Australia's Strategic Position in Global Steel Decarbonization: A Comprehensive Analysis of Technology Pathways, Policy Frameworks, and Competitive Advantages

Claude* Dickson Souza† Fabio Miani‡

November 2025

Abstract

The global steel industry faces an urgent imperative to decarbonize, contributing 7-9% of global CO_2 emissions while remaining essential for infrastructure, construction, and manufacturing. This paper examines Australia's strategic position in the transition toward low-carbon steel production, analyzing technology pathways, policy frameworks, and competitive advantages relative to major steel-producing nations. With 4.8 million tonnes of annual crude steel production and as the world's second-largest iron ore exporter (800+ million tonnes annually), Australia possesses distinctive opportunities: abundant renewable energy resources (solar, wind, hydrogen potential), world-class iron ore reserves, established industrial capabilities, and government commitment through the $1 billion Green Iron Investment Fund and comprehensive policy frameworks. Through detailed analysis of major initiatives including Liberty Steel's Whyalla transformation (EAF and H2-DRI), BlueScope's Port Kembla decarbonization pathways, the NeoSmelt electric smelting furnace pilot, and emerging green steel ventures, this study demonstrates Australia's potential to become a global leader in green iron and steel production despite significant challenges. However, realization requires sustained policy support, substantial capital investment ($10+ billion estimated), resolution of natural gas and hydrogen supply constraints, and navigation of competitive pressures from lower-cost producers. The analysis identifies critical success factors, addresses economic barriers including the need for carbon pricing above $100/tonne CO_2, and provides actionable recommendations for positioning Australia as a key player in the Asia-Pacific green steel market. This research contributes to the industrial decarbonization literature by examining the unique challenges facing a small-scale domestic producer with massive export-oriented upstream resources, providing insights applicable to resource-rich developed economies navigating energy transitions.

*AI Research Assistant, Anthropic PBC, San Francisco, CA, USA

†RHI Magnesita, Brasil

‡Corresponding author: fabio.miani@uniud.it, Department of Polytechnic Engineering and Architecture (DPIA), University of Udine, Italy

Keywords: Steel decarbonization, Australia, green hydrogen, direct reduced iron, electric arc furnace, renewable energy, iron ore, green steel policy, Asia-Pacific steel industry

Contents

1 Introduction

1.1 Global Context: The Steel Decarbonization Imperative

The steel industry stands at a critical crossroads in the global effort to mitigate climate change. As one of the foundational materials of modern civilizationessential to construction, transportation, machinery, and countless manufactured goodssteel production also represents one of the most significant industrial sources of greenhouse gas emissions. Global steel production reached 1,884.6 million tonnes in 2024, with associated CO_2 emissions of approximately 2.6 billion tonnes, representing 7-9% of total global emissions.

The conventional integrated steelmaking route, based on blast furnace-basic oxygen furnace (BF-BOF) technology, produces approximately 2.0 tonnes of CO_2 per tonne of crude steel. This carbon intensity derives from the fundamental chemistry of ironmaking: the reduction of iron oxide using carbon-based reductants (primarily metallurgical coke), which inevitably generates CO_2 as a byproduct. With global steel demand projected to remain stable or grow modestly through 2050, achieving climate targets under the Paris Agreement requires fundamental transformation of steelmaking processes.

1.2 Australia's Unique Position in Global Steel and Iron Ore Markets

Australia occupies a paradoxical position in the global steel value chain: while domestic steel production is relatively modest at 4.8 million tonnes annually (representing less than 0.3% of global production), Australia is the world's second-largest iron ore exporter, shipping over 800 million tonnes annuallyprimarily to China, Japan, South Korea, and other Asian steel producers. This positions Australia uniquely as a resource supplier to the global steel industry while also operating domestic steelmaking facilities facing their own decarbonization challenges.

The Australian steel industry comprises two major integrated producers:

- **BlueScope Steel:** Port Kembla Steelworks (New South Wales), capacity over 3 million tonnes/year, Australia's largest flat-rolled steel producer
- **Liberty Steel Australia:** Whyalla Steelworks (South Australia), capacity 1.2-2.6 million tonnes/year, focused on long products
- **InfraBuild:** Scrap-based electric arc furnace operations, capacity approximately 1.5 million tonnes/year

Combined production in 2024 amounted to 4.8 million tonnes, down 11% from the previous year, reflecting challenges including high natural gas costs, aggressive imports from Southeast Asia, and weak domestic market protection.

1.3 Research Objectives and Contributions

This paper addresses three primary research questions:

1. What technology pathways are available for Australian steel decarbonization, and which are most suitable given the country's resource endowments, industrial structure, and market positioning?

2. How do Australia's decarbonization strategies, policy frameworks, and industry initiatives compare to approaches in other major steel-producing and iron ore-exporting nations?

3. What policy interventions, technological investments, and strategic partnerships would enable Australia to leverage its iron ore resources and renewable energy potential to achieve leadership in green iron and steel production for Asia-Pacific markets?

The research makes several contributions to academic and policy literature:

Empirical contribution: Comprehensive documentation of Australian steel and iron ore decarbonization initiatives, including detailed analysis of Liberty Steel's Whyalla transformation, BlueScope's technology pathways, the NeoSmelt electric smelting furnace pilot, and government policy frameworks.

Comparative analysis: Examination of Australia's unique position as both domestic steel producer and dominant iron ore exporter, identifying distinct challenges and opportunities compared to major steel-producing nations.

Economic assessment: Analysis of economic barriers to green steel production in Australia, including detailed examination of carbon pricing requirements, capital cost challenges, and international competitiveness factors.

Policy recommendations: Actionable policy prescriptions grounded in international best practices and adapted to Australian context, addressing financing mechanisms, infrastructure development, and strategic positioning in Asia-Pacific green steel value chains.

1.4 Paper Structure

The remainder of this paper is organized as follows: Section 2 reviews relevant literature on steel decarbonization technologies and policy approaches. Section 3 describes the methodology and data sources. Section 4 examines Australia's current position, including detailed analysis of major projects and policy initiatives. Section 5 discusses Australia's competitive advantages and strategic opportunities. Section 6 identifies challenges and economic barriers. Section 7 presents a comparative analysis with other steel-producing nations. Section 8 provides policy recommendations and a strategic roadmap. Section 9 concludes with implications for research and practice.

2 Literature Review

2.1 Steel Decarbonization Technologies

The academic and technical literature identifies four primary pathways for steel sector decarbonization, each at different stages of technological maturity and commercial deployment.

2.1.1 Hydrogen-Based Direct Reduction (H2-DRI)

Direct reduction processes using hydrogen as the reductant represent one of the most widely discussed pathways for deep decarbonization of primary steel production. The fundamental chemistry replaces carbon-based reduction:

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

compared to conventional carbon reduction:

$$\mathrm{Fe_2O_3} + 3\mathrm{CO} \rightarrow 2\mathrm{Fe} + 3\mathrm{CO_2} \tag{2}$$

The HYBRIT project in Sweden represents the most advanced commercial-scale demonstration, targeting fossil-free steel production. Key technical challenges include hydrogen embrittlement of equipment, different reduction kinetics requiring process optimization, ore quality requirements (>67% Fe content, low gangue), and integration with intermittent renewable energy sources.

For Australia, natural gas-based DRI could reduce emissions by approximately 60%, while green hydrogen-based DRI could achieve 85% emissions reduction compared to conventional BF-BOF processes.

2.1.2 Electric Arc Furnace (EAF) Expansion

Increased steel production through EAF using scrap as feedstock offers immediate emissions reduction (0.4-0.5 tonnes CO_2 per tonne steel vs. 2.0 for BF-BOF) and leverages circular economy principles. However, Australia faces unique constraints:

- Limited domestic scrap generation (approximately 1.4 million tonnes recycled annually by InfraBuild)
- Quality limitations from tramp elements affecting high-grade steel production
- Geographic isolation affecting scrap imports
- Growing demand exceeding scrap availability

DRI can supplement scrap in EAF operations, enabling production of high-quality steel grades while maintaining lower emissions than BF-BOF.

2.1.3 Electric Smelting Furnace (ESF) Technology

Electric smelting furnaces represent an emerging pathway being explored through the NeoSmelt consortium (Rio Tinto, BHP, BlueScope). ESF technology:

- Uses electrical energy for smelting reduction

- Can process a range of iron ore qualities
- Potentially enables continued use of Australian Pilbara ores
- Not yet proven at commercial scale for ironmaking

BlueScope considers DRI-ESF-BOF as the most viable long-term pathway for Port Kembla Steelworks, though significant technology development is required.

2.1.4 Carbon Capture, Utilization, and Storage (CCUS)

CCUS retrofitted to existing BF-BOF facilities offers an incremental pathway. However, economics remain challenging with capture costs ranging from $40-120 per tonne CO_2, energy penalties of 15-30%, and limited focus in Australian context given preference for transformation to alternative technologies.

2.2 Policy Frameworks for Industrial Decarbonization

2.2.1 Carbon Pricing and Safeguard Mechanism

Australia's Safeguard Mechanism, reformed in 2023, establishes baseline emissions limits for facilities emitting over 100,000 tonnes CO_2-e annually. The steel industry receives tailored treatment as a "hard-to-abate" and trade-exposed sector, with more gradual emissions reduction requirements. However, current carbon pricing signals remain insufficient, with analysis suggesting carbon prices above $100/tonne CO_2 required for green steel economic viability.

2.2.2 Government Funding and Investment Support

The Australian federal government has established multiple funding mechanisms:

- **Green Iron Investment Fund:** $1 billion equity funding for decarbonization projects (March 2025)
- **Powering the Regions Fund:** $200 million granted to BlueScope ($136.8M) and Liberty Steel ($63.2M)
- **National Reconstruction Fund:** $1.96 billion for renewable energy and low-CO_2 technologies
- **Hydrogen Headstart Program:** Supporting hydrogen production infrastructure
- **Hydrogen Energy Development Fund:** $327 million for hydrogen hubs across states

2.2.3 Demand-Side Policies

Public procurement preferences and green building standards incorporating embodied carbon remain underdeveloped compared to European approaches. This represents a policy gap limiting early market creation for low-carbon steel products.

2.3 Resource Advantages and Strategic Positioning

Literature on resource-based industrial strategy provides relevant framework for analyzing Australia's position. The country's renewable energy potential (world-class solar and wind resources) combined with iron ore reserves creates opportunities for:

- Moving up the value chain from ore export to green iron/steel production
- Capturing higher-value products in steel supply chains
- Positioning as green iron supplier to Asia-Pacific steelmakers
- Developing technology and intellectual property in green ironmaking

However, high capital costs ("Australia is an expensive place to build stuff"), limited natural gas availability, and competition from established Asian steelmakers pose significant challenges.

2.4 Research Gaps

Despite growing literature on steel decarbonization, several gaps remain:

1. Limited analysis of small-scale domestic producers with large export-oriented upstream resources
2. Insufficient examination of economic barriers specific to high-cost production environments
3. Minimal research on iron ore value chain transformation opportunities
4. Limited study of Asia-Pacific green steel market development and Australia's potential role
5. Inadequate attention to the interplay between domestic steel industry transformation and iron ore export strategy

This paper addresses these gaps through detailed analysis of Australia's unique position and strategic options.

3 Methodology

3.1 Research Design

This study employs a mixed-methods approach combining:

1. **Policy analysis:** Systematic review of Australian federal and state government policies, regulations, and funding programs
2. **Technology assessment:** Evaluation of decarbonization technology pathways based on technical literature, industry reports, and project documentation
3. **Case study analysis:** Detailed examination of major Australian initiatives including Liberty Steel Whyalla, BlueScope Port Kembla, NeoSmelt pilot, and emerging ventures
4. **Economic analysis:** Assessment of cost structures, economic barriers, and competitiveness factors
5. **Comparative context:** Positioning Australia's approach relative to other major steel-producing nations

3.2 Data Sources

3.2.1 Production and Trade Data

- World Steel Association statistical yearbooks for global production context
- Australian Bureau of Statistics for domestic production and trade data
- Company annual reports and investor presentations (BlueScope, Liberty Steel/GFG Alliance)
- Industry associations (Australian Steel Association)

3.2.2 Policy Documents

- Federal government publications: *Future Made in Australia* plan, Safeguard Mechanism regulations, Green Iron Investment Fund documentation
- State government initiatives: Western Australia low-CO_2 steel support plan, South Australia hydrogen strategy
- Parliamentary records and ministerial announcements
- Regulatory frameworks and environmental assessments

3.2.3 Technical and Project Information

- Company project announcements and feasibility studies
- Technology provider documentation (Danieli, Paul Wurth, Midrex, Primetals)
- Research publications from CSIRO, universities, and international institutions
- Industry analyst reports (IEEFA, Energy Transitions Commission, McKinsey)

3.2.4 Expert Analysis

This research benefited from consultation with artificial intelligence analytical systems (Anthropic Claude) for systematic analysis of policy documents, project tracking, and international benchmarking. All AI-generated insights were validated against primary sources.

3.3 Analytical Framework

The analysis employs a structured framework examining:

1. **Industry structure:** Current production capacity, technology mix, ownership, and market dynamics
2. **Technology pathways:** Assessment of H2-DRI, EAF, ESF, and other approaches for Australian context
3. **Major projects:** Detailed examination of transformation initiatives with timelines, costs, and expected impacts
4. **Policy environment:** Government funding, regulations, carbon pricing, and institutional frameworks
5. **Economic factors:** Capital costs, operating economics, carbon price requirements, and competitiveness
6. **Strategic opportunities:** Iron ore value chain integration, renewable energy advantages, Asia-Pacific market positioning
7. **Challenges and barriers:** Infrastructure constraints, cost factors, international competition, policy gaps

3.4 Limitations

Several methodological limitations should be noted:

- **Data availability:** Some commercial project data is proprietary; cost estimates vary widely across sources
- **Rapidly evolving field:** Policy frameworks and technology projects changing faster than publication cycles; analysis reflects status as of November 2025
- **Uncertainty in projections:** Technology costs, hydrogen prices, carbon prices, and market dynamics inherently uncertain
- **Limited operational data:** Most projects are in planning or early stages; limited empirical performance data available

Despite these limitations, multiple data sources and comprehensive scope provide robust foundation for analysis and recommendations.

4 Australia's Current Position: Projects, Policies, and Capabilities

4.1 Industry Structure and Emissions Profile

4.1.1 Production Capacity and Major Players

Australian steel production in 2024 totaled 4.8 million tonnes, representing an 11% decline from 2023. This reflects ongoing challenges including high energy costs (electricity wholesale prices increased 83% in 2024), aggressive imports from Southeast Asian producers, and limited domestic market protection.

BlueScope Steel - Port Kembla Steelworks (NSW):

- Capacity: Over 3 million tonnes per year
- Technology: Blast furnace-basic oxygen furnace (BF-BOF)
- Products: Flat-rolled steel, primarily for domestic market and export
- Parent company: BlueScope Steel Limited (ASX: BSL), market capitalization approximately $8 billion
- International operations: North Star BlueScope (USA) - scrap-EAF operations
- Current status: No. 5 blast furnace reached end of campaign; No. 6 blast furnace reline project underway ($1.15 billion investment)

Liberty Steel Australia - Whyalla Steelworks (SA):

- Capacity: 1.2-2.6 million tonnes per year (nominal)
- Technology: Currently BF-BOF, transitioning to EAF and planned H2-DRI
- Products: Long products (structural steel, rail, rod, bar)
- Parent company: GFG Alliance (Liberty Steel Group)
- Iron ore: Tamura iron ore mine (magnetite) in New South Wales
- Current status: Transformation plan including new EAF and future DRI plant

InfraBuild (GFG Alliance):

- Capacity: Approximately 1.5 million tonnes per year
- Technology: 100% scrap-based electric arc furnace
- Scrap processing: Annual capacity 1.4 million tonnes, 4 shredders, 26 recycling centers
- Products: Long steel, reinforcing bar, structural sections
- Target: Carbon neutrality by 2030

Other Producers:

- Molycop/Comsteel: Scrap-EAF operations, capacity approximately 0.25 million tonnes per year
- Various specialty and regional producers

4.1.2 Current Emissions Profile

Australian steel industry emissions estimated at 10-12 million tonnes CO_2-e annually. Average emissions intensity: 2.07 tonnes CO_2 per tonne of crude steel for integrated BF-BOF operations (slightly above global average of 2.0 due to aging equipment and operational factors).

Breakdown by technology:

- BF-BOF operations (BlueScope Port Kembla, Liberty Whyalla): 8-10 MT CO_2-e (80-85%)
- EAF operations (InfraBuild, others): 1.5-2 MT CO_2-e (15-20%)
- Grid electricity for EAF relatively clean (renewable energy mix), but natural gas costs high

4.2 Major Decarbonization Initiatives

4.2.1 Liberty Steel Whyalla Transformation

Liberty Steel's Whyalla transformation represents Australia's most advanced steel decarbonization project, combining proven EAF technology with planned hydrogen-based direct reduction.

Project Components:

Phase 1: Electric Arc Furnace Installation

- Supplier: Danieli (Italy), 160-tonne EAF
- Investment: $593 million total project cost
- Government support: $63.2 million federal grant (Powering the Regions Fund), $50 million South Australia government (>20% of total cost)
- Capacity: 1.2 million tonnes per year
- Timeline: Target 2025 completion
- Feedstock: Initially scrap, with DRI supplementation planned
- Expected impact: Enables phase-out of coal-based steelmaking at Whyalla

Phase 2: Direct Reduction Plant

- Capacity: 1.8 million tonnes per annum DRI
- Feedstock: Local magnetite iron ore from Tamura mine
- Initial reductant: Natural gas
- Future pathway: Transition to green hydrogen from renewable energy projects
- Challenge: Limited natural gas supply in South Australia
- Potential solution: Floating LNG terminal at Port of Adelaide (Venice Energy Group proposal)

Phase 3: Green Hydrogen Integration

- Hydrogen production: Electrolyzer powered by GFG Alliance renewable energy projects
- South Australia commitment: World's largest hydrogen electrolyzer planned for Whyalla region
- DRI conversion: Replace natural gas with green H_2 as technology and economics improve
- Target: 90% reduction in direct CO_2 emissions from steelmaking
- Sanjeev Gupta (GFG Executive Chairman): "Whyalla will be the global epicenter for manufacturing low carbon iron and steel"

Strategic Significance:

- Demonstrates viable transformation pathway for integrated steelworks
- Combines mature EAF technology with emerging hydrogen DRI
- Leverages South Australia's renewable energy resources (world-leading wind and solar)
- Addresses scrap constraints through local magnetite ore processing
- Potential model for other regional steelmaking transformations

4.2.2 BlueScope Port Kembla Decarbonization Pathways

BlueScope's approach reflects the complexity of transforming large-scale integrated steelmaking operations in context of technological uncertainty and economic constraints.

Near-Term: Blast Furnace Reline and Incremental Improvements

No. 6 Blast Furnace Reline Project:

- Investment: $1.15 billion total
- Government support: $136.8 million federal grant (Powering the Regions Fund)
- Rationale: "Bridge" technology enabling operations while next-generation technologies mature
- Timeline: Commissioning mid-to-late 2026
- Operational life: 15-20 years
- Upgrades include:
  - Top gas recovery turbine for electricity generation
  - Dual lances enabling hydrogen-rich coke oven gas and renewable hydrogen injection
  - Waste gas heat recovery system reducing fuel consumption

- Expected emissions reduction: Up to 172,000 tonnes CO_2-e per year
- CEO Mark Vassella: Decision made in 2023 due to "absence of key enablers for DRI, such as abundant low-cost natural gas or green hydrogen"

Medium-Term: Technology Development and Partnerships
Australian Direct Reduction Iron (DRI) Options Study:

- Comprehensive analysis of decarbonization pathways for Port Kembla
- Evaluation of technology options and required enablers
- Key challenge: Electricity requirements enormous
  - Natural gas DRI: 2× current Port Kembla electricity consumption
  - Green hydrogen DRI: Up to 15× current electricity consumption
- Conclusion: Effective policies essential for "cost-competitive firmed renewable electricity, sufficient quantities of cost competitive gas, and developing a green hydrogen supply chain"

BlueScope-Shell Hydrogen Partnership (MoU signed December 2021):

- Project 1: Pilot-scale 10 MW renewable hydrogen electrolyzer
- Purpose: Test green hydrogen use in blast furnace, potentially feed pilot DRI plant
- Project 2: Illawarra "hydrogen hub" development
- Scope: Hydrogen supply and offtake, renewable energy supply, infrastructure logistics
- Collaboration: Multiple organizations across industry, energy, transport, research sectors

BlueScope-Rio Tinto Green Iron Partnership (MoU October 2021):

- Objective: Develop pilot DRI plant at Port Kembla using green hydrogen
- Feedstock: Rio Tinto iron ore
- Status: Feasibility and planning stage

Long-Term: Transformation to Low-Carbon Ironmaking
Tania Archibald (CEO Australian Steel Products, BlueScope): "Direct reduced iron technology, DRI... is one of the most promising technologies to achieve a steep reduction in emissions in iron and steelmaking."
Preferred Pathway: DRI-ESF-BOF

- Direct Reduced Iron production using hydrogen
- Electric Smelter Furnace for melting (under development through NeoSmelt consortium)
- Basic Oxygen Furnace for final steelmaking

- Advantage: Enables continued use of Australian Pilbara ores (critical for supply chain)
- Challenge: ESF technology not yet proven at commercial scale for ironmaking
- BlueScope participation in NeoSmelt pilot (see Section 4.2.3)

Alternative: DRI-EAF Pathway

- Direct Reduced Iron fed into Electric Arc Furnace
- Challenge: Australia's limited scrap supply constrains full EAF transition
- BlueScope's North Star operations (USA) demonstrate EAF expertise
- Acquired MetalX scrap recycler (USA) for $240 million to secure scrap supply and expertise

Target and Timeline:

- Net zero by 2050 commitment
- 2030 target: 1% annual emissions reduction (conservative, reflecting "hard-to-abate" challenges)
- Decarbonization budget 2025-2030: $300-400 million
- Beyond 2030: No specific targets pending technology maturity

4.2.3 NeoSmelt Electric Smelting Furnace Pilot

The NeoSmelt consortium represents groundbreaking collaboration between Australia's dominant iron ore producers and major steelmaker to develop potentially transformative technology.

Consortium Partners:

- Rio Tinto (ASX: RIO): World's second-largest iron ore producer
- BHP (ASX: BHP): World's largest iron ore producer
- BlueScope Steel: Australia's largest steelmaker

Project Details:

- Technology: Electric Smelting Furnace (ESF) - also called "melter"
- Objective: Australia's first ironmaking ESF pilot plant
- Location: Kwinana Industrial Area, Western Australia
- Government support: $75 million from WA government (June 2025) - largest government commitment globally to steel industry decarbonization
- Strategic rationale: Prove ESF technology viability for Australian context

Technology Characteristics:

- Uses electrical energy for smelting reduction (instead of coke/coal)
- Can process range of iron ore types and qualities
- Lower emissions than conventional blast furnace
- Modular design enabling scalable deployment
- Combined with hydrogen DRI: Potentially zero-carbon primary ironmaking

Strategic Importance for Iron Ore Producers:
Rio Tinto and BHP participation reflects recognition that steel industry decarbonization threatens long-term iron ore demand. Current dynamics:

- Major customers (China, Japan, South Korea) committed to decarbonizing steel production
- Shift to EAF using scrap reduces ore demand
- Shift to hydrogen DRI requires different ore specifications and processing
- Development of green iron technologies could enable value-added processing in Australia
- Potential to export green iron/DRI instead of raw ore (higher value, lower transport emissions)

However, transporting DRI long distances (Australia to Asia) presents challengesmaterial properties degrade, requiring specialized handling. ESF technology could enable production of high-quality green iron suitable for long-distance transport or direct use in Australian/regional steel production.

Timeline and Technology Readiness:

- Pilot plant construction: 2025-2027
- Initial operations: 2027-2028
- Technology evaluation: 2028-2030
- Commercial scale decision: Post-2030, pending pilot results
- If successful: Potential transformation of Australian iron ore value chain

4.2.4 Emerging Green Steel Ventures

Beyond the major incumbent steelmakers, several new ventures are emerging to capitalize on Australia's renewable energy and policy support:

Green Steel WA - Collie Project

- Location: Collie, Western Australia (former coal mining region)
- Capacity: Target 400,000 tonnes per year
- Technology: Electric arc furnace with renewable energy

- Investment: Approximately $400 million
- Timeline: Target 2026 for initial production
- Significance: Just transition example - steel production in former coal region

GSWA - Geraldton DRI Plant

- Location: Geraldton, Western Australia
- Capacity: 2.5 million tonnes per annum DRI
- Technology: Initially natural gas DRI, transitioning to green hydrogen
- Investment: Estimated $2.5 billion
- Status: Planning and approvals stage
- Rationale: Export green iron to Asia-Pacific markets

These ventures demonstrate growing investor confidence in Australian green steel sector, though significant capital raising and execution risks remain.

4.3 Policy Frameworks and Government Support

4.3.1 Federal Policy Architecture

Future Made in Australia Plan (2024-2025)

Comprehensive industrial strategy emphasizing:

- Green manufacturing and clean energy industries
- Leveraging Australia's renewable energy and mineral resources
- Creating sovereign manufacturing capability
- Supporting hard-to-abate sector transformation

Green Iron Investment Fund (March 2025)

- Capital: $1 billion equity funding
- Structure: Direct government equity investment in decarbonization projects
- Eligible sectors: Steel, other metals processing
- Investment approach: Co-investment with private sector
- Notable allocations:
  - Up to $500 million for Liberty Steel Whyalla transformation
  - Competitive process for remaining $500 million
- Conditions: Projects must demonstrate emissions reduction, economic viability, job creation

- Management: Investment managed through government agency

Safeguard Mechanism (Reformed 2023)

- Coverage: Facilities emitting >100,000 tonnes CO_2-e annually
- Baseline decline: 4.9% annual reduction to 2030
- Steel sector treatment:
  - Recognized as "emissions-intensive, trade-exposed" (EITE)
  - More gradual baseline decline (approximately half standard rate)
  - Production-adjusted baselines (encourages output growth)
  - Extended adjustment period recognizing technology challenges
- Flexibility mechanisms: Australian Carbon Credit Units (ACCUs), Safeguard Mechanism Credits (SMCs), international units (limited)
- Impact: Provides emissions reduction signal but insufficient price incentive for major transformation

Powering the Regions Fund

- Total: $1.9 billion for regional heavy industry transformation
- Steel allocations:
  - BlueScope Port Kembla: $136.8 million (No. 6 BF reline)
  - Liberty Steel Whyalla: $63.2 million (EAF project)
- Rationale: Support regional employment while enabling decarbonization
- Criticism: Some environmental groups argue BF funding delays transformation

National Reconstruction Fund

- Total capital: $15 billion across priority areas
- Renewables and Low Emissions Technologies: $1.96 billion allocation
- Structure: Concessional loans, equity investments, loan guarantees
- Steel relevance: Infrastructure, renewable energy, hydrogen production
- Application: Competitive process, requires commercial viability

Hydrogen Strategy and Support

- Hydrogen Headstart Program: $2 billion supporting large-scale renewable hydrogen production
- Hydrogen Production Tax Incentive: $2/kg hydrogen for 10 years (legislated 2024)
- Hydrogen Energy Development Fund: $327 million for hydrogen hubs
- Australian Renewable Energy Agency (ARENA): Funding hydrogen R&D and demonstration

4.3.2 State Government Initiatives

Western Australia - Low-CO_2 Steel Support

- WA government commitment to supporting steel transformation
- NeoSmelt consortium: $75 million (June 2025) - largest state commitment globally
- Rationale: Protect iron ore industry competitiveness, attract value-added processing
- Focus on green iron production for domestic use and export

South Australia - Hydrogen Superpower Strategy

- Vision: Position SA as global hydrogen production and export hub
- Relevance to steel: Liberty Steel Whyalla critical industrial anchor
- Support: $50 million for Liberty EAF project
- Infrastructure: Hydrogen production, storage, distribution development
- Renewable energy: World-leading wind and solar resources (>70% renewable electricity)

New South Wales - Energy and Industrial Policy

- Electricity Infrastructure Roadmap: Renewable energy zones, transmission
- Relevance: Port Kembla electricity supply and costs critical for BlueScope
- Hydrogen hubs: Illawarra region (Port Kembla) designated priority
- Challenge: Balancing coal phase-out with industrial energy security

4.3.3 Policy Gaps and Limitations

Despite substantial government support, several critical gaps remain:

1. **Carbon pricing insufficiency:** Current Safeguard Mechanism creates weak price signal. Analysis suggests carbon prices >$100/tonne CO_2 required for green steel economic viability. Current effective price: $20-40/tonne through ACCU purchases.
2. **Natural gas supply constraints:** East coast gas shortages and high prices threaten DRI pathway viability. No coherent policy addressing gas supply for industrial transformation vs. residential/commercial needs vs. export commitments.
3. **Import competition:** Limited trade protection for Australian steel despite higher costs and emissions standards. Southeast Asian steel imports (Vietnam, Indonesia, Thailand) increasing market share. No carbon border adjustment mechanism equivalent to EU CBAM.
4. **Electricity infrastructure:** Transmission constraints and renewable energy firming costs create uncertainty for large industrial loads. Port Kembla DRI scenario requires massive grid upgrades.

5. **Lack of demand-side policies:** No substantial public procurement preferences for low-carbon steel. Limited embodied carbon requirements in building codes or infrastructure standards. Contrast with Germany's Steel Action Plan mandating consideration in public projects.

6. **Fragmented hydrogen strategy:** Multiple funding programs but unclear coordination. Hydrogen production for export (LNG replacement) vs. domestic industrial use creates competition. Price targets ($2/kg) may not achieve timeline required for steel transformation.

7. **Technology uncertainty:** Government backing multiple pathways (DRI, ESF, hydrogen) without clear prioritization. Risk of spreading resources too thin vs. focused development.

4.4 Research and Innovation Infrastructure

CSIRO (Commonwealth Scientific and Industrial Research Organisation)

- Minerals Resources Flagship: Steel and ironmaking research
- Hydrogen Industry Mission: Production, storage, applications
- Energy: Integration with renewable electricity systems
- Limited specific steel decarbonization programs compared to international peers (e.g., Japan's NEDO)

Universities

- University of Wollongong: Strong metallurgy and materials programs, proximity to Port Kembla
- University of Adelaide: Process engineering, mining
- University of Melbourne: Energy systems, chemical engineering
- Challenge: Industry-university collaboration weaker than European or Japanese models

Industry-Research Collaboration

- Cooperative Research Centres (CRC) program: Some steel-relevant projects
- ARENA and Australian Renewable Energy Agency funding: Supports applied research
- Gap: No dedicated steel decarbonization research program comparable to EU Clean Steel Partnership or Japan's Green Innovation Fund

5 Australia's Competitive Advantages and Strategic Opportunities

5.1 Renewable Energy Endowment

5.1.1 Current Energy Profile

Australia's electricity generation mix (2024):

- Coal: 50% (declining, numerous closures announced)
- Natural gas: 20%
- Renewables: 30% (rapidly growing)
  - Wind: 10%
  - Solar (utility-scale): 8%
  - Rooftop solar: 10%
  - Hydro: 2%

Regional variation significant:

- South Australia: >70% renewable electricity (world-leading wind penetration)
- Tasmania: >95% renewable (predominantly hydro)
- Queensland: Coal-dominated but transitioning
- Western Australia: Isolated grid, moderate renewable penetration

5.1.2 Renewable Energy Potential

Solar Resources:

- World-class solar irradiation across much of continent
- Northern regions: 2000-2400 kWh/m^2/year
- Capacity factor: 25-30% for fixed-tilt PV
- Land availability: Vast areas suitable for large-scale solar farms
- Cost trajectory: Lowest levelized cost of electricity (LCOE) globally for solar in some regions

Wind Resources:

- Excellent onshore wind: Southern coasts, Great Dividing Range
- Capacity factor: 35-42% onshore
- Offshore wind: Beginning development, massive potential along southern coast
- Proximity to load centers: Southern coastline near major cities and industrial sites

Green Hydrogen Production Potential:

- IRENA assessment: Australia among top 5 countries for low-cost green hydrogen
- Target production cost: \$2/kg by 2030 (Australian Government goal)
- Current electrolyzer projects: Multiple GW-scale projects planned or under development
- Challenge: Scaling to meet both export ambitions and domestic industrial needs

Strategic Implication for Steel:

Australia can produce abundant renewable electricity at competitive costs, providing fundamental advantage for:

- Electric arc furnace operations (renewable electricity = low emissions)
- Green hydrogen production for DRI
- Electric smelting furnace operations
- Position as "green steelmaking nation" in Asia-Pacific

However, grid infrastructure, firming capacity (storage, dispatchable generation), and transmission require massive investment (\$100+ billion nationally over next 20 years).

5.2 Iron Ore Resources and Value Chain Position

5.2.1 Iron Ore Production and Quality

Australia is the world's second-largest iron ore producer (after China) and largest exporter:

- Production: 880 million tonnes in 2024
- Exports: 800+ million tonnes (91% of production)
- Primary destination: China (>80% of exports)
- Major producers: Rio Tinto, BHP, Fortescue Metals Group
- Ore types: Predominantly hematite from Pilbara region (Western Australia)

Ore Quality:

- Fe content: 56-62% (Pilbara fines and lump)
- Premium ores: 65%+ Fe content (higher price, lower transport/processing costs)
- Suitability for DRI: Pilbara ores generally require pelletizing or beneficiation
- Magnetite deposits: Limited production but suitable for DRI (e.g., Liberty's Tamura mine)

5.2.2 Value Chain Transformation Opportunity

Current model: Export raw iron ore Asian steelmaking Import finished steel products
Opportunity: Move up value chain to capture higher value:

1. **Iron ore Green iron (DRI/HBI):**
    - Process ore domestically using renewable energy
    - Export green iron to Asian steelmakers (DRI/HBI)
    - Value addition: $80-120 per tonne ore $400-600 per tonne DRI
    - Emissions reduction: Pre-reduced iron enables lower-emission steelmaking
    - Challenge: DRI transport and handling over long distances
2. **Iron ore Domestic steel production:**
    - Expand Australian steelmaking capacity for domestic market
    - Reduce reliance on imported steel products
    - Capture value-added steel processing
    - Challenge: Small domestic market (5-6 MT), high production costs
3. **Iron ore Green steel exports:**
    - Premium green steel products for carbon-conscious markets
    - Target: Japan, South Korea, potentially Europe
    - Differentiation: Australian-made, renewable-powered certification
    - Challenge: Competing with established Asian producers, high costs

Rio Tinto and BHP Strategic Interest:
Both companies recognize steel decarbonization threatens traditional ore export model:

- Increased scrap recycling reduces ore demand growth
- Shift to DRI requires different ore specifications
- Asian customers demanding lower-emission ore and value-added products
- Participation in NeoSmelt, partnerships with steelmakers reflects strategic positioning

Quote from Rio Tinto executive: "We need to think beyond just digging up rocks and putting them on ships."

5.3 Strategic Geographic Position

5.3.1 Asia-Pacific Market Proximity

Australia's location positions it advantageously for emerging green steel markets:
Japan:

- Major steel producer (84 MT annually) with ambitious decarbonization targets

- Limited domestic iron ore resources (100% import-dependent)
- Strong hydrogen strategy but high production costs
- Opportunity: Supply green iron, DRI, or certified low-carbon steel
- Existing relationships: Australian iron ore exports, technology partnerships

South Korea:

- Major steel producer (63.6 MT annually) with net-zero 2050 target
- Limited resources, import-dependent for ore and energy
- Developing HyREX and other proprietary technologies
- POSCO partnership opportunities: Technology, investment, offtake agreements

Southeast Asia:

- Rapidly growing steel consumption (infrastructure, construction, manufacturing)
- Current reliance on Chinese imports and domestic production (Vietnam, Indonesia, Thailand)
- Emerging environmental standards creating demand for lower-carbon products
- Opportunity: Position as "clean steel" supplier to region

China:

- World's dominant steel producer (>1 billion tonnes) and iron ore importer
- Committed to peak carbon before 2030, net-zero 2060
- Massive steel sector decarbonization underway (EAF expansion, hydrogen pilots, CCUS)
- Opportunity: Green iron supply as China transforms production
- Challenge: China developing domestic capabilities, geopolitical tensions

5.3.2 Shipping and Logistics

Advantages:

- Established iron ore shipping infrastructure (Pilbara ports world-class)
- Shorter shipping distances vs. Brazil or Africa to Asia
- Lower freight costs to Asian markets compared to European or American sources

Challenges:

- DRI transport over long distances technically challenging (reoxidation risk)
- HBI (hot briquetted iron) more stable but requires additional processing
- Steel products higher value but more competitive markets
- Potential solution: Regional processing hubs, specialized transport vessels

5.4 Technology Development and Intellectual Property

Potential Areas for Australian Leadership:

1. **Electric Smelting Furnace Technology:**
   - NeoSmelt consortium developing proprietary ESF approach
   - If successful: Technology licensing, equipment manufacturing, consulting
   - Addresses Australian-specific constraints (ore types, scale, integration)
2. **Renewable-Integrated Hydrogen Production:**
   - Variable renewable energy (solar/wind) integration with electrolyzer operation
   - Storage and buffering solutions for industrial hydrogen supply
   - Hot-climate hydrogen production and handling
3. **DRI from Magnetite Ores:**
   - Liberty Steel Tamura magnetite project develops processing expertise
   - Magnetite's properties suit direct reduction
   - Potential for Australian-specific magnetite-to-DRI technologies
4. **Integration of Multiple Pathways:**
   - Combining DRI, ESF, EAF in flexible production systems
   - Adapting to variable renewable energy availability
   - Small-scale, modular approaches suitable for Australian production volumes

Comparison with International Approaches:

- Europe: Focus on large-scale integrated BF-to-DRI-EAF conversion
- Japan: Emphasis on hydrogen injection into BFs, CCUS, hybrid approaches
- USA: Leveraging abundant natural gas for DRI, expanding scrap-EAF
- Australia: Opportunity for niche specialization in renewable-integrated, ore-to-steel pathways

5.5 Enabling Infrastructure and Industrial Capability

Existing Industrial Infrastructure:

- Port facilities: World-class ore export terminals adaptable for green iron
- Industrial sites: Existing steelmaking sites (Port Kembla, Whyalla) with infrastructure, skilled workforce
- Engineering capabilities: Mining, minerals processing, heavy industry project execution

- Research institutions: CSIRO, universities with relevant expertise

Workforce and Skills:

- Experienced metallurgists, process engineers, trades
- Mining and minerals processing expertise transferable to green iron production
- Challenge: Aging workforce, competition from mining sector for talent
- Opportunity: Retrain fossil fuel workers (coal, gas) for green steel sector

Investment Climate:

- Stable political system, rule of law, strong property rights
- Attractive to international investors (Japanese, Korean, European steel/energy companies)
- Government co-investment through Green Iron Investment Fund, NRF reduces risk
- Superannuation (pension) funds seeking domestic infrastructure investments

6 Challenges and Economic Barriers

6.1 Economic Competitiveness Challenges

6.1.1 High Capital Costs

Australia faces significant cost disadvantages for industrial construction:

International Comparisons:

- DRI plant capital cost (1 million tonne capacity):
  - Middle East: $600-700 million
  - USA: $800-900 million
  - Europe: $900-1,100 million
  - Australia: $1,000-1,300 million (estimated)
- EAF capital cost (1 million tonne capacity):
  - Asia: $200-300 million
  - Europe/USA: $300-400 million
  - Australia: $350-500 million (estimated)

Cost Drivers:

- Labor costs: High wages, strong unions, penalty rates
- Equipment import: Distance from suppliers, shipping costs, tariffs
- Regulatory compliance: Environmental assessments, safety standards, permitting complexity
- Project management: Limited local experience with some technologies (DRI, hydrogen), imported expertise expensive
- Remote locations: Whyalla, potential Pilbara sites add logistics challenges

BlueScope CEO Mark Vassella: "Australia is an expensive place to build stuff. That's not a surprise to anyone."

6.1.2 Operating Cost Challenges

Natural Gas Pricing:

- East coast gas crisis: Supply shortages, export commitments, infrastructure constraints
- Current prices: $12-18/GJ (vs. $3-6/GJ USA, $8-12/GJ Middle East)
- Impact on DRI economics: Natural gas DRI requires 11-12 GJ per tonne iron
- At $15/GJ: $165-180 per tonne DRI in gas costs alone
- Makes natural gas DRI pathway marginally economic or uneconomic

Electricity Costs:

- Wholesale electricity prices (2024): \$80-150/MWh in most regions (83% increase year-on-year)
- EAF electricity consumption: 400-500 kWh per tonne steel
- At \$100/MWh: \$40-50 per tonne steel in electricity costs
- Green hydrogen production: 50-55 kWh per kg H_2
- At \$80/MWh: \$4.00-4.40/kg H_2 in electricity costs alone (target \$2/kg all-in by 2030)
- Challenge: Firming renewable electricity for 24/7 industrial operations adds 20-40% to costs

Labor and Operational Costs:

- Labor costs: 50-100% higher than Asian competitors
- Maintenance: Limited local supply chains for specialized equipment
- Logistics: Transport costs within Australia significant (distances, limited rail/pipeline)

6.1.3 Carbon Price Requirements

Economic modeling (IEEFA, Australian Steel Institute, academic studies) suggests:

Carbon price required for green steel competitiveness:

- Natural gas DRI: \$40-60/tonne CO_2 makes competitive with BF-BOF
- Green hydrogen DRI: \$100-150/tonne CO_2 required (assuming \$3/kg H_2 production cost)
- Current Safeguard Mechanism effective price: \$20-40/tonne (via ACCU purchases)
- Gap: \$60-110/tonne CO_2 shortfall for green hydrogen pathway

Implications:

- Without substantially higher carbon pricing: Green steel uneconomic
- Government subsidies bridge gap: But sustainability of ongoing operational subsidies questionable
- Customer premium required: Green steel price premium of \$100-200/tonne needed
- Market uncertainty: Willingness of customers to pay premium unproven

IEEFA analysis: "Even with capital support through government grants and concessional finance, ongoing operational subsidies or significantly higher carbon prices will be required to make green steel economically viable in Australia."

6.2 Natural Gas and Hydrogen Supply Constraints

6.2.1 East Coast Gas Market Dysfunction

Australia faces paradoxical situation: Major LNG exporter but domestic gas shortages and high prices.

Supply Constraints:

- Export commitments: Three LNG export plants in Queensland lock in offshore sales
- Infrastructure: Limited pipeline capacity from North-South, East-West
- Reserves depletion: Bass Strait (Victoria) and Cooper Basin (SA) declining
- New development delays: Regulatory approvals, environmental concerns, investment uncertainty

Policy Failures:

- Gas reservation: Limited domestic reservation policies (vs. WA's 15% policy)
- Export controls: Minimal restrictions despite domestic shortages
- Price regulation: Limited government intervention in market
- Infrastructure planning: Inadequate pipeline and storage investment

Impact on Steel Transformation:

- Liberty Whyalla DRI plant: May require LNG import terminal (floating terminal proposed for Adelaide)
- BlueScope Port Kembla: Natural gas DRI pathway economically challenged
- Alternative: Skip natural gas, go directly to green hydrogen (higher cost, longer timeline)

6.2.2 Green Hydrogen Supply Chain Development

Massive scale-up required for steel sector hydrogen needs:

Production Requirements:

- Australian steel sector full transformation: 0.3-0.5 million tonnes H_2 annually (for 4-5 MT DRI)
- Current Australian production capacity: Minimal (few MW electrolyzers operating)
- Required electrolyzer capacity: 2-3 GW
- Additional renewable electricity: 5-7 GW dedicated generation
- Investment required: $8-12 billion (electrolyzers + renewables)

Infrastructure Gaps:

- Storage: Large-scale H_2 storage for buffering production/consumption variability
- Pipelines: Dedicated hydrogen transmission from production sites to steel mills
- Safety standards: Codes and workforce training for industrial hydrogen handling
- Supply certainty: Steel operations require 24/7 reliable supply (vs. intermittent renewable generation)

Competition for Hydrogen:

- Export markets: Japan, South Korea, Europe seeking hydrogen imports
- Ammonia production: For fertilizer and energy carrier
- Transport sector: Heavy vehicles, aviation, shipping
- Other industries: Chemicals, refining
- Risk: Steel sector outcompeted for hydrogen supply if export premium higher

Timeline Mismatch:

- Hydrogen cost target ($2/kg): Australian Government target 2030
- Current costs: $5-8/kg for green hydrogen
- Steel transformation decisions: Required 2025-2030 for competitiveness
- Risk: Premature commitment to hydrogen pathway before costs competitive, or delayed transformation missing market opportunities

6.3 Scrap Availability Constraints

Limited Domestic Scrap Generation:

- Current Australian scrap: 1.4 million tonnes collected/processed annually (InfraBuild)
- Per capita generation: Low compared to industrialized nations (reflects younger steel stock)
- Quality issues: Geographic dispersion, contamination, sorting infrastructure limited
- InfraBuild target: 2.5 million tonnes by 2027 (optimistic, requires collection infrastructure investment)

Scrap Growth Projections:

- Scrap availability correlates with historical steel consumption (15-30 year lag)
- Australian steel use increased 2000-2020, but from low base
- Potential 2030: 2.0-2.5 million tonnes domestic scrap
- Potential 2040: 3.0-4.0 million tonnes

- Insufficient for major EAF expansion beyond current capacity

Scrap Import Economics:

- Australia geographically distant from major scrap sources
- Freight costs: $80-120 per tonne from Asia, $150+ from USA/Europe
- Scrap prices: $300-500/tonne (varies with grade and market conditions)
- Transport 20-40% of landed cost makes imports marginal

Implications for Technology Pathways:

- 100% scrap-EAF strategy limited by availability
- DRI supplementation essential for quality and volume
- Shifts emphasis back to primary ironmaking transformation (DRI, ESF)
- Contrasts with USA, Turkey (abundant scrap enables EAF dominance)

6.4 Market and Trade Challenges

6.4.1 Small Domestic Market

Demand Constraints:

- Total Australian steel consumption: 5-6 million tonnes annually
- Population: 26 million (small compared to major steel-producing nations)
- Per capita consumption: 190-230 kg (moderate, below industrialized average)
- Growth prospects: 1-2% annually (infrastructure, construction, manufacturing)

Implications:

- Limited economies of scale for domestic production
- High per-unit costs compared to large-scale Asian producers
- Difficult to justify greenfield large-scale facilities for domestic market alone
- Export orientation essential for viability (but faces competitiveness challenges)

6.4.2 Import Competition

Australian steel faces increasing import pressure:

Import Trends:

- 2024: Steel imports increased despite domestic capacity
- Sources: China, Southeast Asia (Vietnam, Indonesia, Thailand, Malaysia), South Korea
- Products: Structural steel, reinforcing bar, coated products, pipes

- Price advantage: $100-300/tonne lower than Australian production (varies by product)

Trade Policy Limitations:

- WTO commitments: Limited ability to impose tariffs without justification
- Anti-dumping: Case-by-case, slow process, limited effectiveness
- Safeguards: Temporary measures, political challenges
- No carbon border adjustment: Unlike EU CBAM, Australia lacks mechanism to protect domestic producers investing in decarbonization

Competitive Dynamics:

- Asian producers: Lower labor costs, larger scale, government support
- Chinese overcapacity: 100+ million tonnes surplus capacity seeks export markets
- Vietnamese producers: New capacity, competitive costs, export-oriented
- Australian disadvantage: Higher costs not offset by product differentiation or trade protection

Industry Response:

- BlueScope focus on specialty coated products (niche differentiation)
- Liberty targeting domestic construction market (infrastructure projects)
- InfraBuild emphasizing local supply, service, recycling
- All seeking "green steel" premium as future differentiation

6.4.3 Export Market Challenges

Competition for Green Steel Markets:

- Japan and South Korea: Developing own hydrogen DRI capabilities
- Middle East: Abu Dhabi, Saudi Arabia investing in green iron/steel (cheap renewable energy, capital)
- Europe: Swedish H2 Green Steel, German transformation projects targeting premium markets
- Brazil: Renewable energy advantage, biomass pathways
- Australian challenge: Higher costs require offsetting advantages (certification, proximity, reliability)

Customer Requirements:

- Price sensitivity: Green premium willingness uncertain, varies by customer/sector

- Certification: Credible, transparent carbon accounting essential
- Volume/reliability: Customers need consistent supply at scale
- Quality: High-grade steel specifications for automotive, machinery sectors
- Australian capability: Can meet quality/reliability, but cost and volume challenges

6.5 Technology Risk and Uncertainty

6.5.1 Unproven Technologies at Commercial Scale

Electric Smelting Furnace (ESF):

- NeoSmelt pilot: First application for ironmaking at scale
- Technical risks: Electrode life, refractory performance, productivity, product quality
- Commercial risks: Capital cost, operating cost, energy consumption may exceed estimates
- Timeline risk: Pilot 2027-2030, commercial decisions post-2030 (delayed transformation)
- If unsuccessful: BlueScope Port Kembla lacks clear alternative pathway

Large-Scale Green Hydrogen Production:

- Electrolyzer scaling: Few MW to GW-scale requires massive deployment
- Renewable integration: Buffering intermittency for constant industrial supply
- Cost reduction: Target $2/kg by 2030 optimistic (current $5-8/kg)
- Infrastructure: Pipelines, storage, safety systems unproven at required scale
- If costs don't decline as projected: Hydrogen DRI economics fail

Hydrogen DRI Integration:

- Process optimization: Different kinetics vs. natural gas DRI
- Product quality: Ensuring metallization, carbon content meet steelmaking requirements
- Equipment adaptation: Hydrogen embrittlement, different operational parameters
- Supply chain: Continuous hydrogen delivery for 24/7 operations

6.5.2 Stranded Asset Risks

Blast Furnace Investments:

- BlueScope No. 6 BF reline: $1.15 billion, 15-20 year operational life
- Extends carbon-intensive production to 2040-2045
- Risk: Carbon pricing increase, import restrictions, customer requirements force early closure
- Potential stranded asset: $500+ million undepreciated capital
- Counterargument: "Bridge" enables continued operations, generates cash flow for transformation

Natural Gas DRI Plants:

- If Liberty proceeds with natural gas DRI: $1-1.5 billion investment
- Operational life: 20-30 years typically
- Risk: Carbon pricing makes uneconomic before end of life, or customer requirements demand green hydrogen
- Retrofit potential: Some DRI plants can convert from natural gas to hydrogen, but significant costs ($200-400 million estimated)

Infrastructure Investments:

- Hydrogen pipelines, storage: Highly specialized, limited alternative uses
- If hydrogen pathway fails or delayed: Stranded infrastructure investments
- Renewable energy dedicated to hydrogen: Alternative uses possible but require additional infrastructure

6.6 Policy and Regulatory Uncertainty

6.6.1 Carbon Pricing Trajectory

Safeguard Mechanism Evolution:

- Current settings: Gradual baseline decline, generous treatment for steel
- Future trajectory: Unknown, subject to political changes
- Election cycle risk: Change of government could strengthen or weaken mechanism
- Industry concern: Insufficient certainty for long-term investment decisions requiring 10-20 year payback periods

International Carbon Border Adjustments:

- EU CBAM implementation: 2026 full operation

- Potential impact on Australian steel exports to Europe: Limited direct (small trade), but precedent for other markets
- Risk: Japan, South Korea, other Asian nations implement similar mechanisms
- Australian response: No clear policy on domestic CBAM equivalent or export protection

6.6.2 Government Funding Sustainability

Grants and Equity Support:

- Current commitments: $1+ billion Green Iron Investment Fund, $200 million Powering Regions, other programs
- Future funding: Uncertain beyond current allocations
- Political risk: Change of government, budget constraints could limit continuation
- Industry requirement: Sustained support over 15-20 years for full transformation

Hydrogen Subsidies:

- Production tax incentive: $2/kg for 10 years (legislated but subject to revision)
- Headstart program: $2 billion (competitive process, limited slots)
- Sufficiency: Industry analysis suggests need for ongoing support beyond initial programs
- Sustainability: Long-term operational subsidies politically challenging

6.6.3 Trade and Industrial Policy Coherence

Conflicting Policy Objectives:

- Free trade commitments vs. protecting decarbonizing domestic industry
- Iron ore export revenue vs. value-added processing domestically
- Gas export commitments vs. domestic industrial supply
- Climate ambition vs. industrial competitiveness protection

Lack of Integrated Industrial Strategy:

- *Future Made in Australia*: Broad framework but limited steel-specific detail
- Multiple agencies: Federal Industry, Energy, Environment ministries plus states
- Coordination gaps: Renewable energy, hydrogen, steel policies not fully integrated
- Contrast: Japan's comprehensive Green Innovation Fund, Germany's Steel Action Plan, EU Clean Steel Partnership

7 Comparative Analysis with Other Steel-Producing Nations

7.1 Positioning Australia in Global Context

Table 1 presents comparative data on steel production, technology mix, and decarbonization approaches for Australia and selected major producers.

Table 1: Comparative Steel Production and Decarbonization Strategies

Country	Production (MT 2024)	EAF Share (%)	Primary Decarbonization Pathway
China	1,005.1	10	EAF expansion, H2 pilots, CCUS
India	149.4	45	EAF expansion, H2-DRI
Japan	84.0	25	H2 injection in BF, CCUS, H2-DRI
USA	79.5	70	Natural gas DRI, EAF expansion
Germany	37.2	30	H2-DRI transition, EU policy support
South Korea	63.6	30	HyREX technology, H2-DRI
Brazil	33.8	24	Biomass, H2-DRI, EAF
Australia	**4.8**	**30**	**H2-DRI, ESF pilot, EAF**
Sweden	4.2	35	HYBRIT (H2-DRI), leading deployment

7.2 Comparative Assessment of Decarbonization Approaches

7.2.1 Sweden - HYBRIT Model

Similarities with Australia:

- Small-scale domestic steel production (4.2 MT vs. Australia 4.8 MT)
- High-quality iron ore resources (LKAB magnetite vs. Australian hematite/magnetite)
- Abundant renewable energy (hydropower vs. Australian solar/wind)
- Export-oriented mineral sector
- High production costs requiring differentiation

Differences and Lessons:

- **Policy support:** Swedish government strong backing, EU policy framework (Innovation Fund, carbon pricing) provides favorable environment
- **Technology focus:** Clear commitment to H2-DRI-EAF pathway (HYBRIT demonstration successful)
- **Market positioning:** Premium European market willing to pay green steel premium
- **Energy costs:** Swedish electricity \$40-60/MWh (vs. \$80-150/MWh Australia)

- **Hydrogen:** Leveraging existing hydro for firm renewable supply (less firming challenge than Australian solar/wind)

Lesson for Australia: Clear technology pathway focus, strong policy commitment, and premium market access essential for success despite high costs.

7.2.2 USA - Natural Gas and Scrap Advantages

Similarities:

- Large land area with diverse regions
- Federal system with state/federal policy complexity
- Trade-exposed but limited international trade (relatively protected domestic market)

Differences:

- **Scrap abundance:** USA generates 70-80 MT scrap annually, 70% EAF penetration already achieved
- **Natural gas:** Abundant, low-cost ($3-6/GJ) enables economic natural gas DRI
- **Market size:** 80 MT domestic consumption provides scale economies
- **Policy approach:** IRA tax credits ($85/tonne CO_2 for CCUS, $3/kg H_2 for green hydrogen) rather than mandates

Lesson for Australia: Natural resource advantages (USA gas, Australia renewables) enable distinct pathways, but USA scale and scrap advantages not replicable in Australian context.

7.2.3 Japan - Technology Development Leader

Similarities:

- Import-dependent for iron ore and energy
- High production costs, advanced industrial capabilities
- Strong government-industry coordination
- Export-oriented economy requiring competitiveness

Differences:

- **Scale:** 84 MT production (17× Australia) provides R&D economies of scale
- **R&D investment:** NEDO Green Innovation Fund ě450 billion for steel ($3 billion) dwarfs Australian investment
- **Technology approach:** Multiple pathways (H2 injection in BF, COURSE50, CCUS, HyREX) hedging technology risk

- **International collaboration:** Partnerships with Australian iron ore producers (Rio Tinto, BHP) for secure supply

Lesson for Australia: Japan's technology development and international partnerships model applicableAustralia could be technology development partner (pilot/demonstration) and green iron supplier.

7.2.4 Brazil - Renewable Energy and Biomass

Similarities:

- Major iron ore exporter (competing with Australia for Chinese market)
- Abundant renewable energy (Brazil hydro/wind, Australia solar/wind)
- Developing country with capital constraints relative to ambitions
- Federal system with policy coordination challenges

Differences:

- **Biomass advantage:** Brazil's sustainable charcoal from eucalyptus plantations (unique pathway unavailable to Australia)
- **Domestic market:** 34 MT production serves larger Latin American market
- **Technology:** Vale Tecnored proprietary technology, Boston Metal MOE demonstration
- **Policy:** Leverage COP30 (2025 host) for climate finance and partnerships

Lesson for Australia: Leverage unique renewable advantages (as Brazil does with biomass), develop proprietary technologies (NeoSmelt parallel to Tecnored), use international forums for partnerships and finance.

7.2.5 Middle East - Emerging Green Steel Hub

Abu Dhabi and Saudi Arabia Green Steel Initiatives:
Competitive Advantages:

- Lowest-cost renewable electricity globally (solar $15-25/MWh)
- Sovereign wealth capital for large-scale investments
- Strategic positioning between ore suppliers (Australia, Brazil) and Asian markets
- Government commitment to economic diversification from oil/gas

Challenges:

- No domestic iron ore (must import)
- Limited industrial steelmaking heritage (building capabilities from scratch)
- Water scarcity for hydrogen production