Steel Decarbonization in China:

Provincial Implementation Strategies and the Path to Carbon Neutrality by 2060

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MIFUS Project
A Global Journey Through Steel Decarbonization

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This document represents a personal but hopefully comprehensive update and expansion of the preliminary China steel policy analysis (C_ ChinaSteelPolicyDeep01.pdf), incorporating October 2025 government policy drafts and recent provincial developments. The opinion presented here do not reflect those of any specific organization, in Italy and abroad, and are presented here just for teaching purposes

Abstract

This comprehensive study analyzes China's steel decarbonization strategy through the critical lens of provincial implementation during the 15th Five-Year Plan period (2026-2030) and beyond to the 2060 carbon neutrality target. Building upon the preliminary MIFUS framework analysis, this document incorporates the transformative October 2025 draft policy on capacity replacement (implementing a strict 1.5:1 reduction ratio), recent developments in key steel-producing provinces (Hebei, Jiangsu, Shandong, Liaoning), and emerging strategies in Guangdong and Inner Mongolia.

China's approach represents the world's most ambitious industrial decarbonization program, encompassing approximately 1,065 million tonnes of annual crude steel production (54% of global output) and requiring coordinated transformation across diverse provincial contexts. The analysis reveals three fundamental operational pillars: (1) forced industrial consolidation through enhanced capacity swap mechanisms that mandate net capacity reductions, (2) comprehensive ultra-low emissions retrofitting creating a significant CO_2 penalty that paradoxically accelerates innovation, and (3) strategic piloting of breakthrough technologies including hydrogen-based direct reduction (H_2-DRI), carbon capture utilization and storage (CCUS), and expanded electric arc furnace (EAF) capacity.

Provincial analysis demonstrates striking divergence in implementation strategies based on local conditions. Hebei Province (225-250 Mt/a, 21-24% national share) faces the most severe transformation pressure due to Beijing proximity, pioneering HBIS Zhangjiakou's 1.2 Mt operational H_2-DRI facility with plans for 8-10 Mt by 2030. Jiangsu (120-130 Mt/a) pursues an EAF-centric pathway leveraging superior scrap availability and coastal infrastructure. Shandong (100-110 Mt/a) balances conventional BF-BOF optimization with selective H_2-DRI deployment. Liaoning (70-75 Mt/a) exploits China's lowest levelized cost of steel production through abundant renewable energy and nuclear power. Inner Mongolia emerges as the critical enabler, positioned to become China's green hydrogen production hub with pipeline infrastructure connecting to major steel provinces. Guangdong represents the high-value manufacturing integration model, linking steel transformation to advanced automotive and electronics sectors.

Investment requirements are extraordinary: RMB 2.0-2.5 trillion (approximately USD 280-350 billion) nationally through 2040, with Hebei alone requiring RMB 200-300 billion. Social dimensions are equally profound, with 300,000-500,000 direct steel jobs at risk nationally, necessitating comprehensive just transition programs encompassing retraining, early retirement, regional economic diversification, and social safety net strengthening.

Critical success factors include: achieving green hydrogen costs of RMB 8-12/kg by 2030 (from current RMB 18-25/kg), maintaining political will across economic cycles, developing extensive infrastructure (pipelines, electrolyzers, grid reinforcement, CO_2 storage), creating viable markets for green steel products, and managing social transitions without instability. Technology pathways show provincial specialization: Hebei and Liaoning lead H_2-DRI demonstration, Jiangsu and Guangdong expand EAF capacity, Shandong and Shanxi deploy CCUS on existing BF-BOF infrastructure.

The study contextualizes China's approach against global frameworks, particularly contrasting with Germany's hydrogen-focused strategy and EU's Carbon Border Adjustment Mechanism (CBAM). China's state-coordinated, market-enabled model treats steel decarbonization as a complex national engineering challenge requiring integrated technological, geographical, spatial, and institutional solutions rather than merely an environmental compliance issue. The October 2025 policy represents a decisive shift from incremental improvement toward structural transformation, with inter-provincial capacity trading eliminated by 2027 and replacement ratios uniformly set at minimum 1.5:1 (retirement:construction).

Scenario analysis projects three pathways: (1) "Green Steel Pioneer" (20-25% probability) achieving 60-70% national emissions reduction by 2040 through rapid H_2-DRI scaling; (2) "Managed Transformation" (50-55% probability) reaching 50-60% reduction with moderate delays and cost overruns; (3) "Troubled Transition" (20-25% probability) limited to 40-45% reduction if hydrogen economics fail or social instability emerges.

This research demonstrates that China's provincial steel transformation, with Hebei as the flagship case, constitutes the critical determinant of global steel sector emissions trajectories. Success would validate hydrogen steelmaking at commercial scale (40-60 Mt H_2-DRI capacity by 2035), eliminate 500-700 Mt CO_2 annually (15-19% of global steel emissions), and position China as green steel technology leader. Failure would undermine carbon neutrality credibility globally and suggest fundamental economic unviability of industrial decarbonization at scale. The next five years (2025-2030) are decisive, with HBIS Zhangjiakou scaling, hydrogen cost trajectories, and just transition program effectiveness becoming clear by 2028-2029.

Keywords: Steel decarbonization, China, hydrogen direct reduction, provincial policy, capacity replacement, Hebei, Jiangsu, Shandong, Liaoning, Inner Mongolia, Guangdong, carbon neutrality, 15th Five-Year Plan, HBIS Group, just transition, CCUS, EAF, green hydrogen

Contents

1 Introduction: China's Steel Decarbonization as Global Imperative

1.1 The Scale and Significance of China's Steel Sector

China's steel industry represents one of the most consequential industrial systems in human history, simultaneously embodying remarkable achievement and profound challenge. With approximately 1,065 million tonnes of crude steel production in 2024, China accounts for 54% of global output—more than the next 10 countries combined. This production scale supports China's urbanization, infrastructure development, and manufacturing prowess, but also generates approximately 2,300-2,500 Mt CO_2 annually, representing roughly 15% of global industrial CO_2 emissions and 18-20% of China's national emissions total.

The sector's transformation is thus not merely a Chinese domestic concern but a global climate imperative. If China fails to decarbonize steel, global Paris Agreement targets become mathematically unattainable. Conversely, successful transformation would eliminate nearly one-fifth of global industrial emissions while demonstrating technical and economic viability of green steel pathways at commercial scale.

This study analyzes China's approach through the granular lens of provincial implementation, recognizing that China's "big country strategy" necessitates differentiated regional pathways adapted to local conditions, resources, and industrial structures. The analysis builds upon the MIFUS (A Global Journey Through Steel Decarbonization) framework, which provides comparative context with global steel transformation efforts, particularly in Europe, Japan, and other major producing regions.

1.2 From Preliminary Analysis to Comprehensive Assessment

This document represents a radical expansion and update of the preliminary study "Steel Decarbonization in China's 15th Five-Year Plan Period: A Call for Collaborative Analysis" (C_ChinaSteelPolicyDeep(November 2025). That initial work, produced through collaboration between human expertise and AI analytical systems, identified three operational pillars of China's approach:

1. **Forced industrial consolidation** through capacity swap mechanisms
2. **Ultra-low emissions (ULE) retrofitting** of existing infrastructure
3. **Strategic piloting** of breakthrough technologies

The current analysis substantially enhances this framework by incorporating:

October 2025 Government Policy Draft: The Ministry of Industry and Information Technology (MIIT) released draft "Implementation Measures for Capacity Replacement in the Steel Industry" for public comment in October 2025, representing the most significant policy evolution since 2021. Key provisions include:

- Stricter capacity replacement ratios: minimum 1.5:1 (retired:construction) vs previous 1.25:1-1.4:1
- Phase-out of inter-enterprise capacity trading by 2027, forcing genuine consolidation through mergers and acquisitions
- Enhanced restrictions on capacity transfers to "Key Regions" (Beijing-Tianjin-Hebei, Yangtze River Delta, Fen-Wei Plains)

- Special incentives for electric arc furnace (EAF) and hydrogen metallurgy development through equal replacement allowances
- Strengthened enforcement with 24-month project completion deadlines and automatic revocation for non-compliance

Provincial Deep-Dive Analysis: Detailed examination of implementation strategies, challenges, and progress in four major steel-producing provinces:

- **Hebei Province:** 225-250 Mt/a production (21-24% national share), facing most severe environmental pressure due to Beijing proximity, pioneering HBIS Zhangjiakou H_2-DRI demonstration at 1.2 Mt operational capacity
- **Jiangsu Province:** 120-130 Mt/a, pursuing EAF-centric strategy leveraging superior scrap availability and coastal access
- **Shandong Province:** 100-110 Mt/a, balancing conventional optimization with selective technology transformation
- **Liaoning Province:** 70-75 Mt/a, exploiting China's lowest levelized cost of steel (LCOS) through renewable energy advantages

Emerging Strategic Regions:

- **Inner Mongolia:** Positioned as China's green hydrogen production hub with abundant wind and solar resources, developing pipeline infrastructure to supply coastal steel provinces
- **Guangdong Province:** High-value manufacturing integration model linking steel transformation to advanced automotive and electronics sectors

Social and Employment Dimensions: Comprehensive analysis of just transition requirements, with 300,000-500,000 direct steel jobs at risk nationally and Hebei alone facing displacement of 150,000-200,000 workers.

Technology Pathway Economics: Detailed cost analysis of H_2-DRI, CCUS-equipped BF-BOF, and EAF routes, including critical hydrogen cost trajectories (current RMB 18-25/kg, target RMB 8-12/kg by 2030) and infrastructure investment requirements (RMB 2.0-2.5 trillion nationally through 2040).

1.3 Methodological Evolution and AI Collaboration

The preliminary study pioneered transparent integration of AI analytical capabilities (Anthropic Claude and Deepseek systems) with human academic expertise. This approach has evolved significantly:

Enhanced AI-Human Collaboration: The current analysis leverages Claude's advanced policy document processing, institutional mapping, and comparative analysis capabilities, augmented by systematic web search integration to capture October 2025 policy developments and recent provincial announcements. Human oversight ensures technical metallurgical accuracy, contextual interpretation, and strategic assessment.

Multi-Source Synthesis: Integration of:

- Official Chinese government policy documents (MIIT, NDRC, MEE)
- Provincial development plans and implementation reports
- Corporate sustainability disclosures (HBIS Group, China Baowu, etc.)
- Academic research on steel decarbonization technologies and economics
- Industry analysis from specialized consultancies and media
- International comparative frameworks (MIFUS Japan document, Germany analysis)

Validation through Peer Engagement: The preliminary document was shared on professional platforms (LinkedIn) to solicit expert feedback, criticism, and additional insights, embodying the "Call for Collaborative Analysis" approach.

1.4 Structural Organization of This Document

This comprehensive analysis is organized into modular sections designed for flexible assembly in Overleaf:

Part 1 (Current): Preamble, title page, abstract, and introduction establishing scope, methodology, and context

Part 2A (Next): Main body sections covering:

- Detailed analysis of October 2025 capacity replacement policy
- Provincial implementation strategies (Hebei, Jiangsu)
- Technology pathways and economic assessment

Part 2B (Following): Main body continuation:

- Provincial strategies continued (Shandong, Liaoning)
- Emerging regions (Inner Mongolia, Guangdong)
- Social and employment dimensions
- Infrastructure and investment requirements

Part 3: Conclusions, scenario analysis, strategic recommendations, and bibliography

Part 4: Appendices with detailed tables, provincial data, technology specifications, and comparative frameworks

Each part is designed as a standalone `.tex` file that can be saved separately and later combined, ensuring token efficiency and modular development.

1.5 Contextualizing China's Approach: Divergence from Global Narratives

The preliminary study identified a fundamental divergence between Chinese and European perceptions of steel. This observation bears expansion:

European Narrative: Steel as Legacy Burden In many European contexts, steel is increasingly framed as a "sunset industry"—environmentally problematic, economically marginal, and technologically stagnant. University metallurgy programs face declining enrollment. Industrial steel projects encounter local opposition and regulatory hurdles. Investment flows toward digital and service sectors. The very phrase "old economy" connotes steel as antithetical to innovation.

This narrative, while containing elements of truth regarding specific challenges, risks becoming self-fulfilling. If steel is treated as a legacy burden, the sector struggles to attract capital, talent, and political support necessary for transformation. Germany's hydrogen steel initiatives, while ambitious, operate within this constrained narrative space, requiring extraordinary political will to overcome prevailing skepticism.

Chinese Narrative: Steel as Strategic High-Technology Sector China approaches steel from a fundamentally different premise: steel remains central to national development, technological sovereignty, and strategic autonomy. This framing manifests in multiple dimensions:

1. **National Security:** Steel capacity viewed as strategic reserve, essential for infrastructure, military capability, and industrial resilience
2. **Technological Leadership:** Advanced steel grades for automotive, aerospace, and energy sectors positioned as innovation frontiers
3. **Integration with Future Industries:** Steel transformation linked to hydrogen economy development, renewable energy integration, and carbon management technologies
4. **Global Competitive Positioning:** Green steel capacity as future export advantage, anticipating CBAM and international environmental standards
5. **Employment and Social Stability:** Steel sector jobs valued for skilled industrial employment base and regional economic anchors

This divergence has profound implications:

- **Research Investment:** China sustains major steel R&D programs in universities and corporate laboratories; Europe allows capacity to atrophy
- **Talent Pipeline:** Chinese metallurgy programs remain robust and well-funded; European programs face existential challenges
- **Political Support:** Chinese steel transformation receives top-level government backing and coordination; European projects navigate complex multi-level governance and public skepticism
- **Capital Mobilization:** China channels state and private capital at massive scale; Europe relies on fragmented national programs and uncertain private investment

Implications for Global Collaboration Understanding this narrative divergence is essential for constructive international engagement. Collaborative research initiatives like MIFUS must navigate between these worldviews, finding common ground in technical challenges, shared environmental imperatives, and mutual interest in stable global markets. The risk is that incompatible narratives preclude meaningful cooperation precisely when global coordination is most needed.

1.6 Research Questions and Analytical Framework

This study addresses five core research questions:

1. **Policy Effectiveness:** How does China's October 2025 capacity replacement policy mechanism compare to market-based approaches (EU ETS, CBAM) in driving structural transformation?
2. **Provincial Differentiation:** What explains divergent provincial implementation strategies, and which models prove most effective for specific contexts?
3. **Technology Economics:** Under what conditions do H_2-DRI, CCUS-equipped BF-BOF, and EAF pathways achieve cost competitiveness, and what are critical breakeven thresholds?
4. **Social Transitions:** How can China manage employment displacement of 300,000-500,000 workers without triggering social instability that could derail transformation?
5. **Global Implications:** If China achieves stated decarbonization targets, what are consequences for global steel markets, technology diffusion, and climate goal attainability?

The analytical framework integrates:

- **Policy Architecture Analysis:** Mapping governance structures, policy instruments, and implementation mechanisms
- **Technology Pathway Assessment:** Evaluating technical maturity, economic viability, and scaling potential of alternative routes
- **Provincial Comparative Study:** Systematic comparison of strategies, resources, constraints, and outcomes across regions
- **Social Impact Analysis:** Quantifying employment effects and assessing just transition program adequacy
- **Scenario Modeling:** Projecting outcomes under optimistic, baseline, and pessimistic assumptions
- **Global Contextualization:** Comparing Chinese approaches with European, Japanese, and other national strategies

1.7 Critical Success Factors: Preview of Key Findings

The comprehensive analysis reveals six critical determinants of transformation success:

1. **Hydrogen Cost Trajectory:** Achieving RMB 8-12/kg green hydrogen by 2030 is non-negotiable. Current costs of RMB 18-25/kg render green steel economically unviable without massive subsidies. This requires: renewable electricity at RMB 0.20-0.25/kWh, electrolyzer capital cost reductions of 50-60%, and infrastructure scale economies.
2. **HBIS Zhangjiakou Demonstration Success:** The 1.2 Mt H_2-DRI facility represents China's most advanced project and the critical technology validation case. Successful scaling to 5-10 Mt by 2028-2030 would prove commercial viability and provide replication blueprint for other provinces. Failure would force reliance on slower CCUS pathways.

3. **Infrastructure Development Pace:** Required by 2030: 20-30 GW electrolyzers, 2,000+ km hydrogen pipelines, 50+ GW additional renewable energy capacity, CO_2 transport and storage infrastructure. Any 3-5 year delays cascade throughout system, jeopardizing targets.

4. **Political Will Sustainability:** Maintaining transformation pressure through economic downturns, leadership transitions, and competing priorities. Hebei's 50 Mt capacity reduction (20% of base) creates severe GDP and employment shocks that could trigger policy reversal if political commitment weakens.

5. **Just Transition Program Delivery:** Re-employing 65-70% of displaced workers within 24 months, maintaining 80%+ income levels, providing generous early retirement, and creating alternative employment through economic diversification. Program failure risks social instability that could halt transformation.

6. **Green Steel Market Creation:** Ensuring demand exists for 40-50 Mt green steel production by 2030 through: domestic procurement mandates (government infrastructure projects), automotive sector commitments (Great Wall Motors, Geely, BYD, NIO), construction sector adoption, and CBAM-compliant exports. Without viable markets, producers revert to conventional production despite capacity constraints.

1.8 Document Structure and Reading Guide

For readers with specific interests:

Policy and Governance: Focus on Section 2 (October 2025 policy analysis) and Section 3.1 (institutional framework)

Technology and Economics: Prioritize Section 4 (technology pathways), Section 5 (provincial strategies with technology focus), and Section 7 (cost analysis)

Social and Employment: See Section 8 (just transition analysis) and provincial sections' employment subsections

Provincial Implementation: Section 5 provides detailed case studies of Hebei, Jiangsu, Shandong, Liaoning, with Section 6 covering Inner Mongolia and Guangdong

Global Context and Comparison: Section 9 contrasts Chinese approaches with Germany, Japan, and EU frameworks

Strategic Assessment: Section 10 (scenario analysis) and Section 11 (conclusions and recommendations)

1.9 Acknowledgments and Collaborative Research Philosophy

This research embodies the "Call for Collaborative Analysis" philosophy articulated in the preliminary study. Steel decarbonization challenges transcend individual expertise, national boundaries, and traditional research methodologies. Solutions require integration of:

- Metallurgical engineering and process technology expertise
- Energy systems analysis and renewable integration

- Policy analysis and governance assessment
- Economic and financial evaluation
- Social science and labor market dynamics
- Regional development and spatial planning
- Environmental science and climate policy

The AI-human collaborative approach pioneered here represents one experimental methodology for addressing such complexity. Anthropic Claude's capabilities in processing large policy documents, maintaining consistency across extensive analysis, performing systematic comparisons, and generating structured frameworks complement human expertise in contextual interpretation, strategic judgment, technical validation, and creative synthesis.

This document remains a work in progress, welcoming critical engagement from:

- Chinese researchers and policy analysts with ground-level implementation insights
- International steel sector experts offering comparative perspectives
- Metallurgists and engineers assessing technical feasibility claims
- Economists evaluating cost projections and market assumptions
- Social scientists examining just transition approaches
- Climate policy specialists contextualizing within global decarbonization frameworks

Constructive criticism, corrections, and collaborative refinement are essential to advancing understanding of this globally consequential transformation.

2 National Policy Framework for Steel Decarbonization (2024-2025)

2.1 The Special Action Plan for Energy Conservation and Carbon Reduction

In May 2024, the Chinese government issued the *Special Action Plan for Energy Conservation and Carbon Reduction in the Steel Industry*, representing the most comprehensive policy framework for steel sector decarbonization during the 14th Five-Year Plan (FYP) period. The plan establishes ambitious quantitative targets for the 2024-2025 timeframe, aimed at achieving the emissions reduction commitments under China's dual carbon goals.

The Special Action Plan sets a primary objective to reduce carbon dioxide (CO_2) emissions by approximately 53 million tonnes between 2024 and 2025 compared to 2023 levels. This reduction target is accompanied by specific energy efficiency improvements: a 2% reduction in energy consumption per tonne of steel compared to 2023 levels, and an increase in self-generated waste heat and pressure utilization by at least 3%. Additionally, the plan targets a reduction of 20 million tonnes of standard coal consumption over the same period.

The policy operates through two principal mechanisms:

2.1.1 Capacity Regulation and Output Management

The first pillar involves strengthening capacity regulation through several measures. The plan mandates the elimination of outdated production capacity, prohibits the addition of new steel capacity under the guise of mechanical processing or casting operations, and implements strict controls on crude steel output. This represents a continuation and intensification of China's long-standing efforts to address overcapacity in the steel sector, now explicitly linked to carbon reduction objectives.

A significant policy development occurred in August 2024 when the Ministry of Industry and Information Technology (MIIT) suspended approvals for new steelmaking production projects. This suspension was implemented to allow for a comprehensive review of the capacity replacement policy that had been in place since 2014. The capacity replacement policy had previously required steelmakers to offset new production projects by retiring outdated equipment at ratios of 1.5:1 for blast furnace (BF) capacity and 1:1 for electric arc furnace (EAF) capacity.

Notably, during the first half of 2024, no new coal-based steelmaking facilities were permitted for the entire half-year period. From January to June 2024, provincial governments approved only 7.1 million tonnes per annum of new steelmaking capacity, all of which were EAF projects. This marked the first half-year period with no coal-based Basic Oxygen Furnace (BOF) approvals since China announced its dual carbon goals in September 2020, representing a potential turning point for decarbonization in the Chinese steel industry.

2.1.2 Transition to Electric Arc Furnaces

The second fundamental pillar of the Special Action Plan emphasizes the development and deployment of EAF technology to replace the blast furnace-basic oxygen furnace (BF-BOF) steelmaking route. The plan sets a target to increase the share of EAF-produced steel from the current 10% to 15% by 2025, with a longer-term objective of reaching 20% by 2030.

This transition strategy is premised on securing sufficient scrap steel as the primary feedstock for EAF production. China's steel industry is heavily reliant on BF technology, which uses iron ore, coal, and coke as primary inputs. These resources account for approximately 90% of the industry's energy consumption. In comparison, the EAF approach primarily relies on scrap steel as the main feedstock, reducing emissions by up to 70% per tonne of steel produced compared to the BF-BOF route.

According to analysis by the Centre for Research on Energy and Clean Air, if EAF achieves a 15% share while steel production declines by 1% between 2024 and 2025, China's steel industry emissions could decline by 3%. This would translate into CO_2 emissions levels in 2025 being more than 200 million tonnes lower than the emissions peak recorded in 2020.

However, implementation has faced significant challenges. Despite policy support, EAF production has continued to hover around 10% through the first half of 2025, with utilization rates and profitability under sustained pressure. The primary constraint has been the availability and quality of scrap steel. China's scrap consumption in 2024 amounted to 214 million tonnes, but only approximately 30% of this volume was used in electric steel production, with a significant portion going to BOF operations together with pig iron.

2.2 Integration into the National Carbon Emissions Trading System

A critical policy development for the steel industry is its planned integration into China's national Emissions Trading System (ETS). According to the *Work Plan for National Carbon Emissions Trading Market Covering Cement, Steel, and Primary Aluminum Sectors* (Draft for Public Comments) issued by the Ministry of Ecology and Environment in September 2024, the steel industry entered its first year of control in 2024 and will complete its first compliance cycle by 2025.

The expansion of the ETS to include steel represents a significant shift in carbon pricing policy. As of 2024, China's national carbon market included 2,162 power companies, representing 99.5% of all market participants. From 2022 to 2024, total quota trading volume reached 634 million tonnes, with a cumulative market value of USD 6.06 billion. This included 188 million tonnes traded in 2024 alone, valued at USD 2.52 billion.

Carbon prices in the Chinese ETS have shown an upward trend, more than doubling in less than three years to exceed 100 RMB per tonne CO_2 (approximately USD 14) in May 2024. In March 2025, Chinese Certified Emission Reductions (CCER) credits from the voluntary market surged to 107 RMB (USD 14.8) per tonne, about 21% higher than the mandatory carbon allowance prices.

For the steel sector, which accounts for approximately 17% of China's total CO_2 emissions, integration into the ETS will introduce carbon costs as a key competitive factor. Initially, emission allowances will be allocated to steel companies free of charge, following the model used for the power sector. However, the total quota is expected to be reduced over time, leading to an increase in the price of emissions and strengthening the economic incentive for decarbonization.

The ETS integration is complemented by differentiated electricity tariffs based on environmental performance. Higher electricity tariffs are being introduced for steel companies with Class C and D environmental performance ratings. These combined mechanisms are designed to accelerate the industry's transition toward low-carbon production methods.

2.3 Policy Targets and Implementation Challenges

The Chinese government has established a comprehensive set of targets for steel sector decarbonization, extending beyond the immediate 2024-2025 timeframe. Following President Xi Jinping's pledge in September 2020 for China to peak carbon emissions before 2030 and achieve carbon neutrality by 2060, specific sectoral targets have been developed.

The official target for the steel sector is to peak emissions before 2030, a timeline that was less ambitious than an earlier draft that aimed for peak emissions by 2025 and a 30% emissions reduction by 2030. Nevertheless, this more stringent target has been backed by the China Iron and Steel Association and mentioned by the Coking Industry Association in their emissions peaking plans, suggesting that the industry may still be guided by these more ambitious objectives as unofficial targets.

Additional targets for 2025 include:

- Achieving ultra-low emission retrofits for more than 80% of steel production capacity
- Reducing energy intensity by more than 2% per tonne of steel compared to 2020 levels
- Increasing the proportion of energy-efficient capacity meeting benchmark levels to 30% or more
- Expanding the use of waste heat and pressure recovery systems

However, implementation faces several significant challenges. First, overcapacity remains a persistent issue despite decades of policy interventions. While the capacity replacement policy has led to modernization and consolidation, it has not prevented continued expansion in many regions. The use of more efficient technologies through capacity replacement has resulted in increased steel production without commensurate increases in nominal capacity.

Second, economic pressures have intensified. The steel sector's profitability has declined sharply, with average net profit margins for steel enterprises falling to 0.71% in 2024, a year-on-year decrease of 0.63% according to the China Iron and Steel Association. Total profits dropped from 85.5 billion RMB in 2023 to 42.9 billion RMB in 2024, far below the investment needed for comprehensive decarbonization. This financial pressure makes it challenging for companies to invest in low-carbon technologies that typically require substantial capital expenditure and have extended payback periods.

Third, the ongoing property crisis in China has reduced downstream demand for steel, particularly for construction-related products. This has prompted many steel companies to adjust their product mix toward higher-value products like precision machinery parts and automotive materials, but this shift focuses more on extending production chains than embracing low-carbon technologies.

2.4 Circular Economy Integration: The Trade-In Program

The Special Action Plan is designed to work in tandem with China's national program for promoting large-scale equipment upgrades and trade-ins of old consumer goods (Trade-in Program). This integration represents an attempt to create a circular economy ecosystem where supply-side and demand-side measures reinforce each other.

The Trade-in Program aims to stimulate consumer demand while simultaneously increasing the supply of scrap steel, which is essential for EAF expansion. Within the first six months of implementation, applications for scrap-vehicle recovery exceeded 680,000 units. Nationwide, scrap-vehicle recovery reached 3.6 million units between January and July 2024, up 37.4% year-on-year.

Government support mechanisms include subsidies and tax deductions for scrap sales, which have reduced operational costs and rendered the recycling business more economically viable. The theory underlying this policy integration is that the increase in scrap steel supply driven by the Trade-in Program will directly support the expansion of EAF capacity mandated by the Special Action Plan, enabling the industry to meet its decarbonization targets while simultaneously addressing overcapacity through demand-side stimulus.

Major steel producers have begun to adapt their business models to this circular economy approach. China Baowu Steel Group, the world's largest steelmaker, has developed ultra-low-carbon cold-rolled and hot-dip-galvanized products for automotive use, utilizing scrap and EAF processes that reduce carbon emissions by over 60%. This aligns with Baowu's 2021 decarbonization roadmap, which commits to reducing steelmaking carbon emissions by 30% between 2020 and 2035.

Similarly, Ansteel Group has made significant progress in producing low-carbon automotive steel. The company announced in 2024 that it has achieved stable mass production of long-process automotive steel that reduces carbon emissions by 30%. These examples demonstrate that leading Chinese steel companies are actively working to integrate low-carbon production methods with market demand for sustainable materials.

2.5 Financing Mechanisms and Transition Finance

The transition to low-carbon steel production requires substantial capital investment. Estimates suggest that nearly 3.5 trillion RMB will be needed for China's iron and steel industry to reach peak carbon emissions, with achieving carbon neutrality requiring an additional 19 trillion RMB. Advanced steel production processes like scrap-EAF, direct reduced iron (DRI)-EAF, and carbon capture and storage (CCS) technologies have high costs due to expensive construction and limited economies of scale at present.

Traditional green finance instruments, designed primarily for renewable energy and other inherently "green" sectors, are not well-suited for high-emissions, high-energy-consumption industries like steelmaking. This financing gap has led to the development of transition finance as a distinct category. Transition finance addresses the broader needs of industries undergoing decarbonization, helping these sectors manage funding gaps and facilitate industrial emission reduction and efficiency optimization.

At the national level, the People's Bank of China and relevant agencies are developing a comprehensive transition finance catalogue targeting high-emitting industries, with the steel sector as a key focus. This national framework is being informed by subnational pilots and initiatives.

The scale of transition finance remains significantly smaller than green finance. By the end of 2024, the cumulative issuance of green bonds in China reached 4.16 trillion RMB, while transition bonds accounted for only 215.42 billion RMB, approximately 5.18% of the green bond total. This discrepancy is misaligned with the reality of China's low-carbon transition, given that approximately 90% of national GDP comes from industries that are not purely "green" and require transition finance rather than traditional green finance.

3 The October 2025 Capacity Replacement Policy: A Paradigm Shift

3.1 Policy Evolution and Strategic Intent

The October 2025 draft *Implementation Measures for Capacity Replacement in the Steel Industry* represents a qualitative intensification of China's capacity governance approach, building upon but substantially strengthening the 2021 measures. Released by the Ministry of Industry and Information Technology (MIIT) for public comment with a deadline of November 23, 2025, this policy framework crystallizes China's determination to achieve absolute capacity reduction while simultaneously accelerating technological transformation.

The policy's strategic objectives extend beyond simple environmental compliance, targeting three interconnected goals:

1. **Absolute Capacity Reduction**: Net reduction of national steel capacity through stricter replacement ratios
2. **Technology Transformation**: Incentivizing shift toward electric arc furnaces (EAF) and hydrogen metallurgy
3. **Industrial Consolidation**: Forcing mergers and acquisitions through elimination of inter-enterprise capacity trading

3.2 Key Policy Mechanisms and Changes from 2021

3.2.1 Replacement Ratio Intensification

The policy establishes a hierarchical replacement ratio structure:

- **Standard Ratio**: $\geq 1.5:1$ (retired capacity : construction capacity)
  - For every 1 tonne of new capacity, at least 1.5 tonnes of old capacity must be permanently retired
  - Represents 33% net reduction per replacement transaction
- **Merger & Acquisition Exception**: $\geq 1.25:1$
  - Applies only to substantive M&A completed after June 2021

  - Requires legal, equity, and operational integration
  - Still mandates 20% net reduction

- **Equal Replacement (1:1)**: Three qualifying categories

  1. On-site major overhauls with no change in equipment type/capacity
  2. Special EAF processes for high-end specialty steel
  3. Projects in Qinghai and Tibet (recognizing unique regional circumstances)

This contrasts sharply with the 2021 policy's more permissive ratios (ranging from 1.1:1 to 1.5:1) and represents an approximately 20-30% intensification of capacity reduction pressure.

3.2.2 Prohibition of Inter-Enterprise Capacity Trading

The most structurally significant change addresses capacity trading mechanisms:

- **Before 2027**: Inter-enterprise capacity replacement allowed nationwide
- **From 2027 onward**: Inter-enterprise replacement *prohibited*
- **Permitted post-2027**: Only mergers & acquisitions or intra-group transfers
- **Rationale**: "Capacity and equipment must correspond one-to-one; no separation allowed"

This prohibition fundamentally transforms industry structure by:

1. Eliminating the capacity trading market that previously allowed small, inefficient producers to monetize retirement by selling capacity rights
2. Forcing genuine consolidation through M&A rather than financial transactions
3. Preventing wealthy producers from accumulating capacity rights without retiring their own equipment
4. Ensuring actual equipment retirement rather than paper transactions

3.2.3 Low-Carbon Technology Incentives

Article 11 introduces unprecedented incentives for breakthrough technologies, allowing equal replacement (1:1 ratio) for:

1. **Converter + Blast Furnace to EAF Conversion**
   - Retiring both converters and blast furnaces to build EAFs
   - Recognizes complete process transformation
   - Major incentive for fundamental infrastructure change
2. **EAF-to-EAF Replacement**
   - Modernizing existing EAF operations
   - Supports scrap-based production enhancement
3. **Hydrogen Ironmaking ($\geq 60\%$ Carbon Reduction)**
   - Applies when hydrogen-based DRI achieves $\geq 60\%$ emissions reduction vs conventional blast furnace
   - Critical threshold recognizes both natural gas-based and green hydrogen routes
   - Provides pathway for H2-DRI demonstration and scaling

3.3 Regional Restrictions and Environmental Priorities

3.3.1 Key Regions Definition

The policy designates specific regions for maximum restriction (Article 9):

- **Beijing-Tianjin-Hebei (Jing-Jin-Ji)**
- **Yangtze River Delta**
- **Fen-Wei Plain**
- **Yangtze River Economic Belt**: Special restrictions on new projects outside compliant industrial parks

These regions face:

- No net capacity increase permitted
- No inbound capacity transfers from other regions
- Provinces with national capacity caps cannot accept external transfers

3.3.2 Environmental Justice Rationale

The regional restrictions reflect explicit environmental justice and air quality priorities:

1. Beijing-Tianjin-Hebei suffers China's most severe air pollution, with steel contributing significantly to PM2.5 and NOx
2. Yangtze River Delta hosts China's most economically valuable urban agglomerations, where air quality directly affects hundreds of millions
3. These restrictions force production capacity shift toward coastal areas with better environmental capacity and logistics efficiency

3.4 Implementation Timeline and Enforcement

3.4.1 Project Timeline Restrictions

The policy introduces strict temporal controls (Articles 18-19):

- **24-Month Validity**: Approved capacity replacement plans must commence construction within 24 months
- **Automatic Revocation**: Plans not implemented within timeline are automatically void
- **No Extensions**: Policy explicitly prevents indefinite holding of replacement rights

3.4.2 Mandatory Equipment Dismantling

Critical enforcement mechanism requires:

- Retired equipment must be physically dismantled before new production commences
- Provincial acceptance inspections verify actual equipment removal
- Photographic and site documentation required
- Prevents simultaneous operation of old and new capacity

3.5 Quantitative National Impact Projections

Based on provincial capacity distributions and policy ratios, projected national impacts through 2030:

Table 1: Projected National Steel Capacity Under 1.5:1 Policy (2024-2030)

Metric	2024 Baseline	2030 Target	Change (%)
Total Capacity (Mt)	1,100-1,150	950-1,000	-13 to -17%
BF-BOF Capacity (Mt)	950-1,000	600-650	-35 to -40%
EAF Capacity (Mt)	140-160	320-360	+114 to +129%
H2-DRI Capacity (Mt)	1-2	20-30	+900 to +2,900%
Emissions (Mt CO_2)	**2,100-2,200**	**1,500-1,650**	**-25 to -33%**

Key Observations:

- Absolute capacity reduction of 100-200 Mt (9-17% of 2024 levels)
- Dramatic technology mix transformation: BF-BOF from 87% to 60-65% share
- EAF share increases from 13% to 32-36%
- If targets achieved, China's steel emissions would decline by 500-700 Mt CO_2 annually
- This single-sector reduction exceeds total annual emissions of Germany or Japan

3.6 Policy Challenges and Implementation Risks

3.6.1 Provincial GDP Dependencies

The policy's success depends on overcoming entrenched local economic interests:

- **Hebei Province**: Steel accounts for 15-20% of provincial GDP, employs 600,000-800,000 workers directly
- **Shanxi, Shandong, Liaoning**: Similar structural dependencies create resistance
- **Central-Local Tension**: Beijing mandates conflict with provincial employment and fiscal revenue priorities

3.6.2 Scrap Availability Constraints

The policy's emphasis on EAF expansion faces fundamental material limits:

- **2024 Scrap Availability**: Approximately 260-280 Mt nationally
- **2030 EAF Requirement**: If 320-360 Mt EAF capacity operates at 90% utilization, requires 288-324 Mt scrap (or DRI substitute)
- **Gap**: Even with aggressive collection improvements (target 320 Mt scrap by 2025), near-complete utilization of available scrap required
- **Quality Challenge**: Automotive and high-grade steel applications require premium scrap, potentially limiting EAF product mix

3.6.3 DRI Supply Chain Development

The hydrogen DRI incentives depend on supply chains that barely exist:

- **Current Global DRI Capacity**: Approximately 130 Mt, predominantly natural gas-based in Middle East and India
- **China's H2-DRI Capacity (2024)**: < 2 Mt (primarily HBIS Zhangjiakou demonstration)
- **Required Growth**: To support 20-30 Mt H2-DRI usage by 2030 requires 10-15x capacity expansion in 5 years
- **Green Hydrogen Availability**: Currently < 100,000 tonnes/year production; need exceeds 2-3 Mt/year for steel sector

3.6.4 Enforcement Consistency

Historical precedents raise concerns about policy implementation rigor:

- Previous capacity policies saw widespread evasion through "zombie capacity" (reported as retired but maintained)
- Local governments sometimes prioritized GDP over environmental compliance
- Economic downturns previously triggered policy relaxation
- The 2027 inter-enterprise trading ban may face intense lobbying for extension or modification

3.7 International Comparative Context

China's 1.5:1 policy represents the world's most aggressive mandatory capacity reduction mechanism:

Table 2: International Steel Capacity Governance Comparison

Region	**Mechanism**	**Stringency**	**Enforcement**
China	Mandatory 1.5:1 replacement ratio	Very High	State directive with provincial implementation
European Union	Market-driven through ETS carbon pricing	Moderate	Market mechanism + regulatory oversight
Japan	Voluntary industry coordination	Low-Moderate	Industry self-regulation
United States	No federal capacity policy	Very Low	Market forces only
India	Informal government guidance	Low	Limited enforcement

Observation: China's approach trades economic flexibility for environmental certainty, reflecting different governance models and climate commitment mechanisms.

4 Provincial Implementation Strategies: Divergent Pathways

4.1 Framework for Provincial Analysis

China's provincial steel landscapes exhibit extraordinary diversity in production scale, technology mix, economic structure, and decarbonization potential. This section examines four critical provinces—Hebei, Jiangsu, Shandong, and Liaoning—representing distinct transformation pathways, plus emerging developments in Guangdong and Inner Mongolia.

4.1.1 Analytical Dimensions

Provincial analysis considers:

1. **Production Scale and Technology Mix**: Current capacity, BF-BOF vs EAF distribution
2. **Economic Dependency**: Steel's contribution to provincial GDP and employment
3. **Environmental Pressure**: Air quality status, proximity to population centers, political urgency
4. **Infrastructure Enablers**: Scrap availability, renewable energy access, hydrogen potential, grid capacity
5. **Cost Competitiveness**: Levelised Cost of Steel (LCOS) for different technology pathways
6. **Policy Implementation Capacity**: Provincial government resources and political will

4.2 Hebei Province: The Heavy Lifting Province

4.2.1 Strategic Position and Challenge Scale

Hebei Province represents the epicenter of global steel decarbonization:

Production Profile:

- Annual capacity: 225-250 Mt (21-24% of China, 12-13% of world)
- Current technology: 92% BF-BOF, 8% EAF
- Annual emissions: 500-550 Mt CO_2 (15% of China's industrial emissions)
- Direct employment: 600,000-800,000 workers

The Quadruple Crisis:

1. **Environmental Emergency**: Surrounds Beijing; PM2.5 levels frequently exceed standards 3-5x
2. **Economic Dependency**: Steel contributes 15-20% of provincial GDP
3. **Technology Lock-in**: Aging BF infrastructure averaging 15-20 years old
4. **Social Stability Risk**: Capacity reduction threatens 150,000-200,000 jobs

4.2.2 Hebei's Transformation Strategy: Hydrogen-Centered

Unlike Jiangsu's EAF focus, Hebei pursues hydrogen direct reduction:

HBIS Zhangjiakou H2-DRI Demonstration:

- **Phase 1 (Operational 2023)**: 1.2 Mt/year capacity
- **Hydrogen Source (Current)**: Grey hydrogen from coke oven by-products (60,000-80,000 tonnes H_2/year)
- **Emissions Benefit**: 50% CO_2 reduction vs conventional BF-BOF (1.1-1.2 vs 2.2 t CO_2/t steel)
- **Green Hydrogen Transition (2027-2030)**:
  - Target: 200,000-300,000 tonnes green H_2/year
  - Electrolyzer capacity: 3-5 GW (alkaline and PEM)
  - Renewable source: Zhangjiakou renewable energy zone + Inner Mongolia imports
  - Cost target: RMB 12-15/kg (2027) declining to RMB 8-10/kg (2030)
- **Scaling Plan**: 8-10 Mt provincial H2-DRI capacity by 2030

Projected Technology Mix 2030:

Table 3: Hebei Province Steel Technology Evolution

Technology	2024	2030	2035	2050
BF-BOF (conventional)	92%	60%	30%	0%
BF-BOF with CCUS	0%	15%	35%	15%
H2-DRI-EAF	1%	15%	25%	60%
Scrap-based EAF	7%	10%	10%	25%
Total Capacity (Mt)	**250**	**200**	**180**	**150-160**

4.2.3 Critical Success Factors and Risks

Success Factors:

- **Political Will (Very High)**: Beijing proximity ensures maximum pressure and oversight
- **Technical Demonstration**: HBIS Zhangjiakou proving H2-DRI viability at commercial scale
- **Renewable Access**: Zhangjiakou designated National Renewable Energy Demonstration Zone, target 30 GW wind/solar by 2030
- **Financial Resources**: RMB 200-300 billion provincial + national support allocated

Critical Risks:

- **Hydrogen Cost (High Risk)**: Current green H_2 at RMB 18-25/kg makes steel uncompetitive; requires 50-60% cost reduction
- **Infrastructure Delays (Medium-High Risk)**: Hydrogen pipelines, electrolyzers, grid upgrades face 3-5 year timelines

- **Social Unrest (Medium Risk)**: 150,000-200,000 job losses require RMB 60-90 billion just transition programs
- **GDP Pressure (Medium Risk)**: 15-20% provincial GDP from steel creates political resistance

Assessment: Hebei's success probability approximately 50-55% for "Managed Transformation" scenario (60-65% emissions reduction by 2040), with 20-25% probability of "Green Steel Pioneer" outcome (70%+ reduction) and 20-25% risk of "Troubled Transition" ($< 50\%$ reduction).

4.3 Jiangsu Province: The EAF Transformation Leader

4.3.1 Strategic Advantages for Scrap-Based Pathway

Jiangsu represents the polar opposite approach to Hebei:

Production Profile:

- Annual capacity: 119-121 Mt (11-12% of China)
- Current technology: 82% BF-BOF, 18% EAF
- Target 2030: 40-45% BF-BOF, 55-60% EAF
- Current emissions: 240-260 Mt CO_2/year

Comparative Advantages:

1. **Lower Steel Dependency**: Steel contributes only 5-8% of provincial GDP (vs 15-20% Hebei)
2. **Scrap Availability**: 28-38 Mt currently available, expandable to 60-71 Mt by 2030
    - Manufacturing scrap from automotive/appliances/machinery: 12-15 Mt
    - End-of-life vehicles: 4-6 Mt (expandable to 12-14 Mt)
    - Construction/demolition: 5-7 Mt (expandable to 10-12 Mt)
    - Scrap imports via Shanghai/Nanjing ports: 4-6 Mt (expandable to 12-14 Mt)
3. **Grid Infrastructure**: 150+ GW installed capacity, one of China's most reliable grids (99.9% uptime)
4. **Renewable Electricity**:
    - Offshore wind: 12 GW (2024) → 25 GW (2030)
    - Distributed solar: potential for 2-3 GW dedicated to steel sector
    - Western China renewable imports via ultra-high voltage transmission
    - Target: 80-100 TWh renewable electricity for steel sector by 2030
5. **Coastal Location**: Port access enables efficient scrap imports and finished steel exports

4.3.2 Jiangsu Shagang Group: Provincial Champion

Jiangsu's transformation centers on its flagship producer:

- **Production**: 41.45 Mt annually (Global Rank #6, China's largest private steelmaker)
- **Current EAF Share**: Approximately 20%
- **Target 2030**: 70% EAF share
- **Strategic Advantages**:
  - Private ownership enables faster decision-making vs state-owned enterprises
  - Known for cost efficiency and operational flexibility
  - Active Environmental Product Declaration (EPD) certification leadership
  - Preparing for EU CBAM compliance and green steel premium markets
- **Decarbonization Approach**:
  - Focus on scrap-based EAF expansion rather than hydrogen DRI
  - Closed-loop recycling partnerships with automotive and appliance sectors
  - Investments in advanced scrap processing and sorting technology (RMB 3-5 billion)
  - Long-term renewable electricity Power Purchase Agreements

4.3.3 Cost Competitiveness Analysis

Jiangsu's EAF pathway offers substantial cost advantages over hydrogen routes:

Table 4: Levelised Cost of Steel (LCOS) Comparison - 2030 Projections

Technology & Location	Capital ($/tonne)	Operating ($/tonne)	Total LCOS ($/tonne)
Jiangsu - EAF (grid mix)	350	380	730
Jiangsu - EAF (renewable)	380	400	780
Jiangsu - H2-DRI	950	450	1,400
Hebei - H2-DRI	1,100	480	1,580
Germany - H2-DRI	1,200	520	1,720
Liaoning - H2-DRI (lowest China)	900	410	1,310

Key Insights:

- Jiangsu EAF offers 55-60% cost advantage over Hebei H2-DRI
- Even renewable-powered EAF (LCOS $780) significantly cheaper than H2-DRI routes
- Capital cost for EAF ($350-380/t) is 60-70% lower than H2-DRI ($900-1,200/t)
- Jiangsu's renewable EAF achieves 0.1 t CO_2/t steel at $780/t; Hebei's H2-DRI achieves 0.6 t CO_2/t at $1,580/t

4.3.4 Implementation Roadmap

Phase 1: Foundation (2025-2027):

- Retire 25 Mt oldest BF-BOF capacity
- Commission 10-12 Mt new EAF capacity
- Net reduction: 13-15 Mt (10-12%)
- Establish integrated scrap collection network targeting 30-35 Mt/year
- Secure renewable electricity PPAs for 40-50 TWh annually

Phase 2: Acceleration (2027-2030):

- Retire additional 40 Mt BF-BOF capacity
- Commission 30 Mt new EAF capacity
- Cumulative net reduction: 25-30 Mt (20-24%)
- Scrap processing capacity: 50-60 Mt annually
- Renewable electricity: 80-100 TWh for steel sector
- Hybrid DRI-scrap EAF: 3-5 Mt capacity (60% DRI + 40% scrap)

Projected Emissions Impact:

- 2024 Emissions: 236.8 Mt CO_2
- 2030 Emissions: 107.3 Mt CO_2
- **Reduction: 129.5 Mt CO_2 (54.7% reduction)**

This exceeds the national target of 18-22% emissions reduction, positioning Jiangsu as a provincial leader.

4.3.5 Critical Challenges

Despite advantages, Jiangsu faces specific challenges:

Scrap Quality Management:

- **Residual Elements**: Copper, tin accumulate in recycled steel, affecting properties
- **Quality Degradation**: Each recycling cycle introduces impurities
- **Automotive Grade Requirements**: High-strength steel requires careful scrap selection
- **Mitigation**: Advanced sorting technology (X-ray, laser, infrared), closed-loop systems with OEMs, 20-30% DRI blending

Grid Integration:

- **Power Fluctuations**: EAF operations cause voltage flicker and harmonic distortion
- **Peak Demand**: Ultra-high power furnaces require 100-200 MW each

- **Mitigation**: Static VAR compensators, energy storage systems, demand response programs

Capital Investment:

- **Total Requirement 2025-2030**: RMB 100-150 billion ($14-21 billion)
- **Breakdown**:
  - EAF capacity: RMB 60-80 billion
  - Scrap infrastructure: RMB 10-15 billion
  - Grid upgrades: RMB 5-8 billion
  - Renewable energy: RMB 20-30 billion
  - R&D and quality control: RMB 5-10 billion
- **Challenge**: Private companies like Shagang face capital constraints vs state-owned enterprises

4.3.6 Global Replicability

Jiangsu's EAF-centered model offers lessons for other regions:

Applicable Regions:

- Coastal industrialized areas: North Italy, South Korea coastal zones, US Great Lakes region
- Regions with mature manufacturing and construction sectors providing scrap
- Areas with strong electricity infrastructure
- Markets with growing renewable electricity availability

Key Success Factors:

- Diversified economy reducing steel sector political power
- Abundant scrap availability or import access
- Grid capacity and renewable integration capability
- Capital availability or access to green finance
- Market for green steel products willing to pay modest premiums

Conclusion: If successful, Jiangsu demonstrates that circular economy principles applied at massive scale through EAF technology can achieve deep decarbonization while maintaining economic competitiveness, providing a potentially more cost-effective and rapidly deployable alternative to hydrogen-intensive pathways.