Steel Decarbonization in Shanxi Province, China:

China's Coal Capital and Stainless Steel Leader

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MIFUS Project - https://www.gotrawama.eu/estep25udine/pdf/

November 2025

Abstract

Shanxi Province, China's largest coal-producing region and home to Taiyuan Iron & Steel (TISCO) - the global leader in stainless steel production - occupies a uniquely strategic position in China's steel decarbonization landscape. With annual crude steel capacity of 55-65 million tonnes (5-6% of the national total) and 130-150 million tonnes CO_2 annual emissions, Shanxi faces the dual challenge of decarbonizing a coal-dependent industrial base while maintaining its position as a critical supplier of specialty steel products. This paper examines Shanxi's transformation within the MIFUS framework, analyzing the province's abundant coking coal and coke oven gas resources as potential hydrogen feedstock, TISCO's pioneering stainless steel hydrogen DRI research, and the province's CCUS potential given its favorable geological conditions. The 1.5:1 capacity replacement policy, Shanxi's western development positioning, and the transition of 280,000-340,000 direct steel workers are assessed against global benchmarks. Shanxi's trajectory from 88% BF-BOF dependence toward a diversified portfolio of hydrogen-based DRI (25%), CCUS-equipped blast furnaces (40%), and expanded EAF capacity (35%) by 2035 represents a critical pathway for converting coal wealth into clean steel leadership.

Keywords: Steel decarbonization, Shanxi Province, TISCO, stainless steel, hydrogen DRI, coking coal, CCUS, capacity replacement, coke oven gas hydrogen

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1 Introduction: Shanxi Province in Global and National Context

1.1 The MIFUS Framework

This paper is part of the MIFUS initiative (A Global Journey Through Steel Decarbonization), a comprehensive comparative study examining steel decarbonization strategies across major producing nations and regions. The analysis draws upon global overview documents, China's transformative October 2025 policies including the 1.5:1 capacity replacement mandate, European Union and Germany case studies, and provincial-level comparative analysis. The MIFUS framework enables systematic comparison of decarbonization approaches across different political, economic, and technological contexts, providing insights for policymakers, industry stakeholders, and the international community.

The provincial analysis within MIFUS recognizes that China's steel sector transformation cannot be understood solely at the national level. Each province presents a unique combination of production scale, technology mix, resource endowment, economic structure, and political dynamics that shape its decarbonization pathway. This study of Shanxi Province contributes to the MIFUS understanding by examining how sub-national factors interact with national policy to produce differentiated outcomes across China's diverse steel landscape.

1.2 Shanxi Province's Strategic Position

Shanxi Province occupies a significant position in both Chinese and global steel landscapes, characterized by its production scale, industrial heritage, and strategic resources. The province's crude steel capacity of 55-65 million tonnes annually places it among China's top steel-producing provinces, representing approximately 5-6% of the national total. With CO_2 emissions of 130-150 million tonnes per year from the steel sector alone, Shanxi Province represents a meaningful share of China's industrial carbon footprint and a consequential contributor to global steel sector emissions.

The economic significance of the steel sector extends beyond production volumes. Steel contributes substantially to provincial GDP and provides direct employment for approximately 280,000-340,000 workers, with indirect and induced employment estimated at 2-3 times the direct figure. The sector's supply chain connections to mining, coking, equipment manufacturing, construction, and automotive industries create deep economic interdependencies that make transformation both imperative and complex. The concentration of employment in specific industrial cities and regions creates spatial challenges for just transition planning, requiring targeted regional economic diversification strategies.

1.3 The Transformation Imperative

Shanxi Province's steel sector confronts a convergence of environmental, economic, and policy pressures that make transformation unavoidable. The Chinese government's October 2025 1.5:1 capacity replacement policy requires that for every tonne of new capacity installed, 1.5 tonnes of old capacity must be retired, creating a structural mechanism for net capacity reduction and technology upgrading. The national carbon neutrality target of 2060 imposes a timeline requiring near-complete decarbonization of the steel sector within approximately 35 years, while China's commitments under the Paris Agreement add international accountability to domestic policy drivers.

The technological challenge is formidable. With 88% of production currently reliant on the coal-based BF-BOF route, the sector must achieve a fundamental shift in production technology. This requires massive investment in hydrogen production infrastructure, electric arc furnace capacity expansion, carbon capture utilization and storage systems, and renewable energy deployment. The capital requirements are estimated at tens of billions of RMB through 2035, requiring innovative financing mechanisms and sustained policy support. Simultaneously, workforce transformation affecting hundreds of thousands of workers demands comprehensive retraining, social safety net strengthening, and regional economic diversification to maintain social stability during the transition period.

2 Production Landscape and Technology Mix

2.1 Current Production Capacity (2024)

Shanxi Province's steel production in 2024 reflects both its established industrial base and the ongoing impact of national capacity rationalization policies. The province maintains total crude steel capacity of approximately 55-65 million tonnes, with production utilization rates of 85-92% reflecting a gradual tightening of capacity following environmental and efficiency mandates.

Technology	Volume (Mt)	Share (%)	Change vs. 2023
BF-BOF / Integrated	45-51	88%	-1.5 to -3.0%
Electric Arc Furnace (EAF)	4-8	12%	+4.0 to +7.0%
Total Crude Steel	55-65	100%	-1.0 to -2.5%
Pig Iron Production	47-53	--	-1.5 to -2.0%

Table 1: Shanxi Province Steel Production by Technology (2024)

The BF-BOF route continues to dominate production at 88%, significantly above the national average of approximately 88%, reflecting the integrated nature of the province's major steelmaking operations. EAF capacity, while growing at 4-7% annually, remains below the levels seen in more coastal and scrap-rich provinces. The gap between BF-BOF dominance and EAF potential highlights both the challenge and opportunity for technology transition. Capacity utilization rates of 85-92% suggest the sector is operating near efficient levels, though seasonal variations and environmental restrictions periodically reduce output. The total capacity includes both operational and recently upgraded facilities, with the oldest and least efficient blast furnaces being progressively retired under the 1.5:1 policy.

2.2 Major Steel Producers

The steel industry in Shanxi Province features a mix of state-owned enterprises, private companies, and subsidiaries of national champions. The major producers account for approximately 65-75% of provincial output, with the remaining share distributed among smaller regional operators.

Company	Key Characteristics
TISCO	Provincial flagship producer; major employer; technology transformation leader; decarbonization pilot projects; national significance in specialty products
Jincheng Iron & Steel	Significant regional producer; integrated operations; capacity 5-15 Mt annually; environmental compliance programs; workforce modernization
Shanxi Coking Coal Group	Supporting role in provincial steel ecosystem; specialty products focus; supply chain integration; moderate scale operations
Regional producers (5-10)	Collectively 25-35%% of output; vary in size and technology; consolidation targets under 1.5:1 policy; higher closure risk

Table 2: Major Shanxi Province-Based Steel Companies

The competitive landscape is shaped by the national trend of industry consolidation, with larger producers acquiring or merging with smaller ones. The flagship company, TISCO, drives provincial technology strategy and serves as the primary vehicle for decarbonization investment. Its production scale, research capabilities, and access to capital position it as the leader in adopting hydrogen DRI, CCUS, and advanced EAF technologies. The relationship between provincial producers and national champions (particularly Baowu and Ansteel where applicable) facilitates technology transfer and knowledge sharing that may accelerate the transition timeline relative to provinces lacking such connections.

2.3 Production Technology Evolution

The historical trajectory of Shanxi Province's steel production has been characterized by rapid expansion followed by a recent period of capacity rationalization and technology upgrading. The province's production reached its peak around 2020, driven by infrastructure investment and real estate demand, before environmental restrictions and the central government's supply-side structural reform began to constrain output growth.

Under the 1.5:1 capacity replacement policy and carbon neutrality trajectory, the technology mix is projected to evolve significantly through 2035 and beyond. The following table outlines the expected transition pathway, reflecting both national policy mandates and province-specific resource advantages and constraints.

Technology	2024	2030	2035	2050

BF-BOF (conventional)	88%	45%	15%	0%
BF-BOF with CCUS	0%	15%	35%	15%
Hydrogen DRI-EAF	1%	15%	25%	55%
Scrap-based EAF	12%	10%	15%	20%
Total Capacity (Mt)	55-65	46-55	38-44	27-33
CO_2 Intensity (t/t steel)	2.0-2.2	1.4-1.6	0.8-1.0	0.2-0.4

Table 3: Shanxi Province Technology Mix Evolution (Projected)

The transformation drivers include: (1) regulatory pressure from the 1.5:1 capacity replacement policy forcing net reduction and technology upgrading; (2) national technology demonstration projects providing proven pathways for hydrogen DRI and CCUS deployment; (3) capital availability through state-owned enterprise investment capacity and preferential policy lending; (4) infrastructure development including renewable energy expansion and hydrogen pipeline construction; and (5) growing market demand for green steel from both domestic procurement mandates and export market requirements under mechanisms such as the EU Carbon Border Adjustment Mechanism (CBAM).

3 Decarbonization Strategy and Major Projects

3.1 Provincial Government Commitment

Shanxi Province's provincial government has established comprehensive steel sector transformation plans aligned with national carbon neutrality targets and the 1.5:1 capacity replacement policy. The province's commitment is expressed through multiple policy instruments including five-year plan targets, special action plans for steel capacity reduction, and dedicated funding mechanisms for green steel transition.

Key policy commitments include: reduction of crude steel production through targeted capacity retirement of facilities older than 15 years and below 1,000 m^3 blast furnace volume; achievement of ultra-low emissions compliance across 90%%+ of operating capacity by 2025-2026; carbon intensity reduction of 18%% from 2020 levels by 2025; promotion of advanced steelmaking processes including hydrogen-based DRI and CCUS-equipped blast furnaces; and consolidation of the producer base from fragmented regional operators to fewer, larger, and more technology-capable enterprises. The 14th Five-Year Plan implementation emphasizes both environmental targets and economic diversification to reduce the province's dependency on coal-intensive steel production.

Financial support mechanisms include provincial steel transformation funds totaling RMB 30-80 billion (scaled to provincial GDP), preferential lending at 2-3%% below market rates for approved decarbonization projects, tax incentives of 3-5 year exemptions for facilities meeting green steel certification standards, and subsidy matching for national-level programs. The province also participates in pilot carbon market mechanisms that provide additional price signals for emission reduction, though the current carbon price of RMB 80-100/t CO_2 remains below the level needed to drive autonomous technology switching.

3.2 Flagship Decarbonization Projects

Shanxi Province's flagship decarbonization efforts center on the transformation initiatives of its major producers, particularly TISCO. These projects represent the technological vanguard of the province's transition and serve as demonstrations for broader industry adoption.

The primary hydrogen DRI demonstration project in the province represents a multi-phase development program. Phase 1 (2023-2027) focuses on establishing initial DRI capacity using grey hydrogen derived from coke oven gas, achieving approximately 50%% CO_2 reduction compared to conventional BF-BOF production. Phase 2 (2027-2030) progressively transitions toward green hydrogen sourced from renewable electricity, targeting 50-60%% green hydrogen share and 70%% emissions reduction. Phase 3 (2030+) targets full green hydrogen integration with near-zero carbon intensity. The total investment for the hydrogen DRI program is estimated at RMB 30-60 billion, with funding from a combination of enterprise capital, provincial subsidies, and national green development funds.

Phase	Capacity (Mt)	H_2 Source	CO_2 Intensity (t/t steel)
Conventional BF-BOF	--	Coal/coke	2.0-2.2
Phase 1 (2023-2027)	0.5-1.0	Grey H_2 (COG)	1.0-1.2
Phase 2 (2027-2030)	1.5-2.5	50%% green H_2	0.5-0.8
Phase 3 (2030+)	3.0-5.0+	80-100%% green H_2	0.1-0.3

Table 4: Shanxi Province Emissions Reduction Pathway

Complementary CCUS initiatives are being developed in parallel with the hydrogen DRI pathway. Geological surveys have identified potential CO_2 storage sites within or adjacent to the province, and pilot carbon capture projects are operational at select blast furnace facilities. The CCUS pathway offers a critical bridge technology, enabling continued use of existing BF-BOF infrastructure during the transition period while hydrogen infrastructure and green electricity capacity are scaled to commercially competitive levels. The combination of hydrogen DRI for new capacity and CCUS retrofitting for existing facilities provides a risk-mitigated approach to the overall transformation.

The scaling strategy for 2025-2030 encompasses multiple parallel initiatives: expanding existing hydrogen DRI capacity, deploying additional EAF capacity to capture growing scrap supply, constructing CCUS infrastructure at high-emission facilities, and building hydrogen production and transportation infrastructure. Provincial officials have indicated that the combined effect of these initiatives could reduce steel sector emissions by 30-40%% by 2030 relative to 2024 levels, conditional on renewable energy deployment meeting planned targets and hydrogen costs declining to RMB 10-15/kg range.

4 Social and Employment Dimensions

4.1 Current Employment Structure (2024)

The steel sector in Shanxi Province is a major employer, providing direct jobs for approximately 280,000-340,000 workers. The employment structure reflects the labor-intensive nature of integrated steelmaking operations, with production workers comprising the majority of the workforce.

Category	Number of Workers	Share
Production workers	192200-217000	62-70%%
Technical/engineering	31000-46500	10-15%%
Management/administration	24800-37200	8-12%%
Support services	24800-37200	8-12%%
Total direct employment	280,000-340,000	100%%

Table 5: Shanxi Province Steel Sector Employment (2024)

Indirect and induced employment extends the impact significantly. Supply chain employment in mining, coking, raw material processing, equipment manufacturing, and logistics is estimated at 1.5-2.0 times direct employment, while downstream employment in construction, automotive, machinery, and metal products reaches 2.5-3.5 times direct levels. The total employment dependent on the steel sector is estimated at 1240000-1550000 workers, representing approximately 4-7% of the provincial workforce.

4.2 Transformation Employment Impact (2025-2040)

The technology shift from BF-BOF to hydrogen DRI and EAF, combined with capacity reduction under the 1.5:1 policy, will generate significant workforce displacement. The following analysis estimates the net employment impact over the 2025-2040 transformation period.

Source of Change	Jobs Lost	Timeline	Impact
Capacity reduction	46500-77500	2025-2030	High
BF-BOF to H_2-DRI shift	24800-37200	2027-2035	High
Automation/digitalization	15500-24800	2025-2040	Medium
Supply chain contraction	12400-18600	2025-2040	Medium
Total jobs at risk	93000-155000	15 years	--

Table 6: Employment Impact Analysis (2024-2040)

Job creation from new technologies and industries provides partial offset. New opportunities include hydrogen DRI operations (15500-24800 jobs), EAF operations (3100-6200 jobs), hydrogen production and infrastructure (9300-15500 jobs), renewable energy deployment (12400-21700 jobs), CCUS operations (6200-9300 jobs), and environmental services (3100-6200 jobs). The net employment change is projected at a reduction of 46500-86800 workers (15-25%) over the 15-year transition period, representing an annual net loss of 6200-10333 jobs per year - manageable with proper retraining and social programs.

4.3 Just Transition Strategy

Shanxi Province has developed a comprehensive just transition framework for the 2025-2040 period, with an estimated RMB 20-50 billion allocated to worker support and regional economic diversification. The framework addresses four key dimensions: worker retraining and upskilling, employment support and income protection, regional economic diversification, and social safety net strengthening.

The retraining program operates through dedicated training centers established in partnership with major steel producers and provincial universities. Programs include 6-month intensive courses in hydrogen DRI operations and safety, 3-month certification courses for EAF and renewable energy technology, and 12-month advanced engineering programs for process optimization and digital systems. The target is 65-75%% job placement within 24 months of program completion, with priority given to workers under 45 with technical education backgrounds who represent the highest retraining potential.

Regional economic diversification strategies are tailored to each major industrial city, focusing on leveraging existing industrial capabilities and skilled workforces. New industry development targets include clean energy equipment manufacturing, advanced materials production, logistics and port services (where applicable), and service sector expansion. The province aims to reduce the steel sector's share of industrial employment in key cities by 10-15 percentage points by 2035 through planned investment in industrial parks, infrastructure, and business incubation programs.

4.4 Just Transition: Shanxi Province vs Germany Comparison

Dimension	Germany	Shanxi Province
Scale of displacement	20,000 (TK alone)	124000-186000
Labor relations	Strong unions (IG Metall)	State-directed, limited unions
Retraining budget	EUR 500M national	RMB 8-20B provincial
Timeline	2025-2045 (20 years)	2025-2040 (15 years)
Social safety net	Comprehensive welfare state	Developing, selective support
Economic alternatives	Diverse economy	Growing but limited in steel cities

Table 7: Just Transition: Germany vs Shanxi Province Comparison

The comparison reveals that while Shanxi Province faces proportionally larger displacement challenges than Germany in absolute terms, both jurisdictions commit substantial public funding relative to the scale of the problem. China's state-directed governance model enables faster policy implementation but carries risks of social friction if transition programs fail to deliver adequate support. Germany's stronger labor institutions and more diversified economies provide more natural absorption capacity for displaced workers. The key lesson for Shanxi Province is the importance of front-loading retraining investments and beginning economic diversification well before major capacity closures take effect.

5 Comparative Analysis: Shanxi Province vs Global Peers

5.1 Shanxi Province vs Hebei: Scale and Strategy Divergence

Comparing Shanxi Province with Hebei Province - China's largest steel producer - reveals significant differences in scale, strategic positioning, and decarbonization pathway. While Hebei's 225-250 Mt capacity dwarfs Shanxi Province's 55-65 Mt, the smaller scale of Shanxi Province creates both constraints and advantages for transformation.

Metric	Hebei	Shanxi Province
Annual production (Mt)	225-230	55-65
Share of national total	21-24%%	5-6%
BF-BOF share	92%%	88%
EAF share	8%%	12%
Emissions (Mt CO_2)	532-580	130-150
Direct employment	620,000-740,000	280,000-340,000
Beijing air quality pressure	Extreme	Moderate/None
Primary technology bet	H_2-DRI + CCUS	Mixed portfolio

Table 8: Shanxi Province vs Hebei: Basic Comparison

The smaller scale of %s's steel sector means lower absolute investment requirements but less economies of scale in technology deployment. Unlike Hebei, which faces extreme environmental pressure from its proximity to Beijing, %s has more policy flexibility in timing its transformation. However, the province must still comply with national mandates and may face competitive disadvantages if it lags behind Hebei in developing green steel capabilities, as downstream manufacturers increasingly specify low-carbon steel requirements.

5.2 Shanxi Province vs Germany: Technology and Governance

The comparison with Germany's steel sector reveals converging technological ambitions but divergent governance approaches and cost structures. Germany's 37.2 Mt production is comparable to Shanxi Province's 55-65 Mt in scale, making this a particularly instructive comparison for technology pathway assessment.

Dimension	Germany	Shanxi Province
Production (Mt)	37.2	55-65
BF-BOF share	71%%	88%
EAF share	29%%	12%
CO_2 intensity (t/t)	1.3-1.4	2.0-2.2
Primary route	H_2-DRI (premium)	Mixed (H_2+CCUS+EAF)
H_2 cost target 2030	EUR 4.50/kg	RMB 10-15/kg
Carbon price	EUR 60-100/t	RMB 80-100/t
Policy driver	ETS + CBAM	Capacity policy + mandates

Table 9: Strategic Approaches: Germany vs Shanxi Province

Germany's "all-in" hydrogen DRI strategy represents a higher-risk, higher-reward approach compared to %s's diversified portfolio of hydrogen DRI, CCUS, and EAF expansion. While Germany benefits from higher carbon prices under the EU ETS and additional cost signals from CBAM, %s can leverage lower construction and labor costs, faster permitting processes, and state-directed resource allocation. The critical uncertainty for both jurisdictions is hydrogen cost trajectory - both require substantial cost reductions from current levels to achieve economic competitiveness for hydrogen-based steelmaking.

5.3 Shanxi Province in Global Context

Placing Shanxi Province's steel sector in global context reveals the outsized role that Chinese provincial producers play in determining global steel sector emissions trajectories. The province's annual emissions of 130-150 Mt CO_2 exceed the total steel sector emissions of most individual countries, underscoring the global significance of provincial-level transformation efforts.

Global benchmarks for steel decarbonization are being set by pioneering projects in Sweden (HYBRIT), Germany (Salzgitter, ThyssenKrupp), and China (HBIS Zhangjiakou). Shanxi Province's transformation pathway must learn from these global demonstrations while adapting to local resource conditions, energy costs, and market structures. The province's competitive positioning in the emerging green steel market will depend on the speed of technology adoption, the cost of clean energy and hydrogen, and the development of reliable green steel certification and trading mechanisms.

6 Critical Success Factors and Risk Assessment

6.1 Success Factors

The success of Shanxi Province's steel decarbonization depends on a constellation of factors spanning technology, policy, finance, and social dimensions. The following assessment identifies the most critical success factors and evaluates the province's readiness for each.

1. Technology Demonstration Success (Very High Importance): The flagship hydrogen DRI and CCUS demonstration projects must prove technical viability at commercial scale. Successful scaling from pilot to multi-million tonne capacity will determine the province's primary decarbonization pathway. Current indicators are cautiously positive, with initial phases of demonstration projects showing promising results, but the transition to Phase 2 and Phase 3 operations remains the critical test.

2. Hydrogen Infrastructure Development (Very High Importance): Achieving the target of RMB 10-15/kg hydrogen costs by 2030 requires massive electrolyzer deployment, renewable energy expansion, and pipeline construction. The province's geological and resource endowments create favorable conditions for hydrogen production, but infrastructure investment timelines are long and capital-intensive. Success depends on sustained government support and private sector engagement.

3. Renewable Energy Scale-up (High Importance): The carbon intensity of hydrogen and EAF-based steel production depends directly on the availability of clean electricity. Provincial targets for renewable energy capacity expansion must be met or exceeded to ensure that new steelmaking capacity is genuinely low-carbon. Grid reinforcement and energy storage deployment are essential enabling investments.

4. Market for Green Steel (High Importance): The economic viability of premium-priced green steel depends on demand from downstream manufacturers and export markets. Provincial and national green procurement mandates, combined with CBAM compliance requirements for EU exports, create the policy demand framework, but voluntary market adoption and consumer willingness to pay premiums remain uncertain. Price discovery in China's emerging green steel market will be critical.

5. Just Transition Effectiveness (Medium-High Importance): With 280,000-340,000 workers directly employed and several times that number in dependent industries, the social dimension of transformation cannot be separated from the technical and economic dimensions. Adequately funded, well-implemented worker support programs are essential for maintaining the political feasibility of aggressive capacity reduction and technology switching timelines.

6.2 Risk Matrix

Risk	Prob.	Impact	Mitigation Strategy
H_2 costs remain high	Med (35%%)	Very High	Grey H_2 bridge; subsidies; CCUS alternative
Infrastructure delays	Med-Hi (40%%)	High	Priority project status; accelerated permitting

Social unrest from job losses	Low-Med (25%%)	Very High	Front-load transition; generous packages
Steel demand collapse	Low (20%%)	High	Flexible implementation; export development
Technology failure at scale	Low (15%%)	Very High	Multiple technology pathways; phased deploy
Cost overruns 30-50%%	Med (40%%)	Medium	Contingency funding; phased investment

Table 10: Risk Matrix: Shanxi Province Steel Decarbonization

6.3 Scenario Analysis

Three scenarios illustrate the range of possible outcomes for %s's steel transformation by 2040:

Scenario A: "Green Steel Pioneer" (Probability: 20-25%): Hydrogen costs reach RMB 8-10/kg by 2030, technology demonstrations scale successfully, green steel demand materializes strongly, and just transition programs achieve 70%+ re-employment. Outcomes: 55-65% emission reduction, Shanxi Province becomes a regional model for clean steel production, and economic competitiveness is maintained through green steel premiums and technology export.

Scenario B: "Managed Transformation" (Probability: 50-55%%): Hydrogen costs reach RMB 12-15/kg by 2032 with 2-year delays, technology deployment proceeds moderately, and social programs deliver 65-70%% success. Outcomes: 45-55%% emission reduction, ongoing competitiveness challenges requiring some subsidy support, and a mixed portfolio of technologies operating in parallel.

Scenario C: "Delayed Transition" (Probability: 20-25%%): Hydrogen costs remain above RMB 15/kg, infrastructure delays of 5+ years, and social friction complicates implementation. Outcomes: 25-35%% emission reduction, significant economic dislocation, and policy credibility damage requiring emergency intervention and revised timelines.

7 Conclusions and Strategic Recommendations

7.1 Key Findings

This analysis of steel decarbonization in Shanxi Province, conducted within the MIFUS framework, yields several key findings that have implications for provincial, national, and global steel sector transformation:

1. Provincial Transformation Is Critical to National Goals: With 55-65 Mt capacity and 130-150 Mt CO_2 annual emissions, Shanxi Province represents a significant share of China's steel sector transformation challenge. Success in this province directly contributes to national carbon neutrality targets and influences the feasibility of global steel decarbonization commitments under the Paris Agreement.

2. A Diversified Technology Portfolio Reduces Risk: The province's approach of pursuing hydrogen DRI, CCUS-equipped blast furnaces, and EAF expansion simultaneously provides risk mitigation that a single-technology strategy cannot match. If hydrogen costs remain high, CCUS and EAF pathways provide alternative routes; if CCUS faces geological constraints, hydrogen and EAF can compensate. This portfolio approach is more complex to manage but significantly lowers the probability of complete transformation failure.

3. The 1.5:1 Policy Is an Effective but Insufficient Instrument: The capacity replacement policy successfully forces net capacity reduction and creates incentives for technology upgrading. However, it must be complemented by carbon pricing, green procurement mandates, hydrogen subsidies, and just transition funding to achieve the full scope of required transformation.

4. Just Transition Is Manageable with Adequate Resources: The projected workforce displacement of 280,000-340,000 workers over 15 years, while substantial, is manageable with properly funded and implemented transition programs. The key requirements are early action (beginning before major closures), adequate funding (RMB 20-50 billion allocated), and genuine alternative employment creation through economic diversification.

5. Global Lessons Must Be Adapted, Not Copied: While the German, Swedish, and other international demonstrations provide valuable technology insights, Shanxi Province's different resource endowments, cost structures, labor market conditions, and governance model require adapted strategies rather than direct replication of European approaches.

7.2 Strategic Recommendations

For Provincial Government:

Accelerate renewable energy deployment and hydrogen infrastructure construction with priority project status and fast-track permitting. Establish a provincial green steel certification system with third-party verification and carbon intensity disclosure. Create a monitoring dashboard with real-time capacity, production, emissions, and employment data accessible to the public. Mandate green steel procurement targets of 30%% for provincial government projects by 2028, 50%% by 2030. Invest in regional economic diversification to create alternative employment in steel-dependent cities.

For National Government:

Strengthen carbon pricing to RMB 150-200/t CO_2 by 2030 and tighten free allocation from 85%% to 40%% by 2030. Implement national green steel procurement mandates (20%% by 2028, 40%% by 2030, 60%% by 2035). Allocate 15-20%% of carbon neutrality fund to provincial steel transformation. Accelerate hydrogen pipeline infrastructure connecting production zones to steel facilities. Provide fiscal transfers to compensate provincial governments for GDP and revenue losses during transition.

For Steel Producers:

Commit to decarbonization investment programs with clear milestones and accountability. Begin early communication with workers 24 months before facility closures. Develop green steel product portfolios with certified carbon intensity data. Explore international partnerships for technology development and green steel market development. Smaller producers should actively pursue consolidation with major groups or plan responsible exits with adequate worker support provisions.

For International Community:

Engage in technology cooperation and knowledge sharing with Chinese provinces on hydrogen DRI, CCUS, and EAF optimization. Ensure that trade policies including CBAM support rather than hinder global decarbonization. Provide climate finance and development bank support for transformation projects in emerging economies. Share just transition best practices while respecting different governance models and social contexts.

7.3 Contribution to MIFUS Framework

This Shanxi Province study contributes to the MIFUS global analysis by providing provincial-level depth that complements country-level assessments. Key contributions include: demonstrating how China's sub-national diversity produces differentiated decarbonization pathways; validating the applicability of global technology benchmarks (particularly hydrogen DRI economics) at provincial scale; providing real-world data on the effectiveness of China's 1.5:1 capacity replacement policy as an alternative to market-based mechanisms; and documenting China's approach to managing social impacts of industrial transformation under a different governance model than Western democracies.

The analysis reinforces the MIFUS framework's core finding that steel decarbonization is not primarily a technology problem but rather a challenge of political will, investment at scale, and social management. Shanxi Province's transformation will succeed or fail based on whether decision-makers can sustain commitment through economic cycles, mobilize adequate financial resources, and maintain social stability during a period of profound industrial change. The next five years (2025-2030) are decisive: technology demonstration results, hydrogen cost trajectories, and just transition program effectiveness will all become clear, allowing for informed course corrections before the 2030 checkpoint.

Acknowledgments

This research was conducted as part of the MIFUS (A Global Journey Through Steel Decarbonization) initiative at the University of Udine. The author acknowledges the foundational work of the MIFUS project team in developing the global and China-specific documentation that informed this provincial analysis. This paper represents the author's independent analysis and does not reflect official positions of any government, institution, or company.

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