WaveStone ESG Report
Quarter ending September 2023

ESG Quarterly: Decarbonising iron ore: challenges & opportunities for the Pilbara miners

Executive Summary

The Pilbara region of Western Australia accounts for c.1Bt of iron ore exports annually, predominantly to steel-making customers in China, Japan and South Korea. BHP, Rio Tinto (RIO), and Fortescue (FMG) ('Pilbara miners') are the dominant producers in the Pilbara, single-handedly accounting for ~90% of Australia's total annual iron ore production.

On a Scope 1 & 2 emissions basis (direct & imported), the Pilbara miners emitted a combined 7.7Mt CO2e in FY'23 (RIO based on 2022 data). RIO had the highest emission (3.1Mt) reflecting its larger output and relatively greater network complexity. BHP and FMG had emissions of 2.1Mt and 2.6Mt, respectively. Whilst large in absolute terms, BHP and RIO's Pilbara emissions represented <30% of group emissions – despite iron ore representing ~40-50% of copper equivalent production – highlighting that Pilbara iron ore production typically has a lower emissions intensity than other metals.

The miners are proactively looking to reduce their emissions over the next decade, but with quite different strategies. RIO is looking to reduce its emissions by building out renewable capacity to phase out fossil fuel usage at its stationary power installations. BHP has a greater reliance on imported electricity so will switch this to renewables, whilst it also plans to incrementally 'green' its fleet, subject to technology availability. FMG is the most aggressive, with a plan to be net zero by the end of this decade, so is looking to decarbonise both its power sources and switch to a fully renewable fleet.

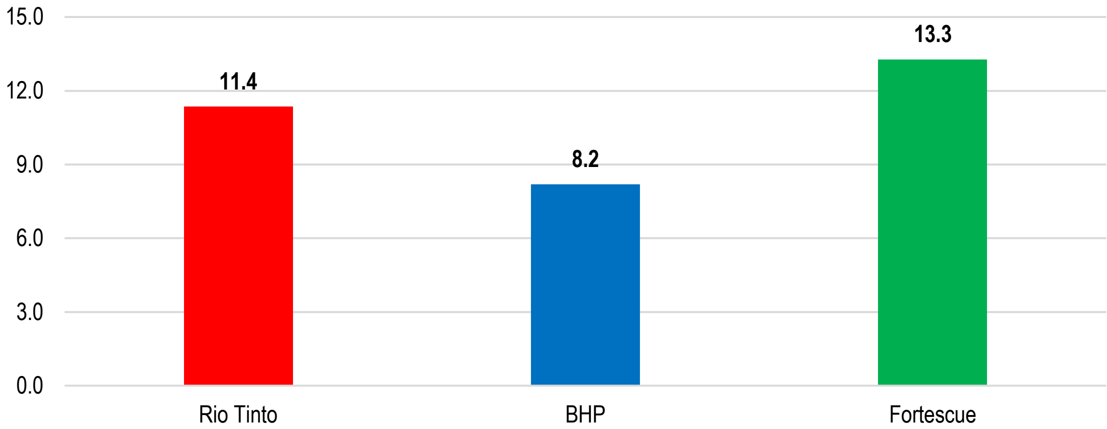
We calculate the Pilbara miners have outlined a cumulative ~US$8.0-8.5bn of gross capex (real) that will be spent on decarbonising their assets through 2030. But this will have to grow further in order for the companies to reach decarbonisation targets. We also identify further upside if BHP and RIO become more ambitious with electrifying their fleet. Note these figures exclude the capex that will have to be spent by third parties, such as contractors and third-party power providers. Into 2030, the capital needs for decarbonisation will likely increase further, as more capex is needed to electrify the fleet as well as match these vehicles' energy needs by building out more renewable capacity.

Concurrently, there's also the challenge for how the iron ore miners address their Scope 3 emissions, given customers (global steelmakers) represents ~9% global emissions. High quality metallic units are an easy way to lower steelmakers' emissions to start with. In the mid-term, modifying the blast furnace's emissions, such as with carbon capture could have a role. Longer-term, technology is critical to reduce steel emissions, with BHP & RIO already actively engaging customers to find a mutually beneficial solution to decarbonisation.

Pilbara emissions typically range between ~8-13kg CO2 per tonne of iron ore, which compares favourably to global peers

Normalising for differences in iron ore production shows there are differences in the emissions intensity between the miners, despite employing similar extraction techniques (drill-blast-load-haul bulk mining) and transportation systems (rail & port) (**Figure 1**). We calculate BHP has the lowest intensity at ~8kg CO2 per tonne of iron ore produced, whilst FMG has the highest at ~13kg CO2.

Figure 1: Pilbara miners' Scope 1 and 2 emissions intensity (kg CO2 per tonne iron ore produced)



Source: Company reports. BHP and FMG emissions based on FY'22 data, RIO emissions based on CY'22 data. Equity basis.

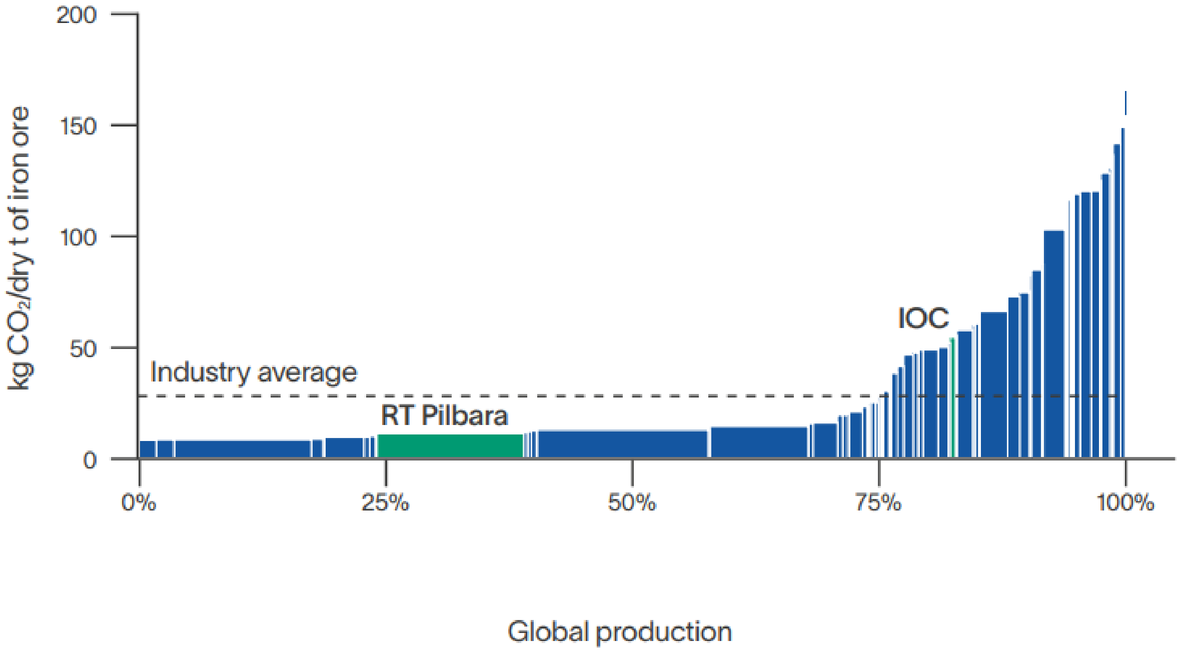
We identify the differences in intensity to idiosyncratic factors such as resource quality & nature of each miners' operating network, for example:

1. Concentrated resources, with lower strip ratios and within closer proximity to export terminals require less mobile fleet to extract and transport the ore, which therefore lowers diesel usage. For example, BHP operates five mines connected by 1,000km of rail infrastructure, RIO operates 16 mines with 1,700km of rail infrastructure, and FMG operates three mining hubs and 760km of rail infrastructure;
2. Higher quality ores require lower processing (eg dry vs. wet beneficiation alters the energy needs).

Despite differences in relative intensity, the source of emissions for the Pilbara miners is typically in two areas: (1) Stationary Power (~25% Scope 1 & 2 emissions), from company-operated power plants that burn fossil fuels (typically natural gas) and/or imported power from a 3rd party that is generated using fossil fuels; (2) Diesel use in the mining fleet (~75%) such as heavy mobile equipment (HME), mining haul trucks, company-operated vessels & rail operations.

Relative to the broader iron ore sector, the Pilbara miners compare favourably on an intensity basis as reflected by a global average of ~30kg CO2/t (**Figure 2**). We note this is skewed higher by lower grade production, such as magnetite which must be beneficiated into concentrate (& potentially pelletised) before it is sold to customers (eg. IOC).

Figure 2: Global iron ore CO2 intensity curve – BHP, RIO and FMG are well placed



Source: Rio Tinto '*2022 Climate Change Report'*, CRU. Based on 2021 data.

Pilbara miners have group level ambitions to decarbonise significantly over the next decade; FMG the most ambitious, with an aim to be net zero by 2030

All three Pilbara miners have broad, group-level ambitions to decarbonise. FMG is the most ambitious, targeting 'real net zero' on a Scope 1 and 2 basis (eg without any offsets) by 2030. RIO is targeting a 50% reduction in emissions by 2030, and BHP is targeting a 30% reduction; both are targeting net zero by 2050 (**Figure 3**).

Figure 3: Pilbara Iron ore miners' decarbonisation targets

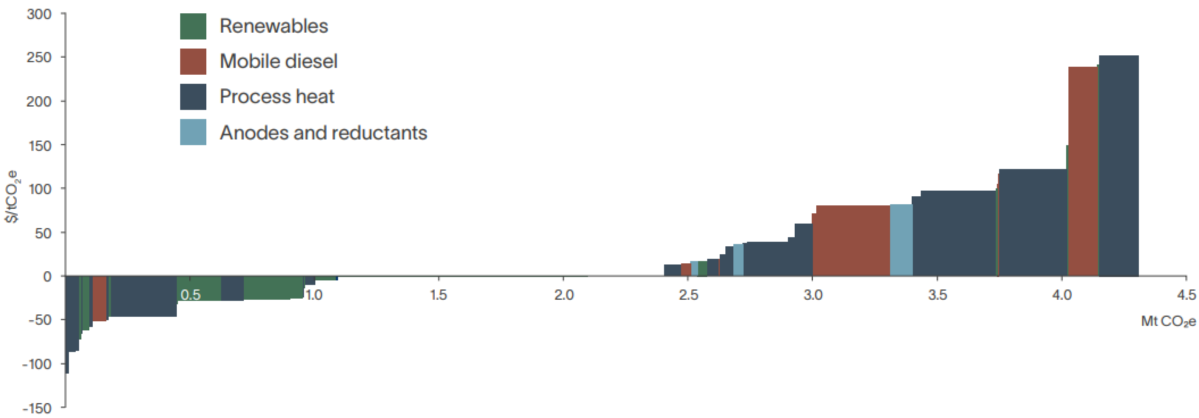
Company	Scope	Target reduction [vs base-line]	Target year	Comment
Rio Tinto	Scope 1 & 2	-50% vs 2018 (group level)	2030	"6+1 abatement" reflects 1) switching electricity generated & purchased to renewables & 2) reducing emissions from process heat (eg alumina)
	Scope 1 & 2	Net zero (group level)	2050	Includes deploying ELYSIS & phase-out of carbon anodes (aluminium), progressing low emissions trucks & mobile equipment
	Scope 3	No target (group level)	n/a	Addressing Scope 3 by engaging with customers & to develop/scale up technologies to decarbonise
BHP	Scope 1 & 2	-30% vs FY'20 (group level)	2030	Includes switching electricity generated & purchased to renewables, displacing diesel in fleet
	Scope 3	"Support" development for -30% intensity in steel "Support" -40% intensity for BHP-chartered ships	2030	New technologies in steelmaking, new fuel options for BHP-chartered ships, influencing existing suppliers to commit to net zero
	Scope 3	Net zero (group level)	2050	Focusing on how BHP can invest, partners and influence to support GHG emission reductions across value chain
Fortescue	Scope 1 & 2	Net zero (group level)	2030	"Real zero" meaning no fossil fuel use and no offsets, where possible
	Scope 3	-7.5% intensity level for steelmaking -50% intensity level for shipping	2030	Includes decarbonising fleet or eight ore carriers via green ammonia, engaging with shipping industry to reduce emissions
	Scope 3	Net zero (group level)	2040	Develop projects & technologies, and work with customers on the application of the technology and the supply of green H2 and ammonia

Source: Rio Tinto 2022 Climate Report (link), BHP FY'23 Annual Report (link), BHP 'Climate Change' webpage (link), Fortescue '*Climate Change*' website (link)

It's worth highlighting that the different decarbonisation strategies in part reflect the different characteristics of each miner's commodity portfolio. FMG's strategy is made easier given the source of group emissions is solely from iron ore. But for BHP and RIO, different commodities can have materially different emissions intensities, which can make it more/less of a priority. For example, a key differentiator of RIO's portfolio vs BHP is its sizeable aluminium division, where the global average emission intensity is ~11t CO2/t Al metal, or ~15x the emission for a typical iron ore mine (on a copper equivalent basis).

Furthermore, each commodity will face varying challenges to decarbonise, such as ease of implementing/scaling, economics, technology readiness, asset replacement cycles, government policy etc. To frame the decision, it is useful to think about a marginal abatement cost (MAC) curve which back-solves the incentive carbon price required to make an abatement project NPV neutral (**Figure 4**). Projects with a negative carbon price (left-hand side of chart) have a positive NPV at a CO2 price of $0/t; projects with the highest abatement cost are shown on the right & require CO2 price support to break-even (or some form of technology break-through, which is outside of the scope/time frame analysed).

Figure 4: MAC curve for Scope 1 & 2 decarbonisation projects



Source: Rio Tinto '*2021 Climate Change Report*'.

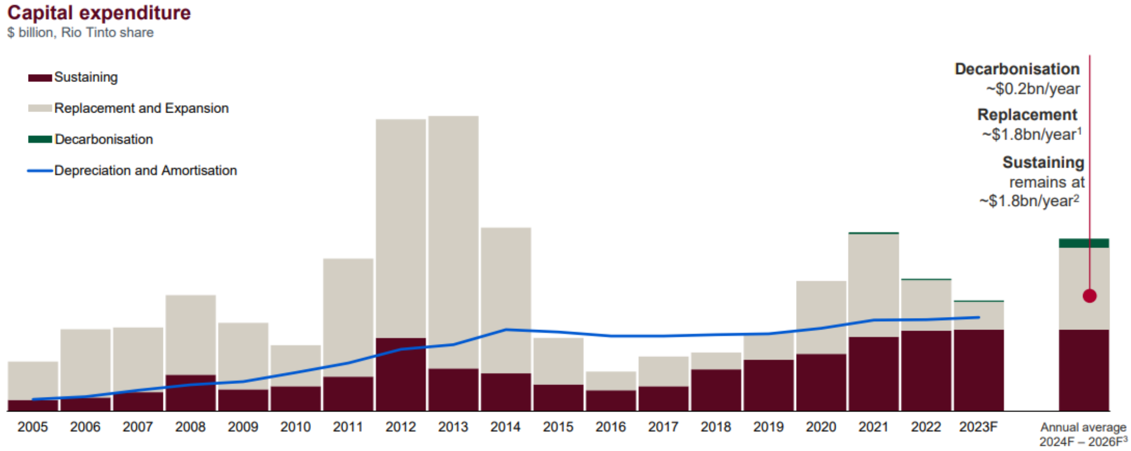
Abatement curves highlight the "easy wins" are typically transitioning stationary power; greening the diesel fleet is a larger prize, but will be a tougher proposition

As it pertains to the Pilbara operations, the MAC curve highlights that switching stationary power to renewables is likely the easiest to implement. We note that all three Pilbara producers have plans to switch to renewable installations, including:

- **Rio Tinto:** Planning 1GW of renewable power in the Pilbara by 2030. The first 34MW of solar capacity has already been installed at Gudai-Darri. RIO is planning further investments of US$600m for solar, storage and transmission to deliver an incremental 230MW solar capacity & 200MWh storage over 2023-26.
- **BHP:** BHP's Pilbara operations are currently supplied by the 190MW Yarnima gas fired power station. BHP is planning an additional ~500MW of renewable generation and storage capacity installed by the 2030, with Yarnima still operational to provide power during periods of lower renewable generation;
- **Fortescue:** In Sep'22, FMG announced a plan to deploy an additional 2-3GW of renewable energy generation & battery storage, and the estimated incremental costs associated with a green mining fleet and locomotives.

Turning to capital budgets, RIO has guided to ~US$0.2bn pa over 2024-2026 towards decarbonising its Pilbara assets (**Figure 5**). There is no longer-term guidance on the full amount that will need to be spent on renewables capacity, nor electrifying its fleet. As such, we believe further investment will be required into the back end of the decade. Assuming a capital intensity of US$700-1,200/kW for solar/onshore wind capacity, and that 2/3 of installed capacity is solar, then we estimate a further ~US$0.6bn (real) would be required from 2027-2030 to get to close to the 1GW goal (inclusive of ESS). We also note that RIO currently operates all its energy infrastructure; assuming this remains the case for installed renewable capacity, then we highlight that RIO will likely have a higher capital intensity on decarbonisation spend vs its Pilbara peers, all else equal.

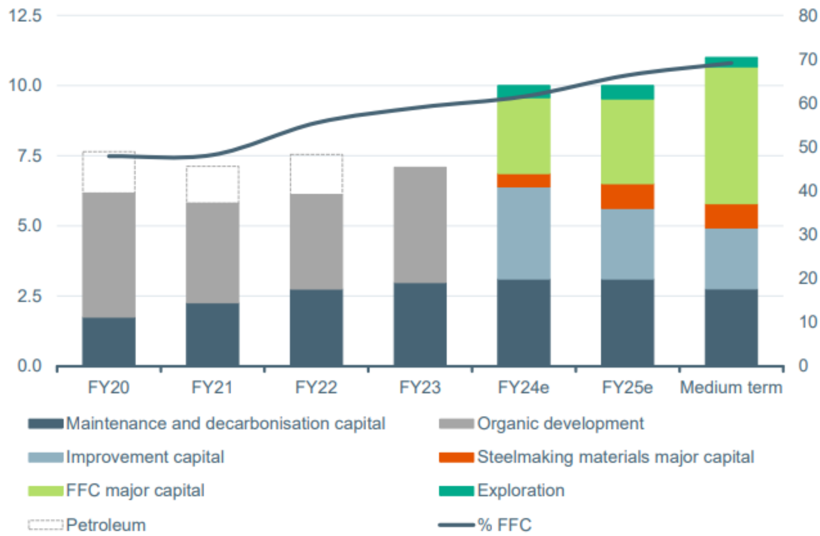
Figure 5: RIO decarbonisation capital (US$m)



Source: Rio Tinto Pilbara Site trip presentation, October 2023.

BHP has indicated it expects to spend ~US$4bn at the group level on "operational decarbonisation" through to FY'30 (
Figure 6). Of this, 40% (US$1.6bn) will be spent in the Pilbara, which roughly equates to ~US$0.2bn pa. However, most of this relates to diesel replacement for incremental spend above internal combustion engines (ICE) replacement costs, as well as site infrastructure, which will be end-decade weighted and technology dependent. The US$1.6bn is also nominal, so more like c.US$1.4-1.6bn on a real basis (at 2.5% inflation). BHP has not specifically guided to renewable capacity build-out, but we estimate this would be smaller cf. Pilbara peers, given BHP sources a sizeable share of its energy needs from 3rd parties.

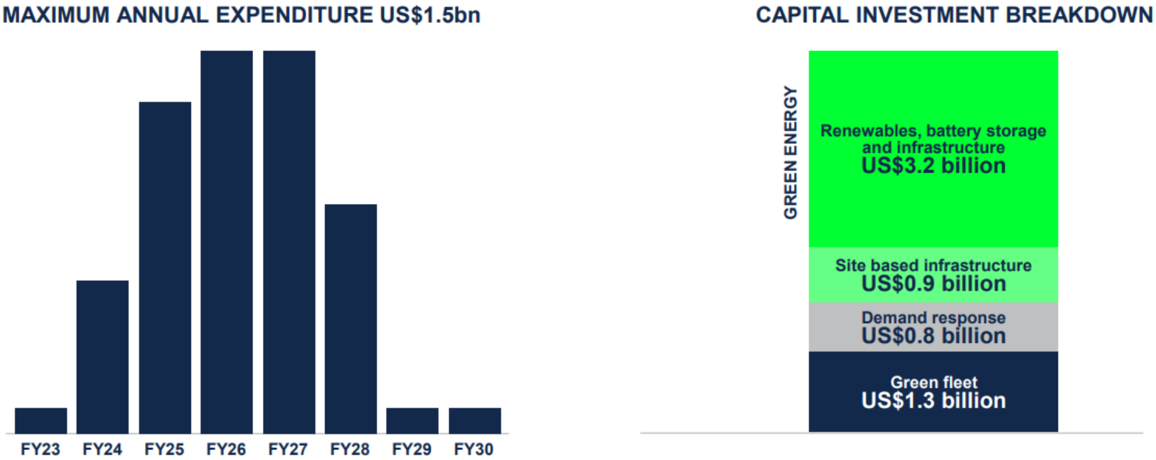
Figure 6: BHP decarbonisation capital (US$m)



Source: BHP FY'23 Presentation, August 2023.

FMG has outlined a strategy to decarbonise its Pilbara operations by spending US$6.2bn of capex by 2030, mostly over FY'24-28 (**Figure 7**). This budget includes renewable capacity build-out of 2-3GW and battery storage capacity for US$3.2bn, as well as US$1.3bn on a green mining fleet & locomotives. We are not aware of specific targets on solar/wind roll-out.

Figure 7: FMG decarbonisation capital



Source: Company report (link).

Tackling fleet emissions represents a tougher proposition for the sector, particularly given the technology is not yet at a point which would warrant full-scale roll-out. Again, FMG is the most aggressive in its ambitions (full green fleet by end of decade, with a mix of electric and hydrogen vehicles). BHP and RIO are taking a more measured approach, and partnering with original equipment manufacturers (OEMs) to trial technologies that could be accelerated into an operating setting.

Figure 8: BHP plans to implement 'green' fleet into Pilbara operations

Partners	Operating prototype	BHP operating trial	BHP target deployment[1]
Caterpillar	2022[2]	2024	From 2028[3]
Komatsu	2021	~2025	
Progress Rail	2022	2024	From 2029
Wabtec	2021	2024	
Liebherr	-	2024	~2027

Source: BHP 'Operational Decarbonisation' Presentation, June 2023.

Putting this altogether, we calculate the Pilbara miners have outlined a cumulative ~US$8.0-8.5bn of gross capex (real) that will be spent on decarbonising their assets through 2030. In all likelihood this will have to grow (eg up to ~US$9.0-9.5bn at a minimum) if the companies want to achieve stated ambitions on things like renewable capacity installations. We also identify further upside if BHP and RIO become more ambitious with electrifying their fleet. These capex figures also exclude the spend that will have to be spent by third parties.

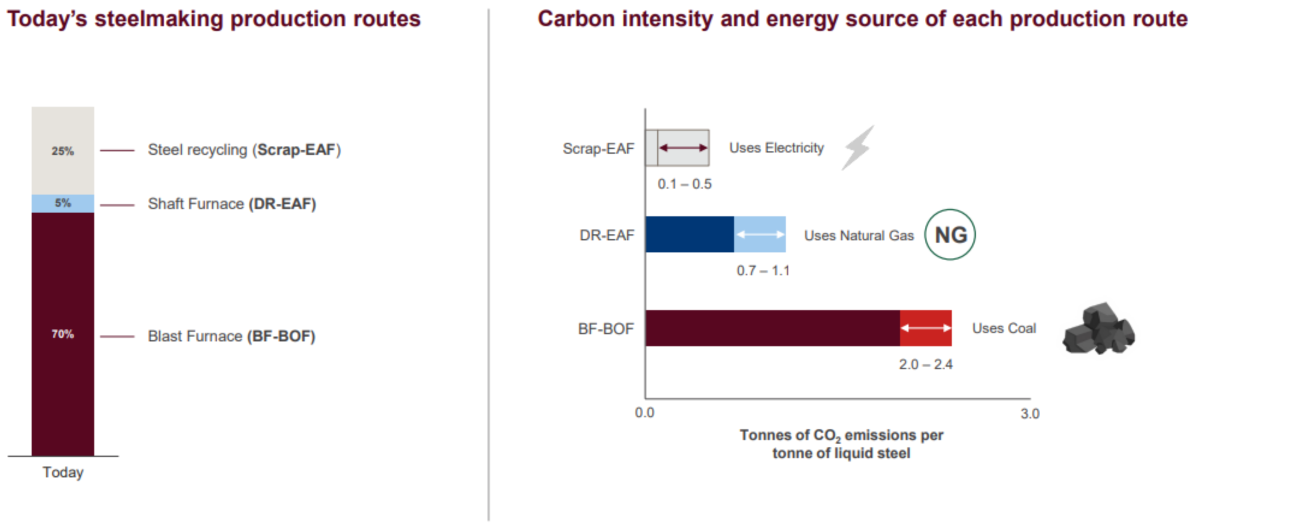
Then as we look into 2030, the capital needs for BHP and RIO will likely have to increase further, as more capex is needed to electrify the fleet as well as match these vehicles' energy needs by building out more renewable capacity.

The elephant in the room: How do the Pilbara miners address Scope 3 emissions for the steel industry, which account for ~9% global emissions?

Scope 3 emissions generated from ~1.9Bt of annual steel production represents a much larger challenge for the iron ore industry. The emissions intensity to produce a tonne of steel vary materially based on the production route. An integrated facility using a blast furnace/basic oxygen furnace (BF-BOF) has the greatest share of global steel production (~70%), reflecting the dominance of this processing route in China (**Figure 9**). A blast furnace emits 2.0-2.4tCO2 per tonne of crude steel. Steel can also be made using an electric arc furnace (EAF), which uses electricity to reduce iron units into liquid metal; depending on the type of quality of material used, emissions can be >50% lower vs a traditional BF-BOF.

The net implication is the global steel industry emits ~3.0-3.5Bt of CO2e pa, or ~9% of global emissions.

Figure 9: Share of global steelmaking, by production route (LHS) & emissions intensity for each production route (tCO2/t crude; RHS)



Source: Rio Tinto '*2021 Climate Change Report'*.

There are a number of ways that the steel industry can decarbonise. The most practical (and least capital intensive), is to use higher quality iron units. For example, replacing sintered fines with pellet/concentrate could reduce a BF-BOF's emissions by up to 15-20% (here).

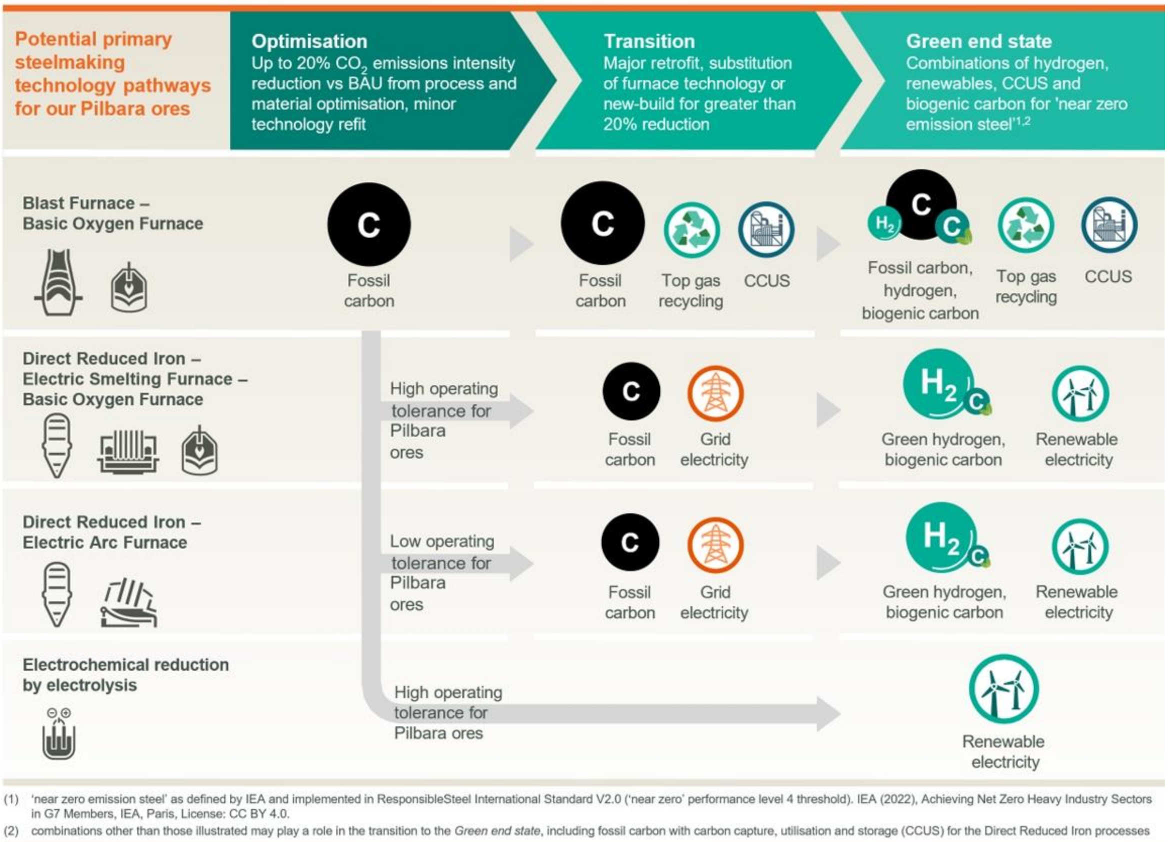
Given the lower emissions intensity of an EAF, it also makes sense to switch towards a greater proportion of EAF-based production. But this comes with a number of logistical issues, including:

1. **Scrap availability** – you need to have sufficient scrap availability which requires (1) established supply chains to collect the scrap & deliver it to where it is needed; and (2) a mature scrap cycles (to limit dependence on external sources). The type of scrap used in an EAF will also dictate the quality of the steel produced. For example, end of life scrap (eg from a building) is usually more abundant than prime scrap (eg offcuts from manufacturing), but end of life scrap has greater impurities which results in an inferior quality steel that can often only be used for low-value end uses. As key users of steel – such as China – shift away from FAI eg property, then the quality of steel they require will likely increase, all else equal;
2. **Access to renewable power** – EAF's use external power as the source of energy to reduce iron units (eg scrap/DRI) into liquid metal. But without access to cheap & dependable renewables it is hard to justify moving away from BF-BOF production. Dependability is something that has become increasingly in focus, especially in other commodities such as aluminium (similarly energy intensive), where smelters in Yunnan Province in China have had to curtail capacity given limited hydro availability;

3. **Asset replacement cycle** – A potential impediment of wholescale switching from BF-BOF to EAF is the age of the existing BF-BOF fleet. For example, the older the fleet is, the easier the capital decision is to replace with an EAF – assuming available scrap & power – as opposed to relining the existing furnace. Major relines are typically required every 10-20yrs & can cost US$50-100m per furnace. However, the age of China's BF fleet is only ~10yrs vs Germany >40yrs and US >60yrs, which means we are unlikely to see large amounts of capex spent for new EAF buildout in China in the next decade.

So with these constraints in mind, what other options are available to decarbonise steelmaking? The industry appears to be coalescing around four alternate steelmaking process routes: (1) modified BF, (2) EAF with DRI, (3) ESF with DRI, (4) direct electrolysis (**Figure 10**).

Figure 10: Primary steelmaking process routes to decarbonise the global steel industry



Source: BHP 'Pathways to decarbonisation (2023)'. Link

- **Modified BF** – modifying an existing BF to reduce emissions leverages existing infrastructure (eg provides a low capital intensity option), whilst concurrently circumventing the problem around fleet age, product quality and requirements around metallic units. These technologies include top gas recycling, Carbon Capture, Utilisation & Storage (CCUS), hydrogen injection (eg displacing PCI coal) and the use of biomass as a reductant. Some of the options could credibly be rolled out over the short/medium-term (eg biomass is already used in small scale) so will likely have a role to play in steels' decarbonisation over the next decade. CCUS is increasingly viewed as a mid-term solution, but we are more cautious given the potential difficulty in rolling out at large integrated facilities (with many emission points, therefore make capturing troublesome).

- **Electric Arc Furnace (EAF) with DRI** – Direct reduced iron (DRI) is a metallised form of iron ore. Unlike BF's, DRI plants do not require CO2-containing coke & instead use hydrogen-containing gas to convert the iron ore into iron, therefore lowering the emissions intensity of the process. Currently natural gas is used as the feed but in the future this could be displaced by hydrogen, with cost being the major impediment to full-scale adoption. Furthermore, the power for the process is supplied by an external electricity source; if this is renewable, then it is theoretically possible to produce an entirely CO2-free steel. A number of steelmakers have plans to role out H2 DRI-EAF, such as SSAB's HYBRIT and H2GreenSteel. A key impediment is it requires significant capital investment to build out new DRI & EAF capacity, as well as the associated renewable (& hydrogen electrolyser) capacity that would be required.

Opex is also likely uneconomic (vs incumbent methods) unless hydrogen can be delivered cheaply (order of <US$2/kg) which will prohibit many geographies from operating these facilities. There are also uncertainties with the end quality of steel produced (eg brittleness, which could prohibit use in automotive). Finally, the large amounts of gangue produced mean very high spec iron ore is needed as an input (eg 67% Fe+ with low impurities), but physical constraints on ore – such as the ore mined in the Pilbara – mean it becomes almost technically impossible to achieve this quality levels, even with a beneficiation plant (low magnetism means higher amounts of iron ore rejected at higher grades). Wood Mackenzie estimates only 3% of global iron ore output is amenable to this process (link).

- **Electric Smelting Furnace (ESF) with DRI** – the ESF represents an alternative option to an EAF but with (potentially) greater feedstock flexibility & superior operating performance. Unlike the incumbent EAF, solid material can be fed into the furnace continually and the rate of slag production (which forms on the top of the molten metal) can be controlled carefully which lowers the ore quality threshold. It could potentially represent a more capital-lite option as it would only replace the front-end of a blast furnace (eg can be used with existing finishing lines) and help maintain product quality. BHP has partnered with Tata Steel Europe, ThyssenKrupp, voestalpine, BlueScope and POSCO to develop this technology, whilst RIO has an agreement with Baowu to build a pilot-scale plant in China. We view this technology as particularly interesting for the Pilbara miners given the lower threshold on ore quality means Pilbara ore is amenable to the process. Furthermore, proximity to abundant renewable energy sources (solar, wind) in the Pilbara means a mid-stream industry producing a "green" metallic unit could emerge over time out, where it could then be shipped to global steel mills.

- **Direct electrolysis / "Molten Oxide Electrolysis" (MOE)** – this is a nascent technology that would result in a completely new steelmaking process route. The benefits are that it is agnostic to ore quality, delivers high CO2 reduction (when coupled with renewable power sources) and theoretically has no product quality issues. However, the major bottleneck is the electricity requirements, which is ~4MWh per tonne crude steel, or ~10x that needed for a typical EAF (link). We note that BHP and Vale are early backers of Boston Metals, a company based in the US which is spear-heading this technology (website).

Carbon Emission and Intensity Tracker:

WaveStone – Australian Share Fund (WASF)	Carbon Emissions		
	Portfolio	Benchmark	Difference
Carbon Emissions Scope 1+2 (tonnes CO2e/USD M invested)	93.2	137.4	-32.2%
Carbon Intensity Scope 1+2 (tonnes CO2e/USD sales)	126.0	170.9	-26.3%

Source: MSCI ESG (as at 30/09/2023)
Benchmark is the S&P ASX 300 Accumulation Index

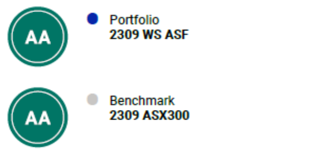
Engagement

ESG-related Engagements during the Quarter

Company	ESG Category	Topics
ALL	Social Governance	Regulation (land based, iGaming & digital), cashless gaming, capital allocation, succession planning
CKF	Social Governance	Solar panels installation & waste diversion. Staff equity incentive program
CWY	Environment Social Governance	Safety, REM, waste diversion, Energy from Waste Strategy, ACCU movements relating to GRL sale and repurchase of offshore offsets. Capital allocation.
WDS	Environment	Climate strategy & demand resilience, emission reduction pathway, Scope 3, use of offsets, decarbonisation projects pipeline, 2024 Climate Report, impact on cost of capital of real/perceived non-compliance with global decarbonisation ambitions
CSL	Environment Social Governance	Strategy and management team succession, business strategy, ESG metrics in REM and FY24 LTI grant.
TCL	Governance	Management succession, strategy and capital management
GMG	Environment	DC energy intensity and efficiency
ORA	Environment	SaverGlass acquisition and associative energy usage, decarbonisation plans
RWC	Governance	Management succession, strategy, capital management
IAG	Environment Social Governance	Climate strategy, social license and alignment to REM, affordability
TWE	Governance	REM structure, strategy, Board succession
BLD	Environment Governance	Strategy, decarbonisation challenges
EDV	Governance	Dan Murphy’s strategy, capital deployment and growth strategy, balance sheet

MSCI ESG Ratings*

MSCI ESG Ratings

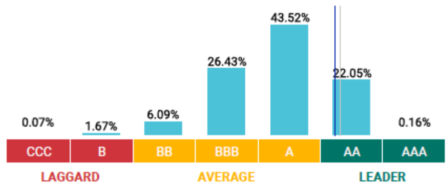


How the MSCI ESG Rating is calculated

	Portfolio	Benchmark
Weighted Avg ESG Score	7.49	7.62
ESG Quality Score	7.49	7.62
ESG Rating	AA	AA

Distribution of MSCI ESG Fund Ratings Universe

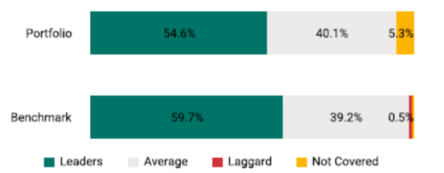
As of: 04/11/2023



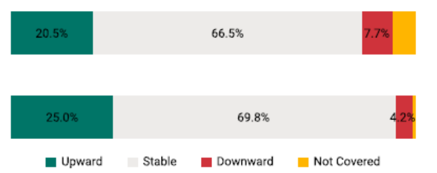
Portfolio ESG Rating Summary

ESG Quality	Leader 1.73% below benchmark
ESG Ratings Distribution	Leaders 5.10% under benchmark Laggards 0.53% under benchmark
ESG Ratings Momentum	Upward momentum 4.50% under benchmark Downward momentum 3.55% over benchmark

ESG Ratings Distribution



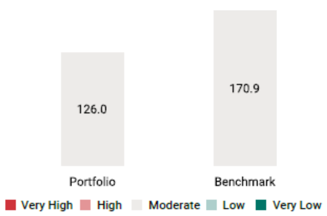
ESG Ratings Momentum



Carbon Risk

(t CO2e/$M SALES)

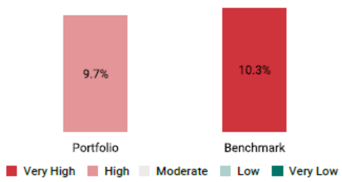
Moderate Carbon Risk
26.30% less than benchmark



Reputational Risk

(Very Severe Controversy Exposure)

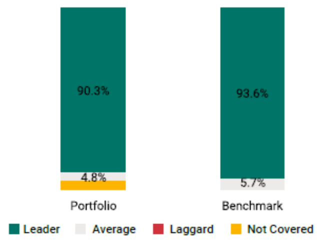
High Reputational Risk
0.67% less than benchmark



Governance Risk

(Global Percentile)

Leaders 3.36% less than benchmark
Laggards 0.38% less than benchmark



Memberships and initiatives

- Principles of Responsible Investment (PRI)
- Climate Action 100+
- 40:40 Vision

Links to WaveStone Policies

- ESG Policy: **WaveStone ESG Policy**
- ESG Activity Report: **WaveStone ESG Activity Reports**
- Proxy Voting Policy: **WaveStone Proxy Voting Policy**
- Proxy Voting Records: **WaveStone Proxy Voting Records**
- Engagement Policy: **WaveStone Engagement Policy**
- **WaveStone PRI Transparency Report 2020**
- **WaveStone PRI Assessment Report 2020**

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