India's Steel Sector Decarbonization: A Journey Towards Net-Zero by 2070

MIFUS Course - Steel Decarbonization Policies Worldwide
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November 22, 2025

Abstract

India, as the world's second-largest steel producer with approximately 135-154 million tonnes of crude steel capacity, faces significant challenges in decarbonizing its steel sector. The sector accounts for 10-12% of India's total carbon emissions and is projected to triple production by 2050. This document provides a comprehensive overview of India's national steel decarbonization policies, technological pathways, and state-level initiatives towards achieving net-zero emissions by 2070.

Contents

1 Introduction to India's Steel Industry

1.1 Production Landscape

India's steel industry represents a cornerstone of national economic development:

- **Global Position:** Second-largest crude steel producer globally
- **Current Capacity:** 154-179.5 million tonnes per annum (FY 2023-24)
- **Growth Rate:** 12% CAGR in crude steel production, 14% in finished steel consumption
- **2030 Target:** 300 million tonnes production capacity
- **Employment:** Over 2.5 million people directly employed
- **GDP Contribution:** Approximately 2% of national GDP

1.2 Current Emissions Profile

- **Total Annual Emissions:** Approximately 240 million tonnes CO_2 (2023)
- **Emission Intensity:** 2.64 tonnes CO_2 per tonne crude steel (2020)
- **Target Intensity:** 2.4 tonnes CO_2 per tonne crude steel by 2030
- **Projected Growth:** Emissions expected to double by 2030 without intervention
- **Share of National Emissions:** 10-12% of India's total CO_2 emissions

1.3 Production Technology Mix

India's steel production is characterized by unique technological diversity:

Production Route	Capacity Share	Key Characteristics
Blast Furnace - BOF	45-50%	Most carbon-intensive
Coal-based DRI-EAF	40-45%	Unique to India, uses domestic coal
Scrap-based EAF	30%	Lower emissions, scrap-dependent
Induction Furnaces	Secondary	Wide distribution

Table 1: Steel Production Routes in India

Note: India's heavy reliance on coal-based DRI (Direct Reduced Iron) due to abundant domestic coal reserves distinguishes it from other major steel producers and presents unique decarbonization challenges.

2 National Policy Framework

2.1 Key Policy Initiatives

2.1.1 Green Steel Taxonomy (2024)

India officially notified the Green Steel Taxonomy in 2024:

- **Definition:** Steel produced without using fossil fuels in the production process
- **Low-Carbon Steel:** Technologies that reduce but don't eliminate fossil fuel use
- **Rating System:** National Institute of Secondary Steel Technology (NISST) assigns ratings
- **Certification:** Bureau of Energy Efficiency (BEE) maintains state register
- **Procurement Priority:** Green steel prioritized under Green Government Procurement Policy

2.1.2 Greening the Steel Sector: Roadmap and Action Plan

Published by the Ministry of Steel, this comprehensive framework outlines:

- Technology-neutral approach allowing multiple decarbonization pathways
- No single prescribed technology route (unlike EU or US approaches)
- Flexibility to adapt to regional resource availability
- Focus on both breakthrough and incremental technologies
- Timeline: Net-zero by 2070, aligned with national targets

2.1.3 Steel Scrap Recycling Policy (2019)

- Promotes circular economy in steel sector
- Framework for establishing metal scrapping centers
- Guidelines for scrap processing facilities
- End-of-Life Vehicle (ELV) scrapping guidelines
- Target: Increase domestic scrap availability for EAF route

2.1.4 Production-Linked Incentive (PLI) Schemes

PLI Scheme 1.0 (2021):

- Total outlay: 6,322 crore (approximately $760 million)
- Duration: 5 years
- Focus: Specialty steel manufacturing

- Phase 1 Results: 44 projects from 26 companies, 27,106 crore investment

PLI Scheme 1.1 (2025):

- Relaxed norms and lower investment thresholds
- Carry-forward provision for excess production
- Enhanced incentives for green steel technologies

2.1.5 National Green Hydrogen Mission (NGHM)

Announced by the Ministry of New and Renewable Energy:

- Target: Make green hydrogen cost-competitive
- Current Cost: $4.6-6.3 per kg (2024)
- Target Cost: $1 per kg for commercial viability in steel sector
- Steel Sector Integration: Industry made key stakeholder
- Potential Consumption: 1.1 million tonnes per year at target price
- Recent Policy Support: Eliminated transmission fees, reduced distribution tariffs and VAT

2.2 Regulatory Mechanisms

2.2.1 Perform, Achieve and Trade (PAT) Scheme

- Market-based energy efficiency mechanism
- Sets specific energy consumption reduction targets for steel plants
- Energy Savings Certificates (ESCerts) trading system
- Applicable to large energy-intensive steel facilities
- Ongoing cycles with progressively stringent targets

2.2.2 Task Forces for Decarbonization

Ministry of Steel established 13-14 Task Forces:

- Engagement with industry, academia, think tanks, S&T bodies
- Different levers of decarbonization explored
- Cross-ministerial collaboration
- Stakeholder participation from multiple sectors
- Recommendations for policy formulation

3 Decarbonization Pathways

3.1 Technology Options Overview

India's approach recognizes five primary decarbonization levers:

1. **Energy Efficiency (EE):** 9% emission reduction potential
2. **Renewable Electricity:** 19% emission reduction potential
3. **Alternative Fuels:** 6% emission reduction potential
4. **Carbon Management (CCUS):** 56% emission reduction potential
5. **Scrap-based Production:** Significant potential with infrastructure development

3.2 Detailed Technology Pathways

3.2.1 Green Hydrogen-based Steel

Description: Cleanest method, using green hydrogen as reducing agent

Current Status:

- Technology demonstrated but not commercially viable
- High cost of green hydrogen main barrier
- Several pilot projects initiated by major producers
- Expected to become dominant pathway for new capacity post-2030

Key Projects:

- Tata Steel: Green hydrogen initiatives in Jamshedpur
- JSW Steel: Hydrogen-ready infrastructure in Karnataka
- SAIL: Research on hydrogen injection in blast furnaces

3.2.2 Electric Arc Furnace (EAF) Expansion

Current Share: 30% of steelmaking capacity

Advantages:

- Can use 100% renewable electricity
- Lower capital cost than BF-BOF
- Flexible production scale
- Suitable for both scrap and DRI feedstock

Challenges:

- Limited high-quality scrap availability

- Current utilization: 74% (vs 84% for BF-BOF)
- Need for scrap collection infrastructure
- Competition for scrap resources

Pipeline: 33.54 million tonnes of new EAF capacity planned

3.2.3 Carbon Capture, Utilization and Storage (CCUS)

Potential: Can abate 56% of steel sector emissions

Status:

- Technology not commercially mature in India
- Current abatement cost: $50-60 per tonne CO_2
- Limited geological storage assessment
- Research on CO_2 utilization in downstream products
- Expected cost reduction through innovation and scale

Requirements:

- Development of CO_2 transport infrastructure
- Geological storage site identification and development
- Policy framework for CCUS deployment
- R&D funding for technology maturation

3.2.4 Renewable Energy Integration

Current Energy Consumption: 6-6.5 Gcal/tonne (higher than global best 4.5-5 Gcal/tonne)

Requirements:

- 5.9 GW of round-the-clock renewable capacity needed
- Integration of solar, wind, and energy storage
- Grid infrastructure upgrades
- Power purchase agreements for green power

State-level Support:

- Waiver of open access charges recommended
- Reduction in transmission charges at state level
- Banking facilities for renewable power
- Dedicated green power corridors

3.2.5 Alternative Fuels

Options:

- **Natural Gas:** Transition fuel, limited availability
- **Biomass Pellets:** Partial coal replacement, sustainability concerns
- **Biochar:** Under investigation
- **Waste-derived Fuels:** Circular economy approach

Limitations: Only 6% overall emission reduction achievable

3.3 Emission Reduction Trajectory

Achievable without Breakthrough Technologies (by implementing EE, RE, AF):

- 28% emission reduction
- Equivalent to 92 million tonnes CO_2
- Uses currently available technologies
- Positive or neutral abatement costs

Remaining 72% requires:

- CCUS at scale
- Green hydrogen deployment
- Complete technology transformation
- Substantial investment and policy support

4 Financial and Investment Landscape

4.1 Investment Requirements

- **Total Investment Needed:** $283 billion by 2070 (Ministry of Steel estimate)
- **Pipeline Capacity:** 195 million tonnes per annum awaiting financial closure (2023)
- **Transition Finance:** Critical for gradual decarbonization of existing assets

4.2 Financing Mechanisms

4.2.1 Green Bonds and Sustainability-Linked Bonds

Recent developments:

- JSW Steel: Raised significant capital through sustainability-linked bonds
- Ultratech: International market green financing
- Growing investor interest in low-carbon steel assets
- Demonstration of market appetite for green steel financing

4.2.2 Transition Finance

Emerging as critical financing category:

- Enables funding for transitional activities in hard-to-abate sectors
- Bridges gap until green technologies become viable
- Credible transition plans required for access
- Supports gradual decarbonization of existing BF-BOF plants
- Partial CCUS retrofits as transition finance candidates

4.2.3 Concessional Finance

- Access to international climate finance mechanisms
- Development bank lending for green steel projects
- Technology transfer agreements
- Multilateral funding opportunities

4.3 Policy Recommendations for Financing

- Green steel mandates in public procurement (government consumes 25 MT/year, projected 67-73 MT by 2030-31)
- Carbon border tariffs to level playing field
- Mandating renewable energy use in steel production
- Green financing options and incentives
- Technology-specific R&D grants
- Risk-sharing mechanisms for early-stage technologies

5 Challenges and Barriers

5.1 Technical Challenges

- **Green Hydrogen Cost:** Current cost 3-4x higher than target
- **CCUS Maturity:** Technology not commercially proven at required scale
- **Scrap Availability:** Limited high-quality scrap for EAF expansion
- **Energy Intensity:** Higher than international benchmarks
- **Technology Lock-in:** Large existing BF-BOF capacity with long lifespans
- **Limited Investment Cycles:** Only one full investment cycle available for deep decarbonization

5.2 Infrastructure Challenges

- **Renewable Power Grid:** Need for 5.9 GW RTC capacity
- **Hydrogen Infrastructure:** Production, storage, distribution networks required
- **CO_2 Transport:** Pipeline and sequestration infrastructure absent
- **Scrap Collection:** Informal sector dominance, lack of organized collection
- **Port Facilities:** Upgrades needed for increased steel exports

5.3 Economic and Market Challenges

- **High Production Costs:** Coal and power costs affecting competitiveness
- **Global Competition:** Imports affecting domestic market (25% increase in imports)
- **Export Decline:** 40% decrease in exports (April-August FY25)
- **Price Sensitivity:** Steel is highly commoditized product
- **Green Premium:** Limited willingness to pay for low-carbon steel

5.4 Policy and Regulatory Gaps

- **Comprehensive Roadmap:** Lack of binding, government-adopted sectoral roadmap
- **Carbon Pricing:** No effective price on carbon emissions
- **Standards Harmonization:** Need for alignment with global standards
- **R&D Funding:** Insufficient government and corporate investment
- **State-level Coordination:** Varying policies across major steel-producing states
- **Import Protection:** Mechanisms under discussion but not finalized

5.5 Data and Monitoring Challenges

- Complex supply chains
- Unreliable and fragmented emissions data
- Inadequate measurement infrastructure
- Shortage of skilled carbon management experts
- Inconsistent reporting methodologies (WSA methodology adoption ongoing)

State	Production (FY24) (Million Tonnes)	Share (%)	Key Players
Odisha	26-27	20.5%	Tata Steel, JSW, SAIL, AMNS
Jharkhand	18-20	15-16%	Tata Steel, SAIL (Bokaro), ESL
Chhattisgarh	18-19	13-15%	SAIL (Bhilai), JSPL
Karnataka	13-16	12-13%	JSW Steel (Vijayanagar)
Maharashtra	12-15	9-10%	JSW, Tata, Various ISPs
Gujarat	8-10	5-6%	Essar, Others
West Bengal	5-6	4-5%	SAIL (DSP), IISCO
Andhra Pradesh	4-5	3-4%	Rashtriya Ispat, New Projects

Table 2: State-wise Steel Production in India (FY 2024)

6 State-Level Production and Policies

6.1 Major Steel-Producing States

India's steel production is concentrated in resource-rich states:

Note: Odisha, Jharkhand, and Chhattisgarh together account for over 60% of India's total steel production.

6.2 State-Specific Initiatives

6.2.1 Odisha

- **Target:** 100 million tonnes capacity by 2030
- **Current Capacity:** 47 plants with 32.45 MMT installed capacity
- **Resource Base:** Abundant high-grade iron ore
- **Strategic Projects:** Multiple new plants under development
- **Focus:** Becoming India's primary steel hub

6.2.2 Chhattisgarh

- **Position:** Second-largest capacity, third-largest production
- **Growth Projection:** 50% increase to 27 MT by FY30
- **Key Asset:** Bhilai Steel Plant (SAIL)
- **Coal Resources:** SECL production: 187 MT in FY24, target 206 MT in FY25
- **Expansion:** BF, BOF, and EAF capacity all growing

6.2.3 Jharkhand

- **Legacy:** Historic steel center (Jamshedpur)
- **Major Units:** Tata Steel, SAIL Bokaro, ESL Steel

- **Capacity:** Approximately 17 MTPA from three major units
- **Innovation:** Green hydrogen pilots and R&D

6.2.4 Karnataka

- **Largest Plant:** JSW Vijayanagar Works (12 MTPA)
- **Technology Focus:** Advanced steel production methods
- **Renewable Energy:** Strong solar and wind potential
- **Green Steel:** Hydrogen-ready infrastructure development

7 International Context and Trade

7.1 Global Standards and Alignment

7.1.1 ResponsibleSteel Standard

- Two major Indian producers signed up: Tata Steel and JSW Steel
- International certification for green steel
- Framework for credible interoperability between standards
- Scrap variable recognition in classification

7.1.2 EU Carbon Border Adjustment Mechanism (CBAM)

Impact on Indian Steel:

- Estimated 4-6% cost increase from 2026
- Potential 49% cost increase by 2034 (as free allowances phase out)
- Driving improvements in emissions reporting
- Spurring engagement in global green steel discussions
- Catalyst for domestic carbon accounting improvements

7.2 Export and Import Dynamics

- **Export Markets:** UAE, Southeast Asia, others
- **Export Value:** Approximately $10 billion annually
- **Recent Trend:** 40% decline in exports (April-August FY25)
- **Import Increase:** 25% rise compared to previous year
- **Trade Balance:** India remains net importer of steel
- **Port States:** Gujarat and Andhra Pradesh key for coastal access

7.3 International Collaboration

- Global Low-Carbon Metallurgical Innovation Alliance (Baowu initiative)
- Technology transfer agreements with developed nations
- Participation in global steel climate forums
- Multilateral climate finance mechanisms
- Knowledge exchange programs
- Need for National Green Steel Think Tank

8 Future Outlook and Recommendations

8.1 Near-Term Actions (2025-2030)

1. **Define and Standardize:**
    - Implement Green Steel Taxonomy rigorously
    - Establish clear certification processes
    - Create transparent rating systems
2. **Enhance Energy Efficiency:**
    - Deploy Best Available Technologies (BAT)
    - Set progressive benchmarks with BEE
    - Achieve international energy consumption norms
3. **Expand Renewable Integration:**
    - Commission 5.9 GW RTC renewable capacity
    - Establish green power purchase frameworks
    - State-level open access charge waivers
4. **Formalize Scrap Sector:**
    - Implement Steel Scrap Recycling Policy fully
    - Establish organized collection networks
    - Enhance ELV scrapping infrastructure
5. **Pilot Breakthrough Technologies:**
    - Green hydrogen demonstration projects
    - CCUS pilot installations
    - Technology clusters for knowledge sharing

8.2 Medium-Term Actions (2030-2045)

1. **Scale Green Hydrogen:**
    - Achieve $1/kg target cost through policy support
    - Develop hydrogen production and distribution infrastructure
    - Deploy H2-DRI-EAF at commercial scale
2. **Expand EAF Capacity:**
    - Commission planned 33.54 MT new EAF capacity
    - Increase scrap-based steelmaking share
    - Enhance scrap quality and supply chains
3. **Deploy CCUS:**
    - Mature CCUS technology through R&D
    - Identify and develop CO_2 storage sites
    - Retrofit existing BF-BOF plants
    - Explore CO_2 utilization pathways
4. **Establish Carbon Pricing:**
    - Internal carbon pricing mechanisms
    - Domestic emissions trading system for steel
    - Alignment with international carbon markets
5. **Green Public Procurement:**
    - Mandate green steel targets (leveraging 25+ MT government consumption)
    - Premium pricing for certified green steel
    - Public infrastructure projects as anchor demand

8.3 Long-Term Actions (2045-2070)

1. **Technology Transformation:**
    - Phase out unabated fossil fuel use
    - Deploy emerging technologies (direct electrolysis, etc.)
    - Achieve complete renewable energy integration
2. **Circular Economy Maturity:**
    - Maximize scrap-based production
    - Closed-loop steel value chains
    - Zero-waste steel manufacturing
3. **Net-Zero Achievement:**
    - Offset remaining emissions through verified methods
    - Achieve 2070 net-zero target
    - Maintain competitiveness in global green steel market

8.4 Critical Success Factors

- **Policy Certainty:** Long-term, stable policy framework binding on industry
- **Finance Availability:** $283 billion investment mobilization
- **Technology Innovation:** Continued R&D investment and breakthrough development
- **Infrastructure Development:** Hydrogen, renewable power, CO_2 transport, and scrap collection
- **State-Central Coordination:** Harmonized policies across steel-producing states
- **Industry Commitment:** Voluntary targets backed by concrete action plans
- **International Engagement:** Technology transfer and standards alignment
- **Skilled Workforce:** Training in carbon management and new technologies
- **Data Infrastructure:** Robust emissions monitoring and reporting systems
- **Market Creation:** Demand signals for green steel through procurement and pricing

9 Conclusion

India's steel sector stands at a critical juncture. With production expected to reach 300 million tonnes by 2030 and potentially triple by 2050, decarbonization is essential not only for meeting climate commitments but also for maintaining competitiveness in an increasingly carbon-constrained global market.

The sector's transformation requires a balanced approach:

- **Pragmatic Deployment** of available technologies (energy efficiency, renewable energy, scrap utilization) to achieve near-term 28% emission reductions
- **Aggressive Innovation** in breakthrough technologies (green hydrogen, CCUS) for deep decarbonization
- **Strategic Investment** of $283 billion over four decades
- **Strong Policy Framework** providing certainty and incentives
- **Collaborative Approach** involving government, industry, finance, and international partners

India's unique position—with coal-based DRI dominance, abundant renewable resources, growing demand, and diverse technology options—provides both challenges and opportunities. Success will require coordination across India's major steel-producing states, each bringing distinct strengths and capabilities to the national decarbonization effort.

The goal of net-zero by 2070 is ambitious but achievable with sustained commitment, adequate financing, and rapid technology deployment. India's steel sector transformation will be pivotal not only for national climate goals but also for demonstrating viable pathways for steel decarbonization in developing economies worldwide.