

# Australia Faces Growing Green Iron Competition From Overseas

Research and development to enable the use of Pilbara iron ore in low-carbon steelmaking must be accelerated

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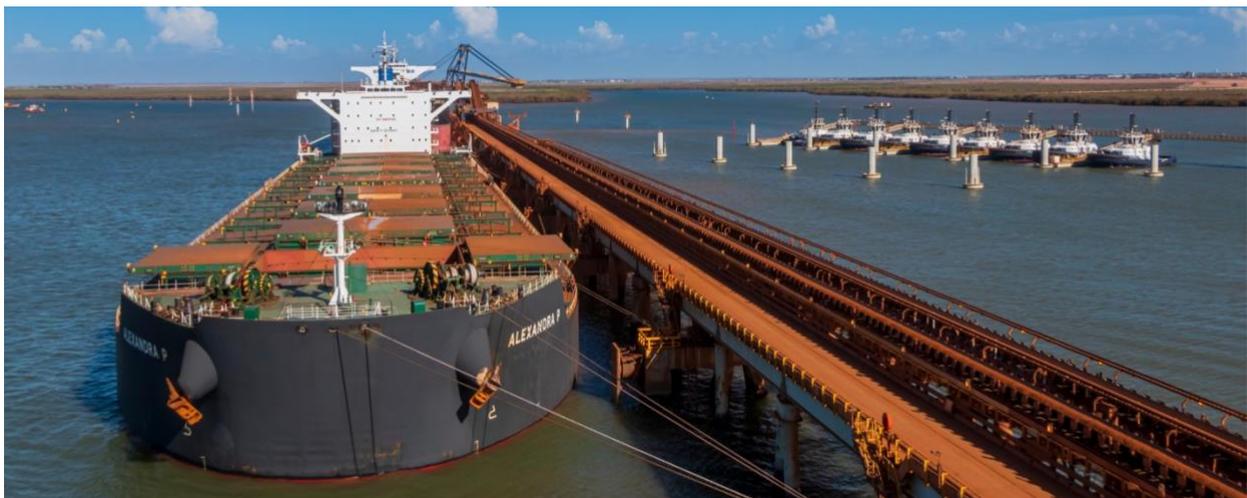
## Key Findings

**Australian iron ore faces growing competition in the emerging green iron market from countries and regions that produce higher-grade ore better suited to non-coal-based steelmaking.**

The cost of shipping green hydrogen means it should be used at the place of production wherever possible. Australia has an opportunity to shift towards onshore processing of iron ore using green hydrogen to produce low-carbon iron for export.

The global steel sector is considering a future that involves shipping green iron rather than shipping both green hydrogen and iron ore. Brazil, the Middle East and Africa are in a prominent position for producing green hydrogen-reduced iron.

Technology developments that allow the use of Pilbara iron ores in low-carbon ironmaking using direct reduced iron (DRI) processes need to be accelerated to prevent Australian iron ore losing market share to other countries and regions that are also eyeing this opportunity.



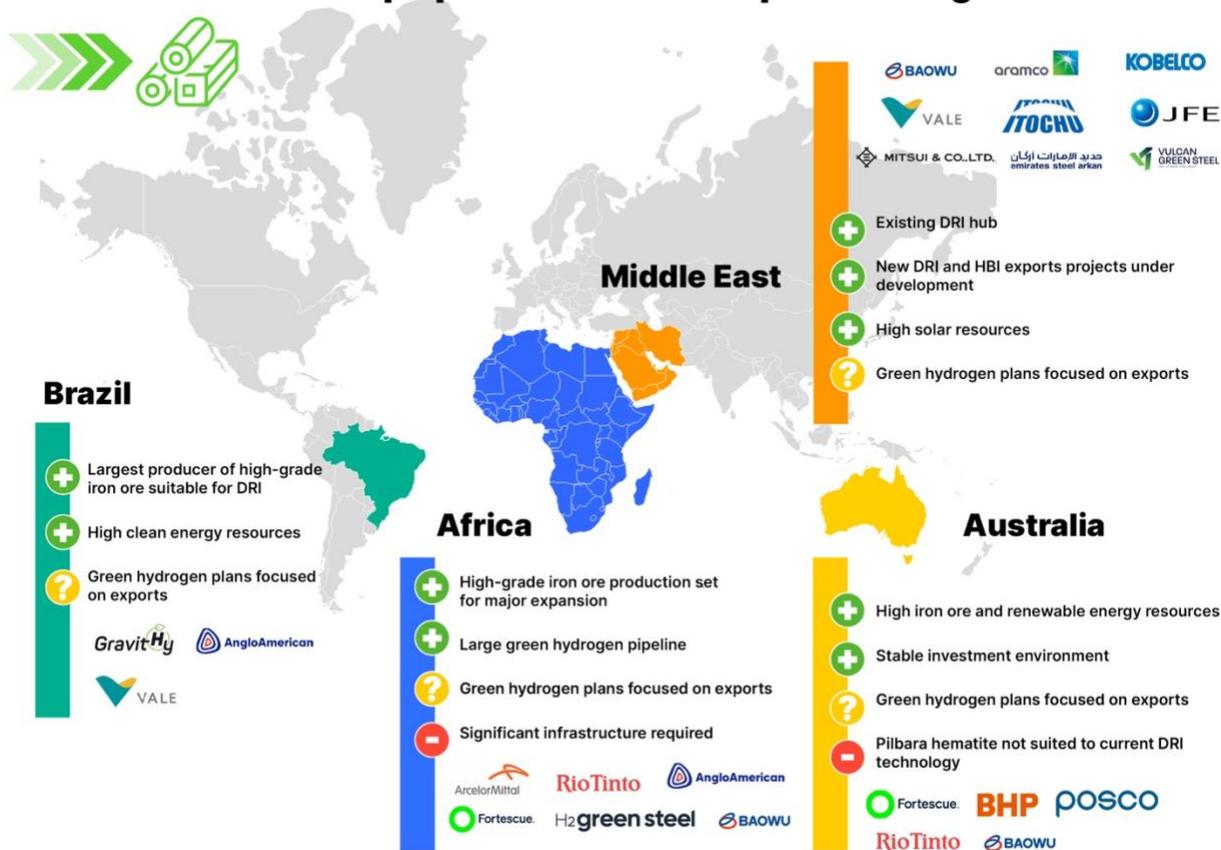
## Executive Summary

Australian iron ore – the nation’s biggest export – risks losing ground to other nations in the accelerating global shift towards green iron and low-carbon steel if research and development projects are not sped up.

With carbon capture technology looking unlikely to play a major role in steel decarbonisation, steel companies are increasingly planning a shift away from coal-consuming blast furnaces towards direct reduced iron (DRI) technology that can run on green hydrogen.

A recent report from the Minerals Research Institute of Western Australia (MRIWA) found that a global steel industry shift away from coal towards DRI on a pathway to net zero emissions steelmaking presents “a material, structural change to Western Australia’s iron ore industry, and the economy more broadly”. It also highlighted that, in a scenario where the steel technology transition is accelerated, Western Australia’s iron ore industry would be “in a precarious position assuming no change to the current product mix”.

### Australia needs to step up if it wants to compete in the green steel race



Australia faces a distinct disadvantage due to the quality of its hematite iron ore compared with other nations. DRI-based steelmaking currently requires ores with a high iron content, typically 67% or more. Most of the Pilbara's commercial deposits contain between 56% and 62% iron, currently suitable only for incumbent, highly carbon-intensive blast furnace technology.

There is a growing focus on the development of a major green hydrogen production and export industry in Australia. However, given the inefficiency and cost of shipping green hydrogen or green ammonia, it makes sense to use more of this planned production domestically to produce value-added products like green iron from iron ore.



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Green iron – made via DRI and exported as hot briquetted iron (HBI) – is now being considered for import by major global steelmakers instead of importing both iron ore and green hydrogen, as part of decarbonisation plans for an industry currently based on the import of iron ore and metallurgical coal. In its assessment of options for Western Australia's iron ore industry to position itself for a decarbonising steel sector, the MRIWA found that, "pathways which involve the development of intermediate iron products, such as HBI, are the most prospective for Western Australia."

South Korean steel giant POSCO is considering a US\$40bn investment in Australia with US\$28bn earmarked for green hydrogen production and a further US\$12bn for the production and export of green HBI. Japan's largest steelmaker, Nippon Steel, is considering a US\$700m investment in hydrogen-based green steel outside Japan with Australia a possible location. In addition, China Baowu Group – the world's largest steelmaker – is considering a major green iron project in Western Australia.

However, in a sign of the growing competition Australia faces as steelmakers start thinking about the offshoring of green iron production, both China Baowu and Nippon Steel are considering other locations. China Baowu is also looking at South America, Africa and the Middle East as possible green iron/steel investment locations and has signed an agreement with Aramco and the Saudi Public Investment Fund to set up a DRI-based steelmaking plant in Saudi Arabia to supply the domestic and regional market. Nippon Steel is considering Brazil – with its high-quality iron ore reserves – in addition to Australia.

Although Australia leads the world in iron ore exports, other nations and regions have the opportunity to combine their higher-grade iron ore and renewable energy resources to produce green iron for export in response to future demand growth.

## Brazil

Brazil is the world's largest producer of high-grade iron ore and has significant renewable energy and hydro power resources. As such, Brazil is in a position to produce green hydrogen at a competitive price compared with many other regions as hydrogen electrolyser costs come down.

Brazilian iron ore miner Vale – the world's leading producer of direct reduction-grade (DR-grade) iron ore – considers that it has an advantage over the other major iron producers when it comes to the steel technology transition towards DRI-based steelmaking. Its DR-grade ore can be used in standard and well-established DRI-electric arc furnace (DRI-EAF) steelmaking operations without the need for an additional melting furnace step required to enable the use of blast furnace-grade ore (such as that produced in the Pilbara) in DRI processes.

In May 2023, Vale announced it had signed a memorandum of understanding (MoU) with GravitHy to jointly evaluate a hydrogen-based DRI plant in France. The intention is to begin production as soon as 2027 with Vale supplying the DR-grade iron ore. The DRI produced is planned to be used directly or traded globally as HBI. In August 2023, H2 Green Steel – which is aiming to produce steel using green hydrogen from 2025 – agreed a multi-year deal with Vale that will see it supply the steelmaker with DR-grade iron ore pellets. H2 Green Steel also made a similar agreement with Rio Tinto, which will supply pellets from its Canadian – not Australian – operations. The deal will also see Rio buy and on-sell HBI from H2 Green Steel.

## Middle East

The Middle East is already a hub of DRI-based steelmaking based on the region's plentiful gas supply and has an opportunity to convert its steel industry from gas to green hydrogen utilising the region's abundant solar resources. This prospect is already drawing interest from steelmakers and miners, who are eyeing the region becoming a green iron hub based on growing DR-grade iron ore supply from Vale.

In addition to China Baowu's agreement with Aramco, Japanese companies Kobe Steel and Mitsui & Co. have signed a MoU to explore the feasibility of DRI production and export as HBI from Oman beginning in 2027. Vulcan Green Steel plans to invest US\$3 billion in a DRI-EAF plant with the annual capacity of 5 million tonnes in Oman. The company is targeting low-carbon steel demand in the Middle East, Europe and Japan. In the UAE, Emirates Steel Arkan has partnered with Japanese steelmaker JFE Steel and trading house Itochu Corporation in a plan to produce DRI in Abu Dhabi for shipping to Asia from 2025.

## Africa

Although a smaller iron ore producer, Africa already produces grades of higher quality than Australia and there is the prospect of much more to come, including from Australian companies that are now

shifting into the continent. Africa also has well over 100 gigawatts (GW) of green hydrogen capacity in the pipeline.

The potential suitability of at least some African iron ore output for DRI-EAF steelmaking operations has been demonstrated by Anglo American's recent MoU with H2 Green Steel. The agreement will see ore from Anglo's South African and Brazilian operations trialled in H2 Green Steel's DRI process in Sweden.

Africa's most significant iron ore development is now moving forward in Guinea. In the coming years, Guinea looks set to become the third-largest iron ore producer in the world after Australia and Brazil, with a quality significantly higher than Australia's. If the Simandou projects led by Rio Tinto and Chinese companies run smoothly, the deposits could produce 200 million tonnes per annum of high-grade, 65-66% Fe ore by the end of the decade. Rio Tinto has stated that the deposit is estimated to have 40% of high-quality iron ore resources that are "well suited to meet DRI specification and could be processed using the DRI-EAF route".



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Fortescue is also targeting high-grade iron ore in Africa and signed a Mining Convention in February 2023 with Gabon for the Belinga Iron Ore Project in the north-east of the country. The Belinga project is on course to deliver the first shipment of iron ore before the end of 2023. Former Fortescue CEO Fiona Hick has stated that "every indication we have, shows the project has the potential to be significant scale and very high-grade", and that, "initial indications are that it could be similar in scale and size to Simandou in Guinea."

## Australia's Iron and Steel Decarbonisation Challenge in Context

As well as contributing to the global supply of high-grade iron ore required as the steel technology transition away from coal accelerates, Simandou will also help China achieve its strategic aim to reduce reliance on Australian iron ore.

As the world's largest steelmaker, China is the biggest importer of iron ore globally and Australia's key iron ore export market. However, as the Chinese economy matures, its steel demand will enter long-term decline. Steel production in China has been declining since 2020, and there are early signs that production in 2023 will be below the previous year.

In addition, as well as developing Simandou with Rio Tinto, China is aiming to increase domestic iron ore production and increase recycling from scrap steel – a resource that will become increasingly available in China as its economy continues to mature. Increased recycling of scrap steel will be a

significant steel decarbonisation tool going forward and represents a growing source of competition for Australian iron ore.

Within the context of these trends, Australia is challenged with the task of making its lower-grade iron ore suitable for DRI-based iron and steelmaking operations. This could include beneficiating Pilbara hematite iron up to DR-grade and a switch to more magnetite mining, which is more amenable to beneficiation up to a higher grade. Fortescue is already producing and shipping magnetite containing 67% Fe, which meets DR-grade.

In addition, steel technology developments will likely also be part of the solution. Rio Tinto, BHP and Fortescue are all investigating technology solutions that would allow the use of their blast furnace-grade Pilbara iron ore in DRI-based processes. Furthermore, both Fortescue and Rio Tinto have signed agreements with China Baowu to investigate steel emissions reduction. Both agreements will investigate the use of Pilbara iron ore in DRI-based steelmaking in China, while Rio Tinto's agreement will also investigate the possibility of low-carbon iron production in Australia.

Australia has numerous advantages that present it with an opportunity to lead the global steel sector into a low-carbon future, including abundant iron ore and renewable energy resources, established infrastructure, and political and regulatory stability providing a strong investment environment. In addition, the sheer size of the Western Australian iron ore industry is a further advantage – the global steel sector will need Western Australian iron ore to be heavily involved in decarbonisation if net zero global steel emissions are to be achieved.

However, Australia faces multiple long-term iron ore challenges, and one of these is that Pilbara ore is generally well below the quality currently required for lower-emissions DRI-based processes. Research and development efforts need to be accelerated if Australia and its miners are to remain global leaders in iron ore and do not lose out amid growing demand for low-carbon iron and steel. Some refocusing of Australian green hydrogen projects towards more domestic use can help Australia lead the green iron export opportunity going forward.

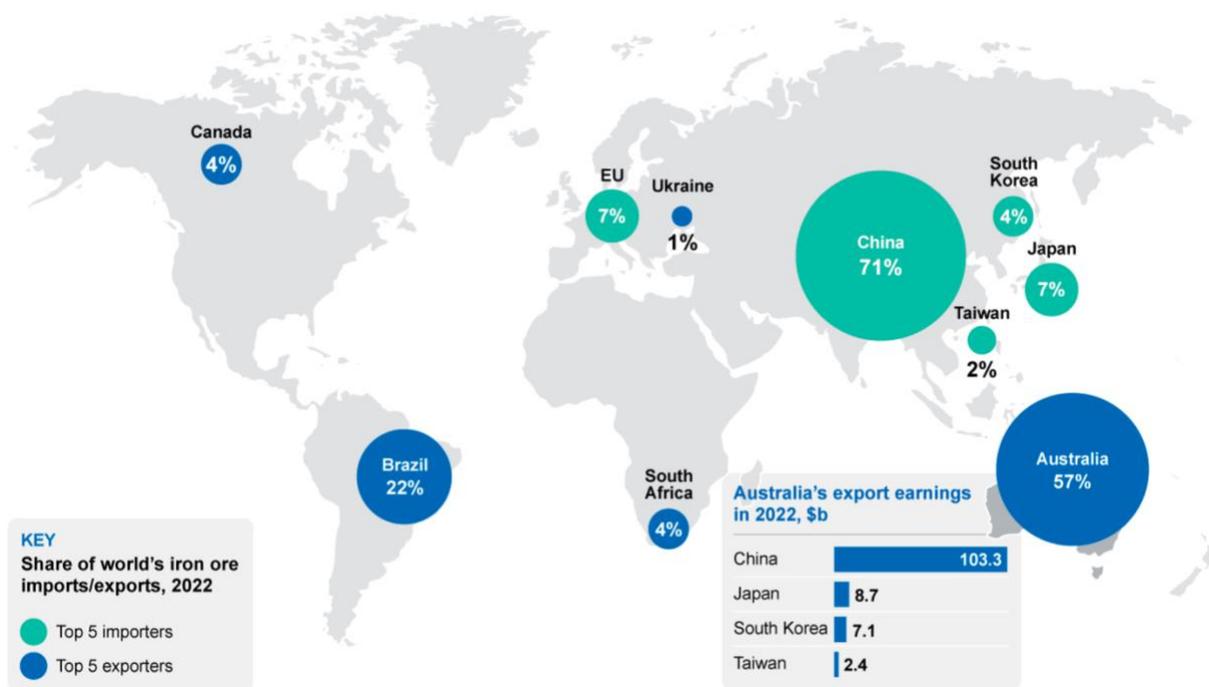
The MRIWA noted that shifting towards green iron production “represents the greatest economic opportunity” for Western Australia when it comes to positioning the iron ore industry for a low-carbon future. It also warned of a possible scenario where “other global suppliers of iron ore and iron feedstock better position to succeed in a Green Steel world”, a scenario that becomes more likely if technology developments that allow the use of Pilbara hematite in DRI processes are delayed.

## Introduction

Australia is the world's largest producer of iron ore – it is the country's biggest resource and energy export by far, totalling A\$132bn in exports in FY2021-22. However, the value of iron ore exports is forecast to fall over the coming years as prices moderate.<sup>1</sup>

As the world's largest steelmaker, China is the biggest importer of iron ore globally and Australia's key iron ore export market (Figure 1), but as the Chinese economy matures, steel demand will enter long-term decline. Under the International Energy Agency's (IEA) Announced Pledges Scenario – which reflects China's targets to reach net zero emissions in 2060 and peak carbon emissions by 2030 – Chinese steel production is 40% lower in 2060 than in 2020.<sup>2</sup> China may already be past, or very close to peak steel demand. Steel production in China has been declining since 2020<sup>3</sup>, and there are early signs that production in 2023 will be below the previous year.<sup>4</sup>

**Figure 1: World Iron Ore Trade Map**



Source: Resources and Energy Quarterly June 2023, Department of Industry, Science and Resources

<sup>1</sup> Department of Industry, Science and Resources. [Resources and Energy Quarterly](#). June 2023.

<sup>2</sup> IEA. [An Energy Sector Roadmap to Carbon Neutrality in China](#). September 2021. Page 102.

<sup>3</sup> S&P Global. [China's 2022 crude steel output falls for second straight year](#). 17 January 2023.

<sup>4</sup> S&P Global. [China's Baowu receives output control targets; others to follow](#). 24 July 2023.

Rio Tinto CEO Jakob Stausholm stated in August 2023 that Chinese steel production has probably peaked but that steel demand in other parts of Asia was set for growth.<sup>5</sup> India in particular will see significant steel demand growth. However, China dominates Australia's iron ore export earnings at A\$103bn in 2022. The next largest destination was Japan at A\$8.7bn. China imported 1.1 billion tonnes of iron ore in 2022 while India imported just 7 million tonnes (Mt).<sup>6</sup>

In addition, China is targeting reduced reliance on Australian iron ore by increasing domestic production<sup>7</sup> and accessing new overseas sources such as the significant, high-quality reserves in Simandou, Guinea,<sup>8</sup> where development is now proceeding.<sup>9</sup>

A further long-term headwind for Australian iron ore comes from China's aim to increase steelmaking via recycling scrap steel – a resource that will become increasingly available in China as its economy continues to mature.<sup>10</sup>

On top of these trends, the accelerating steel decarbonisation trend<sup>11</sup> represents a further long-term challenge to Australian iron. The same trend is also starting to challenge the long-term outlook of Australia's third-largest resources and energy export – metallurgical coal.<sup>12</sup> In July 2023, BHP outlined that the twin trends of decarbonisation and China's shift towards less steel-intensive development will see demand for Australia's iron ore, coal and gas decline.<sup>13</sup>



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China's shift towards more scrap-based steelmaking – a much less emissions-intensive method of steelmaking than blast furnaces – is further supported by China's efforts to decarbonise its steel industry,<sup>14</sup> a trend that will also be seen in Australia's other major iron ore export destinations<sup>15</sup>. Increased recycling of scrap steel will be a significant steel decarbonisation tool going forward and represents a growing source of competition for Australian iron ore.<sup>16</sup>

With carbon capture for blast furnaces making little headway and not expected to make a major contribution to decarbonising the steel sector<sup>17</sup>, global steelmakers are increasingly targeting direct

<sup>5</sup> Australian Financial Review. [Rio Tinto puts five-year deadline on low carbon aluminium fix](#). 1 August 2023.

<sup>6</sup> Department of Industry, Science and Resources. [Resources and Energy Quarterly](#). June 2023.

<sup>7</sup> Reuters. [China to speed up iron ore projects to secure domestic supply](#). 19 April 2023.

<sup>8</sup> Australian Financial Review. [China leaps ahead on unlocking huge African iron ore deposit](#). 23 January 2023.

<sup>9</sup> Australian Financial Review. [The big threat to Aussie iron ore is coming to life](#). 26 July 2023.

<sup>10</sup> IEEFA. [New From Old: The Global Potential for More Scrap Steel Recycling](#). December 2021.

<sup>11</sup> IEEFA. [German steel giant tech breakthrough to steer industry away from coal](#). 28 September 2022.

<sup>12</sup> IEEFA. [HSBC joins major miners in turning away from further metallurgical coal development](#). 30 January 2023.

<sup>13</sup> BHP. [Geraldine Slattery at the American Chamber of Commerce](#). 27 July 2023.

<sup>14</sup> IEEFA. [China's peak steel emissions shift unlikely to delay carbon reductions](#). 9 March 2022.

<sup>15</sup> Fastmarkets. [Japan's steel decarbonization drive forecast to slash scrap exports, raise imports](#). 25 July 2023.

<sup>16</sup> Australian Financial Review. [Rio Tinto in billion-dollar recycling push](#). 22 July 2023.

<sup>17</sup> Agora Industry. [15 Insights on the Global Steel Transformation](#). June 2023.

reduced iron (DRI)-based steelmaking that can use green hydrogen to reduce emissions significantly<sup>18</sup>. DRI-EAF steelmaking – using DRI and electric arc furnaces (EAFs) – is well established using natural gas but requires high-grade (high iron content) iron ore. In addition, replacing natural gas in this process requires a large supply of green hydrogen made via electrolysis powered by renewable energy.

As such, some major steelmakers are considering relocating the ironmaking step of the steelmaking process to places that have both suitable iron ore and high renewable energy resources to support green hydrogen production.<sup>19</sup> Green iron could then be exported for processing into steel closer to centres of steel demand via EAFs. A recent report on the steel technology transition by Agora Industry highlighted that an international green iron trade can be a win-win for exporters and importers, lowering the cost of the transition away from fossil fuels.<sup>20</sup>



**A key issue faced by Australia’s major iron ore producing region – the Pilbara – is that the quality of its ore mainly falls well below direct reduction-grade (DR-grade).**

A key issue faced by Australia’s major iron ore producing region – the Pilbara – is that the quality of its ore mainly falls well below direct reduction-grade (DR-grade).<sup>21</sup> Technology and mining/processing developments that allow use of Pilbara ore in low-carbon DRI-based steelmaking will be needed to prevent the Pilbara losing market share to other countries and regions that are also eyeing this opportunity.

A recent report from the Minerals Research Institute of Western Australia (MRIWA) found that the global steel industry’s shift away from coal towards DRI presents “a material, structural change to Western Australia’s iron ore industry, and the economy more broadly”. It also highlighted that in a scenario where the steel technology transition is accelerated, Western Australia’s iron ore industry would be “in a precarious position assuming no change to the current product mix”.<sup>22</sup>

Technology transitions have a history of happening faster than expected.

In August 2023, BlueScope CEO Mark Vassella admitted that steel emissions reduction momentum is moving faster than he predicted just two years ago, saying: “The technology is moving faster than we might have expected.”<sup>23</sup>

<sup>18</sup> IEEFA. [“Hard-to-abate” must not become code for delaying steel decarbonisation](#). 24 January 2023.

<sup>19</sup> Bloomberg. [Japan’s Top Steelmaker Eyes \\$700 Million ‘Green Steel’ Project](#). 3 March 2023.

<sup>20</sup> Agora Industry. [15 Insights on the Global Steel Transformation](#). June 2023.

<sup>21</sup> IEEFA. [Iron ore quality a potential headwind to green steelmaking: Technology and mining options are available to hit net-zero targets](#). June 2022.

<sup>22</sup> Minerals Research Institute of Western Australia. [Western Australia’s Green Steel Opportunity](#). 19 June 2023. Page 36-37.

<sup>23</sup> Australian Financial Review. [BlueScope to spend \\$1.15b on old-school steelmaking](#). 21 August 2023.

## Accelerating Green Hydrogen Export Focus

With excellent renewable energy resources and land available for the installation of wind and solar, Australia has a target to become a major hydrogen exporter. The most recent Australian federal budget outlined a A\$2bn ‘Hydrogen Headstart’ program that will support green hydrogen projects with the ambition to help develop up to one gigawatt of green hydrogen electrolyser capacity by 2030.<sup>24</sup> The government wants to see Australia producing green hydrogen at a competitive A\$2/kg by 2030.<sup>25</sup>

Proponents of green hydrogen exports point to the many decarbonising applications it can have across energy systems. However, many of the proposed uses for green hydrogen – such as decarbonising domestic heating, road transport and power generation – look far more likely to be achieved via electrification and the use of now well-established wind and solar power backed up by battery storage.<sup>26</sup> Sectors where it looks like green hydrogen will make a significant impact in decarbonisation include fertiliser and steel production via DRI.

DRI is produced by reducing iron ore without melting it, typically using a mixture of carbon monoxide and hydrogen derived from natural gas or gasified coal. However, the use of green hydrogen, derived from renewable energy sources, can replace fossil fuel-derived hydrogen and carbon monoxide in the direct reduction process, significantly reducing carbon dioxide emissions. Some steel manufacturers have started to implement industrial-scale green hydrogen-ready DRI projects, which could support the steel industry in achieving the 2050 net zero emissions target.<sup>27</sup>

While green hydrogen can help reduce emissions in the iron and steel sector, not all regions will be able to produce it at the same low cost. As a result, there has been a push to transport cheap, green hydrogen to these regions. However, the efficiency and cost of transporting hydrogen over long distances looks like a major challenge.

## Hydrogen Transportation Barriers

Hydrogen shipping poses challenges such as low efficiency, high pressures, and the need for extreme temperatures during conversion and reversion. All of these inefficiencies and losses add additional costs to the hydrogen value chain.

Hydrogen is the lightest element and has a very low volumetric energy density compared with other sources of energy. This is problematic when it comes to transporting and storing hydrogen. The

<sup>24</sup> Department of Climate Change, Energy, the Environment and Water. [Hydrogen Headstart program](#).

<sup>25</sup> Bloomberg. [Australia Needs Bigger Ambitions to Be a Hydrogen Powerhouse](#). 11 May 2023.

<sup>26</sup> Hydrogen Insight. [Liebreich: ‘Hydrogen is starting to look like an economic bubble – and here’s why’](#). 13 October 2022.

<sup>27</sup> IEEFA. [“Hard-to-abate” must not become code for delaying steel decarbonisation](#). 24 January 2023.

small molecule can leak easily and compressing it for transportation and storage poses a real engineering challenge.

Due to these features, it is not possible to transport hydrogen as easily as oil and liquefied natural gas (LNG). Hydrogen can be liquefied at  $-253^{\circ}\text{C}$  (compared to  $-162^{\circ}\text{C}$  for LNG). The colder the temperature required for liquefaction, the greater the cost.<sup>28</sup> It also requires 2.5 deliveries to transport the same amount of energy as one cargo of LNG.<sup>29</sup>



**Almost all of the available technologies for hydrogen conversion and reconversion to gaseous form, including conversion to ammonia for shipping, consume considerable energy that leads to higher cost.**

Almost all of the available technologies for hydrogen conversion and reconversion to gaseous form, including conversion to ammonia for shipping, consume considerable energy that leads to higher cost. While hydrogen liquefaction consumes 30-40% of its energy content, LNG needs nearly 10%<sup>30</sup> – another argument for keeping hydrogen in gaseous form to avoid energy loss. Provaris Energy, a leading company in green hydrogen shipping technologies, has highlighted the significant challenges involved in transporting hydrogen. It has emphasised that converting hydrogen to a liquid form or into ammonia for shipping can result in a loss of up to half of the hydrogen's energy content. This makes it inefficient for end users that require gaseous hydrogen, according to Provaris chief executive Martin Carolan.<sup>31</sup>

Figure 2 illustrates the energy consumption involved in the conversion to hydrogen carriers (i.e., ammonia ( $\text{NH}_3$ ), liquified hydrogen ( $\text{LH}_2$ ) and liquid organic hydrogen carriers (LOHC)) and subsequent reconversion to hydrogen again. This is represented in terms of the equivalent energy contained in the hydrogen.<sup>32</sup> Although these processes typically utilise electricity and other heat sources in practice, representing them in terms of the equivalent energy in hydrogen provides an understanding of the efficiency associated with different transportation alternatives.

<sup>28</sup> Bloomberg. [There Won't Be a Saudi Arabia of the Green Hydrogen Age](#). 17 May 2023.

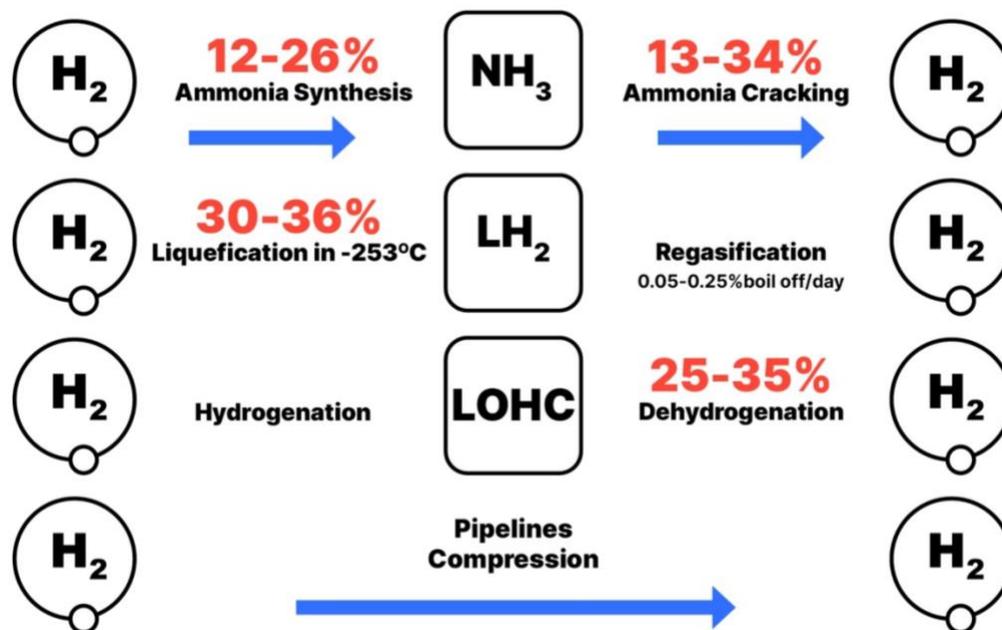
<sup>29</sup> BloombergNEF. [Hydrogen for Beginners](#). 8 September 2021.

<sup>30</sup> BloombergNEF. Liebreich: [The Unbearable Lightness of Hydrogen](#). 12 December 2022.

<sup>31</sup> Australian Financial Review. [Hydrogen exports yet to clear technical hurdles, shipper warns](#). 22 May 2023.

<sup>32</sup> IRENA. [Global hydrogen trade to meet the 1.5°C climate goal: Part II – Technology review of hydrogen carriers](#). 27 April 2022. Pages 22-23.

Figure 2: Hydrogen Carriers' Energy Consumption in Conversion and Reconversion\*



Source: IRENA, *Technology review of hydrogen carriers* Pages 22-23. Note: As an example, to convert ammonia to hydrogen via an ammonia cracking process, high temperatures and low pressures are required. The energy consumption of this process is 4 to 11 kilowatt-hours per kilogram of hydrogen, which is equivalent to the heat of 13-34% of that hydrogen when it's combusted.

\*Percentages calculated based on energy contained in hydrogen

In regions where the cost of hydrogen production is higher compared with countries with abundant renewable resources, the transportation costs pose a significant challenge in making it economically viable. The difference in hydrogen production costs between countries with strong and weak renewable sources has been projected to be US\$0.82/kg in 2030 and US\$0.52/kg in 2050.<sup>33</sup> However, these cost differentials are not sufficient to justify the transportation of hydrogen over long distances. Hydrogen transportation via hydrogen carriers is projected to add an additional cost of US\$2.5 to US\$4.5 per kilogram of hydrogen delivered by 2030.<sup>34</sup>

## Export Green Iron Not Green Hydrogen

Given that the shipping of green hydrogen appears to be expensive, there should be more focus in Australia on using green hydrogen domestically in sectors where it makes sense to do so, such as steelmaking.

Australia is not a major steelmaker, but it is the world's largest exporter of iron ore, giving it a highly significant position in the global steel supply chain. Australia's Pilbara region is blessed with high

<sup>33</sup> BNEF. *Hydrogen: The Economics of Transportation and Delivery*. 17 October 2019.

<sup>34</sup> IRENA. *Global hydrogen trade to meet the 1.5°C climate goal: Part II – Technology review of hydrogen carriers*. 2022. Page 11.

renewable energy resources as well as iron ore – green iron could be produced via DRI adjacent to the places where iron ore and renewable energy for producing green hydrogen are available. Green iron could be shipped cost-effectively to other countries for low-carbon steelmaking in EAFs and finishing processes, instead of freighting both iron ore and hydrogen separately at higher cost.

Potentially, the full steelmaking process using Australian iron ore, green hydrogen and renewable energy could be completed on shore via DRI-EAF, with low-carbon crude steel exported instead of iron. However, many nations are likely to be reticent to fully offshore their steelmaking capacity and may strategically prefer to import green iron that could be processed into steel domestically via EAFs that could be powered by renewable energy. This replacement of the import of iron ore with the import of green iron is now being considered by some major steelmakers.



**It is crucial for the future to prioritise the production of green iron in regions with competitive advantages.**

According to H2 Green Steel executive vice president Kajsa Rytberg-Wallgren, it is crucial for the future to prioritise the production of green iron in regions with competitive advantages. Breaking the traditional ironmaking process within the steel value chain is unavoidable, especially considering the impracticality of producing DRI in many EU countries given the available renewable energy resources and the cost of importing green hydrogen. Rytberg-Wallgren highlighted the strategy employed by Kobe Steel, which is planning to import green iron from H2 Green Steel's Swedish plant, avoiding the expense of hydrogen imports. Noting that cost was key in a low-margin industry, she stated "You will be out of cost. So they want to buy green iron, or HBI [hot briquetted iron, blocks of sponge iron] from places in the world where it makes sense to produce it."<sup>35</sup>

Furthermore, studies on green hydrogen investment primarily focus on addressing the significant risks associated with the green hydrogen economy. Alongside tackling technical hurdles related to production, storage, transmission and distribution, lenders and sponsors are particularly concerned about securing long-term offtake agreements and effectively managing the demand side for end users.<sup>36</sup>

Local consumers have the ability to organise the purchase agreements for green hydrogen. The most advantageous approach to mitigate project risks is to allocate hydrogen to the domestic market in areas where opportunities exist. Key sectors such as local fertiliser and chemical producers, refineries and steel companies are well-positioned to utilise the available hydrogen capacity.<sup>37</sup> By converting the green hydrogen into valuable products instead of exporting it in liquid or other derivative form, it is possible to reduce the risks involved with hydrogen production and transportation.

<sup>35</sup> Hydrogen insight. '[Coal-based steel will have an advantage over hydrogen-derived green steel due to EU carbon allowance scheme](#)'. 26 June 2023.

<sup>36</sup> BCG. [Breaking the Finance Barrier for Hydrogen and Carbon Capture](#). 21 February 2023.

<sup>37</sup> IHS Markit. [Low-carbon hydrogen ambitions in Africa and the Middle East: An overview](#). 30 December 2022.

Green iron and steel projects are now being backed by banks and credit guarantors.<sup>38</sup> The demand for green steel is experiencing a significant surge, primarily driven by carmakers and white goods producers aiming to reduce carbon emissions throughout their value chain.

## Hot Briquetted Iron

HBI is a compressed form of DRI that is compacted at the discharging point of DRI shaft furnaces. It is an established product that does not react with oxygen in the atmosphere, making it safe for shipping. Compared to DRI, HBI has a higher density, making it more efficient for transportation and storage purposes.<sup>39</sup> HBI is a bulk export product that can be shipped in a similar way to iron ore.

Moreover, it has better mechanical strengths, another factor that makes it a better option for transport and storage.<sup>40</sup> HBI has the highest quality among the iron ore metalics with a metallisation rate above 90%. As a result, it is the best ore-based metallic that can be used in EAFs to produce high-quality steel.

Another benefit of trading reduced iron rather than iron ore is the reduced shipping costs for end-users. During the reduction process, iron ore loses its oxygen content, resulting in an average weight that is nearly 30% lower than that of iron ore pellets.<sup>41</sup> Figure 3 illustrates the difference between two pathways for green iron production and transportation.

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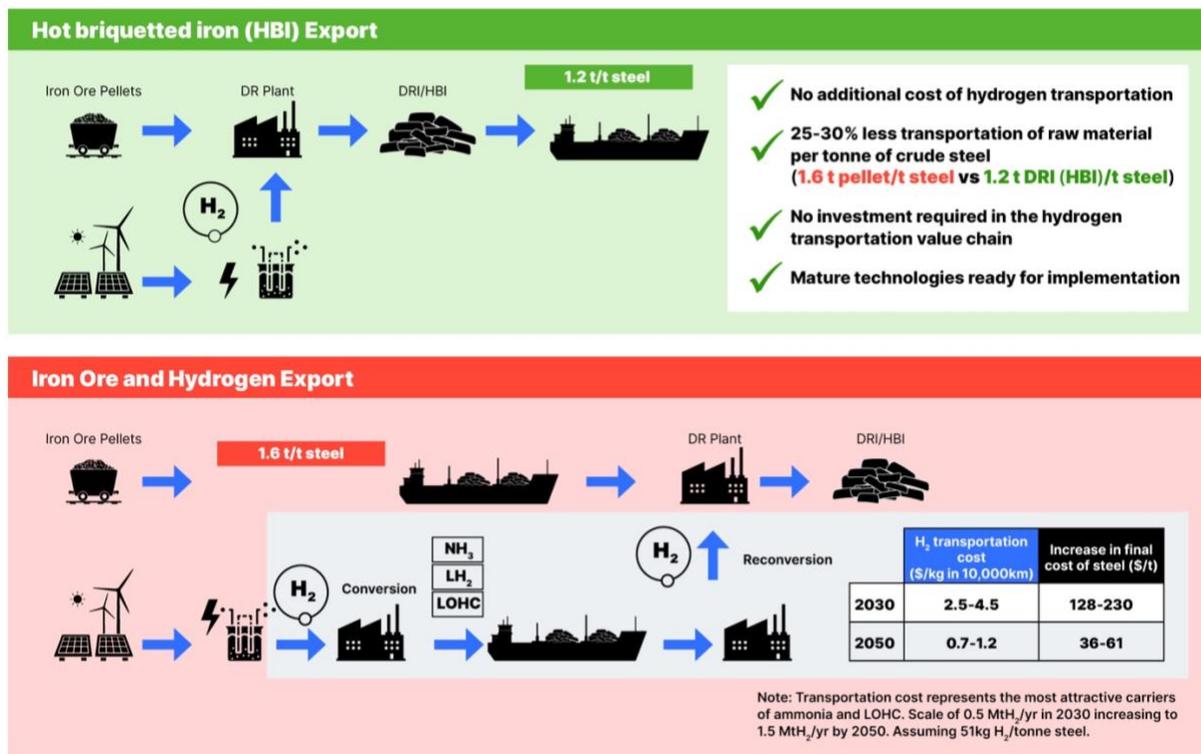
<sup>38</sup> IEEFA. [Green finance has begun to flow into green steel funding](#). 11 November 2022.

<sup>39</sup> IIMA. [Hot Briquetted Iron \(HBI\)](#).

<sup>40</sup> Australian Financial Review. [How Sweden's dash for green steel could trigger a Pilbara revolution](#). 9 December 2022.

<sup>41</sup> Energy Transitions Commission. [Unlocking the First Wave of Breakthrough Steel Investments](#). April 2023.

Figure 3: HBI Export vs Iron Ore and Hydrogen Export



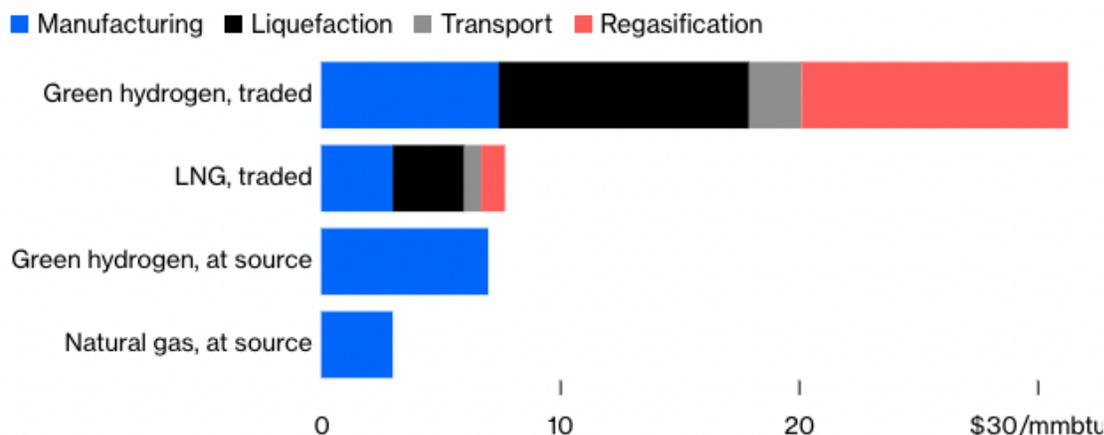
Source: IRENA Technology review of hydrogen carriers, IEFEA calculations

By 2030, hydrogen transportation via hydrogen carriers is projected to add an additional cost of US\$2.5 to US\$4.5 per kilogram of hydrogen delivered.<sup>42</sup> Assuming 51kg<sup>43</sup> of hydrogen for one tonne of steel, this increase in cost translates to an additional US\$128 to US\$230 per tonne of crude steel. While the technology is maturing and holds the potential to alleviate high costs in the value chain in the coming decades, hydrogen transportation still represents an extra cost for steelmakers.

<sup>42</sup> IRENA. *Global hydrogen trade to meet the 1.5°C climate goal: Part II – Technology review of hydrogen carriers*. 2022. Page 11.

<sup>43</sup> Journal of Cleaner Production. *Assessment of hydrogen direct reduction for fossil-free steelmaking*. December 2018.

**Figure 4: Transportation Costs Make Importing Green Hydrogen Expensive Even at US\$1/kg Production Cost**



Source: BloombergNEF, Hydrogen Council, Deloitte, Bloomberg Opinion calculations

Note: Based on hydrogen conversion via ammonia. Assumed hydrogen production cost of \$1 per kilogram. Converted to mmbtu at a rate of 7.44kg/mmbtu.

The current state of the hydrogen transportation value chain indicates that it is not yet fully developed, requiring significant investments in infrastructure at ports, dedicated vessels for each type of hydrogen carrier, and new conversion plant at the production region and reconversion facilities near steel mills.

The export of HBI is a well-established pathway. In 2021, 8Mt of gas-based HBI was shipped overseas and a further 15Mt was transported by trains and inland vessels.<sup>44</sup> HBI production and transportation offer energy efficiency and eliminate energy losses that may occur when hydrogen and iron ore pellets are transported separately. Green iron exports would take the form of HBI created from DRI that has been produced using green hydrogen (H<sub>2</sub> DRI) powered by renewables.<sup>45</sup>

Japan's Renewable Energy Institute has found that the import of HBI made via hydrogen-based DRI can be one of three key pillars of the decarbonisation of the nation's steel sector. HBI imports would help eliminate the need for unnecessary hydrogen import infrastructure investment, reducing the cost of zero-carbon steelmaking, and helping to keep the Japanese steel industry competitive.<sup>46</sup>

Recently, a report by CSIRO outlined a potential scenario for ironmaking in Australia and completing the steelmaking process in Japan and South Korea. According to the analysis, using natural gas and then green hydrogen to reduce iron ore and produce DRI in Australia (specifically in Pilbara region) results in a more sustainable value chain with lower total carbon emissions compared with performing these processes in Japan and South Korea. By shifting from blast furnace and basic oxygen furnace technology, which relies on iron ore fines (Fe=57% sinter feed), to the H<sub>2</sub> DRI-EAF

<sup>44</sup> Agora Industry. [15 Insights on the Global Steel Transformation](#). June 2023. Page 22.

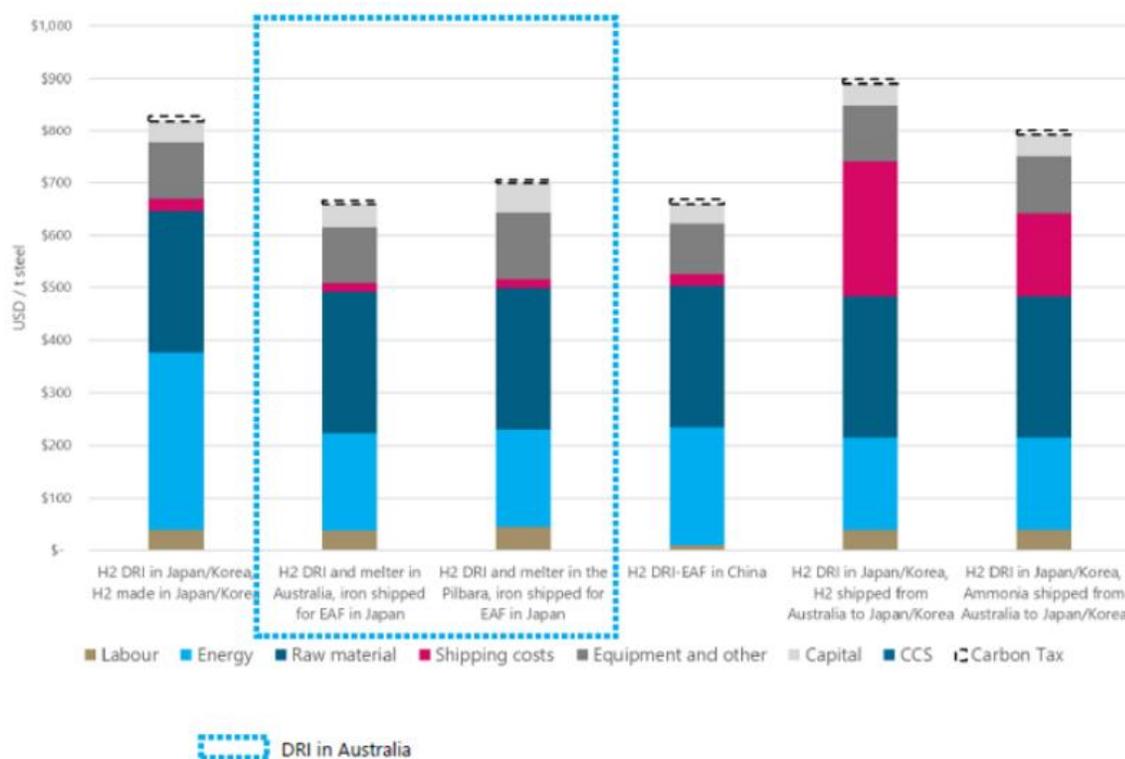
<sup>45</sup> Primetals. [The new age of HBI](#). 28 February 2023.

<sup>46</sup> Renewable Energy Institute. [The Path to Green Steel: Pursuing Zero-Carbon Steelmaking in Japan](#). February 2023.

route that uses green DR-grade pellets, a carbon dioxide reduction of 80% is achievable.<sup>47</sup> It also potentially cost-competitive in the short term and becomes increasingly cost-competitive as the cost of green hydrogen declines.

Reducing iron ore to iron could potentially enable Australia to save the necessary investment required for developing the hydrogen value chain and infrastructure, which includes the shipping process, terminals in both producing and destination countries, and compression and liquefaction.

**Figure 5: H<sub>2</sub> DRI-EAF Production Cost 2050 (US\$/tonne)**



Source: CSIRO. *Low emissions steel transition: Value chain considerations to support accelerated transition.*

The CSIRO report also addressed the issue of the high cost of shipping hydrogen from Australia to these countries, highlighting it as an unfeasible option. However, producing H<sub>2</sub> DRI in Australia is a financially viable solution when compared with exporting both iron ore and green hydrogen to Japan and South Korea for green steel production.<sup>48</sup> The cost gap between producing green steel in Japan or South Korea through imported H<sub>2</sub> DRI and using imported hydrogen and iron ore is projected to exceed US\$200 per tonne of steel in some scenarios (Figure 5).

<sup>47</sup> CSIRO. *Low emissions steel transition: Value chain considerations to support accelerated transition.* February 2023.

<sup>48</sup> Ibid.

The MRIWA recently found that a shift towards the production and export of HBI is a natural extension of Western Australia's current place in the global steel value chain and would allow the state to capture additional value without the infrastructure investment to produce steel itself.<sup>49</sup>

Green hydrogen-based HBI will be cost-competitive with its fossil fuel-based equivalent before green steel, according to MRIWA, such that green iron exports (in the form of HBI) can be an aspirational target for Western Australia in the medium term. The MRIWA finds that green hydrogen-based HBI will become economic once green hydrogen reaches A\$4/tonne (in today's dollars). It finds the current delivered price for green hydrogen in Western Australia is A\$7/tonne.

In its assessment of options for the Western Australian iron ore industry to position itself for a decarbonising steel sector, the MRIWA finds that, "pathways which involve the development of intermediate iron products, such as HBI, are the most prospective for Western Australia."<sup>50</sup>

## Potential Hubs for Green Iron

Requirements for any nation considering the production and export of green iron include: supply of iron ore of a grade high enough to be used in DRI processes using green hydrogen; good renewable energy resources capable of producing increasingly cheap green hydrogen; along with appropriate infrastructure. Major southern hemisphere iron ore exporters such as Australia, Brazil and South Africa are also home to very high renewable energy resources. Additional considerations include the availability of suitable land to support large renewable energy installations, water availability, and developments to overcome technical challenges associated with DRI.<sup>51</sup> This last consideration is of particular note for Australia, which – despite being the world's largest iron ore exporter – produces the lowest grades of the world's major exporters (Figure 6).

Wood Mackenzie has estimated that for iron and steel transition nearly 750Mt of DR-grade iron ore are required – a fivefold increase compared to current consumption – in a scenario where global warming is limited to 1.5°C. Wood Mackenzie found that the potential to increase supply of high-grade iron ore of a type suitable for use in DRI-based ironmaking is greatest in Brazil, which is already the largest producer of such grades. The Simandou projects in Guinea also have the potential to add to high-grade iron ore supply. As a result, Brazil and Africa look like becoming the key sources of DR-grade iron ore according to Wood Mackenzie, while Australia and the Middle East "will try to keep pace".<sup>52</sup> Countries that produce lower-grade ores, like Australia, may need to depend on technology developments that allow their ore to be used in DRI-based processes

<sup>49</sup> Minerals Research Institute of Western Australia. [Western Australia's Green Steel Opportunity](#). 19 June 2023.

<sup>50</sup> Ibid.

<sup>51</sup> Nature Communications. Devlin, A., Kossen, J., Goldie-Jones, H. *et al.* [Global green hydrogen-based steel opportunities surrounding high quality renewable energy and iron ore deposits](#). 4 May 2023.

<sup>52</sup> WoodMackenzie. [Pedal to the metal](#). September 2022.

regardless of whether they shift towards processing iron ore onshore and exporting green iron or continue to focus on ore exports.

**Figure 6: Potential Incremental Sources of High-Grade Iron Ore**



Source: Wood Mackenzie. *Pedal to Metal*

## Australia

In the field of steel sector decarbonisation, Australia has advantages including its renewable energy resources for the production of green hydrogen, large iron ore reserves, mining expertise and existing infrastructure. In particular, existing iron ore mining centres such as the Pilbara are suited to the production of green hydrogen because of both their renewable energy resources and the presence of existing road and power infrastructure.<sup>53</sup> Australia, the world's largest iron ore producer and exporter, and specifically the giant iron ore miners in Pilbara region can play a major role in green iron production if they act fast.<sup>54</sup>

However, most Pilbara iron ores have a distinct disadvantage compared with higher-grade ores in other parts of the world.<sup>55</sup> DRI-based iron and steelmaking processes currently require a high grade

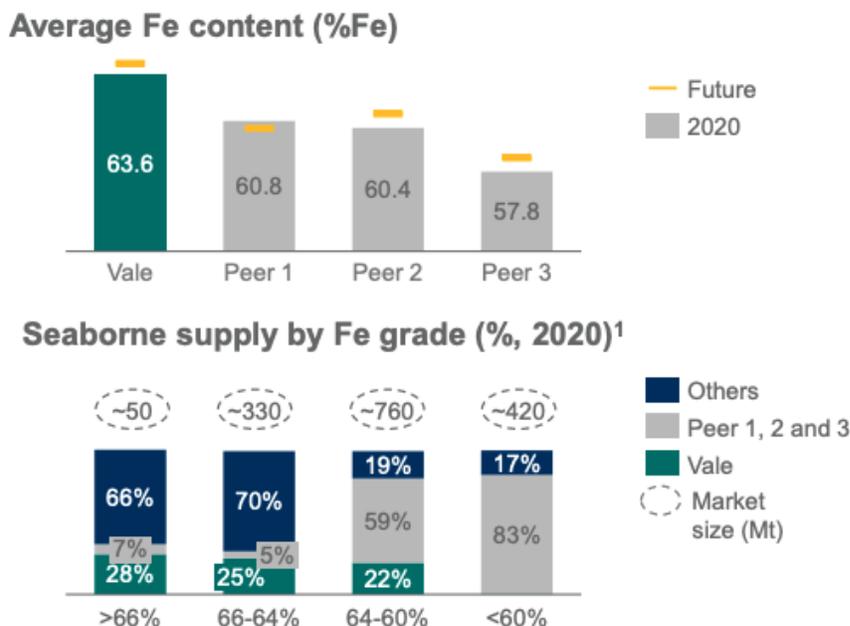
<sup>53</sup> International Journal of Hydrogen Energy. Changlong Wang, Stuart D.C. Walsh, Zhehan Weng, Marcus W. Haynes, Daisy Summerfield, Andrew Feitz. [Green steel: Synergies between the Australian iron ore industry and the production of green hydrogen](#). 18 May 2023.

<sup>54</sup> IEEFA. [Opportunities and challenges for the Pilbara amid the accelerating steel technology transition](#). 27 March 2023.

<sup>55</sup> IEEFA. [Iron ore quality a potential headwind to green steelmaking: Technology and mining options are available to hit net-zero targets](#). 28 June 2022.

of iron ore with at least 67% Fe content. Most of the Pilbara's commercial deposits contain between 56% and 62% Fe.<sup>56</sup>

**Figure 7: Average Iron Content of Vale vs. its Peers (BHP, Rio Tinto and Fortescue)**



Source: Vale

<sup>1</sup> Considering final products sales grade, including blended products. Does not include Chinese domestic production

Meanwhile, major international steelmakers have started to consider the role that the import of green iron instead of iron ore may play in the decarbonisation of their operations, with Australia's renewable energy resources and a willingness to collaborate with existing Australian suppliers in mind.

South Korean steel giant POSCO is planning a US\$40bn investment in Australia with US\$28bn earmarked for green hydrogen production and a further US\$12bn for the production and export of green HBI.<sup>57</sup> At the end of December 2022, the Western Australian government granted POSCO a land lease within the Boodarie Strategic Industrial Area for its HBI project.<sup>58</sup>

<sup>56</sup> Minerals Research Institute of Western Australia. [Western Australia's Green Steel Opportunity](#). 19 June 2023.

<sup>57</sup> POSCO. [POSCO Group CEO, Jeong-woo Choi, Meets the Prime Minister of Australia, Anthony Albanese, to Discuss Future Eco-friendly Projects](#). 7 December 2022.

<sup>58</sup> POSCO. [POSCO promotes the preemptive acquisition of low-carbon steel raw materials in Australia](#). 7 March 2023.

Japan's largest steelmaker, Nippon Steel, is considering a US\$700m investment in hydrogen-based green steel outside of Japan, with Australia a possible location.<sup>59</sup> In addition, China Baowu Group – the world's largest steelmaker – is thinking about a major green iron project in Western Australia.<sup>60</sup>

However, in a sign of the growing competition Australia faces as steelmakers start thinking about the offshoring of green iron production, both China Baowu and Nippon Steel are considering other locations. China Baowu is also looking at South America, the Middle East and Africa as possible green iron/steel investment decisions, while Nippon Steel is considering Brazil – with its high-quality iron ore reserves – as well as Australia.

Australia is challenged with the task of making its lower-grade iron ore suitable for DRI-based iron and steelmaking operations. This could include beneficiating Pilbara hematite iron ore up to DR-grade, though this is likely to be difficult in many cases. An alternative could be to switch to more magnetite iron ore mining, which is more amenable to beneficiation up to higher grade (see below).

In addition, DRI processes with additional melting stages to deal with lower-grade ore – as is already being implemented in Europe<sup>61</sup> – will likely also be part of the solution. Rio Tinto has been investigating the use of a melting step that could see Pilbara iron ore used in DRI-based steelmaking with Australian steelmaker BlueScope since 2021.<sup>62</sup>

BHP announced a development project along similar lines in March 2023. BHP is working with Hatch to design a pilot electric smelting furnace (ESF) that can allow the use of BHP's Pilbara iron ore in a DRI-based process.<sup>63</sup> However, BHP also remains focused on carbon capture solutions, signing agreements with ArcelorMittal<sup>64</sup> and Chinese steelmaker HBIS<sup>65</sup> despite doubts over how much such technology could contribute to steel decarbonisation.<sup>66</sup>

Fortescue is working with Mitsubishi Corp and Primetals Technologies on the use of its iron ores in the latter's HYFOR DRI process for net zero carbon ironmaking.<sup>67</sup> Furthermore, both Fortescue<sup>68</sup> and Rio Tinto<sup>69</sup> have signed agreements with China Baowu to investigate steel emissions reduction. Both agreements will investigate the use of lower-grade Pilbara iron ores in DRI-based steelmaking in China, while Rio Tinto's agreement will also investigate the possibility of low-carbon iron production in Australia.

<sup>59</sup> Bloomberg. [Japan's Top Steelmaker Eyes \\$700 Million 'Green Steel' Project](#). 3 March 2023.

<sup>60</sup> Australian Financial Review. [World's biggest steel maker looks to WA for massive green investment](#). 12 May 2023.

<sup>61</sup> IEEFA. [German steel giant tech breakthrough to steer industry away from coal](#). 28 September 2022.

<sup>62</sup> Rio Tinto. [Rio Tinto and BlueScope to explore low carbon-steelmaking pathways](#). 29 October 2021.

<sup>63</sup> BHP. [BHP and Hatch commence design study for an electric smelting furnace pilot](#). 23 March 2023.

<sup>64</sup> BHP. [Carbon capture in the steel industry: ArcelorMittal, Mitsubishi Heavy Industries Engineering, BHP and Mitsubishi Development sign collaboration agreement](#). 27 October 2022.

<sup>65</sup> BHP. [BHP signs Carbon Capture and Utilisation pilot agreement with China's HBIS Group](#). 27 March 2023.

<sup>66</sup> IEEFA. [No, metallurgical coal is not a critical material...and carbon capture won't save it](#). 3 July 2023.

<sup>67</sup> Fortescue. [Fortescue, Primetals Technologies, and voestalpine to jointly evaluate groundbreaking green ironmaking plant](#). 20 December 2022.

<sup>68</sup> Fortescue. [Fortescue partners with world's largest steel maker to reduce emissions across iron and steel making](#). 14 June 2023.

<sup>69</sup> Rio Tinto. [China Baowu and Rio Tinto extend climate partnership to decarbonise the steel value chain](#). 12 June 2023.

In August 2023, Rio Tinto announced a multi-year agreement to supply DR-grade iron ore pellets to H2 Green Steel in Sweden; which is aiming to produce steel using green hydrogen from 2025. However, this will be supplied from Rio's Canadian iron ore operations, not from Australia. Rio's Iron Ore Company of Canada produces a significantly higher grade of iron ore than its Pilbara operation. The deal will also see Rio buy and on-sell HBI from H2 Green Steel.<sup>70</sup>

Fortescue is also piloting a renewable energy-powered chemical electrolysis process to produce iron without coal or hydrogen. The pilot plant has processed 150kg of Pilbara iron ore and Fortescue is now looking to scale up the technology. The technology has an advantage over its electrochemical iron ore reduction competitors in the market due to its low temperature process.<sup>71</sup>

## Magnetite Ores

As well as investigating technology solutions that allow use of lower-grade Pilbara ores in low-carbon ironmaking processes, Fortescue is also leading the big Australian miners into higher-grade Australian iron ore production.

Fortescue is already producing and shipping magnetite containing more than 67% Fe, which meets DR-grade.<sup>72</sup> Former CEO Fiona Hick has stated that, though the output from the Iron Bridge mine may be blended with lower-grade ore in the future, the intention for now is to sell it as a separate high-grade product, for which interest from customers has been high.<sup>73</sup>

Magnetite requires more processing than hematite but is easier to beneficiate to a high grade suitable for DRI.<sup>74</sup> Nearly 96% of Australia's iron ore exports come from Pilbara region in Western Australia where the hematite direct shipping ore (DSO) has been mined for decades. Reserves of magnetite are located in Western Australia (Pilbara and Mid West regions), South Australia and Tasmania. South Australia's magnetite iron ore reserves total 16 billion tonnes, of which 6 billion tonnes are identified as economically demonstrated resources.<sup>75</sup>

Iron Bridge may only be the first of Fortescue's magnetite developments<sup>76</sup>, which could increase the supply of DR-grade ore it produces for low-carbon steelmaking, helping it achieve its Scope 3 emissions target. In significant contrast to BHP and Rio Tinto, Fortescue has committed to reaching net zero Scope 3 emissions by 2040.

<sup>70</sup> Rio Tinto. [Rio Tinto and H2 Green Steel partner to accelerate the green steel transition](#). 9 August 2023.

<sup>71</sup> Australian Financial Review. [Fortescue lab succeeds in turning iron ore into green iron](#). 23 March 2023.

<sup>72</sup> Fortescue. [Fortescue ships first magnetite product from Iron Bridge](#). 24 July 2023.

<sup>73</sup> Australian Financial Review. [Fortescue aims for fifth consecutive export record](#). 27 July 2023.

<sup>74</sup> Minerals Research Institute of Western Australia. [Western Australia's Green Steel Opportunity](#). 19 June 2023.

<sup>75</sup> Government of South Australia. [Magnetite: South Australia's resource potential](#).

<sup>76</sup> Australian Financial Review. [Why magnetite matters more to Fortescue in the green iron era](#). 7 May 2023.

Iron Bridge isn't the only magnetite project in Western Australia, with CITIC's Sino Iron mine and the Karara mine already operating. Hancock Prospecting is also developing the Ridley and Mt Bevan magnetite projects and there are several other magnetite developments across Australia.<sup>77</sup>

In South Australia, Liberty Steel – the second-largest steel producer in Australia – announced in March 2023 that it would phase out coal-based steelmaking at Whyalla and switch to new DRI-EAF steel technology that initially consumes natural gas and hydrogen before shifting completely to green hydrogen. The plant's emissions are planned to drop 90% by 2025. The plant already uses magnetite ore from a linked mine and has tested the possibility of producing DR-grade iron ore pellets to utilise that in new direct reduction shaft furnaces. The plan is to increase magnetite production to 15Mt, and 10Mt of green DRI will be produced for both the domestic and export markets.<sup>78</sup>



**Magnetite may need to become more prominent in Australia going forward, both for direct exports and for the onshore production of green iron for shipping.**

Thanks to its suitability for non-coal-based iron and steelmaking, magnetite may need to become more prominent in Australia going forward, both for direct exports and for the onshore production of green iron for shipping. As the MRIWA noted in June 2023, “Understanding the pathways to enable Western Australia to maximise use of its hematite and magnetite iron ore resources, and to maximise emerging hydrogen and renewable energy potential are key to supporting global Green Steel ambitions and creating new markets for Western Australian iron ores.”<sup>79</sup>

## Positioning For the Future

As the MRIWA noted, Western Australia has numerous advantages that present it with an opportunity to lead the global steel sector into a low-carbon future. “The State's existing iron ore comparative advantage, abundance of reserves, established infrastructure, political and regulatory stability, and existing energy and emerging renewable energy advantages, can combine to provide a platform to meaningfully contribute to the decarbonisation of steelmaking, and continued economic development.”<sup>80</sup> The sheer size of the Western Australian iron ore industry is a further advantage – the global steel sector will need Western Australian iron ore to be heavily involved in decarbonisation if net zero global steel emissions are to be achieved.

However, Australia faces multiple long-term iron ore challenges, and one of these is that Pilbara ore is generally well below the quality currently required for lower-emissions DRI-based processes. Australia's iron ore majors are already working on mining and technology solutions that could ensure

<sup>77</sup> IEEFA. [Iron ore quality a potential headwind to green steelmaking: Technology and mining options are available to hit net-zero targets](#). June 2022.

<sup>78</sup> GFG Alliance. [LIBERTY Steel In Whyalla Announces The Phase Out Of Coal-Based Steelmaking With Purchase Of A Low Carbon Emissions Electric Arc Furnace](#). 4 April 2023.

<sup>79</sup> Minerals Research Institute of Western Australia. [Western Australia's Green Steel Opportunity](#). 19 June 2023. Page ES-2.

<sup>80</sup> Ibid.

their products are suitable for a decarbonising global steel industry, but research and development efforts need to be accelerated if Australia and its miners are to remain global leaders in iron ore and don't lose out amid growing demand for low-carbon iron and steel. Some refocusing of Australian green hydrogen projects towards more domestic use could help Australia lead the green iron export opportunity going forward.

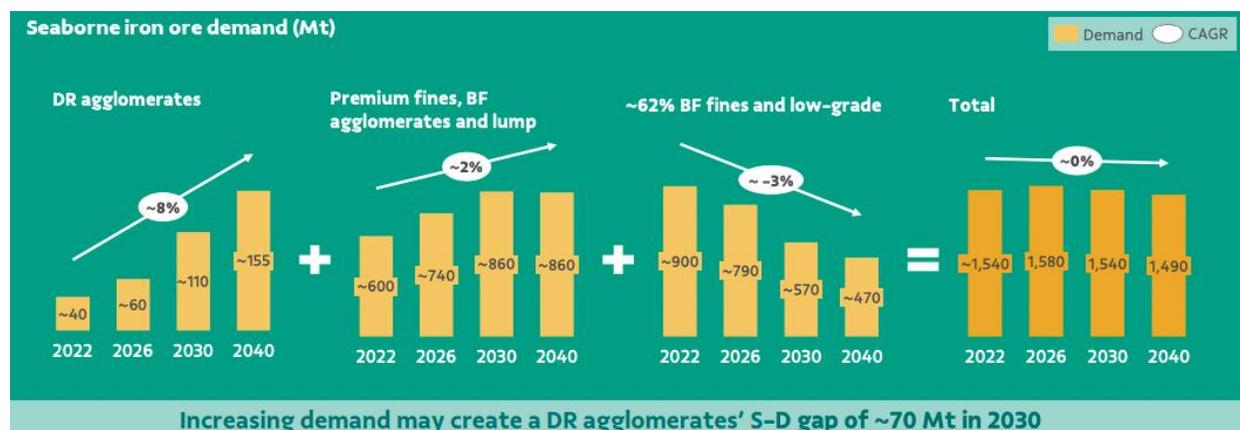
The MRIWA noted that shifting towards green iron (HBI) production “represents the greatest economic opportunity” for Western Australia when it comes to positioning the iron ore industry for a low-carbon future. It also warned of a possible scenario where “other global suppliers of iron ore and iron feedstock better position to succeed in a Green Steel world”, a scenario that becomes more likely if technology developments that allow use of Pilbara hematite in DRI processes are delayed.<sup>81</sup>

Importantly, “other global suppliers of iron ore” are already taking steps to position themselves for a decarbonised global steel sector.

## Brazil

Major steelmakers have their eyes on Brazil as one of the options for future hydrogen-based green steel expansion projects, in competition with Australia. Nippon Steel has stated it is considering Brazil as well as Australia as potential sites for a US\$700m green steel project.<sup>82</sup> China Baowu is also considering green iron investments overseas. In addition to Australia, it is considering a path forward in West Africa, the Middle East and South America.<sup>83</sup>

**Figure 8: Vale’s Long-Term Iron Ore Segment Forecast**



Source: Vale

<sup>81</sup> Minerals Research Institute of Western Australia. [Western Australia's Green Steel Opportunity](#). 19 June 2023.

<sup>82</sup> Bloomberg. [Japan's Top Steelmaker Eyes \\$700 Million 'Green Steel' Project](#). 3 March 2023.

<sup>83</sup> Australian Financial Review. [World's biggest steel maker looks to WA for massive green investment](#). 12 May 2023.

As the world's largest producer of high-grade iron ore, Brazil is the natural destination for green iron investment in South America and possesses significant potential to solidify its position due to its abundant resources. The Brazilian iron ore miner Vale – the world's leading producer of DR-grade iron ore – projects that by 2030, global DRI/HBI production will increase 55% to 200 million tonnes per annum (Mtpa), and demand for seaborne DR-grade iron ore will more than double to 110Mtpa.<sup>84</sup> Vale sees DR-grade ore demand continuing to rise beyond 2030 while demand for benchmark 62% (blast furnace-grade) iron ore has now entered permanent decline (Figure 8).

Vale forecasts that a DR-grade demand-supply gap of around 70Mtpa could emerge by 2030 and it is intending to fill much of that gap, with the company focusing more on raising the quality of its iron ore output than the quantity. Vale is following three major strategies to fulfil this.

The first strategy for development is focused on increasing concentration capacity, aiming to produce a greater quantity of iron ore concentrate to supply agglomeration plants. Major plans include tailings filtration, dry concentration, utilisation of third-party concentration facilities, and ore concentration in its Northern System. These initiatives are aimed at providing high-quality feedstock to agglomeration plants.<sup>85</sup>

Secondly, Vale is increasing the capacity of high-grade agglomerates from an innovative briquetting solution that has been adapted for direct reduction pathways and can reduce 80% of Scope 1 and 2 emissions as well.<sup>86</sup> The company's target is to triple the high-grade iron ore pellets and briquettes production to 100Mt by 2030.<sup>87</sup>

Fostering "Mega Hubs" creation in high-potential regions is the third pillar of Vale's green transition. The concept behind these Mega Hubs is to transport Vale's high-grade iron ore fines to strategically located centres in the Middle East, Brazil and potentially the US, where they are processed and agglomerated into pellets or briquettes. The pellets and briquettes will be supplied to DRI-based operations located within the hubs for the production of HBI. The resulting HBI will be either supplied to EAF operations within the hubs for processing into steel or transported to external customers.<sup>88</sup>

Vale considers that it has an advantage over the other major iron producers when it comes to the steel technology transition towards DRI-based steelmaking (Figure 7). Its DR-grade ore can be used in standard and well-established DRI-EAF operations without the need for an additional melting furnace step required to enable blast furnace-grade ore in DRI processes. This need for an additional furnace increases CAPEX and OPEX requirements for operations based on lower-grade ore.

<sup>84</sup> Vale. [Iron Solutions webinar Decarbonization of steel and impacts in iron ore supply](#). 14 April 2023.

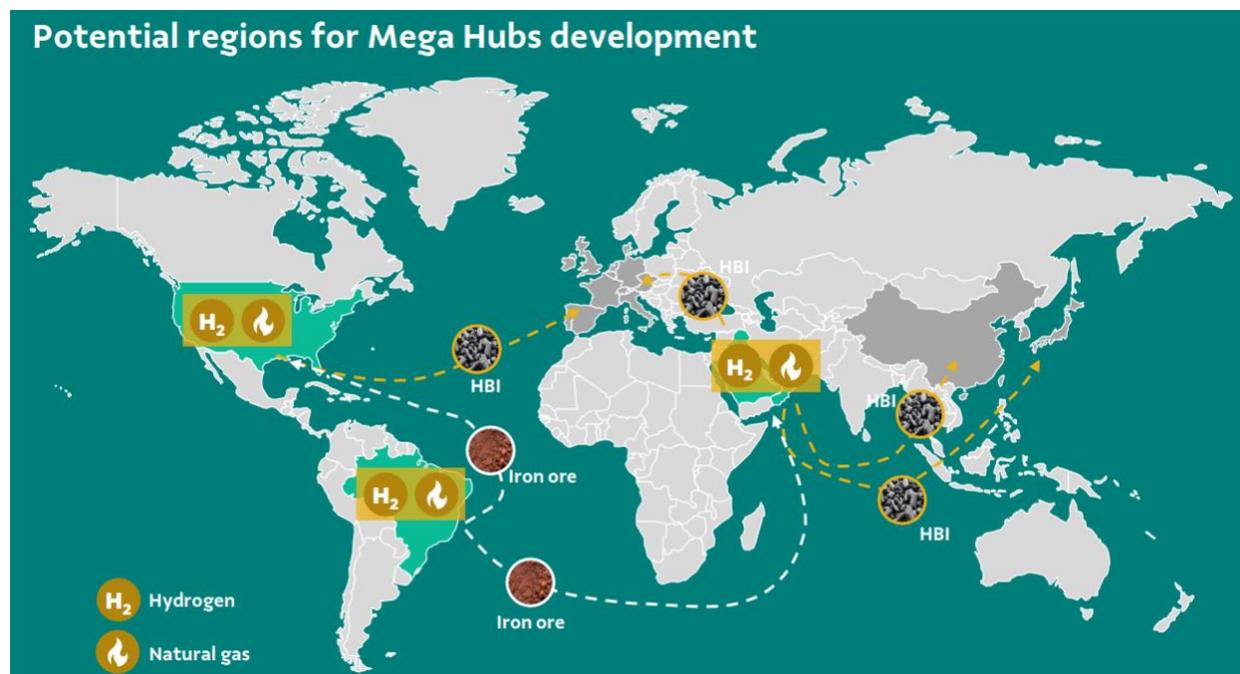
<sup>85</sup> Vale. [Iron Solutions webinar Decarbonization of steel and impacts in iron ore supply](#). 14 April 2023.

<sup>86</sup> Vale. [Vale successfully tests new briquette for direct reduction that makes steel production 'cleaner'](#). 5 February 2023.

<sup>87</sup> Vale. [The BMO 32<sup>nd</sup> Global Metals & Mining Conference](#). 27 February 2023.

<sup>88</sup> Vale. [Iron Solutions webinar Decarbonization of steel and impacts in iron ore supply](#). 14 April 2023.

Figure 9: Vale's Mega Hubs across the Globe



Source: Vale

The suitability of Brazil's high-grade iron ore for the type of low-carbon DRI-based iron and steelmaking that will become increasingly prevalent is already being demonstrated. In May 2023, Vale announced it had signed a memorandum of understanding (MoU) with GravitHy to jointly evaluate a hydrogen-based DRI plant in France. The intention is to begin production as soon as 2027 with Vale supplying the DR-grade iron ore. The DRI produced is planned to be used directly or traded globally as HBI.<sup>89</sup>

In August 2023, H2 Green Steel – which is aiming to produce steel using green hydrogen from 2025 – agreed a multi-year deal with Vale that will see it supply the steelmaker with DR-grade iron ore pellets.<sup>90</sup> China Baowu has also reportedly held talks with Vale about future co-operation on mineral resources and low-carbon metallurgical technology.<sup>91</sup>

Anglo American also produces high-quality iron ore in Brazil with 67% Fe content.<sup>92</sup> In April 2023, Swedish company H2 Green Steel signed an MoU with Anglo American to investigate the use of iron ore from Anglo American's mines in South Africa and its Minas-Rio mine in Brazil in H2 Green Steel's DRI process in Sweden. The agreement underlines that even in Sweden, which is known for its high-

<sup>89</sup> Vale. [Vale and GravitHy sign MoU to develop a plant dedicated to direct reduction iron ore briquettes production](#). 9 May 2023.

<sup>90</sup> H2 Green Steel. [H2 Green Steel and Vale in agreement for the supply of direct reduction iron ore pellets](#). 9 August 2023.

<sup>91</sup> Reuters. [China Baowu wants new models of cooperation with Vale](#). 4 August 2023

<sup>92</sup> Anglo American. [H1 2023 Results](#). 27 July 2023.

grade iron ore, there may be a need to procure the raw materials for green steel from other regions.<sup>93</sup>

As well as high-grade iron ore, Brazil has significant renewable energy and hydro power resources. As such, Brazil is in a position to produce green hydrogen at a competitive price compared with many other regions as hydrogen electrolyser costs come down.<sup>94</sup> Brazil is now planning to launch a green transition plan worth hundreds of billions of dollars to help decarbonise the nation's economy. The intention is to make Brazil a hub of clean technologies like green hydrogen.<sup>95</sup> Bloomberg New Energy Finance forecasts that new green hydrogen production will outcompete traditional hydrogen made by steam methane reforming (grey hydrogen) in Brazil by 2030.<sup>96</sup>

In common with other regions and nations, including Australia, much of the focus on future green hydrogen production in Brazil is on exports to places like Europe for use in the steel sector.<sup>97</sup> Fortescue Future Industries has a green hydrogen export project under development in north-eastern Brazil. A feasibility study is underway with a target to reach final investment decision in 2024, and production commencing in 2027.<sup>98</sup>

However, with the cost and efficiency of hydrogen shipping highly questionable, emphasis may well swing towards targeting domestic consumption of green hydrogen to make and export green iron using the country's high-grade iron ore. In July 2023, Brazil joined the Industrial Deep Decarbonisation Initiative, a coalition of governments and private-sector organisations working to decarbonise heavy industry with a focus on steel, cement and concrete.<sup>99</sup>

## Middle East

Despite lacking abundant iron ore reserves, the Middle East region can leverage low-cost renewable resources and existing direct reduction plants to produce green iron and steel at competitive prices. This prospect is drawing interest from steelmakers and miners, who are investing in the region to establish a low-carbon iron hub.<sup>100</sup> The area's current direct reduction plants are either supplied by captive mines or have secured long-term contracts with DR-grade iron ore pellet producers for their feedstock.

The Middle East is already a hub of DRI-based steelmaking drawing on the region's plentiful gas resources. With governments in the region keen to diversify their economies away from fossil fuels, and well placed to supply markets of growing low-carbon steel demand such as Europe and rapidly

<sup>93</sup> Anglo American. [Anglo American partners with H2 Green Steel to advance low carbon steelmaking](#). 04 April 2023.

<sup>94</sup> Bloomberg. [With Plenty of Green Energy, Brazil Aims for Green Hydrogen Export Market](#). 29 June 2023.

<sup>95</sup> Financial Times. [Brazil to launch 'most ambitious' green transition package](#). 27 July 2023.

<sup>96</sup> Bloomberg New Energy Finance. [2023 Hydrogen Levelized Cost Update: Green Beats Gray](#). 25 July 2023.

<sup>97</sup> S&P Global. [Brazil 'well-positioned' as green hydrogen exporter to EU steel: speakers](#). 22 June 2023.

<sup>98</sup> Fortescue Future Industries. [Fortescue Future Industries and the State of Ceará reinforce joint commitment to develop green hydrogen project at COP27](#). 10 November 2022.

<sup>99</sup> UNIDDI. [Brazil joins the Industrial Deep Decarbonisation Initiative](#). 24 July 2023.

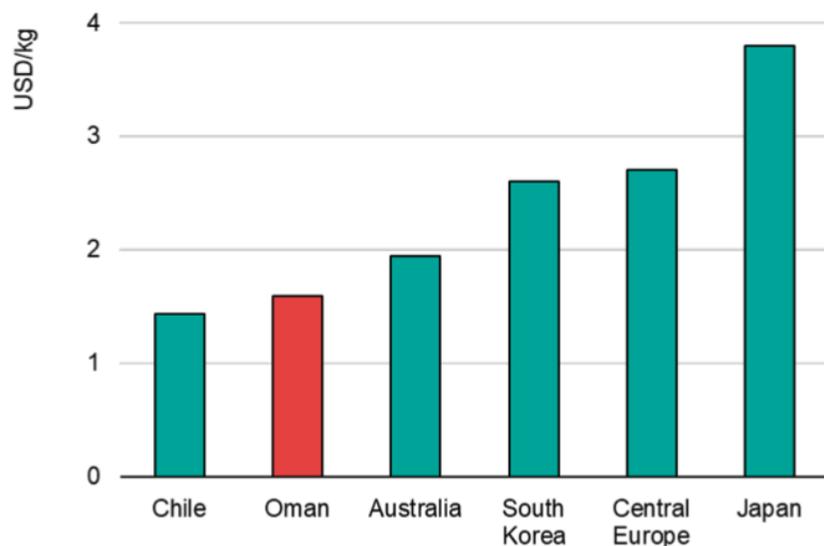
<sup>100</sup> IEEFA. [MENA, a potential new hub for green steel and green iron metallurgy](#). 8 December 2022.

growing steel demand such as India, the region has significant incentives to convert its steel industry from gas to green hydrogen.

The region's abundant solar energy resources provide a favourable opportunity for the production of green hydrogen at a competitive price. However, it is noteworthy that most of the ongoing green hydrogen projects in the Middle East are primarily focused on export. By allocating a larger portion of the planned green hydrogen production to domestic markets instead of exports, truly low-emission iron and steel can be made in the region, catering to growing global demand.<sup>101</sup>

The UAE is planning a US\$54 billion investment in renewable energy, with a focus on hydrogen, in an effort to achieve its 2050 net zero emissions target.<sup>102</sup> As well as planning green hydrogen developments in Australia, South Korean steelmaking giant POSCO is collaborating with Saudi Arabia on a green hydrogen and ammonia project.<sup>103</sup> In addition, POSCO is involved in a green hydrogen export project in Oman and plans to use some of the output in steelmaking.<sup>104</sup>

**Figure 10: Forecast 2030 Renewable Hydrogen Production Costs in Selected Import and Export Markets**



Source: IEA

Oman could become the largest exporter of hydrogen in the Middle East this decade, according to the IEA. Oman announced its own 2050 net zero emissions target in 2022, and more use of green hydrogen domestically rather than for export could help it achieve this aim. The IEA predicts that the

<sup>101</sup> IEEFA. [Green steel opportunity in the Middle East and North Africa](#). 14 September 2022.

<sup>102</sup> Bloomberg. [UAE Plans to Invest \\$54 Billion in Renewables in Net Zero Push](#). 3 July 2023.

<sup>103</sup> Argus Media. [Korea's POSCO plans \\$28bn Australian green H2 investment](#). 2 December 2022.

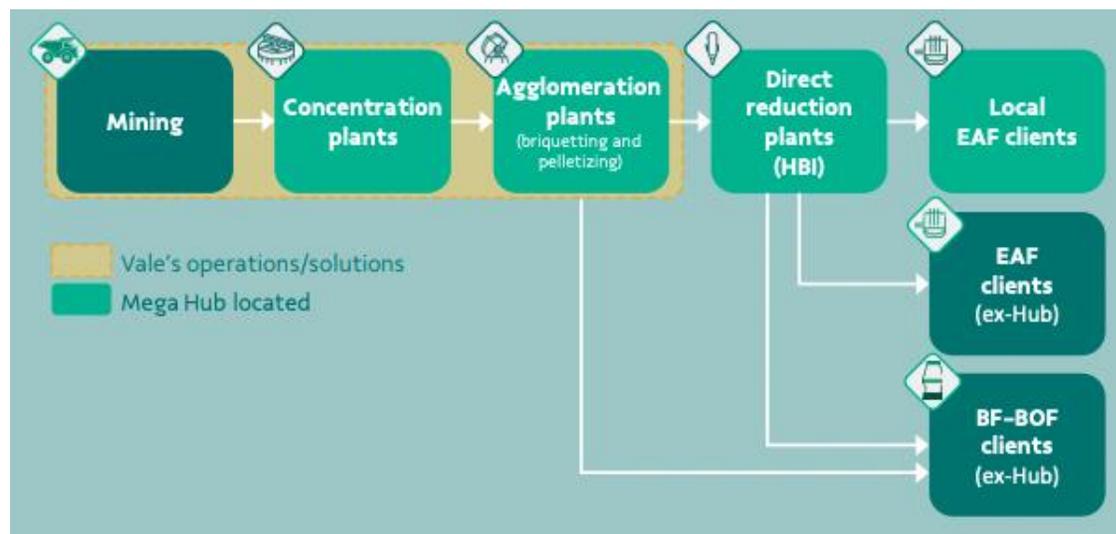
<sup>104</sup> S&P Global. [Oman awards green hydrogen/ammonia project to South Korea's top steelmaker POSCO, France's Engie](#). 22 June 2023.

cost of producing green hydrogen in Oman in 2030 could be as low as US\$1.6/kg, cheaper than Australian production (Figure 10).<sup>105</sup>

Given the steel industry in the Middle East is already based on DRI, the region has a well-established DR-grade iron ore supply. Vale is currently engaged in expanding its facilities in the region to solidify its regional strategy. The company already operates a pelletising plant with a capacity of 9Mt in Oman and has a distribution centre there that has the capability to manage up to 40Mt of iron ore and pellets annually.<sup>106</sup>

As part of its expansion plans in the Middle East, Vale is planning to build iron ore “green briquette Mega Hubs” in Oman, Saudi Arabia<sup>107</sup> and the UAE.<sup>108</sup> Under the Mega Hubs concept, Vale will supply iron ore fines to the hubs where they will be beneficiated and agglomerated into pellets and briquettes of suitable high grade for DRI operations. The pellets and briquettes will be supplied to DRI-based operations located within the hubs for the production of HBI. The resulting HBI will be either supplied to EAF operations within the hubs for processing into steel or transported to external customers. (Figure 11)<sup>109</sup>

**Figure 11: Vale’s Mega Hubs Concept**



Source: Vale

Vale’s plan will increase the supply of HBI from the Middle East that is lower-carbon than the average blast furnace-based iron production but could be even lower if the DRI process that produce it were

<sup>105</sup> IEA. [Renewable Hydrogen from Oman](#). June 2023. Page 7.

<sup>106</sup> SteelOrbis. [Vale assumes full control of Oman pellet plant](#). 15 February 2023.

<sup>107</sup> S&PGlobal. [Brazil’s Vale, Saudi Arabia’s NIDC sign MOU for iron ore pellet plant](#). 1 November 2022.

<sup>108</sup> Vale. [Iron Ore Solutions webinar](#). 14 April 2023.

<sup>109</sup> Fastmarkets. [Inside Vale’s green briquette megahubs and how they will work](#). 18 November 2022.

green hydrogen-based. In addition, there are a number of low-carbon iron/steel production plans across the region<sup>110</sup> (Table 1).

In the most recent announcement, Kobe Steel and Mitsui have signed a MoU to explore the feasibility of DRI production and export as HBI using Kobe Steel's MIDREX DRI technology in Oman. Their target is to produce 5Mt of DRI by using natural gas initially and in the following steps could shift completely to green hydrogen as a reducing agent.<sup>111</sup> The proposed DRI is planned to be operational from 2027.<sup>112</sup>

Mitsui and Kobe Steel have considered the strong renewable energy resources of Oman in considering the proposed project location, which will be close to planned green hydrogen developments. The plant will also have access to iron ore pellet supply from Vale's Oman operations. It is expected that the project will export HBI to Europe and Asian markets.<sup>113</sup>

**Table 1: Low-Carbon Iron and Steel announcements and projects in MENA**

Co-operating companies	Plant description	End User
<b>Emirates Steel Arkan, ADP, Itochu and JFE Steel</b>	DRI/HBI in Abu Dhabi	JFE Steel, other Asian steelmakers
<b>Vale and Saudi Arabia's NIDC, Emirates Steel Arkan and Oman's MOCIIP</b>	Three Mega Hubs in Saudi Arabia, UAE and Oman <sup>114</sup>	Domestic consumption in the region
<b>Vulcan Green Steel</b>	5Mt H <sub>2</sub> -DRI plant	Middle East, Europe and Japan
<b>Kobe Steel, and Mitsui &amp; Co. and OPAZ</b>	5Mt of H <sub>2</sub> ready DRI/HBI	Asia and Europe Market
<b>Aramco and Baosteel and PIF</b>	Integrated steel plate mill, 1.5Mt (H <sub>2</sub> ready DRI-EAF)	Middle East Market

Source: Companies press releases. IEEFA

Note: National Industrial Development Center (NIDC), Ministry of Commerce, Industry and Investment Promotion of the Sultanate of Oman (MOCIIP), Oman's Public Authority for Special Economic Zones and Free Zones (OPAZ), Public Investment Fund (PIF).

This is not the only low-carbon DRI plan in Oman. Vulcan Green Steel plans to invest US\$3 billion in an integrated greenfield H<sub>2</sub>-DRI-EAF plant with an annual capacity of 5Mt. The plant will be located in the Special Economic Zone at Duqm, adjacent to green hydrogen facilities that can directly supply the DRI plant with green hydrogen, reducing transportation costs, though the plant will initially be

<sup>110</sup> IEEFA. [MENA, a potential new hub for green steel and green iron metalics](#). 8 December 2022.

<sup>111</sup> Kobelco. [Kobe Steel to accelerate feasibility study of Low-CO<sub>2</sub> Iron Metalics Project in Oman](#). 10 April 2023.

<sup>112</sup> Fastmarkets. [Mitsui's move into green metalics sets tone for steel's future in Middle East](#). 6 June 2023.

<sup>113</sup> Fastmarkets. [Mitsui-Kobe Steel joint venture cements Middle East as vital DRI hub, but further efforts required](#). 2 May 2023.

<sup>114</sup> Vale. [Vale signs agreements to develop Mega Hubs in the Middle East and provide decarbonization solutions for steelmaking](#). 1 November 2022.

based on gas.<sup>115</sup> The company is targeting low-carbon steel demand in the Middle East, Europe and Japan.<sup>116</sup>

In the UAE, Emirates Steel Arkan has partnered with Japanese steelmaker JFE Steel and trading house Itochu Corporation in a plan to produce reduced iron in Abu Dhabi to be shipped to Asia for use in steelmaking by JFE Steel and other steelmakers. Production via DRI is intended to begin in the second half of 2025.<sup>117</sup> Developer Abu Dhabi Ports (ADP) has joined the venture to provide land, logistics, and probably in the future a specific jetty for receiving iron ore and shipping final products.<sup>118</sup>

Meanwhile, China Baowu Group has signed an agreement with Aramco and the Saudi Arabian Public Investment Fund (PIF) to set up a DRI-based steelmaking plant in Saudi Arabia to supply the domestic and regional market with steel.<sup>119</sup>

## Africa

Africa is another potential source of iron ore suitable for producing green iron. Much of the current and potential ore production is of a significantly higher grade than that produced in the Pilbara. South Africa ranks as the third-largest exporter of iron ore after Australia and Brazil, producing 58Mt of iron ore in 2022.<sup>120</sup> Mauritania and Liberia are also iron ore producers, though the full potential of Africa's iron production remains untapped and new mines capable of producing many millions of tonnes of high-quality ore are on the horizon.

Anglo American operates the largest iron ore mine in South Africa via its subsidiary Kumba Iron ore. Kumba's mines yield a significantly higher-grade iron ore than the great majority of Australian production (Figure 12). The potential suitability of at least some of Kumba's output for DRI-EAF steelmaking operations has been demonstrated by Anglo American's recent MoU with H2 Green Steel, which aims to produce steel using green hydrogen from 2025.<sup>121</sup> The agreement was signed in April 2023 and will see ore from Kumba's mines (as well as Anglo American's Brazilian iron ore output) trialled in H2 Green Steel's DRI process in Sweden.<sup>122</sup>

India's Jindal Steel & Power is hoping to develop a US\$2 billion magnetite mine in South Africa, capable of producing DR-grade iron ore.<sup>123</sup>

<sup>115</sup> Green Steel World. [Vulcan Green Steel master plan manifests sustainability and resilience](#). 28 February 2023.

<sup>116</sup> Bloomberg. [Jindal Shadeed Group Plants \\$3 Billion Green Steel plant in Oman](#). 4 December 2022.

<sup>117</sup> Itochu Corporation. [Decarbonization of the Steel Industry: Supply Chain of Ferrous Raw Material for Green Ironmaking with Low Carbon Emission](#). 1 September 2022.

<sup>118</sup> Argus. [Japanese, UAE firms expand low-carbon iron alliance](#). 19 July 2023.

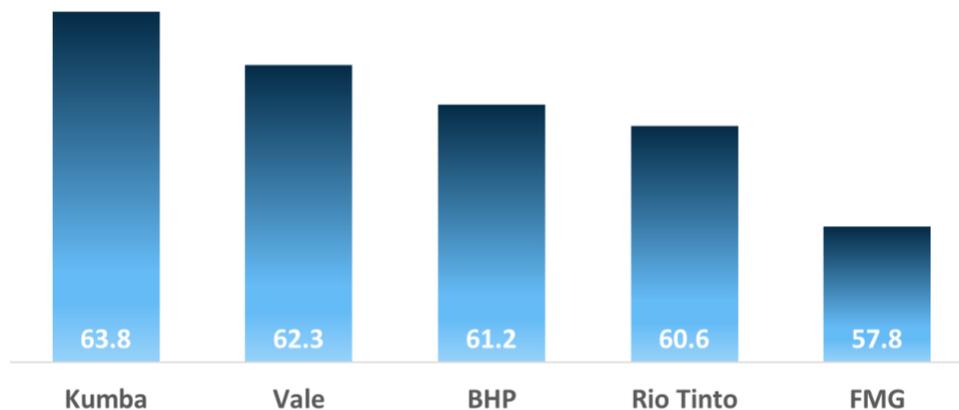
<sup>119</sup> Public Investment Fund. [Aramco, Baosteel and PIF sign agreement to establish first integrated steel plate manufacturing complex in Saudi Arabia](#). 2 May 2023.

<sup>120</sup> Department of Industry, Science and Resources. [Resources and Energy Quarterly](#). June 2023. Page 45.

<sup>121</sup> H2 Green Steel. [On course for large-scale production from 2025](#). 7 July 2022.

<sup>122</sup> Anglo American. [Anglo American partners with H2 Green Steel to advance low carbon steelmaking](#). 04 April 2023.

<sup>123</sup> Bloomberg. [Graves a Barrier for Jindal's \\$2 Billion South African Iron Mine](#). 8 August 2023

**Figure 12: Kumba Iron Ore Fe% vs the Big Four Iron Ore Producers**

Source: Kumba Iron Ore

<sup>1</sup>Vale excludes pellets

South Africa – in line with much of the continent – has excellent renewable energy resources that will enable the production of low-cost green hydrogen in the near future.<sup>124</sup> The continent has well over 100 gigawatts (GW) of green hydrogen capacity in the pipeline supported by European countries and international companies like Fortescue Future Industries.<sup>125</sup> As in other parts of the world, the focus for African green hydrogen development is on hydrogen exports. However, decades of resource extraction from Africa by richer nations and large international companies have failed to spur African development, and an opportunity exists for local use of green hydrogen production to make value-added materials such as green iron for export, marrying Africa’s excellent renewable energy resources with its high-quality iron ore.<sup>126</sup>

South Africa itself is to receive support from Denmark and the Netherlands to set up a US\$1bn hydrogen fund to invest in green hydrogen in the country. The fund also involves state finance institutions the Development Bank of South Africa and the Industrial Development Corporation of South Africa.<sup>127</sup> Germany has also recently signed an agreement with South Africa to help create green hydrogen projects in the country.<sup>128</sup>

Outside South Africa, ArcelorMittal – the world’s second-largest steel producer – entered into an MoU in May 2022 with Mauritanian iron ore miner SNIM to investigate the feasibility of jointly producing iron ore pellets and DRI. A pre-feasibility study is underway to assess the possibility of

<sup>124</sup> Bloomberg. [South Africa Moves Closer to Building Port For Hydrogen Exports](#). 26 July 2023.

<sup>125</sup> Australian Financial Review. [Africa leads Australia in green hydrogen race](#). 26 March 2023.

<sup>126</sup> Financial Times. [EU turns to Africa to build green hydrogen supply](#). 15 June 2023.

<sup>127</sup> Bloomberg. [Netherlands and Denmark to Help Create \\$1 Billion South African Hydrogen Fund](#). 20 June 2023.

<sup>128</sup> Bloomberg. [South Africa Forms Hydrogen Pact With Germany to Grow Market](#). 28 June 2023.

producing green iron via DRI based on the West African country's high potential in renewable and green hydrogen.<sup>129</sup>

The European Investment Bank has already noted Mauritania's potential to become an African green hydrogen hub, with an eye on exports to Europe.<sup>130</sup> Oil and gas major bp is already exploring the opportunity for green hydrogen production in the country.<sup>131</sup> ArcelorMittal's Mauritanian interest comes on top of plans to expand its iron ore mining operation in Liberia.<sup>132</sup>

In Namibia, Hylron is establishing the initial phase of a green iron project that is intended to produce 15,000 tonnes of green DRI by late 2024.<sup>133</sup> Following this, the plan is to scale up the plant to eventually export 2Mt of green iron per year to the German steel industry.<sup>134</sup>

Meanwhile China Baowu is also considering West Africa as it eyes green steel developments, in addition to Australia.<sup>135</sup> The company is likely to be thinking particularly of Guinea where, along with Rio Tinto and other Chinese companies, it is developing the very large Simandou iron ore deposit.<sup>136</sup> In the coming years, Guinea looks set to become the third-largest iron ore producer in the world after Australia and Brazil, with a quality significantly higher than Australia's. Development of Simandou has been delayed many years in the face of the huge infrastructure investment required but, with the global steel industry now beginning its decarbonisation journey, the value of the deposit's high-grade ores has increased.<sup>137</sup>

Rio Tinto controls half of the Simandou deposit along with its project partners Aluminium Corporation of China (Chinalco) and China Baowu, with the other half controlled by a consortium of Chinese and Singaporean companies (SMB-Winning). Rio Tinto, Chinalco and China Baowu's half could potentially produce 100Mt of high-grade iron ore per year. Taking SMB-Winning's share into account, Simandou could produce 200Mt per annum of high-grade, 65-66% Fe ore by the end of the decade (if the projects proceed smoothly), making it the most significant development globally for increasing supply of high-grade iron ore.

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<sup>129</sup> ArcelorMittal. [ArcelorMittal signs MoU with SNIM to evaluate the opportunity to jointly develop a pelletisation plant and DRI production plant in Mauritania](#). 25 May 2022.

<sup>130</sup> European Investment Bank. [New study confirms €1 trillion Africa's extraordinary green hydrogen potential](#). 21 December 2022.

<sup>131</sup> BP. [BP and Mauritania to explore green hydrogen at scale](#). 8 November 2022.

<sup>132</sup> ArcelorMittal. [2Q 2023 and 1H 2023: Financial results and strategic update](#). 27 July 2023.

<sup>133</sup> Hylron. [Project Oshivela](#).

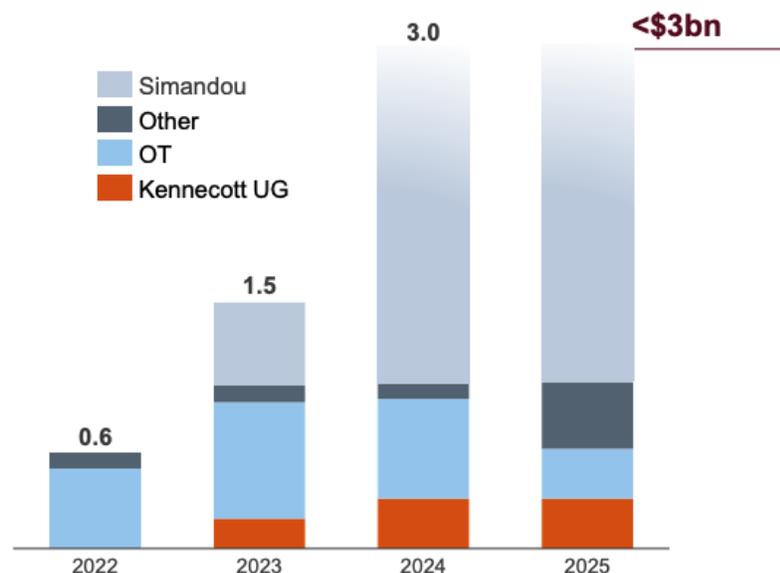
<sup>134</sup> Hylron. [Opening of the hydrogen direct reduction plant in Lingen by Lower Saxony's Environment and Energy Minister Meyer](#). 14 August 2023.

<sup>135</sup> Australian Financial Review. [World's biggest steel maker looks to WA for massive green investment](#). 12 May 2023.

<sup>136</sup> Australian Financial Review. [China leaps ahead on unlocking huge African iron ore deposit](#). 23 January 2023.

<sup>137</sup> The Australian. [How Rio Tinto's Simandou mine is now a valuable iron ore asset](#). 2 August 2023.

**Figure 13: Rio Tinto's Planned Growth Capital Expenditure is Dominated by the Simandou Project (US\$bn)**



Source: Rio Tinto 2023 Half Year Results

Rio Tinto has stated that the deposit is estimated to have 40% of high-quality iron ore resources that are “well suited to meet DRI specification, which could be processed via the lower-carbon DRI-EAF route”.<sup>138</sup> As such, Guinea could add very significantly to the global supply of ore already suitable for processing into green iron.

However, China remains the dominant force in Guinean mining and is now pressing ahead with the expensive transport infrastructure required to export Simandou ore as it aims to reduce reliance on Australian iron ore.<sup>139</sup> State-owned China Baowu has struck a deal with the mining joint venture partners, and this has paved the way for the infrastructure build to begin.<sup>140 141</sup>

Fortescue is also targeting high-grade iron ore in Africa. Fortescue signed a Mining Convention in February 2023 with Gabon for the Belinga Iron Ore Project in the north-east of the country.<sup>142</sup> The Belinga project is on course to deliver the first shipment of iron ore before the end of 2023. Former Fortescue CEO Fiona Hick has stated that “every indication we have, shows the project has the

<sup>138</sup> Rio Tinto. [Climate change report 2022](#). Page 25.

<sup>139</sup> Australian Financial Review. [Politics behind China's iron ore ambitions in Africa, says former exec](#). 23 January 2023.

<sup>140</sup> Australian Financial Review. [China leaps ahead on unlocking huge African iron ore deposit](#). 23 January 2023.

<sup>141</sup> Rio Tinto. [Agreements reached on trans-Guinean in milestone for Simandou iron ore project](#). 11 August 2023.

<sup>142</sup> Fortescue Metals Group. [Mining Convention signed for the Belinga Iron Ore Project](#). 8 February 2023.

potential to be significant scale and very high-grade”<sup>143</sup>, and that “initial indications are that it could be similar in scale and size to Simandou in Guinea”<sup>144</sup>.

If the Belinga iron ore project shows similarity to the Simandou deposit in terms of iron ore grade and characteristics, it bodes well for future additions to the DR-grade iron ore market with the potential to contribute to green steel or green HBI production capability.

New investments in other African countries could also add to high-grade iron ore supply. A key issue remains the amount of infrastructure investment required to deliver iron ore to ports for global transportation. Establishing these infrastructures is both expensive and time-consuming. Development of the Simandou deposit in Guinea has been held up for many years by the need for extensive port and rail infrastructure investment that is estimated to cost US\$15-US\$20 billion<sup>145</sup>. However, this project now appears to be proceeding, driven in part by China’s efforts to become less dependent on Australian iron ore.

There remain doubts as to whether international companies will seriously consider relocating steel supply chain processes such as ironmaking to locations in Africa. Across extractive industries the model in Africa has largely been one of production of minerals and fossil fuels for immediate shipping to other nation, with limited benefit to the majority of Africans.<sup>146</sup> The processing of iron ore in Africa into green iron, and shipping as HBI, will require a determination to shift value-adding processing steps to African nations<sup>147</sup>, as has occurred in Botswana’s diamond industry, where some cutting and polishing of mined diamonds takes place domestically instead of overseas.<sup>148</sup> However, even if Africa’s contribution to global steel decarbonisation is via the export of DR-grade iron ore, it will provide increasingly significant competition with the Pilbara going forward, particularly among Chinese customers.

## Other Potential HBI Sources

Russia is a significant supplier of HBI to Europe. In 2021, Russian steelmaker Metalloinvest was the largest supplier of HBI in the world, supplying 4.2Mt of HBI and DRI. Russian HBI exports to the EU held up in 2022 and appear not to be impacted by sanctions.<sup>149</sup> Before the invasion of Ukraine, Russian HBI capacity had been expected to double.<sup>150</sup> However, as it stands it’s hard to see how steelmakers in markets like Europe could plan to increase HBI imports from Russia, regardless of emissions.

<sup>143</sup> Fortescue Metals Group. [World Mining Congress speech](#). 28 June 2023.

<sup>144</sup> Australian Financial Review. [After years of fruitless drilling, Fortescue is ready to change tactic](#). 17 May 2023.

<sup>145</sup> Reuters. [Work set to resume at Simandou iron ore after Guinea, shareholders agree terms](#). 15 March 2023.

<sup>146</sup> World Bank. [Was the resource boom more akin to a resource curse for Africa?](#) 11 October 2016.

<sup>147</sup> Argus Media. [Africa should avoid only exporting raw minerals: UNCTAD](#). 17 August 2023.

<sup>148</sup> Financial Times. [De Beers and Botswana strike deal on diamond sales after tense talks](#). 2 July 2023.

<sup>149</sup> Fastmarkets. [US, UK sanctions on Russia’s Metalloinvest to have limited impact on HBI market](#). 21 April 2023.

<sup>150</sup> S&P Global. [Feature: Russia’s hot-briquetted, direct-reduced iron capacity set to double](#). 18 February 2022.

However, Ukraine is also a producer of high-grade iron ore and plans are already being formulated to base the nation's post-war reconstruction on renewables.<sup>151</sup> There will be potential to rebuild Ukraine's iron and steel industry based on low-carbon technology that could see green hydrogen produced via renewables used to reduce its high-grade iron ore for export as HBI to Europe.

Ukrainian iron ore miner Ferrexpo is a supplier of iron ore pellets and had been planning to significantly expand its production of DR-grade pellets prior to the invasion.<sup>152</sup> Metinvest is another Ukrainian producer of high-grade iron ore. Canada-listed Black Iron was seeking to advance its Shymanivske iron ore project in Ukraine, set to produce a 68% Fe product, prior to the invasion.

Venezuela used to be the world's largest exporter of HBI, but this was significantly impacted by U.S. sanctions on the country. Venezuela's installed capacity for producing 6.9Mt of HBI per year remains largely underutilised, with operational output hovering at around just 10%. There seems to be no optimistic outlook for Venezuela to revitalise its production capacity in the foreseeable future.<sup>153</sup>

Sweden's iron ore producer LKAB is the most significant pellet supplier in Europe with high-quality ore bodies largely consisting of magnetite. As Sweden, along with other European steelmakers, has already announced plans to shift towards green iron and steel, most of its high-quality iron ore may be consumed for green steel projects in the EU region. Given the quality of its ore, the country has an opportunity to shift towards HBI exports going forward.<sup>154</sup> Sweden's H2 Green Steel has stated that Japan's Kobe Steel is interested in importing its HBI made using green hydrogen.<sup>155</sup>

In other countries there are opportunities and plans for expanded DR-grade iron ore and DRI capacity, but in many cases, this will likely be earmarked to supply domestic steelmaking operations rather than exported as HBI. India and Iran currently hold the top positions as the world's largest producers of DRI from domestic pellets and both countries are poised to increase their steelmaking capacities in the coming years. However, almost all of their new capacity will be allocated to domestic production.

The U.S. has some HBI capacity including Cleveland-Cliffs's plant in Ohio<sup>156</sup> and ArcelorMittal's Texas plant, which exports HBI to Voestalpine's Austrian operations.<sup>157</sup> The U.S. government passed the Inflation Reduction Act (IRA) in 2022, which utilises a tax credit scheme to make green hydrogen cost-competitive. The combination of the capacity in the iron and steel sector and the IRA put the U.S. in a prominent position for producing green iron. However, such capacity may largely meet the needs of the domestic steel industry rather than increasing the supply of low-carbon HBI exports.

<sup>151</sup> S&P Global. [INTERVIEW: Renewables to play bigger role in Ukraine's postwar energy mix](#). 28 June 2023.

<sup>152</sup> Ferrexpo. [A Low Carbon Pathway](#).

<sup>153</sup> S&P Global. [FEATURE: The demise of Venezuela's once thriving HBI industry](#). 4 November 2022.

<sup>154</sup> Primetals. [The new age of HBI](#). 28 February 2023.

<sup>155</sup> Hydrogen insight. ['Coal-based steel will have an advantage over hydrogen-derived green steel due to EU carbon allowance scheme'](#). 26 June 2023.

<sup>156</sup> Steel Times International. [Cleveland-Cliffs introduces HBI-based steel surcharge](#). 31 July 2023.

<sup>157</sup> ArcelorMittal. [ArcelorMittal acquires majority stake in voestalpine's state-of-the-art HBI facility in Texas](#). 14 April 2022.

In Canada, Champion is seeking to increase its supply of DR-grade iron ore pellets.<sup>158</sup> In 2021, ArcelorMittal announced a CAD\$205m project at its existing Port-Cartier pellet plant to convert its entire 10Mtpa pellet production into DR-grade product by the end of 2025.<sup>159</sup> The plant will become one of the world's largest producers of DR-grade pellets. ArcelorMittal has announced several DRI projects that will need a DR-grade feedstock in Europe and Canada, so ArcelorMittal's DR-grade pellet production looks unlikely to supply the wider DRI market. However, with high-grade iron ore and clean energy resources to make green hydrogen, Canada could be in a position to begin producing and exporting green HBI.

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<sup>158</sup> Champion Iron. [First Quarter of the 2024 Financial Year](#). 28 July 2023.

<sup>159</sup> ArcelorMittal. [ArcelorMittal announces CAD\\$205 million decarbonisation investment in its flagship Canadian mining operations with support from the Quebec government](#). 3 November 2021.

## About IEEFA

The Institute for Energy Economics and Financial Analysis (IEEFA) examines issues related to energy markets, trends and policies. The Institute's mission is to accelerate the transition to a diverse, sustainable and profitable energy economy. [www.ieefa.org](http://www.ieefa.org)

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