

# China's Top 20 Steel Producers: Geographic Distribution and Strategic Implications of the 1.5:1 Capacity Replacement Policy

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## Abstract

This report analyzes China's top 20 steel producers with emphasis on their geographic distribution across Chinese provinces and the strategic implications of the October 2025 draft capacity replacement policy mandating a minimum 1.5:1 ratio. The policy requires at least 1.5 tons of old capacity to be scrapped for every ton of new capacity added, representing a significant tightening from previous 1.25:1 ratios in key pollution control areas. With China producing over 1 billion tonnes of steel annually—representing approximately 54% of global production—and top producers concentrated in Hebei, Jiangsu, Shandong, and Liaoning provinces, this policy will reshape the industry's decarbonization trajectory. The analysis identifies priority regions for policy implementation, examines provincial steel production patterns, and assesses where capacity rationalization efforts will be most effective in achieving China's carbon neutrality goals by 2060.

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# 1 Executive Summary

China's steel industry stands at a critical juncture. In 2024, China's total crude steel production declined by 1.7% year-on-year to 1.005 billion tonnes, reflecting government efforts to control capacity and reduce emissions. The newly proposed 1.5:1 capacity replacement policy represents the most stringent approach yet to managing the industry's environmental footprint.

## Key Findings:

- Hebei province accounts for 21.7% of China's steel production, making it the epicenter of both production and decarbonization efforts
- Jiangsu ranks second with significant production volumes, while Shandong holds third place
- The 1.5:1 policy creates a net capacity reduction mechanism: for every 100 Mt of new capacity, 150 Mt must be retired
- Three categories qualify for equal-capacity swaps: on-site upgrades, high-end specialty steel using advanced smelting, and projects in Qinghai and Xizang
- Geographic concentration in northern coastal provinces offers logistical advantages but presents concentrated environmental challenges

# 2 The 1.5:1 Capacity Replacement Policy Framework

## 2.1 Policy Evolution and Current Status

Following suspension of the previous capacity-swap scheme in August 2024, new policy guidelines were unveiled in late 2025. This represents the culmination of a decade-long journey of steel capacity management policies.

### Historical Context:

- **2015-2017:** First implementation measures with variable ratios
- **2017-2021:** Second version saw capacity expansion due to loopholes
- **2021-2024:** Stricter measures with 1.5:1 ratio in key pollution areas, 1.25:1 elsewhere
- **October 2025:** New draft rules mandate minimum 1.5:1 ratio nationwide, with 1.25:1 permitted for post-June 2021 mergers and acquisitions

## 2.2 Core Policy Mechanisms

### Standard Replacement Ratio:

- Baseline: 1.5 tonnes of old capacity eliminated per 1 tonne of new capacity
- M&A exception: 1.25:1 for mergers completed after June 2021
- Result: Net capacity reduction of 33% (1.5:1) or 20% (1.25:1)

### **Equal-Capacity Swap Exceptions (1:1 ratio):**

1. On-site equipment upgrades and modernization
2. High-end specialty steel using advanced smelting processes
3. Projects in Qinghai Province and Xizang Autonomous Region

### **Technology Priorities:**

- Encouragement for steelmakers to expand electric arc furnace capacity, promote hydrogen metallurgy, and retrofit existing plants with low-carbon technologies
- Integration with China's broader industrial greening strategy
- Alignment with 2060 carbon neutrality target

## **2.3 Strategic Objectives**

### **Capacity Control:**

- Market estimates suggest steel production in 2025 will be less than 980 million tonnes, at least 25 million tonnes lower than 2024
- During the 14th Five-Year Plan (2021-2025), China planned to replace 236 million tonnes/year of old capacity with 221 million tonnes/year of new capacity
- Long-term goal: Supply-demand balance while advancing decarbonization

### **Environmental Goals:**

- Special Action Plan targets 53 million tonnes emissions reduction in steel industry from 2024 to 2025
- Ultra-low emissions compliance across facilities
- Preparation for full CBAM implementation in January 2026

## **3 Geographic Distribution of China's Top 20 Steel Producers**

### **3.1 Provincial Steel Production Landscape**

China's steel industry exhibits strong geographic concentration, with critical implications for the 1.5:1 policy implementation.

Table 1: Major Steel-Producing Provinces (2023-2024 Data)

Province	Annual Production (Mt)	Share of National Total	Key Producers	Policy Priority
Hebei	225-250	21-24%	Baowu, HBIS, Shougang, Jingye	Critical
Jiangsu	119-121	11-12%	Shagang, Provincial mills	High
Shandong	76-80	7-8%	Regional producers	High
Liaoning	60-65	6-7%	Ansteel, Benxi Steel	High
Shanxi	45-50	4-5%	Regional producers	Medium
Guangdong	35-40	3-4%	Regional producers	Medium
Hubei	20-25	2-3%	Wuhan Iron & Steel (Baowu)	Medium

## 3.2 Top 4 Priority Provinces for 1.5:1 Policy Implementation

### 3.2.1 1. Hebei Province - The Epicenter

#### Production Scale:

- 2020 production: nearly 250 million tonnes, accounting for 23.7% of China's total
- 2021: approximately 225 million tonnes despite 9.9% decline
- Capacity exceeds 250 Mt/year
- Consistently China's largest steel-producing province

#### Major Producers Based in Hebei:

1. **HBIS Group (Hesteel):** Headquarters in Shijiazhuang, 41 million tonnes annually
2. **Jingye Steel Group:** Headquarters in Shijiazhuang, 35-40 million tonnes
3. **Shougang Group facilities:** Multiple production sites
4. **China Baowu subsidiaries:** Expanded presence through acquisitions

#### Strategic Significance:

- Geographic proximity to Beijing creates intense environmental pressure
- Designated key area for air pollution prevention and control

- Projected to lead in BOF route through 2050, requiring substantial CCUS deployment
- Historical air quality challenges drive aggressive policy enforcement

#### **1.5:1 Policy Impact:**

- Highest priority province for capacity reduction
- Net reduction of 37.5 Mt if 150 Mt replaced at 1.5:1 ratio
- Opportunity to modernize aging blast furnace infrastructure
- Critical for achieving national emissions targets

### **3.2.2 2. Jiangsu Province - EAF Leader**

#### **Production Profile:**

- Second-largest producer: 119-121 million tonnes annually
- More stable production patterns than Hebei
- Located in economically dynamic East China region

#### **Major Producer:**

- **Jiangsu Shagang Group:** Headquarters in Zhangjiagang
- China's largest privately-owned steelmaker
- 41.45 million tonnes production (2024)
- Known for cost efficiency and production flexibility

#### **Competitive Advantages:**

- Projected leader in EAF deployment by 2050
- Strong grid infrastructure for electrification
- Ranks 6th nationally in Levelised Cost of Steel (LCOS) for hydrogen-based DRI
- Access to scrap steel from developed manufacturing regions
- Coastal location facilitates iron ore imports

#### **1.5:1 Policy Opportunities:**

- Accelerate transition from BF-BOF to EAF routes
- Leverage renewable electricity infrastructure
- Model province for green steel transformation
- Integration potential with nearby renewable energy provinces

### 3.2.3 3. Shandong Province - Rapid Growth Hub

#### Production Growth:

- Surpassed Liaoning to become third-largest in 2020 with 79 million tonnes
- 25.7% year-on-year growth in 2020
- Benefited from major mill relocations and modernization

#### Major Developments:

- Rizhao Steel works expansion (Shandong Iron and Steel Group)
- Ji'nan Steel relocation from Ji'nan to Rizhao (2017-2019)
- New steelmaking facilities commissioned 2019-2020

#### Strategic Position:

- Among top three provinces projected for BOF routes through 2050
- Key candidate for CCUS deployment and hydrogen DRI
- Ranks 17th in LCOS but remains promising for green steel
- Major port facilities (Qingdao) for raw material imports

#### 1.5:1 Policy Considerations:

- Recent modernization may reduce near-term capacity retirement needs
- Focus on technology upgrades at existing facilities
- Potential for hydrogen infrastructure integration
- Balance growth trajectory with environmental imperatives

### 3.2.4 4. Liaoning Province - Hydrogen Leader

#### Production Heritage:

- Fourth-largest steel producing province
- Approximately 60-65 million tonnes annually
- Historical steel center with established infrastructure

#### Major Producers:

##### 1. Ansteel Group: Headquarters in Anshan

- 59.55 million tonnes production (2024)
- Third-largest producer nationally
- World's first green hydrogen demonstration project in Bayuquan (10,000 tonnes capacity)



## 2. **Benxi Steel Group:** 20 million tonnes capacity

### **Green Steel Leadership:**

- Boasts lowest Levelised Cost of Steel (LCOS) across all Chinese regions
- Strong industrial base, skilled labor pool, logistical infrastructure, and robust grid connections present compelling opportunity for early H2-DRI-EAF pilots
- Pioneer in hydrogen metallurgy demonstration
- Excellent renewable energy resources

### **1.5:1 Policy Strategic Role:**

- Ideal testbed for hydrogen-based capacity replacement
- Retrofit potential for existing BF-BOF facilities
- Technology demonstration leadership
- Model for other provinces' transformation pathways

## 3.3 Secondary Priority Provinces

### **Shanxi Province:**

- 45-50 million tonnes annually
- Coal-rich region with established coking operations
- Transition challenges due to coal dependency
- Potential for carbon capture integration

### **Guangdong Province:**

- 35-40 million tonnes production
- Southern China's major industrial center
- Projected EAF leader alongside Jiangsu and Sichuan by 2050
- Access to coastal trade routes

### **Hubei Province:**

- 20-25 million tonnes annually
- Home to Wuhan Iron & Steel (China Baowu subsidiary)
- Central China strategic position
- Integration with Yangtze River economic corridor

## 4 China's Top 20 Steel Producers: Detailed Profiles

### 4.1 Top 10 Producers (Global Scale)

#### 4.1.1 1. China Baowu Steel Group Corporation Limited

##### Basic Information:

- **Headquarters:** Shanghai
- **2024 Production:** 130.09 million tonnes
- **Global Rank:** #1 worldwide
- **Ownership:** State-owned enterprise
- **Formation:** 2016 merger of Baosteel and Wuhan Iron & Steel

##### Geographic Footprint:

- Primary facilities in Shanghai, Hubei (Wuhan), and expanding nationwide
- Multiple subsidiaries across key steel provinces
- Integrated operations from iron ore to finished products

##### Decarbonization Leadership:

- Net-zero target: 2050
- Peak emissions: 2023
- 30% reduction by 2035 (from 2020 baseline)
- HyCROF technology achieving 20% CO<sub>2</sub> reduction
- 400m<sup>3</sup> industrial hydrogen furnace in Xinjiang: 85,021 tonnes CO<sub>2</sub> reduction annually
- Near-zero carbon mill in Guangdong (4.5 billion yuan investment, completion 2025)
- Hydrogen DRI demonstration: 1 million tonne capacity in Zhangjiang
- 50 billion yuan carbon neutrality equity fund

##### 1.5:1 Policy Positioning:

- Scale enables strategic capacity rationalization
- Financial resources for technology deployment
- National champion status supports policy compliance
- Model for industry transformation

#### 4.1.2 2. Ansteel Group Corporation Limited

##### Basic Information:

- **Headquarters:** Anshan, Liaoning Province
- **2024 Production:** 59.55 million tonnes
- **Global Rank:** #3 worldwide
- **History:** One of China's oldest steel manufacturers

##### Provincial Context:

- Anchor producer in Liaoning Province
- Proximity to iron ore resources in Northeast China
- Established infrastructure and skilled workforce
- Critical to regional economic development

##### Green Hydrogen Pioneer:

- World's first green hydrogen-based demonstration project
- Location: Bayuquan, Liaoning
- Capacity: 10,000 tonnes (demonstration scale)
- Focus on ultra-low emissions compliance
- Target: 80% of Chinese capacity compliant by 2025

##### 1.5:1 Policy Implications:

- Leverage Liaoning's low LCOS advantage
- Scale up hydrogen demonstrations under policy framework
- Potential to retrofit existing facilities
- Provincial leadership in technology transition

#### 4.1.3 3. HBIS Group Co., Ltd (Hesteel)

##### Basic Information:

- **Headquarters:** Shijiazhuang, Hebei Province
- **2024 Production:** 41 million tonnes
- **Global Rank:** #5 worldwide
- **Subsidiaries:** Includes former Handan Iron and Steel

##### Hebei Provincial Champion:

- Leading producer in China's largest steel province
- Multiple production sites across Hebei
- Supplies steel to over 120 countries
- Digital transformation focus

**Ambitious Decarbonization:**

- Peak emissions: 2022
- 10% reduction by 2025
- 30% reduction by 2030
- Carbon neutrality: 2050

**Hydrogen Metallurgy Leadership:**

- China's first hydrogen DRI demonstration plant
- Location: Zhangjiakou, Hebei
- Capacity: 1.2 million tonnes (operational 2023)
- Phase 1: Grey hydrogen from coke ovens
- Phase 2: Green hydrogen from renewables
- Planned capacity: 3.6 million tonnes (14th Five-Year Plan)
- Hydrogen refueling station for trucks at Tangsteel

**1.5:1 Policy Strategic Importance:**

- Scale hydrogen DRI to replace BF-BOF capacity
- Demonstrate pathway for Hebei province transformation
- Model for transitioning from grey to green hydrogen
- Critical for provincial emissions reduction

#### 4.1.4 4. Shagang Group

**Basic Information:**

- **Headquarters:** Zhangjiagang, Jiangsu Province
- **2024 Production:** 41.45 million tonnes
- **Global Rank:** #6 worldwide
- **Ownership:** China's largest privately-owned steelmaker

**Jiangsu Provincial Leader:**

- Five production facilities nationwide
- Concentrated operations in Jiangsu
- Known for cost efficiency and flexibility
- Private ownership enables agile decision-making

**Environmental Approach:**

- Environmental Product Declaration (EPD) reports issued
- Addressing international carbon requirements (CBAM preparation)
- Limited public disclosure of specific net-zero commitments
- Focus on operational efficiency and emissions intensity

**1.5:1 Policy Positioning:**

- Private ownership may enable faster transformation
- Leverage Jiangsu's EAF potential
- EPD leadership supports green steel marketing
- Position for premium green steel markets

#### 4.1.5 5. Jingye Steel Group

**Basic Information:**

- **Headquarters:** Shijiazhuang, Hebei Province
- **2024 Production:** 35-40 million tonnes (estimated)
- **Global Rank:** #7 worldwide
- **Certifications:** ISO 9001, ISO 14001

**Hebei Provincial Significance:**

- Major contributor to provincial production (13-16% of Hebei total)
- Part of Hebei's decarbonization imperative
- Green and sustainable development commitment
- Ultra-low emission transformation programs

**1.5:1 Policy Context:**

- Subject to Hebei's stringent environmental oversight
- Modernization opportunities under equal-capacity swap provisions
- Integration with provincial decarbonization strategy
- Potential consolidation with other Hebei producers

#### 4.1.6 6. Shougang Group

##### Basic Information:

- **Headquarters:** Beijing
- **2024 Production:** 34-38 million tonnes (estimated)
- **Global Rank:** #8 worldwide
- **History:** Founded 1919, over 100 years of operations

##### Geographic Distribution:

- Historical Beijing facility (Shijingshan Plant)
- Operations relocated from Beijing center
- Facilities in Hebei and other provinces
- Nine production plants total

##### Modernization Focus:

- Ultra-low emission steel production
- Environmental Product Declaration participation
- Facility upgrades for environmental performance
- Integration of electronics and machinery businesses

##### 1.5:1 Policy Opportunities:

- Beijing proximity drives environmental excellence requirements
- Facility modernization aligns with on-site upgrade provisions
- Model for urban-adjacent steel production transformation

#### 4.1.7 7. Tata Steel Limited (Chinese Operations)

**Note:** While Tata Steel's global operations rank #9-10, this section addresses only Chinese context.

#### 4.1.8 8-10. Regional and Provincial Producers

Multiple smaller producers in the 20-30 million tonne range operate across:

- Hebei Province (various local state-owned enterprises)
- Shandong Province (Shandong Iron and Steel Group subsidiaries)
- Shanxi Province (regional producers)
- Liaoning Province (Benxi Steel and others)

These producers collectively account for 100-150 million tonnes of capacity and will be significantly affected by 1.5:1 policy implementation.

## 4.2 Producers 11-20: Provincial Champions and Specialists

This tier includes:

- Provincial state-owned enterprises
- Specialized steel producers (stainless, special grades)
- Regional consolidation candidates
- Producers in secondary steel provinces (Fujian, Guangxi, Sichuan, Yunnan)

## 5 Strategic Analysis: Where Will the 1.5:1 Policy Be Most Effective?

### 5.1 Priority Ranking Framework

**Evaluation Criteria:**

1. **Production Volume:** Scale of potential capacity reduction
2. **Environmental Pressure:** Air quality imperatives
3. **Technology Readiness:** Availability of replacement technologies
4. **Economic Impact:** GDP dependency and employment considerations
5. **Infrastructure:** Energy grid, hydrogen, renewable resources

### 5.2 Tier 1 Priority: Maximum Impact Regions

#### 5.2.1 Hebei Province - Critical Priority

**Rationale for Highest Priority:**

- Largest absolute production volume (225-250 Mt)
- 21-24% of national total steel production
- Geographic proximity to Beijing creates political urgency
- Designated key air pollution control area
- Aging infrastructure requiring modernization

**Expected Policy Impact:**

- If 100 Mt replaced at 1.5:1 ratio: Net reduction of 33 Mt
- If 150 Mt replaced: Net reduction of 50 Mt (20% of provincial capacity)
- Combined with consolidation: Potential 60-80 Mt reduction by 2030

**Implementation Pathway:**

1. **Phase 1 (2025-2027):** Retire oldest, least efficient BF capacity
2. **Phase 2 (2027-2030):** Replace with hydrogen DRI-EAF (HBIS model)
3. **Phase 3 (2030-2035):** CCUS deployment on remaining BF facilities
4. **Phase 4 (2035-2050):** Full transition to near-zero emissions

**Key Enablers:**

- HBIS Zhangjiakou hydrogen DRI demonstration scalability
- Provincial government environmental enforcement capacity
- Access to renewable energy from Inner Mongolia
- Existing ultra-low emissions infrastructure

**Challenges:**

- Steel more important to Hebei's GDP growth than coastal provinces, making output cuts more difficult
- Large workforce requiring just transition programs
- Coordination among multiple producers
- Balancing capacity reduction with economic stability

### **5.2.2 Jiangsu Province - EAF Transformation Leader**

**Rationale for High Priority:**

- Second-largest production (119-121 Mt)
- Projected EAF deployment leader by 2050
- Strong grid infrastructure for electrification
- Economically developed with lower steel GDP dependency
- Coastal location facilitating scrap imports

**Expected Policy Impact:**

- Focus on BF-BOF to EAF transition rather than absolute reduction
- If 50 Mt BF capacity replaced with 33 Mt EAF: 50% emissions reduction
- Accelerate path to 70-80% EAF share by 2040

**Implementation Pathway:**

1. Leverage equal-capacity swap for EAF expansion
2. Retirement of smaller, inefficient BF facilities
3. Integration with scrap collection infrastructure



#### 4. Renewable electricity grid connections

##### **Shagang Group Leadership Role:**

- Private ownership enables faster technology adoption
- Model for EAF-based transformation
- EPD leadership supports green steel premium markets
- Technology demonstration for other Jiangsu producers

##### **Advantages:**

- Coastal provinces find it easier to cut supply given lower reliance on steel and lower contribution to GDP
- Strong financial capacity for capital investment
- Access to international scrap markets
- Developed manufacturing ecosystem generating scrap

### **5.3 Tier 2 Priority: Strategic Transformation Regions**

#### **5.3.1 Shandong Province - Balanced Approach**

##### **Strategic Position:**

- Third-largest producer (76-80 Mt)
- Recent modernization (2017-2020 relocations)
- Port infrastructure advantages (Qingdao, Rizhao)
- Balanced economic structure

##### **Policy Implementation Strategy:**

- Focus on technology upgrades at recently modernized facilities
- Leverage on-site upgrade provisions for equal-capacity swaps
- Selective capacity reduction on older remaining facilities
- Integration with hydrogen infrastructure development

##### **Expected Outcomes:**

- Net capacity reduction: 15-20 Mt by 2030
- Technology leadership in CCUS deployment
- Model for provinces with recent capital investments

### **5.3.2 Liaoning Province - Hydrogen Technology Hub**

#### **Strategic Advantages:**

- Fourth-largest producer (60-65 Mt)
- Lowest Levelised Cost of Steel (LCOS) nationally
- Ansteel's green hydrogen demonstration leadership
- Strong renewable energy resources
- Established industrial infrastructure

#### **Policy Implementation Model:**

- Technology demonstration province for hydrogen metallurgy
- Scale up Ansteel's 10,000 tonne demonstration to commercial levels
- Replace aging BF capacity with H2-DRI-EAF at 1.5:1 ratio
- Export technology and operational knowledge to other provinces

#### **Transformation Pathway:**

1. **2025-2027:** Scale Bayuquan demonstration to 100,000 tonnes
2. **2027-2030:** Deploy 1-2 million tonne commercial H2-DRI facilities
3. **2030-2035:** Replace 20-30 Mt BF capacity with hydrogen routes
4. **2035-2050:** Achieve 70-80% hydrogen-based production

#### **National Significance:**

- Proof-of-concept for hydrogen steel production economics
- Training center for hydrogen metallurgy workforce
- Technology licensing opportunities for other producers
- Model for Northeast China industrial transition

## **5.4 Tier 3 Priority: Secondary and Specialty Regions**

### **5.4.1 Shanxi Province - CCUS Focus**

#### **Profile:**

- Production: 45-50 Mt annually
- Coal-rich province with coking operations
- Dependency on coal value chain
- Less immediate pressure than coastal regions

**Policy Approach:**

- Gradual capacity rationalization at 1.5:1 ratio
- Focus on CCUS integration given coal infrastructure
- Selective retirement of oldest facilities
- Maintain specialty steel and coking capacity

**5.4.2 Guangdong Province - Southern Gateway****Profile:**

- Production: 35-40 Mt annually
- Southern China's industrial center
- Projected EAF leader by 2050 (alongside Jiangsu, Sichuan)
- Access to Southeast Asian scrap markets

**Policy Opportunities:**

- Accelerate EAF deployment using 1:1 equal-capacity provisions
- Leverage Baowu's near-zero carbon mill as provincial model
- Integration with Pearl River Delta manufacturing ecosystem
- Premium green steel for export and high-tech applications

**5.4.3 Other Provinces****Hubei, Inner Mongolia, Fujian, Sichuan, and others:**

- Combined production: 150-200 Mt
- Regional consolidation opportunities
- Specialty steel production preservation
- Selective capacity reduction aligned with local conditions

## **6 Comparative Effectiveness Analysis**

### **6.1 Capacity Reduction Potential by Province**

**Key Observations:**

- National capacity could decline by approximately 138 Mt (14%) if 415 Mt replaced at 1.5:1
- Top 4 provinces account for 100 Mt (72%) of total reduction
- Hebei alone contributes 36% of national capacity reduction
- Policy most effective in concentrated production regions

Table 2: 1.5:1 Policy Impact Projections (2025-2030)

Province	Current Capacity (Mt)	Capacity Retired (Mt)	New Capacity (Mt)	Net Change (Mt)	Net Reduction (%)
Hebei	250	150	100	-50	-20%
Jiangsu	120	75	50	-25	-21%
Shandong	80	45	30	-15	-19%
Liaoning	65	30	20	-10	-15%
Shanxi	50	15	10	-5	-10%
Others	440	100	67	-33	-8%
<b>Total</b>	<b>1,005</b>	<b>415</b>	<b>277</b>	<b>-138</b>	<b>-14%</b>

## 6.2 Emissions Reduction Potential

Table 3: CO<sub>2</sub> Emissions Reduction Scenarios by Province

Province	Current Annual Emissions (Mt CO <sub>2</sub> )	Projected Reduction (Mt CO <sub>2</sub> )	Reduction vs 2024 (%)
Hebei	500-550	120-140	24-25%
Jiangsu	240-260	60-70	25-27%
Shandong	160-180	35-40	22-24%
Liaoning	130-145	25-35	19-24%
<b>Top 4 Total</b>	<b>1,030-1,135</b>	<b>240-285</b>	<b>23-25%</b>

### Assumptions:

- Average BF-BOF intensity: 2.2 tonnes CO<sub>2</sub> per tonne steel
- Average EAF intensity: 0.4 tonnes CO<sub>2</sub> per tonne steel
- H2-DRI-EAF intensity: 0.1 tonnes CO<sub>2</sub> per tonne steel
- Mixed technology deployment across provinces

## 6.3 Technology Deployment Priorities

# 7 Economic and Social Implications

## 7.1 Employment Impact Analysis

### Workforce Considerations:

- Steel industry employs approximately 3-4 million workers directly
- Hebei Province: 600,000-800,000 steel sector jobs
- Average BF-BOF facility: 3,000-5,000 workers

Table 4: Optimal Technology Pathways by Province

Province	Primary Technology Pathway
Hebei	Hydrogen DRI-EAF (60%), CCUS on remaining BF (30%), EAF scrap (10%)
Jiangsu	EAF scrap-based (70%), H2-DRI-EAF (20%), CCUS (10%)
Shandong	Balanced: CCUS (40%), H2-DRI (30%), EAF (30%)
Liaoning	H2-DRI-EAF demonstration leader (70%), EAF (20%), CCUS (10%)
Shanxi	CCUS on coal-integrated facilities (60%), selective H2-DRI (25%), EAF (15%)
Guangdong	EAF scrap-based (60%), H2-DRI-EAF (30%), advanced processes (10%)

- Average EAF facility: 500-1,000 workers (75-85% reduction)
- Hydrogen DRI: 1,500-2,500 workers (40-50% reduction)

#### Net Capacity Reduction of 138 Mt Implications:

- Direct job displacement: 250,000-350,000 workers
- New technology jobs created: 80,000-120,000 workers
- Net employment reduction: 150,000-250,000 positions
- Retraining requirements: 300,000+ workers

#### Provincial Employment Vulnerabilities:

1. **Hebei:** Highest risk with 150,000-200,000 affected workers
2. **Jiangsu:** Moderate risk, better alternative employment opportunities
3. **Liaoning:** High risk due to limited alternative industries
4. **Shandong:** Moderate risk, diversified economy

#### Just Transition Requirements:

- Comprehensive retraining programs for hydrogen metallurgy, EAF operations, and renewable energy
- Social security provisions for early retirement (workers 55+)
- Regional economic diversification strategies
- Investment in alternative industries in steel-dependent cities

Table 5: Capital Cost Estimates for Capacity Replacement (2025-2030)

Technology Route	Cost per Tonne Capacity (\$/tonne)	Total for 277 Mt New Capacity (USD)
Hydrogen DRI-EAF	800-1,200	\$133-200 billion
Scrap-based EAF	300-500	\$42-70 billion
CCUS retrofit	200-400	\$28-56 billion
<b>Weighted Average</b>	<b>600-800</b>	<b>\$83-111 billion</b>

## 7.2 Capital Investment Requirements

### Technology Deployment Costs:

#### Additional Infrastructure Costs:

- Hydrogen production and distribution: \$30-50 billion
- Grid upgrades for electrification: \$15-25 billion
- CO<sub>2</sub> transport and storage infrastructure: \$10-20 billion
- Scrap collection and processing: \$5-10 billion

**Total Investment Requirement (2025-2030):** \$143-216 billion USD

#### Financing Mechanisms:

- State-owned enterprise internal resources
- Government subsidies and preferential loans
- Carbon neutrality equity funds (Baowu model)
- International climate finance
- Green bonds and sustainable finance instruments

## 7.3 Economic Competitiveness

### Green Steel Premium Potential:

- Current global green steel premium: \$40-100 per tonne
- CBAM compliance value (2026+): \$50-150 per tonne CO<sub>2</sub> saved
- Chinese producers with EPD certifications positioned for premiums
- Domestic demand from auto, construction, and appliance sectors

#### Cost Competitiveness Concerns:

- Green hydrogen costs: \$3-6/kg (target \$1-2/kg by 2030)
- Renewable electricity costs: \$0.03-0.06/kWh and declining
- CCUS operational costs: \$30-80 per tonne CO<sub>2</sub> captured

- Transition period cost disadvantage versus conventional production

#### **Provincial Competitiveness Rankings:**

1. **Liaoning:** Best positioned (lowest LCOS, renewable access)
2. **Jiangsu:** Strong position (grid infrastructure, scrap availability)
3. **Guangdong:** Favorable (coastal location, technology access)
4. **Hebei:** Challenging (scale, but capital requirements high)
5. **Shandong:** Moderate (balanced but high infrastructure needs)
6. **Shanxi:** Difficult (coal dependency, limited renewables)

## **8 Policy Implementation Challenges and Recommendations**

### **8.1 Key Implementation Challenges**

#### **8.1.1 Challenge 1: Provincial GDP and Employment Pressures**

##### **Problem:**

- Steel contributes 15-20% of GDP in Hebei, making capacity cuts politically difficult
- Local governments reliant on steel sector tax revenues
- Social stability concerns in single-industry cities
- Resistance from provincial leadership to aggressive reductions

##### **Mitigation Strategies:**

- Central government fiscal transfers to compensate revenue losses
- Economic diversification programs with multi-year support
- Performance metrics beyond GDP (environmental quality improvements)
- Gradual implementation with clear multi-year roadmaps

#### **8.1.2 Challenge 2: Technology Readiness and Scale**

##### **Problem:**

- Hydrogen DRI demonstrations at 10,000-1.2 million tonne scale
- Commercial deployment requires 3-5 million tonne facilities
- Green hydrogen production infrastructure underdeveloped
- CCUS never demonstrated at blast furnace scale in China

**Mitigation Strategies:**

- Accelerated demonstration-to-commercial transition programs
- Technology risk-sharing mechanisms (government guarantees)
- International technology partnerships and licensing
- Phased deployment starting with provinces having lowest LCOS

**8.1.3 Challenge 3: Capital Availability and Allocation****Problem:**

- \$150-200 billion investment required over 5-6 years
- Smaller producers lack financial resources for transformation
- Uncertain returns on green steel investments
- Competition for capital with other industrial sectors

**Mitigation Strategies:**

- Dedicated green steel transformation fund (national level)
- Preferential lending rates for decarbonization projects
- Consolidation incentives for smaller producers
- Green steel procurement mandates creating demand certainty

**8.1.4 Challenge 4: Coordination and Enforcement****Problem:**

- 20+ major producers with different capabilities and strategies
- Provincial governments with competing interests
- Monitoring and verification of capacity retirement
- Potential for "zombie capacity" and unreported production

**Mitigation Strategies:**

- Digital monitoring systems for production and capacity
- Strict enforcement with financial penalties for non-compliance
- Third-party verification of capacity retirement
- Regular reporting requirements and public disclosure



## 8.2 Policy Recommendations

### 8.2.1 For Central Government

#### Immediate Actions (2025-2026):

1. **Finalize and publish 1.5:1 policy implementation guidelines** with clear timelines, verification procedures, and enforcement mechanisms
2. **Establish National Steel Transformation Fund** with initial capitalization of RMB 100-150 billion
3. **Launch pilot programs** in Hebei (CCUS/H2-DRI mix), Jiangsu (EAF), and Liaoning (H2-DRI) provinces
4. **Mandate green steel procurement** for government infrastructure projects starting 2026
5. **Accelerate CBAM response strategy** to capture value from low-carbon production

#### Medium-term Actions (2026-2028):

1. **Implement domestic carbon pricing** for steel sector at RMB 50-80 per tonne CO<sub>2</sub>
2. **Scale hydrogen infrastructure** with focus on Hebei, Liaoning, Shandong corridors
3. **Establish Centers of Excellence** for hydrogen metallurgy (Liaoning), EAF operations (Jiangsu), and CCUS (Shanxi)
4. **Create Just Transition programs** with retraining and social support in top 4 provinces
5. **Monitor and adjust policy** based on first 2-year implementation results

### 8.2.2 For Provincial Governments

#### Hebei Province:

- **Target:** 50 Mt net capacity reduction by 2030
- **Strategy:** Prioritize oldest 30% of BF capacity for retirement
- **Investment:** RMB 200-300 billion in hydrogen DRI and CCUS
- **Action:** Scale HBIS Zhangjiakou demonstration to 5 Mt by 2028
- **Support:** Establish provincial retraining programs for 150,000 workers

#### Jiangsu Province:

- **Target:** 25 Mt net capacity reduction by 2030 through BF-to-EAF conversion
- **Strategy:** Leverage Shagang leadership for EAF transition model

- **Investment:** RMB 100-150 billion primarily in EAF capacity
- **Action:** Develop integrated scrap collection and processing network
- **Advantage:** Position as China's green steel premium market leader

**Shandong Province:**

- **Target:** 15 Mt net capacity reduction by 2030
- **Strategy:** On-site technology upgrades at recently modernized facilities
- **Investment:** RMB 80-120 billion in CCUS and selective H2-DRI
- **Action:** Leverage port infrastructure for hydrogen imports and scrap sourcing

**Liaoning Province:**

- **Target:** 10 Mt net capacity reduction through technology substitution
- **Strategy:** National hydrogen DRI technology demonstration hub
- **Investment:** RMB 60-80 billion focused on H2-DRI-EAF
- **Action:** Scale Ansteel demonstration and license technology nationally
- **Goal:** Export hydrogen steel technology and expertise

### 8.2.3 For Steel Producers

**China Baowu (National Champion):**

- Lead industry transformation as technology developer and deployer
- Leverage 50 billion yuan carbon neutrality fund strategically
- Complete Guangdong near-zero carbon mill as national showcase
- Establish industry standards for green steel certification
- Support smaller producers through technology licensing

**Provincial Leaders (HBIS, Ansteel, Shagang):**

- Scale demonstration projects to commercial deployment rapidly
- Publish detailed technology roadmaps and cost trajectories
- Collaborate on workforce retraining program development
- Engage with international partners for technology access
- Lead EPD certification and green steel marketing

**Smaller Producers:**

- Evaluate strategic options: consolidation, specialization, or modernization

- Form consortia to share technology development costs
- Focus on specialty steel grades with lower volume, higher value
- Consider merger opportunities with larger groups
- Invest in energy efficiency as first-step decarbonization

## 9 International Context and CBAM Implications

### 9.1 Carbon Border Adjustment Mechanism (CBAM) Impact

#### Timeline and Requirements:

- **Transitional phase:** 2023-2025 (reporting only)
- **Full implementation:** January 1, 2026
- **Coverage:** Steel products among first commodities covered
- **Mechanism:** Tariffs based on embedded carbon emissions

#### Implications for Chinese Producers:

- EU is major export market for Chinese specialty steel
- Carbon-intensive steel faces \$50-150/tonne tariff based on intensity
- Chinese average (1.9-2.2 t CO<sub>2</sub>/t steel) vs EU average (1.5-1.7 t CO<sub>2</sub>/t)
- Potential tariff exposure: \$25-80 per tonne on current production

#### Strategic Responses:

1. **EPD Certification:** 44 reports issued (2023), expand to all major producers
2. **Low-carbon product lines:** Develop certified green steel grades
3. **Market segmentation:** Reserve cleanest production for EU exports
4. **Technology acceleration:** 1.5:1 policy aligns with CBAM competitiveness

#### Provincial Export Exposure:

Table 6: EU Steel Export Exposure by Province (2024 estimates)

Province	EU Exports (Mt)	CBAM Tariff Exposure (\$M)	Incentive for Decarbonization
Jiangsu	3-5	75-400	Very High
Hebei	2-4	50-320	High
Guangdong	2-3	50-240	High
Shandong	1-2	25-160	Medium
Others	3-5	75-400	Variable

Table 7: International Steel Decarbonization Policy Comparison

Region/Country	Policy Approach
China	1.5:1 capacity replacement; ultra-low emissions mandates; hydrogen demonstrations; 2060 carbon neutrality
European Union	CBAM border tariffs; \$2.3B subsidies (Thyssenkrupp); HYBRIT project (Sweden); 2050 net-zero
United States	Market-driven with IRA incentives; voluntary programs; EAF adoption; 2050 net-zero aspirations
Japan	COURSE50 technology development; gradual BF retirement; 2050 net-zero; limited near-term action
South Korea	Corporate commitments (POSCO 2050); government support; hydrogen R&D; moderate pace
India	2070 net-zero; National Steel Policy; emphasis on scrap and efficiency; rapid growth challenge

## 9.2 Comparative International Context

### China vs Global Decarbonization Strategies:

#### China's Unique Position:

- **Scale advantage:** 54% of global production enables unmatched demonstration scale
- **Policy coordination:** Centralized decision-making can drive rapid transformation
- **Financial capacity:** State ownership facilitates capital-intensive transitions
- **Challenges:** Balancing economic growth, employment, and environmental goals

## 10 Technology Deep Dive: Implementation Pathways

### 10.1 Hydrogen Direct Reduction Iron (H2-DRI) Deployment

#### Current Status in China:

- HBIS Zhangjiakou: 1.2 million tonnes operational (grey hydrogen)
- Ansteel Bayuquan: 10,000 tonnes demonstration (green hydrogen)
- China Baowu Zhangjiang: 1 million tonnes planned
- Multiple provincial pilots in planning stages

#### Scale-Up Requirements for 1.5:1 Policy:

- Target: 50-80 Mt H2-DRI capacity by 2030
- Required: 40-65 commercial-scale facilities (1.5-2 Mt each)
- Green hydrogen demand: 4-6 million tonnes annually by 2030

- Renewable electricity: 150-250 TWh annually for hydrogen production

**Provincial Deployment Priorities:**

1. **Liaoning (Phase 1):** 5-8 Mt by 2028 (leveraging lowest LCOS)
2. **Hebei (Phase 2):** 15-25 Mt by 2030 (scale from HBIS demonstration)
3. **Shandong (Phase 2):** 8-12 Mt by 2030 (port-based hydrogen imports)
4. **Inner Mongolia (Phase 3):** 5-10 Mt by 2032 (renewable energy hub)

**Technology Pathway:**

- **2025-2027:** Grey/blue hydrogen from coke ovens and natural gas with CCUS
- **2027-2030:** Increasing green hydrogen share (20-40%)
- **2030-2035:** Majority green hydrogen (60-80%)
- **2035-2050:** Near-100% green hydrogen with falling costs

## 10.2 Electric Arc Furnace (EAF) Expansion

**Current Chinese EAF Capacity:**

- Current share: 10-15% of national production (100-150 Mt)
- Global average: 28-30% (China significantly behind)
- Target: 30-40% by 2030 (300-400 Mt)
- Long-term target: 50-60% by 2050

**Scrap Availability Constraints:**

- Current scrap generation: 200-250 million tonnes annually
- Quality issues: High copper, tin contamination from consumer goods
- Recycling rate: 80-85% collection efficiency
- Import potential: 30-50 Mt annually from global markets
- Projected 2030 availability: 320-350 Mt (government target)

**Provincial EAF Expansion:**

**Investment Requirements:**

- Unit cost: \$300-500 per tonne capacity
- Total for 150 Mt new EAF capacity: \$45-75 billion
- Scrap processing infrastructure: \$10-15 billion
- Grid upgrades for high-power EAF: \$8-12 billion

Table 8: Provincial EAF Expansion Targets (2025-2030)

Province	Current EAF Share (%)	2030 Target EAF (%)	New Capacity Required (Mt)
Jiangsu	15-20%	40-50%	30-40
Guangdong	20-25%	50-60%	12-18
Sichuan	25-30%	50-60%	5-8
Hebei	5-8%	15-20%	15-25
Shandong	10-12%	25-30%	12-18

### 10.3 Carbon Capture, Utilization, and Storage (CCUS)

#### Role in Chinese Steel Decarbonization:

- Bridge technology for facilities too new to retire (10-20 year asset life remaining)
- Particularly relevant in Shandong, Shanxi, and parts of Hebei
- Target: 30-50 Mt steel capacity with CCUS by 2030
- Capture 40-70 million tonnes CO<sub>2</sub> annually

#### Technology Status in China:

- China Baowu HyCROF: 20% CO<sub>2</sub> reduction demonstrated
- Xinjiang facility: 85,021 tonnes CO<sub>2</sub> reduction annually
- Limited full-scale blast furnace CCUS deployment globally
- China's geological storage capacity: 2.4 trillion tonnes CO<sub>2</sub>

#### Provincial CCUS Priorities:

1. **Shanxi:** Integrate with coal infrastructure, geological storage sites
2. **Shandong:** Offshore storage potential in Bohai Bay
3. **Hebei:** Selective deployment on newest BF facilities
4. **Inner Mongolia:** Enhanced oil recovery applications

#### Cost and Feasibility:

- Retrofit cost: \$200-400 per tonne capacity
- Operational cost: \$40-80 per tonne CO<sub>2</sub> captured
- Energy penalty: 10-15% additional energy consumption
- Storage infrastructure: \$10-20 billion national investment needed

#### 1.5:1 Policy Integration:

- CCUS retrofits may qualify for on-site upgrade provisions (1:1 ratio)
- Extends economic life of facilities scheduled for retirement
- Reduces net capacity reduction requirements in some provinces
- Transitional pathway to full hydrogen conversion post-2035

# 11 Timeline and Implementation Roadmap

## 11.1 Phase 1: Foundation (2025-2027)

### Policy Framework:

- Q1 2025: Finalize 1.5:1 policy implementation guidelines
- Q2 2025: Establish verification and monitoring systems
- Q3 2025: Launch pilot programs in Hebei, Jiangsu, Liaoning
- 2025-2026: First wave capacity retirements (30-40 Mt)
- 2026: CBAM full implementation drives urgency
- 2027: Mid-term policy review and adjustments

### Technology Deployment:

- Scale HBIS Zhangjiakou from 1.2 Mt to 3-5 Mt
- Scale Ansteel Bayuquan from 10,000 t to 100,000-500,000 t
- First commercial H2-DRI facilities (1.5-2 Mt) operational
- 20-30 Mt new EAF capacity commissioned
- Initial CCUS retrofits on 5-10 facilities

### Provincial Targets:

- Hebei: 15 Mt net capacity reduction
- Jiangsu: 8 Mt net reduction (primarily BF-to-EAF conversion)
- Liaoning: 3 Mt net reduction with H2-DRI substitution
- Shandong: 5 Mt net reduction with technology upgrades

## 11.2 Phase 2: Acceleration (2027-2030)

### Scaled Deployment:

- 40-60 Mt H2-DRI capacity operational across 4-5 provinces
- 100-120 Mt additional EAF capacity (total 200-270 Mt national)
- 30-50 Mt BF capacity with CCUS retrofit
- Total capacity reduction: 138-160 Mt from 2025 baseline

### Provincial Milestones:

- Hebei: 50 Mt cumulative net reduction (20% of provincial capacity)
- Jiangsu: 25 Mt cumulative reduction; 35-40% EAF share

- Shandong: 15 Mt cumulative reduction; advanced CCUS deployment
- Liaoning: 10 Mt cumulative reduction; 25-30% H2-DRI share

**Infrastructure Development:**

- Green hydrogen production: 4-6 million tonnes annually
- Renewable electricity: 200-300 TWh dedicated to steel sector
- CO<sub>2</sub> pipeline network: 2,000-3,000 km in key regions
- Scrap processing capacity: 320-350 Mt annually

**Market Development:**

- Green steel certification standards established
- Domestic carbon price: RMB 80-120 per tonne CO<sub>2</sub>
- Green steel premium market: 50-100 Mt capacity
- CBAM compliance achieved for EU export products

### 11.3 Phase 3: Transformation (2030-2040)

**Long-term Trajectory:**

- National capacity stabilizes at 850-900 Mt
- H2-DRI share: 30-40% (270-360 Mt)
- EAF share: 40-50% (360-450 Mt)
- BF-BOF with CCUS: 15-20% (135-180 Mt)
- Remaining conventional BF: <5% (phase-out by 2040)

**Provincial Leadership Models:**

- **Liaoning:** 60-70% H2-DRI, technology export hub
- **Jiangsu:** 70-80% EAF, green steel premium leader
- **Hebei:** Balanced portfolio, 50% emissions reduction vs 2025
- **Guangdong:** 75-85% EAF, southern China model

### 11.4 Phase 4: Carbon Neutrality (2040-2060)

**Final Transformation:**

- Near-complete elimination of conventional BF-BOF
- Green hydrogen dominance in DRI operations
- Renewable electricity at 90-95% of EAF power
- Residual emissions offset through carbon removal
- Carbon intensity: 0.2-0.3 tonnes CO<sub>2</sub> per tonne steel
- Achievement of 2060 carbon neutrality commitment



## 12 Monitoring, Verification, and Governance

### 12.1 Capacity Retirement Verification System

#### Physical Verification Requirements:

- Photographic and video documentation of decommissioning
- Third-party engineering certification of equipment destruction
- GPS-tagged documentation of blast furnace demolition
- Removal of key components (tuyeres, hearths, casings)
- Site restoration and repurposing plans

#### Digital Monitoring Platform:

- Real-time production monitoring via energy consumption tracking
- Satellite imagery analysis for facility operations
- Emissions monitoring systems (CEMS) data integration
- Blockchain-based capacity registry (immutable records)
- AI-powered anomaly detection for unreported production

#### Penalties for Non-Compliance:

- Financial penalties: RMB 500-1,000 per tonne unreported capacity
- Suspension of new capacity approvals
- Exclusion from government procurement and subsidies
- Criminal liability for officials approving illegal capacity
- Public disclosure of violators

### 12.2 Environmental Performance Tracking

#### Key Performance Indicators (KPIs):

##### Reporting Requirements:

- Quarterly production and emissions reports by facility
- Annual third-party sustainability audits for producers >5 Mt
- Environmental Product Declarations for all major grades
- Lifecycle assessment (LCA) data submission
- Public disclosure of scope 1, 2, and 3 emissions

Table 9: National and Provincial Decarbonization KPIs

Indicator	2025 Baseline	2030 Target	2040 Target	2060 Target
Total Capacity (Mt)	1,050	900	850	800
Avg. CO <sub>2</sub> Intensity (t CO <sub>2</sub> /t steel)	2.0	1.5	0.8	0.2-0.3
H2-DRI Share (%)	2-3%	15-20%	35-40%	60-70%
EAF Share (%)	12-15%	30-35%	45-50%	40-45%
Ultra-Low Emissions Compliance (%)	60%	90%	100%	100%

## 12.3 Governance Structure

### National Level:

- **Ministry of Industry and Information Technology (MIIT):** Policy formulation and national coordination
- **National Development and Reform Commission (NDRC):** Investment planning and approval
- **Ministry of Ecology and Environment (MEE):** Environmental compliance and enforcement
- **National Energy Administration (NEA):** Hydrogen and renewable energy integration

### Provincial Level:

- Provincial Steel Industry Transformation Offices
- Provincial environmental protection bureaus
- Local economic development commissions
- Inter-agency coordination mechanisms

### Industry Participation:

- China Iron and Steel Association (CISA) technical committees
- Provincial steel industry associations
- Technology working groups by pathway (H2-DRI, EAF, CCUS)
- Sustainability reporting consortium

## 13 Case Studies: Provincial Implementation Models

### 13.1 Case Study 1: Hebei Province - Aggressive Transformation

#### Starting Position (2025):

- Capacity: 250 Mt (24% of national total)
- Emissions: 500-550 Mt CO<sub>2</sub> annually
- Technology mix: 92% BF-BOF, 8% EAF
- Major producers: HBIS, Jingye, Shougang facilities
- GDP dependency: 15-20% from steel sector

#### 2030 Targets:

- Net capacity reduction: 50 Mt (to 200 Mt)
- Emissions reduction: 120-140 Mt CO<sub>2</sub> (25% reduction)
- Technology mix: 60% BF-BOF, 25% H2-DRI, 15% EAF
- Investment: RMB 200-300 billion

#### Implementation Strategy:

1. **Year 1-2 (2025-2026):** Retire 75 Mt oldest BF capacity
2. **Year 2-3 (2026-2027):** Commission 15 Mt H2-DRI, 10 Mt EAF (total 25 Mt new)
3. **Year 3-5 (2027-2030):** Scale H2-DRI to 50 Mt, EAF to 30 Mt
4. **Ongoing:** CCUS retrofit on 30 Mt newest BF capacity

#### Specific Projects:

- HBIS Zhangjiakou: Scale from 1.2 Mt to 10 Mt by 2028
- Jingye modernization: 5 Mt BF retirement, 3 Mt H2-DRI replacement
- Tangshan region consolidation: 8 producers merged into 3 groups
- Shijiazhuang relocation: Urban facilities moved to coastal areas

#### Social Support Programs:

- Retraining for 150,000 workers (hydrogen tech, EAF operations, renewables)
- Early retirement packages for 50,000 workers aged 55+
- Economic diversification: RMB 50 billion in alternative industry development
- Unemployment insurance extensions and job placement services

#### Expected Outcomes:

- Air quality improvement: 30-40% reduction in PM2.5 in steel cities
- Green steel production: 40-50 Mt low-carbon certified by 2030
- Technology leadership: Model for other BF-dominated provinces
- GDP transition: Steel share reduced to 12-14% through diversification

## 13.2 Case Study 2: Jiangsu Province - EAF Excellence

### Starting Position (2025):

- Capacity: 120 Mt (11-12% of national total)
- Emissions: 240-260 Mt CO<sub>2</sub> annually
- Technology mix: 82% BF-BOF, 18% EAF
- Major producer: Shagang Group (dominant position)
- Advantages: Grid infrastructure, scrap availability, coastal access

### 2030 Targets:

- Net capacity reduction: 25 Mt (to 95 Mt)
- Emissions reduction: 60-70 Mt CO<sub>2</sub> (26% reduction)
- Technology mix: 55% EAF, 30% BF-BOF, 15% H2-DRI
- Investment: RMB 100-150 billion

### Implementation Strategy:

1. **Scrap Infrastructure:** Develop integrated collection network for 50-60 Mt annually
2. **EAF Expansion:** Commission 40 Mt new EAF capacity (2025-2030)
3. **BF Retirement:** Eliminate 65 Mt conventional BF capacity
4. **Grid Integration:** Secure 80-100 TWh renewable electricity contracts

### Shagang Group Leadership:

- Target: 70% EAF share by 2030 (from 20% in 2025)
- Investment: RMB 40-60 billion in EAF and scrap processing
- Technology: Advanced ultra-high power EAF with 90% renewable electricity
- Market positioning: Premium green steel for automotive and appliances
- EPD certification: All major product lines by 2027

### Regional Integration:

- Shanghai-Jiangsu steel cluster coordination
- Scrap imports through Shanghai, Nanjing, Zhangjiagang ports
- Offshore wind power purchase agreements (Jiangsu coast)
- Joint ventures with automotive OEMs for closed-loop recycling

### Expected Outcomes:

- Lowest carbon intensity among major steel provinces: 1.0-1.2 t CO<sub>2</sub>/t steel
- Green steel premium capture: \$50-80 per tonne on 40-50 Mt production
- Model for coastal, developed regions with strong circular economy
- Economic benefits from premium products offsetting capacity reduction

### 13.3 Case Study 3: Liaoning Province - Hydrogen Hub

#### Starting Position (2025):

- Capacity: 65 Mt (6-7% of national total)
- Emissions: 130-145 Mt CO<sub>2</sub> annually
- Technology mix: 90% BF-BOF, 10% EAF
- Major producer: Ansteel Group (dominates provincial production)
- Key advantage: Lowest LCOS for green steel in China

#### 2030 Targets:

- Net capacity reduction: 10 Mt (to 55 Mt)
- Emissions reduction: 25-35 Mt CO<sub>2</sub> (20-24% reduction)
- Technology mix: 35% H<sub>2</sub>-DRI, 50% BF-BOF, 15% EAF
- Investment: RMB 60-80 billion
- Strategic role: National hydrogen steel technology demonstrator

#### Implementation Strategy - Ansteel Leadership:

1. **2025-2026:** Scale Bayuquan from 10,000 t to 500,000 t green H<sub>2</sub>-DRI
2. **2026-2028:** Deploy 3-5 commercial facilities at 1.5-2 Mt each (total 5-8 Mt)
3. **2028-2030:** Scale to 20 Mt H<sub>2</sub>-DRI capacity provincial total
4. **Technology licensing:** Export proven technology to Hebei, Shandong, others

#### Hydrogen Infrastructure:

- Green hydrogen production: 1.5-2 million tonnes annually by 2030
- Renewable capacity: 15-20 GW wind/solar dedicated to hydrogen
- Electrolyzer capacity: 3-4 GW installed
- Pipeline network: 500-800 km connecting steel plants to H<sub>2</sub> production
- Integration with port facilities for potential hydrogen exports

#### Technology Development Center:

- National Hydrogen Metallurgy Research Institute (Anshan)
- Workforce training programs: 20,000 technicians by 2030
- International partnerships: Technology licensing from European leaders
- Pilot testing facilities for next-generation H<sub>2</sub>-DRI processes

- Cost reduction target: \$400-500 per tonne steel production cost by 2030

**Expected Outcomes:**

- Technology leadership: Proven commercial H2-DRI pathway for China
- Cost competitiveness: Demonstrate viability at \$2-3/kg hydrogen cost
- Licensing revenue: Export technology and expertise to other provinces/countries
- Regional transformation: Model for Northeast China rust belt modernization
- National impact: Enable 50-80 Mt H2-DRI deployment nationally by 2035

## 14 Risk Analysis and Contingency Planning

### 14.1 Key Implementation Risks

#### 14.1.1 Risk 1: Hydrogen Cost and Availability

**Risk Description:**

- Green hydrogen costs remain at \$4-6/kg through 2030 (vs target \$1-2/kg)
- Renewable electricity capacity insufficient for electrolysis demand
- Electrolyzer manufacturing bottlenecks
- Hydrogen pipeline infrastructure delays

**Impact:**

- H2-DRI deployment limited to 20-30 Mt vs 50-80 Mt target
- Continued reliance on grey hydrogen (limited emissions benefit)
- Cost disadvantage of \$150-250 per tonne steel vs conventional BF
- Hebei and Liaoning transformation plans delayed 3-5 years

**Mitigation Strategies:**

- Phase 1: Grey/blue hydrogen from coke ovens with CCUS (achieves 40-50% reduction)
- Accelerate renewable capacity deployment with priority grid connections
- Import green hydrogen or ammonia from Australia, Middle East
- Government subsidies of RMB 1-2 per kg hydrogen to bridge cost gap
- Technology partnerships with global electrolyzer manufacturers

**Contingency Plan:**

- Shift emphasis to EAF expansion if H2 costs remain high
- Extend CCUS deployment on BF facilities
- Adjust 2030 targets: 30-40 Mt H2-DRI instead of 50-80 Mt
- Delay full decarbonization timeline by 5-7 years to 2067

### **14.1.2 Risk 2: Economic Downturn and Demand Collapse**

#### **Risk Description:**

- Chinese steel demand declines faster than expected (urbanization slowdown)
- Real estate sector contraction deepens
- Global recession reduces export opportunities
- Overcapacity crisis despite 1.5:1 policy

#### **Impact:**

- Steel prices collapse, threatening producer profitability
- Unable to fund \$150-200 billion transformation investments
- Accelerated bankruptcies of smaller producers
- Political pressure to maintain capacity and employment
- Policy implementation stalls or reverses

#### **Mitigation Strategies:**

- Flexible implementation timeline with economic circuit breakers
- Government financial support packages for viable producers
- Accelerate consolidation to improve industry structure
- Export promotion for green steel to premium international markets
- Strategic reserves or buyback programs to stabilize prices

#### **Contingency Plan:**

- Extend implementation timeline from 5 to 7-10 years
- Prioritize most efficient producers for transformation support
- Temporary suspension of aggressive capacity reduction targets
- Focus on technology readiness rather than immediate deployment

### **14.1.3 Risk 3: Social Instability and Employment Disruption**

#### **Risk Description:**

- 150,000-250,000 workers displaced faster than retraining programs absorb
- Single-industry cities (Tangshan, Anshan) face economic collapse
- Labor unrest and protests in Hebei, Liaoning
- Political backlash against environmental policies

**Impact:**

- Provincial governments resist capacity reduction targets
- Central government forced to slow implementation
- Social stability concerns override environmental goals
- Reputation damage for green transition policies

## &gt;Mitigation Strategies:

- Front-load just transition programs with 2-3 year lead time before layoffs
- Generous early retirement packages (85% salary for 55+ workers)
- Massive retraining: 100,000 workers for hydrogen/EAF operations
- Economic diversification investments: RMB 80-100 billion over 5 years
- Guaranteed employment in new facilities for qualified workers

**Contingency Plan:**

- Staged workforce reduction over 10 years instead of 5
- Temporary employment programs (infrastructure, environmental remediation)
- Enhanced unemployment benefits and social services
- Gradual plant closures with 18-24 month notice periods

**14.1.4 Risk 4: CBAM and Trade Tensions****Risk Description:**

- CBAM implementation stricter than anticipated
- Additional countries adopt similar border carbon adjustments
- Chinese exports face compound tariffs (\$100-200/tonne)
- WTO challenges create legal uncertainty
- Retaliatory trade measures

**Impact:**

- Chinese steel exports decline 30-50%
- Loss of \$20-40 billion annual export revenue
- Domestic overcapacity crisis intensifies
- Pressure to accelerate domestic decarbonization or face market loss

**Mitigation Strategies:**



- Accelerate EPD certification for all export-grade products
- Develop premium green steel product lines specifically for CBAM markets
- Diplomatic engagement on CBAM design and Chinese producer treatment
- Pivot to domestic high-value markets (automotive, appliances, construction)
- Explore green steel exports to non-CBAM markets (ASEAN, Africa, Latin America)

#### Contingency Plan:

- Accept reduced export volumes, focus on domestic market
- Accelerate capacity reduction beyond 1.5:1 targets if exports collapse
- Technology leapfrogging to achieve CBAM compliance faster
- Joint ventures with EU producers for market access

## 14.2 Success Probability Assessment

Table 10: 1.5:1 Policy Implementation Success Scenarios

Scenario	Description and Probability
<b>Optimal Success</b> (20% probability)	Full implementation by 2030: 138 Mt net reduction, 50-80 Mt H2-DRI, 200-250 Mt EAF, 25% national emissions reduction. Requires: hydrogen costs <\$2/kg, strong economy, effective just transition, CBAM compliance achieved.
<b>Moderate Success</b> (50% probability)	Partial implementation by 2030: 100-120 Mt net reduction, 30-40 Mt H2-DRI, 180-200 Mt EAF, 18-20% emissions reduction. Timeline extends to 2032-2033 for full targets. Some provinces (Jiangsu, Guangdong) exceed goals; others (Hebei) lag.
<b>Limited Success</b> (25% probability)	Slow implementation: 60-80 Mt net reduction by 2030, primarily through EAF (150-170 Mt) with minimal H2-DRI (10-20 Mt). 12-15% emissions reduction. Major delays in Hebei, Liaoning. Full goals pushed to 2035-2040.
<b>Implementation Failure</b> (5% probability)	Policy largely ineffective: <50 Mt net reduction, continued overcapacity, minimal technology transformation. Caused by: severe economic crisis, social instability, policy reversal, or combination. Emissions reduction <10%.

## 15 Conclusions and Strategic Recommendations

### 15.1 Key Findings

#### 1. Geographic Concentration Creates Policy Leverage:

- Top 4 provinces (Hebei, Jiangsu, Shandong, Liaoning) account for 45-50% of national production
- Focused implementation in these provinces yields 70%+ of national emissions reductions
- Provincial diversity enables multiple technology pathways to be demonstrated simultaneously

## **2. 1.5:1 Policy Drives Structural Transformation:**

- Net capacity reduction of 138 Mt (14%) achievable by 2030
- Forces technology upgrade rather than simple capacity replacement
- Creates economic incentive for consolidation and modernization
- Aligns with carbon neutrality 2060 trajectory requirements

## **3. Technology Readiness Varies Significantly:**

- EAF expansion: Proven technology, limited by scrap availability
- Hydrogen DRI: Demonstrated at pilot scale, requires massive scaling
- CCUS: Bridge technology, never proven at BF scale commercially
- Success depends on parallel infrastructure development (H<sub>2</sub>, renewables, CO<sub>2</sub> storage)

## **4. Provincial Priorities Must Reflect Local Conditions:**

- **Hebei:** Aggressive capacity reduction due to environmental pressure, H<sub>2</sub>-DRI and CCUS mix
- **Jiangsu:** EAF transformation leader, leverage grid and scrap advantages
- **Liaoning:** Hydrogen technology hub, lowest LCOS enables demonstration
- **Shandong:** Balanced approach, recent investments require on-site upgrades

## **5. Implementation Faces Significant Challenges:**

- \$150-200 billion capital requirement over 5-6 years
- 150,000-250,000 worker displacement requiring just transition programs
- Hydrogen infrastructure underdeveloped relative to 2030 needs
- Provincial GDP and employment pressures create resistance
- CBAM compliance adds urgency but also complexity

## 15.2 Strategic Recommendations for Prof. Miani's Course

### For Academic Analysis:

1. **Comparative framework:** China's 1.5:1 policy represents unique approach globally—capacity reduction linked to technology transformation, unlike market-based EU or voluntary US approaches
2. **Provincial case studies:** Use Hebei, Jiangsu, Liaoning as three distinct models (aggressive reduction, EAF transition, H2 demonstration) for comparative policy analysis
3. **Technology pathway assessment:** Evaluate relative cost, timeline, and feasibility of H2-DRI vs EAF vs CCUS for different provincial contexts
4. **Just transition analysis:** Chinese steel workforce displacement may be largest industrial transition in history—examine social support mechanisms and effectiveness

### For Policy Evaluation:

1. **Effectiveness metrics:** Monitor 2025-2027 implementation to assess whether 1.5:1 achieves stated goals or faces same loopholes as previous policies
2. **Provincial variation:** Track whether environmental pressure provinces (Hebei) or economically advanced provinces (Jiangsu) achieve faster progress
3. **Technology scaling:** Assess whether Chinese H2-DRI demonstrations successfully transition to commercial scale, providing model for global industry
4. **International implications:** Analyze how Chinese transformation affects global steel markets, CBAM effectiveness, and decarbonization pathways elsewhere

### For Industry Practitioners:

1. **Investment priorities:** Understand where \$150-200 billion will flow—opportunities in electrolyzer manufacturing, EAF technology, scrap processing, renewable energy
2. **Technology partnerships:** Chinese scale-up of H2-DRI and EAF creates opportunities for international equipment suppliers and technology licensors
3. **Supply chain implications:** Transformation affects iron ore demand (decreases), scrap demand (increases), hydrogen demand (new market), renewable electricity (massive increase)
4. **Market positioning:** Early movers in green steel certification and premium markets will capture value; laggards face CBAM penalties and market loss

## 15.3 Critical Success Factors

**The 1.5:1 policy will succeed if:**

1. **Political commitment sustained:** Central government maintains pressure despite provincial resistance and economic challenges
2. **Financing mechanisms effective:** \$150-200 billion mobilized through combination of state support, enterprise resources, and green finance
3. **Hydrogen costs decline:** Green hydrogen reaches \$2-3/kg by 2028-2030, enabling commercial H2-DRI viability
4. **Just transition programs robust:** Worker displacement managed without social instability through comprehensive retraining and support
5. **Technology demonstrations scale:** HBIS Zhangjiakou and Ansteel Bayuquan successfully transition from pilot to commercial operations
6. **Market mechanisms aligned:** Domestic carbon pricing, green steel premiums, and CBAM compliance create economic incentives for transformation

**The policy will face significant challenges if:**

1. Economic downturn reduces steel demand and producer profitability
2. Hydrogen infrastructure development lags targets by 3-5 years
3. Provincial governments prioritize GDP and employment over environmental goals
4. Social instability emerges in steel-dependent cities
5. International trade tensions intensify, reducing export opportunities

## 15.4 Outlook and Final Assessment

China's 1.5:1 capacity replacement policy represents the most ambitious steel sector decarbonization effort globally. With 54% of world steel production, Chinese policy choices will determine whether the global industry can achieve Paris Agreement targets.

**Probable Outcome (2025-2030):**

- Net capacity reduction: 100-120 Mt (moderate success scenario)
- Technology deployment: 30-40 Mt H2-DRI, 180-200 Mt EAF, 30-40 Mt CCUS
- Emissions reduction: 18-22% versus 2025 baseline
- Timeline extension: Full targets achieved by 2032-2033 rather than 2030
- Provincial variation: Jiangsu and Guangdong exceed targets; Hebei and Shandong achieve 70-80% of goals

**Geographic Effectiveness Ranking:**

1. **Jiangsu (Highest):** EAF transition most effective given scrap availability, grid infrastructure, economic capacity, and coastal advantages

2. **Liaoning (High):** Hydrogen demonstration success enables technology scaling, but smaller absolute capacity limits national impact
3. **Guangdong (High):** Southern model with EAF focus, premium markets, and advanced manufacturing integration
4. **Shandong (Moderate):** Balanced approach slowed by recent capital investments, but achieves meaningful progress
5. **Hebei (Moderate-Low):** Critical for national goals but faces greatest challenges—scale, GDP dependency, workforce displacement, coordination complexity
6. **Shanxi and others (Low-Moderate):** Slower transformation due to coal dependency, limited infrastructure, economic constraints

**National Impact:** By 2030, China’s 1.5:1 policy will likely achieve 12-20% emissions reduction in the steel sector, positioning the country ahead of most global competitors but still requiring sustained effort through 2060 to achieve carbon neutrality. The policy’s success in Hebei Province—accounting for 21-24% of national production—will ultimately determine whether China meets its overall decarbonization commitments.

**Global Significance:** If successful, China’s transformation will:

- Validate hydrogen DRI at unprecedented commercial scale
- Demonstrate that large-scale steel decarbonization is technically and economically feasible
- Create supply chain and technology export opportunities
- Pressure other major producers (India, Japan, South Korea, US, EU) to accelerate their own transitions
- Establish Chinese producers as leaders in green steel certification and premium markets
- Prove or disprove viability of centralized, government-directed industrial transformation versus market-based approaches

The next 3-5 years (2025-2030) will be decisive. Monitoring provincial implementation, technology demonstration results, and economic/social impacts will provide critical insights for global steel decarbonization policy.

## 16 Appendix A: Provincial Steel Production Data

## 17 Appendix B: Technology Cost Comparisons

### Key Observations:

- EAF currently cost-competitive with BF-BOF where scrap available
- H2-DRI requires \$90-180/tonne premium at current hydrogen costs
- Liaoning’s LCOS advantage: \$50-100/tonne lower than national average for H2-DRI

Table 11: Detailed Provincial Production and Capacity Data (2024)

Province	Capacity (Mt)	2024 Production (Mt)	Capacity Utilization	Major Cities
Hebei	250-260	225-230	88-90%	Tangshan, Shijiazhuang
Jiangsu	125-130	119-121	92-95%	Zhangjiagang, Nanjing
Shandong	82-85	76-80	90-92%	Rizhao, Ji'nan
Liaoning	68-70	60-65	88-93%	Anshan, Benxi
Shanxi	52-55	45-50	87-91%	Taiyuan, Linfen
Guangdong	40-42	35-40	88-95%	Zhanjiang, Shaoguan
Hubei	25-28	20-25	80-89%	Wuhan
Inner Mongolia	22-25	18-22	82-88%	Baotou
Fujian	18-20	15-18	83-90%	Sanming
Sichuan	18-20	14-18	78-90%	Chengdu
Others	180-200	150-180	83-90%	Various
<b>National Total</b>	<b>1,050-1,100</b>	<b>1,005</b>	<b>88-92%</b>	-

- Hydrogen cost reduction to \$1.5/kg makes H2-DRI competitive with conventional production
- CCUS adds \$110-110/tonne premium, less than H2-DRI but inferior long-term solution

## 18 Appendix C: Emissions Calculation Methodology

### Provincial Emissions Estimates:

Emissions calculated using:

$$E_{province} = \sum_i (P_i \times I_i) \quad (1)$$

Where:

- $E_{province}$  = Total provincial emissions (Mt CO<sub>2</sub>)
- $P_i$  = Production by technology route  $i$  (Mt steel)
- $I_i$  = Emission intensity of technology route  $i$  (t CO<sub>2</sub>/t steel)

### Technology Route Intensities Used:

- BF-BOF: 2.2 tonnes CO<sub>2</sub> per tonne steel (Chinese average, slightly below global 2.33)
- EAF (grid average): 0.4 tonnes CO<sub>2</sub> per tonne steel

Table 12: Levelized Cost of Steel Production by Technology and Province

Technology/Province	Capital Cost (\$/tonne)	Operating Cost (\$/tonne)	Total LCOS (\$/tonne)
<i>Conventional BF-BOF (baseline)</i>			
National Average	150-200	400-450	550-650
<i>Scrap-based EAF</i>			
Jiangsu	40-60	380-420	420-480
Guangdong	45-65	390-430	435-495
Hebei	50-70	410-450	460-520
<i>H2-DRI-EAF (green hydrogen at \$3/kg)</i>			
Liaoning	120-150	520-580	640-730
Hebei	130-160	560-620	690-780
Shandong	135-165	580-640	715-805
National Average	140-170	600-660	740-830
<i>BF-BOF with CCUS</i>			
National Average	180-220	480-540	660-760
<i>H2-DRI-EAF (green hydrogen at \$1.5/kg, 2030 target)</i>			
Liaoning	100-130	420-480	520-610
National Average	120-150	460-520	580-670

- EAF (renewable): 0.1 tonnes CO<sub>2</sub> per tonne steel
- H2-DRI-EAF (grey H2): 1.2 tonnes CO<sub>2</sub> per tonne steel
- H2-DRI-EAF (green H2): 0.05-0.1 tonnes CO<sub>2</sub> per tonne steel
- BF-BOF with CCUS (90% capture): 0.3-0.5 tonnes CO<sub>2</sub> per tonne steel

#### Example Calculation - Hebei Province 2030:

Current (2025):

- BF-BOF:  $230 \text{ Mt} \times 2.2 = 506 \text{ Mt CO}_2$
- EAF:  $20 \text{ Mt} \times 0.4 = 8 \text{ Mt CO}_2$
- **Total: 514 Mt CO<sub>2</sub>**

Target (2030):

- BF-BOF:  $90 \text{ Mt} \times 2.2 = 198 \text{ Mt CO}_2$
- BF-BOF with CCUS:  $30 \text{ Mt} \times 0.4 = 12 \text{ Mt CO}_2$
- H2-DRI (grey/green mix):  $50 \text{ Mt} \times 0.6 = 30 \text{ Mt CO}_2$
- EAF:  $30 \text{ Mt} \times 0.3 = 9 \text{ Mt CO}_2$
- **Total: 249 Mt CO<sub>2</sub>**
- **Reduction: 265 Mt CO<sub>2</sub> (52%)**

Note: These are illustrative calculations. Actual emissions depend on technology mix, energy sources, and operational efficiency.

## 19 Appendix D: Key Chinese Steel Industry Terms and Organizations

### Government Bodies:

**MIIT** Ministry of Industry and Information Technology—primary industrial policy authority

**NDRC** National Development and Reform Commission—investment planning and macroeconomic management

**MEE** Ministry of Ecology and Environment—environmental regulation and enforcement

**NEA** National Energy Administration—energy policy and infrastructure

### Industry Organizations:

**CISA** China Iron and Steel Association—industry association representing major producers

**Global Low-Carbon Metallurgical Innovation Alliance** Baowu-led consortium with 60+ members from 15 countries

### Policy Terms:

**1.5:1 Capacity Replacement** Requirement to retire 1.5 tonnes old capacity per 1 tonne new capacity added

**Ultra-Low Emissions** Stringent standards for particulate matter, SO<sub>2</sub>, NO<sub>x</sub> emissions from steel facilities

**14th Five-Year Plan** National development plan covering 2021-2025

**Environmental Product Declaration (EPD)** Standardized disclosure of product environmental impacts per ISO 14025

### Technology Terms:

**HyCROF** Hydrogen-enriched Carbonic Oxide Recycling Oxygenate Furnace—Baowu's hydrogen injection technology

**COURSE50** Nippon Steel's carbon capture and hydrogen injection program (referenced as comparison)

**DRI** Direct Reduced Iron—iron produced by gas-based reduction without melting

**HBI** Hot Briquetted Iron—compacted form of DRI

**EAF** Electric Arc Furnace—steelmaking using electric arcs to melt scrap or DRI

**BF-BOF** Blast Furnace - Basic Oxygen Furnace—conventional integrated steelmaking route

### Geographic Terms:



**Jing-Jin-Ji** Beijing-Tianjin-Hebei integrated region—key air quality control area

**Yangtze River Delta** Economic region including Shanghai, Jiangsu, Zhejiang—advanced manufacturing hub

**Pearl River Delta** Guangdong economic region—southern China’s industrial center

**Northeast China** Liaoning, Jilin, Heilongjiang—traditional heavy industry base, "rust belt"

## 20 Appendix E: Further Reading and Resources

### Academic and Research Reports:

- University of Oxford Institute for Energy Studies: *Decarbonising Steel Production in China: Progress, Challenges and Opportunities* (2024)
- Global Efficiency Intelligence: *Steel Climate Impact—International Benchmarking* (2022)
- Carbon Brief: *Steel Industry Makes ‘Pivotal’ Shift Towards Lower-Carbon Production* (2023)

### Industry Data Sources:

- World Steel Association: Annual statistics and sustainability indicators
- China Iron and Steel Association (CISA): Chinese steel industry data
- GMK Center: Global steel producer rankings and analysis
- Mysteel: Chinese steel market data and analysis

### Policy Documents:

- China’s 14th Five-Year Plan for Industrial Development
- Action Plan for Carbon Dioxide Peaking Before 2030
- Guidance on Promoting High-Quality Development of the Steel Industry (MIIT)
- Draft Measures for Steel Capacity Replacement (October 2025)

### Company Sustainability Reports:

- China Baowu Steel Group Sustainability Report (annual)
- HBIS Group Low-Carbon Development Report
- Ansteel Group Environmental and Social Responsibility Report
- Shagang Group Corporate Social Responsibility Report

### Technology References:

- World Steel Association: Steel’s Contribution to a Low Carbon Future—Position Paper (2021)
- International Energy Agency: Iron and Steel Technology Roadmap
- ResponsibleSteel: Certification standards and certified facilities database
- Global Steel Climate Council: Science-Based Target methodology

## 21 Appendix F: Maps and Visualizations (Descriptions)

*Note: Actual maps would be included in a full publication. Descriptions provided for LaTeX document:*

### Map 1: Provincial Steel Production Intensity

- Heat map of China showing steel production by province
- Color intensity: Hebei (darkest), Jiangsu, Shandong, Liaoning (dark), others (lighter)
- Major production cities marked: Tangshan, Shijiazhuang, Anshan, Zhangjiagang, Rizhao
- Overlay: Air quality zones and pollution control regions

### Map 2: Hydrogen Infrastructure Development Plan

- Renewable energy zones: Inner Mongolia (wind), Northwest China (solar)
- Planned hydrogen pipelines connecting to Hebei, Liaoning, Shandong steel regions
- Existing and planned hydrogen production facilities
- Major steel plants marked with technology pathway icons (H2-DRI, EAF, CCUS)

### Map 3: LCOS by Province for Green Steel

- Provincial ranking by levelized cost of steel production
- Liaoning (lowest), Jiangsu, Guangdong (low), Hebei, Shandong (moderate)
- Factors overlay: renewable resources, grid infrastructure, scrap availability

### Chart 1: Technology Deployment Timeline

- Stacked area chart 2025-2060
- Technology routes: BF-BOF (declining), H2-DRI (increasing), EAF (increasing), CCUS (temporary increase then decline)
- Provincial breakdowns for top 4 provinces

### Chart 2: Emissions Trajectory by Province

- Line graph showing emissions path 2025-2060
- Separate lines for Hebei, Jiangsu, Shandong, Liaoning, others
- Target trajectory line for national carbon neutrality by 2060
- Milestone markers: 2030 targets, 2040 checkpoints, 2060 neutrality

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- World Steel Association global production and sustainability data
- University of Oxford Institute for Energy Studies research on Chinese steel decarbonization
- China Iron and Steel Association industry statistics
- Individual company sustainability reports and environmental disclosures
- Chinese government policy documents and implementation guidelines
- International Energy Agency steel sector analysis
- Academic research on levelized cost of steel production and technology pathways

The author acknowledges the complexity of Chinese steel industry data collection, with variations across sources due to reporting methodologies, consolidation treatments, and data availability. This analysis represents a comprehensive synthesis of publicly available information as of November 2025.

Special recognition to the pioneering decarbonization efforts of Chinese steel producers including China Baowu, HBIS Group, Ansteel Group, and Jiangsu Shagang Group, whose demonstration projects and transparency in environmental reporting enable academic analysis of this critical industrial transformation.

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