanisms, optimize industrial layout to foster emerging industries, diversify funding to sustain industrial development, and establish a climate and just transition governance framework that strengthens the region's role in green and low-carbon development. These approaches would promote a secure and low-carbon energy transition.

The specific policy recommendations are as follows:

First, formulate a national strategy for energy transition and regional coordinated development in the Coal Triangle Region, and establish green and low-carbon transition targets for the area. It is recommended that the "15th Five-Year" energy-related plans explicitly introduce the concept of **"sustainable coal phase-down"**, positioning it as a central measure to achieve carbon peaking and carbon neutrality goals and build a renewable energy-dominated new energy system. Concurrently, clear targets and a roadmap for sustainable coal phase-down should be formulated, with the Coal Triangle Region serving as a demonstration area to explore innovative transition pathways to facilitate this sustainable coal phase-down.

Second, develop innovative intra- and inter-regional coordination mechanisms to advance the Coal Triangle Region's green and low-carbon transition. Regional coordination should be strengthened by establishing a national-local joint policy framework for energy security and low-carbon transition and systematically integrating industrial restructuring, energy security, ecological governance, and high-quality development. Coal-based industry scale in the Coal Triangle Region should be strictly controlled, and energy, industrial, and infrastructure systems within the region should be coordinated. Partnerships with economically developed neighbouring regions should be encouraged, focusing on cultivating diversified industries such as specialty agriculture, ecotourism, and the digital economy and forming a "clean energy + diversified industries" structure to support green and sustainable regional economic development. At the same time, leveraging the Coal Triangle Region's green energy, location, and industrial advantages, cross-regional resource complementarity and efficient integration should be promoted, establishing an "energy supply–industrial collaboration—benefit sharing" mechanism. This approach will help the Coal Triangle Region efficiently cultivate alternative industries and new growth drivers, ultimately achieving mutual benefits across regions.

Third, position new energy as a regional growth engine to drive industrial restructuring and emerging industry cluster development in the Coal Triangle Region. The region's abundant green power resources provide a solid foundation for building a clean and efficient industrial system and are key supports for high-quality regional economic development. Leveraging this advantage, efforts should accelerate the "Three New Pillars," focusing on

developing a new power system, advancing hydrogen-based industries, and demonstrating carbon removal technologies. Technological innovation should facilitate the integration and application of low-carbon and zero-carbon technologies in coal-based industries, systematically advancing the Coal Triangle Region's green and low-carbon transition. Building on zero-carbon park initiatives, breakthroughs should be achieved in green power allocation, low-carbon and zero-carbon certification, and carbon accounting mechanisms, while cultivating zero-carbon industry clusters such as green hydrogen, green steel and green chemical products. Simultaneously, institutional innovation should establish carbon emission tracing, deepen electricity market reform by leveraging industrial parks as platforms, establish zero-carbon product standards, and implement carbon asset management systems to create a zero-carbon trade demonstration zone, guiding the Coal Triangle Region from a "high-carbon industrial hub" to a "zero-carbon industrial highland." Through technology innovation and industrial coordination, new sectors such as energy storage, digital economy, and green services can be fostered, enhancing regional economic resilience and diversification and establishing a benchmark for zero-carbon transformation.

Fourth, improve the diversified financing scheme in the Coal Triangle Region to ensure funding for its green and low-carbon transition. It is recommended to establish a Green Development Fund targeting the region, creating a diversified investment and financing system guided by the government and operated by the market. Fiscal transfers should be used to set up dedicated funds for mine ecological restoration, subsidence area management, and just transition arrangements. Innovate fund operation mechanisms can promote multi-level coordination and social participation, with a focus on supporting low-carbon, zero-carbon, and disruptive technological innovations, particularly favouring technology-driven private enterprises to accelerate large-scale deployment. Establish local fund tolerance mechanisms to enhance policy flexibility and improve financial services such as green credit and bonds. Broadly leverage social capital to build an efficient and diversified investment and financing system.

Fifth, establish an international exchange platform for low-carbon transition in resource-based regions; develop an inclusive, just transition governance framework to provide the Coal Triangle Region with experience sharing; and explore regional transition practices. Just transition in traditional energy regions is a common global challenge, with the core difficulty lying in the structural impact of the transition on employment. Emerging non-coal industries will struggle to offset job losses from coal-based industries in the short term. To address employment pressure in the Coal Triangle Region, it is necessary to focus on employment tracking, community dialogue, and women's employment needs, to accelerate the construction of a robust employment-support system, to accurately identify affected groups, to strengthen differentiated skills training and placement assistance, to implement targeted social-safety-net measures for vulnerable groups, and to ensure job transition and income continuity. At the same time, bilateral and multilateral dialogues — notably China–Europe exchanges — should be deepened, and policy learning and project cooperation with Asia–Africa–Latin America regions should be expanded. By transforming the Coal Triangle region into a demonstration zone for green, low-carbon, and just energy transition, it can provide valuable experience for a global just transition.

Key words: Coal Triangle Region; Green and Low-carbon transition; Energy transition; regional coordination mechanisms; Coal-based industries; New energy industries; Zero-Carbon Industrial Park; Just transition; Green Development Fund.

Nomenclature

Abbreviation	Annotate
CCUS	Carbon Capture Utilization and Storage
CDR	Carbon Dioxide Removal
CGE	Computable General Equilibrium
CRiT	Coal Regions in Transition Initiative
ERDF	European Regional Development Fund
ESF	European Social Fund
EGD	European Green Deal
GDP	Gross Domestic Product
IEA	International Energy Agency
IPCC	Intergovernmental Panel on Climate Change
JTF	Just Transition Fund
LMDI	Logarithmic Mean Divisia Index
UNFCCC	United Nations Framework Convention on Climate Change
SCF	Social Climate Fund
SDG	Sustainable Development Goals

Contents

Low-Carbon Transition of Traditional Energy Regions of China: A Case Study of the Coal Triangle Region

Amid the urgent global climate crisis, controlling greenhouse gas emissions and driving a low-carbon energy transition have become critical for sustainable development. However, geopolitical conflicts, energy security crises, and other factors have caused some countries to backtrack on fossil energy policies. For example, the United States reversed its climate policies by withdrawing from the Paris Agreement and emphasizing "energy sovereignty", promoting expanded coal, oil, and gas extraction, creating significant uncertainty for global climate mitigation efforts.

Faced with the new landscape of global climate governance, China has demonstrated firm determination. On September 24, 2025, President Xi Jinping announced China's nationally determined contribution targets for 2035 at the United Nations Climate Change Summit, committing to reduce net greenhouse gas emissions across the entire economy by 7% to 10% from the peak level, with efforts to achieve even better outcomes. China's solid advancement of the "Dual-Carbon" strategy reflects both its fulfillment of major power international responsibilities and the inherent need to drive a profound green and low-carbon transformation of the domestic energy system. Currently, the coal-dominated energy system faces multiple challenges: high carbon emissions, significant environmental externalities, and ongoing ecological pressure. It struggles to adapt to the construction of a modern energy system guided by green low-carbon principles, system resilience, and strategic autonomy. Moreover, it deviates from the dual goals of sustainability and security emphasized in the new energy security strategy. Overreliance on coal exacerbates carbon lock-in, raises systemic transition costs, and limits energy structure optimization and resilience. Therefore, promoting the transformation of the energy structure and gradually reducing dependence on coal has become an inevitable path for China to achieve high-quality development and a high level of security. As the State Council's White Paper *China's Energy Transition* notes, China's energy transition "is based on high-quality development, focuses on ecological civilization, and serves the construction of a community with a shared future for mankind." This statement profoundly reveals the urgency and strategic significance of the clean and low-carbon transformation of the energy system, providing guidance for China's and the world's green future.

Against this backdrop, this study, supported by the China Council for International Cooperation on Environment and Development (CCICED), focuses on the **Coal Triangle Region, comprising Shanxi Province, Inner Mongolia Autonomous Region, Shaanxi Province, and Ningxia Hui Autonomous Region. As a core area for national energy security, the region's low-carbon transition affects not only regional economic sustainability and social well-being but also the national carbon peaking and carbon neutrality progress and the resilience of the energy system.** This report examines transition pathways for high-carbon industry phase-out, just transition, and green low-carbon industry development while analyzing supporting policy frameworks, aiming to provide a regional practice model and institutional innovation example to guide China's construction of a clean, low-carbon, safe, and efficient energy system.

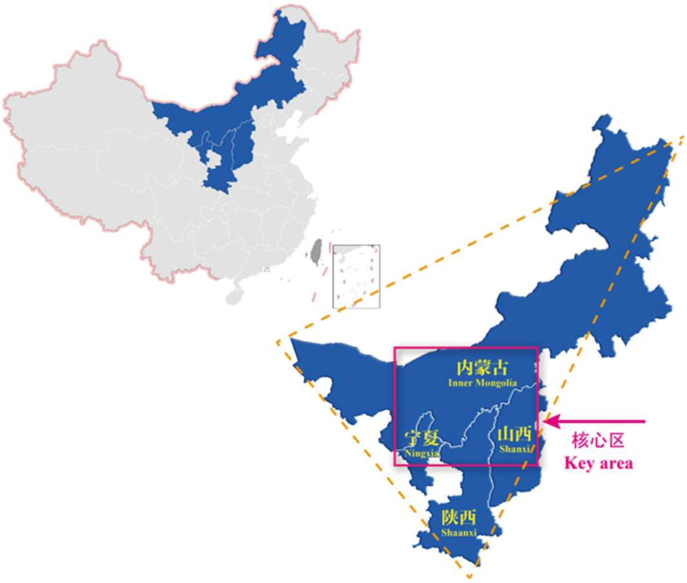

Figure 1-1. Geographical Location Map of the Coal Triangle Region

1. Overview of the Development Context in the Coal Triangle Region

Key Findings:

- In 2024, China's Coal Triangle region produced 3.45 billion tonnes of coal, accounting for 79% of the nation's total output and 37% of global production, underscoring its pivotal role in both domestic and international energy landscapes.
- The region's economy remains heavily reliant on coal resources and coal-based industries. The secondary sector's contribution to GDP exceeds the national average, with coal-based industries constituting 20.3% of industrial value-added, highlighting significant structural transition pressures.
- The Coal Triangle serves as a critical energy base for China, accounting for 69% of its coal output and 37% of locally generated electricity being transferred to other regions, reflecting its longstanding responsibility in ensuring national energy supply security.
- Over the past decade, the region's carbon emissions rose from 1.547 billion tonnes in 2015 to 2.407 billion tonnes in 2024. Coal-related activities remain the primary driver, contributing 85% of local emissions through coal production and consumption.
- The Coal Triangle Region's heavy reliance on coal-based industries exposes its ecological environment to multiple challenges, including mine subsidence, water scarcity, air pollution, and solid waste disposal.
- In its energy transition, the Coal Triangle Region faces prominent issues, such as a single industrial structure, insufficient transition momentum, and inadequate financial support.

1.1 Overview of Economic and Industrial Development in the Coal Triangle Region

1.1.1 Economic Development of the Coal Triangle Region

The Coal Triangle Region covers 16.8% of China's total land area and is home to 7.5% of the national population. In 2024, it contributed 6.9% of the country's GDP. Among the region's provinces and autonomous regions, only Inner Mongolia had a per capita GDP of 110,000 RMB, roughly $15,500 ($ denotes USD), exceeding the national average of 96,000 RMB, roughly $13,500, while Shanxi (74,000 RMB, roughly $10,400), Ningxia (73,000 RMB, roughly $10,300), and Shaanxi (85,000 RMB, roughly $12,000) all fell below the national average. Notably, the per capita GDPs of Shanxi and Ningxia were approximately 18% lower than the national average. In addition, 2024 data show that, with the exception of Shanxi, the primary industry share in Inner Mongolia, Shaanxi, and Ningxia all exceeded the national average of 7.4%. All four provincial-level regions reported a secondary industry share higher than the national average (36.5%), while their share of the tertiary industry lagged behind the national average (56.7%).

Table 1-1. Socio Economic Profile of the Four Provincial-level Administrative Regions in the Coal Triangle Region

Items		Shanxi	Inner Mongolia	Shaanxi	Ningxia	Total
Population (at the end of 2023)	Population (10,000 people)	2,396	3,466	3,953	729	10,543
	Share of the national total	1.7%	2.5%	2.8%	0.5%	7.5%
GDP (2024)	GDP (trillion RMB)	2.63 ($370.4 billion)	2.55 ($359.2 billion)	3.55 ($498.6 billion)	0.55 ($77.5 billion)	9.28 ($1305.7 billion)
	Share of the national total	2%	1.9%	2.6%	0.4%	6.9%
	GDP per capita (1000 RMB per capita)	110 ($15.5K)	74 ($10.4K)	90 ($12.7K)	75 ($10.1K)	88 ($12.4K)
	GDP of coal-based industries (100 million RMB)	1,876 ($26.4 billion)	3,746 ($52.8 billion)	1,889 ($26.6 billion)	501 ($7.1 billion)	8,012 ($112.8 billion)
	The proportion of GDP contributed by the coal-based industry to the total GDP	7.2%	14.7%	5.3%	9.1%	8.6%
	The proportion of GDP from the coal-based industry in the total industrial GDP	16.2%	34.0%	13.0%	21.4%	20.3%
Area	Land area (1,000 km^2)	118.3	156.7	205.6	66.4	1611.7
	Share of the national total	12.3%	1.6%	2.1%	0.7%	16.8%

Data sources: National Bureau of Statistics, China Industrial Statistical Yearbook, China Industrial Enterprise Database.

1.1.2 Coal-Based Industry Development in the Coal Triangle Region

Coal production and consumption are primarily driven by downstream demand. In this report, the coal-based industry includes not only upstream coal mining and washing processes, but also the midstream sectors that rely on coal as a raw material or energy—specifically coal-fired power generation and coal chemical industries—as well as downstream sectors with high coal consumption such as steel and cement industries (see Appendix A for details).

Figure 1-2 compares the GDP development trends of the Coal Triangle Region to the national average. From 2015 to 2024, the regional GDP growth trend broadly aligned with the national trend, but the share of coal-based industries in GDP exhibited a fluctuation pattern of "initial decline followed by a rebound." Although this share declined somewhat after 2015, the decrease was modest and remained consistently above the national average. Notably, between 2019 and 2022, the proportion of coal-based industries in the regional GDP increased markedly, reflecting the continued heavy reliance of the regional economy on coal extraction and utilization. By 2024, coal-based industries accounted for 20.3% of the industrial GDP in the Coal Triangle Region, with Shanxi Province recording the highest proportion at 34%. This indicates that coal-based industries continue to play a significant role in supporting the regional industrial system. Economic trends in the Coal Triangle Region reveal that heavy dependence on coal has not generated commensurate value-added benefits. Taking Shanxi as an example: although it has the highest share of coal-based industries in industrial GDP among the four provinces, its provincial GDP growth rate has remained among the lowest nationally for years. This contrast underscores the diminishing capacity of traditional coal-dependent industries to drive economic expansion.

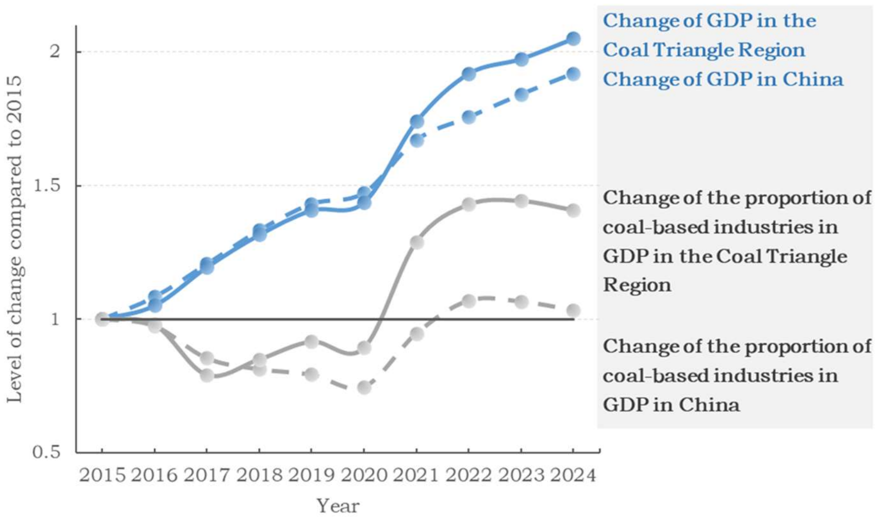

Figure 1-2. Changes in GDP and the Share of Coal-Based Industries in GDP for the Coal Triangle Region and the Whole Country, 2015-2024

By sorting out the composition of the coal-based industry system in the Coal Triangle Region, the basic conditions of its main industries are summarized as follows.

(1) Coal Mining and Washing Industry: Resource Advantage and Heavy Economic Dependence

In 2024, operating revenue of coal mining and washing in this region accounted for 75.1% of the national total for this sector. The industry contributed 5.7% to the region's total GDP, establishing it as an important pillar of local economic development. However, this resource-dependent economic model harbours inherent challenges-marked by an overly concentrated industrial structure and fragile risk resilience. These not only constrain the region's economic diversification but also increase the difficulty of achieving carbon neutrality.

(2) Coal-Fired Power Industry: Significant Scale Advantage and Pressing Efficiency Bottlenecks

Coal power remains the primary source of energy consumption and carbon emissions in the Coal Triangle Region. The four provincial-level regions account for 22.4% of the national total coal-fired power installed capacity, and 22.6% of coal-fired electricity generation. Although ultra-supercritical and advanced ultra-supercritical units have been gradually deployed, the region’s average coal consumption per unit of electricity generated remains above the national average. This can be largely attributable to the high proportion of aging units, delayed flexibility retrofits, and inadequate grid peak-shaving capacity.

(3) Coal Chemical Industry: Low Added Value and High-Carbon Lock-In. The Coal Triangle Region is the core cluster of China’s coal chemical industry, with modern coal chemical production capacity (such as coal-to-oil, coal-to-gas, and coal-to-olefins), accounting for more than 60% of the national total. However, the industry here has presented prominent high-carbon lock-in effects: first, carbon emissions from both raw material coal and fuel coal; second, the high cost of applying deep decarbonization technologies, which hinders the potential of carbon reductions; and third, inadequate development of high-value-added products, with the industry chain still focused on basic chemical raw materials, and the product added value lower than the national average for the chemical industry.

(4) Steel Industry: Dominance of Long Process and Strong Coal-Coke Linkages. In 2024, the steel sector in the region accounted for about 10% of the national total operating revenue. Currently, local steel enterprises generally exhibit higher energy consumption and carbon emission intensities per unit of product than the national average. At the same time, heavy reliance on coke has driven the growth of the coal-coking industry, forming a tightly integrated coal mining—coking—steel production chain.

(5) Cement and Other Coal-Based Industries: Prevalence of Small-to-Medium-Scale Capacity and Marginal Support Role

Cement and other coal-using industries constitute a relatively small proportion of the Coal Triangle Region’s economy. In 2024, the region’s clinker production accounted for 9.4% of the national total, and the operating revenue of cement, lime, and gypsum manufacturing industries accounted for approximately 8.4% nationally. Their added value contributed only 0.53% to the local GDP. Although these industries do not serve as core drivers of regional coal consumption, their widespread small- to medium-scale production lines still contribute to coal demand to some extent, thereby complicating regional carbon-reduction efforts.

1.2 Current Status of Energy Production and Consumption in the Coal Triangle Region

1.2.1 Energy Production

From 2015 to 2024, coal production in the Coal Triangle Region showed an overall upward trend. By 2024, the region’s coal output reached 3.45 billion tonnes, with Inner Mongolia Autonomous Region, Shanxi Province, and Shaanxi Province producing 1.297 billion tonnes, 1.27 billion tonnes, and 780 million tonnes respectively. Inner Mongolia and Shanxi accounted for 29.5% and 28.9% of the national coal output, while Shaanxi held a 17.8% share. The Ningxia Hui Autonomous Region contributed 2.4%, bringing the total share of national coal production from the Coal Triangle Region to 78.6%. This underscored its crucial role as a key energy supply base for China.

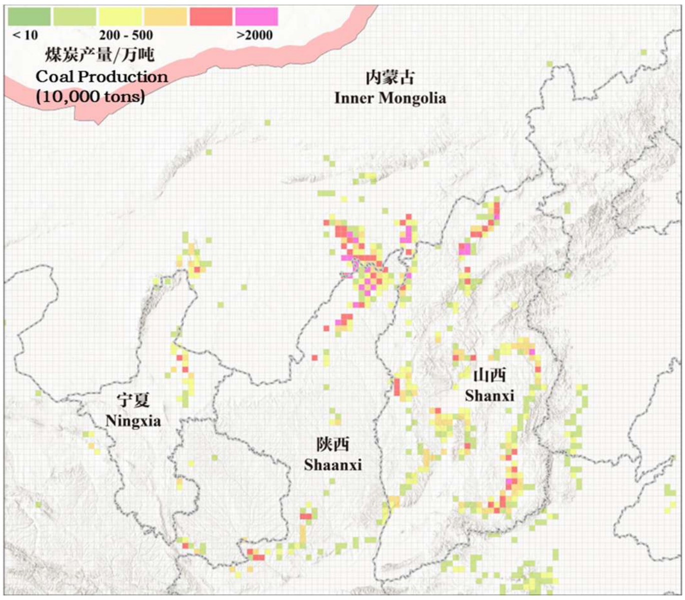

Figure 1-3. Coal Production Pattern in China's Coal Triangle Region (10 km Grid)

In electricity production, the Coal Triangle Region had a coal-fired power installed capacity of 300.04 GW in 2024, representing 20.8% of the national total installed coal power capacity. The region's coal-fired power generation reached 1,435.2 TWh, accounting for 22.5% of the country's total coal-fired power output. Renewable energy capacity and generation in the region have also grown rapidly. In 2024, the Coal Triangle Region's wind power installed capacity was 144.03 GW, accounting for 27.7% of the national total, with Inner Mongolia holding a significant advantage due to its abundant wind resources and land area, reaching 86.89 GW of installed wind capacity. Regarding solar power, the installed capacity in the Coal Triangle Region reached 143.45 GW in 2024, accounting for 16.2% of the national total solar capacity. Due to limited water resources, hydropower capacity in the region remains relatively small, with only 8.06 GW installed in 2024.

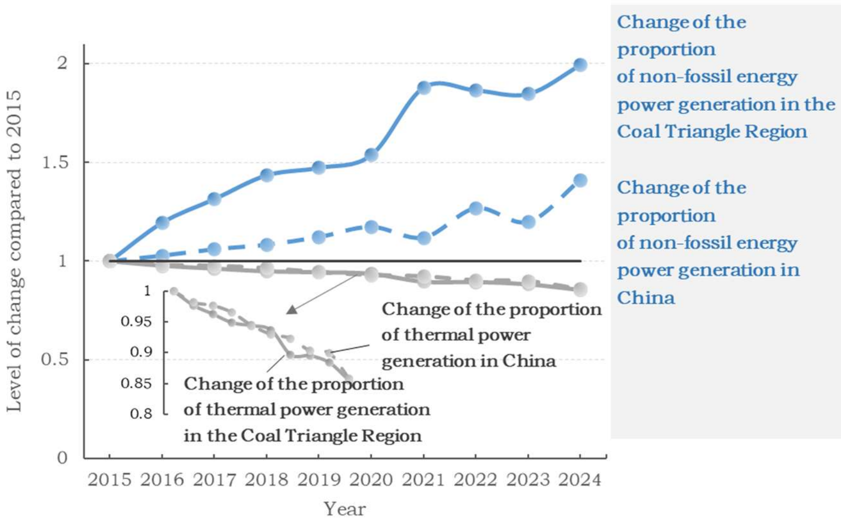

Figure 1-4. Changes in Power Generation Structure in China and the Coal Triangle Region, 2015-2024

Figure 1-4 summarizes the changes in power generation structures nationwide and in the Coal Triangle

Region from 2015 to 2024. The data indicate that, over the past decade, despite the significantly higher average annual growth rate of non-fossil energy generation's share in the Coal Triangle Region compared to the national average, this share consistently remained below the national total. During this period, the region's coal-fired power installed capacity increased by 124 GW, and coal-fired power generation rose by 620 TWh. The share of coal power in total generation declined from 89.5% in 2015 to 76.5% in 2024. However, this proportion remains substantially higher than the national average (67.4% in 2024). Benefiting from the abundant wind and solar resources and national policy support, the share of non-fossil power generation in the Coal Triangle Region rose to 20.9% from 2015 to 2024, with the total power generation growing by 4.1 times compared with 2015, and the annual growth rate far exceeding the national average.

1.2.2 Energy Consumption

In 2024, China's total energy consumption reached 5.96 billion tonnes of standard coal equivalent (tce). Coal consumption accounted for 53.2% of the total, and raw coal consumption was approximately 4.5 billion tonnes (physical volume). The Coal Triangle Region accounted for 34.9% of the national coal consumption; Shanxi, Inner Mongolia, Shaanxi, and Ningxia consumed about 600 million, 550 million, 240 million, and 170 million tonnes of coal, respectively. Furthermore, coal processing and conversion consumption accounted for 87.7% of the region's coal consumption, slightly above the national average of roughly 81.5%. Within the processing and conversion segment of coal consumption, the share of thermal power generation in the Coal Triangle Region was 47.3%, which is 15.8 percentage points lower than the national average (63.1%), while coal washing accounted for 19.8%, substantially higher than the national level (2.7%). In terms of end-use consumption, coal use by the industrial sector made up a striking 91.1% of total regional coal consumption, exceeding the national average by 6.6 percentage points. Electricity consumption also showed a strong industrial bias, with 79% used by the industrial sector, 15.3 percentage points higher than the national average. Although this energy consumption structure has supported regional economic development, it has also placed significant pressure on energy transition efforts and the ecological environment. There is an urgent need to drive green and low-carbon transformation through industrial upgrading and technological innovation.

1.2.3 Outbound Energy Transfers

The Coal Triangle Region is a key coal and coal-fired power exporting area in China, long bearing an important responsibility for ensuring the nation's energy supply. In 2024, the Coal Triangle Region transported over 2 billion tonnes of coal out of the region, accounting for more than 60% of its total coal production. Among the provinces, Shanxi had the highest outbound volume, with an annual average of about 750 million tonnes over the past two years. Given that official national statistics have not yet been released, according to incomplete statistics, the total electricity outbound transmission from the Coal Triangle Region is approximately 0.6 trillion kWh in 2024, accounting for 37% of the region's total power generation. Within the region, Inner Mongolia Autonomous Region leads in electricity outbound transmission, reaching about 0.3 trillion kWh. Therefore, in the course of the energy transition, urgent interregional cooperation with major traditional coal and power-importing provinces is needed to achieve complementarity and shared benefits in new-energy development, industrial upgrading, technical support, green investment, as are market mechanisms, to ensure that energy-producing regions can achieve economic diversification and sustainable development while continuing to fulfill their responsibility for meeting the nation's energy needs.

1.3 Carbon Emissions and Ecological–Environmental Status of the Coal Triangle Region

1.3.1 Current Status and Driving Factors of Carbon Emissions

In 2024, the Coal Triangle Region emitted 2.41 billion tonnes of carbon dioxide, accounting for 19.6% of China's total emissions and 6.4% of global emissions. Of this, energy-related activities contributed 88.5% of the total emissions, while industrial processes accounted for 6.2%. Within energy-related activities, the power sector was the largest contributor, followed by direct emissions from energy use in the steel industry. In addition, energy use in the transport and building sectors contributed 2.8% and 2.4% of total emissions, respectively. Out of the region's total emissions in 2024, coal production and consumption contributed 2.05 billion tonnes, representing 85.2% of the total. From a time-series perspective, carbon emissions in the Coal Triangle Region rose from 1.55 billion tonnes in 2015 to 2.41 billion tonnes in 2024. Of this increase, coal-related emissions accounted for as much as 86.0%.

Economic growth is the core variable driving carbon emissions growth in the Coal Triangle Region and its four provinces, while a reduction in energy consumption intensity serves as the main factor for carbon emissions mitigation. Between 2015 and 2024, growth in per capita GDP in the region led to an increase of 1.058 billion tonnes in carbon emissions. Historical data show that for every 1% increase in GDP, carbon emissions rose by 2.69 million tonnes; for every 1% reduction in energy intensity, emissions decreased by 3.55 million tonnes; and for every 1% reduction in carbon emissions per unit of energy consumption, total emissions dropped by 1.72 million tonnes. Technological improvements that reduced energy intensity led to a cumulative reduction of 276 million tonnes of CO_2 emissions in the Coal Triangle Region over this period.

Industrial structure adjustment contributed to emission reduction during 2015-2020. However, it led to emission increases from 2020 to 2024. The primary reason is that the rising coal prices significantly boosted the output value of coal and related industries, which in turn drove a rebound in the share of industrial value added. This delayed the industrial structure optimization process and exacerbated regional carbon emission pressure. The industrial structure, dominated by traditional manufacturing and heavy industries, has constrained industrial diversification and high-quality development, hindered the regional green transition process, and consequently led to increased carbon emissions. Regarding energy structure optimization, although renewable energy in the Coal Triangle Region developed rapidly between 2015 and 2024—with the share of non-fossil energy in power generation increasing from 10.5% to 20.4%—its proportion in the primary energy consumption structure remained limited. This has resulted in an insufficient overall contribution from energy structure adjustments to carbon reduction.

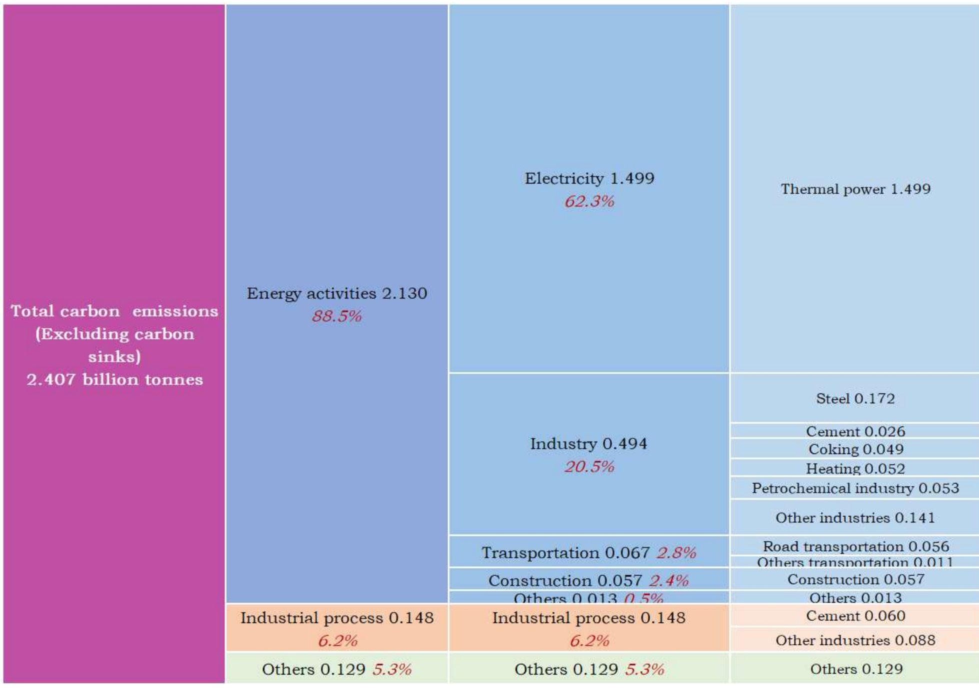

Figure 1-5. CO_2 Emissions in the Coal Triangle Region in 2024 (100 million tonnes)

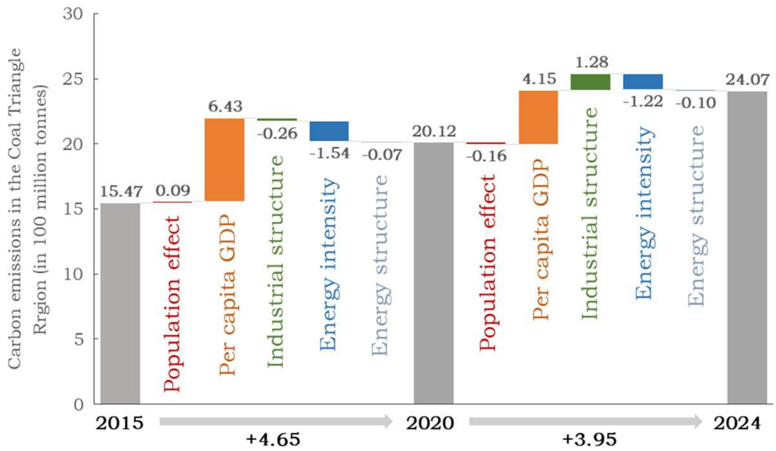

Figure 1-6. Decomposition of Carbon Emission Drivers in the Coal Triangle Region, 2015-2024

1.3.2 Overview of the Current Ecological and Environmental Conditions

The Coal Triangle Region spans multiple ecological units, including the Loess Hills, the Ordos Sandy Land, the Fen-Wei Plain, and the Helan Mountains–Ningxia Plain. It features diverse landforms but fragile ecological systems, where wind erosion and desertification, soil erosion, coal mining subsidence, and salinization coexist, leaving the land generally low in resilience. Long-term coal-based industrial development has exposed the region to pronounced natural vulnerability, excessive resource exploitation, and overlapping water, air, and solid waste pollution, with ecological degradation showing strong historical accumulation and structural rigidity.

First, under prolonged high-intensity resource exploitation, regional ecosystems have been severely disturbed. Large-scale underground mining has caused expanding surface subsidence, accelerated grassland degradation and desertification, and significantly reduced land productivity. Statistics show that in 2023, newly subsided mining areas in the region accounted for 47% of the national total, mostly due to cumulative coal mining over many years, making ecological restoration extremely difficult.

Second, the region has inherently limited water resources, accounting for only 4.6% of the national total, yet it has long supplied about one-fifth of the water demand for coal-based industries nationwide. High water-consuming sectors such as coal chemical, coal power, and metallurgy consume around 80% of withdrawals, mainly from the Yellow River's main and tributary channels and shallow groundwater. This has kept the region in a long-term "red alert" status, creating a dual contradiction of resource-based water scarcity and structural over-extraction.

Third, overlapping emissions from high-pollution industries, including coal, coke, power, and metallurgy, have kept the regional air environment under sustained pressure, with pronounced $PM_{2.5}$ and ozone co-pollution. Although the Fen-Wei Plain and surrounding areas have focused on scattered coal management, overall improvements have been limited. Meanwhile, legacy issues such as mining dust, spontaneous combustion of gangue piles, and coke oven fugitive emissions remain severe, with total suspended particulate concentrations several to ten times above background levels and exhibiting significant cross-provincial transport. Methane leakage from coal mining further exacerbates regional greenhouse gas emissions.

Fourth, solid waste generated during coal mining and utilization is particularly serious, mainly including coal gangue and fly ash. Producing 1 tonne of raw coal generates roughly 0.1 tonnes of coal gangue and 0.15 tonnes of coal by-products (ash and gypsum), totalling about 0.25 tonnes of solid waste. It is estimated that over 500 million tonnes of solid waste remain annually from coal transported out of the Coal Triangle Region. Long-term gangue storage not only occupies land but also risks landslides and spontaneous combustion, releasing SO_2, CO, and polycyclic aromatic hydrocarbons, worsening secondary air pollution. Fly ash, containing heavy metals, can migrate and leach under wind and rain conditions, contaminating soil and groundwater and significantly increasing environmental risk.

Overall, ecological governance in the Coal Triangle Region remains in a tug-of-war between localized restoration and widespread degradation, with historical ecological deficits yet to be systematically addressed. Therefore, it is essential to transform the energy and industrial structure at the source, gradually reduce reliance on coal resources, and accelerate the development of a green and low-carbon industrial system. On this basis, coordinated efforts in energy substitution, ecological restoration, spatial management, and governance innovation are needed to achieve a fundamental shift from end-of-pipe control to systemic regulation, fostering high-quality regional development in harmony with ecological security.

Table 1-2. Statistical Overview of Mining Subsidence and Key Water Resource Indicators in the Four Provinces and Autonomous Regions of the Coal Triangle Region

Indicators		Shanxi	Inner Mongolia	Shaanxi	Ningxia	Total
Mining-damaged land area (2023)	Existing mining-damaged land area (hectares)	93,871	119,636	32,439	11,736	257,682
	Share of national total	11.0%	14.1%	3.8%	1.4%	30.2%
	Newly added mining-damaged land area (hectares)	18,410	15,531	17,850	734	52,525
	Share of national total	16.5%	13.9%	16.0%	0.7%	47.1%

Indicators		Shanxi	Inner Mongolia	Shaanxi	Ningxia	Total
Water resources (2023)	Total water resources (100 million cubic metres)	143.9	491.9	546.3	8.1	1,190.2
	Share of national total	0.6%	1.9%	2.1%	0.03%	4.6%

Data source: China Environmental Statistics Yearbook.

1.4 Challenges and Problems in the Transition of the Coal Triangle Region

The Coal Triangle Region has developed a “coal lock-in” effect in its industrial development, resulting in a relatively single economic structure with limited resilience, while coal mining and utilization have exerted significant pressure on the local ecological environment. Considering its industrial base, strategic significance, and current green development status, establishing a safe, low-carbon, and sustainable modern energy system in the Coal Triangle Region and achieving its green low-carbon transition will not only enhance the long-term stability of China’s green energy supply but also drive industrial upgrading and optimization, promoting sustainable development and social stability in this resource-dependent region. The main challenges currently facing the Coal Triangle in achieving a green and low-carbon transition include:

First, the Coal Triangle Region has long shouldered the responsibility of national energy supply, with its regional economy deeply dependent on coal-based industries. This has resulted in a persistent lack of transformation momentum and unclear targets. The region lacks a clear and feasible direction for alternative industries, constraining strategic planning and pathway selection for the green and low-carbon transitions. Coal-based industries dominate the region’s economic system, and the mutual reinforcement between coal production and regional economic growth has significantly raised the institutional and societal costs of adjusting the energy structure. Meanwhile, as a national energy base, the Coal Triangle Region faces dual pressures of emission reductions and energy supply assurance. Its transition process is thus highly complex and difficult. Local governments must coordinate competing interests under multiple layers of policy pressure. The region’s industrial structure adjustment still relies on external impetus, and its endogenous transformation mechanisms have yet to form.

Second, zero-carbon green technologies for coal-based industries remain in the experimental and demonstration phases, characterized by high application costs and insufficient technological stability. These factors create uncertain development prospects and significant challenges for widespread adoption, thereby imposing multiple constraints on technological substitution and the emission reduction transition in the Coal Triangle Region. Achieving a regional transformation of the energy structure hinges on accelerating breakthroughs and the application of zero-carbon green technologies in coal-based industries, gradually weakening coal’s dominant position in the industrial chain. However, green alternatives for energy-intensive industries have yet to form scalable solutions, with the absence of a comprehensive low-carbon and zero-carbon technology system and a lack of endogenous technological momentum for industrial upgrading. At present, insufficient technical support has become the primary bottleneck restricting the region’s green transition and carbon-reduction efforts. In particular, amid the still-uncertain prospects for alternative industrial pathways, enhancing research and development (R&D) investment intensity, building a systematic policy support framework, and promoting the integrated demonstration and commercialization of key zero-carbon technologies have become essential to unlocking the transition.

Third, there is still no unified consensus among enterprises, industries, and local governments on the

need for transformation in the Coal Triangle Region. Overall, there is a lack of forward-looking planning and proactive deployment for a just energy transition and related industrial adjustments. Public understanding of climate change and energy transition remains insufficient, which hinders the systematic design and efficient implementation of relevant policies. Energy structure adjustments and the substitution of high-carbon industries will trigger widespread employment impacts. Workers in traditional energy sectors face limited opportunities for skill transfer and high reemployment difficulty. Meanwhile, alternative industries meant to absorb labour and drive the economic transition—such as specialty agriculture, cultural tourism, and modern services—have developed slowly and possess limited driving capacity, failing to provide new and sustainable growth momentum for the regional economy. Balancing social stability and green development has created mounting pressure on local governments and enterprises. How to ensure sustained economic growth while aligning environmental responsibility with social equity, safeguarding the rights of vulnerable groups and workers, and establishing a more inclusive and just green transition mechanism has become a central issue for enabling high-quality transformation in the Coal Triangle Region.

Fourth, disruptive green zero-carbon technologies with significant carbon-reduction potential, while promising, require substantial investment for widespread application. However, the existing fund and financial support systems remain inadequate, lacking diversified funding channels, with insufficient fiscal guidance and financial investment. As a strategic national energy base, the region's low-carbon transition path is deeply intertwined with the national "Dual-Carbon" targets and urgently requires preferential support from the national fiscal system—particularly through vertical transfer payment mechanisms to enhance financial security. However, existing regional green development funds suffer from structural mismatches, especially in key areas such as green technology innovation and clean production upgrades in traditional heavy industries, reducing the effectiveness of these funds in supporting low-carbon transformation. Green zero-carbon technologies represented by CCUS and hydrogen-based metallurgy require a fundamental restructuring of existing production processes. Characterized by substantial upfront R&D investments, long demonstration cycles, and the slow realization of commercial returns, these technologies have faced insufficient investment willingness from financial institutions, leading to the underutilization of their supporting effectiveness for regional low-carbon transition. In addition, local transition finance and funds have not yet effectively attracted private capital, limiting the leveraging effect of public funds and slowed the pace of green and low-carbon development.

2. Green and Low-Carbon Transition Targets for the Coal Triangle Region Under the "Dual-Carbon" Goals

Key Findings:

- The Coal Triangle Region is projected to reach peak carbon emissions between 2026 and 2029, with peak emissions estimated at 2.51 billion to 2.7 billion tonnes. By 2060, approximately 275 million tonnes of residual emissions are expected to remain, requiring offset measures such as carbon sinks and external carbon removal technologies.
- Coal power and coal chemical industries are projected to be the primary sources driving carbon emissions and coal consumption growth in the Coal Triangle Region over the next five years. It is urgently necessary to promote proactive emission reduction and deep decarbonization of the region's coal-based industries through technological breakthroughs and system optimization.
- Following national policies for energy transition and coal capacity optimization, coal production in the Coal Triangle Region is anticipated to reach a peak of roughly 3.68 billion tonnes in 2026-2027, entering a period of gradual decline over approximately 3-4 years at an average rate of 1-2% per year. Between 2030 and 2040, production is projected to decrease more rapidly, at an average annual rate of approximately 4%-5%, as part of a sustainable phase-out, reaching about 680 million tonnes by 2060.
- To achieve national and regional carbon neutrality goals, the Coal Triangle Region should pursue an industrial transition path centred on the "Three New Pillars": new energy systems, hydrogen-based industries, and deploying carbon removal technologies, while simultaneously upgrading traditional energy systems and fostering emerging industries.

2.1 Analysis of Carbon Emission Pathways in the Coal Triangle Region Under the "Dual-Carbon" Goals

According to long-term tracking of regional carbon emissions and projections of future emission pathways under different scenarios conducted by the Chinese Academy of Environmental Planning (CAEP), Ministry of Ecology and Environment, China's total carbon emissions—covering both energy activities and industrial processes—are expected to peak between 2026 and 2028, with peak annual emissions ranging from 12.51 to 13.04 billion tonnes. However, as a key traditional energy base, the Coal Triangle Region undertakes a critical role in energy supply security. Meanwhile, the lock-in effect of high-carbon industries, such as the coal chemical industry, is significant, causing the region's carbon emissions to peak between 2026 and 2029, with peak year emissions ranging from 2.51 billion to 2.7 billion tonnes. In the process of achieving carbon neutrality, under policy scenarios, the Coal Triangle Region may still have residual carbon emissions ranging from 15 million to 275 million tonnes by the carbon neutrality target year. This residual mainly originates from sectors like transportation and construction, where carbon removal technologies are currently difficult to apply effectively, as well as from certain coal-based industrial processes that are hard to fully decarbonize.

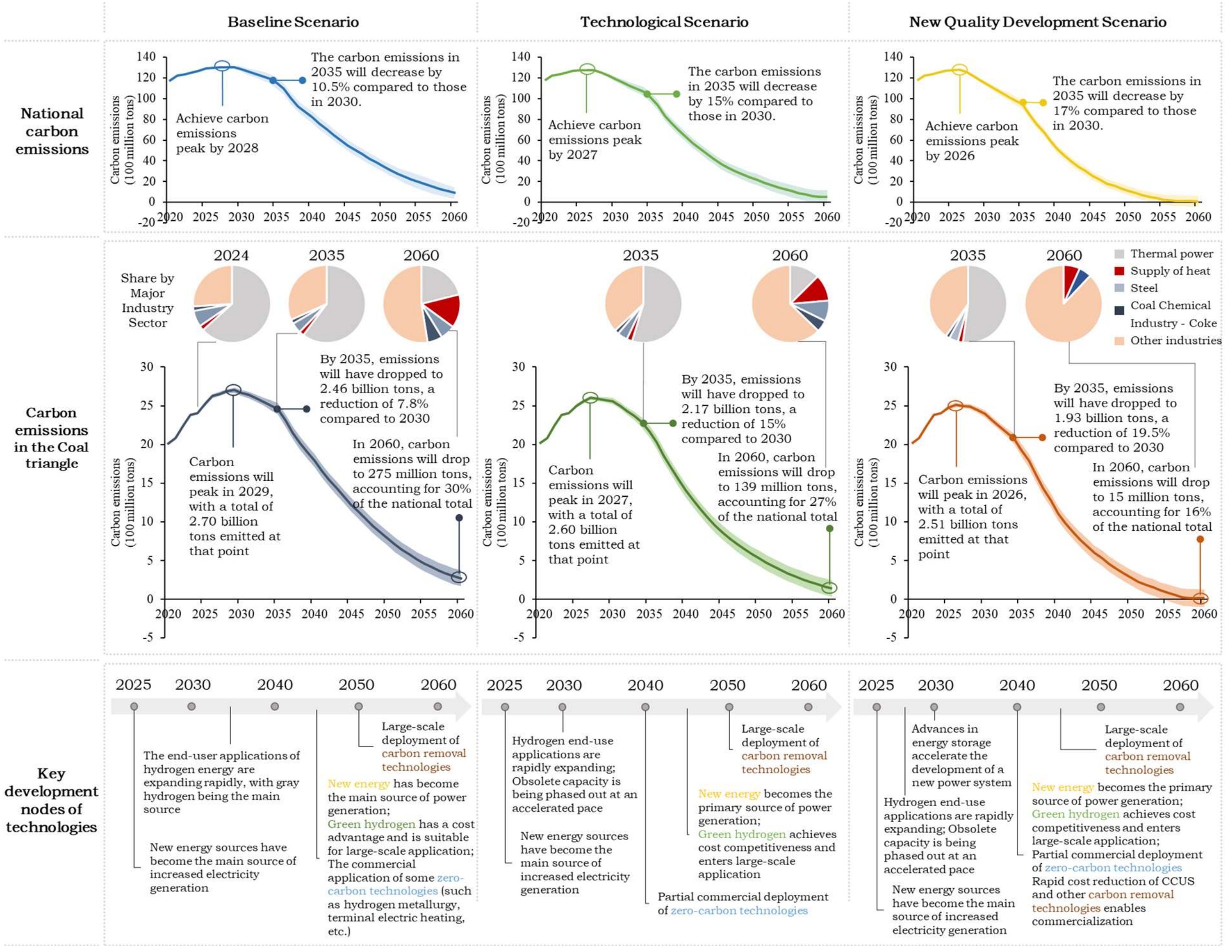

Figure 2-1. Carbon Emission Pathway of the Coal Triangle Region Under the "Dual-Carbon" Targets[1]

From the peak year until 2035, the Coal Triangle Region's annual average carbon emission reduction rate is expected to be 1.0% to 2.6%, which is lower than the national average of 1.7% to 3.0%. This is primarily due to the regional concentration of high-carbon industries, making emission reduction more difficult. On one hand, technical bottlenecks, equipment renewal cycles, and industrial path dependencies slow the decarbonization progress of high-carbon sectors compared to other regions nationwide; on the other hand, although renewable energy usage continues to advance, the substitution speed in end-use energy remains lagging, and clean energy infrastructure construction urgently needs strengthening. Further analysis of carbon emission pathways in the four provinces and regions of Shanxi, Inner Mongolia, Shaanxi, and Ningxia reveals that, due to high coal-based industry dependence, a large share of heavy industry, relatively backward grid integration technologies for wind and solar resources, and insufficient application of clean power and low-carbon technologies in key industries, Shanxi and Inner Mongolia are expected to peak carbon emissions between 2027 and 2029, while Shaanxi and Ningxia are expected to peak between 2026 and 2028.

[1] Carbon emission accounting for the aforementioned scenarios incorporates industrial-scale carbon removal, such as CCUS, but excludes biological carbon sinks. Regarding the different scenario categories: **the Baseline Scenario** represents continuing current policies and implemented technologies under "Dual-Carbon" goals, adopting relatively conservative emission reduction measures; **the Technology Scenario** builds upon the baseline by strengthening the proactive deployment of technologies such as renewable energy, hydrogen-based industries, and CCUS; and **the New Quality Development Scenario** introduces more aggressive adoption of cutting-edge technologies, such as green hydrogen, zero-carbon processes, and negative-emission technologies, while simultaneously accelerating demand-side transformation.

Notably, under more aggressive scenarios of technological progress and new quality development, if the proactive deployment of low-carbon and zero-carbon technologies is accelerated, and the Coal Triangle Region's advantages in large-scale demonstration and industrial application are fully leveraged, the region's emission reduction pathway is expected to keep pace with the national trajectory, or even achieve a faster rate of reduction than the national average after 2035. This contrast underscores that the proactive deployment of green and low-carbon technologies is not only a crucial means to overcome regional emission reduction bottlenecks but also holds the potential to transform the Coal Triangle Region from a traditional high-carbon energy base into an exemplary region for nationwide zero-carbon technology application and the realization of "Dual-Carbon" goals.

2.2 Analysis of Development Pathways for Coal-Based Industries in the Coal Triangle Region Under the "Dual-Carbon" Goals

The core of industrial transformation in the Coal Triangle Region lies in responding to low-carbon development demands by actively promoting the orderly exit of coal-based industries and implementing technological substitution and system optimization for high-carbon emission segments. Among these, fluctuations in product demand from coal-based industries constitute a key influencing factor. From the perspective of industry evolution, steel production has passed its peak demand, and cement output is on a downward trajectory, with both sectors showing diminishing pull on coal consumption. Modern coal chemical industries remain in a capacity-expansion phase, while coal-fired power generation continues to grow in line with overall electricity demand. Overall, **coal chemicals and coal power sectors will continue to lock in substantial coal consumption in the short term.**

As a core hub of China's coal chemical industry, the Coal Triangle Region's coal chemical sector demonstrates a dual focus on scale growth and green transition. In terms of coal consumption structure, traditional coal chemical processes still account for 18.6% of regional coal use but are gradually shrinking and accelerating their phase-out; modern coal chemical processes currently account for around 4% of consumption, maintaining a steady annual growth of 3%. The product structure is increasingly upgrading toward high-end chemicals such as olefins, aromatics, and biodegradable materials, with high-value product output expected to reach 25% by 2025 and exceed 35% by 2030. Between 2025 and 2030, nationwide new investment in modern coal chemical industries is projected to exceed 1 trillion RMB (approximately $140.85 billion), with the Coal Triangle Region accounting for 85% of this investment. Regarding carbon-reduction pathways for coal chemicals, the region should implement decarbonization systematically across source, process, and end stages: at the source, by substituting with green hydrogen and green electricity and utilizing carbon-containing waste; during processing, by adopting advanced gasification, high-efficiency catalysts, and waste heat recovery; at the end stage, through "emission reduction–value addition" technologies such as CO_2 conversion to chemicals and enhanced oil recovery. Additionally, provincial development paths differ: Shaanxi strictly controls capacity and focuses on quality and decarbonization; Inner Mongolia and Ningxia leverage cluster advantages, integrating green electricity, green hydrogen, and CCUS; Shanxi emphasizes capacity replacement and high-end transformation. Going forward, enhanced regional coordination and policy alignment are needed to build a diversified, complementary, green-efficient, and modern coal chemical system that can serve as a demonstration for national industrial transformation.

Regarding coal-fired power, driven by rigid electricity demand growth, nationwide coal power installed capacity is expected to still have room for growth by 2030, with generation reaching its peak around 2027. The development trajectory of coal power in the Coal Triangle Region largely aligns with the national trend. Overall, the role of coal power is gradually shifting from a primary power source to a peaking resource. At the current stage, coal power in the Coal Triangle Region still serves as the main electricity supply, but as the installed capacity of renewables expands and coal power's peaking role strengthens, its operating hours are very likely to decline, leading to potential increases in per-unit power consumption and carbon emission intensity. After 2035, renewable energy is expected to dominate the power generation structure, accelerating the retirement of existing coal power capacity in the region.

Furthermore, relying solely on market-driven demand contraction will not achieve effective long-term reductions in coal consumption; "proactive reduction" through technological innovation is necessary. Beyond market mechanisms, the low-carbon transition requires breakthroughs in key shared technologies. Critical technological directions for low- and zero-carbon transformation of coal-based industries include electrification, hydrogen substitution, CCUS, and resource recycling. Currently, most of these key technologies remain at the demonstration or early industrialization stage, facing challenges such as limited maturity, high costs, and insufficient policy support systems. Going forward, accelerating the integrated innovation and large-scale application of low-carbon technologies is essential to establish a systematic carbon reduction framework covering the full chain of coal mining, processing, conversion, and end use and providing a solid foundation for the safe, green, and deep decarbonization of coal-based industries.

Box 2-1: Low-Carbon Development Case Study of Ordos Coal Chemical Industrial Park

With the increasing global focus on carbon emissions and the advancement of the dual-carbon targets, the traditional coal chemical industry faces tremendous pressure to transform. In response, the Ordos Coal Chemical Industrial Park plans to implement low-carbon technologies in two phases to achieve sustainable development.

Phase I (2023-2040): High-Concentration CO_2 Capture and Green Hydrogen Utilization

In the first phase, the industrial park will focus on capturing high-concentration CO_2 generated during coal chemical processes and using green hydrogen to produce low-carbon methanol and olefins, which are high value-added products. Currently, the cost of capturing high-concentration CO_2 is about 100 RMB per tonne of CO_2. With technological advancements, decreasing green hydrogen costs, and the inclusion of the coal chemical industry in the national carbon market, the production costs of low-carbon methanol and olefins are expected to become competitive than traditional coal-based products in the coming years. This phase of transformation will not only significantly reduce CO_2 emissions but also double the output of key chemical products, thereby improving the economic benefits of the industrial park.

Phase II (Post-2040): Low-Concentration CO_2 Capture and Direct Air Capture Technology

In the second phase, the industrial park will gradually capture low-concentration CO_2 and introduce direct air capture (DAC) technology to offset the reduced carbon content from coal-based chemicals. Meanwhile, the output of coal-based chemical products will gradually decrease, replaced by chemical products produced with green hydrogen. This stage of transformation requires reliance on low-cost zero-carbon electricity, which should be considered from the initial process design stage, particularly in leveraging low-cost solar and wind resources. Although Ordos possesses abundant solar PV resources, the current development cost remains high. Technological innovation and policy support are needed to reduce these costs and ensure the economic viability and market competitiveness of zero-carbon electricity.

Source: *2024 Ordos Low-Carbon Transition and Case Study Report*

2.3 Analysis of Fossil Energy Development Targets in the Coal Triangle Region Under the "Dual-Carbon" Goals

Guided by the "Dual-Carbon" goals, the development of fossil energy in the Coal Triangle Region must align with the broader China energy transition trend. It is predicted that China's coal consumption will peak during the 2026-2027 period, with raw coal production also reaching its zenith around the same time, at approximately 5.16 billion tonnes. This will be followed by a 3 to 5-year period of stabilization. As a critical national energy supply base, and considering that coal production in regions such as Xinjiang is still in a growth phase, the raw coal output of the Coal Triangle Region is expected to largely align with the national trend, peaking at 3.68 billion tonnes in 2026-2027. At the provincial level, Shaanxi and Ningxia are forecasted to reach peak coal production earlier in 2026, at approximately 839 million tonnes and 108 million tonnes, respectively. Shanxi and Inner Mongolia are expected to peak in 2027, at around 1.37 billion tonnes and 1.347 billion tonnes, respectively.

Following the peak, coal production is projected to enter a slow decline phase lasting 3 to 4 years, with an average annual decrease of about 1%-2%. Taking into comprehensive consideration the sustained rapid growth of coal production in Xinjiang (China's fourth-largest coal-producing province) and structural changes in national coal consumption, the regional coal supply and demand dynamics are undergoing adjustment. Given that Xinjiang primarily produces high-quality thermal coal with its sales radius concentrated in surrounding regions, while the Coal Triangle Region focuses mainly on coking coal and chemical coal, the two regions exhibit inherent complementarity in coal types and application fields, resulting in limited direct competition in the near term. Consequently, changes in coal production within the Coal Triangle Region are primarily driven by shifts in coal demand from key industrial sectors: on one hand, industries such as steel and cement have already achieved dual peaks in both capacity and output, leading to a rapid decline in coal consumption; on the other hand, the expansion of modern coal-to-chemicals drives an increase in coal demand, while the decline of traditional coal chemical industries (particularly coal-based coke production) contributes to a gradual reduction. Additionally, although coal-fired power generation is expected to peak around 2027, the role of thermal power in grid peak regulation has led to increased coal consumption per unit of electricity generated. As a result, coal consumption for power generation is projected to enter a plateau phase between 2027 and 2030.

After 2030, with the power sector as a whole reaching its peak (coal power generation expected to peak in 2027, and installed capacity projected to peak in 2030), along with the broad implementation of clean production technologies, national coal production is expected to enter a rapid decline phase. During this period, the annual decline rate of national coal production is expected to reach 4%-5% between 2030 and 2040, and 5%-6.5% between 2040 and 2050. The decline in coal production in the Coal Triangle Region is expected to largely mirror the national trend. Between 2050 and 2060, coal production will likely enter a slow-decline phase. By 2060, China's total raw coal output is projected to stabilize at approximately 950 million tonnes, with the Coal Triangle Region contributing around 680 million tonnes. The remaining coal production will serve specific functions in "safety net" and "strategic reserve" capacities. Meanwhile, the carbon emissions generated by residual coal usage in critical energy security sectors will be primarily neutralized through carbon removal technologies such as CCUS and biological carbon sinks, ensuring the achievement of carbon neutrality goals by 2060.

2.4 Development Roadmap for the Coal Triangle Region Under the "Dual-Carbon" Goals

The core of achieving green and low-carbon development in the Coal Triangle Region lies in accelerating the green and low-carbon transformation and innovation of coal-based industries, promoting the transition and upgrading of traditional coal industries toward cleaner, more efficient, recycling-oriented, and diversified directions. Key focuses include developing green technology applications such as hydrogen energy, upgraded coal chemicals, optimized coal power, and advanced coal processing; facilitating integration across the upstream and downstream segments of the industrial chain; enhancing overall energy utilization efficiency and environmental benefits; and ultimately achieving synergistic improvement of economic and ecological outcomes. Table 2-1 presents the development targets for industrial transformation in the Coal Triangle Region under China's national "Dual-Carbon" goals. It is worth noting that if the adoption of renewable energy accelerates on the power generation side and substitution by electric or hydrogen-based industries accelerates on the end-demand side, leading to a faster decline in coal demand, the emission reduction volume projected in the table through carbon removal may be lower.

Guided by this core objective, the region's industrial structure optimization should adopt a "technology-driven, tri-sector coordinated" approach, implementing a "dual-track strategy" that progressively advances both traditional energy cleanup and emerging industry cultivation. In the short term (2025-2035), the Coal Triangle Region should prioritize low-carbon retrofitting and extension of traditional coal-based industrial chains while gradually reducing the secondary sector's share in energy consumption. During the medium-to-long term (2035-2060), the region must accelerate the structural shift from "secondary-sector dominance" to "tertiary-sector leadership," establishing a virtuous cycle of "coal phase-out–new industry cultivation–value addition" to elevate the tertiary sector's proportion above 60%.

Building on this foundation, to systematically advance the low-carbon transition of the regional industry, this report proposes focusing on the "Three New Pillars" to address the fundamental objective of carbon reduction: First, at the energy system level, based on resource endowments, it is essential to balance carbon reduction, energy security, and economic feasibility, promote the clean and efficient use of fossil fuels and the large-scale development of clean energy, and establish a new power system dominated by renewable energy. Second, accelerate the electrification and hydrogen-based transition of coal-related industries, positioning hydrogen energy as a key support for industrial restructuring and fostering a new energy consumption system centred on green hydrogen. Third, strengthen carbon removal capacity building, utilizing technologies such as CCUS as a foundational safeguard to support deep decarbonization and ultimate emission reductions in coal-based industries. Through technology integration and pathway evolution, promote the transformation of coal-based industries from "black dependence" to "green dominance," achieving a systematic green and low-carbon leap. **In the short to medium term, the "Three New Pillars" may not directly generate economic gains, but their long-term economic benefits will emerge as technology costs decline and policies improve. Therefore, pathway planning should combine technology forecasting with socioeconomic benefit assessment. Through supportive industrial and skills policies, technological advantages can be transformed into development dividends and employment opportunities, thereby reducing transition resistance and building social consensus.**

Table 2-1. Energy Industry Transition and Development Goals for the Coal Triangle Region

Development Goals		2024	2030	2035	2060
		Black Energy	Blue Energy		Green Energy
Energy production	**Coal production**	3450 Mt	3250 Mt	2830 Mt	680 Mt
Power system	**Power generation mix** (Thermal power / Other)	21% / 79%	38% / 62%	51% / 49%	11% / 89%
Hydrogen	**Sources of hydrogen**	Grey hydrogen >99%	Grey : Green 6:1	Grey : Green 3:1	Green hydrogen >90%
	The main application fields	Chemical industry	Chemical industry, transportation	Chemical industry, transportation, steel	Chemical industry, transportation, steel, cement, etc.
	Hydrogen demand	~18 Mt	~23 Mt	~28 Mt	>45 Mt
Carbon Removal	**Remove quantity**	< 1 Mt	> 1 Mt	> 10 Mt	300-500 Mt
Industry	**Direct employment in the coal-based industry**	2.03 million people	1.6 million people	1.2 million people	0.3 million people
	Direct employment in the new energy industry	0.18 million people	0.27 million people	0.42 million people	0.65 million people
	The proportion of the GDP in the tertiary industry	49%	50%	52%	>60%

In addition, there are significant differences in industrial foundation among the provinces within the Coal Triangle Region, leading to varied pathways in promoting industrial transformation. Therefore, the focus of industrial restructuring efforts should be tailored accordingly. Shaanxi, leveraging the Yulin National Energy Revolution Innovation Demonstration Zone, focuses on coal grading and utilization, advanced coal-based chemical technologies, and CCUS, while fostering the development of industries such as coal-based specialty fuels and biodegradable materials. Inner Mongolia should prioritize building an integrated industrial cluster encompassing wind, solar, hydrogen, and energy storage, while exploring products that combine “green power + carbon sinks.” Ningxia, highlighting its unique “photovoltaic + desertification control” model, seeks to advance the integration of the solar photovoltaic (PV) industry chain with green hydrogen and coal chemical development. It needs to coordinate low-carbon retrofits in the Ningdong Base with an integrated mechanism for "new energy–ecological restoration–carbon sink development," balancing economic benefits with ecological protection. For Shanxi, however, its transformation should not be limited to energy structure adjustment alone. This is due to its limited renewable energy endowments (as discussed in Section 3) and a notable skill mismatch between job opportunities in emerging renewable energy industries and the existing coal workforce. Consequently, a smooth transition would be difficult to achieve if solely reliant on energy transformation. Therefore, the key to Shanxi achieving a just transition lies in unlocking the diverse potential of industries such as agriculture, cultural tourism, big data, and advanced manufacturing. This approach aims to gradually reduce coal dependence and create safer, more dignified, and sustainable employment opportunities, thereby ensuring the orderly exit of coal-based industries and the seamless integration of successor industries.

3. Development Pathways of Emerging Industries in the Coal Triangle Region

Key Findings:

- The Coal Triangle region boasts exceptional wind and solar resources. Driven by the "Dual-Carbon" goals, its total installed capacity of wind and solar PV power is projected to reach 2.18 billion kW by 2060—7.6 times the 2024 level—establishing it as a nationally leading renewable energy base. Explore the establishment of a "transition development partnership", leveraging the proven model of "paired assistance" to create a framework of cooperation encompassing mutual energy supply, industrial collaboration, and shared benefits.
- During the 15th Five-Year Plan period, the installed capacity of renewable energy is expected to maintain an average annual growth rate of around 15%. Given its inherent variability, the development of smart microgrids, cross-regional transmission, and energy storage systems should be accelerated simultaneously to enhance the integration and utilization of renewable energy.
- Leveraging its large-scale renewable power generation capacity, the region could promote the production and application of green hydrogen. In the near to medium term, it should accelerate the deployment of hydrogen application scenarios, prioritizing technological demonstration for green hydrogen production and transportation. Efforts should focus on expanding its use in sectors such as transportation, chemical manufacturing, and new energy equipment production. This will provide stable low-carbon energy support for downstream industries and comprehensively enhance the competitiveness of the regional new energy industrial chain.
- By integrating renewable energy development with low-carbon retrofitting of traditional industries, the region can foster emerging sectors like carbon removal technologies and artificial intelligence (AI), while promoting innovative models such as "renewables + agriculture" and "renewables + desert control" to achieve the synergistic development of energy transition and eco-service industries.

3.1 Analysis of Renewable Energy Development Pathways in the Coal Triangle Region

The Coal Triangle Region is rich in wind and solar energy resources. Considering geographic features such as land attributes and slope, the total wind power installed capacity potential in the region is estimated to reach

4,071 GW, accounting for 46.8% of the national total installed capacity potential. The wind power generation potential is 8,178 billion kWh, accounting for 27.9% of the national total potential. In terms of solar power generation, the installed capacity potentials of centralized PV and distributed PV are 9,975 GW and 451 GW, respectively, accounting for 23.8% and 12.1% of the national total installed capacity potential. The total solar power generation potential reaches 15,455 billion kWh, accounting for 23.2% of the national total potential. However, in the Coal Triangle Region, the distribution of renewable energy resources varies significantly among the four provinces and regions. Inner Mongolia Autonomous Region, with its vast land area and higher utilization hours for wind power and solar PV than other provinces, provides exceptional conditions for large-scale renewable energy development. In contrast, the total wind and solar resources in Shanxi, Shaanxi, and Ningxia are relatively limited, making it difficult to establish a significant economic advantage solely through resource development scale. Therefore, these provinces should focus more on building a complete industrial chain around new energy, leveraging high-value segments such as new energy equipment manufacturing, integrated energy storage solutions, and the "wind and solar plus other industries" model to drive regional economic growth through industrial chain competitiveness.

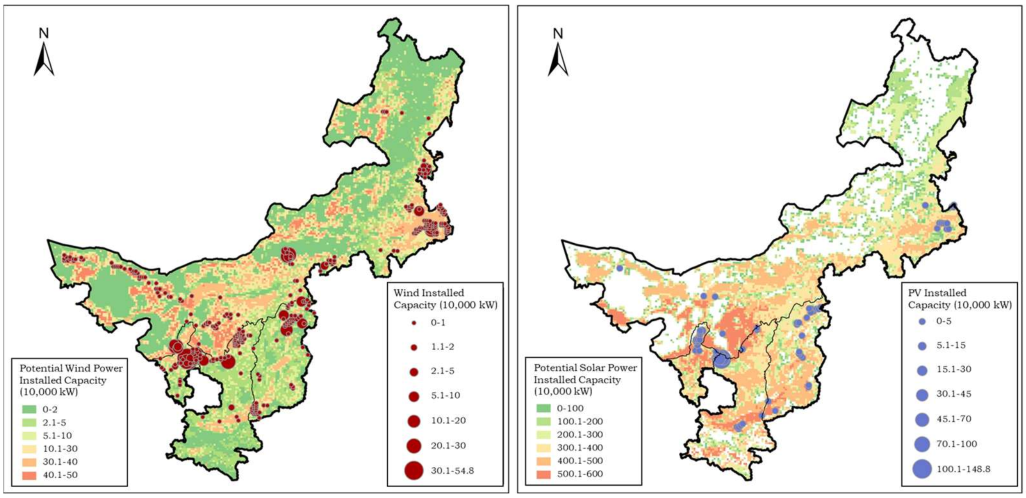

Figure 3-1. Current Status and Potential Distribution of Wind and Solar Power Installations in the Coal Triangle Region

Under the guidance of the national "Dual-Carbon" Goals, China's renewable energy sector is expected to experience rapid development. By 2030, the country's total installed capacity of wind and PV power is projected to reach 2.8 billion kilowatts, with a further increase to 11 billion kilowatts anticipated by 2060. In this process, the Coal Triangle Region—particularly Inner Mongolia Autonomous Region—will play a critically important role in the national renewable energy layout. It is estimated that by 2030, the total installed capacity of wind and PV power in the Coal Triangle Region will reach 590 million kilowatts, rising sharply to 2.18 billion kilowatts by 2060. This highlights the region's central position and immense potential in driving the nationwide energy structure transition.

However, the rapid expansion of large-scale wind and PV power will also pose a series of challenges to the power infrastructure in the Coal Triangle Region. To address the inherent intermittency, instability, and variability of wind and solar power generation, corresponding optimization and upgrades of infrastructure and grid systems are necessary. Especially in the remote areas of the Coal Triangle Region, insufficient infrastructure may hinder project construction and operational efficiency. Therefore, strengthening infrastructure, improving project accessibility, and enhancing operational convenience are critical to realizing large-scale renewable energy development.

Furthermore, as China's major electricity consumption hubs are concentrated in coastal regions, the development of large-scale clean energy bases in the Coal Triangle Region must rely on cross-regional transmission infrastructure and market mechanisms to achieve efficient power delivery. To advance the growth of emerging industries in the Coal Triangle Region, it is essential to explore the establishment of Transformation Development Partnerships with economically developed provinces that have traditionally relied on coal imports. Such partnerships would establish industrial cooperation mechanisms through which these provinces could provide reciprocal support. Building on the proven model of "paired assistance," deep collaboration could be pursued in areas including renewable energy integration, industrial chain coordination, joint market development, technology transfer, and talent cultivation. These efforts would enhance complementary regional advantages and enable efficient resource integration across multiple domains, such as new energy utilization, industrial chain support, technological R&D, and green finance. Coastal provinces could accelerate renewable energy development and industrial upgrading in the Coal Triangle Region through investment and technical support; in return, the Coal Triangle Region could provide a stable supply of green energy and equipment products to its partner provinces, forming a pattern of "mutual energy supply–industrial collaboration–benefit sharing."

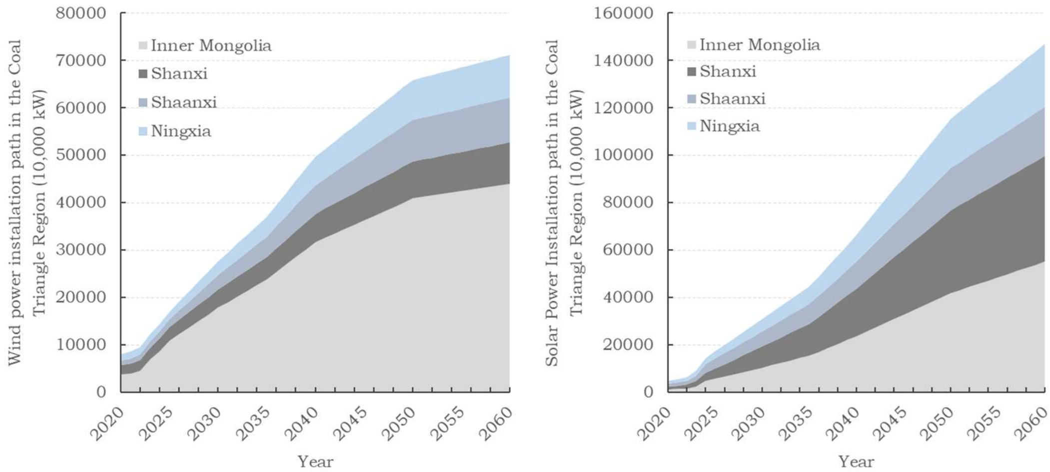

Figure 3-2. Wind and Solar Power Installation Pathway in the Coal Triangle Region Under the "Dual-Carbon" Targets

3.2 Analysis of Green Hydrogen Industry Development Pathways in the Coal Triangle Region

Driven by the large-scale development of renewable energy, the Coal Triangle Region possesses a solid foundation for developing the green hydrogen industry. The abundant wind and solar resources in the region provide a stable and low-carbon power supply for green hydrogen production via water electrolysis, significantly reducing the marginal cost of hydrogen production and expanding its applications in energy and industrial feedstocks. The development of a green hydrogen industrial chain will not only enhance the flexibility regulation capacity and absorption efficiency of renewable energy systems but also drive growth across upstream and downstream manufacturing sectors, including electrolysis equipment, advanced materials, and storage/transportation infrastructure, ultimately establishing a new growth engine to support regional energy transition and industrial upgrading and supporting the sustainable phase-out of coal consumption.

Currently, coal-based industries, particularly coal chemical production, represent the primary consumers of hydrogen in the Coal Triangle Region. The demand for hydrogen as a raw material in processes such as coal-to-ammonia and coal-to-methanol production will persist. Leveraging its abundant renewable electricity resources, the region can promote comprehensive transformation from source to process to system—gradually replacing coal gasification-based hydrogen production with green hydrogen—and establish a new near-zero emission system characterized by green hydrogen supplementation, CO_2 resource utilization, and pipeline network adaptation. Under the pressure of constraints such as emission indicators, coal chemical enterprises should be urged to shift gradually from gray hydrogen to blue and green hydrogen, achieving systemic technological improvements rather than simply expanding coal-based hydrogen production. Over the next 5-10 years, the Coal Triangle Region should take the lead in large-scale application of green hydrogen in new modern coal chemical projects, progressively expanding into existing systems, thereby facilitating deep decarbonization in applications such as hydrogen-based metallurgy and aviation fuel. Meanwhile, hydrogen application in the transportation sector continues to advance, with the region's renewable electricity advantage providing a foundation for large-scale green hydrogen production. It should be noted that, due to constraints in storage and transportation technology, infrastructure, and economic feasibility, green hydrogen will primarily serve local consumption before 2050. By 2060, the annual hydrogen demand in the region is expected to exceed 40 million tonnes, with the chemical industry as the major consumer. As the cost of green hydrogen continues to decline, its annual consumption is projected to reach 37 million tonnes, accounting for over 90% of total demand, thereby providing critical support for the deep decarbonization transition of coal-based industries.

Today, due to the limited application scenarios for hydrogen energy, the development pathway of green hydrogen remains uncertain. The Coal Triangle Region needs to balance technological substitution and risk management by establishing a phased transition plan. In the short term, reliance on gray and blue hydrogen will ensure supply stability while promoting demonstration projects that integrate hydrogen energy with CCUS in coal chemical processes. In the medium to long term, a gradual shift toward green hydrogen should be advanced, coupled with the active development of integrated systems linking renewable power, green hydrogen, and green chemical production. Diversified technology reserves must also be established to ensure the security and feasibility of the energy transition under various development scenarios.

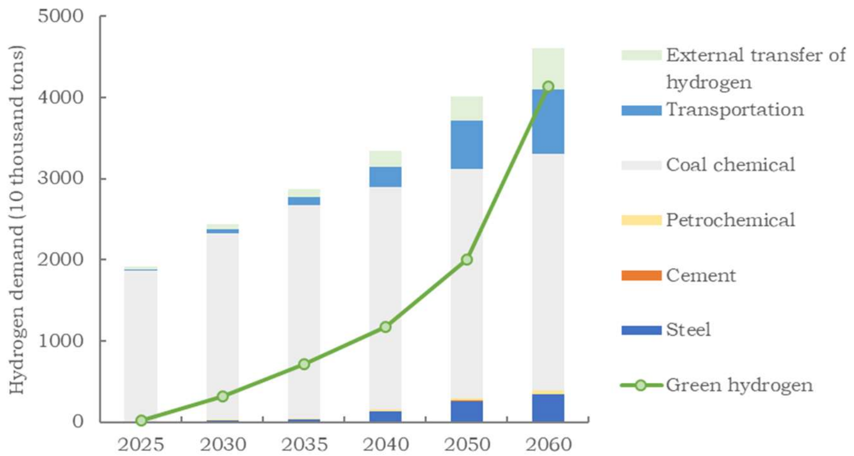

Figure 3-3. Total Hydrogen Demand and Green Hydrogen Demand by Industry in the Coal Triangle Region

Box 3-1：Hydrogen Industry Research in Lvliang, Shanxi Province: Transformation Practices and Challenges of Pengfei Group

Pengfei Group has established a comprehensive production system covering coal (30 million tonnes), coal washing (34 million tonnes), coke (5 million tonnes), methanol (300,000 tonnes), liquefied natural gas (200 million cubic metres), synthetic ammonia (100,000 tonnes), and high-purity hydrogen (20,000 tonnes). It has also expanded into commercial vehicle manufacturing, core hydrogen equipment production, zero-carbon smart logistics, highway and railway transportation, cultural tourism real estate, five-star hotels, and 5G intelligent applications, becoming a large-scale energy enterprise characterized by digitalization, circularity, and low carbon. In recent years, Pengfei Group has accelerated its hydrogen industry development, establishing a full-chain model covering production, storage, transportation, refuelling, utilization, and research while continuing to invest in hydrogen heavy-duty trucks, fuel cell stacks, and equipment manufacturing. During its transition, the enterprise faces several major issues, which to some extent reflect challenges commonly encountered by traditional energy companies:

(1) Inadequate carbon reduction incentives: Currently, China's national carbon emissions trading market has not yet fully covered sectors such as chemicals and transportation, and green hydrogen-related projects remain excluded from the China Certified Emission Reduction (CCER) mechanism. The emission reductions achieved through green hydrogen applications in zero-carbon logistics cannot be effectively quantified or translated into economic benefits, which undermines corporate motivation for emission reduction and weakens the industrial economic viability.

(2) Limited Downstream Hydrogen Applications: The promotion of hydrogen-powered heavy trucks still relies heavily on policy support. Penetration in civilian transportation (e.g., buses and light trucks) remains low, with inadequate market-driven demand, which constrains the sustainable development of the hydrogen value chain.

(3) Cost Pressures and Technological Uncertainty: Influenced by its coal chemical industry base, the cost of gray hydrogen remains below 20 RMB/kg (about $2.82/kg), significantly lower than the cost of producing hydrogen from renewable energy sources such as wind and solar. At present, green hydrogen production capacity is limited and not yet cost-competitive. Meanwhile, hydrogen technologies are evolving rapidly, fuel cell technology routes remain in competition, and derivative industries such as green hydrogen-to-methanol (with a national target of 100 million tonnes) have ambitious development plans, posing potential risks of overinvestment.

Source: Field research conducted by the project team at Shanxi Lüliang Pengfei Group in April 2025.

3.3 Analysis of Development Pathways for Other Emerging Industries in the Coal Triangle Region

In advancing the green and low-carbon transition of the Coal Triangle Region, it is essential to break away from the existing industrial framework and actively diversify into emerging sectors to mitigate potential phased economic downward pressure caused by overcoming the "carbon lock-in" effect. It is recommended to accelerate the development of a new industrial system centered on "wind and solar plus" models and promote context-specific integrated formats such as "renewable power + energy storage", "renewable power + data centres," and "renewable power + low-carbon manufacturing." These efforts will gradually form a cluster-based development pattern characterized by positive interaction between green energy and emerging industries, providing solid support for building a stable, sustainable, and long-term new economic growth pole for the region.

Energy Storage and Power System Support Measures: Accelerate the large-scale deployment of energy storage technologies and multi-energy complementary systems to enhance the regulation capacity and operational stability of the power grid. Promote the development of advanced grid technologies, such as smart grids and flexible DC transmission, to improve electricity transmission and integration capacity. Inner Mongolia can leverage its abundant resources to expand the scale of its clean energy and energy storage industries and boost regional absorption capacity. Shanxi, Shaanxi, and Ningxia should coordinate wind and solar installation planning with grid development, promote synergy between traditional and clean energy sources, and achieve optimized energy structures and efficient system operation.

AI and Data Centres: The Coal Triangle Region holds significant potential for developing low-carbon digital industries. With abundant green power resources and relatively low land and cooling costs, areas such as Inner Mongolia and Ningxia can accelerate the deployment of low-carbon data centres and AI industry clusters, contributing to the implementation of the national "Eastern Data, Western Computing" initiative and serving the data processing needs of eastern China. To fully leverage local advantages such as rich renewable electricity and a robust manufacturing base, planning and guidance for high-performance computing centres should be strengthened, coupled with precise engagement with leading enterprises in the information industry and the promotion of green energy supply systems for data centres, alongside the construction of green energy supply systems for data centres, enabling integrated development of generation–grid–load–storage–computing. Meanwhile, digital technologies can support the intelligent upgrading of regional industries, offering digital transformation solutions for sectors such as traditional energy and manufacturing.

Carbon Removal Industries: The Coal Triangle Region has both the necessity and potential to develop a carbon removal industry. Estimates suggest that by 2060, the region's carbon removal demand will reach approximately 300 million to 500 million tonnes. The region can participate through multiple pathways such as CCUS, biomass energy with carbon capture and storage (BECCS), soil carbon sequestration, and mineralization storage. Although current carbon removal technologies are unlikely to generate significant economic benefits in the short term, it is noteworthy that China's voluntary greenhouse gas emission reduction program has already included carbon sink projects such as afforestation. Moreover, as the national carbon market mechanism continues to improve, emission-reduction benefits achieved through other carbon removal technologies are expected to be incorporated into the national carbon trading system. This will further stimulate the development of related technologies while generating substantial low-carbon revenue and green benefits for enterprises. Additionally, carbon removal projects can be integrated with cultural tourism industries—for instance, by establishing negative-carbon ecotourism demonstration zones—to enhance industrial diversification value and regional ecological service functions.

New Energy–Ecotourism Coupled Industries and Green Services: The region should fully tap into its traditional energy legacy and ecological resources to promote the integration of renewable energy, ecological restoration, and cultural tourism. For example, solar PV projects can be built on decommissioned coal mine sites, serving both power generation and environmental remediation. Coal enterprises are encouraged to shift investment toward renewable energy, broaden their business scope, and drive the integrated development of "wind and solar + agriculture/desertification control" models. These efforts aim to create emerging service industry clusters supported by green energy, facilitating the transition of traditionally energy-dependent areas toward green service economies, optimizing employment structures, and promoting high-quality regional economic development.

Cultural and Tourism Industry: The Coal Triangle Region lacks in-depth exploration and broad development of its cultural tourism potential, as well as the necessary infrastructure and promotional channels. These are precisely the strengths possessed by governments, scholars, and businesses in the Pearl River Delta and Yangtze River Delta, where market-oriented economies have a longer history. Building on local cultural and natural resources, efforts should focus on jointly planning themed tourism activities, developing cultural creative products, creating digital twins of scenic spots, and co-establishing regional tourism brands to drive the growth of the cultural tourism market.

Agriculture: As a distinctive industry in the Coal Triangle Region, agriculture should prioritize the refinement and upgrading of coarse grain processing. Leveraging industrial resources from developed regions, bridges should be built to connect with high-end enterprises, fostering deep collaboration in areas such as origin management, product deep processing, brand marketing, and e-commerce channel development. Simultaneously, driven by local demand, advanced technology and production capacity should be introduced to promote the localized manufacturing of wind and solar power equipment, facilitating the transition of local manufacturing toward green, low-carbon, and high-end smart production.

From an overall industrial development perspective, the Coal Triangle Region urgently needs to leverage industrial parks as platforms to promote the deep integration of emerging industries with regional resources. By developing zero-carbon parks, especially through cooperation with "Transformation Development Partnership" provinces and regions, diverse sectors, such as renewable energy equipment manufacturing, carbon removal technologies, hydrogen utilization, digital economy, and modern services, can be clustered, creating industrial chain synergies and scale effects. In this process, zero-carbon parks serve not only as key hubs for the transformation and upgrading of traditional industries but also as experimental grounds for nurturing emerging industries and exploring institutional innovations.

Box 3-1: Datong's Energy Transition – From "Coal Monoculture" to "Diversified Economic Pillars"

Datong, once renowned as the "Coal Capital," has supplied over 3 billion tonnes of coal to the nation since the founding of the People's Republic. However, this reliance led to ecological degradation and an overly narrow economic base. In the late 1990s, Datong prioritized structural adjustment, shutting down mines and phasing out backward production capacity to create space for industrial transformation.

Energy City: While upholding its political responsibility to ensure national energy security through coal, Datong has deepened comprehensive energy revolution reforms, steadfastly pursuing a green future. During the 14th Five-Year Plan period, the city leveraged its abundant wind and solar resources and cool climate to accelerate the construction of the Northern Shanxi New Energy Base. By 2024, Datong's total power installation reached 17.55 GW, with renewables accounting for 54% of the mix—nearly 4 percentage points higher than the provincial average. Four independent energy storage projects, with a total capacity of 320 MW, were connected to the grid, ranking first in Shanxi.

Computing Capacity City: Leveraging green electricity, Datong integrated its computing capacity industry into the national "East Data, West Computing" initiative, the Beijing-Tianjin-Hebei synergy, and the nationwide computing capacity network. The city expanded its computing industry scale, optimized policy support, and built industrial chain clusters, accelerating its development as an influential computing power hub near the capital. Since 2018, leading enterprises such as Qinhuai Data, JD.com, and Douyin have invested over 28.2 billion RMB (approximately $3.97 billion) in computing infrastructure, propelling Datong to third place nationally in urban computing capacity sub-index rankings.

Cultural City: Datong has strengthened the protection and utilization of cultural relics, advanced research in Yungang studies, and vigorously developed cultural tourism. The city is transforming its ancient urban core into a comprehensive tourism and consumption hub, pursuing UNESCO 5A status for the Hengshan scenic area, and accelerating the development of high-quality clusters like the Yungang Grand Scenic Area. By integrating culture and tourism with wellness, agriculture, industry, commerce, and sports—and synergizing with museums, creative industries, and the arts—Datong is fast becoming an internationally renowned cultural tourism destination. The Jinhua Palace Mine, once a source of pollution near the Yungang Grottoes, has been repurposed into a mining park and is now one of China's first industrial heritage tourism bases, and a key stop on tourist itineraries.

Source: Shanxi Youth Sustainable Development Public Service Center

4. Research on the Construction Model of Zero-Carbon Industrial Parks in the Coal Triangle Region

Key Findings:

- Industrial parks serve as the cornerstone of economic development in the Coal Triangle Region, with resource-dependent industrial parks accounting for 33.7% of provincial-level and above parks—representing the dominant model—while emerging industry parks remain underdeveloped.
- Building upon the establishment of Zero-Carbon Industrial Parks, upgrading to create Zero-Carbon Trade Demonstration Zones will serve as a strategic opening move in building green zero-carbon industrial chains and products. It will also act as a key mechanism for driving green transformation in traditional high-carbon regions and stimulating domestic industrial upgrading, while providing a pilot platform for integrated innovation in policy, market, and financial mechanisms.
- Leveraging the energy base advantages of the Coal Triangle Region and aligning with international carbon accounting standards, the development of Zero-Carbon Trade Demonstration Zones should establish a core indicator system covering carbon footprint accounting, energy mix optimization, and green supply chains. This will enable effective alignment with both domestic and international standards.

4.1 Current Status of Industrial Park Development in the Coal Triangle Region

Industrial parks are vital platforms for advancing green and low-carbon industrial transformation. Since the concept of zero-carbon industrial parks was first introduced in 2024, their role in fostering resource aggregation and driving technology adoption has become increasingly significant. In the Coal Triangle Region, where the industrial structure remains highly dependent on energy inputs, the regional energy mix directly shapes the carbon footprint and international competitiveness of local products. This highlights the need to explore more systemic and distinctive mechanisms to guide the transition.

According to statistics, the Coal Triangle Region hosts a total of 169 provincial-level and above industrial parks, including 14 national-level economic development zones, 14 national-level high-tech industrial development zones, and 141 provincial-level development zones. Among the leading industries of these parks, resource-dependent sectors—such as coal, coal chemicals, coal-fired power, electricity, metallurgy, and chemicals—dominate, with 57 parks (33.7% of the total), reflecting the region's heavy reliance on coal resources and energy-intensive industries. The equipment manufacturing sector follows, with 47 parks (27.8%). Although it accounts for a relatively large proportion, its sub-sectors are primarily concentrated in mining machinery and coal chemical equipment, meaning it still remains embedded within the coal industrial system. In contrast, the development of emerging industries—including new energy, biopharmaceuticals, electronics, and automotive manufacturing—remains underdeveloped, accounting for only 36 parks (21.3%). This reveals a notable structural imbalance in the region's industrial development.

The 169 industrial parks at or above the provincial level are core economic platforms for the region. In 2023, they generated 4.8 trillion RMB in industrial output above the designated size, accounting for 48.5% of the total industrial output of the four provinces. However, these parks also contributed significantly to emissions: total carbon emissions reached 636 million tonnes, accounting for about 33% of the region's total emissions, with an average carbon intensity of 1.325 tonnes per 10,000 RMB output. Coal chemical industries, which remain the region's most strategically important pillar sector, showed strong economic output but disproportionately high emissions. In 2023, Ordos Modern Coal Chemical Industry Demonstration Zone achieved an output of 208 billion RMB; Shaanxi Yulin Coal Chemical Demonstration Zone reached 133.83 billion RMB; Ningxia Ningdong Coal Chemical Demonstration Zone reached 180 billion RMB. Together, these three zones—Yulin, Ordos, and Ningdong—generated a total of 521.84 billion RMB, accounting for 10.9% of total park output. However, their combined carbon emissions reached 174 million tonnes, accounting for 27% of total industrial park emissions, with an average carbon intensity of 3.334 tonnes per 10,000 RMB output, far exceeding the national average for development zones. This underscores the urgency of emission reduction efforts in the sector.

4.2 The Practical Implications of Zero-Carbon Industrial Park Development

Since the Central Economic Work Conference first proposed "establishing a batch of zero-carbon industrial parks" in late 2024, their development has gradually become a national strategic priority. The 2025 Government Work Report listed it as a key annual task, and in July 2025, the National Development and Reform Commission (NDRC), the Ministry of Industry and Information Technology (MIIT), and the National Energy Administration (NEA) jointly issued the Notice on Promoting the Development of Zero-Carbon Industrial Parks. This document, for the first time, unified construction standards, certification procedures, and supporting policies at the national level, marking the transition of zero-carbon parks from local pilots to a systematic and scaled implementation phase.

Concurrently, in May 2025, the NDRC and NEA released the Notice on Orderly Promoting Direct Green Electricity Connections, which clarified institutional incentives such as "dedicated green power transmission lines, separate electricity quota management, and negotiated pricing mechanisms." This laid the policy foundation for establishing stable and traceable green power supply systems within industrial parks.

Against this backdrop, the development of zero-carbon industrial parks has evolved beyond mere technological upgrades into a systematic engineering endeavour involving energy system restructuring, industrial adjustment, and institutional innovation. On one hand, it requires deep decarbonization of key sectors within parks—including industrial production, building operations, and transportation—while accelerating the large-scale application of advanced low- and zero-carbon technologies. On the other hand, it necessitates the integration of negative emission approaches, such as carbon removal and ecological carbon sinks to ensure net-zero emissions at the park level. For the Coal Triangle Region, this process not only entails the green transformation of traditional industrial parks but also emphasizes a comprehensive pathway centred on direct green power connections, energy-efficiency improvements, carbon management services, and industrial structure optimization.

However, current zero-carbon park initiatives primarily focus on Scope 1 and Scope 2 emissions.[2] These efforts aim to increase the share of green power through integrated "source-grid-load-storage" systems, supplemented by green certificate trading and carbon offset mechanisms to achieve net-zero operational emissions. Due to constraints in data availability, accounting capabilities, and management responsibilities, the accounting and management of Scope 3 emissions have not yet been systematically incorporated into the zero-carbon park framework. Looking ahead, zero-carbon park development should target comprehensive coverage of Scopes 1 to 3, driving full-process net-zero greenhouse gas emissions while balance phased implementation, feasibility, and strategic vision in pathway design. **Based on this, the report proposes exploring the establishment of a Zero-Carbon Trade Demonstration Zone in the Coal Triangle Region as an upgrade and extension of the Zero-Carbon Industrial Park. From an industrial chain perspective, the demonstration zone will strengthen the park's exemplary and leading role, expand the scope of demonstration, and promote industrial upgrading and energy mix optimization in high-carbon areas.**

4.3 Positioning and Development Objectives of the Zero-Carbon Trade Demonstration Zone

The core mission of establishing the Zero-Carbon Trade Demonstration Zone lies in innovating the institutional system for domestic and regional export of zero-carbon products, building a demonstration hub for low-carbon technologies and enterprise applications and establishing a cross-regional resource integration platform based on the entire industrial chain. The zone should focus on formulating standards, certification, and international alignment of zero-carbon products, thereby comprehensively enhancing the competitiveness of green and low-carbon industries in the Coal Triangle Region. **It emphasizes a full industrial chain perspective, promoting multi-park collaboration to systematically embed green electricity direct supply, carbon footprint certification, and green finance into industrial clusters. This enables deep integration of the domestic green economy, achieving unified development of industrial synergy and low-carbon transactions.** While zero-carbon industrial parks focus on corporate emissions reduction and energy substitution, the demonstration zone places greater emphasis on integrated innovation in policy coordination, market mechanisms, and financial instruments. It particularly aims to attract private and foreign capital participation to stimulate market vitality. Therefore, establishing a Zero-Carbon Trade Demonstration Zone serves both as a key lever to drive the green transition of traditional high-carbon regions and domestic industrial upgrading, and as a demonstration measure to promote the development of zero-carbon industrial chains.

As the core production base of China's energy-intensive products, the Coal Triangle Region plays a critical role in highly carbon-intensive industries such as the energy and coal chemical sectors. It also constitutes a decisive link in the lifecycle carbon footprint of many products. Compared with other regions, the manufacturing sector is heavily reliant on energy supplied by the Coal Triangle Region, and the product carbon intensity is deeply intertwined with the regional energy mix. Therefore, optimizing the region's energy structure and building a green production system will directly support efforts to reduce the carbon footprint of

[2] Scope 1 covers direct emissions within the park; Scope 2 covers indirect emissions from purchased electricity and heat; Scope 3 includes other indirect emissions across the lifecycle, such as upstream and downstream supply chains, product use, and disposal.

Chinese manufacturing.

The Coal Triangle Region possesses significant renewable energy resources that allow for large-scale green power integration. It can not only take the lead in achieving direct green power supply and industrial integration, thereby systematically reducing the carbon intensity of export products, but also develop an advanced model that goes beyond conventional green power supply parks and zero-carbon industrial parks. The Zero-Carbon Trade Demonstration Zone can leverage international carbon trading mechanisms, such as the Paris Agreement Article 6 framework.[3] By adopting such mechanisms, the zone can facilitate compliant carbon asset trading and international cooperation on emission reductions, ultimately driving the restructuring and upgrading of regional industrial chains. In addition, leveraging its comprehensive datasets on coal, coal-based production, and the full coal chemical process, the region is well-positioned to establish a traceable and verifiable carbon footprint accounting system that meets international standards for carbon disclosure and certification, thereby enhancing the compliance and competitiveness of its products in overseas markets.

Therefore, the development indicator system for the Zero-Carbon Trade Demonstration Zone must align with five key dimensions—environmental, economic, technological, policy, and social objectives—and precisely connect with international standards and China's domestic "Dual-Carbon" policy framework. Table 4-1 summarizes the proposed core development indicators for the zone, organized around seven key action areas. Quantitative targets should be adapted based on the specific characteristics and adaptability of local parks. Overall, the development indicators for the Zero-Carbon Trade Demonstration Zone should adhere to the principles of measurability, traceability, and benchmark ability. They must not only comply with internationally advanced carbon footprint accounting standards but also remain consistent with China's carbon accounting systems for zero-carbon parks, ensuring methodological coherence. By dynamically optimizing the indicator system, weaknesses (such as technological bottlenecks or policy delays) can be accurately identified, facilitating the zone's transition from a "low-carbon pilot" to a "global zero-carbon benchmark."

Table 4-1. Recommended Indicators for the Development of Zero-Carbon Trade Demonstration Zones

Evaluation Framework	Indicators	Explanation of Indicators
Carbon Emissions and Resource Efficiency	Carbon Intensity Indicators	• Carbon emissions per unit of GDP (tonnes CO_2 / 10,000 RMB) • Carbon footprint of key industries (steel, aluminum, chemical) products (kg CO_2e/tonne of product) • Proportion of green electricity usage (%) • Installed capacity of renewable energy (GW)
	Resource Efficiency in Recycling	• Industrial solid waste comprehensive utilization rate (%) • Water resource reuse rate (%) • Raw material substitution rate in key industries (e.g., proportion of green hydrogen substituting coke)
Low-Carbon Industry and Supply Chain	Effectiveness of Industrial Transformation	• The proportion of value added by low-carbon industries in GDP (%) • The export scale of green products, such as green hydrogen, green steel, and green aluminum (10,000 tonnes/year).
	Supply Chain Sustainability	• Percentage of key enterprises' suppliers meeting carbon performance standards (%) • The proportion of green logistics (such as the usage rate of hydrogen-powered transport vehicles, penetration rate of

[3] The Article 6 mechanism establishes an intergovernmental cooperation framework for international emissions reduction trading, emphasizing mutual recognition and transfer of nationally determined mitigation outcomes to help countries collectively achieve climate targets. It incorporates the "cooperative approaches" (Article 6.2) and "sustainable development mechanism" (Article 6.4), featuring strong international coordination and compliance standards

Evaluation Framework	Indicators	Explanation of Indicators
		electric heavy trucks, and the fleet size of new energy commercial vehicles).
Technological Innovation and Infrastructure	Technology Research, Development, and Application	• Zero-carbon technology patent quantity (items/year) • Proportion of disruptive technology commercialization application
	Infrastructure Support	• Smart grid coverage rate (%) • Green hydrogen refuelling stations/charging and swapping network density • Carbon capture and storage facility capacity (million tonnes CO_2/year) • Proportion of star-rated green buildings (%) • Establishment of a unified carbon emission data platform • Real-time monitoring of direct and indirect emissions during the production process of enterprises
Policy and Market Mechanism	Effectiveness of Policies	• Whether specific carbon accounting standards have been established for the demonstration zone, and whether they are consistent with the EU's accounting boundaries • Whether tax reductions, subsidies, and other incentive measures have been formulated and implemented to encourage the use of renewable energy and low-carbon technologies • Corporate carbon tax/carbon trading participation rate (%) • Scale of green financial tools (such as the issuance of transition bonds, carbon-backed loans)
	Market Incentive Mechanism for Zero-Carbon Products	• Whether to establish a "Green Product List" to give priority support to low-carbon products and promote market recognition of their emission reduction contributions • Whether to implement a "Zero-Carbon Whitelist" system, classifying and managing products that use over 70% green electricity and rank in the top 5% in industry carbon intensity, granting them preferential support in market access, procurement guidelines, and certification labelling
Social Equity and Coordinated Development	Employment and Just Transition	• Number of new jobs in the new energy industry (hundreds/year) • Retraining rate of traditional energy workers (%) • Female employment proportion (%)
	Public Participation and Well-Being	• Public awareness of low-carbon practices • Air quality improvement index (annual $PM_{2.5}$ concentration reduction rate)
International Compliance	Alignment with International Rules	• Types of zero-carbon products certified internationally • Number of cases involved in the formulation of international standards • Number of international technology cooperation projects

5. Financial and Fund Mechanisms to Support the Transition of the Coal Triangle Region

Key Findings:

- Although the Coal Triangle Region has initially established a transition finance support system, with each area developing distinct pathways and priorities, problems such as a mismatch between capital supply and demand, insufficient policy coordination, and the absence of risk-sharing mechanisms persist. These issues have yet to effectively stimulate capital participation in the transition process.
- Estimates indicate that the Coal Triangle Region will require approximately 1.8 trillion RMB ($254 billion) for low-carbon transition over the next 5 years, of which 1 trillion RMB ($141 billion) can be addressed through market-based financing, mainly for renewable energy and industrial retrofitting. The remaining demand, such as for just transition and ecological restoration, will continue to rely on fiscal support.
- It is recommended to establish a regional Green Development Transition Fund, with the primary goal of systematically advancing the low-carbon transformation of energy and industry in the Coal Triangle Region through diversified financing support and targeted investment, with a focus on projects that deliver significant carbon reduction benefits and inclusive development outcomes.

5.1 Current Status of Policies, Funds, and Financial Support for the Coal Triangle Region's Low-Carbon Transition

5.1.1 Financial Support for the Low-Carbon Transition in the Coal Triangle Region

Under the guidance of the national Dual-Carbon strategy, the provinces within the Coal Triangle Region have preliminarily established transition finance support systems, each with distinct pathways and focal points (Table B-1 in Appendix B). In August 2023, Shanxi issued the country's first Just Transition Loan to support the low-carbon transition of Jinneng Coal Group, with part of the funding specifically allocated for employee skills training. This marked an early exploration of a dual-focus model that integrates enterprise decarbonization with employment protection. Leveraging its foundations in green and intelligent coal transformation, Inner Mongolia has actively sought policy-based financial support from institutions such as the China Development Bank and has developed coal power transition loan products and dedicated funds. Shaanxi has focused on advancing the R&D and application of technologies for the clean and efficient utilization of coal, offering diversified financing tools through innovative financial products like green credit and green bonds. Ningxia, in addition to utilizing national and local green finance policies, has strengthened cooperation with multilateral development finance institutions to secure international low-cost capital and design financial tools tailored to the region's coal industry transformation needs.

Overall, current financial practices supporting transition in the Coal Triangle Region primarily centre on five areas:

First, supporting R&D of key technologies such as carbon capture and storage and integrated gasification combined cycle, promoting clean and efficient use of coal;

Second, encouraging the development of clean energy sources such as wind power, solar PV, and natural gas to enhance energy substitution capacity;

Third, promoting financial institutions to develop diversified financing products, including transition loans, green bonds, and sustainability-linked bonds;

Fourth, leveraging fiscal interest subsidies, industrial guidance funds, and fast-track green approval channels to mobilize broad participation of private capital;

Fifth, actively seeking low-cost financing and technical cooperation from multilateral financial institutions to strengthen financial security for regional green transition efforts.

5.1.2 Current Status of Fund Support for the Low-Carbon Transition in the Coal Triangle Region

The provinces in the Coal Triangle Region have been actively exploring the use of dedicated funds to support low-carbon transition, but there are significant disparities among local transition funds, and overall, the momentum they provide for the region's energy transformation remains insufficient.

In Shanxi, government-guided funds mainly focus on the energy sector, commercialization of technological achievements, and innovation-driven transformation of private enterprises. These efforts aim to support the energy revolution and economic upgrading. However, issues such as idle capital persist, and differentiated adjustments are urgently needed to improve targeting and effectiveness.

Inner Mongolia's transition funds started relatively late but are larger in scale. Their investments cover areas such as state-owned enterprise transformation and major projects. In recent years, these funds have begun to shift toward cities and counties, with increasing emphasis on innovation, entrepreneurship, energy conservation, environmental protection, and new energy sectors. However, due to limited experience and a weak industrial base at the county level, investment efficiency remains suboptimal.

Shaanxi has a relatively high proportion of industrial guidance funds with a broad investment scope. Nevertheless, it faces challenges such as small fund size and lack of synergy and thus requires structural optimization and enhanced coordination.

Ningxia's industrial guidance funds span multiple sectors, but some investments have been directed toward overcapacity industries or high-risk enterprises. Stronger alignment with industrial policy is needed, and green performance indicators should be incorporated into investment decision-making processes.

Overall, while local funds have played an active role in promoting low-carbon transition, a number of problems have also surfaced. Targeted improvements are needed to enhance their effectiveness.

5.1.3 Existing Issues in Transition Finance and Fund Support for the Coal Triangle Region

The financial and funding support for the low-carbon transition in the Coal Triangle Region faces three prominent issues. First, there is a mismatch between capital supply and demand. High-tech private enterprises struggle to secure financing, while some government funds remain underutilized due to overly stringent criteria and unclear exit mechanisms, creating a paradox where "companies await funds, and funds await viable projects." Second, inadequate policy coordination results in inconsistent eligibility requirements and accounting standards across green credit, bonds, and subsidies. Cumbersome approval processes lead to financial institutions being "willing to lend but hesitant to act" and enterprises "eligible but unable to navigate applications." Third, the absence of risk-sharing mechanisms means existing credit enhancement and insurance systems fail to cover technological and market uncertainties. The lack of rational risk and benefit distribution among government entities, financial institutions, and social capital hinders effective capital inflow.

5.2 Analysis of Funding Demand for Industrial Low-Carbon Transformation in the Coal Triangle Region

Achieving a low-carbon industrial transition requires substantial financial investment. Based on the coal industry chain, including coal mining, coal chemicals, power systems, and major coal-consuming sectors such as steel and cement, this report estimates the Coal Triangle Region's funding needs for 2025-2030. The total investment required is approximately 1.8 trillion RMB ($253.52 billion), with an average annual demand of more than 300 billion RMB ($42.25 billion). For key projects, cumulative investment in coal mine closures and retrofitting between 2025 and 2030 is projected at 15.14 billion RMB ($2.13 billion), averaging 3.03 billion RMB ($0.43 billion) annually. In terms of industrial transformation, low-carbon technological upgrades in the coal chemical sector will require particularly large investments, totalling 437.28 billion RMB ($61.61 billion) over 2025-2030, or 87.46 billion RMB ($12.32 billion) per year. For downstream industries, the steel sector's transition—including electric arc furnace steelmaking, hydrogen-based direct reduction, energy efficiency upgrades, and carbon capture technologies—is estimated to need 306.3 billion RMB ($43.15 billion), averaging 61.26 billion RMB ($8.63 billion) annually. The cement industry will require around 37.74 billion RMB ($5.32 billion) for low-carbon transformation during the same period, equivalent to 7.55 billion RMB ($1.06 billion) per year. Regarding the energy transition, total funding needs for 2025-2030 in the Coal Triangle are estimated at 987.33 billion RMB ($139.02 billion), with an annual average of 197.47 billion RMB ($27.76 billion). Compared with existing estimates, the transition funding gap for Shanxi's three major industries—coal-fired power generation, steel, and coking—alone is expected to exceed 800 billion RMB ($112.68 billion) during 2025-2035.

Table 5-1. Key Focus Areas and Investment Pathways for Low-Carbon Transition in the Coal Triangle Region[4]

Coal Industry Chain	Main Industries	Direction of Transition	Capital Requirements for 2025-2030 (billion RMB)	Capital Requirements for 2025-2030 (billion USD)
Upstream	Coal mining and washing industry	Coal mine shutdown and renovation	15.1	2.13
Midstream	Coal chemical industry	Low-carbon transformation technology upgrading	437.3	61.61
Downstream	Power systems	Development of new-type power systems	987.3	139.06
	Steel industry	Capacity optimization and low-carbon transformation technology renovation	306.3	43.15
	Cement industry	Capacity optimization and low-carbon transformation technology renovation	37.7	5.32
Personnel compensation and skills training			215.0	30.28

4 The items "personnel compensation and skills training," "ecological restoration in coal mining areas," and "Construction of zero-carbon industrial parks" are overlapping categories and therefore are not double-counted in the total capital requirements.

Coal Industry Chain	Main Industries	Direction of Transition	Capital Requirements for 2025-2030 (billion RMB)	Capital Requirements for 2025-2030 (billion USD)
Ecological restoration in coal mining areas			12.2	1.72
Construction of zero-carbon industrial parks			216.0	30.42
Total			**1,781.0**	**253.52**

Data source: Derived from the transition pathway estimations conducted in Chapters 2 and 3 of the report.

5.3 Coal Triangle Region Green Development Fund Proposal Study

The financing potential of transition projects in the Coal Triangle Region shows clear polarization. Public-welfare-oriented projects—such as coal mine closures, ecological restoration, and just transition measures (approximately 230 billion RMB, $32.4 billion)—are highly dependent on central and local fiscal transfers and policy-based funding support. In contrast, projects with clear revenue prospects, including emerging industries such as renewable energy and energy storage (exceeding 1 trillion RMB, $140.8 billion) as well as traditional industrial retrofitting projects (over 780 billion RMB, $110.0 billion), demonstrate relatively high bankability. These projects are expected to attract 50%-90% of market-based financing and will become priority areas for diverse financial instruments, such as green credit, bonds, industrial funds, and REITs. Therefore, the key to successfully advancing the green and low-carbon transition in the Coal Triangle Region lies in **fully leveraging fiscal transfers to mitigate social costs, fill fiscal revenue gaps, and prevent systemic risks, while also activating the commercial viability of operational projects through institutional innovation to effectively crowd in private capital**.

Based on this, it is recommended to establish **a regional Green Development Fund** in the Coal Triangle Region and build a diversified financial support system centred on fiscal transfers, supplemented by coordinated market and private capital participation. Especially in the initial stage of the fund, within the limits of available resources, general transfers should be optimized to ensure fiscal stability at the grassroots level. At the same time, special transfer programs—such as those for coal phase-down, emerging technology cultivation, and cross-regional ecological compensation—should be introduced and combined with market-based financing to gradually form a multi-level financial toolbox. Under the framework of relevant national transition funds established by the government, sub-funds dedicated to this region or key industries can be established to leverage the guiding role of existing platforms such as the National Green Development Fund, optimize capital allocation, unify policy standards, and diversify investment risks, thereby providing comprehensive and systemic support for the Coal Triangle Region's green and low-carbon transition. Fund investments should strictly follow the policy orientation of the Coal Triangle Region's energy and industrial transition. Priority should be given to mature projects with significant carbon-reduction benefits, with preference for those that commit to absorbing transitioning workers and promoting employee stock ownership programs. Inclusive development models, such as "solar PV + community employment," should also be actively explored. The Green Development Fund should focus its investments on the following areas:

Energy Structure Optimization: Support flexibility retrofitting projects for existing coal power facilities, as well as large-scale new energy base projects and industrial chain upgrading initiatives under the "renewable energy+" model.

Industrial Energy Conservation and Carbon Reduction: Invest in modern coal chemical projects that achieve industry-leading energy-efficiency and carbon emission indicators, including efficient utilization projects for low-quality coal resources and merger and acquisition projects.

Circular Economy Field: Projects for the treatment and resource utilization of bulk industrial solid wastes such as fly ash and coal gangue.

Innovative Technology Application: Green hydrogen, CCUS projects, and their integrated applications with traditional coal-based industries.

Ecological Protection and Restoration: Ecological restoration of mines, desertification control, “photovoltaics + ecological restoration”, and other ecological product value realization projects.

Zero-Carbon Industrial Parks Construction: Special support for the development of Zero-Carbon Trade Demonstration Zones, Zero-Carbon Industrial Parks, and cluster-based industrial incubation.

In terms of investment approaches, equity investment, equity-debt combinations, and investment-loan linkages will be the primary flexible instruments, while innovative tools such as private REIT funds and market-oriented debt-to-equity swaps will also be explored. At the operational level, fiscal transfer payments will serve to “stabilize the fundamentals and cover reform costs”, while the Green Development Fund will “leverage new investment and foster new growth engines”. Together, they will work in synergy to form a systematic financial solution that balances equity and efficiency, stability and development.

Table 5-2. Financing Feasibility Analysis of the Coal Triangle Region’s Industrial Transition Funding Needs

Category	Transition Direction	Bankability	Estimated Market-Based Financing (billion RMB)	Estimated Market-Based Financing (billion USD)	Funding Sources
Traditional energy industry transition	Coal mine closure and ecological restoration	Low (★)	0	0	Lead: Government fiscal funds
	Thermal power capacity retrofitting	Relatively high (★★★) Expected to attract 60%-80% of market-based financing	25-34	3.5-4.8	Lead: Green credit, infrastructure REITs Supplementary: Fiscal subsidies
	Low-carbon technological transformation in the coal chemical industry	Medium (★★) Expected to attract 50%-70% of market-based financing	200-300	28.2-42.3	Lead: Green credit, green bonds, financial leasing Supplementary: Self-investment, fiscal subsidies
	Steel capacity optimization and low-carbon		150-220	21.1-31.0	

Category	Transition Direction	Bankability	Estimated Market-Based Financing (billion RMB)	Estimated Market-Based Financing (billion USD)	Funding Sources
	technological transformation				
	Cement capacity optimization and low-carbon technological transformation		10-27	1.4-3.8	
New energy industry	New energy and related industries development	High (★★★★) Expected to attract 80%-90% of market-based financing	750-850	105.6-119.7	Lead: Green credit, infrastructure REITs, government industry funds Supplementary: Self-investment, green bonds
	Energy storage and a new power system	Medium (★★) Expected to attract 50%-70% of market-based financing	30-45	4.2-6.3	Lead: Government industry funds, venture capital (VC)/private equity (PE) Supplementary: Green credit
Others	Just transition	Low (★)	0	0	Lead: Government fiscal funds

6. Study on the Just Transition of Traditional Energy in the Coal Triangle Region

Key Findings:

- Just transition aims to ensure that affected groups and regions achieve dignified and sustainable development during the process of climate and environmental governance through coordinated resource allocation, improved social safeguards, and complementary industrial policies.
- The energy transition in the Coal Triangle Region will lead to a significant reduction in jobs in coal-related industries, while the short-term capacity of emerging industries to absorb labor remains limited, potentially resulting in temporary employment gaps and structural unemployment pressures. By 2060, the number of direct jobs created in new energy industries is expected to exceed 650,000, with total employment generated by the sector surpassing 1.4 million, helping to ease long-term employment pressures. At the same time, the transition is expected to create more opportunities for women in the workforce.
- The Coal Triangle Region's strategic role in China's energy security system means transition costs and social risks are heavily concentrated locally. Proactive deployment of just transition mechanisms can mitigate social disruptions and promote more equitable benefit distribution.
- Policy mechanisms for a just transition should include: regional differentiated transition planning, diversified vocational training systems, enhanced social security and reemployment support, incentivized private capital investment in emerging industries, a monitoring and regulatory mechanism for employment loss in coal-based industries, protections for gender and vulnerable groups, and collaborative governance between central/local governments and market actors, etc.

6.1 Concept and Definition of Just Transition

The concept of "just transition" was first proposed by U.S. labour unions in the late 1970s to protect workers' rights who lost jobs due to environmental regulations. It was introduced into international climate governance during the 1997 Kyoto Protocol negotiations and has since been continuously incorporated in agreements such as the 2010 Cancun Agreement and the 2015 Paris Agreement. The 2019 Madrid conference further promoted its institutionalization, and the 2022 Sharm El-Sheikh conference formally established the "Just Transition Pathways Work Program" agenda, attracting wide attention. Currently, the European Union, the United States, and others have included just transition in their national climate agendas, promoting partnerships for just energy transitions between developed and developing countries, pushing the issue from concept to action.

Due to differing understandings of the scope, connotation, and involved parties of just transition, there is currently no unified definition. Regarding scope, the earliest focus of just transition was "primarily on workers whose jobs were threatened by environmental regulations in the oil, chemical, and nuclear industries." In terms of connotation, just transition concerns both direct job losses caused by climate and environmental changes—such as the loss of jobs due to key scenic sites being damaged and infrastructure destroyed, leading to tourism decline—and job losses across entire industrial chains caused by climate policy implementation. It also includes the increased living burdens on vulnerable groups during the transition due to rising prices of certain resources and energy. Concerning involved parties, some research holds that just transition specifically refers to the transformation of people and labour markets, while others view it as encompassing regional or urban economic transitions—a broader concept that includes both employment transformation and economic development mode shifts.

Overall, just transition research focuses on groups and regions potentially affected in climate/environment governance or transition development processes. These groups and regions require policy and external support to overcome difficulties and seek new development opportunities. Therefore, this report defines **just transition as the dignified, high-quality transformation needed by the decline of certain industries, job losses, and regional economic difficulties caused by anthropogenic climate/environment changes and related governance processes. This transformation requires coordinated resources from international and domestic levels, employing comprehensive economic and social development measures—such as transition planning, social protection, investment, and education/training—to help affected people and regions realize equitable development rights with minimal social welfare loss, achieving sustainable development within climate and environmental governance.**

Just transition has become a core mechanism of global climate governance and is rapidly integrating into national carbon neutrality pathways. Its key values lie in three aspects: first, resolving the global challenge of disconnect between low-carbon transitions and economic-social systems by institutionalizing mechanisms to balance transition pace differences; second, serving as a buffer between climate policies and economic-social development by using social dialogue and compensation policies to reduce secondary impacts of emission reduction policies and improve policy acceptance; third, creating synergistic effects with the 2030 Sustainable Development Goals by generating systemic value in health, energy, social equity, and other areas. Studies show that the effective implementation of just transition can increase ambition in emission reduction targets by over 30% and reduce resistance to policy implementation by 40%, effectively becoming an accelerator for high-quality transition rather than a cost burden.

6.2 Economic and Social Impacts of Green and Low-Carbon Transition in the Coal Triangle Region

6.2.1 Impact on the Economy

Currently, China's tertiary industry now accounts for over half of the national GDP, reflecting a rapid evolution of the economic structure toward modernization and diversification. However, in the Coal Triangle Region, the secondary industry proportion in GDP remains significantly higher than the national average, indicating a continued strong regional dependence on traditional industry. As of now, coal-based industries constitute about 20.3% of the industrial GDP in this region, contributing approximately 8.7% to the total GDP, while the new energy industry's contribution to GDP is only 0.9%, still at an early development stage.

Before 2030, coal will maintain its dominant position in the energy structure and will not be phased out in the short term. Instead, it will continue to provide critical support for energy security and stable economic operation through optimized layout, efficiency improvements, consumption reduction, and synergy with new energy sources. From 2030 to 2040, the region will enter a structural transition window: coal's share in the primary energy mix will decline year by year, old and new economic drivers will shift at an accelerated pace, and the proportion of coal-based industries in industrial GDP will fall rapidly, dropping to around 10% by 2040. Economic dependence on coal will be significantly reduced. After 2040, the region will enter a mature phase of transition. New energy and strategic emerging industries will gradually become the dominant forces, and coal will complete its functional shift from a dominant energy source to a cleaner and strategic reserve resource. By 2060, the coal industry's contribution to industrial GDP is projected to decline to approximately 4%, and its dominant role in the regional economy will markedly weaken.

Table 6-1. Trend of the Share of Coal-Based Industries in Industrial GDP in the Coal Triangle Region

Year	Shanxi	Inner Mongolia	Shaanxi	Ningxia	Coal Triangle Region
2024	34.0%	16.2%	13.1%	21.4%	20.3%
2030	30.8%-32.8%	14.4%-15.4%	12.3%-12.7%	19.0%-20.4%	18.3%-20.1%
2035	24.5%-30.5%	11.2%-13.2%	10.9%-11.7%	16.4%-18.4%	14.5-17.1%
2060	3.6%-7.6%	2.5%-4.9%	1.4%-3.0%	2.7%-5.7%	2.5%-5.5%

Data source: Based on the China Industrial Statistical Yearbook, Chinese industrial enterprise data, and the transition pathway calculations conducted in Chapters 2 and 3 of the report.

6.2.2 Impact on Employment

The current labour market in the Coal Triangle Region exhibits typical resource-dependent characteristics. The coal-based industry directly employs approximately 2,026,000 people, including 1,232,000 in Shanxi, and 374,000, 311,000, and 109,000 in Inner Mongolia, Shaanxi, and Ningxia, respectively; related indirect employment exceeds 2,500,000 people. In contrast, the new energy sector (including manufacturing, power generation, and operations and maintenance) directly employs only 181,000 people, with about 150,000 in indirect employment, reflecting its early stage of development and limited labour absorption capacity.

By 2030, regional employment is expected to generally maintain a "stable total, optimized structure" pattern. The coal-based industry will remain an important employment pillar, with direct employment projected to decline to 1,603,000 people, representing a total job loss of about 831,000. During this period, traditional positions will be partially retained, while demand gradually rises for technical workers and new roles in intelligent operations and maintenance. Direct employment in the new energy sector will increase to 270,000 people, generating over 250,000 indirect jobs, as the development of wind, solar, supporting grids, and energy storage begins to form a preliminary green industry chain. However, clean energy sectors such as green hydrogen and green transportation remain in early development, and their overall employment contribution is still insufficient to fully offset the ongoing loss of coal-based jobs.

Between 2030 and 2040, traditional employment positions will decline more rapidly, with structural employment pressure significantly increasing. As capacity-reduction policies advance, direct employment in the coal-based industry is expected to fall to 835,000, with indirect employment dropping below 900,000. In the new energy sector, particularly green hydrogen and green transportation, accelerated growth will drive total employment in related areas above 900,000, providing some support for regional employment stability. Nevertheless, workers will continue to face practical challenges such as skill mismatches, job transitions, and early retirement. After 2040, the regional employment structure is expected to be largely reconfigured toward green industries. The coal sector will retain only a small number of high-skilled positions, while the traditional employment system gradually exits. New energy and related emerging sectors will become the main employment drivers, transforming the employment structure toward greener, higher-skilled, and more diversified forms. By 2060, direct employment in the coal-based industry is projected to fall to 306,000, with indirect employment under 200,000, while direct employment in new energy will reach 650,000, driving total employment to 1,400,000. Between 2025 and 2060, employment in coal-based industries in the Coal Triangle Region is projected to see a net reduction of approximately 3,380,000 positions, accounting for evolving workforce trends.

It must be acknowledged that between 2025 and 2060, the historically accumulated employment scale in the highly labor-intensive coal industry will far exceed the number of jobs that the clean energy sector can provide. Even with the large-scale development of new energy, clean energy sources are still unlikely to fully compensate for the job losses in coal-based industries. This implies that regional labor markets may face prolonged structural pressures, with persistent challenges particularly in terms of skill mismatches, difficulties in job transitions, and social security needs.

Meanwhile, the new energy industry has a relatively high proportion of female employment. Compared with the coal-based industry, where the female employment ratio is about 14%-19% (varying slightly by industry and region), the new energy industry's female employment ratio is approximately 33%–37%. Calculations indicate that as the industrial transformation and upgrading of the Coal Triangle Region advance, around 1,400 new female-suitable jobs can be created annually, providing important support for enhancing women's employment participation in the transition process and promoting gender equality.

Table 6-2. Trend of Employment in Coal-Based Industries in the Coal Triangle Region (1,000 persons)[5]

Province	Employment Loss Category	2025-2030	2030-2035	2035-2040	2040-2050	2050-2060	2025-2060
Shanxi	Direct employment loss	254	259	216	223	99	1051
	Indirect employment loss	243	249	207	214	95	1009
	Total employment loss	497	508	423	437	194	2059
Inner Mongolia	Direct employment loss	88	74	66	64	30	323
	Indirect employment loss	87	73	65	63	29	317
	Total employment loss	175	147	131	127	59	640
Shaanxi	Direct employment loss	59	59	54	52	30	254
	Indirect employment loss	59	58	53	51	29	251
	Total employment loss	118	117	107	103	59	505
Ningxia	Direct employment loss	21	19	21	21	11	92
	Indirect employment loss	20	18	19	19	10	87
	Total employment loss	41	37	40	40	21	179
Coal Triangle Region	Direct employment loss	422	411	357	360	170	1720
	Indirect employment loss	409	398	344	347	163	1664
	Total employment loss	831	809	701	707	333	3383

6.2.3 Just Transition Issues Arising from Energy Supply Security

The Coal Triangle Region has long been responsible for ensuring national energy supply, which has objectively reinforced the regional economy's structural dependence on the coal industry, delaying its transition to a diversified industrial system. Should the Coal Triangle Region continue to make energy supply assurance

[5] **Direct employment loss** refers to the number of formal employees directly reduced in a specific industry or sector due to enterprise closures, production cuts, or industrial transformation. This indicator reflects changes in the direct labour absorption capacity of the industry. **Indirect employment loss** refers to the number of jobs reduced in upstream and downstream industries and related services as a result of the direct employment reductions, through effects such as supply chain linkages, income decline, and weakened consumption. This indicator reflects the systemic impact of a specific industry on the regional employment ecosystem.

the core basis for its local industrial development, it will further delay the systematic phasing out of production capacity, exacerbate the structural misalignment between regional emission reduction trajectories and the national overall pace, and escalate risks related to stranded assets, employment, and local fiscal pressure. This highlights justice challenges within the energy system transition that urgently require systemic responses. Overall, should coal-centric traditional energy development policies persist between 2025 and 2030, they will, in the short term, further reinforce high-carbon path dependence and inhibit the breakthrough development of the clean energy industry. This institutional lock-in will lead the regional economy post-2030 to confront more acute transition pains, higher risks of stranded assets, and more severe structural employment challenges, ultimately resulting in intergenerational inequity of transition costs.

Therefore, it is imperative to establish effective compensation and industrial replacement mechanisms. Cross-provincial collaboration should be fostered to create a system for sharing both the benefits and costs of transition, thereby alleviating the structural pressures on energy-producing regions. Although coal will continue to serve as a “ballast” and “stabilizer” in the energy system for the foreseeable future, the binding constraints of the “Dual-Carbon” goals and the new national energy security strategy necessitate that the Coal Triangle Region proactively pursues technological upgrades. This forward-looking approach is crucial for achieving a high-quality regional energy and industrial transition and minimizing long-term overall costs. Delaying action risks worsening asset stranding, societal disruption, and industrial competitive disadvantages. Regional collaboration in the early stages of transition—through integrating renewable energy, developing supporting industrial chains, and implementing reskilling programs—can help mitigate the acute social and economic pressures expected during the concentrated phase of transition later on.

6.3 Exploring Policy Mechanisms for a Just Transition in the Coal Triangle Region

In China, the concept of a just transition has been increasingly understood as a systematic task that coordinates economic, social, and environmental objectives within the pursuit of the “Dual-Carbon” goals and broader climate governance efforts. On April 23, 2025, President Xi Jinping delivered an important speech at the Leaders’ Video Summit on Climate and Just Transition, proposing four key initiatives: upholding multilateralism, deepening international cooperation, advancing just transition, and strengthening pragmatic actions. This address, which introduced the concept of “just transition” for the first time at the national leadership level, emphasized that the green transition must remain people-centred, balancing improvements in public well-being with climate governance. This position not only provides a Chinese approach to global climate governance but also reflects China’s determination and sense of responsibility to work with the international community in building a clean, beautiful, and sustainable world.

From a domestic perspective, China has explored elements related to just transition during past industrial restructuring processes. Measures such as reemployment programs for laid-off workers, improvements in social security, and fiscal transfer payments have helped alleviate social shocks caused by industrial contraction and structural adjustments. However, these policies have mainly focused on short-term stabilization and basic livelihood protection rather than establishing a comprehensive, full-cycle mechanism tailored to low-carbon transition needs. In particular, during the critical stages of industrial transformation, there is a greater need for forward-looking just transition policies that create an integrated framework—including industrial substitution, skills training, regional fiscal support, and green investment guidance—to ensure that resource-dependent regions and affected populations have stable and equitable opportunities for development within the low-carbon transition. Therefore, this section recommends designating the Coal Triangle Region as a priority industrial area in which to pilot and develop just transition policy mechanisms.

(1) At the national level: provide policy preference based on regional contributions. It is necessary to fully acknowledge the historical, current, and near-term contributions that the Coal Triangle Region has made to China's economic and social development. In future national economic and industrial planning, the region's dependence on coal and other fossil energy industries should be reduced by deploying a larger share of strategic emerging industries. Preferential policies and financial support should be introduced to foster the growth of these new industries, encouraging them to gradually enter and expand within the Coal Triangle Region, thereby creating the conditions for sustainable local economic development.

Box 6-1: Postal Savings Bank of China Issues the Nation's First Just Transition Loan

In August 2023, Postal Savings Bank of China successfully issued the nation's first Just Transition Loan in Datong City, Shanxi Province. This marks a significant innovative practice for the banking industry in supporting the low-carbon transition of high-carbon industries. The loan, totaling 100 million RMB, was extended to Jinneng Holding Coal Industry Group Co., Ltd., a company primarily engaged in coal production and thermal power generation. PSBC, strictly adhering to the G20 Transition Finance Framework, developed innovative just transition financial instruments to provide targeted support to enterprises in achieving a high-quality just transition during their low-carbon transformation. The innovation of this loan lies in the specific allocation of a portion of its funds to human resource enhancement initiatives, such as employee rotation training and operational qualification training. This approach primarily aims to ensure the improvement of employees' employability and vocational skills during the enterprise's transformation, fully embodying the core principles of just transition-ensuring employment security and social equity.

As the nation's first just transition loan, this project not only achieves the integration of environmental, social, and economic values, but also provides the industry with a replicable and scalable innovative paradigm. It holds significant demonstrative and reference value for the banking sector in supporting high-quality and just transitions in carbon-intensive industries.

Source: China Post News, August 8, 2023.

(2) **At the local level, formulate just transition plans and implement them systematically.** Provinces and cities within the Coal Triangle Region should formulate medium- to long-term just transition plans and integrate them into local overall development plans and relevant specialized plans, such as Five-Year Plans for economic and social development, master urban plans, industrial plans, territorial spatial plans, and education and human resources plans. Clear just transition objectives should be explicitly incorporated and regularly updated. Establishing a just transition-oriented "energy-industry" dual-dimensional coordination mechanism is encouraged. While ensuring regional energy and industrial chain security and supporting development in advanced regions, efforts should accelerate the construction of alternative industries to achieve cross-provincial sharing of green and low-carbon benefits. A cross-departmental collaboration mechanism should be established, with clear lead agencies and responsible departments covering industry, land use, social security, education, and other relevant areas. A 5-year cycle implementation evaluation mechanism should be set up to regularly assess plan execution and develop subsequent work plans. Simultaneously, a dynamic monitoring and early warning system for job losses in coal-based industries should be created, accompanied by economic and social response measures.

Box 6-2: Shanxi's Multi-channel Workforce Resettlement: Reducing Overcapacity, Facilitating Employee Re-employment Without Layoffs

A survey of over 9,000 residents in Shanxi conducted by the Shanxi Youth Sustainable Development Public Service Center revealed that coal industry employees prioritize "employment rate" significantly more than "employment income." Therefore, the foremost principle of any transition must be to ensure the reemployment of direct employees and avoid large-scale unemployment, which also underscores the necessity of promoting economic diversification and the development of non-coal industries. Against this backdrop, during the capacity reduction process in Shanxi in 2017, Jincheng Anthracite Mining Group effectively addressed employee relocation through multi-channel and multi-level placement strategies, ensuring that "employees were reassigned rather than laid off":

First, internal job transfer served as one of the core channels. Leveraging its extensive industrial system, the group prioritized transferring employees from closed mines to other stable production sites or new projects, ensuring continued employment.

Second, cross-industry training and relocation were implemented. The group invested resources in professional training, systematic certification, and paid training programs, successfully transitioning some employees from coal production to emerging non-coal industries.

Third, support for self-employment was provided. Through favourable policies such as unpaid leave with job security, entrepreneurship parks, and financial support, the group encouraged and assisted employees in exploring new career paths.

Fourth, early retirement and asset protection measures were introduced. Eligible older employees were offered early retirement packages, while some were assigned to remain and oversee the disposal and maintenance of assets at shuttered mines.

Through enterprise-led initiatives and multi-channel redistribution, the Jincheng Anthracite Mining Group achieved a steady and orderly resolution of employee relocation during capacity reduction without simply pushing workers into society.

Source: Shanxi Youth Sustainable Development Public Service Center

(3) At the public level, build training systems to strengthen transition capabilities. Just transition is not only a transformation of industries, regional economies, and societies—it is also a transition for every individual within communities affected by carbon neutrality policies. The public has the right to be informed about the economic, social, and personal development of their region. Governments and companies have a responsibility to provide clear channels of information, enabling people to understand and even participate in shaping and evaluating future development directions. Enhancing public awareness of just transition should not be limited only to directly affected youth groups; it should also extend to students and their parents in the Coal Triangle Region, to avoid inefficient investment in education and human resources. Systematic capacity-building programs should be implemented to strengthen public understanding and proactive engagement in the transition. The government, in turn, should take the lead in promoting just transition initiatives and guide the public in transitioning in a proactive and structured manner.

(4) At the regional level, establish cooperative mechanisms to jointly promote high-quality transition. The Coal Triangle Region is characterized by multiple overlapping attributes: energy abundance, ecological fragility, and ethnic concentration. The provinces within the region exhibit significant industrial homogeneity and face similar socio-economic development challenges. Establishing a regional cooperation mechanism to advance a just transition offers several advantages:

- First, it facilitates the sharing of transition experiences, reduces overall transition costs, and enhances the efficiency of high-quality transformation.
- Second, it enables the exploration of regional coordination mechanisms to jointly cultivate new industries and business models, leveraging a unified market to expand demand and investment scale, while collaboratively building successor industries and a talent ecosystem.
- Third, it strengthens the region's collective bargaining power when seeking optimized industrial planning and financial support from the central government, consolidates policy synergy, and avoids internal disordered competition that could drive up transition costs.

Through efficient coordination, the region can transform from an "energy highland" into a "green engine," achieving a high-quality just transition and sustainable development, while providing Chinese solutions and practical experience for coal-resource-dependent regions globally.

7. Comparative Analysis of International Experiences in Traditional Energy Region Transitions

Key Findings:

- International case studies of traditional coal-producing nations demonstrate that policy-driven initiatives and market dynamics are the twin engines of energy transition. Several countries have integrated just transition mechanisms—including fiscal support, job transition programs, and social safeguards—into their policy frameworks, offering valuable lessons for China's fossil fuel-dependent regions.
- The Coal Triangle Region exhibits significantly lower industrial diversification and service-sector representation compared to advanced economies, amplifying its exposure to systemic risks during the energy transition.
- International experience and lessons demonstrate that through state coordination, phased withdrawal, and fiscal support, the impacts of transition on the economy and society can be effectively mitigated.

7.1 Review of Transition Progress in Traditional Coal-Producing Countries

This section reviews the transition practices of major traditional coal-producing countries and regions, including the United Kingdom, Germany, Poland, Spain, Indonesia, and Canada. These cases represent typical pathways of developed economies, transition economies, and energy-exporting nations, offering valuable insights for China.

(1) United Kingdom: Rise and Decline, Proactively Embracing the Trend of the Times

Coal mining in the UK began before the Industrial Revolution and expanded massively during the 19th century alongside industrialization, becoming a core pillar of the economy, military, and society. Between 1850 and the 1910s, the UK was the world's largest coal producer and exporter, supporting the steel, shipbuilding, and power generation industries. Coal production peaked at 292 million tonnes in 1913, with over 3,000 mines employing more than one million workers, meeting over 90% of the nation's energy demand. After World War II, the coal industry declined due to shrinking global markets and the rise of oil and gas, especially North Sea oil and gas. By 1970, production fell to 145 million tonnes—only half of the 1913 peak—and the number of miners dropped sharply from 700,000 in 1950 to 230,000 in 1979. In the 1980s, the Thatcher government implemented neoliberal policies, closing inefficient coal mines and triggering nationwide strikes. After privatization in 1994, imported coal and natural gas squeezed the domestic coal market, causing the miner workforce to plummet from 70,000 to fewer than 10,000 by the late 1990s. In the early 21st century, coal-fired power's share remained stable, but after 2012, influenced by the EU Large Combustion Plant Directive and the UK's "Carbon Price Floor" policy, coal power's share dropped sharply from 39% to 7% in 2017, and to just 2% after 2020. In 2015, the UK announced plans to phase out coal power by 2025, which was accelerated to 2024. On September 30, 2024, the last coal-fired power plant—the Ratcliffe-on-Soar Power Station—was shut down, marking the end of Britain's 142-year coal power era.

(2) Germany: Policy Leadership and Institutional Guarantees in Tandem

Germany's coal industry has witnessed eight centuries of growth and decline, peaking in the mid-20th century (with West Germany's hard coal output reaching 150 million tonnes per year and employing over 600,000 people). After its first structural crisis in 1958, the industry continued to decline amid energy market reforms and intensified international competition. The reunification of Germany in 1990 triggered abrupt changes: lignite production in East Germany was significantly scaled back, and the government implemented structural reforms—including energy privatization, integrated environmental regulation, and the elimination of subsidies—to establish an institutional framework for transition. This phase revealed the inevitability of traditional energy transition: when hard coal production costs exceeded market prices by threefold, the industry's continuation defied economic logic. Since the 21st century, Germany has achieved a systematic transition through iterative policy upgrades: in 2007, legislation ended four decades of hard coal subsidies, and the last two hard coal mines were closed in 2018. The Climate Action Plan 2050 (2016) established the coal phase-out strategy, and the Coal Exit Law (2020) created a legal closure, codifying the 2038 coal phase-out target. Innovative design was reflected in the use of market mechanisms: from 2019 to 2023, seven rounds of reverse auctions for coal exit were implemented, phasing out 46.8 GW of coal power capacity through a dynamic compensation mechanism, while simultaneously raising climate targets to achieve carbon neutrality by 2045. This dual-track model of "legislative mandate + market incentives" ensured a secure and stable energy transition, demonstrating the decisive role of institutional design in industrial transformation. For example, in its latest coal phase-out policy, Germany simultaneously cancelled the corresponding carbon emission allowances (totalling 514,000 tonnes of CO_2) for decommissioned coal power units in the EU Emissions Trading System to prevent a "waterbed effect" and ensure that the emission reductions resulting from the coal exit are genuinely reflected and realized in the carbon market.

(3) Poland: Gradual Transition Under External Pressure

Poland's coal industry originated in the 15th century, with industrialization in the 19th century driving a surge in mining employment. After World War II, coal became the core driver of Poland's industrial development, and by the 1950s, the country had emerged as a major global coal producer. During the 1970s oil crisis, Poland relied on coal exports to alleviate foreign debt pressure, achieving a historic peak of 201 million tonnes of hard coal exports in 1979. To enhance energy security, the government integrated lignite into the strategic energy system, rapidly increasing its production. After transitioning to a market economy in 1989, the coal industry underwent restructuring reforms. Large numbers of inefficient mines were closed, and employment in the sector dropped sharply from 415,000 in 1990 to 160,000 in 2002, leading to significant industrial adjustment. Following its accession to the European Union in 2004, Poland's coal sector faced sustained pressure from the EU carbon market and climate policies. As the EU member state most dependent on coal, Poland has experienced a growing contradiction between energy security and emission reduction targets amid rising carbon prices, reflecting the complex challenge of balancing transition and stability. It was not until 2020 that the Polish government reached an agreement with mining unions to completely phase out hard coal mining by 2049. The adoption of Energy Policy 2040 (PEP2040) in 2021 marked a clear pathway for the country's energy transition, serving as a critical turning point toward a low-carbon energy system. In July 2025, Poland approved an updated National Energy and Climate Plan (NECP), aiming to increase the share of renewable energy in electricity generation to over 50% and reduce greenhouse gas emissions by 53.9% compared to 1990 levels by 2030. Poland is the largest beneficiary of the EU Just Transition Fund.

(4) Spain: Practice of Just Energy Transition in the Energy Industry

Since reaching a coal production peak of 40 million tonnes in 1984, Spain's coal output has steadily declined. After the closure of 26 coal mines in 2018, production fell to 2.5 million tonnes, and in 2021, the government announced a complete coal phase-out by 2030: current production stands at approximately 70,000 tonnes. Spain's energy transition centres on the principle of Just Transition (Transición Justa), encompassing both industrial upgrading and social employment. The 2024 Energy Transition Act sets a target of at least 23% emissions reduction by 2030 and restricts the development of new fossil fuel projects. The Institute for Just Transition, under the Ministry for Ecological Transition and Demographic Challenge, is responsible for delineating transition zones, formulating agreements, coordinating funding and training, and implementing social security measures through tripartite government–union–enterprise dialogue. To date, Spain has supported 427 commercial projects and 83 energy projects, leveraging €2.587 billion in social investment, with renewable energy investments expected to create 2,276 long-term jobs. The innovative "Just Transition Node Tender" mechanism converts retired coal-fired power plant nodes into platforms for renewable energy and energy storage bidding. By the end of 2024, total capacity exceeded 3,796 MW, providing replicable experiences for the green transition in high-carbon regions.

(5) Indonesia: Export Orientation and International Cooperation

Indonesia's coal industry evolved from nationalization to market liberalization. Early growth was limited by infrastructure and investment constraints, and coal scale remained small. After independence in 1945, coal resources were nationalized, but energy strategy in the mid-20th century remained focused on oil and gas. In the 1980s, Indonesia amended its Mining Law to attract private investment; combined with rising East Asian coal demand and currency depreciation, this spurred rapid coal export growth.

The government simultaneously promoted coal-fired power plant construction and implemented a "domestic market obligation" policy, making coal a core of power supply. In the 2010s, faced with slowing Chinese demand and global low-carbon trends, Indonesia's coal industry confronted market downturn and financing constraints. The government strengthened mining regulation and promoted energy structure adjustment. In 2021, Indonesia announced a net-zero emissions target by 2060. In 2022, it launched a $20 billion clean energy investment plan under the G20 "Just Energy Transition Partnership," marking the initial clarity of its path toward a renewable energy system transition.

(6) Canada: Coordinated National and Local Government Efforts

To achieve a cleaner energy structure and advance the goals of the Paris Agreement, as early as 2012, Canada enacted the Regulations Limiting Carbon Dioxide Emissions from Coal-Fired Generation of Electricity, setting national greenhouse gas emission standards for coal-fired power plants. These regulations were further revised in 2018 to accelerate the decarbonization process. Additionally, Canada initiated and co-chairs the Powering Past Coal Alliance (PPCA), promoting the global phase-out of coal power and the transition to clean energy. As for the provincial-level actions, Ontario began gradually shutting down coal-fired power plants in 2003 and completed the phase-out by 2014. By 2015, it became the first province in North America to eliminate reliance on coal for electricity generation, significantly increasing its share of clean energy. Alberta retired its last coal-fired power plant in 2024, leveraging a diversified energy mix to align with the national goal of zero coal use by 2030. Saskatchewan, Nova Scotia, and New Brunswick have also set targets to phase out coal by 2030, implementing policies to replace it with cleaner alternatives. As a result, there was a 59% reduction in greenhouse gas emissions from the power sector between 2005 and 2022. The carbon intensity of the national grid dropped to approximately 100 gCO_2e/kWh in 2022, a 55% decrease from the 2005 level of 220 gCO_2e/kWh. In order to ensure a just transition, in 2018, Canada established the Task Force on Just Transition for Canadian Coal Power Workers and Communities, bringing stakeholders together to discuss transition pathways and support mechanisms. In 2024, the federal government introduced the Sustainable Jobs Act, institutionalizing support systems to assist workers and communities reliant on fossil fuels through transition and reemployment programs.

(7) EU Funding Support for Member States

The European Union has established a systematic funding framework to support member states' coal transition, primarily leveraging three structural fund instruments: the Just Transition Fund (JTF), the European Social Fund (ESF), and the European Regional Development Fund (ERDF). Among these, the JTF offers targeted assistance specifically for coal-producing regions, focusing on worker retraining, clean energy industry transformation, and ecological restoration of mining areas; the ESF covers the entire coal-producing states, mitigating transition impacts through vocational training, education enhancement, and social inclusion programs; the ERDF also operates at the state level, promoting economic restructuring by funding small and medium-sized enterprise innovation, infrastructure modernization, and low-carbon technology development. It is worth noting that the ESF was originally established to mitigate the social impacts on vulnerable groups in the building and transport sectors under the EU Emissions Trading System Phase II and to promote their green transition. The fund will provide €86.7 billion between 2026 and 2032, and each member state is required to develop social climate plans specifying the use of funds for measures such as building energy efficiency improvements, decarbonization of heating and cooling, or temporary income support. This study calculates the support intensity per unit of coal production and per coal worker provided by the JTF, ESF, and ESDF in Germany, offering policy references that could inform the transition of China’s coal-producing regions (see Table 7-1).

Table 7-1. Support From the EU’s Three Funds to Germany’s Three Major Coal-Producing Regions

Coal-producing area	Funding project	The amount of patronage (10,000 EUR, 2021-2027)	Funding per-unit output (EUR/10,000 tonnes)	Funding per capita (EUR/person)
Rheinland	JTF	68,291	109,091	80,523
	ESF	56,034	89,511	66,070
	ERDF	130,000	207,668	153,284

Coal-producing area	Funding project	The amount of patronage (10,000 EUR, 2021-2027)	Funding per-unit output (EUR/10,000 tonnes)	Funding per capita (EUR/person)
Mitteldeutsches Revier & Lausitz	JTF	179,476	281,752	190,648
	ESF	96,791	151,948	102,816
	ERDF	410,719	644,771	436,285

Data source: The research team calculated based on the data provided by the European Commission.

Box 7-1: Just Transition Policies and Mechanisms for Coal Regions in the European Union

The European Union has played a coordinating role in the coal region transition and undertaken the following key actions to support a just transition:

Fiscal subsidies for the coal industry: The hard coal mining sector in many EU member states relied heavily on state aid to ensure energy security and maintain employment in mining regions. This provided a justification for continued public support despite poor economic performance. In 2002, the EU adopted Regulation No. 1407/2002 on state aid to the coal industry, allowing member states to continue subsidizing coal companies. This regulation remained in effect until 2010. Between 2000 and 2012, EU member states provided approximately € 87 billion in aid to hard coal producers. In 2010, the EU Council adopted Decision No. 2010/787, which introduced transitional rules allowing limited state aid from 2011 to 2027, aimed at facilitating the gradual closure of uncompetitive coal mines. From 2011 to 2020, nearly €19.3 billion in national aid was allocated to coal mining companies in eight member states. During this period, EU energy policy began to shift toward renewable energy and a low-carbon economy.

Funding support for coal regions: To create jobs and promote sustainable investment, the EU allocated five major funding instruments under its 2014-2020 budget framework, collectively known as the European Structural and Investment Funds (ESIF). These included the European Regional Development Fund, the European Social Fund, the Cohesion Fund, the European Agricultural Fund for Rural Development, and the European Maritime and Fisheries Fund. Among them, the first three were eligible to support coal regions during the transition.

Coal Regions in Transition Initiative (CRiT): In 2017, the European Commission launched CRiT to help coal, peat, and oil shale regions mitigate the social impacts of the low-carbon transition. CRiT brings together local communities, regional and national governments, businesses, trade unions, non-governmental organizations, and academic institutions, fostering knowledge sharing and peer-to-peer learning among coal regions across the EU, and supporting them in developing locally tailored approaches to just transition.

Just Transition Mechanism: CRiT works closely with the Just Transition Mechanism (JTM). The JTM is a crucial policy instrument under the EU s European Green Deal, aimed at ensuring a fair transition towards climate neutrality for all of society, leaving no one or no region behind. It provides targeted support to regions most affected by the green transition, with a total budget of €55 billion for the 2021-2027 period. The mechanism is structured around three pillars: **The Just Transition Fund (JTF)** offers grants to regions heavily impacted by the transition; **the Invest EU Just Transition Scheme** mobilizes public and private investments through dedicated investment windows aligned with EU priorities, and **the Public Sector Loan Facility** provides loans and grants to public authorities for sustainable development projects in just transition regions, supporting local governments and public institutions in implementing the transition.

Source: According to the information compiled by the European Commission

7.2 Comparison Between China's Coal Triangle Region and Traditional Coal-Producing Countries

Policy drivers and market supply-demand changes are the main forces promoting coal industry transformation. Comparatively, Germany's transition benefited primarily from domestic policy drivers, while Poland's accelerated transition was supported by policies at the European Union level. By summarizing key indicators across economic development, energy structure, and employment dimensions for China's traditional coal-producing regions (represented by Shanxi and Shaanxi provinces) and international coal regions (see Table 7-2), it is evident that China's traditional coal regions have significantly lower levels of industrial diversification and a smaller share of the service sector compared to developed countries. This implies that the energy transition may face higher systemic risks. At the same time, coal industry employment remains a key pillar of the regional economy, so its social impacts must be given significant attention during the transition.

7.3 Experience and Lessons from the International Transition of Traditional Energy Regions

International experience shows that the low-carbon transition in traditional coal-producing regions must balance fairness and efficiency. **Without systematic planning, regional economies risk prolonged decline. Conversely, nationally coordinated strategies, a managed coal phase-down, and supportive fiscal measures can effectively mitigate socioeconomic shocks. European practices further indicate that a just transition requires full inclusion of stakeholders—including local governments, enterprises, and worker representatives—in policy formulation and implementation. This not only ensures procedural justice but also enhances policy execution efficiency and public acceptance, strengthening the social sustainability of the transition.** Drawing on international experience, China's traditional energy transition regions are developing a governance framework characterized by "national coordination, provincial implementation, multi-stakeholder consultation, fiscal support, and social inclusiveness". This framework is led by development and reform authorities with interdepartmental coordination, integrating strategic planning, fund oversight, and implementation measures; at the provincial level, differentiated transition plans help avoid social risks associated with uncoordinated coal phase-down; at the societal level, consultation mechanisms among enterprises, trade unions, and communities enhance policy transparency and grassroots acceptance, reducing unemployment and social instability risks.

Innovation in funding and policy tools is central to implementing a just transition. Establishing a national-level Just Transition Fund (drawing on the EU's JTF) could focus on supporting employment training, industrial upgrading, and clean infrastructure construction in the Coal Triangle Region. At the same time, developing green and transition finance can encourage banks to provide low-interest loans, explore PPP models to attract social capital, and improve investment efficiency. Drawing on international cooperation experience, mechanisms involving global partners can jointly advance R&D and demonstration projects in emerging industries, such as hydrogen, smart grids, and green manufacturing, accelerating the deployment of low-carbon technologies and achieving economic transition alongside enhanced international green competitiveness.

Besides valuable experiences, European countries' earlier coal transitions also offer lessons worth noting:

(1) Germany: Lack of clear transition plans risks resource waste

Germany's long-term subsidies to the hard coal sector and improvements in coal-fired power efficiency, if not accompanied by a clear exit plan, can lead to resource waste, stranded assets, and delayed decarbonization. Germany continuously subsidized its coal industry from the 1950s until 2018; during the 2000s and 2010s, it also invested in coal power retrofits, treating them as a "transition solution." However, with the tightening of climate policies, Germany set a coal phase-out target for 2038 in 2019, though the timeline has remained subject to revisions and uncertainty. The previous government expressed an intention to phase out coal before 2030 but did not enshrine it in law; the current government explicitly opposes an early phase-out, leaving 2038 as the latest coal exit date. It is estimated that the total cost of a full coal phase-out could reach 1% to 1.4% of the federal annual budget.

(2) Poland: Single compensation mechanisms cannot sustainably resolve coal region employment

Poland faced large-scale layoffs in the 1990s due to economic restructuring and launched a "Golden Handshake" policy in 1998, offering one-time compensation and early retirement to encourage voluntary miner exits. By 2006, coal mining employment had fallen from over 400,000 in 1990 to about 120,000, easing initial social pressures.

However, this policy revealed significant issues. Between 1998 and 2002, coal restructuring costs reached approximately 9 billion zlotys, mostly spent on personnel compensation, with under 10% allocated to retraining and reemployment programs. A 2004 Supreme Audit Office report found that only about 15% of compensated miners found re-employment within IISD Leankit 2 years; over 10% returned to mines as outsourced or temporary workers. Traditional coal areas like Bytom suffered unemployment rates reaching 15% around 2010, far above the national average, due to a lack of industrial alternatives. This indicates that compensation-only exit strategies may temporarily alleviate pain but cannot sustain fair, structural transitions.

(3) United Kingdom: Neglecting fairness in transition leads to long-term socio-economic issues in coal regions

The UK's coal transition history shows that reducing coal's share to below 1% in the energy mix does not equal a complete transition. The country experienced multiple unfair transition phases, notably under the Thatcher government in the 1980s, which closed many mines for economic efficiency reasons. Over 250,000 jobs disappeared in a decade without sufficient worker re-employment support or regional development planning, triggering nationwide strikes and deep social divisions. After privatization reforms in the 1990s, coal mines further declined, with government withdrawing regulation and private companies prioritizing profits, severely neglecting fairness considerations. These historical phases highlight the lack of systematic transition support, with ongoing effects today—recent studies show that the UK's last coal region, South Wales, scores lower on just energy transition assessments than some still coal-producing German regions, due to economic mono-structure, lack of innovation, and insufficient social equity. This case profoundly illustrates that a genuine just transition cannot be measured only by coal output or share but must focus on the sustainable development capacity and equitable participation opportunities of affected groups and regions.

(4) Implications for China: Existing transition practices in traditional energy-based countries reveal that few have managed the phase-out of their coal industries in a truly just manner. However, a critical examination of the political, social, and economic factors—both historical and contemporary—in these cases holds important lessons for China and other coal-dependent nations. These experiences offer the following insights for China's own coal transition:

- The earlier the coal exit path is planned, the less resource waste and fewer social costs occur;
- Delays and prolonged efficiency improvements increase fiscal costs and slow low-carbon transition;
- Transitional technology investments must support exit goals, not obscure exit uncertainties;
- Clear policy timelines and exit schedules are necessary to manage market and social expectations.

Table 7-2. Comparison between China's Coal Triangle Region and Traditional Coal-Producing Countries

Indicator		Shanxi	Shaanxi	Germany	Poland	Indonesia	United Kingdom
Economics	Per capita GDP (RMB/person)	73,769 ($10,390/person)	85,448 ($12,035/person)	395,854 ($55,754/person)	162,778 ($22,926/person)	35,833 ($5,047/person)	363,484 ($51,195/person)
	GDP growth rate (5-year average)	5.2%	6.8%	0.7%	3.8%	3.4%	0.7%
	Share of the service sector	42.7%	44.6%	63.7%	57.5%	42.9%	72.5%
Energy	Peak coal era	Sustained increase in coal and coal power capacity	Sustained increase in coal and coal power capacity	Hard coal: 1957 Lignite: 1980	Late 1970s to early 1980s	Sustained Increase in Coal and Coal Power Capacity	1913
	Peak output	-	-	Hard coal: 150 million tonnes Lignite: 258 million tonnes	Hard coal: 148 million tonnes	-	292 million tonnes
	Current production (100 million tonnes)	13.3	7.6	10.23	8.87	6.95	0.02
	Coal-fired power share	78.90%	68%	26.6%	60.3%	66.0%	1.6%
	Share of coal exports and outbound transfers	63%	81%	6%	21%	64%	140%
Employment	Employment in the coal industry at its peak	-	-	Hard coal: 600,000 workers (1957) Lignite: 130,000 workers (1990)	388,000 workers (1990)	-	1.1 million workers
	Coal industry employment (current)	909,300 workers	197,800 workers	26,300 workers (2024)	72,900 workers (2022)	159,900 workers (2023)	-
Transformation momentum		Policy-driven	Policy-driven	Market-policy balance	Market-led with EU support	Policy-driven with international support	Market-driven

Data source: Compiled by the project team based on data from the National Bureau of Statistics of China, the Federal Statistical Office of Germany, the German Coal Statistics Association, and the Bozhong Zhihé Energy Transition Report "Comparative Study of Energy Transition in Coal-Producing Regions of China and Europe."

8. Policy Recommendations

This report recommends, under the national "Dual-Carbon" targets, upholding the new energy security strategy: coordinating regional energy supply and emission reductions through policy mechanisms; optimizing the development of emerging regional industries through industrial layout adjustments; supporting industrial continuity with diversified funding; and promoting the establishment of international exchange mechanisms through transition governance, thereby jointly advancing the energy transition and strengthening energy security. The specific policy recommendations are as follows:

(1) Guided by the "Dual-Carbon" goals, uphold the new energy security strategy, and clarify the targets and roadmap for the green and low-carbon transition of the Coal Triangle Region.

Promoting the sustainable phase-out of coal and optimizing the energy structure is an urgent task for achieving the carbon peaking and carbon neutrality targets and an inherent requirement for building a sustainable energy system. It is recommended to strengthen top-level design and regional coordination by establishing a transition strategy centered on the "sustainable coal phase-down" at the national level. This strategy aims to gradually reduce coal dependence while ensuring energy security, accommodating regional differences, and promoting a just transition. It requires the development of clear timelines and roadmaps that coordinate energy supply security, consumption transformation, technological innovation, and institutional reforms, and increased policy focus and resource support should be directed toward major coal-producing regions. By improving standards, enhancing regulatory enforcement, and optimizing policy incentives, local governments can be encouraged to raise their sense of urgency and take decisive action, forming a collaborative governance effort between central and local authorities. On the premise of ensuring energy security, upgrading the industrial structure can stimulate new growth drivers, jointly advancing energy transition, high-quality economic development, and ecological protection.

(2) Promote the development of the Coal Triangle Region as a national demonstration zone for green, low-carbon energy and just transition, integrating it into the overall framework of the national regional coordinated development strategy and coordinating green and low-carbon transitions both within the region and across regions.

A coordinated mechanism should be established to integrate the energy transition, industrial restructuring, ecological restoration, regional collaboration, employment protection, and improvements in people's livelihoods, enabling the Coal Triangle Region to play a stronger supporting role in national energy and ecological security, the ecological protection of the Yellow River basin, and high-quality development. Key recommendations focus on the following three aspects:

First, strengthen central coordination and interdepartmental collaboration. Establish a coordination mechanism among the National Development and Reform Commission, the National Energy Administration, the Ministry of Ecology and Environment, and other relevant agencies to unify planning for coal capacity control and energy output strategies. Scientifically set reduction targets, prevent disorderly competition and resource waste, and promote the orderly downsizing and upgrading of coal-based industries while fostering alternative industries, ensuring that regional transition aligns with the national "Dual-Carbon" strategy.

Second, develop an energy-just transition roadmap for the Coal Triangle Region. Build a comprehensive policy framework encompassing ecological protection, economic development, employment creation, and poverty alleviation. Clearly define coal capacity reduction pathways and the adjustment directions of coal-based industries, guiding more proactive low-carbon energy development goals.

Third, establish regional cooperation and industrial coordination mechanisms based on energy transition. Drawing on the “pairing assistance” coordination model, explore the creation of “transition development partnerships” for the Coal Triangle Region, forming industrial backfeeding and collaboration mechanisms with economically developed provinces that traditionally rely on coal imports, thereby supporting the optimization and upgrading of emerging industries in the Coal Triangle Region. Focus on industrial chain coordination, joint market development, technology transfer, and talent cultivation to achieve complementary regional advantages and efficient resource integration, forming a pattern of “energy supply–industrial collaboration–benefit sharing.”

(3) Building on the region’s industrial and resource endowments, the goal is to create a new economic growth engine centred on new energy, leveraging the “Three New Pillars” and zero-carbon park development to explore mechanisms for establishing zero-carbon trade demonstration zones, thereby providing institutional frameworks and platform support for regional green development.

The Coal Triangle Region’s abundant green electricity resources provide a solid foundation for developing a clean and efficient industrial system, capable of advancing the region’s high-quality economic development to a new stage. Efforts should accelerate the “Three New Pillars,” focusing on building a new power system, developing hydrogen-based industries, and demonstrating carbon removal technologies. By relying on technological innovation, low-carbon technologies can be integrated into coal-based industries, systematically driving the region’s green transition. Zero-carbon parks should serve as the primary leverage, exploring modern energy systems and industrial forms supported by “new energy-energy storage,” systematically promoting the electrification of coal-based industries, and deploying direct green power supply, green hydrogen production, storage and transport, and hydrogen refuelling networks. The integration of hydrogen in industry, transportation, and energy storage should be expanded, forming an integrated demonstration system of “green power–green hydrogen–end use.” Multiple carbon removal pathways, including CCUS and biocarbon sinks, should be coordinated to build innovation and demonstration clusters for carbon removal technologies. Based on a zero-carbon industrial and supply chain system, national or regional zero-carbon trade demonstration zones can be developed, producing zero- and low-carbon products aligned with international advanced standards.

(4) Establish a diversified financing support system for the Coal Triangle Region’s transition by comprehensively leveraging policy tools such as fiscal transfer payments and green development funds, while establishing risk-sharing and fail-safe mechanisms, forming an integrated “funds + mechanisms + policies” support framework.

To strengthen financial support for the Coal Triangle Region’s green transition, it is recommended to build a Green Development Fund specifically for the region’s transition under the guidance of top-level designs such as the National Low-Carbon Transition Fund and the National Green Development Fund, creating a diversified investment and financing system guided by government and operated by the market. The fund should prioritize support for zero-carbon park infrastructure, low-carbon retrofitting of traditional industries, cultivation of emerging industrial clusters, and workforce transition training, effectively alleviating social structural pains and nurturing new regional development momentum. On this basis, policy tools such as fiscal transfer payments should be actively applied to establish special safeguard funds for mine ecological restoration, goaf area management, and the resettlement of workers affected by just transition, forming a coordinated “ecology–livelihood” support mechanism that provides sustainable fiscal backing for resource-declining regions. Innovative fund operation mechanisms should promote multi-level coordination and social participation, emphasizing support for low-carbon, zero-carbon, and disruptive technological innovation, particularly favoUring technology-oriented private enterprises to accelerate the scaling of new technologies. At the same time, a local fund fail-safe mechanism should be established to enhance policy flexibility and improve the provision of financial services, such as green loans and bonds. Ultimately, broad mobilization of social capital will help build an efficient and diversified investment and financing system, providing sustainable support for the region's green transition.

(5) Establish an international platform for green and low-carbon transition in resource-dependent regions, building a transition framework centred on just transition and climate governance, and positioning the Coal Triangle Region as a Chinese benchmark for global energy transition.

Just transition in traditional energy regions is a common challenge faced by many countries, particularly due to the structural employment impacts of energy transition. Although emerging non-coal industries can create new job opportunities, they are unlikely in the short term to fully offset the employment losses caused by the coal-based industry's transformation. To address the employment challenges in the Coal Triangle Region's transition, it is necessary to accelerate the development of a stable employment support system: first, accurately identify and dynamically track workers affected by the coal-based industry; second, strengthen differentiated vocational training and targeted placement assistance to ensure effective alignment of job relocation and income protection; third, implement targeted safety-net measures, with particular attention to vulnerable groups such as women, ensuring fairness of opportunity and adequate support throughout the employment transition process. On this basis, the practical experience of the Coal Triangle Region's green transition demonstration should be tracked and summarized, while simultaneously building an international alliance for just transition in traditional energy regions. This includes promoting international exchanges through mechanisms such as China-EU regional transition dialogue, enhancing learning from regional cooperation experiences, policy design, and practical implementation. Multilateral exchanges and cooperation with regions in Asia, Africa, and Latin America should also be expanded, using policy, technology, and solution sharing as well as project development collaboration to provide Chinese approaches for advancing just transition globally.

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Appendix A: Research Methodology and Technical Approach

1. Research Techniques and Methods

The methodology integrates desk studies, field research, expert consultations, and policy roundtables.

Desk Study: Systematically reviewed global and domestic literature on green low-carbon transitions in traditional industries, synthesizing empirical cases and best practices.

Field Research: Conducted on-site investigations in the Coal Triangle Region with leading experts and research teams on energy. Systematically assessed regional energy consumption/production baselines and evaluated coal and renewable energy development statuses.

Expert Consultations: Held consultation meetings on future industrial development directions and integrated renewable energy infrastructure pathways, deriving recommendations on development and strategic pathways.

Policy Roundtables: Engaged government agencies (Development & Reform Commissions, Ecology & Environment Departments, etc.) and research institutes across Inner Mongolia, Ningxia, Shaanxi, and Shanxi. Examined energy transition pathways and their socio-economic impacts on regional economic development, rural revitalization etc., generating evidence-based policy proposals for future transitions.

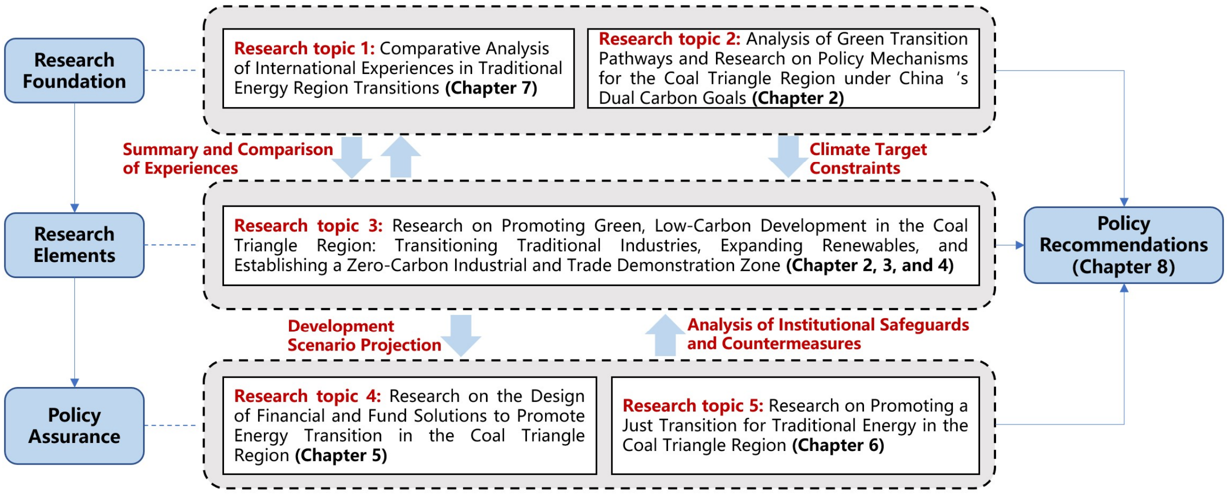

Figure A-1. Logical Relationships among the Sub-topics of This Project

2. China Medium- and Long-Term Emissions Pathway Model CAEP-CP 3.0

The CAEP-CP 3.0 model, led by Academician Wang Jinnan of the Ministry of Ecology and Environment's Environmental Planning Academy, is China's integrated emissions pathway framework. It combines top-down macro-modelling and bottom-up evolutionary modelling. The core modules include: high-resolution gridded emissions mapping, medium-to-long-term energy system analysis, the M3C-CGE model, spatial renewable energy potential assessment, emission reduction technology evaluation, carbon removal integration, key industrial sector forecasting, etc. The top-down macro-modelling is constrained by socioeconomic development goals, carbon peak (pre-2030), and neutrality (pre-2060) targets, with iterative optimization for sectoral emission pathways. The bottom-up evolutionary modelling spatially resolves annual emissions at the grid-cell level under defined rules and constraints.

The CAEP-CP 3.0 model outputs have been presented at high-level forums including the 29th Group Study Session of the Political Bureau of the CPC Central Committee, high-level meetings of the Chinese Academy of Engineering (CAE), and executive conferences of the Ministry of Ecology and Environment (MEE). The model is currently serving as the integrated modelling framework for CAE's major advisory project "Research on China's Carbon Peak and Neutrality Strategies and Pathways." It synthesizes foundation data and research findings from over 40 academicians and over 300 experts, undergoing continuous refinement and iterative upgrades.

The model has been extensively applied in China's national greenhouse gas emission scenario analysis and carbon peak/neutrality pathway simulations. It provides technical support for national policy formulation. The model has been applied in provincial decarbonization pathways studies for Ningxia, Jiangxi, Fujian, and Shanxi, and municipal studies for Yantai (Shandong), Nanping (Fujian), and Wuyishan (Fujian). Its application supports the development of regional decarbonization plans.

2.1 M3C-CGE Module: Macro-Micro Multi-dimensional Carbon Neutrality CGE

The M3C-CGE Module is a critical module in the CAEP-CP 3.0 model for addressing the interlinked impacts of regional energy, industry, and economy. It is a multi-sector, multi-region dynamic model constructed based on the CGE model, considering the interactions among different economic entities and different markets. The CGE model employs mathematical equations to simulate the production, consumption, investment, import, and export behaviours of different economic entities (enterprises, residents, government, investors, importers/exporters, etc.). Given the conditions of maximum resident utility, enterprise profit, minimum cost, and constraints on resource and budget, it generates the supply and demand of production factors or other commodities at market equilibrium, thereby obtaining equilibrium prices. The Environmental Planning Academy of the Ministry of Ecology and Environment, jointly with the Center for Foresight Science of the Chinese Academy of Sciences and the School of Economics and Management of the University of Chinese Academy of Sciences, based on the CGE model, comprehensively considers the interconnections among environmental, economic, and social systems, incorporates environmental and energy accounts, and analyzes the interactions and feedback among different economic entities across regions. Thus, it obtains the impacts of different emission reduction scenarios on the economy, society, and environment under the Dual-Carbon constraints.

Using the 2020 provincial input-output tables as the socioeconomic baseline data, combined with the 2020 provincial energy balance sheets, provincial statistical yearbooks, and provincial carbon emission data, the baseline year data is formed. The model covers 40 sectors, including a production module, domestic and international trade market module, government and resident fiscal module, and carbon emission module. With a 1-year time step, it dynamically simulates the changes in provincial industrial economic performance, industrial structure, energy consumption, and corresponding carbon emissions during 2020-2060 under different carbon emission constraint scenarios.

2.2 New Energy Potential Assessment Module

Based on a GIS spatial analysis platform and high-resolution wind and solar resource atlases—including wind resource maps at 100 metres heigh, surface total radiation data, and photovoltaic (PV) power potential equivalent hours data—combined with a constraints database (including ecological red lines, water bodies, residential areas, airport runways, etc.), terrain parameter databases (such as elevation data from SRTM, slope, and aspect), geomorphology, equipment databases, and regional characteristic parameters, the module uses GIS spatial analysis, optimal equipment selection, and operational period power generation estimation algorithms to evaluate the developable areas for wind and photovoltaic power within the region. Considering the terrain and resource characteristics within the region, suitable equipment is selected, ultimately yielding the theoretical developable capacity and power generation hours for wind and solar PV in the region. The optimal power generation equipment is matched according to the resource characteristics of the potentially developable renewable resource areas.

Specifically, for wind power development, the wind energy conversion efficiency is determined by factors such as the rotor swept area of the wind turbine, generator capacity, and tower height. By combining wind resource endowments at heights between 80 and 140 meters, the goal is to achieve the lowest levelized cost of electricity. Wind resource data are sourced from high-resolution wind resource atlases corrected with long-term historically measured wind data from the wind power industry. Turbine information is derived from mainstream industry model technical parameter databases and projections of future technological development.

3. New Energy Potential Assessment Module

To facilitate scenario simulation and policy analysis in this report, a unified baseline assumption is made for the main economic and social indicators of the Coal Triangle Region from 2025 to 2060. Specific parameters are detailed below.

Table A-1. Average Annual GDP Growth Rate Assumptions for the Coal Triangle Region

Provincial-Level Administrative Division/Region	2020-2025	2025-2030	2030-2035	2035-2040	2040-2045	2045-2050	2050-2055	2055-2060
Inner Mongolia	6.0%	5.5%	3.2%	1.5%	1.6%	2.5%	2.5%	3.1%
Shanxi	4.9%	3.8%	3.5%	3.1%	3.1%	3.7%	3.1%	3.5%
Shaanxi	5.2%	3.5%	4.1%	3.7%	4.5%	4.2%	4.2%	4.2%
Ningxia	5.8%	4.5%	4.4%	4.6%	3.1%	3.9%	4.0%	3.9%

Table A-2. Per Capita GDP Assumptions for the Coal Triangle Region (Unit: 10,000 RMB/person)

Provincial-Level Administrative Division/Region	2030	2035	2040	2045	2050	2055	2060
Inner Mongolia	12.8	15.0	17.4	19.2	22.1	25.8	30.2
Shanxi	8.2	9.8	11.6	13.8	16.9	20.2	25.0
Shaanxi	11.4	13.9	16.8	21.2	26.7	30.9	35.4
Ningxia	8.4	10.2	12.6	14.5	17.6	21.4	26.3

4. Scope Definition of Coal-Based Industries

This report's study scope of coal-based industries covers the production and processing of coal resources as well as their primary downstream utilization segments. According to the industrial chain logic, the scope is divided into three main segments: upstream, midstream, and downstream. The upstream segment mainly includes coal resource extraction and washing. The midstream segment focuses on the coal processing and conversion process, primarily the coal chemical industry. The downstream segment encompasses typical coal utilization scenarios, mainly including coal-fired power generation and heating, steel production, and other industrial sectors. Based on this industrial chain division, the report systematically reviews the transformation dynamics and economic and social impacts of each segment of the coal-based industry, providing fundamental support for the regional transformation pathway analysis.

Table A-3. The Division of the Coal-Based Industry Scope Covered in this Report

Main industry classification	Position in the coal industry chain	Industry code
Coal mining and washing	Upstream	06 Coal mining and washing (0610 Bituminous coal and anthracite mining and washing, 0620 Lignite mining and washing, 0690 Other coal mining and washing); 1110 Other coal mining and washing
Coal chemical industry	Midstream: Coal processing	252 Coal processing (2521 Coke production, 2522 Production of synthetic gas from coal, 2523 Production of liquid fuels from coal, 2524 Coal products manufacturing, 2529 Other coal processing)
Coal-fired power generation and heating	Downstream: Coal usage	441 Power generation (4411 Thermal power generation, 4412 Combined heat and power generation); 4430 Heating and power supply
Steel	Downstream: Coal usage	3110 Iron smelting; 3120 Steelmaking
Cement	Downstream: Coal usage	301 Cement, lime and gypsum manufacturing (3011 Cement manufacturing, 3012 Lime and gypsum manufacturing)
Other industrial industries	Downstream: Coal usage	251 Refined petroleum product manufacturing; 26 Chemical raw materials and chemical manufacturing; 303 Building materials manufacturing (bricks, stones, etc.); 304 Glass manufacturing; 306 Ceramic products manufacturing

Appendix B: Overview of Policies, Funds, and Financial Support for Low-Carbon Transition in the Coal Triangle Region

This report systematically reviews the practical explorations in transition finance and the current fund operations across major provinces within the Coal Triangle Region, as detailed in Tables B-1 and B-2.

Table B-1. Overview of the Current Status of Financial Support for the Coal Triangle Region's Low-Carbon Transition

Province	Current Status of Financial Support
Shanxi	• By the end of September 2024, financial institutions in Shanxi Province had issued a total of 3.77 billion RMB in carbon reduction loans, supporting 372 projects such as wind power and photovoltaic, with a weighted average interest rate as low as 3.22%. • Through the “Green Bill Discount” service, 2.35 billion RMB in bill financing support has been provided to green enterprises. • In terms of innovation in carbon finance mechanisms, Shanxi Province has taken the lead in implementing the “Carbon Account + Carbon Credit” model. Based on the pilot experience in Changzhi City, carbon emissions data from enterprises is collected and used to generate carbon credit reports. By the end of the third quarter of 2024, financial institutions had issued 23 transformation loans totalling 645 million RMB based on this model. • In terms of product services, Jinshang Bank and others have launched energy management loans, offering low-cost funds through energy-saving revenue pledge, and jointly initiated a clean energy fund, supporting emission reduction projects through government interest subsidies.
Inner Mongolia	• As of the end of December 2024, the total balance of green loans in Inner Mongolia reached 599.63 billion RMB, representing a year-on-year increase of 26.8%. • The Inner Mongolia branch of the People’s Bank of China leveraged policy tools such as technology-innovation refinancing to precisely support 621 technology-based SMEs and 225 technological renovation projects, achieving full coverage of financing services. Cumulative loan agreements amounted to 4.73 billion RMB, with 2.3 billion RMB actually disbursed, including 240 million RMB in specialized refinancing support. • Financial institutions have continued to strengthen support for private and small, micro, and medium-sized enterprises (SMEs), with outstanding loans to private enterprises reaching 749.57 billion RMB (up 10.4% year-on-year) and loans to SMEs reaching 1,185.7 billion RMB (up 5.5% year-on-year).
Shaanxi	• As of the end of December 2024, the province's green loan balance reached 822.904 billion RMB, a year-on-year increase of 19%, with growth ranking among the top in the country. • The People’s Bank of China, Shaanxi Branch, actively utilized two policy tools: the carbon reduction support tool and the special reloan for the clean and efficient use of coal, guiding funds to be precisely directed toward the green sector. By the end of November, the cumulative issuance of policy funds exceeded 56 billion RMB. • Shaanxi Province is actively promoting financial institutions to innovate green financial products. Banks within the jurisdiction have developed over 120 types of green financial products, with more than 70 of them being implemented. These products cover key areas such as carbon reduction and clean energy, providing strong support for the province's green and low-carbon economic transformation.
Ningxia	• By the end of 2024, the region's green loan balance reached 162.732 billion RMB, a year-on-year increase of 11.0%, leading the growth across all loan categories. In the entire year, 16.131 billion RMB in new green loans were issued, accounting for 39.8% of the total loan growth, with a focus on major projects such as solar energy utilization and the clean transformation of traditional energy. • The People’s Bank of China, Ningxia Branch, effectively leveraged its policy guidance role, with the balance of the carbon reduction support tool surpassing 20 billion RMB, effectively

Province	Current Status of Financial Support
	attracting social capital. In the field of technological innovation, 3.441 billion RMB in technological transformation loan contracts were signed, with actual investment totalling 653 million RMB.

Table B-2. Overview of the Current Status of Transition Fund Support in the Coal Triangle Region

Region	Name of the Fund	Year of Fund Establishment	Initial Fund Size (Billion RMB)	Target Sectors	Challenges Faced
Shanxi	Energy Transition Development Fund	2021	50.0	Hydrogen, photovoltaic, wind power, biomass, geothermal, and other green, low-carbon new energy industrialization projects.	Contribution to promoting regional economic development is limited
	SDIC Green Energy Development Fund	2018	10.0	Green energy projects	
	Taihang Industrial Fund	2017	100.0	Supports Shanxi's transformation and cultivates new growth-driver industries.	
	Coal Clean Utilization Investment Fund	2016	100.0	In areas such as coal-power integration, modern coal chemical industry, coalbed methane extraction and utilization, carbon trading and emission reduction, as well as carbon capture and storage.	
Inner Mongolia	Carbon Neutral Fund	2022	100.0	Energy conservation, emission reduction, and green development, etc.	County- and district-level guidance funds often lack sufficient experience, and many of the lower-level counties and districts have relatively weak industrial foundations.
	State-Owned Enterprise Transformation and Upgrade Fund	2019	300.0	Transformation of state-owned industrial enterprises and optimization and upgrading of the state-owned economic layout and structure.	
	Emerging Industries Venture Capital Guidance Fund	2015	5.0	Emerging Industries	
Shaanxi	Green Energy Fund	2023	10.7	Related fields such as hydrogen energy, intelligent manufacturing, and	The overall scale is relatively small,

Region	Name of the Fund	Year of Fund Establishment	Initial Fund Size (Billion RMB)	Target Sectors	Challenges Faced
				negative carbon emissions, etc.	collaborative efforts from all parties are insufficient, and the operational mechanisms need improvement.
	Carbon Neutral Industry Investment Fund	2022	8.1	Core industries of the Dual-Carbon strategy, including various clean energy sectors primarily focused on hydrogen energy, energy storage, new energy vehicles, smart manufacturing, and green buildings.	
	Government-guided investment fund	2019	200.0	Emerging industries, modern service industries, modern agriculture, infrastructure, and public services.	
Ningxia	Fund for the Construction of Pilot Zones for Ecological Protection and High-Quality Development in the Yellow River Basin	2021	100.0	Provides capital support for infrastructure projects related to the construction of the pilot zone, including Yellow River flood control, ecological environment protection, pollution prevention, water conservation and consumption reduction, modern irrigation districts, transportation, and water network system development.	Some industry guidance funds are invested in enterprises with overcapacity and significant financial risks.
	Government Industrial Guidance Fund	2015	30.0	Emerging strategic industries, high-end equipment manufacturing, biomedicine, big data, and other advantageous and distinctive sectors related to opening up.	

Appendix C: Domestic and International Research and Cooperation Status

The project team conducted focused field research in Lüliang City, Shanxi Province, engaging in in-depth visits and exchanges with local steel enterprises, hydrogen energy companies, and coal logistics firms. The investigation found that, although preliminary progress has been made in decarbonization and upgrading of traditional industries, the promotion and application of zero-carbon technologies and the systematic layout of emerging industries remain relatively weak. The surveyed enterprises generally exhibit a high dependence on the coal-dominated industrial structure, with most clean energy projects still at the demonstration or initial stages, and the transformation pathways remain unclear. At the same time, breaking through existing technological routes and achieving structural adjustments still face significant transformation costs and policy uncertainties.

Figure C-1. The project team conducted a field survey and held a seminar in Lvliang City, Shanxi Province

In terms of international research, the project team visited traditional energy transition regions in the European Union, including Poland, Germany, and Spain, to gain an in-depth understanding of their practical experiences in orderly coal industry phase-out, industrial substitution, and employment placement. The investigation found that the EU has established a "just transition" framework through legislation, set up just transition funds, and promoted multi-stakeholder participation involving local governments, enterprises, and labour unions, gradually building a policy system characterized by "multi-level governance, stakeholder collaboration, and transparent participation." Although the EU experience offers valuable lessons, its transition scale is relatively small, and its economy has largely decoupled from high-carbon industries. The overall path differs significantly from China's dual pressures of "decarbonization" and "development." Therefore, China urgently needs to explore a systemic transition pathway more suited to its national conditions.

Figure C-2. The project delegation conducted research on international just energy transition in Poland, Spain, and Germany

The project team actively engaged in international dialogue by inviting Mr. Selwin Hart, Special Adviser on Climate Action to the UN Secretary-General and Assistant Secretary-General of the Climate Action Team, to hold a dedicated seminar on the theme of “Accelerating Green and Just Energy Transitions.” During the meeting, the project team and international experts conducted in-depth exchanges on global climate governance, just transition mechanisms, and the practical demands of developing countries. The meeting noted that although China has made significant achievements in new energy development—with photovoltaic and wind power industries among the global leaders—its traditional energy industry system remains large and the exit pathways complex. The country still faces multiple challenges, such as insufficient transition momentum in resource-dependent regions, high cost pressures, and difficulties in employment transfer. Therefore, there is an urgent need for enhanced forward-looking planning and top-level design at the national level to guide local governments in proactively planning industrial restructuring, technological substitution, and cultivation of green drivers, thereby constructing a just transition pathway combining policy coordination, mechanism guarantees, and financial support.

Figure C-3. The project team held discussions with Mr. Selwin Hart on China's green and just energy transition