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Research on Policy Response, Technological and Economic Bottlenecks, and Equitable Transition Path of China's Mining Areas under the Dual Carbon Target

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Abstract. Under the "dual-carbon" strategic framework, coal, as a cornerstone of China's energy security and local finances, faces unprecedented pressure to decarbonize. This paper, based on a micro-perspective of Shaanxi mining areas, systematically analyzes the policy response, operational frictions, and strategic optimization paths of coal enterprises through case studies, comparative policy assessments, and empirical survey data. The study finds that coal enterprises face severe technical and economic bottlenecks in their low-carbon transformation, including significant parasitic power consumption, a cost-price loss exceeding 60% due to the inverted cost of commercial carbon capture, utilization, and storage (CCUS), and extremely high dependence on regional finances and employment. To resolve the "energy trilemma" and achieve a balance between emission reduction and economic equity, this paper proposes a dual-track transformation framework that integrates "existing technology-based carbon reduction" with "incremental diversified development," and proposes a three-pillar institutional guarantee that includes a "just transition fund." The relevant conclusions provide specific policy references for China's low-carbon transformation that balances energy security, economic feasibility, and social equity.

Keywords: Just transition, carbon, energy trilemma, CCUS, stranded assets

1. Introduction

With the Paris Agreement setting a 1.5-degree Celsius temperature limit, global climate governance is accelerating the decarbonization process of the economic system [1]. In response, China has proposed a "dual-carbon" strategy—striving to peak carbon emissions before 2030 and achieve carbon neutrality before 2060 [2]. Achieving this goal requires a fundamental and systematic restructuring of China's high-carbon energy structure. Existing academic literature largely assesses energy transition from a macroeconomic model or corporate financial accounting perspective; however, these studies often overlook the technological frictions, commercial inversions, and the real-world social vulnerabilities faced by front line enterprises at the micro level, as well as resource-based mining areas. The coal industry plays an irreplaceable and dominant role in China's energy security system. In 2023, China's coal production reached 4.71 billion tons, accounting for 55.3% of primary energy consumption. Although thermal power accounts for only 47% of the

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country's total installed capacity, it provides over 60% of the actual power generation volume, serving as an indispensable base load provider for the power system. However, under the dual pressures of tightening compliance rules in the domestic carbon emissions trading market (ETS) and rising international green trade barriers such as the EU's Carbon Border Adjustment Mechanism (CBAM), the coal industry chain faces enormous pressure to reduce emissions. Based on field investigations and research conducted in Shaanxi mining areas during the summer, this study aims to bridge the significant gap between macroeconomic policy expectations and the micro economic implementation capabilities of enterprises.

This paper focuses on exploring the following three core research questions: 1. How do current policy tools (such as carbon emission trading and dual energy control) specifically affect the actual production and operation of coal enterprises? 2. What are the true attitudes of enterprise operators towards low-carbon transition policies, and what are the core technological and economic bottlenecks they face? 3. Under the framework of "just transition," how can a feasible optimization path that balances decarbonization efficiency and social equity be formulated?

This paper employs case analysis, literature analysis, and comparative analysis to connect the macro and micro perspectives of climate policy research, providing policymakers with a reference for resolving the "energy trilemma"—namely, balancing energy security, economic affordability, and environmental sustainability.

2. Current situation analysis, policy pressure, and implementation realities

2.1. China's coal base and asset stranding risk

China's energy structure exhibits the typical characteristics of being "rich in coal, poor in oil, and scarce in gas." Data from 2023 shows that thermal power, as the foundation of the power grid, bears more than 60% of the nation's electricity supply. However, CO_2 emissions from coal combustion account for more than 70% of the nation's total energy-related emissions, making it the absolute core of the country's decarbonization process. Since the coal industry chain holds trillions of yuan in fixed assets, a "radical cliff-edge withdrawal" could easily trigger huge "stranded assets" risks, thereby impacting regional financial systems and local economic security [3].

2.2. Dual policy pressures: the national carbon market and the EU CBAM

Coal companies are currently caught in a "double squeeze" of domestic administrative regulations and international trade rules. Domestically, the compliance requirements of the China Emissions Trading System (China ETS) are becoming increasingly stringent, while free allowances are continuously being reduced, directly raising the compliance costs for high-emission thermal power companies. Internationally, the EU's CBAM imposes carbon tariffs on imported high-carbon products. This mechanism, transmitted through the supply chain, forces downstream high-energy-consuming customers such as steel, aluminum, and chemicals to transition to low-carbon electricity, indirectly compressing the market space for traditional coal-fired power [4].

2.3. Theoretical framework of the "Energy Trilemma"

The "Energy Trilemma" as proposed by the World Energy Council, constitutes the core theoretical tool for analyzing coal transition [5]. Policy implementation must achieve a dynamic balance among the following three dimensions: energy security (ensuring uninterrupted and stable power supply and

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baseload reliability), economic affordability (maintaining industrial and residential electricity costs within a reasonable range and ensuring the health of local finances), and environmental sustainability (meeting stringent carbon emission reduction and ecological protection targets).

As a typical resource-based region characterized by "carbon lock-in," Shaanxi's mining areas face a predicament that is representative of the national situation yet possesses unique characteristics. Consequently, national policies must strike a balance between tailoring measures to local conditions and providing a social safety net.

3. Friction between enterprise response and frontline operations

3.1. Enterprise managers' attitudes

Abstract Support and Implementation Resistance Micro-level surveys in Shaanxi mining areas show that enterprise management generally expresses agreement with the national "dual-carbon" strategy at the macro level. However, at the implementation level, frontline managers have shown significant resistance and a wait-and-see attitude. This resistance does not stem from skepticism about climate change, but rather from the direct financial debt pressure faced by enterprises, the uncertainty of technological evolution, and the real risks to safe production.

3.2. Technical and economic constraints

Excessive CCUS Costs Adding a CCUS system to an existing thermal power plant will generate a huge "parasitic load (internal power consumption)." Capturing 1 ton of carbon dioxide requires 140-160 kWh of electricity, which amounts to 12%-15% of the power plant's total electricity generation, directly reducing net power supply efficiency by 8 to 10 percentage points. Furthermore, the capture costs for commercial CCUS implementation are severely out of sync with carbon market prices [6]. The 500,000-ton/year thermal power CCUS demonstration project at Guoneng Taizhou Power Plant and the enhanced oil recovery (EOR) cooperation case at Shaanxi Yanchang Oilfield's Xingzichuan Oil Production Plant fully demonstrate this point. Despite achieving a capture rate of 90.86% and a capture purity of 99.94%, and increasing crude oil recovery by 7.4%, the project itself would struggle to maintain commercial self-sufficiency without government subsidies.

3.3. Socioeconomic vulnerability: empirical evidence from Shaanxi mining areas

Data from surveys of typical resource-based counties and cities in Shaanxi Province reveals the potential socioeconomic shocks that coal withdrawal could trigger. Taking Shenmu City, Shaanxi Province, a typical resource-based city, as an example in 2024 [7]: its secondary industry (mainly coal mining, washing, and related energy industries such as coal chemicals and electricity) accounted for over 83% of its GDP. This indicates that among the 126,000 urban employees enrolled in the city's pension insurance program, a significant proportion are in the energy sector. A severe reduction in production capacity without alternative industries and subsidy mechanisms could easily lead to local fiscal collapse and structural unemployment, highlighting the urgency of introducing an equitable transition.

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4. Strategic optimization path and just transition mechanism

4.1. Technological optimization

Energy companies should promote the establishment of carbon capture and storage (CCUS) technologies and their extension projects, such as CCUS EOR [8], among chemical companies. Simultaneously, policies should establish a more comprehensive special subsidy system for new technologies like CCUS and a carbon market offsetting mechanism to use market-based means to compensate for corporate losses and encourage technological innovation. The emerging concept of "integrated wind, solar, thermal, and energy storage" can also play a significant role in optimizing corporate energy allocation.

4.2. Policy recommendations

A comprehensive and just transition policy system is crucial for achieving the dual goals of decarbonization and social stability. Firstly, for enterprises, special subsidies for new technologies such as CCUS should be established, and a sound carbon market offsetting mechanism should be implemented to compensate for the significant upfront costs of equipment investment. Secondly, for local governments, central government transfer payments to resource-based cities should be established to alleviate the impact of coal production cuts on local public finances and to diversify the output structure, encouraging the development of local service industries. Thirdly, for local residents, the government should learn from the EU's €17.5 billion "Just Transition Fund" and establish a special fund for just transition [9], to be used for re-training and up-skilling of the workforce in industrial zones.

5. Conclusion

Based on field research in mining areas and using case studies, policy comparisons, and relevant data, it systematically shows the challenges the coal industry faces during its transformation. The findings reveal that the pressure on coal enterprises to undergo economic transformation stems not only from macroeconomic policies but also from technological and socio-economic factors, leading to a widespread "wait-and-see" attitude among these enterprises.

To alleviate this situation, this paper proposes a technology transition framework and constructs a support system encompassing technology subsidies, central government transfer payments, and a equitable transition fund from three dimensions: enterprises, local governments, and local residents. The study argues that achieving both low-carbon transition and social stability requires striking a balance to avoid the social pain associated with structural adjustments.

However, this study only used a small-scale case study and field research in a single mining area, resulting in limited sample coverage. The generalizability of the research conclusions needs further verification. If the study could be expanded to other regions and a large-scale questionnaire survey could be used for quantitative evaluation, the reliability and reference value of the research conclusions would be improved.

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