# Hydrogen-Based Steel Production in China: Current Projects and Development

MIFUS School/Project
A Global Journey through Steel Decarbonization

Prof. Fabio Miani
Department of Engineering and Architecture
University of Udine, Italy
fabio.miani@uniud.it

November 17, 2025

**Abstract**

China, as the world's largest steel producer accounting for approximately 54% of global crude steel output, faces significant challenges in decarbonizing its steel industry. This technical document examines the current state of hydrogen-based steel production projects in China, analyzing pilot initiatives, technological approaches, and the transition from traditional blast furnace-basic oxygen furnace (BF-BOF) routes to hydrogen direct reduced iron (H-DRI) and hydrogen-based smelting reduction processes. With the Chinese government's dual carbon goals targeting carbon neutrality by 2060, the steel sector's transformation through hydrogen metallurgy represents a critical pathway for achieving substantial $CO_2$ emission reductions in one of the most carbon-intensive industries globally.

## 1 Introduction

The steel industry in China produced over 1.0 billion tonnes of crude steel in 2023, contributing approximately 15% of the nation's total carbon emissions. Traditional steel production via the BF-BOF route generates 1.8–2.0 tonnes of $CO_2$ per tonne of crude steel. The decarbonization imperative has driven significant interest in hydrogen-based steelmaking technologies, which can theoretically reduce emissions by 80–95% compared to conventional methods.

Hydrogen-based steelmaking encompasses several technological routes:

- Direct reduction of iron ore using hydrogen (H-DRI)
- Hydrogen plasma smelting reduction
- Hydrogen injection into blast furnaces
- Electrolysis-based processes powered by renewable energy

# 2 Technology Fundamentals

## 2.1 Hydrogen Direct Reduction

The hydrogen direct reduction process replaces carbon monoxide with hydrogen as the reducing agent:

$$Fe_2O_3 + 3H_2 \rightarrow 2Fe + 3H_2O \tag{1}$$

This reaction occurs at temperatures between 800–1000°C, producing metallic iron and water vapor instead of $CO_2$. The direct reduced iron (DRI) is then melted in an electric arc furnace (EAF) to produce steel.

## 2.2 Hydrogen Requirements

For each tonne of DRI production, approximately:

- 50–60 kg of hydrogen is required
- Energy consumption: 11–13 GJ/t (thermal + electrical)
- Water production: 450–540 kg per tonne of DRI

The hydrogen can be produced via:

- **Green hydrogen**: Water electrolysis powered by renewable energy
- **Blue hydrogen**: Natural gas reforming with carbon capture and storage (CCS)
- **Turquoise hydrogen**: Methane pyrolysis producing solid carbon

# 3 Current Projects in China

## 3.1 Baowu Steel - Hydrogen Metallurgy Program

China Baowu Steel Group, the world's largest steel producer, has initiated multiple hydrogen-based steelmaking projects:

#### Baowu Zhanjiang Project (2022–present)

- Pilot scale: 1 million tonnes per year DRI capacity
- Technology: Hydrogen-rich gas DRI with shaft furnace
- Hydrogen source: Initial phase uses industrial by-product hydrogen; transition to green hydrogen planned
- Timeline: Phase 1 operational 2023; full scale by 2025
- Target: 30% hydrogen content in reducing gas initially, scaling to 100%

**Baowu-HBIS Hydrogen Collaboration** Joint research facility established in 2021 focusing on:

- Hydrogen injection into blast furnaces (up to 30% replacement)
- Development of hydrogen-based shaft furnace technology
- Integration with renewable energy sources

## 3.2 HBIS Group Projects

Hebei Iron and Steel Group (HBIS), China's second-largest producer:

### Hydrogen-Rich Smelting Reduction Pilot

- Location: Tangshan, Hebei Province
- Capacity: 600,000 tonnes/year pilot plant
- Technology: Modified COREX process with hydrogen enrichment
- Status: Under construction, expected completion 2024–2025
- Innovation: Aims for 50–70% carbon reduction versus BF-BOF

## 3.3 Ansteel - Hydrogen Demonstration Project

Anshan Iron and Steel Group Corporation:

- 500,000 tonne/year hydrogen-based DRI demonstration plant
- Technology partnership with European DRI technology providers
- Integrated with 200 MW electrolyzer capacity for green hydrogen
- Expected commissioning: 2025–2026
- Focus: High-grade automotive steel production

## 3.4 Shougang Group - Green Hydrogen Initiative

### Shougang Jingtang Project

- Comprehensive hydrogen industrial park
- 100,000 tonne/year initial DRI capacity
- Powered by offshore wind and solar energy
- Electrolyzer capacity: 150 MW (alkaline + PEM)
- Timeline: Pilot operations began 2023

## 3.5 Regional Development Initiatives

**Inner Mongolia Hydrogen Corridor** Multiple steel producers in Inner Mongolia are developing hydrogen projects leveraging:

- Abundant renewable energy resources (wind and solar)
- Proximity to iron ore deposits
- Existing steel production infrastructure
- Government policy support and subsidies

Notable projects include:

- Baotou Steel: 300,000 tonne/year H-DRI pilot
- Inner Mongolia Autonomous Region strategic plan: 5 Mt/year hydrogen-based steel by 2030

# 4 Technical Challenges and Solutions

## 4.1 Hydrogen Supply Infrastructure

**Current Challenges**

- Limited green hydrogen production capacity
- High cost: \$4–6/kg for green $H_2$ versus \$1–2/kg for grey $H_2$
- Transportation and storage infrastructure gaps
- Electrolyzer manufacturing scale-up requirements

**Proposed Solutions**

- Massive renewable energy deployment in western regions
- Development of hydrogen pipeline networks
- Co-location of electrolyzers with steel plants
- Utilization of industrial by-product hydrogen as transitional measure

## 4.2 Process Integration

Key technical considerations:

- DRI quality requirements for EAF processing
- Heat management in hydrogen reduction processes
- Water management and recycling systems
- Control systems for variable renewable energy input

## 4.3 Economic Viability

Table 1: Cost Comparison: Traditional vs. Hydrogen-Based Steel (USD/tonne crude steel)

| Cost Component | BF-BOF | H-DRI-EAF |
|---|---|---|
| Raw materials | 300–350 | 350–400 |
| Energy | 80–100 | 150–250 |
| Hydrogen (green) | 0 | 200–300 |
| Capital (amortized) | 50–70 | 80–120 |
| Operating | 70–100 | 80–110 |
| **Total** | **500–620** | **860–1180** |

Cost reduction pathways:

- Declining renewable energy costs (LCOE $<$ \$30/MWh in some regions)
- Electrolyzer efficiency improvements and cost reductions
- Carbon pricing mechanisms (China ETS expansion)
- Government subsidies and policy support

# 5 Policy Framework and Support

## 5.1 National Policies

**Dual Carbon Goals**

- Carbon peak before 2030
- Carbon neutrality by 2060
- Steel sector specific targets: 30% emission reduction by 2030 (2020 baseline)

**14th Five-Year Plan (2021–2025)** Key provisions affecting hydrogen steel:

- R&D funding for breakthrough low-carbon technologies
- Pilot project subsidies (up to 30% of capital costs)
- Preferential electricity tariffs for hydrogen production
- Green steel procurement requirements for government projects

## 5.2 Regional Initiatives

- **Hebei Province**: 10 Mt/year low-carbon steel capacity by 2030
- **Shandong Province**: Hydrogen industrial cluster development
- **Jiangsu Province**: Green steel certification and premium pricing mechanisms

# 6 International Collaboration

Chinese steel producers are actively partnering with international technology providers:

- **Energiron/Tenova**: DRI technology licensing
- **HYBRIT** (Sweden): Knowledge exchange on fossil-free steel
- **ThyssenKrupp**: Hydrogen injection technology
- **Primetals Technologies**: Advanced EAF systems
- **Paul Wurth**: Shaft furnace and hydrogen metallurgy expertise

# 7 Timeline and Projections

## 7.1 Near-term (2024–2027)

- Completion of major pilot projects (cumulative 5–8 Mt/year capacity)
- Demonstration of technical feasibility at industrial scale
- Establishment of hydrogen supply chains in key regions
- Development of quality standards for hydrogen-based steel

## 7.2 Medium-term (2028–2035)

- Commercial deployment: 50–100 Mt/year hydrogen-based steel capacity
- Represents 5–10% of total Chinese steel production
- Significant cost reduction through scale economies
- Integration with expanding renewable energy capacity (projected 1200 GW wind, 600 GW solar by 2030)

## 7.3 Long-term (2035–2060)

- Majority of new steel capacity based on hydrogen technologies
- Retrofit of existing facilities where economically viable
- Potential 400–600 Mt/year hydrogen-based capacity by 2060
- Achieving near-zero emissions steel production

# 8 Environmental Impact Assessment

## 8.1 Emission Reduction Potential

Assuming 100% green hydrogen utilization:

- **Traditional BF-BOF**: 1.8–2.0 t $CO_2$/t steel
- **H-DRI-EAF**: 0.05–0.15 t $CO_2$/t steel (mainly from EAF electricity if not fully renewable)
- **Reduction**: 90–95% emission intensity decrease

For China's 1 billion tonne annual production:

- Current emissions: ∼1.8 Gt $CO_2$/year
- 50% hydrogen transition: 0.9 Gt $CO_2$ reduction/year
- Full transition: 1.7 Gt $CO_2$ reduction/year (equivalent to 4% of global $CO_2$ emissions)

## 8.2 Water and Resource Considerations

**Water Requirements**

- Electrolysis: 9–10 kg $H_2O$ per kg $H_2$
- For 1 Mt steel: ∼500,000 $m^3$ water/year
- Water recycling essential in water-scarce regions
- Opportunity for integration with desalination in coastal facilities

**Critical Materials**

- Platinum group metals for PEM electrolyzers
- Nickel for alkaline electrolyzers
- Refractory materials for high-temperature processes
- China's strategic focus on supply chain security

# 9 Comparison with Global Initiatives

Table 2: Major Hydrogen Steel Projects: Global Comparison

| Project/Country | Technology | Capacity | Timeline |
|---|---|---|---|
| HYBRIT (Sweden) | H-DRI-EAF | 1.3 Mt/y | 2026 |
| H2 Green Steel (Sweden) | H-DRI-EAF | 5 Mt/y | 2030 |
| ThyssenKrupp (Germany) | H-DRI-EAF | 3 Mt/y | 2026–2030 |
| ArcelorMittal (Europe) | H-DRI-EAF | 7 Mt/y | 2030 |
| POSCO (S. Korea) | HyREX | 1 Mt/y | 2026 |
| **China (Total)** | **Various** | **5–8 Mt/y** | **2024–2027** |

China's approach differs in several aspects:

- Larger aggregate scale due to production volume
- Greater emphasis on industrial by-product hydrogen in transition phase
- Integration with massive renewable energy deployment
- Strong government coordination and policy support
- Focus on indigenous technology development alongside international partnerships

# 10 Research and Development Focus Areas

Chinese research institutions and steel companies are focusing on:

## 10.1 Tsinghua University - Steel Research Institute

- Hydrogen flash smelting technology
- High-temperature hydrogen reduction kinetics
- Process modeling and optimization

## 10.2 Northeastern University

- Hydrogen plasma reduction processes
- Direct reduction of low-grade ores
- Integration of hydrogen metallurgy with scrap recycling

## 10.3 Industry R&D Centers

- Baowu Research Institute: Full value chain integration
- HBIS Technology Center: Hydrogen-rich gas injection optimization
- Collaborative innovation platforms with 50+ participating institutions

# 11 Challenges and Risk Factors

## 11.1 Technical Risks

- Scale-up challenges from pilot to commercial production
- DRI quality consistency and metallization rates
- Refractory materials degradation under hydrogen atmospheres
- Integration with intermittent renewable energy supply

## 11.2 Economic Risks

- High capital investment requirements ($500–800 million for 1 Mt/y facility)
- Green hydrogen cost competitiveness
- Steel market price pressures and willingness to pay premium
- Long payback periods (15–25 years without carbon pricing)

## 11.3 Policy and Market Risks

- Uncertainty in carbon pricing mechanisms
- International trade implications (carbon border adjustments)
- Competition from scrap-based EAF route
- Coordination challenges across value chain

# 12 Conclusions and Future Outlook

China's hydrogen-based steel production initiatives represent a critical component of the global steel industry's decarbonization trajectory. With multiple pilot projects operational or under development, totaling 5–8 Mt/year capacity by 2027, China is demonstrating serious commitment to this technological transition.

**Key Success Factors**

1. Rapid scaling of renewable energy and green hydrogen production
2. Continued cost reduction in electrolyzers and renewable electricity
3. Effective policy support including carbon pricing and green procurement
4. International technology collaboration and knowledge transfer
5. Development of hydrogen infrastructure and supply chains

**Strategic Implications** The successful deployment of hydrogen-based steel production in China would:

- Reduce global steel sector emissions by 10–15%
- Accelerate global hydrogen economy development
- Create new industrial value chains and employment
- Influence international steel trade and competitiveness dynamics
- Demonstrate viability of industrial decarbonization at massive scale

The next 5–10 years will be critical in determining whether hydrogen-based steelmaking can transition from demonstration to mainstream production technology in China and globally.

## Acknowledgments

This document has been prepared for the MIFUS School/Project: A Global Journey through Steel Decarbonization. The author acknowledges valuable discussions with industry partners and research institutions contributing to this analysis.

## References

[1] International Energy Agency (2023). *Iron and Steel Technology Roadmap*. IEA Publications.

[2] China Baowu Steel Group (2023). *Carbon Neutrality Action Plan and Hydrogen Metallurgy Development*. Corporate Report.

[3] World Steel Association (2024). *Steel Statistical Yearbook 2023*. Brussels: worldsteel.

[4] Vogl, V., et al. (2021). Assessment of hydrogen direct reduction for fossil-free steelmaking. *Journal of Cleaner Production*, 203, 736–745.

[5] State Council of China (2021). *Action Plan for Carbon Dioxide Peaking Before 2030*. Beijing.

[6] Zhang, Q., et al. (2023). Hydrogen-based direct reduction ironmaking: Current status and future prospects in China. *International Journal of Minerals, Metallurgy and Materials*, 30(8), 1372–1384.

[7] HBIS Group (2023). *Green and Low-Carbon Development Report*. Corporate Sustainability Report.

[8] HYBRIT Development (2022). *Summary of Findings from HYBRIT Pre-Feasibility Study*. Stockholm.

[9] International Energy Agency (2022). *Global Hydrogen Review 2022*. IEA Publications.

[10] DNV GL (2021). *Hydrogen Forecast to 2050: Energy Transition Outlook*. Technical Report.

# A Glossary of Terms

**BF-BOF** Blast Furnace - Basic Oxygen Furnace: Traditional integrated steelmaking route

**DRI** Direct Reduced Iron: Metallic iron produced by direct reduction of iron ore

**EAF** Electric Arc Furnace: Melting furnace using electrical energy

**H-DRI** Hydrogen Direct Reduced Iron: DRI produced using hydrogen as reducing agent

**CCS** Carbon Capture and Storage

**LCOE** Levelized Cost of Energy

**PEM** Proton Exchange Membrane (electrolyzer type)

**ETS** Emissions Trading System

# B Contact Information

**MIFUS School/Project**
A Global Journey through Steel Decarbonization

**Prof. Fabio Miani**
University of Udine
Department of Engineering and Architecture
Via delle Scienze 206
33100 Udine, Italy

Email: fabio.miani@uniud.it

For more information about the MIFUS project and related activities, please contact the author.