Deloitte.

Mined the gap: Australia's place in the emerging green iron value chain

Technical Appendix A

March 2025

Contents

List of Abbreviations & Definitions

Acronym	Full name	Acronym	Full name
APAC	Asia-Pacific	**HBI**	Hot Briquetted Iron
ACCU	Australian Carbon Credit Unit	**HPTI**	Hydrogen Production Tax Incentive
ARENA	Australian Renewable Energy Agency	**IRS**	Internal Revenue Service
ATO	Australian Tax Office	**ITC**	Investment Tax Credit
BF-BOF	Blast Furnace – Basic Oxygen Furnace	**kWh**	Kilowatt Hour
CBAM	Carbon Border Adjustment Mechanism	**Kg**	Kilogram
CCUS	Carbon Capture, Utilisation and Storage	**LCOE**	Levelised Cost of Energy
CIS	Commonwealth Investment Scheme	**Met**	Metallurgical coal
COP	Conference of the Parties	**MECLA**	Materials and Embodied Carbon Leaders' Alliance
CSIRO	Commonwealth Scientific and Industrial Research Organisation	**NABERS**	National Australian Built Environment Rating System
DR	Direct Reduced	**NG**	Natural Gas
DRI	Direct Reduced Iron	**PTC**	Production Tax Credit
EAF	Electric Arc Furnace	**PV**	Photovoltaic
ESP	Environmentally Sustainable Procurement	**R&D**	Research and Development
ETS	Emissions Trading System	**RE**	Renewable Energy
EU	European Union	**RET**	Renewable Energy Target
Fe	Iron	**UK**	United Kingdom
FY	Financial Year	**US**	United States
GHG	Greenhouse Gas	**VRE**	Variable Renewable Energy
GDP	Gross Domestic Product	**WWF-A**	WWF-Australia
H2	Hydrogen		

Term	Definition
Low emissions iron/steel	Steel produced with an emissions intensity of between 0.05 to 0.4 tons of CO2e per ton of steel depending on scrap ratio used. (ResponsibleSteel & IEA)[1]
Green iron/steel	Iron and steel produced using solely renewable energy sources and renewable hydrogen, mitigating fossil fuel use[2].

Source(s): 1. Global Efficiency Intelligence, 2023. 2. World Economic Forum, 2022.

Executive Summary

Executive Summary

How can Australia become a green iron partner of choice?

Purpose

Global steel production is a significant energy consumer and responsible for 7-9% of global greenhouse gas emissions. With steel demand projected to rise by nearly a third by 2050, this problem is only expected to grow. For the world to collectively achieve net-zero targets, the global steel value chain needs to decarbonise rapidly.

In July 2024, WWF-Australia (WWF-A) released "Australia's Green Iron Key: Unlocking Asian steel decarbonisation, securing Australia's economic future". The report focuses on the imperative and opportunities for Australia to lead in the decarbonisation of the steel industry. Asian steelmakers account for the bulk of global steel emissions and are looking for partners to tackle emissions. Australia, as the world's largest iron ore and metallurgical coal exporter, forms an integral part of steel's abatement challenge.

In "Australia's Green Iron Key", WWF-A presents a comprehensive opportunity thesis for Australia to become a global leader in green iron production, with significant economic and environmental benefits should it capture this window of opportunity. The transition to green iron would secure Australia's position as a key player in the global steel supply chain and could generate significant economic benefits, including GDP growth, taxation benefits and job creation. In addition, Australia could unlock and accelerate the abatement of steel in Asia Pacific.

This report builds on previous WWF-A work. It further investigates the statements above and analyses what needs to happen for Australia to strike the iron while it's hot and grasp its green iron and steel opportunity. The analysis highlights whether Australia is a competitive player compared to other fast-moving regions, provides the evidence base to strategically inform which part of the value chain Australia should play in, and underscores key conditions to become a partner of choice for Asian steel decarbonisation. The study suggests concrete actions to build on public and private sector mobilisation work and ensure the cleanest transition for steel.

This report explores 4 fundamental questions about green steel

1. *Why is the APAC region essential to global steel decarbonisation?*
2. *Is Australia a competitive partner to support Asian steelmakers to decarbonise?*
3. *What does Australia need to do to become a partner of choice for Asian steelmakers?*
4. *What is needed to mobilise the public and private sectors to accelerate decarbonisation of steel in APAC?*

Responding to these questions will provide an understanding of the key intervention points and opportunities to maximise green steel within Australia.

Note: This analysis focuses on Japan, South Korea and China as early movers.

Executive Summary

Australia can maximise its economic opportunity by supporting Asia to go greener faster

The speed and scale of steel decarbonisation will be determined in Asia. The steel sector is responsible for 7-9% of global greenhouse emissions, with the majority generated in Asia. Over the next decade, Asian steelmakers face a choice to invest in aging facilities: doubling down on existing processes or going green. Choosing to decarbonise is necessary to remain on a Paris-aligned trajectory.

Asian steelmakers are acting slower than regional competitors, and policy settings remain loose. While there is a growing push to decarbonise the steel sector globally, Asian economies are punching well below their weight with announced green steel projects. A closer inspection of economic incentives suggests that Asian emissions trading schemes price carbon too low, and Asian end steel users are not yet willing to pay the premiums associated with near-zero emissions steel. **Without coordinated action, Asian steel decarbonisation risks coming too little too late.**

There are green shoots – momentum for green iron and steel is accelerating in a range of regions including Australia, Brazil, Canada, and the Middle East. The market has aligned around a value chain configuration which would see iron ore reduced with green hydrogen to produce a briquette for export. Alternative pathways such as exporting iron ore and hydrogen have been found to be materially less efficient.

Australia's renewables endowment and proximity to Asia make us a competitive green iron partner for Asian steelmakers. A wide array of countries have the potential to become green iron suppliers – it promises to be a more competitive market than some of our existing exports. And while Australia is not likely to offer the cheapest green electricity or hydrogen, after transport costs & policy are factored in, we emerge a clear preferred supplier.

An Australian green iron industry represents an important pathway for value-added exports and could deliver significant global abatement.

Asian steelmakers are unlikely to jump straight to green iron, with natural gas emerging as the most likely transition pathway. Green iron manufacturing may not be commercially viable until the 2040s, with timing determined by Asian carbon pricing. Gas-based iron reduction is cheaper and could reduce steelmaking emissions by 35-55%. Australia will need to consider a diversified approach to establish a foothold in the market.

Natural gas is a transitory solution only – significant effort will be needed to ensure a smooth gas-to-green transition. The cost structures of gas DRI and green hydrogen, and international misalignment of regulatory standards for steel decarbonisation may inhibit an orderly transition to green iron. It will be important that high integrity standards support green iron projects to overcome the commercial inertia of the market and retain line of sight to Paris commitments.

It is in Australia's economic interests for a swift transition to green iron, where our comparative advantage is unassailable. 5 fundamental prerequisites must be satisfied for Australia to emerge as Asia's primary steel decarbonisation partner.

1. Australia must develop lost-cost ironmaking inputs including renewables and DR grade orders
2. Australia must invest in ironmaking capacity soon
3. Australia needs Asian steelmakers to prioritise a diversity of low carbon suppliers
4. Australia needs Asian governments to raise carbon pricing & incentives for green steel adoption
5. Australia needs to influence market rules and norms to favour green iron over gas-based processes.

We need to strike while the iron is hot and make progress across these five areas. Australia and the Asia Pacific region have a critical role to play in accelerating development of a pan-Asian green steel value chain. This has the potential to deliver a step change in emissions reduction, speed the economic transition of regional communities, and lock in regeneration through policy conditions.

Executive Summary

Turning Australia's Green Iron Key will require coordinated action across 5 domains

Rapid deployment innovation	Gas-to-green transition path	High integrity standards	Regional carbon pricing	Pragmatic green statecraft
Ensuring Australia sets the path to cost competitive green iron inputs in renewables,	*Ensuring Australian ironmaking and APAC steelmaking achieve real and accelerated decarbonisation*	*Ensuring standards and definitions alignment to avoid investment in adverse economic and environmental outcomes*	*Ensuring a higher willingness-to-pay for green iron and steel through appropriate pricing on pollution*	*Ensuring collaboration across the value chain and jurisdictions on investment, policy support and offtake*
1. Significantly raise deployment rates for wind and solar	1. Identify least emissions gas supply options for prospective ironmaking	1. Convene APAC working group to harmonise green iron standards	1. Establish focus on green steel at COP31	1. Agree new bilateral or multilateral green iron corridors between Australia and trading partners
2. Accelerate project approvals for green iron precursors: magnetite, renewables and hydrogen while delivering nature positive outcomes	2. Leverage conditionality of production incentives to drive hydrogen blending by 2035	2. Support alignment on how emissions thresholds should be ratcheted over time for steel end users	2. Create an awareness campaign to address misconceptions of carbon pricing & build support	2. Encourage Japan and Korea to leverage existing hydrogen contract-for-difference programs to target blended green iron
3. Make common user infrastructure (e.g. transmission) the deployment priority	3. Require government-supported ironmaking feasibility studies to include hydrogen blending scenarios and timeframes	3. Identify the highest impact green iron pricing mechanisms	3. Conduct thorough analysis regarding appropriate scale and trajectories of Asian carbon prices	3. Stand up a green steel buyers' coalition with Australian and Asian offtakers
4. Invest in R&D to reduce deployment costs and enable use of Australian hematite ores	4. Provide technical and commercial assistance to Asian economies to accelerate renewable rollouts		4. Assess implementation viability of a regional Carbon Border Adjustment Mechanism for Asia	

1. Asia is essential to global green steel decarbonisation. Why?

The hard-to-abate steel sector is responsible for 7-9% of global GHG emissions

Asian steelmakers will make or break regional decarbonisation targets

Figure 1: Share of world **crude steel production** by country in 2023[3]

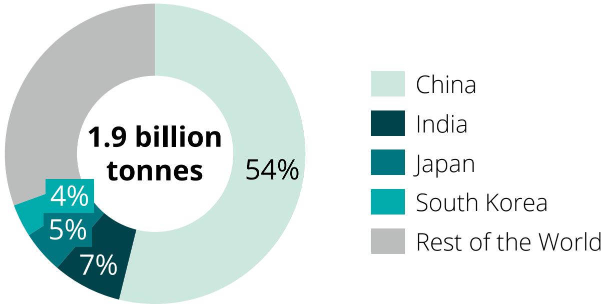


Figure 2: Share of world **steel emissions** by country in 2023[4]

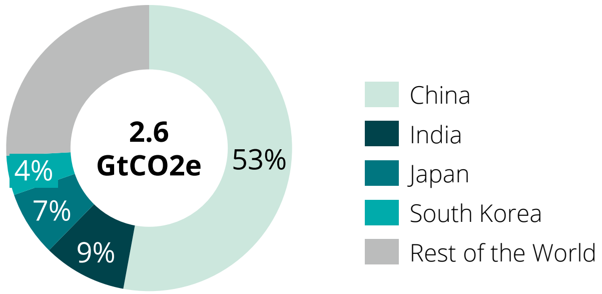
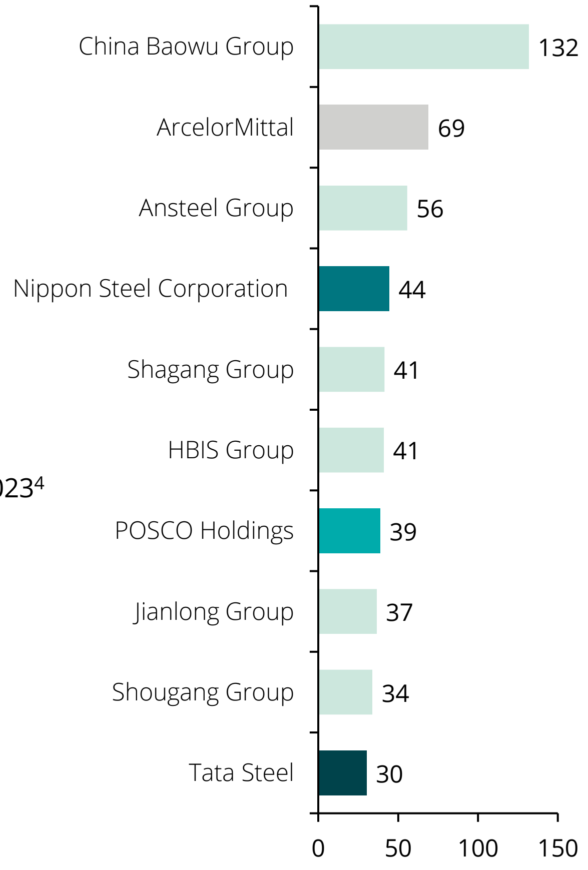


Figure 3: Top 10 **steel producers** by production in 2022 (Mt)[5]



Key Takeaways

Steel is one of the most emissions-intensive industries in the world. Steel manufacturing accounts for 7-9% of global GHG emissions.[1] The steel value chain has large energy requirements and significant process emissions related to its major inputs, metallurgical coal and iron. It is a hard-to-abate sector, with attempts to reduce emissions in steelmaking facing costly infrastructure changes or technological challenges.

The problem is projected to grow. A 33% rise in steel demand, driven largely by growing urbanisation in developing countries such as India, is projected by 2050.[2] In the absence of development and uptake of abatement technologies, steel's emissions challenge is exacerbated.

The issue disproportionately impacts the Asia Pacific (APAC) region. China, South Korea, Japan and India represented 69% of global steel production in 2023 (Figure 1) and are responsible for 73% of global steel emissions (Figure 2).[3,4] These countries house 9 out of 10 of the world's largest steel companies (Figure 3).[5] Similarly, the majority of steel production is consumed domestically, highlighting the importance of behaviour change in these consumer markets.[3]

It is paramount that APAC steel players step up and accelerate their decarbonisation efforts. For the world to collectively achieve net-zero targets, the global steel value chain needs to decarbonise rapidly. APAC steel producers and consumers are essential to the solution.

Source(s): 1. World Steel Association, 2021. 2. Mission Possible Partnership – Steel, 2022. 3. World Steel Association, 2024. 4. Climate Trace, 2023. 5. Green Steel Tracker, 2024.

Australia plays an integral role in steel's emissions challenge

Failure to act in adapting revenue streams to a decarbonising world risks leaving Australia worse off

Figure 4: Australia's **iron ore** exports earnings by destination in 2022-2023 ($bn)[1]

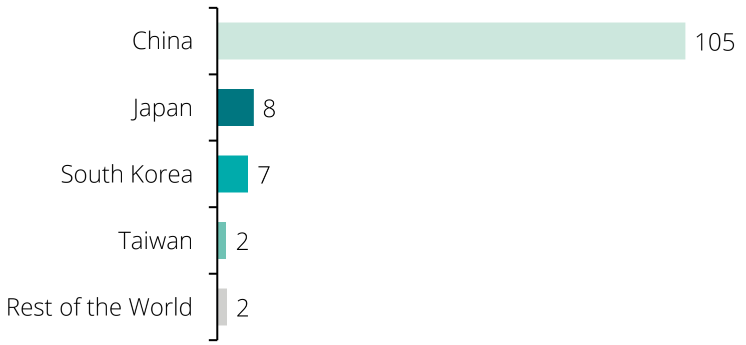


Figure 5: Australia's **metallurgical coal** export earnings by destination in 2022-23 ($bn)[1]

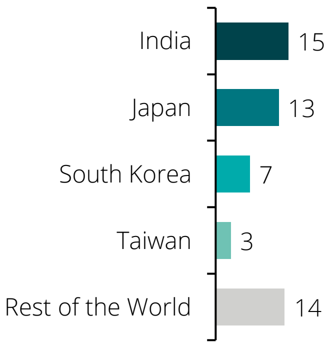


Figure 6: Australia's share of **iron ore** supply by importing country[5]

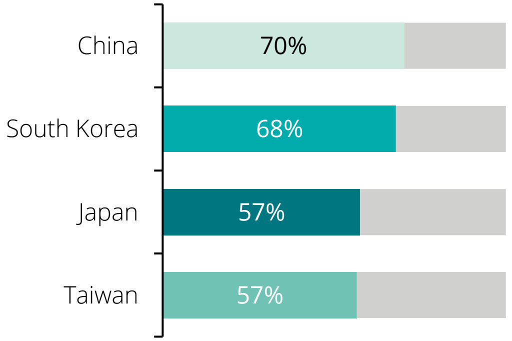
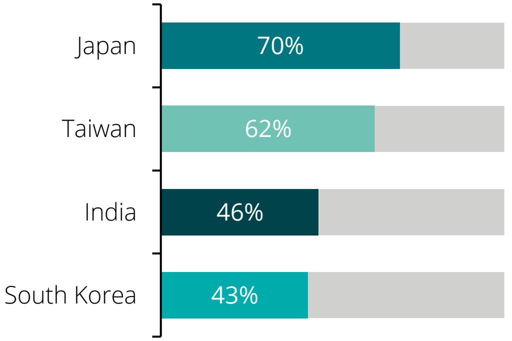


Figure 7: Australia's share of **coal briquettes** supply by importing country[5]



Source(s): 1. Resources and Energy Quarterly, March 2024. 2. Assuming Australia's global share of metallurgical coal emissions (1.33 Gt in 2022, from Climate Analytics, August 2024) are responsible for steel emissions only, 2022 steel demand of 1840.2 Mt (from World Steel Association, no date) and 2022 average global steel emissions intensity of 1.41 tCO2e/t steel (from IEA, 2023). Refer to slide 25 for specific emissions intensity numbers used in the report modelling and analysis results. 3. Queensland Budget Strategy, 2024. 4. Western Australia State Budget, 2024 5. OEC, 2022

Key Takeaways

As the primary supplier of the world's iron and metallurgical coal,[1] **Australia is a significant enabler of the embodied emissions of steel**. Through exports of iron ore and met coal, Australia is indirectly responsible for 51% of global steel emissions.[2]

Australia's economic and social prosperity are reliant upon these two export products. During FY23, Australian met coal represented 13% of total commodity export earnings, with iron ore valued at 27%.[1] In FY23, Australia exported $124bn worth of iron ore and $62bn worth of met coal (Figure 4 and 5).[1] Australian states are dependent on mining royalties, in particular Queensland and Western Australia. Royalties in FY24 amounted to $10.5bn for coal in QLD and $0.9bn for iron ore in WA.[3,4]

Australia's key trade partners are the emissions-intensive Asian steelmaking countries. Australia is the key supplier of iron ore to China, South Korea, Japan and Taiwan (Figure 6). Similarly, Australia is the majority supplier of Japan, Taiwan, India and South Korea's coal needs (Figure 7). In the long term, these players will seek to decarbonise their value chains.

Failure to act in adapting these revenue streams to a decarbonising world will leave Australia worse off. By neglecting first mover advantages, Australia will miss the opportunity to future-proof its largest industries and economy as decarbonisation policy, carbon pricing, green technological advancements and emission regulation place ever shortening horizons on coal usage.

In the next decade, Asian steelmakers will make long-term investment decisions

Decarbonisation could spark a reorganisation of the global steelmaking value chain

Figure 8: Asian steel fleet by age[1]

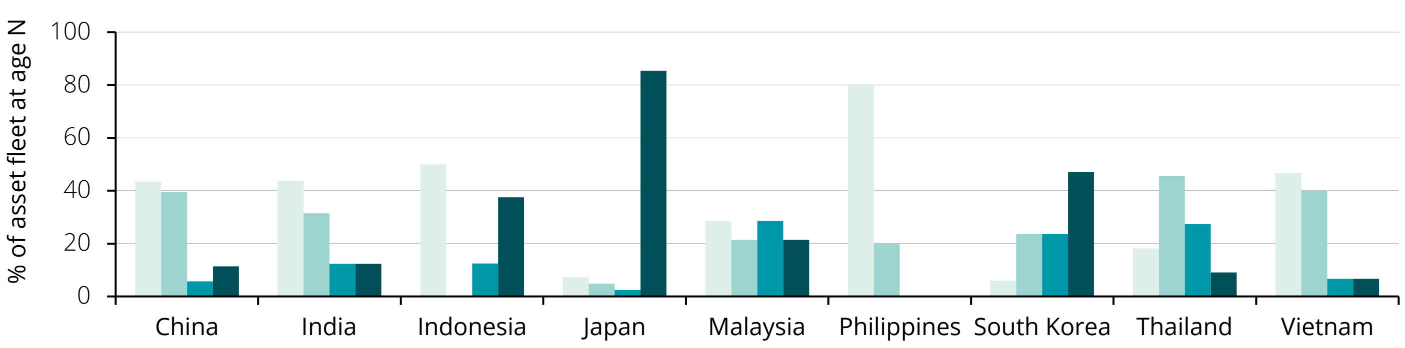
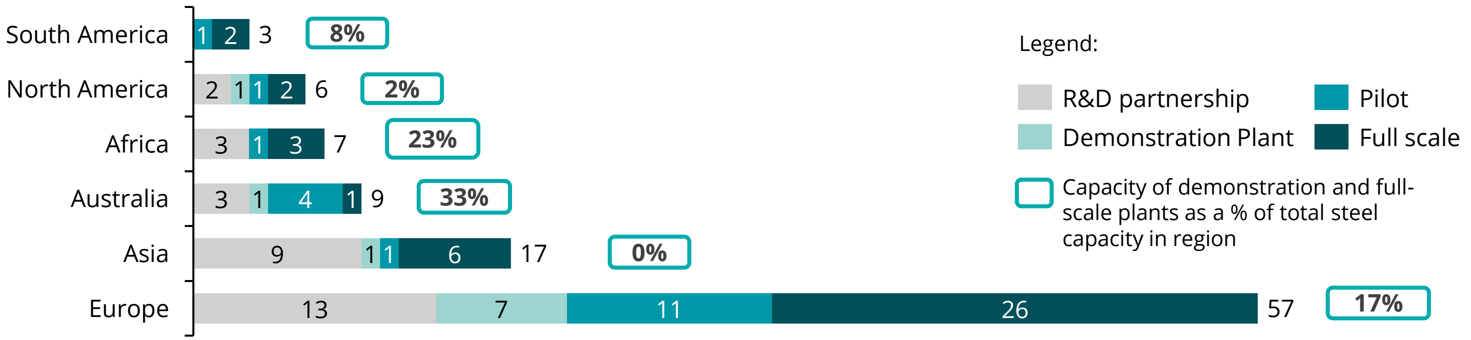


Figure 9: Count of low-carbon iron and steel investment projects by region and status vs total regional steel capacity[2]



Notes: Countries with project(s) per region – Africa (Mauritania, Namibia, South Africa) ; Middle East (Oman, Saudi Arabia) ; Asia (China, Japan, Malaysia, South Korea, Thailand) ; Australia ; Europe (Austria, Belgium, Finland, France, Germany, Italy, Netherlands, Norway, Romania, Spain, Sweden, United Kingdom) ; North America (Canada, United States) ; South America (Brazil, Chile, Mexico). Includes active and prospective projects before 29 April 2024. Definition of "low-carbon": Green Steel Tracker includes a project in its database if it is a project phasing out BF (Considers technologies moving away from Blast Furnaces (BF) including H-DRI, MOE, Electrowinning, ESR, NG-DRI to H-DRI, Biogenic syngas DRI, Electrochemical process) or if it complements conventional steelmaking (Considers technologies that complement existing primary steel production set-ups including: CCS for BF-BOF, CCUS for BF-BOF, CCU for BF-BOF, Biomass for BF, BF-BOF to EAF for green iron, BF-BOF to Hisarna). Projects are evaluated and categorised into "main tracking" (projects using renewable energy and renewable-sourced hydrogen) and "complementary tracking" depending on the technology and transparency level.

Source(s): 1. Global Energy Monitor, 2024. 2. Green Steel Tracker, 2024.

Key Takeaways

APAC steelmakers will be making long-term investment decisions that will shape production and emissions for the next 50 years. For now, Asia's steelmaking fleet remains young and the cost of switching to alternatives is high. However, Japan and South Korea have the oldest fleet (85% and 47% of their fleet respectively is older than 45 years, Figure 8)[1] and will have to make decisions on their way forward, without risking stranded assets or a loss of sovereign capability.

Ultimately, APAC steelmakers are faced with a choice in the advent of a net zero world. As decarbonisation pressures and green premiums ramp up, there is an incentive to split the iron and steelmaking processes.

Asian countries' energy structures are not well suited to low-carbon ironmaking, suggesting a focus on partnerships while they prioritise green steelmaking with Electric Arc Furnaces (EAF). Cost implications and challenges with renewable energy availability spur a decoupling trend of ironmaking from steelmaking. Through partnerships, Asian steelmakers will likely outsource low-emissions iron making (DRI) to a different location.

Partnerships across jurisdictions are already being formed, with announced low-carbon iron projects in Asia lagging the rest of the world as a share regional installed steel capacity (Figure 9).

Note: The Green Steel Tracker consolidates and classifies low-carbon projects in the primary steel sector. In contrast to often-used definitions of green steel, it includes projects with technologies that reduce steel emissions, rather than adopting a specific definition of "green" linked to an emissions intensity.

There is currently little incentive for Asian steelmakers to decarbonise

Policy settings are insufficient to decarbonise the 73% of global steel emissions in Asia

Figure 10: Interaction of carbon prices & green steel cost premium (willingness-to-pay) [1]

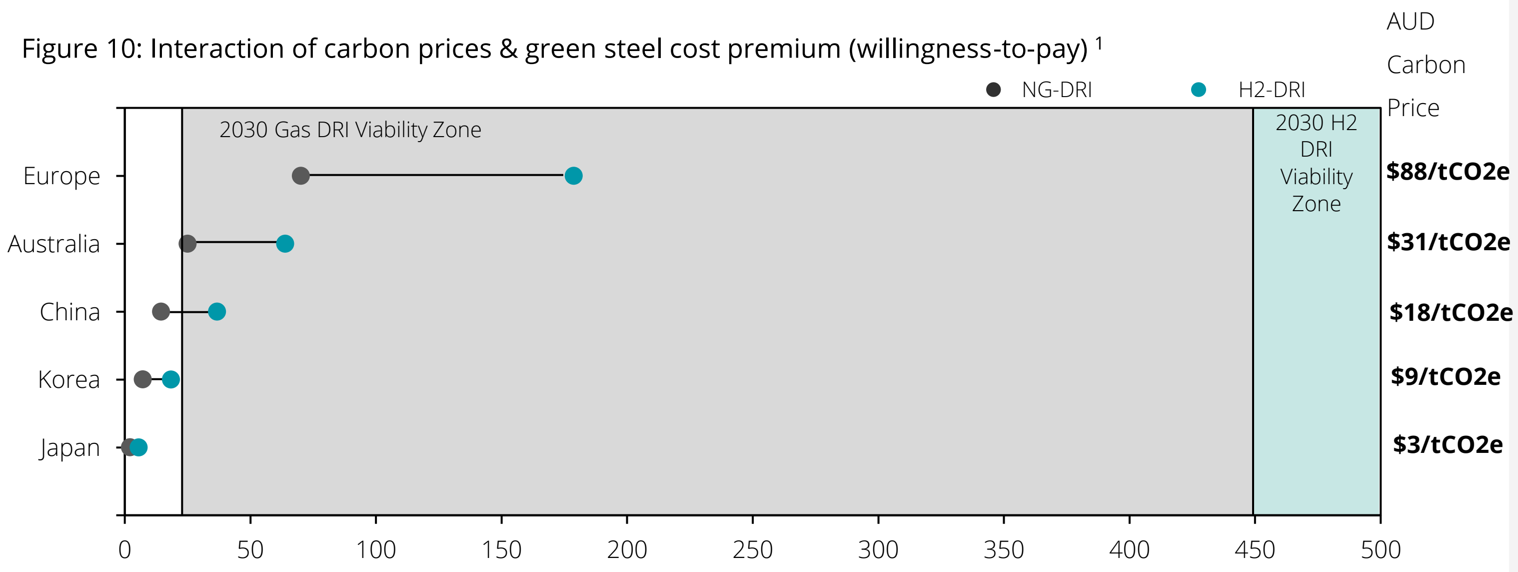
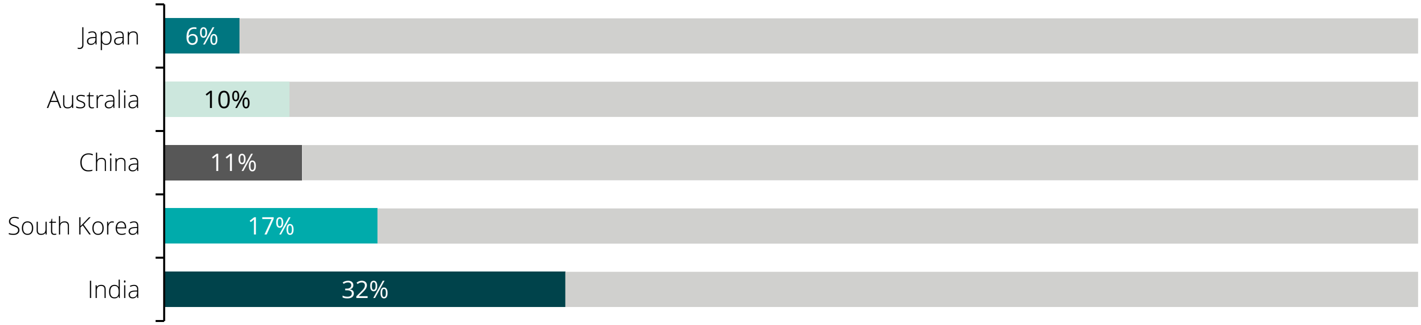


Figure 11: European Union Carbon Border Adjustment Mechanism (EU CBAM) Exposure:
Share of iron and steel exports destined for the European Union **by exporting** country in 2022[2]



Source(s): 1. Deloitte calculations based on World Bank, 2024 and Deloitte Green Value Chain Explorer: Iron and Steel. A 'viability zone' indicates where the carbon price is high enough that the willingness to pay for decarbonisation is greater than the cost premium of the DRI process. Willingness to pay expresses the carbon price as a premium on BF-BOF steel. 2. OEC, 2022

Key Takeaways

Asian steelmakers' willingness-to-pay for low-emissions iron is currently too limited to catalyse investment in steel abatement. Exceptionally low-carbon prices see DRI adoption as a cost to the business in a highly competitive industry (Figure 10). In contrast to Asian markets, the combination of ETS and CBAM has insulated Europe from this dynamic while closing the cost gap for green steel. As carbon prices rise, the cost premium for H2 DRI green steel falls dramatically. In fact, the European dynamic may create a short-term green premium for DRI steel.

Existing policy mechanisms in APAC lack the magnitude or incentivisation needed to drive industry to implement decarbonisation solutions. Supply-side policy for green iron and steel production is emerging, however, is to date insufficient to stimulate market creation and bridge the commercialisation gap. Demand-side policies that enforce the uplift of green iron and steel production are lacking**.**

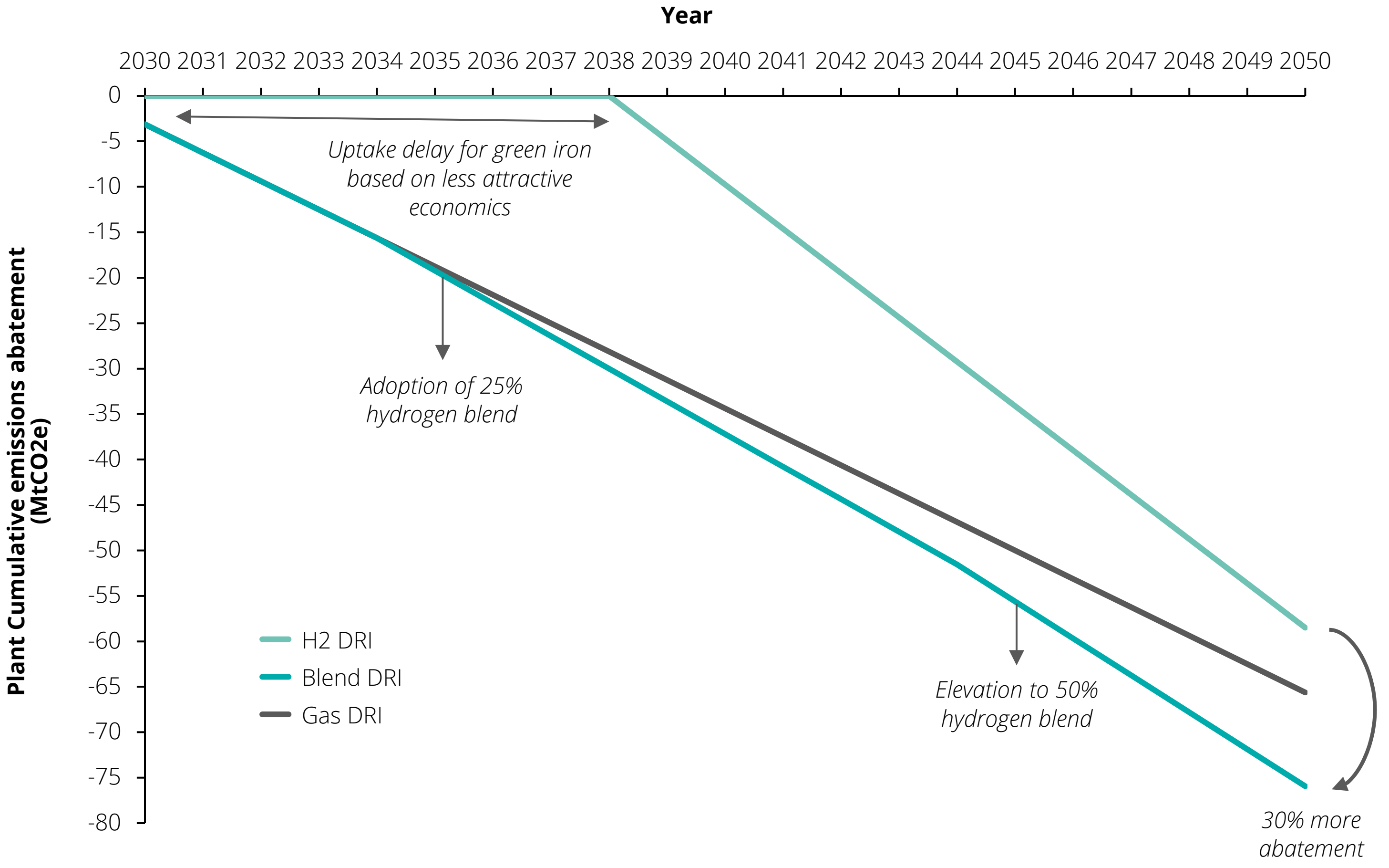
Spillovers from Europe's CBAM could drive some change at the margin. However, only a small portion of APAC steelmakers' exports are exposed to the EU CBAM, suggesting they will be able to manage the impacts of the policy (Figure 11).

Coordinated action across APAC is needed to shift the dial. Higher carbon prices and the adoption of a CBAM in target markets improve the case for green steel.

Without coordinated action, Asian steel decarbonisation comes too little too late

Australia can play a role as a green iron key to accelerate Asian steelmakers' decarbonisation

Figure 12: Potential cumulative emissions abatement for a single 2.5Mt vertically integrated low carbon steel project fed by either gas-, blended or green hydrogen-DRI.[1]



Source(s): 1. Deloitte Green Value Chain Explorer: Iron and Steel, 2024. Abatement is only achieved if the cost of steel via a BF-BOF route is higher than via the DRI-EAF route. This chart assumes imposition of a linearly increasing regional carbon price beginning at $5/tCO2e in 2030 and reaching $100/tCO2e in 2050, which sees BF-BOF prices gradually rise

Key Takeaways

Limited incentives for green steel adoption will materially delay the decarbonisation of the Asian steel fleet. Leaving the adoption of green iron and steel production to the incumbent market could delay adoption until beyond 2040, locking in higher cumulative emissions (Figure 12).

1. **Green iron** (green DRI) **abates significantly more than gas-based iron** (gas DRI)**, but timing matters**. Higher costs mean steelmakers are slow to adopt green iron, delaying its abatement potential**.** In reality, to deliver more abatement than gas DRI by 2050, it needs uptake by the mid 2030s.

2. **Small changes in carbon prices would make gas DRI commercially viable earlier than green DRI.** Gas DRI could deliver 12% more abatement by 2050.

3. **A gas-DRI process that transitions to a hydrogen blend represents the highest abatement pathway for Asian steelmakers.** This could deliver 30% more abatement than waiting for green iron.

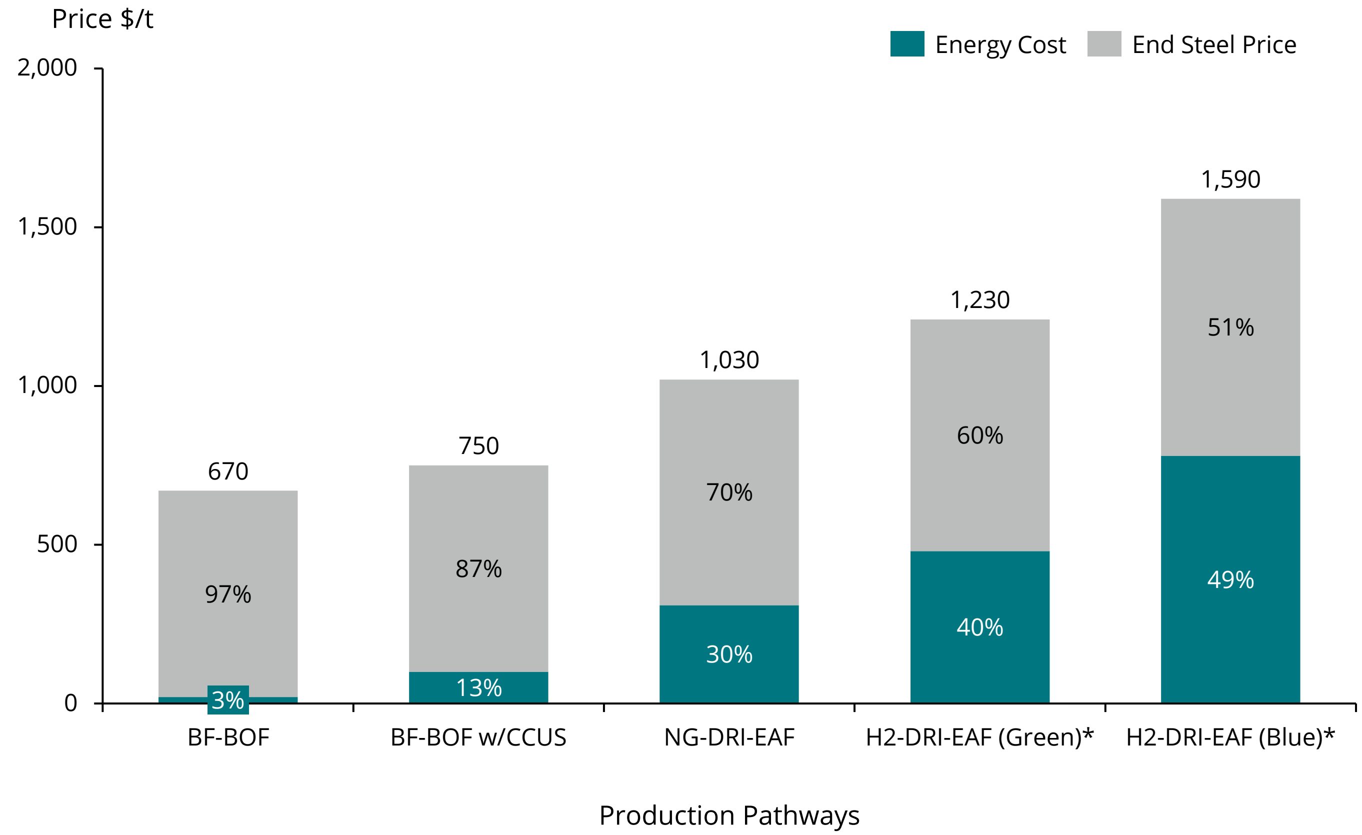
Australia can grasp this opportunity and be the green iron key to accelerating Asian steel decarbonisation. In doing so, it can capture greater value in a new green steel value chain**.** However, Australia needs to proceed strategically in terms of its production pathway (timing and technology) and play in parts of the value chain where it has a comparative advantage.

2. Can Australia be a competitive green iron partner for Asian steelmakers?

Investment in steel abatement will be driven by unit economics and abatement costs

To play a role in steel decarbonisation, Australia will need to be a cost-competitive supplier

Figure 13: Comparison of future Australian delivered end-steel prices by production route (H2-DRI-EAF, NG-DRI-EAF, BF-BOF, BF-BOF-CCUS) when exporting to Japan, with energy share of cost illustrated for 2030[1].



Source(s): 1. Deloitte Green Value Chain Explorer: Iron and Steel, 2024

Notes: 1. In figure 13, the EAF process has been modelled using renewable electricity (green electricity). 2. H2-DRI-EAF (Green)* is referring to green hydrogen used in the hydrogen DRI process. Similarly, H2-DRI-EAF (Blue)* refers to blue hydrogen used in the DRI process. Note transport costs are not included for simplicity which reduces comparability with other charts.

Key Takeaways

The high cost of hydrogen makes green iron and steel production economically challenging in the short-term. Energy costs for hydrogen-based steel are a significantly higher share of the end-price of steel than conventional methods (Figure 13). Immaturity of global hydrogen technologies and markets, expensive initial capital investments and high operational costs of industrial scaled hydrogen plants significantly inflates the price consumers pay for green steel.

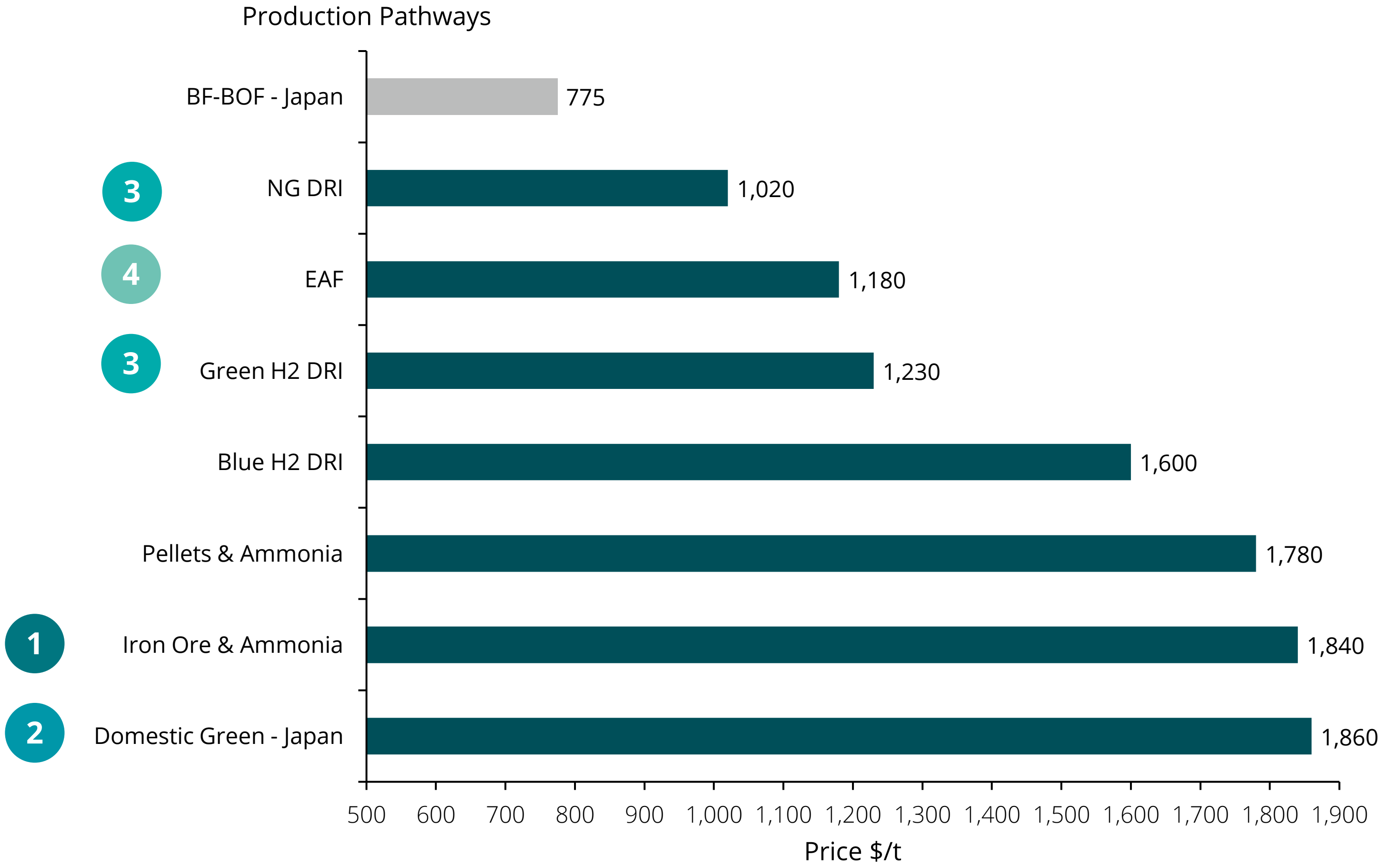
As mentioned in section 1, **the uptake of green steel in the APAC region is delayed by inadequate carbon pricing and a low willingness-to-pay** for low-emissions iron and steel. These factors increase the cost of adopting DRI capabilities and underpin the investment decision surrounding steel emissions abatement; with a lack of global policy preventing widespread uptake of green steel in APAC.

In the absence of carbon pricing and green premiums, current economics provide investment signals that lock in high-emitting steel pathways globally and delay the adoption of green production routes. The current economic competitiveness of green steel production cannot compete with the significantly leaner capital and operational costs of conventional blast furnace technologies (Figure 13). Moreover, blue H2-DRI-EAF steel production presents the highest cost due to the underlying cost of hydrogen. When it comes to green investments, the use of scrap metals in secondary steel is prioritised.

Exporting green iron is Australia's natural sweet spot

Across a range of value chain configurations, green iron is likely to strike the right balance of cost and viability

Figure 14: Comparison of future delivered end steel prices along the Australian export value chain to Japan in 2030[1].



Source(s): 1. Deloitte Green Value Chain Explorer: Iron and Steel, 2024. 2. Recycling Today, 2023

Key Takeaways

There are multiple export pathways available for Australia to support decarbonisation of Asian steelmaking (Figure 14). Different green production technologies and value chain configurations exist, with varying investment and abatement implications (see appendix 16).

1. **Commercially, exporting green hydrogen and iron ore products for low-emissions ironmaking in Asia is unlikely to be viable.** The need to import hydrogen and high costs associated with conversion to ammonia and transportation present barriers to greening the iron making process domestically.

2. **Similarly, the cost of producing fully green steel in Asia is likely to be prohibitively high** due to constrained renewable generation potential (such as Japan and South Korea) and higher value uses for renewable resources**.**

3. **Australia can supply gas-** (NG DRI) **or green-iron** (Green H2 DRI) **to Asian markets at a manageable premium to existing prices** but green H2-DRI is cheaper**.**

4. **While the chart also implies that Australia could be a lower cost supplier of EAF-based green steel,** Asian countries have long prioritised domestic production and offered support mechanisms to retain these capabilities. Key APAC players will look to protect domestic steelmaking capacity from offshoring.

Low-cost inputs will determine leading suppliers of green iron

Australia's renewables endowment can deliver low cost green iron, but ore quality will prove a challenge

Figure 15: Comparison of future delivered end-steel prices by iron-producing country (DRI), with steel production (EAF) occurring in Japan in 2030 and 2050.[1]

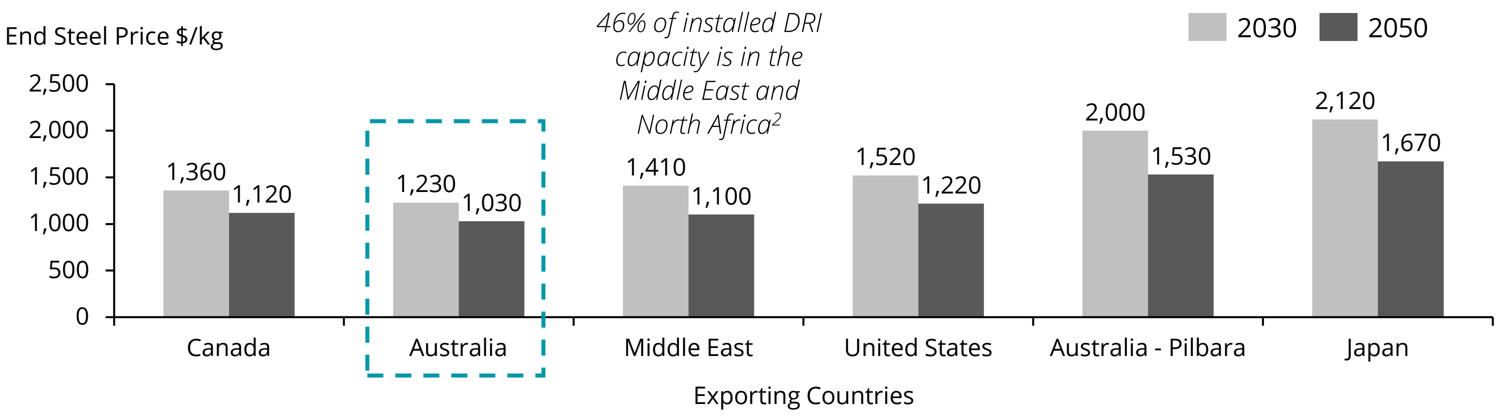
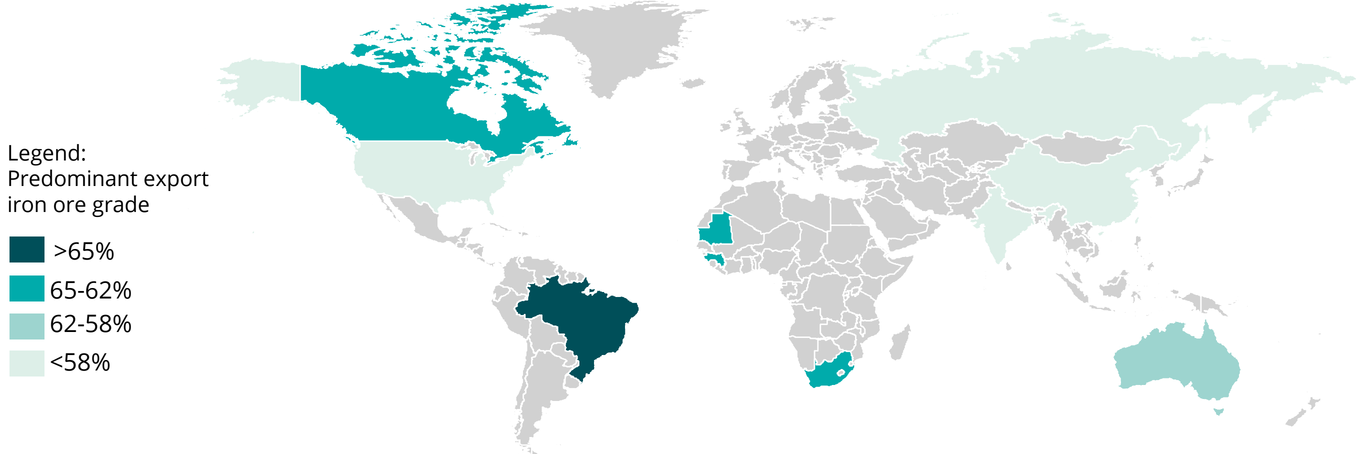


Figure 16: Comparison of predominant iron ore qualities across exporting nations.[3]



Key Takeaways

The energy-intensive nature of green iron and steel production means low-cost energy producers will have a comparative advantage in green production.

This factor puts Australia in a competitive position compared to other jurisdictions (Figure 15). Australia's favourable climate conditions and vast amounts of land allow for cheap and uninterrupted renewable energy, reducing the cost of green steel significantly.

Coupling low-cost energy with access to high-quality ores offers the most cost-effective pathway to decarbonise the green steel value chain. Green iron corridors from low-cost energy suppliers with access to high-quality ores to steelmaking countries are therefore likely to emerge. At first glance Australia appears well-positioned to capture this comparative advantage, being one of the largest producers of high-grade hematite ores globally.

However, while plentiful, Australia's Pilbara hematite is incompatible with existing green steel technologies, and its quality is inferior to other key exporters (Figure 16). Existing green steel technologies such as DRI require a superior hematite; with iron contents of 67% and above. Australia is largely endowed with hematite containing 56 to 62% iron ore content in Western Australia[4], putting it at a disadvantage compared to more compatible countries such as Brazil, Canada and South Africa.[5] This suggests new deposits of more suitable magnetite, such as in South Australia may need to be brought online.

Source(s): 1. Deloitte Green Value Chain Explorer: Iron and Steel, 2024. 2. Midrex, 2023 3. Institute for Energy Economics and Financial Analysis, 2023. 4. Australian Government (Geoscience Australia), 2023. 5. Institute for Energy Economics and Financial Analysis, 2023.

A wide array of countries have potential to become green iron suppliers

Australia performs less well on capex and opex costs compared to prospective competitors

Figure 17: Comparison of factors underpinning competitive advantage in the green steel value chain

Relative disadvantage → Relative advantage

Factor underpinning competitive advantage		Proxy metric*	AUS	BRA	AFR	CAN	ME	USA	CHN	EU	IND
CAPEX	**Construction costs**	*Construction cost index[1]*									
	Cost of capital	*Risk premium[2]*									
ELECTRICITY	**Renewable energy potential**	*Solar potential (specific PV power output)[3]*									
		Wind potential[4]									
	Renewable energy investment	*Market attractiveness[5]*									
		Renewables deployment (5y average GW/yr)[6]									
		Installed renewable capacity per capita[7]									
	Cost of grid electricity (current)	*USD/kWh[8]*									
LABOUR	**Cost of labour**	*Nominal monthly wage (AUD/month)[9]*									
	Labour standards	*Existing labour practices/standards[10]*									
INPUTS	**Access to high-quality iron ore**	*Production (H/M/L/N) and quality[11]*									
	Hydrogen production	*Hydrogen strategy, policies and projects[12]*									
GENERAL	**International investment**	*Ease of doing business index[13]*									
	Economic development	*Political stability index[14]*									
	Export infrastructure	*Logistics performance index[15]*									
	Manufacturing expertise	*Economic complexity index[16]*									
	Carbon pricing	*Carbon price in 2024 ($AUD)[17]*									
	Green iron/steel state support	*Case studies / stakeholder engagement[18]*									

Key Takeaways

Australia is competing on an international scale to attract investment in the steel value chain. For iron ore mining, Australia is challenged by Brazil, Canada and African countries such as Guinea and South Africa. Contenders for ironmaking include countries particularly in the Middle-East, like Oman and the United Arab Emirates.

Australia is an appealing destination for green iron and steel making (Figure 17). Notably, its abundance of iron ore reserves and leading market position in iron ore supply, its renewable energy potential and hydrogen investment are considered strategic advantages. In addition, Australia is viewed as a reliable and credible partner to do business with.

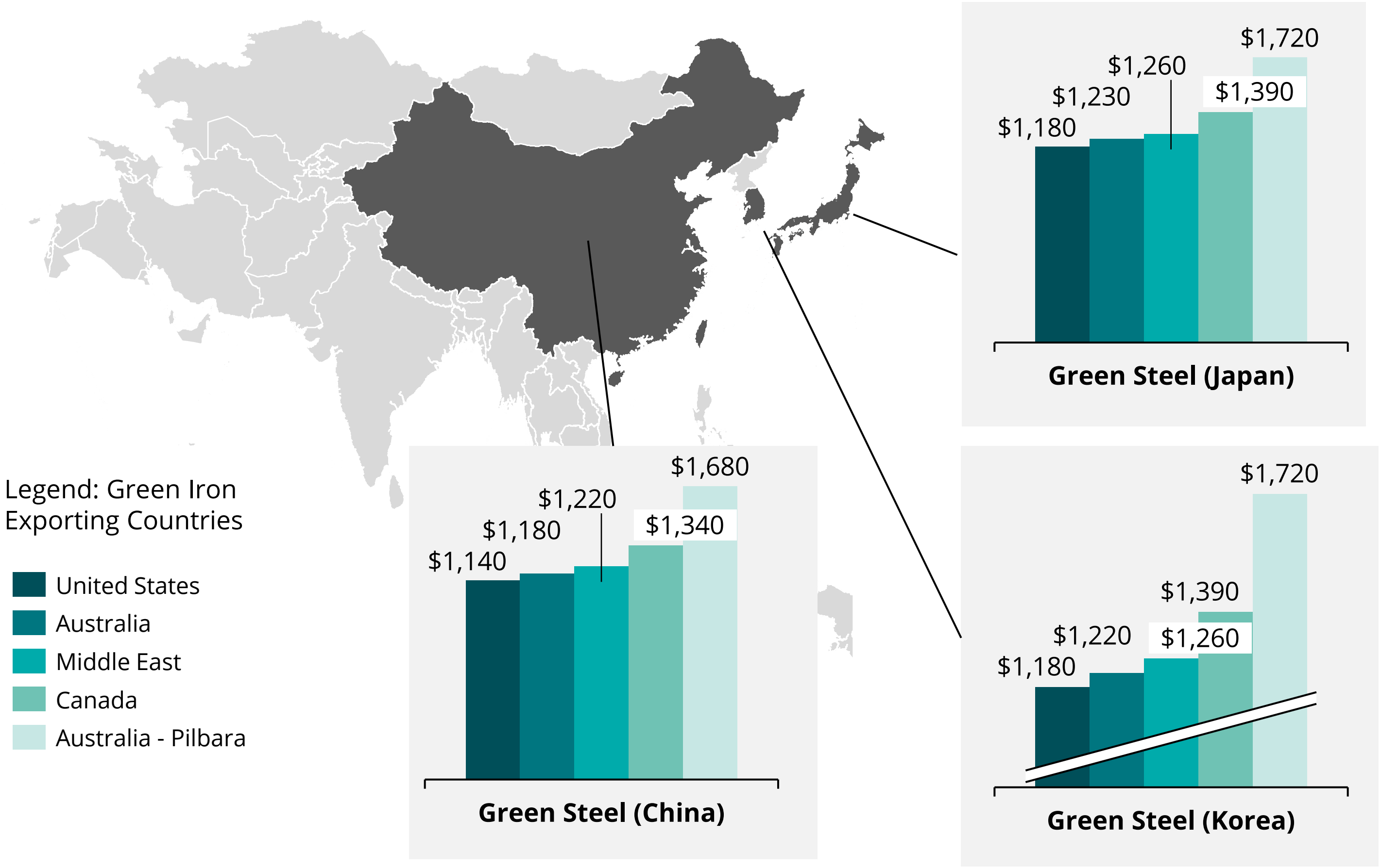
However, high CAPEX and labour costs, in combination with current electricity costs are eroding these comparative advantages. The Middle East is performing better on all these indicators. Moreover, Australia has limited manufacturing expertise and lower grade iron ores compared to other countries like Brazil. The deployment of renewable energy projects is also reported to experience significant delays.

Note: The table shows a high-level assessment of different factors underpinning competitive advantage. The chosen metric may not fully reflect the factor but is used as a proxy and based on national averages rather than a specific region within a country. Ratings for each metric are scored on a relative and not absolute basis. A country is scored with "N/A" (not assessed) when the source does not include information for the country or region. AUS – Australia; BRA – Brazil, AFR – Africa proxied by Egypt, Guinea, South Africa, Gabon, Mauritania, CAN – Canada, ME – Middle East includes Qatar, Saudi Arabia, United Arab Emirates and Oman, US – United States of America, CHN – China, EU – Europe proxied by Germany, Sweden, Spain, France, Romania; IND – India. H = High, M = Medium, L = Low. N = Limited to None. 1. Arcadis 2. NYU, risk premium used as a proxy for cost of capital, representing the additional return investors expect for taking on higher risks, with premiums in countries varying due to economic stability, inflation rates, currency risk and political environment. 3. Solar Atlas 4. Wind Atlas 5. BloombergNEF 6. IRENA 7. IRENA 8. Global Petrol Prices 9. International Labor Organization 10. Deloitte Analysis 11. Statista & Deloitte Analysis 12. Deloitte Analysis 13. World Bank 14. World Bank 15. World Bank 16. Harvard 17. World Bank 18. Deloitte Analysis

Australia has a competitive advantage exporting green iron to Asia

Transport costs could make Australia a low-cost supplier even accounting for policy support in other regions

Figure 18: Comparison of future green steel costs in importing APAC countries in 2030 based on delivered green iron cost from different potential exporters.[1]



Notes: The chart shows the cost of steel production in each region using a delivered green iron price supplied by different export regions. A delivered (or landed) cost factors in differential transport costs in addition to other factors. In 2030, US hydrogen makers are assumed to be in receipt of the IRA. Similarly, Australia benefits from Hydrogen Headstart and the Hydrogen Production Tax Incentive. Actual rates of policy support may vary and reorder these results.

Key Takeaways

Australia has an economic advantage in supplying green iron to the APAC region if it can rapidly drive down the cost of deployment of renewable energy domestically (Figure 18). Australian transport distances are between 7%-50% shorter than other prospective exporters. The introduction of additional initiatives and funding programs can further incentivise and expedite renewable energy investment and supply; building on existing initiatives such as the Renewable Energy Target (RET) and funding schemes such as the Advancing Renewables Program.

To further capture this economic advantage and overcome competition from key players**, Australia requires consistent and standardised definitions, quality standards and pricing of green steel to be upheld globally**. Inconsistencies across jurisdictions reduces the domestic cost advantage, as any permissible use of conventional steelmaking processes embedded into foreign green steel manufacturing chains will significantly reduce the production costs of their green products.

Additionally, Australia is required to take a leading role in driving technological research and development into pathways that can best utilise Australian hematite and magnetite ore grades. To move further up the value chain Australia must innovate to utilise a broader range of ores in green steel processes to truly capture its economic advantage and avoid upgrading costs.

It is important to note that place-based labour cost disparity could serve as an anchor on Australia's green export aspirations, given the current prevalence in the Pilbara region. Due to significantly higher labour costs, green iron from the Pilbara would not be competitive with competing jurisdictions (Figure 18).

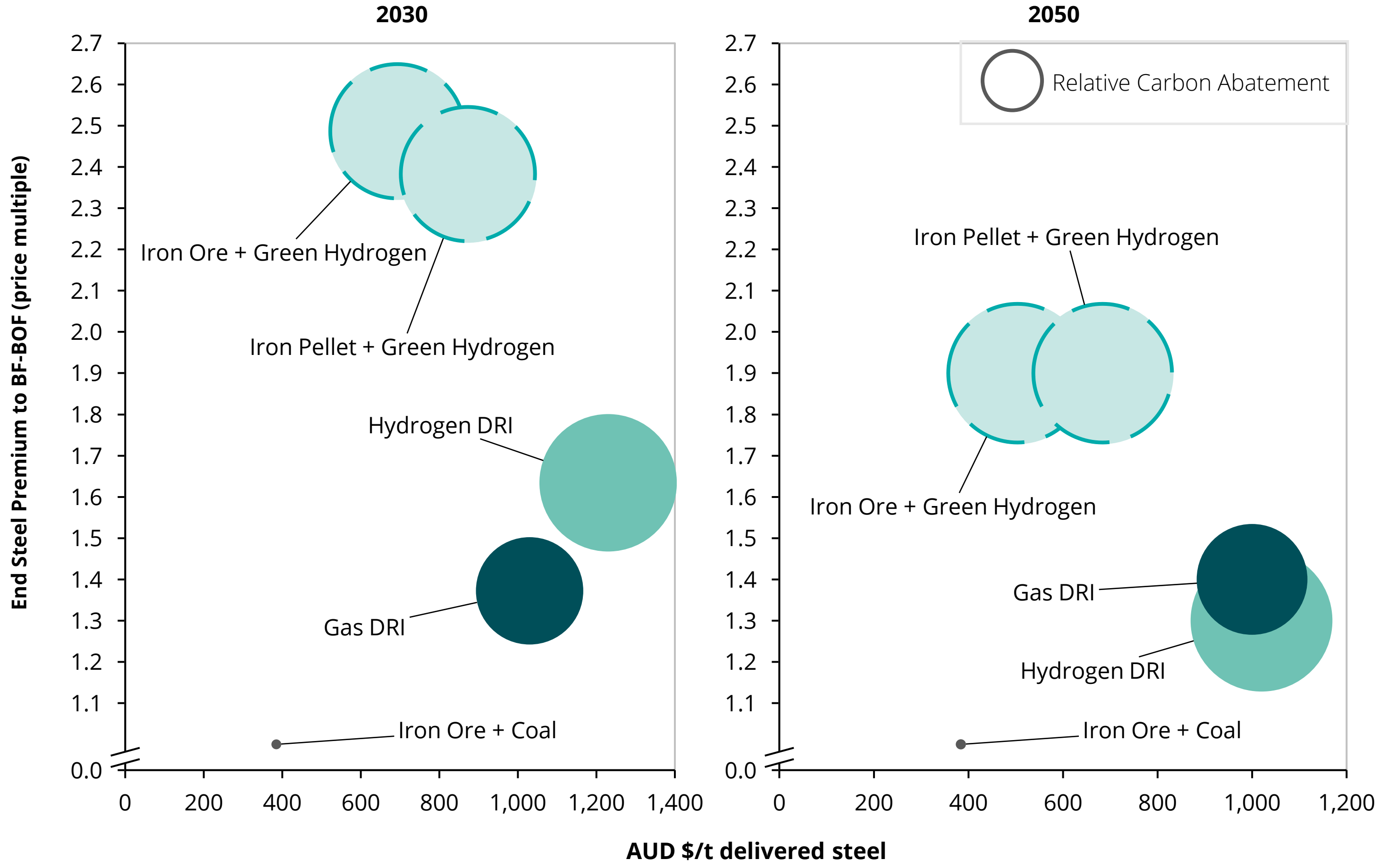
Sources: 1. Deloitte Green Value Chain Explorer: Iron and Steel, 2024

3. As a partner of choice, how can Australia accelerate adoption of green iron production in Asia to maximise abatement & economic opportunity?

A green iron export industry is the most viable pathway to value-added mineral exports

Green iron exports would deliver more export revenue and 64% more abatement than gas by 2050

Figure 19: Australian delivered steel price (AUD$/t steel), end steel product premium and carbon abatement for a project delivering to Japan in 2030 and 2050.[1]



Source(s): 1. Deloitte Green Value Chain Explorer – Iron & Steel. Export revenues assume the sale of the export products at the cost of production with a 15% margin or at an existing market price where available. Carbon abatement is relative to BF-BOF steel production in Japan using Australian iron ore and metallurgical and thermal coal. Carbon abatement does not include the emissions associated with export of green hydrogen to Japan, which would reduce the relative abatement in 2030 and 2050.

Key Takeaways

Australia has an opportunity to expand its industrial base while replacing diminishing revenue from fossil-fuel industries in a decarbonising world. Australia is reliant upon fossil-fuel revenue from metallurgical and thermal coal to support our economic position. Without diversification into new industries where Australia has a comparative advantage, such as iron and steel manufacturing, Australia risks missing out on the economic advantage.

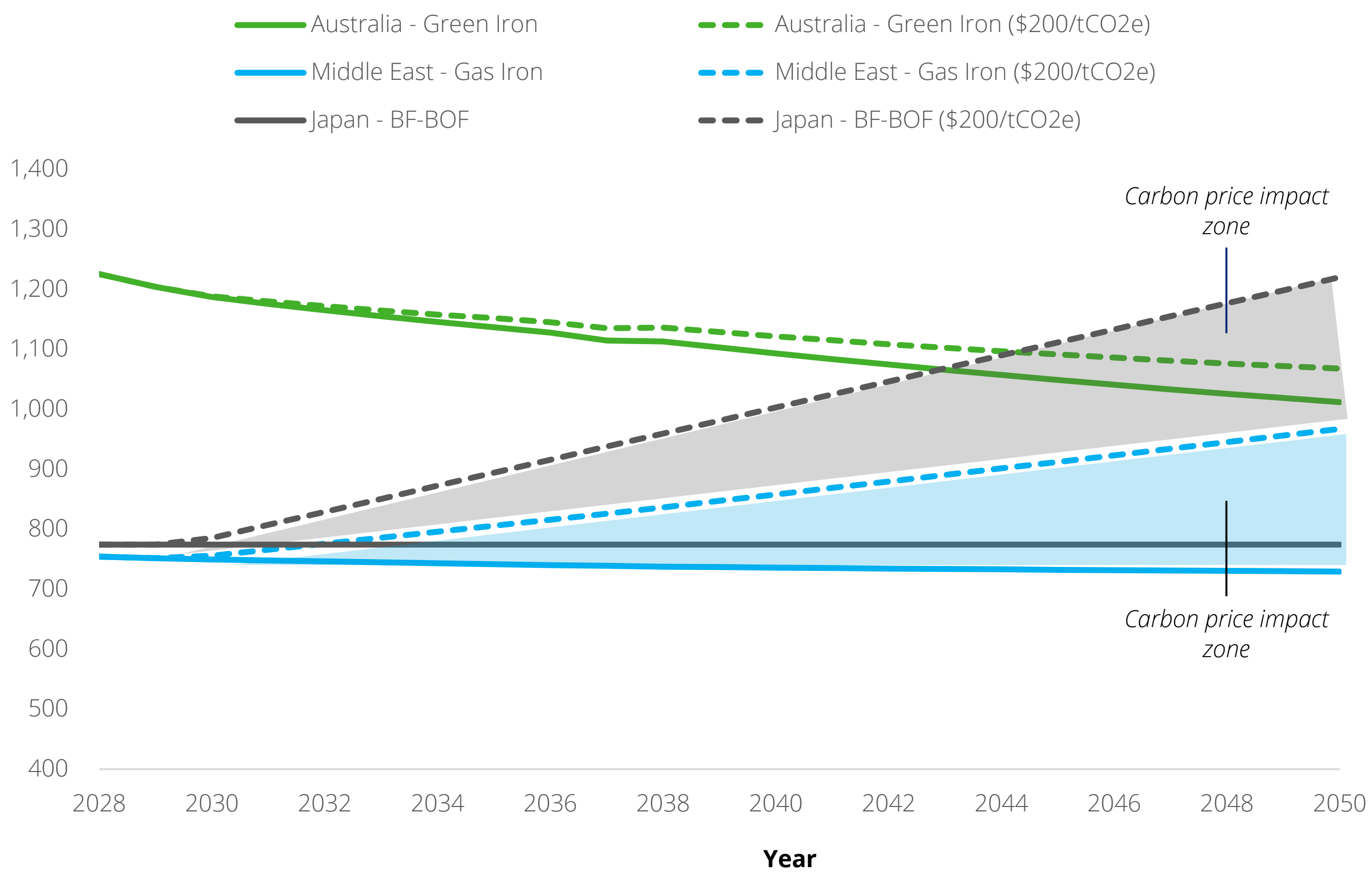
Hydrogen DRI offers a clear avenue to move up the steel value chain and capitalise on our comparative advantage. In the long-run, DRI is most likely to be cost competitive with gas-based DRI and existing BF-BOF production routes (Figure 19). Carbon pricing across markets will likely drive a reduction in the premium experienced today, highlighting the value in targeting this as an export route.

Australia needs to adapt to maintain the usefulness of our iron ore deposits. The adoption of green steel manufacturing will place downward pressure on the value of low-grade Pilbara hematite iron ores. Investment is required today into processes which can utilise Australian iron ores, including Pilbara hematite and magnetite found across the country, to ensure Australia is not left out during the transition towards green steel.

Green iron manufacturing may not be commercially viable until the 2040s

Asian carbon prices will determine when green iron becomes a viable alternative to gas-based production

Figure 20: End steel price for green hydrogen-based and gas-based DRI delivered to Japan from Australia and the Middle East with an escalating regional carbon price from $5/tCO2e in 2030 to $200/tCO2e in 2050 (dotted line) and no carbon price (full line).[1]



Source(s): 1. Deloitte Green Value Chain Explorer - Iron and Steel. Linear growth in the carbon price is assumed between 2030 and 2050. Australian green iron is assumed to utilised hydrogen supported by Hydrogen Headstart and a Hydrogen Production Tax Credit. Domestic support for green steel on the demand-side in Japan may accelerate the dynamic illustrated.

Key Takeaways

Timing of Australian green iron competitiveness will be driven by how rapidly hydrogen and renewables costs decline. As illustrated in section 2, the competitiveness of green iron production hinges on energy costs. The combined effect of falling renewable equipment costs and declining deployment costs are needed to support the greening of all industries, including green iron and steel manufacturing. However, uncertainty exists globally with respect to the pace and capacity of cost reductions.

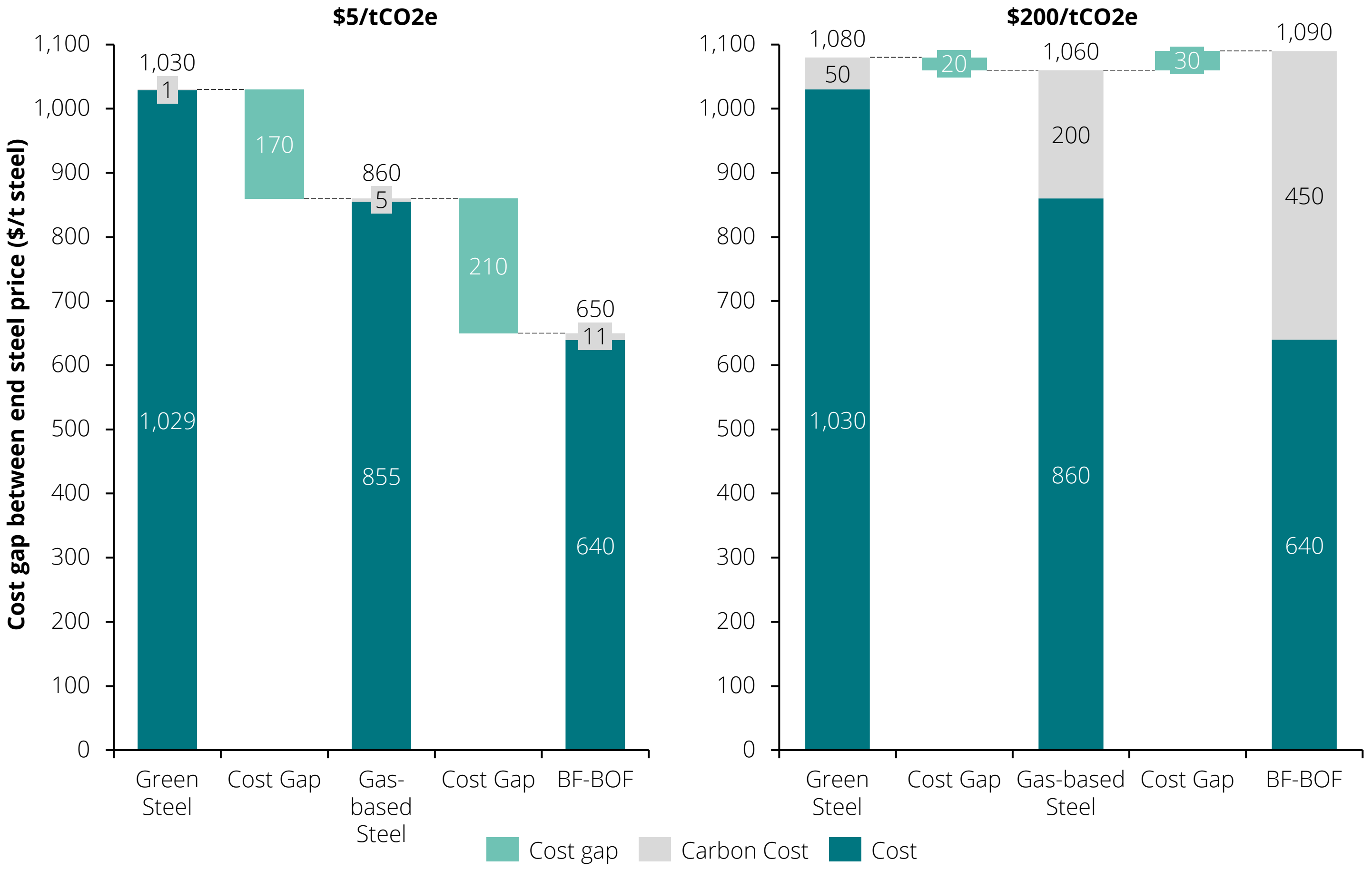
Green iron and steel manufacturing is unlikely break even with incumbent processes until 2040 if carbon price asymmetries remain (Figure 20). Given projections of cost reductions in renewables generation and hydrogen production, it is unlikely green iron and steel manufacture will be commercially viable until beyond 2040. Dynamics within iron ore, thermal and metallurgical coal and gas markets, cost decline rates for green hydrogen and renewables and the degree of carbon pricing between markets will govern when breakeven occurs.

Variations in carbon price may shift the breakeven point between regions. The development of global green iron and steel value chains is contingent upon the establishment of uniform carbon pricing between regions, given the globally integrated nature of value chains. As such, the continued variability in carbon pricing across the APAC region and globally would contribute to delaying the adoption of green steel.

No change in Asian carbon prices will favour gas-based DRI for Australia and other exporters

With current carbon pricing, both green and gas-based iron are at a premium to fossil steel

Figure 21: Cost gap between Australian steel products through different production routes under a $5/tCO2e and $200/tCO2e carbon price in 2030.[1]



Key Takeaways

The public investment necessary to transition directly to green iron and steel production is high. In a world with persistent asymmetric carbon pricing, this is likely to remain a challenge for the foreseeable future. Hence to viably accelerate the adoption of green steel production, significant government funding would be required.

Production pathways initially prioritising the use of natural gas are likely to dominate during the transition to commercially viable green steel production. Natural gas-based production allows for abatement relative to existing BF-BOF production routes at a commercially competitive cost of production today. However, elevated natural gas prices in Australia may inhibit industry development in Australia.

While natural gas DRI will provide important early emissions reductions, sunk costs and path dependence could delay uptake of hydrogen DRI. By initially establishing investments in regions where natural gas production is viable, this could lock in emissions for longer, given the greater cost gap.

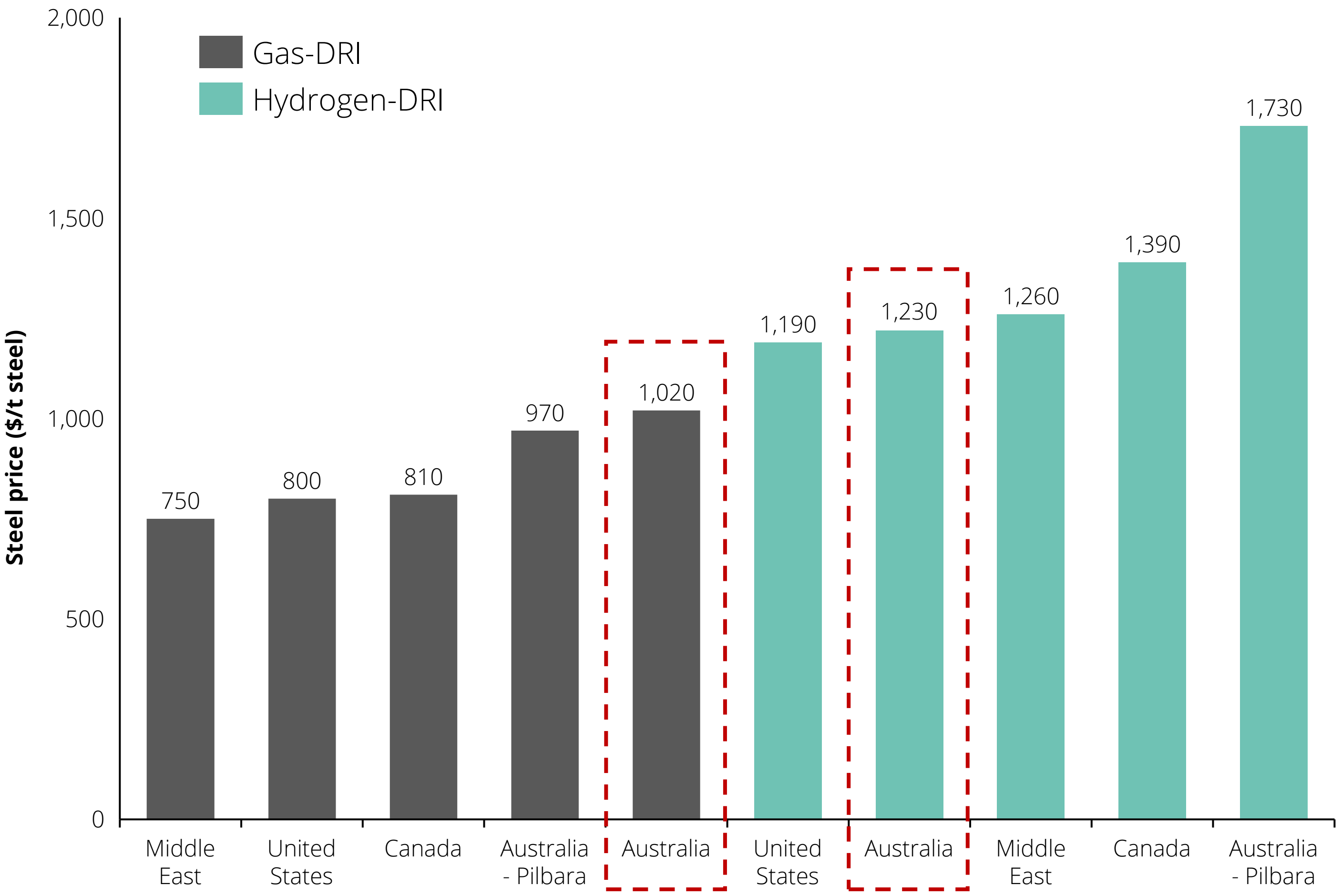
Rapid technological development is required to support the use of Australian ores in DRI processes. Beneficiation processes for both Australian hematite and magnetite ores need to be advanced to capture the green DRI opportunity. This challenge is global in the long-run, with DR-grade ore supply constraints likely to impact gas-based DRI player.

Source(s): 1. Deloitte Green Value Chain Explorer - Iron and Steel. The carbon price is assumed to grow linearly between 2030 and 2050.

Australian gas-based iron is less competitive than other potential exporters

Australia's competitive advantage in green iron suggests we need buyers to quickly transition through gas

Figure 22: Cost of steel production by gas and green hydrogen DRI routes between countries, 2030.[1]



Source(s): 1. Deloitte Green Value Chain Explorer - Iron and Steel. For Australia, Canada and USA export pathways (beneficiation & pelletisation, DRI), a pre-concentrate magnetite ore is used. For the Middle East, a moderate grade hematite (62-67% Fe) is used.

Key Takeaways

Private sector players are initially anticipated to target regions with a comparative advantage in natural gas-based DRI. Natural gas-based production regions such as the Middle East and North America will likely be targeted for APAC-based production given the relative low-cost of natural gas (Figure 22). By contrast, Australian iron production for natural gas is at a significant relative premium.

The timing of the transition to hydrogen-based DRI in the lowest cost regions is uncertain. In the Middle East, the role of hydrogen for these investment decisions is likely to be of secondary consideration without a clear policy framework to drive adoption. Given the inherent uncertainty with respect to the economic viability of green hydrogen production, this risks locking in the use of natural gas for longer.

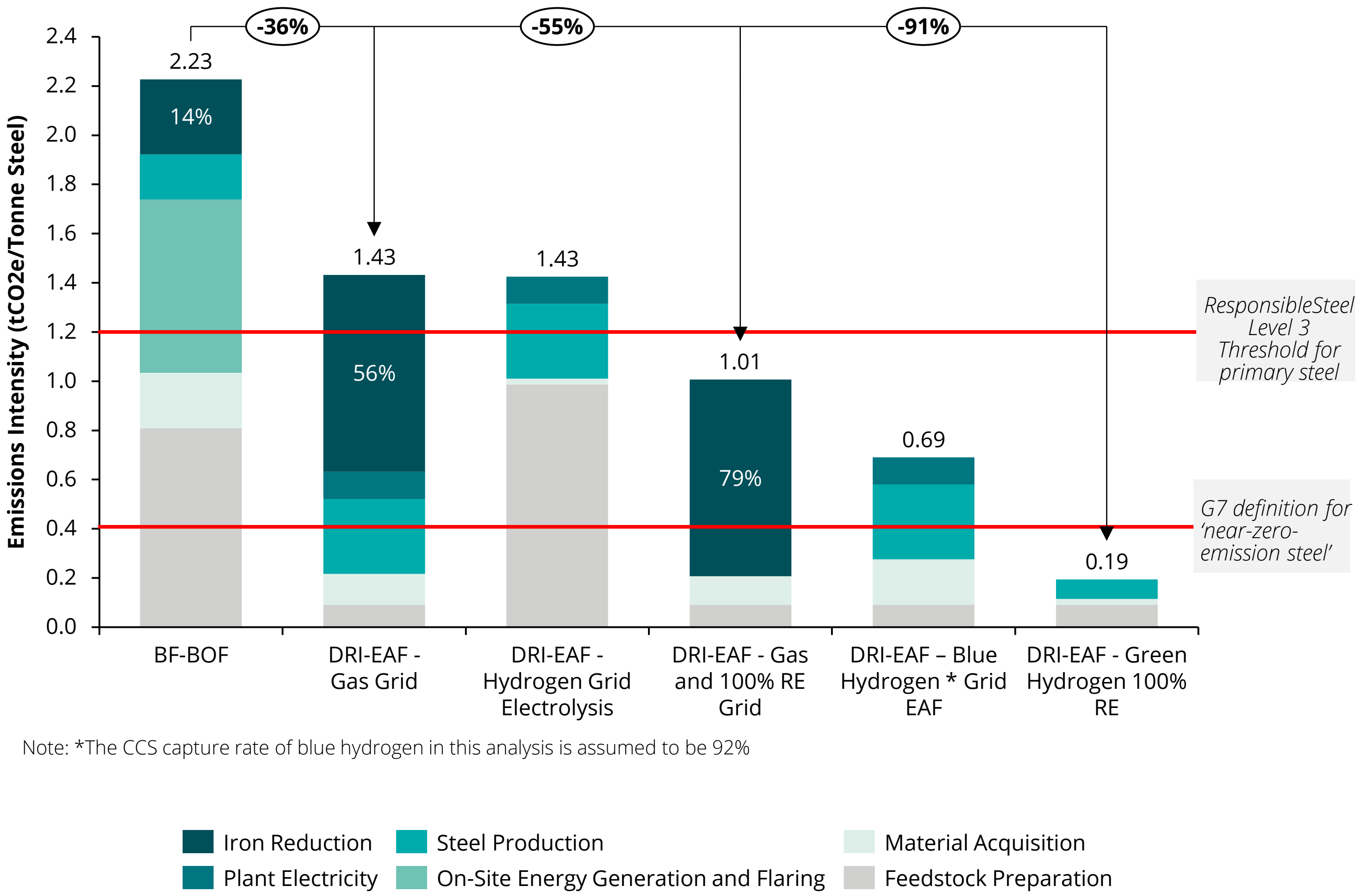
Australia is a more competitive supplier of green iron to Asia than the Middle East and Canada. Australia's low-cost renewable potential and iron ore access could drive competitiveness in green iron. However, this is contingent upon improvement in technology to commercially support Australian ore use.

Australia's green iron advantage can only be realised if demand moves rapidly past gas. As such, it is imperative the Australian Government advocates for a rapid transition to green steel. In doing so, it is in Australia's interest to provide the supporting infrastructure necessary to attract early investment in gas-based domestic production.

Gas-based ironmaking is unlikely to deliver net zero and will be a transition solution only

Guardrails will be needed to ensure abatement is maximised within the commercial constraints

Figure 23: Carbon intensity by production route for steel.



Note: *The CCS capture rate of blue hydrogen in this analysis is assumed to be 92%

Source(s): 1. Deloitte Green Value Chain Explorer - Iron and Steel

Key Takeaways

Transitioning to green hydrogen DRI is essential to deliver net zero green steel. Gas DRI can only be a transition technology and grid emissions intensity standards will be important for green hydrogen – an intensity below 0.25kg/kWh is needed for hydrogen to match gas DRI. Ensuring electric arc furnaces are powered by renewables should be a key focus for Asian economies, with significant emissions reduction potential.

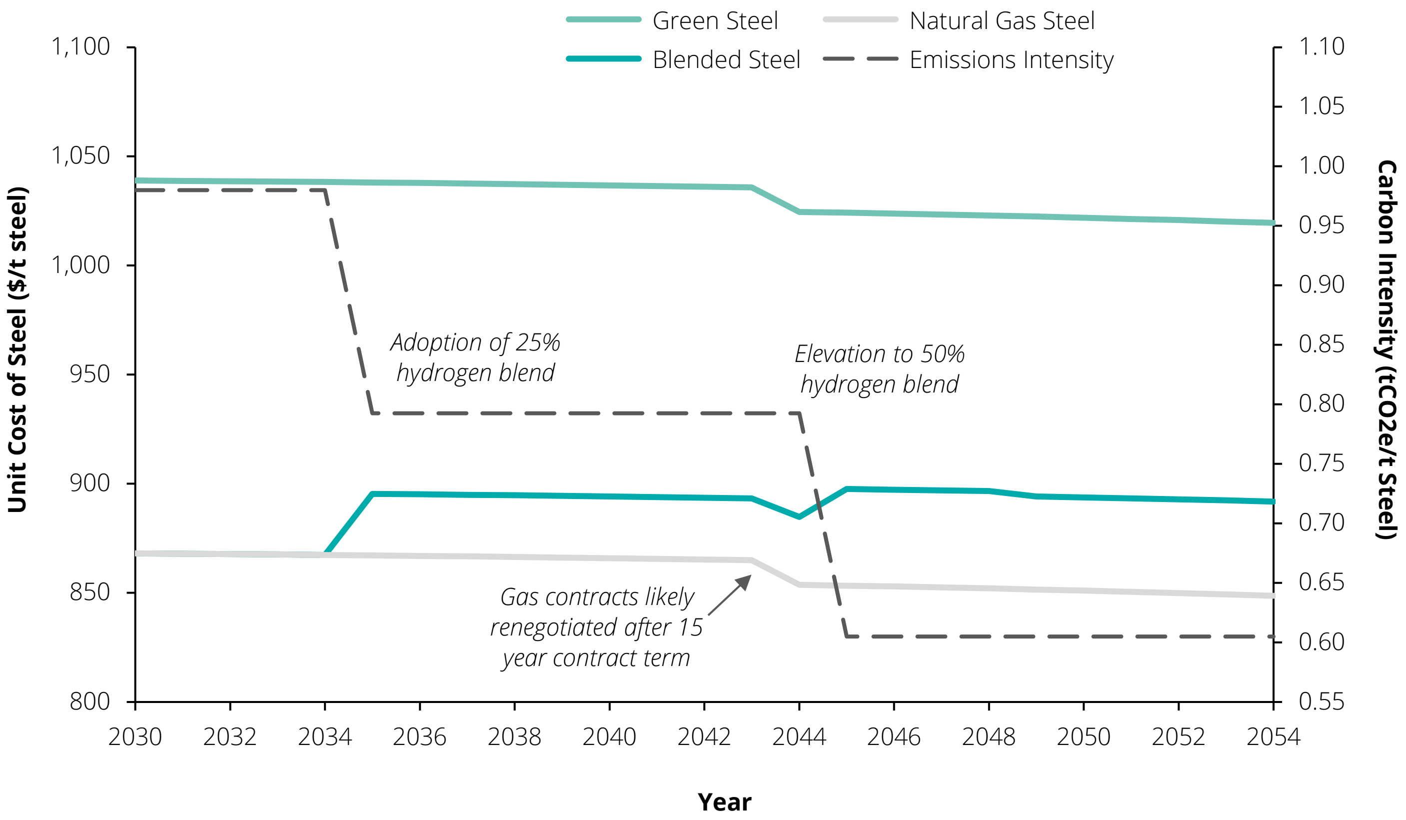
Manufacturing green steel demand is inhibited by an absence of consistent standards and carbon intensity thresholds. End consumers buying low-carbon or green steel are effectively purchasing decarbonisation. However, without verifiable and traceable standards, consumers cannot trust abatement outcomes. Lifecycle assessments of emissions reductions are important to define thresholds for each abatement pathway.

The commercial constraints of the market risk setting green iron & net zero up for failure. The significant cost premium of green iron relative to gas-based production, and the material near term abatement offered by gas are likely to incentivize steelmakers to set early market rules around gas-based production and resist incremental decarbonization beyond this. In turn, this could inhibit or delay adoption of green and realization of further emissions reductions. To overcome this, **high integrity standards with ratcheting expectations are needed to provide necessary guardrails.**

Intervention will be required to exceed abatement from gas-based iron production

The market is unlikely to shift to green iron without hard policy requirements

Figure 24: Unit cost and emissions intensity of a blended hydrogen and natural gas DRI-EAF facility, assuming hydrogen blending of 25% in 2035 and 50% in 2045.[1]



Source(s): 1. Deloitte Green Value Chain Explorer - Iron and Steel. 2. ABC News, 2024

Key Takeaways

Shifting from gas-based ironmaking to hydrogen presents two commercial challenges.

1. New capex is required to support the blending process, add storage tanks, control and hazard systems.
2. Hydrogen costs are expected to decline gradually over time but are likely to require a long-term offtake contract. As a result, an early move to lock in supply locks this in at a higher cost than waiting.

Hydrogen project economics are likely to inhibit gradual blending in favour of large step-ups in use. Finance for hydrogen projects requires revenue certainty, which in turn could require a 10-to-15-year offtake agreement for hydrogen. A minimum offtake volume will be required which is likely to be a double-digit percentage of total consumption.

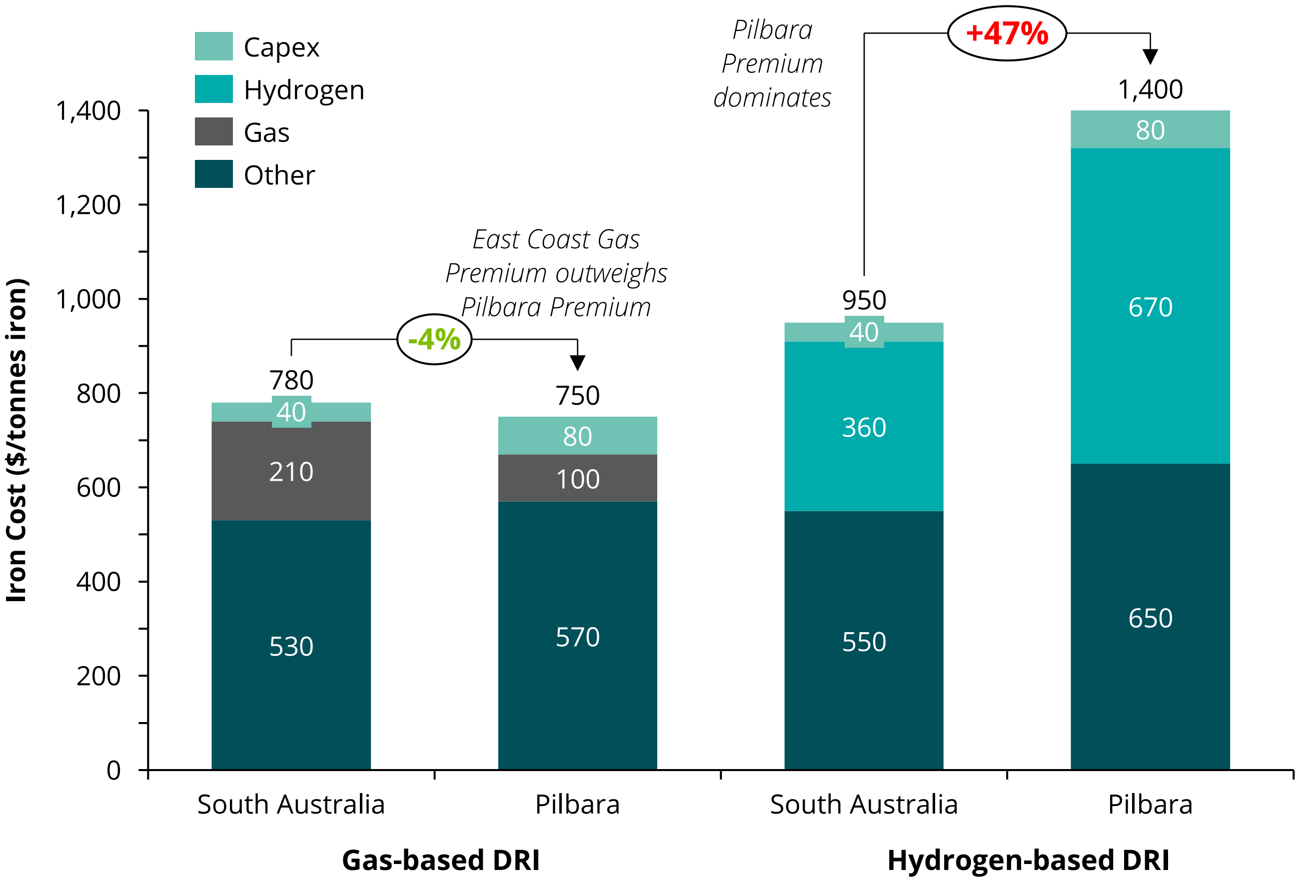
Before 2050, any shift to hydrogen blending will increase the cost of ironmaking and therefore end steel prices (Figure 24). Because the shift to hydrogen incurs elevated capex and opex, production costs will increase relative to a pre-transition cost. **This dynamic creates a disincentive to blend.** Actual costs will hinge on hydrogen volumes, price, and adoption year.

Tight regulation will be required to overcome commercial inertia to deliver greater steel decarbonisation. Governments have tried to support hydrogen-ready gas turbines with mixed success.[2] Alternative policy options may be required to lock in an elevated abatement pathway.

The gas-to-green transition has implications for where to build shaft furnaces

The Pilbara premium could ultimately lead to a slower uptake trajectory of hydrogen

Figure 25: Comparison of gas-based DRI and hydrogen-based DRI between South Australia and the Pilbara, 2030.[1]



Key Takeaways

Within Australia, market-led investment in DRI could see projects in the Pilbara prioritised, given ease of access to lower-cost gas and iron ore. As shown in Figure 25, access to low-cost gas could favour investment within the Pilbara region for gas-based DRI. Costs within the East Coast gas market are anticipated to rise as the depletion of Victorian gas fields reduces network supply.[2] This could leave the East Coast gas market more exposed to international price fluctuations, and, given the integrated nature of the market, could result in elevated prices for all Eastern States, including South Australia. This could make investment decision-making in the East Coast riskier and projects higher cost.

High build costs in the Pilbara make the decarbonisation of a gas-based DRI facility more costly, likely delaying green hydrogen adoption. High build costs in the Pilbara mean the construction of renewables can exceed 2x the cost of production in the rest of Australia.[3] This would mean the cost of hydrogen production within the Pilbara could exceed to cost in other regions of Australia without significant construction cost reductions.

A Pilbara-based project could serve as a hidden viper which risks greater relative reliance upon government support. The higher cost of renewables build-out would mean a greater production subsidy from government to incentivise transitioning a facility to hydrogen relative to a project in another region. Governments need to be cognisant of this risk when determining projects to provide environmental approvals and financial support to.

Source(s): 1. Deloitte Green Value Chain Explorer - Iron and Steel. 2. AEMO, 2024. 3. Climate Energy Finance, 2024

Australia has 5 prerequisites to become a leading supplier of green iron

Becoming a partner of choice for Asian steelmakers will hinge on public-private and cross-border collaboration

Figure 26: Steel production value chain and associated background conditions

Value Chain Step	**RAW MATERIALS EXTRACTION & ENERGY INPUTS**	**IRON MAKING**	**STEEL PRODUCTION**	**END-USERS**
Prerequisite	**1. Australia develops low-cost ironmaking inputs**	**2. Australia invests in ironmaking capacity**	**3. Asian steelmakers prioritise diversity of low-carbon suppliers**	**4. Asian governments introduce carbon pricing and incentives for green steel adoption**
Background Conditions	❑ Availability of low-cost natural gas	❑ Early investment in production capacity establish Australia as a player in early market	❑ Asian steelmakers invest in renewable PPAs for EAFs	❑ Rising carbon prices push steel users to demand lower carbon products
	❑ Availability of low-cost renewables and hydrogen	❑ Market incentives push towards early transition from gas to green	❑ Asian steelmakers continue to partner with prospective Australian producers	❑ Asian steelmakers prioritise access to regional over long-distance partners for ironmaking
	❑ Availability of DR-grade ore			
		5. Australia influences market rules and norms to favour green iron		
	❑ Process innovation to unlock value from Pilbara ores	❑ Aligned definitions for green iron and steel between Australia and Asia		
		❑ Standards are reflected in contracts and market pricing		

4. What coordinating action is required to realise Australia’s green iron export potential?

Prerequisites from the analysis highlight 5 factors essential to the success of Australia's strategic positioning

Prerequisite	*Implication*
1. Australia develops low-cost ironmaking inputs. Australia's green iron potential will hinge on green electricity and hydrogen prices, alongside availability of DR-grade iron ore.	Accelerating renewable deployments and innovations to use Australian ores and lower deployment costs are a downpayment for green iron exports.
2. Australia invests in ironmaking capacity. Au-based DRI is expected to retain a significant cost advantage over green iron into the 2030s - Australia will need installed capacity to play in the market.	Net zero steel will depend on regulation to overcome path dependence and sunk costs which could delay the transition from natural gas to hydrogen DRI.
3. Australia influences market rules and norms to favour green iron over the long term. Policy and standards alignment drives market development and expedited decarbonisation	Australia's investment in extending the Guarantee of Origin scheme to green metals is important, but must align with the needs of Asian steelmakers & must be reflected in pricing.
4. Asian governments introduce carbon pricing and incentives for green steel adoption. Carbon prices in steel producer markets will modulate demand and the emergence of price premiums for green steel.	In the absence of policy change, low-carbon prices in Asia will limit willingness to pay material green premium for Australian green iron.
5. Asian steelmakers prioritise diversity of low-carbon suppliers, with Australia in the mix. Commercial & trade partnerships between Australia and Asia ensure a ready market as our advantages emerge.	Policymakers and industry players need to remain in the race, with an emphasis on cross-value chain partnerships, development projects, and explicit opportunities for mutual economic benefit.

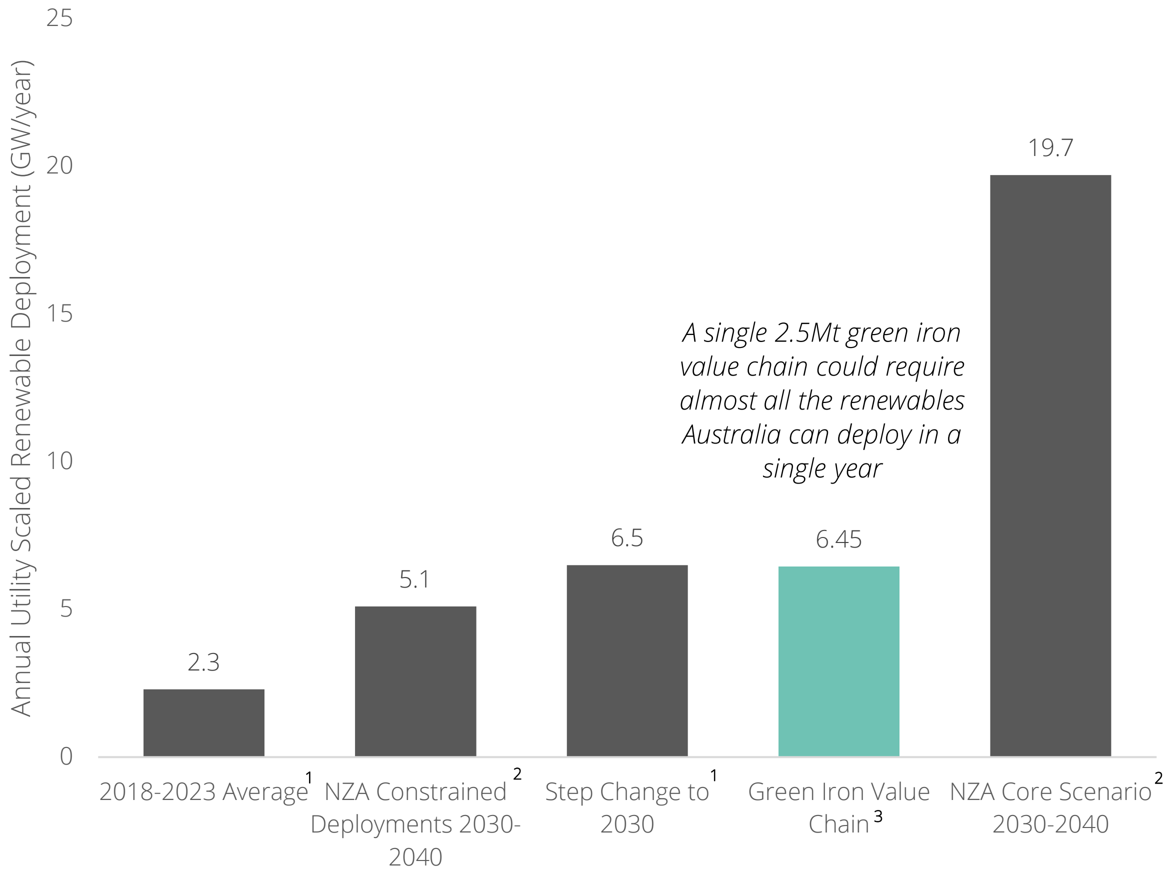
In order for success, Australia must ensure:

- **Rapid deployment innovation**
- **Gas-to-green transition path**
- **High integrity market standards**
- **Regional carbon pricing**
- **Pragmatic green statecraft**

Rapid deployment innovation

Coordinated efforts to accelerate renewable deployments and develop new infrastructure are required

Figure 27: Annual renewable deployment rates compared to required installed capacity for a 2.5Mt green iron value chain assuming exports to Japan (and therefore exclusive of EAF energy requirements)



Source(s): 1. [AEMO ISP](), 2024. 2. [Net Zero Australia](), 2023. 3. Deloitte Green Value Chain Explorer - Iron and Steel: energy requirements of beneficiation, hydrogen production, and shaft furnace. 4. [Longden et al](), 2024.

Areas for Exploration

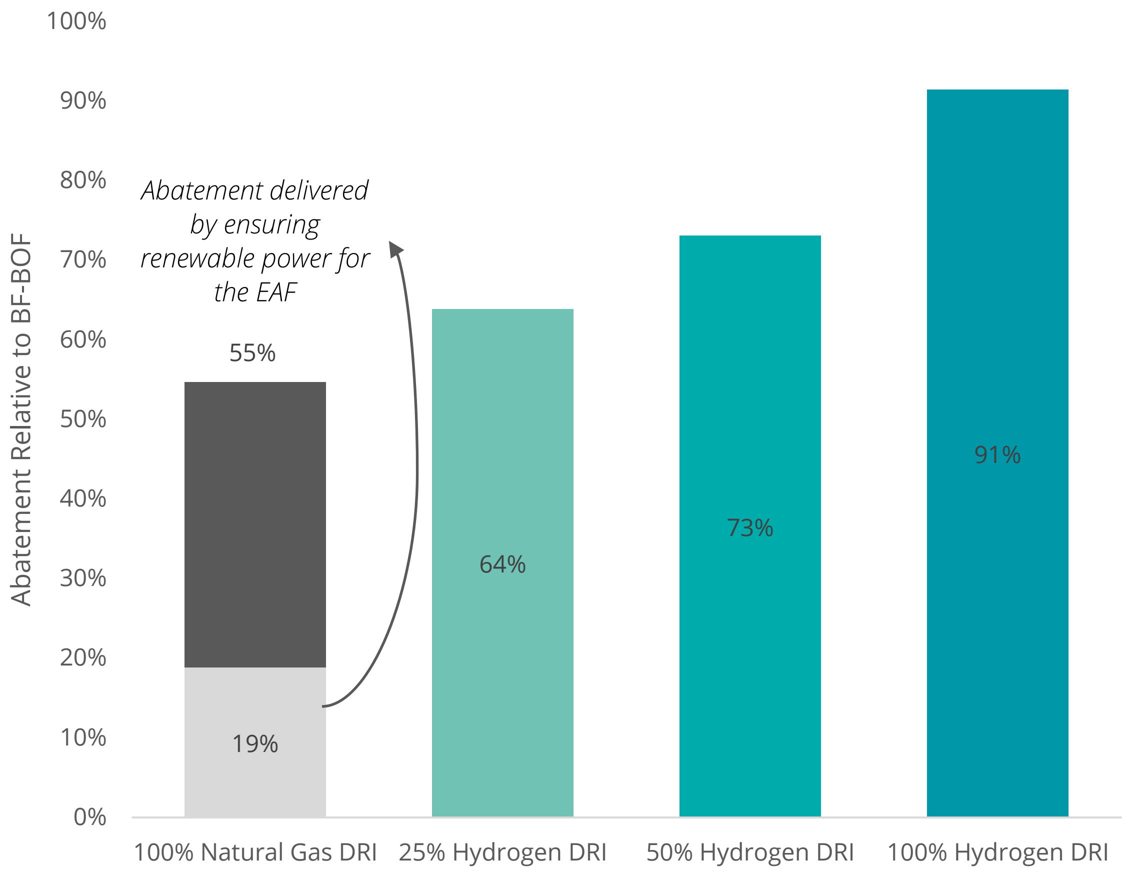
Australia risks losing out to competing regions if it moves too slowly across the green steel value chain. To become a leading green iron supplier Australia must ensure low-cost renewables deliver low-cost green hydrogen, and the availability of DR-grade iron ores. Realising these goals demands that Australia:

1. **Significantly raise deployment rates for wind and solar**. Between 2018 and 2023, Australia deployed an average of 2.3GW of utility-scale renewables. More than doubling this feat is required to deliver the 2030 82% renewables target set by the government. Significantly exceeding this will be required to both drive down costs and ensure availability of renewables to feed green iron projects (Figure 27).
2. **Accelerate project approvals pathways while delivering nature positive outcomes.** Between 2016-2020 it took 4.4 years to develop, build and energise an average wind project, and 3.4 years for a solar project.[4] Approvals speed is a key element of this. But an appropriate balance needs to be struck between public and private risks and benefits to approval acceleration, and to ensure nature positive returns. A closer look at nature impacts and guardrails needed to guarantee better outcomes for climate and biodiversity are the key focus point of the Phase 2 report, “Ore else: the nature impacts of a green iron value chain”.
3. **Common user infrastructure should be the deployment priority.** Investment shy processes & poor coordination risk compounding deployment delays and foreclosing Australia’s green iron window of opportunities.
4. **Invest in R&D to reduce deployment costs & enable use of Australian hematite ores.**

Gas-to-green transition

Proactive regulation and future facing conditionalities on incentives must drive uptake of hydrogen at gas DRI facilities

Figure 28: Abatement potential of different DRI pathways relative to a BF-BOF route



Source(s): 1. Deloitte Green Value Chain Explorer - Iron and Steel. 2 For example [MiQ provides independent emissions certification](#) and monitoring of natural gas transactions.

Areas for Exploration

Any support given to industry should guarantee real abatement outcomes and ensure the transition to green hydrogen is accelerated, not delayed. Apart from clear decarbonisation benefits, this is also in Australia's economic interest through a comparative advantage on green iron. The Australian Governments can:

1. **Identify least emissions gas supply options for prospective ironmaking.** The gas-to-green transition will depend on short-dated gas offtake contracts for emissions verified natural gas[2] supplying DRI projects, which in turn depend on a shorter payback period on capex for new supply. Traditional gas contracts can run for 10-20 years.
2. **Leverage conditionality of production incentives to drive hydrogen blending by 2035**. Clawback or forfeiture of HPTI incentives or other forms of long-dated public support would provide a strong commercial incentive for facility operators to shift towards hydrogen blending – for example if a hydrogen uptake date was missed.
3. **Require ironmaking feasibility studies to include hydrogen blending scenarios and timeframes**. ARENA or state development funding for green iron planning studies should use a transition to green hydrogen as a base case and include blend rates in feasibility studies. Higher blending rates achieve greater abatement (Figure 28).
4. **Provide technical & commercial assistance to Asian economies to accelerate renewable rollouts.** Greater decarbonisation is achieved when EAFs in steelmaking countries are powered with 100% renewable energy. Efforts should focus on enabling the choice for renewables amongst Asian steelmakers.

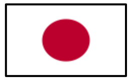
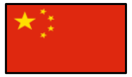
High integrity standards

Government-to-government alignment is needed to ensure the emerging market remains net zero aligned

Figure 29: Comparison of low-emissions hydrogen definitions across APAC jurisdictions

Stricter

Less Strict

Country	Low-emission Definition
	0.6 kg CO2e / kg hydrogen[1]
	2 kg CO2e / kg hydrogen[2]
	3.38 kg CO2e / kg hydrogen[3]
	3.4 kg CO2e / kg hydrogen[4]
	4 kg CO2e/ kg hydrogen[5]
	14.5 kg CO2e/ kg hydrogen[6]

Source(s): 1. Australian Hydrogen Council, 2024. 2. S&P Global, 2023. 3. European Parliament, 2023. 4.GR Japan, 2024. 5. Argus, 2024. 6. International Energy Agency, 2022.

Areas for Exploration

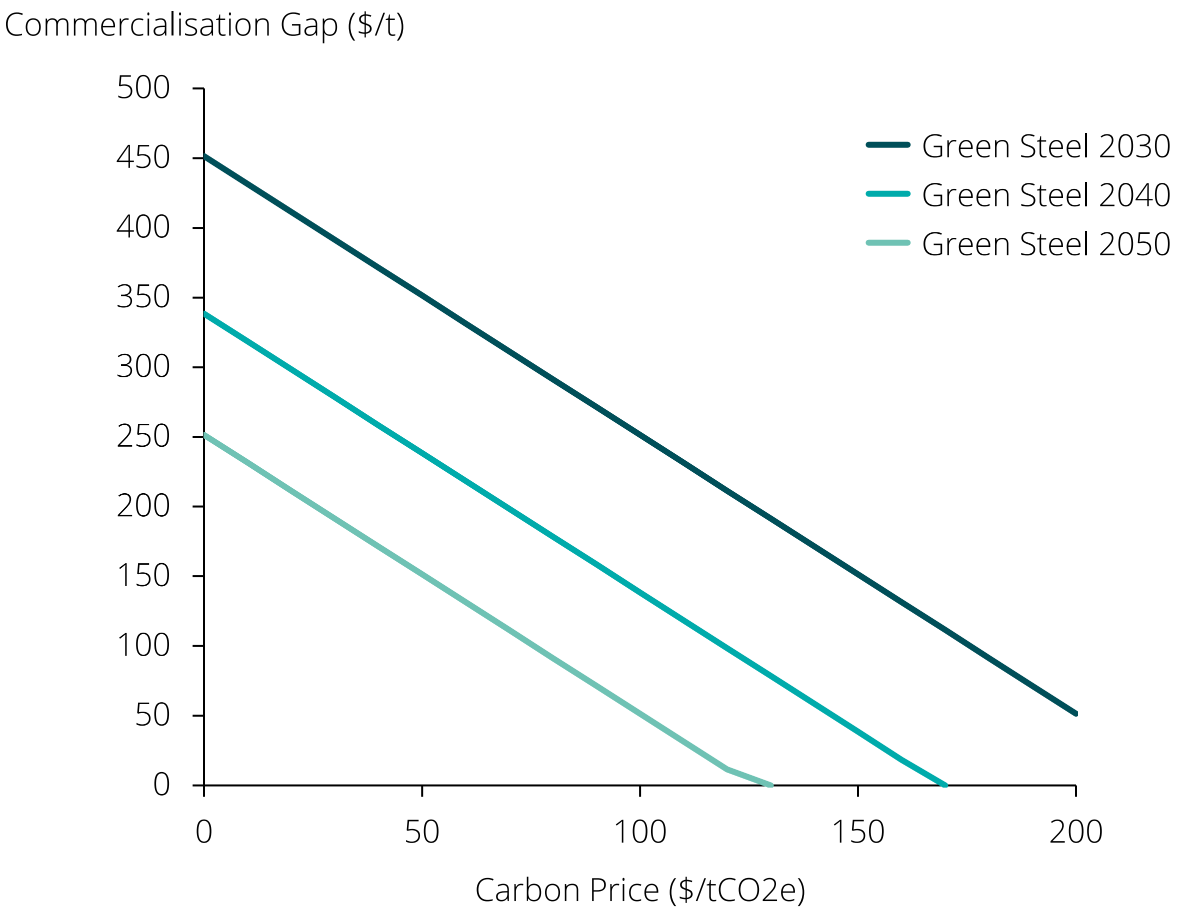
Efforts in developing a green steel value chain suffer from contradictory standards and definitions. What constitutes as "green" or "low-emissions" hydrogen/iron/steel is often very different across jurisdictions (Figure 29), inhibiting investment signals and undermining green premiums. Government-to-government alignment is needed to ensure the emerging green steel market remains net zero aligned. Actions for players could be:

1. **Convene an APAC working group to harmonise standards.** Collaboration across industry and jurisdictions to establish common emission intensity thresholds for low-emissions hydrogen and alignment on emissions boundaries for a global green steel definition.
2. **Support alignment on how emissions thresholds should be ratcheted over time for steel end users.** Organisations like WWF-A are already leading the way in accelerating a shift to green materials via MECLA. Cross-border integration of manufacturing and construction standards with clear steel emissions intensity targets over time are required to underpin long term demand for abatement that exceeds gas-based DRI.
3. **Identify the highest impact green iron pricing mechanisms**. Contracts are the prime movers of the global economy, specifying the terms and conditions of all purchases. It remains unclear how contracts for low carbon will be implemented, and importantly how premiums for lower carbon intensity products will be calculated and reflected in price signals. Early contracting norms cast a long shadow on early-stage markets and wide carbon intensity bands or the absence of an elevated premium for emissions reductions beyond gas DRI will inhibit decarbonisation. Organisations like WWF-A could support studies to compare pricing formulas, impacts and suitability for adoption.

Regional carbon pricing

Raising carbon price ambitions in Asia will reduce the burden worn by taxpayers in decarbonising steel

Figure 30: Relationship between the commercialisation gap of a 2030 Australian green iron project exporting to Japan and a prevailing carbon price.



Source(s): 1. Deloitte Green Value Chain Explorer - Iron and Steel

Areas for Exploration

A higher carbon price and adoption of a CBAM in Asia Pacific markets would bridge the cost gap and improve the commercialisation case for (Australian) green iron (Figure 30). Efforts should be focused on advocating for more ambitious carbon pricing across Asia. This includes:

1. **Establish focus on green steel at COP31.** Ensure green steel becomes a key focus area at COP31 and run stakeholder sessions. Climate diplomacy on this world stage can accelerate the alignment and ambition of Asian carbon pricing.

2. **Create an awareness campaign to address misconceptions of carbon pricing and build support.** Investigate the implications of carbon pricing and taxes on end users. It can analyse the added costs across different industries and spread awareness on how to appropriately manage different impacts.

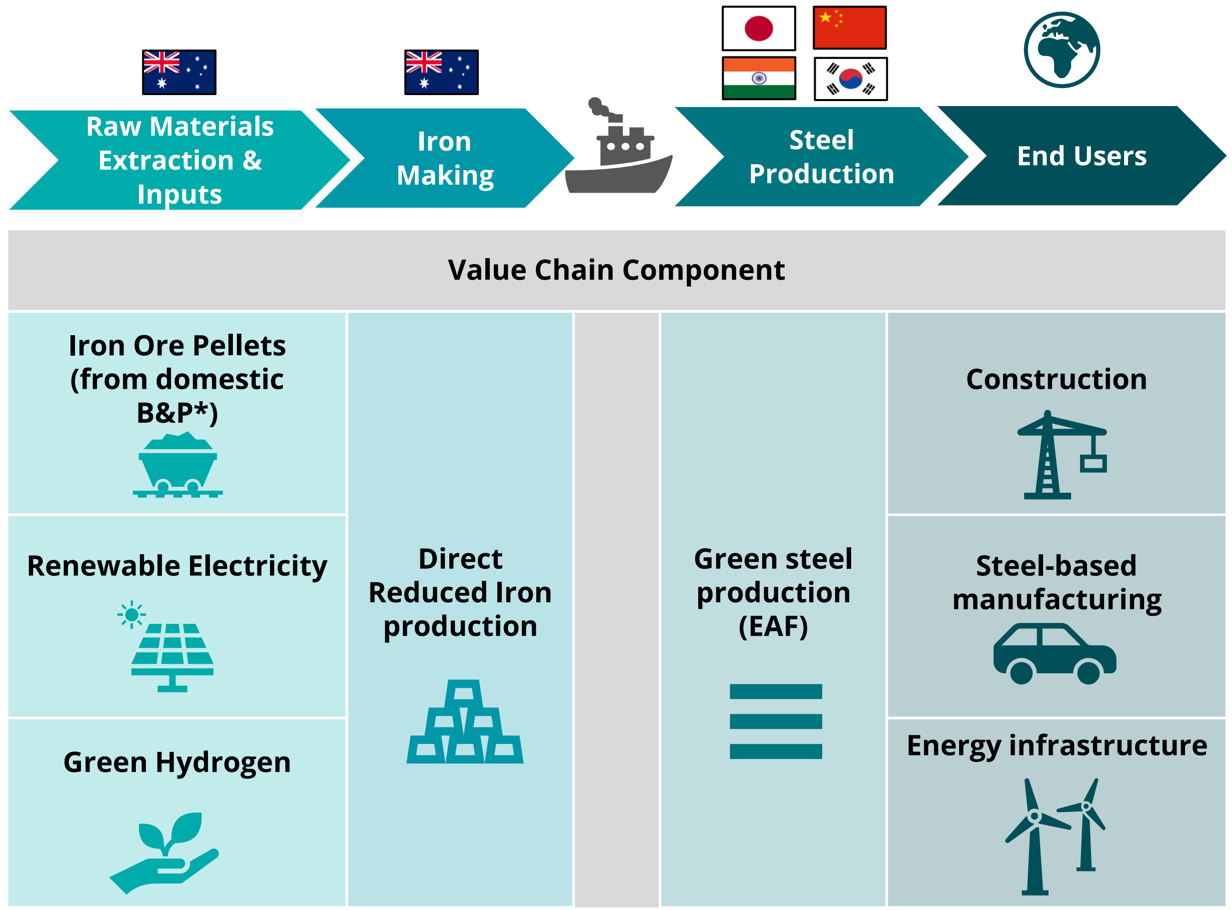
3. **Conduct analysis regarding appropriate scale and trajectory of carbon prices.** Similarly, organisations like WWF-A can lead research efforts on the appropriate sizing and transition of carbon prices in Asia, as well as which consequences (investment and consumer behaviour) it would catalyse.

4. **Assess implementation viability of an Asian Carbon Border Adjustment Mechanism (CBAM) to avoid leakage.** An Asia Pacific CBAM would help ensure local efforts to reduce emissions through carbon pricing are effective and not undone by imports of more carbon intensive products. However, it isn't clear how such a mechanism could be designed and placed into force across the range of high and middle income economies across Asia.

Pragmatic green statecraft

Unlock a new green steel value chain through collaboration across jurisdictions on investment, policy support and offtake

Figure 31: Outline of a potential Australia-Asia green iron corridor



Notes: *B&P is an abbreviation for beneficiation and pelletisation.
Source(s): 1. Clean Hydrogen in Asia Pacific: Fuel for Thought, Deloitte, 2024

Areas for Exploration

To ensure success of a new green steel value chain, Australia must collaborate with its most important partners (current and prospective). It must anticipate what action trading partners are going to take. At the same time, Australia should be clear on what it needs partners to do in order to achieve greater mutual benefits.

1. **Agree new bilateral or multilateral green iron corridors between Australia and trading partners.** Green iron corridors offer a pathway that minimises environmentally undesirable impacts of a green steel value chain. Reducing operational span delivers co-benefits such as reduced operational costs (i.e. transport costs) and environmental footprint (i.e. transport emissions). This also focuses infrastructure deployment only in productive areas that reduces ecosystem disruption and degradation.

2. **Encourage Japan and Korea to leverage existing hydrogen contract-for-difference programs to target blended green iron.** Japan and Korea are currently operating contract-for-difference schemes to support low carbon hydrogen uptake in their markets. Deloitte estimates collectively the two schemes will provide $30bn USD of public investment.[1] At present, these schemes are largely focused on the power sector. Tacit government support for steelmakers to bid into these schemes with Australian-supplied green iron would provide complementary support to Future Made in Australia in absence of rapid movement on carbon pricing.

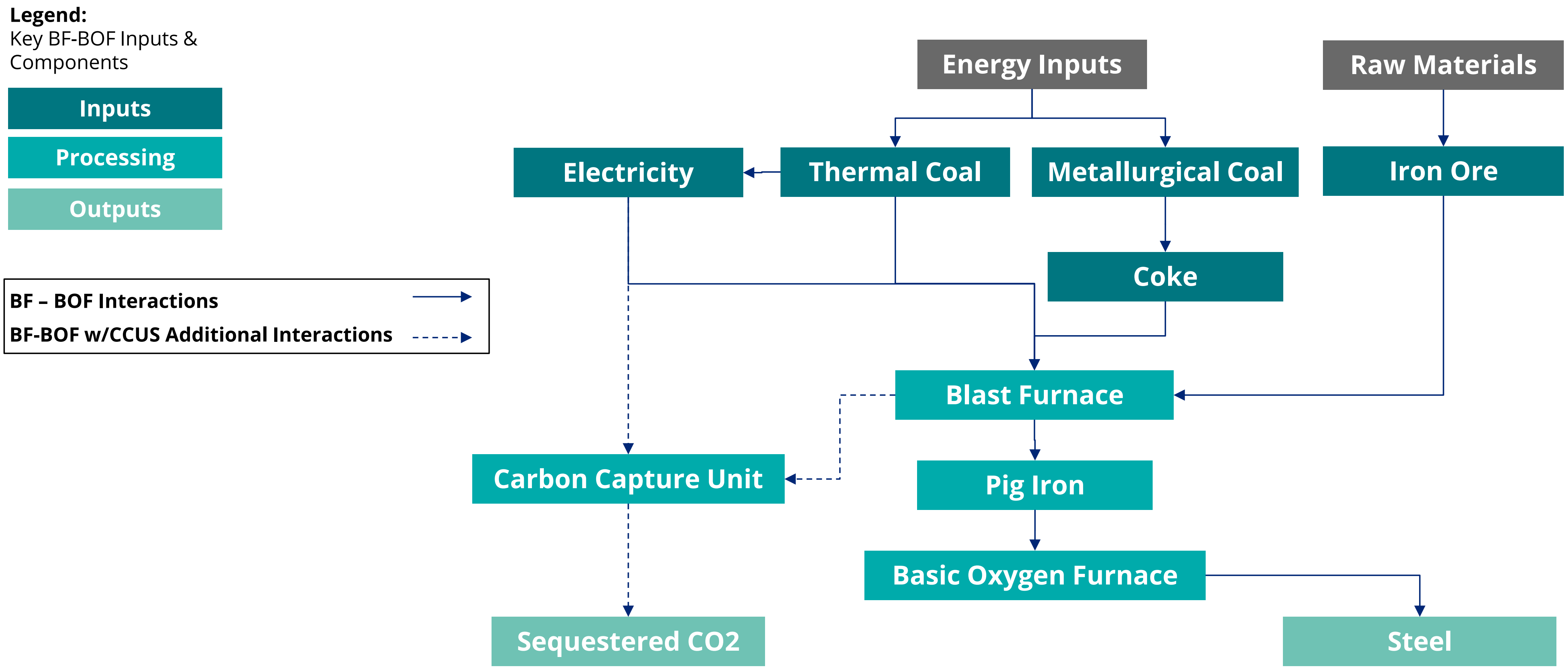
3. **Stand up a green steel buyers' coalition with Australian and Asian offtakers:** In the short term and in absence of carbon pricing, Australia could target end-users that are willing to pay the green premium. This includes industries for which steel represents a relatively small portion of total costs, such as car making.

Appendices

Appendix A – Model Overview & Major Assumptions

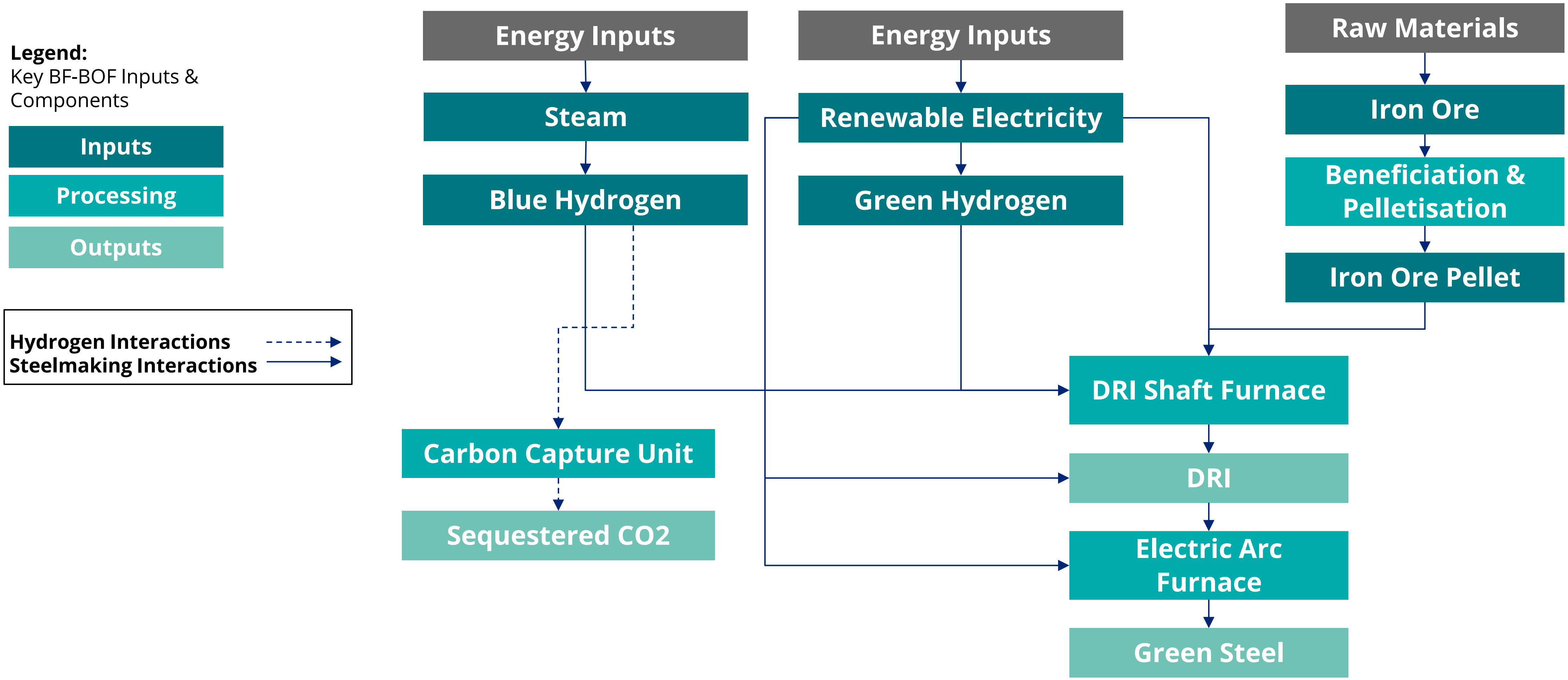
BF-BOF and BF-BOF with CCUS Supply Chains

Figure A.1: Key elements of the BF-BOF value chain configuration (with CCUS included).



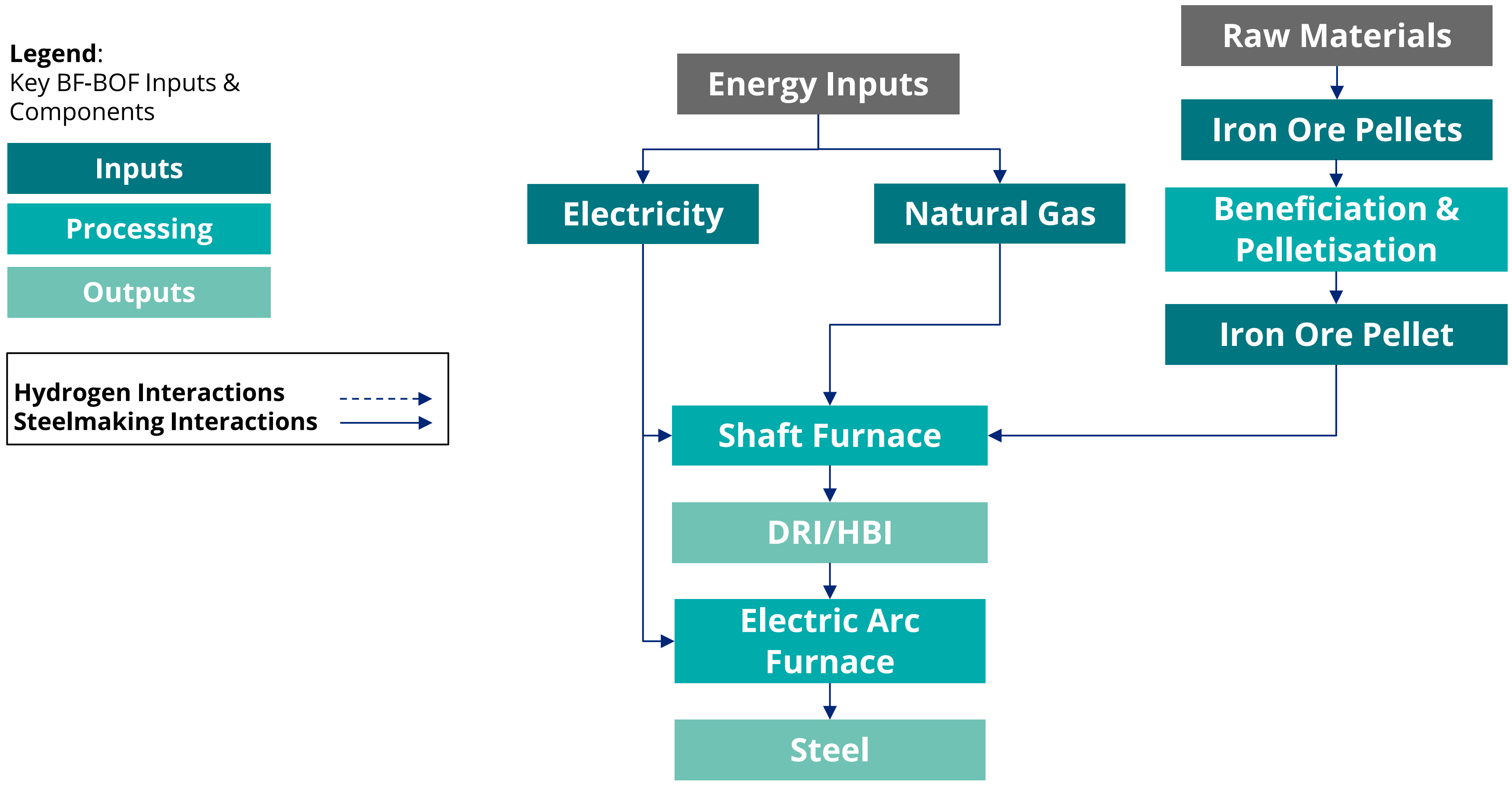
Hydrogen DRI-EAF

Figure A.2: Key elements of the green hydrogen DRI-EAF value chain configuration.



Gas DRI-EAF

Figure A.3: Key elements of the natural gas DRI-EAF value chain configuration.



Major Cost Inputs (Magnetite Only)

Process	Thermal Coal (AU$/t)	Metallurgical Coal (AU$/t)	Delivered Iron Ore – Preconcentrate (AU$/t)	Natural Gas (AU$/GJ)
Australia Price	175	450	73	16.7
Scaling Factor by Region				
Australia	1.0	1.0	73	1.0
Australia – Pilbara	1.0	1.0	73	0.5
United States	0.7	0.7	76	0.3
Canada	1.3	1.3	66	0.4
Middle East	1.3	1.3	149 (Hematite Ore)	0.2
China	1.2	1.2	109	1.1
Korea	1.3	1.3	109	1.2
Japan	1.3	1.3	109	1.2
Source	*Australia Price:* Department of Industry, Science and Resources (March 2024 quarterly, FY29 price estimate) *Country Scaling:* Our World in Data	*Australia Price:* Focus Economics *Country Scaling:* Our World in Data	*Australia Price:* Monash University *Canada Price:* Monash University *Guinea Price:* Australian hematite price (Australian Treasury) with market quality premium S&P Global *Transport Assumptions:* United States utilises Canadian Magnetite Middle East Utilises Guinea Hematite China, Korea and Japan utilise Canadian Magnetite	*Australia Price:* Commonwealth Bank of Australia *Country Scaling:* Parliament of Australia, Domestic Gas Supply and Pricing

Major Policy Definitions

All value impacts from policy have been assumed, broadly aligning with market understand of the potential magnitude.

Policy	Revenue Support	Capital Grant	Production Tax Incentive	Source
Australia Australia - Pilbara	Green Hydrogen: Hydrogen Headstart[1] (AU$1.50/kgH2)	Green Hydrogen: Powering the Regions Fund[2] (50% of capex)	Green Hydrogen: Hydrogen Production Tax Incentive[3] (AU$2/kgH2)	1.) Department of Climate Change, Energy, the Environment and Water 2.) Minister for Industry and Science 3.) Australian Tax Office
United States	-	Hydrogen: Bipartisan Infrastructure Law Support[4] (50% of capex) DRI/EAF: Industrial Demonstration Program[5] (50% of capex)	Hydrogen: IRA Hydrogen Production Tax Incentive[6] (AU$4.50/kg for Green and $1.28/kg for Blue)	4.) U.S. Department of Transportation 5.) Office of Clean Energy Demonstrations 6.) Inflation Reduction Act
Canada	-	Hydrogen: Low-carbon and Zero-emissions Fuels Fund[7] (50% of capex) DRI/EAF: Net Zero Accelerator[8] (25% of capex)	Electricity: CTITC[9] (AU$15/MWh) Green Hydrogen: Clean Hydrogen Investment Tax[10] Credit (AU$1.50/kg) Blue Hydrogen: CCUS Investment Tax Credit[10] (AU$1.50/kg)	7.) IEA 8.) Government of Canada 9.) Government of Canada 10.) EY Global
Middle East	-	-	-	-
China	-	-	-	-
Korea	-	-	-	-
Japan	Hydrogen: Japan is assumed to be a hydrogen importer. As such the CFD has been excluded from this analysis.	-	-	-

Note, each policy mechanism has eligibility criteria and time limitations. These have been accounted for in modelling. Where supports are stackable, it is assumed that developers will be incentivised to maximise available support. For example, Australian hydrogen costs in 2030 assume support from Hydrogen Headstart, the Hydrogen Production Tax Incentive and a capital grant.

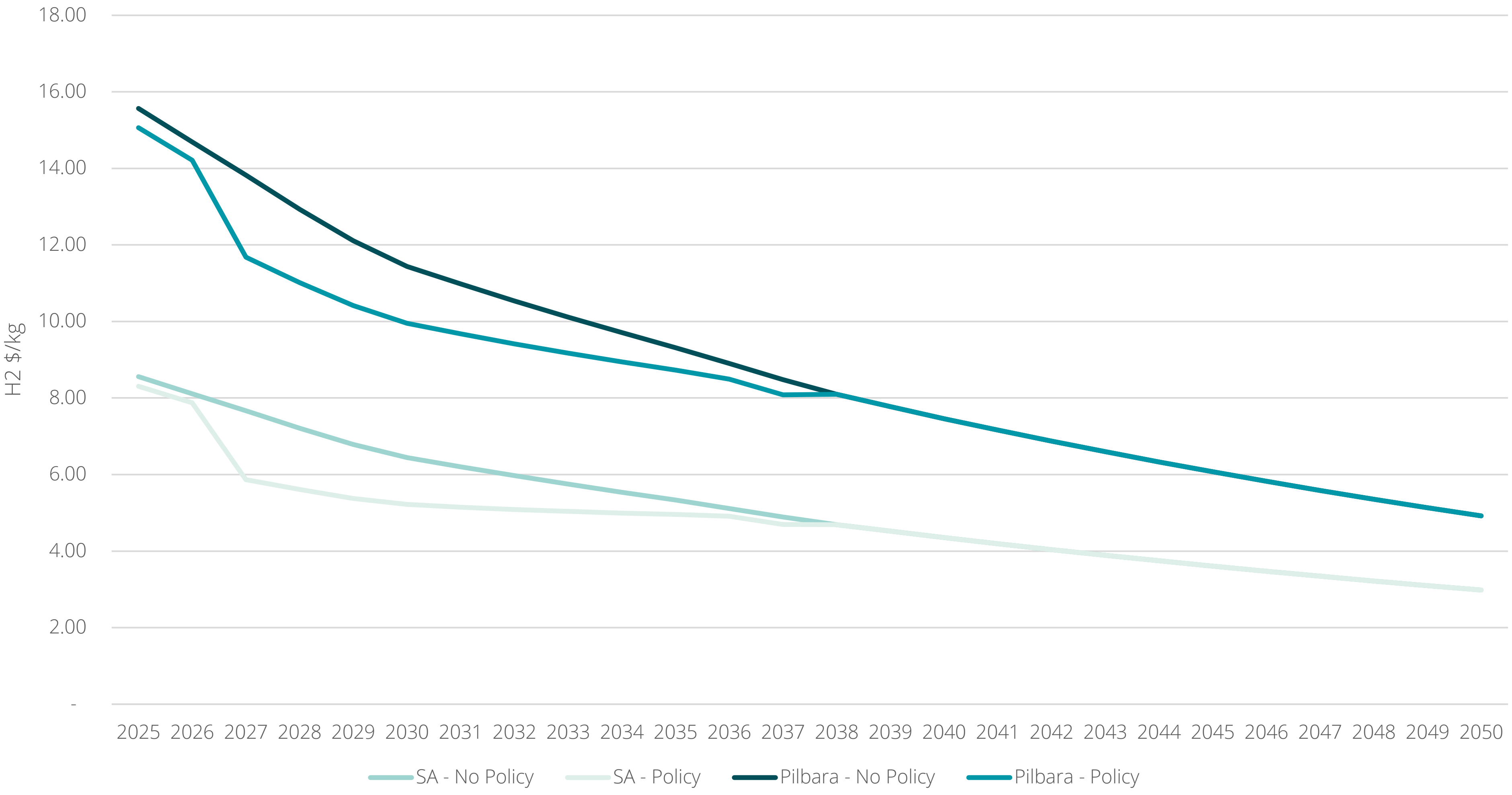
Hydrogen Estimates

The analysis leverages estimates from Deloitte's hydrogen model with and without announced policies. Locational differences in project design and costs are assumed within the model.

Prices in each year represent the levelised cost of hydrogen of a project built in that year and decline over time. In the modelling framework, contracts for hydrogen supply to a green iron project lock in a price in a contract in the commissioning year for the green iron facility.

Assessment of the Pilbara includes a material premium associated with the capital costs for renewable deployments which are assumed to be recovered through the PPA with the hydrogen production facility. PPAs are assumed to lock in electricity prices for 15 years.

Australian hydrogen costs in 2030 assume support from Hydrogen Headstart, the Hydrogen Production Tax Incentive and a capital grant. Policy only applies during the window support is announced for, so has a diminishing impact for projects built later in time.



Other Major Financial Inputs (Magnetite Only)

Financial Inputs	Value	Units	Source
Beneficiation & Pelletisation	198	$/t pellet	Minerals Research Institute of Western Australia
DRI Facility	1,400	$/t DRI	Mission Possible Partnership
EAF Facility	313	$/t Steel	
BF-BOF Facility	1,592	$/t Steel	
BF-BOF Facility with CCUS	1,836	$/t Steel	

Financial Inputs	Value	Source
Interest Rate	6%	Assumed for all countries
Leverage Ratio	60%	Assumed for all countries
Discount Rate	7%	Assumed for all countries
Margin	15%	Assumed for all countries and value chain processes between non-integrated stages

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