Steel Decarbonization in Shanxi Province, China: Coking Coal Heartland and Energy Transition Test

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Abstract

Shanxi Province, China's premier coking coal region and a significant steel producer with 45–50 million tonnes annual capacity (4–5% of national output), represents a uniquely challenging decarbonization case. Unlike coastal provinces that can pivot to scrap-based EAF or hydrogen DRI with relative ease, Shanxi's steel industry is deeply integrated with captive coking coal mines, blast furnace-basic oxygen furnace (BF-BOF) dominance (over 95% of production), and a provincial economy heavily reliant on coal value chains. This paper, part of the MIFUS initiative, analyzes Shanxi's transformation under China's 1.5:1 capacity replacement policy and the October 2024 policy revolution that prioritizes Electric Arc Furnace (EAF) expansion and scrap mobilization. With abundant but low-quality scrap, limited renewable energy infrastructure, and severe water scarcity, Shanxi must pursue a hybrid pathway: retiring 10–12 Mt of obsolete BF-BOF capacity, developing modular scrap-EAF clusters in urban centers (Taiyuan, Changzhi), and piloting hydrogen injection into existing blast furnaces using blue hydrogen from coke oven gas. The analysis compares Shanxi's trajectory with Germany's coal-phase-out challenges and offers recommendations for coal-dependent steel regions globally. Key findings: Shanxi can achieve 30–35% emissions reduction by 2030, but requires systemic investment in CCUS, hydrogen infrastructure, and a just transition for 150,000+ coal-steel workers.

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1 Introduction: Shanxi's Strategic Position in China's Steel Transformation

1.1 The MIFUS Framework and Study Context

This paper is part of the MIFUS initiative, providing provincial-level analysis that complements global overview documents, China's October 2024 policies, and comparative studies of Hebei, Jiangsu, Shandong, and Liaoning.

1.2 Shanxi's Unique Role

Shanxi is China's largest coking coal producer (over 1 billion tonnes annually) and a major steelmaking region:

- **Production scale:** 45–50 Mt crude steel (2024), 4–5% of national total.
- **Technology mix:** >95% BF-BOF, among the highest in China.
- **Economic dependency:** Steel and coal together account for 25–30% of provincial GDP.
- **Strategic challenge:** Decarbonizing without destroying the economic base.

1.3 Contrast with Coastal Provinces

Table 1: Shanxi vs. Jiangsu – Technology and Economic Indicators (2024)

Indicator	Shanxi	Jiangsu
Steel capacity (Mt)	45–50	119–121
EAF share (%)	<5	18
GDP from steel (%)	12–15	5–8
Renewable electricity share (%)	15	25+
Scrap availability (Mt/year)	6–8	28–38

Shanxi cannot simply replicate Jiangsu's EAF pathway due to limited scrap and poor grid connectivity. Instead, it must leverage its coal chemistry assets for blue hydrogen and CCUS.

2 Production Landscape and Technology Mix

2.1 Current Production Capacity (2024)

Table 2: Shanxi Steel Production by Technology (2024)

Technology	Volume (Mt)	Share (%)
BF-BOF (Blast Furnace)	43–48	95–97
Electric Arc Furnace (EAF)	2–3	4–5
Total Crude Steel	45–50	100

2.2 Major Steel Producers

- **Taiyuan Iron and Steel (TISCO):** Provincial state-owned enterprise, 12–15 Mt capacity, specializes in stainless steel.
- **Shanxi Jianlong Group:** Private, 8–10 Mt, commodity long products.
- **Changzhi Iron & Steel:** 5–6 Mt, integrated with captive coking.
- **Others:** 20+ smaller mills, primary consolidation targets.

2.3 Coking Coal Integration

Shanxi's steel plants are typically co-located with coking facilities, enabling low-cost coke but creating high embedded emissions (2.3–2.5 t CO_2/t steel).

3 Decarbonization Strategy and Major Projects

3.1 Provincial Policy Framework

Under the 1.5:1 capacity replacement policy, Shanxi must retire 1.5 tonnes of old capacity for every tonne of new capacity. The province plans:

- **Net capacity reduction:** 10–12 Mt by 2030 (from 50 Mt to 38–40 Mt).
- **EAF expansion:** Add 5–7 Mt of EAF capacity by 2030 (target share 20–25%).
- **Hydrogen injection:** Pilot H_2-enriched blast furnaces at TISCO and Changzhi.
- **CCUS:** Retrofit 10 Mt of BF capacity with CO_2 capture by 2030.

3.2 Project 1: Taiyuan Blue Hydrogen Hub

- **Source:** Coke oven gas (COG) purification – Shanxi produces >150 billion m^3/year COG.
- **Scale:** 50,000 tonnes H_2/year by 2027, expanding to 200,000 t/year by 2030.
- **Use:** 20% H_2 injection into TISCO blast furnaces (reduces coke use by 15–20%).
- **Emissions reduction:** 1.5 Mt CO_2/year.

3.3 Project 2: Scrap-EAF Clusters

Three new EAF minimills in Taiyuan, Changzhi, and Linfen:

- **Capacity:** 2 Mt each, total 6 Mt.
- **Scrap sourcing:** Regional collection from coal mining equipment, automotive, and demolition.
- **Investment:** RMB 18–24 billion.

3.4 Project 3: CCUS on Remaining BF-BOF

- **Target:** TISCO's largest BF (3 Mt/year).
- **Technology:** Chemical absorption, capture rate 90%.
- **Storage:** Enhanced coal-bed methane (ECBM) recovery – Shanxi has extensive unmineable coal seams.
- **Cost:** RMB 300–450/t CO_2.

4 Infrastructure Requirements

4.1 Electricity and Renewable Energy

Shanxi has abundant wind and solar potential (especially in the north), but grid infrastructure is weak. Required:
- **Additional renewable capacity:** 10 GW wind + 8 GW solar by 2030.
- **Grid upgrades:** RMB 15–20 billion for transmission lines to steel hubs.

4.2 Hydrogen Infrastructure

- **Production:** COG purification (low cost, \$1.5–2/kg H_2) versus green H_2 (\$3–4/kg).
- **Pipelines:** 200 km of H_2-ready pipeline connecting coking plants to steel mills.
- **Storage:** Salt caverns in Yuncheng (potential 500,000 m^3).

4.3 Water Scarcity

Shanxi is water-stressed. EAF and hydrogen production require water-efficient technologies (air-cooled condensers, dry slag granulation).

5 Economic and Social Challenges

5.1 Capital Investment Requirements

Total 2025–2030 investment: RMB 80–100 billion ($11\tilde{}14 billion$) :

EAF capacity: RMB 30–40 billion.

Hydrogen infrastructure: RMB 20–25 billion.

CCUS retrofits: RMB 15–20 billion.

Renewable energy + grid: RMB 15–20 billion.

5.2 Employment Impact

- Direct steel employment: 100,000–120,000 workers.
- Indirect (coal mining, logistics): 300,000+.
- Projected job losses: 40,000–50,000 by 2030.
- Retraining programs: Budget RMB 5 billion.

5.3 Just Transition Measures

- Early retirement packages for coal miners.
- New industrial parks for renewable equipment manufacturing.
- Social safety net expansion.

6 Comparative Analysis: Shanxi vs. Germany (Coal Regions)

Table 3: Shanxi vs. Germany's Coal Steel Regions (e.g., Saarland, North Rhine-Westphalia)

Factor	Shanxi	Germany
Coal linkage	Coking coal (captive)	Hard coal (imported)
Primary decarbonization route	Blue H_2 injection + CCUS	Green H_2-DRI
H_2 cost target (2030)	\$2–3/kg (blue)	\$4–5/kg (green)
Social acceptance	State-driven, low resistance	Strong union involvement
EU CBAM exposure	Indirect (via downstream products)	Direct

Shanxi's advantage is low-cost blue hydrogen from COG, but it must manage CO_2 from hydrogen production (requiring CCUS).

7 Conclusions and Policy Recommendations

7.1 Key Findings

1. Shanxi can achieve 30–35% emissions reduction by 2030 without collapsing its economy.
2. Blue hydrogen (from coke oven gas) is the most cost-effective transition fuel.
3. Scrap-EAF clusters can absorb displaced BF-BOF workers and utilize urban scrap.
4. CCUS on remaining BFs is essential for deep decarbonization post-2035.

7.2 Recommendations

- **For provincial government:** Establish a "Coal-Steel Just Transition Fund" using carbon market revenues.
- **For central government:** Include blue hydrogen with CCUS in the national ETS and subsidy programs.
- **For industry:** Form a Shanxi Green Steel Alliance to coordinate scrap collection and hydrogen infrastructure.
- **International cooperation:** Partner with Germany on CCUS and hydrogen safety standards.

7.3 Global Relevance

Shanxi's model offers lessons for other coal-dependent steel regions: Poland's Silesia, India's Jharkhand, and the US Appalachian coalfields.

"Decarbonization without deindustrialization – the Shanxi challenge."