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An Iron Giant With Feet of Clay?
In the Midst of the Steelmaking Transition Strategy

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Abstract

This report contains a detailed analysis of the Vale S.A. Ferrous Minerals operations, including a deep dive into the global iron ore demand under future steelmaking scenarios. Finally, an analysis of the main value drivers is performed, providing the necessary assumptions for the forecasts of the segment's revenues and costs upon which its valuation is performed.

Keywords
Mining
Iron Ore
Steelmaking
Base Metals

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This report is part of the "*An Iron Giant With Feet of Clay? – In the Midst of the Steelmaking Transition Strategy*" report (annexed), developed by Pedro Ferreira and Rui Ramalhão and should be read has an integral part of it.

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Introduction

The joint report "*An Iron Giant With Feet of Clay? – In the Midst of the Steelmaking Transition Strategy*" has the purpose of performing a valuation of Vale S.A., one of the world's leading mining companies, with operations spanning all continents.

The joint report starts by including a description of the company and its business segments, as well as the ownership structure. Then, the report is structured in two chapters, one for each segment of the company: Ferrous Minerals (mainly comprising the production of iron ore) and Base Metals (mainly comprising the production of nickel and copper). Each chapter describes the segment's portfolio and operations, providing a detailed, in-depth analysis of the markets in which the company operates, namely the iron ore, nickel, and copper markets. The market analysis include both short- and long-term overviews, main trends, and demand and price forecasts. Furthermore, an explanation of the two possible scenarios relatively to mineral consumption in the context of the steelmaking and energy transitions (the Stated Policies Scenario – STEPS – and the Sustainable Development Scenario – SDS) is also provided. Each chapter ends with the main revenue and cost forecasts for the corresponding segment. In the end of the joint report, the Valuation chapter clarifies the methodology and the discount rate calculation, presenting as well the cash flows, the Enterprise Value and the Equity Value. An explanation of the dividend policy and a sensitivity analysis of the most influential inputs have also been included in the aforementioned chapter. Finally, the report concludes with the target share price of $14.06 for FY2023, which translates into a "Sell" recommendation.

This individual report includes the whole chapter dedicated to the Ferrous Minerals segment. This chapter describes the segment's product portfolio and operations, the iron ore market overview, and the main revenue and cost assumptions the built in the segment's valuation.

Company Overview

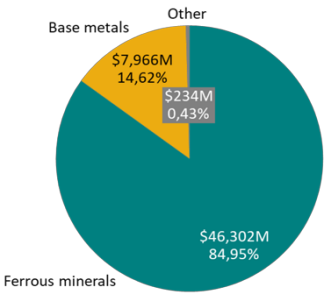


Figure 1 - Revenue per segment (FY21)

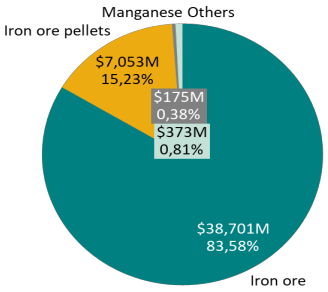


Figure 3 - Ferrous Minerals revenue per product (FY21)

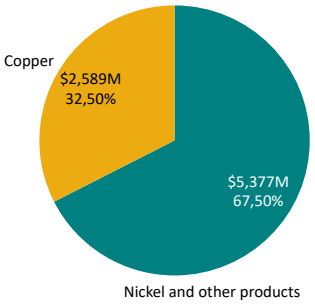


Figure 2 - Base Metals revenue per product (FY21)

Vale S.A. was founded in 1942, as "Companhia Vale do Rio Doce", by the Brazilian government. It is currently the fifth largest mining and metals company in the world, based on market capitalization, as well as one of the world's largest producers of iron ore and nickel. It also produces iron ore pellets, copper, platinum group metals (PGMs), gold, silver and cobalt. Its greenfield mineral explorations are present in all five continents. Besides mining, it operates several logistics complexes. As stated in the annual reports, Vale operates in three different business segments: Ferrous Minerals, Base Metals and Others.

Ferrous Minerals The segment comprises the production of iron ore fines and pellets, as well as the sale of ore prior to processing (ROM). Vale is the world's largest supplier of iron ore, operating nine mines and nine pellet plants in Brazil. The company also conducts pelletizing operations in Oman, having two pellet plants integrated in its distribution centre. Ferrous Minerals is the most significant segment of the company, corresponding to 85% of total company revenues ($46,302m) and $31,589m of Adjusted EBITDA in FY2021. Most total Ferrous Minerals' revenues come from the sale of iron ore fines (84%), with pellets (15%) and other products (i.e., ROM and manganese) being less significant.

Base Metals The segment involves mining and refining operations related with the sale of nickel, copper, PGMs, gold, silver and cobalt. The company mines nickel in Canada, Indonesia and Brazil, having refining facilities in the United Kingdom, Canada and Japan. Vale is then the second largest producer of nickel on a volume basis, only being surpassed by the Russian company MMC Norilsk Nickel. Vale's copper operations are located in Brazil and Canada, where it is also mined as a co-product of nickel mining activities. Furthermore, PGMs, gold, silver and cobalt are obtained as by-products from nickel and copper mining operations. Base Metals represent the second largest segment, corresponding to 15% of total revenues ($7,966m) and $3,193m of Adjusted EBITDA in 2021.

Others This segment is intended to the allocation of revenues and costs of other products, services, research and development, investments in joint ventures and associates of other business and unallocated corporate expenses.

Discontinued Operations Vale has been pursuing a portfolio consolidation strategy, focusing on its core mining operations. US-based Mosaic Company US bought Vale's fertilizers business for $1.4B in 2016, except for the Cubatão assets, which were bought for $255M by the Norwegian Yara International ASA in 2017. The company divested its coal operations in 2021, selling its Mozambique coal assets to Vulcan Resources for $270M plus a 10-year royalty

agreement subject to the evolution of mine production and coal prices. Vale divested its manganese mining operations at Morro da Mina (sold to VDL Group in 2022) and its ferroalloys operations in Barbacena and Ouro Preto. Until April 2022, Vale also conducted mining operations in the Midwestern System through the subsidiary Mineração Corumbaense Reunida S.A., entering into an agreement with J&F Mineração Ltda. for the sale of all iron ore, manganese ore and logistics assets in the Midwestern System, which was concluded in July 2022. Other less significant transactions were conducted over the last years.

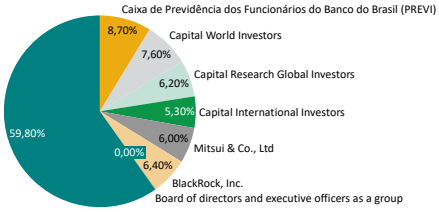


Figure 4 - Main shareholders
(as reported in the 2021 Annual Report)

Ownership Structure Vale S.A., despite being headquartered in Rio de Janeiro, Brazil, is traded in the B3 (Vale3), the New York Stock Exchange (VALE) and the Bolsa de Madrid (XVALO). The company's outstanding share capital is represented by 4.6B common shares. There are also 12 golden shares belonging to the Brazilian government, providing limited veto power over changes to the name of the firm, the location of headquarters and the corporate purpose. Currently, there are six shareholders owning more than 5% of total stock (totaling 40.2% of outstanding share capital). In 2021, a share repurchase program was completed, with 270M shares (5.3% of the outstanding common shares) being bought at an average price of $19.95. As of FY2021, roughly 21.85M common shares were bought (0.4% of the outstanding common shares) at an average price of $12.47 ($0.3B investment) under the program announced in October 2021. In April 2022, a new share repurchase program was announced, under which 500M common shares (10% of the outstanding common shares) would be bought over the next 18 months.

Ferrous Minerals

Operations and Product Portfolio Vale conducts its iron ore business in Brazil primarily at the parent-company level, running its mining and beneficiation operations in three main systems: Northern, Southern and Southeastern. The Northern System comprises three mining complexes. Serra Norte (three mining areas and three beneficiation plants), Serra Sul (one main mining area and one beneficiation plant) and Serra Leste (one mining area and one beneficiation plant) are open pit mining operations with high-grade hematite ore type (iron ore grade around 65%). There is also a minor amount of itabirite material (iron grade of 35-60%). Most mining concessions have no expiration date. Brazilian operations are subject to extensive environmental regulation, requiring Vale to modify mining plans or to incur additional costs that may limit production volumes, costs or mineral reserves. Two mining complexes, Vargem Grande (five mines and five major beneficiation plants) and Paraopeba (five mines and three major beneficiation plants) incorporate the Southern System, open pit mining

operations with high ratios of itabirite ore relative to hematite ore type (lower average iron ore grade, 35-60%). Part of the ore is concentrated to achieve shipping grade (higher than 60%) and part is shipped and blended in Asia with the high-grade ore from the Northern System. The Midwestern System operates three mining complexes (Itabira, Minas Centrais and Mariana) with the same mine type and mineralization style.

Vale produces iron ore pellets in Brazil and Oman, directly (Fábrica, Vargem Grande and São Luís are fully owned by the company, as well as a 70% stake in Vale Oman Pelletizing Company LLC and majority stakes in Tubarão pelletizing plants) and through joint ventures (Vale holds a 50% stake in Samarco Mineração S.A., the remaining being held by BHP Billiton). Although the company reports a combined pelletizing capacity of 59.3 mtpy (excluding Samarco joint venture), operations in Fábrica (4.5 mtpy pelletizing capacity) have been suspended since February 2019 following new regulations concerning the use of the dams. Operations in the JV of Samarco are resuming with approximately 26% of the productive capacity (7-8 mtpy) after having been halted since the 2015 dam rupture. The current run rate capacity should be revised to fall within the 61.8 - 62.8 mtpy range.

Products and Pricing Mechanism Pursuant the company's portfolio consolidation strategy, the sale of its ferroalloys and manganese mining operations has scaled down the ferrous minerals segment to three sources of revenue, reliant on the steel industry performance: iron ore fines, iron ore pellets and run-of-mine (ROM). Products in the form of fines, pellet and lump are sold both under long-term contracts with customers and on a spot basis through tenders and trading platforms, generally priced based on an impurity discount or premium to the Platts IODEX 62% Fe CFR China index base specification.[1] In August 2018, Fastmarkets MB launched the 62% Fe low-alumina index, which is based on the Brazilian blend fines product (BRBF) launched by Vale in 2015. BRBF is a product with silica content limited to 5% and lower alumina (1.5%) that is produced by blending fines from Carajás ores (Northern System) with Southern and Southeastern ores. In 2019, Vale also launched the GF88 product (obtained by grinding Carajás fines in Chinese ports) with the intention of supplying the growing market of pellet production in China. At the same time, to avoid an oversupply of 65% Fe content fines in the seaborne market, the company introduced the use of Carajás fines as a pellet feed, being able to sustain a premium product sales share above 80%. Therefore, to align the chemistry of the pellet products with that of the feed used by the company, Vale's quarterly-

[1] Iron ore fines with 62% iron, 2.25% alumina, 4% silica and 0.09% phosphorus

negotiated pellet premium has been quoted as a dollar figure above the Fastmarkets MB 65% Fe Fines Index.

Market Overview

- Long-Term Outlook

Chinese Demand Amid Environmental Regulations China has been the main driver of global demand for metal commodities over the last decades and accounted for 74% of demand for iron ore and 64% of Vale's iron ore fines and pellets shipments in 2021. Economic growth in the 2000s [2] has consolidated China as the leading steel producer [3] and exporter,[4] responsible for 52.97% of global output (1032.8 million metric tonnes) and 14.44% of total export volume in 2021 (66.9 million metric tonnes).

China Baowu Group	119,95
Ansteel Group	55,65
Shagang Group	44,23
HBIS Group	41,64
Jianlong Group	36,71
Shougang Group	35,43
Delong Steel Group	28,82
Shandong Steel Group	28,25
Valin Group	26,21
Fangda Steel	19,98
Top 10 Output	436,87
Total Crude Steel Output	1032,8
Top 10 Output (% Total)	42,30%

Figure 5 - Chinese steel industry concentration

As the Chinese economy leaves a rapid growth stage (heavily dependent on investment) towards an innovation-led high-quality development era (driven by consumption), the steel industry is also being reformed, transitioning from the "quantity-phase" to the "quality-phase" of lower output and growing environmental concerns (the sector is responsible for about 8% of global final energy consumption and 7% of energy sector CO_2 emissions). China introduced in 2015 a capacity swap program incentivizing steelmakers to replace old facilities with more efficient ones, attempting to curb steelmaking capacity in environmental sensitive regions. Nonetheless, given the decentralized structure of the industry (Figure 5), some steel mills were able to expand production capacity under the framework of the capacity swap scheme. This event led the Chinese government to release a new draft version of a capacity swap program in December 2020, demanding the capacity swap ratio for environmentally sensitive regions to be raised from 1.25:1 to 1.5:1 whenever the renewed capacity is based on the blast furnace - basic oxygen furnace (BF-BOF) route.[5] Steel mills operating in environmentally sensitive regions and planning to replace existing capacity with electric arc furnaces (EAFs) or hydrogen-based facilities will maintain their current capacity.

While the Chinese steelmaking industry evolves towards environmentally friendly production processes, the characteristics of the required metallic inputs will also reshape the seaborne market dynamics. The BF-BOF route typically requires unprocessed iron ore in a blend of fines and lumps, being the highly concentrated

[2] GDP per capita CAGR of 8.07% from 2000 to 2021 (constant LCU)
[3] Chinese crude steel production increased from 127.2 to 1032.8 million metric tonnes from 2000 to 2021 (CAGR = 10.49%)
[4] Peaked at 112.4 million metric tonnes in 2015, approximately 26.32% of total export volume
[5] As of 2021, 89.4% of Chinese crude steel output was produced in BF-BOF (above the 71.1% global average)

forms of the latter [6] directly used without further processing in steelmaking (typically commanding a premium over fines). Iron ore fines, on their turn, need to be agglomerated, either by producing sinter or pellets. As these processes consume great quantities of coal, coke and natural gas, Chinese governmental authorities have already put sintering operations on halt in the past. Development guidelines for the local steel industry urge producers to meet high-level environmental protection standards while sustaining historical annual crude steel output figures. For reducing particulate and carbon emissions from BOFs while keeping productivity, high-grade products' (65% Fe fines and pellets) lower level of impurities may be favoured to improve sinter quality, thus reducing BOFs' slag volumes and metallurgical coal usage. Accordingly, Vale's Carajás high-grade iron ore fines enjoy a strong long-term demand profile, with Chinese BF-BOF producers avoiding pollution penalties and forced shutdowns potentially widening the spread over lower-grade iron ore fines and pellets' prices.

Secondary Steel Production on the Rise Simultaneously, the goal of Chinese carbon neutrality by 2060 relies on domestic steel industry consolidation. Mergers between steelmakers to form large-scale companies [7] will allow to cut steel production, cap seaborne iron ore prices and further reduce carbon emissions by implementing scrap-based EAFs, which are 1/8 as energy intensive as production from iron ore (using electricity as the main energy input). Scrap can contribute to future crude steel production, negatively impacting demand for iron ore. However, persistent growth in steel demand and the lifetime lag between products coming into use and becoming obsolete (end-of-life scrap) will not allow scrap inputs to fully meet the higher demand requirements of the next decades.

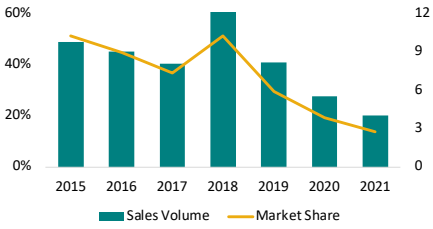


Figure 6 - Southeast Asian steel production and net export position (figures in mmt)

The Emergent Steelmaking Hubs Southeast Asian steel demand growth has been attracting foreign investment projects, mainly supported by Chinese companies. Although additional production has been absorbed by domestic demand (Figure 6), major BF-BOF capacity developments in the Philippines, Malaysia and Myanmar have risen concerns of significant overcapacity in the region. The Southeast Asia Iron and Steel Demand Institute estimates that steelmaking capacity in the ASEAN region could increase to about 151 million metric tonnes (mmt), raising total excess capacity to more than 60 mmt by 2026 with demand taking c.20 years to catch up with this capacity level. With profitability under pressure, local steel manufactures have urged governments to take protectionist measures and curb finished steel imports (which stand at 60% of consumption). Vietnam has levied duties of up to 25% on cold-rolled sheets and coil from China and Indonesia has also imposed duties on several flat

[6] High-grade lumps are typically supplied from Australian mining operations owned by BHP and Rio Tinto
[7] China wants its top five steelmakers to account for 40% of the country's total steel output by 2025

product imports from China, Russia and India. This path towards self-reliance coupling with rising steel demand from infrastructure, automotive and industrial investments is set to expand regional demand for iron ore. Vale's blending operations in the Malaysian Teluk Rubiah Maritime Terminal, one of the 18 Asian ports in which the BRBF premium product is produced, allows the company to pursue an ambitious strategy of supplying the growing regional steelmakers.[8]

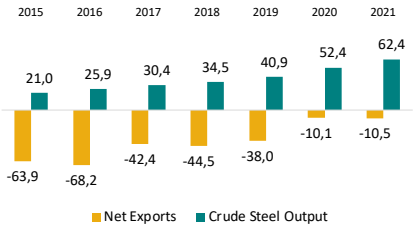


Figure 7 - Vale's sales volume (figures in mmt) and market share in the Middle East

Steelmaking capacity is also increasing in the Middle East due to expansions in Iran. Conditional on all projects currently underway being concluded as scheduled, Iran's crude steelmaking capacity can reach 68.7 mmt by 2023 and become the seventh largest in the world. An idiosyncrasy of the industry in the Middle East is that, given the abundance of natural gas, around 80% of the nominal steel production comes from the gas-based direct reduced iron-electric arc furnace route (DRI-EAF). Unlike other production processes, DRI-EAF has less flexibility to use iron ore with more impurities, typically using high-quality direct reduced iron ore pellets. Vale's Oman pelletizing operations allowed the company to supply the largest DRI-EAF steelmakers in the Middle East, being able to capture higher premiums due to the scarcity of such high-grade DRI pellet products.[9] However, since 2018, Iran's largest steel producer, Mobarakeh Steel Co, and other state-owned companies have expanded pellet production capacity, halting most of their imports. Adding to the US-imposed sanctions that weakened the local currency and made imports more expensive, Vale's regional market share has suffered a major setback (Figure 7) without apparent signs of significant recovery. Only marginal DRI-EAF capacity developments from other Middle Eastern countries can sustain the current market share.

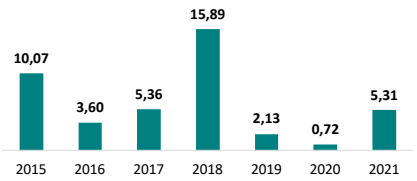


Figure 8 – India's iron ore import volume (figures in mmt)

An Ever-growing Giant Called India Despite being the second largest steel-producing country in the world (118.2 mmt output in 2021), further growth is expected in the long-term [10] to meet the demand from infrastructure development, construction, and automotive industry. Given the extensive use of DRI-EAF and scrap-based EAF in the country, India has become world's largest producer of direct reduced iron while maintaining a modest iron ore net export position. India's minimal iron ore imports (Figure 8), which are set to remain at low levels given recent developments, mostly comprise high-grade fines and lumps to offset the inconsistent quality of domestic products. Last May, the Indian Ministry of Mines imposed a 45% export tax on all grades of iron ore to increase the availability of low-grade ores (58% Fe content and below), mandating as well that 80% of total iron ore produced by a mining leaseholder that is below 58% Fe

[8] In 2021, the terminal unloaded 20.4 million metric tonnes of iron ore and loaded 20.1 million metric tonnes of iron ore
[9] The Oman plant is supplied by iron ore from the Southeastern System and by high-grade iron ore from Carajás (65% Fe content)
[10] The National Steel Policy of 2017 set a target to more than double capacity by 2030

content shall be beneficiated to 62% Fe content and above. These policies will be implemented for an initial period of five years and seek to guarantee there is no shortage of iron ore to meet present domestic demand and the National Steel Policy target of 300 mmt steelmaking capacity by 2030. Despite the promising steelmaking industry prospects, Vale's market development opportunities in the subcontinent are limited amid the expected high-grade domestic feed availability.

- Short-Term Outlook

Global Landscape As higher interest rates in response to inflation raise the chance of recession in some countries, global steel demand is set to increase a modest 0.4% by the end of 2022 up to 1,840.2 mmt.[11] Russia's invasion of Ukraine, notwithstanding the impact on energy prices that drove inflation up, may account for a 13.9 mmt decrease in steel demand that offsets other expected regional developments. Chinese demand is set to stagnate by the end of 2022 at 972 mmt, with the country's debt-strapped real estate sector dip in H1 2022 (down 4.2% *vis-à-vis* H1 2021) unlikely to be reverted until 2023. Furthermore, China's zero-COVID policy has also impacted the recovery of domestic consumption and manufacturing logistics, a key driver of steel demand. Historically, government subsidies and other forms of state intervention have created market distortions, the most impactful being a persistent oversupply of steel that worsened in 2021, amid the substantially lower demand caused by the delta variant resurgence-related economic crisis.[12] The substantial inventory build-up coupled with weak consumer and manufacturer confidence have cut global steel production by 5.5% in H1 2022 *vis-à-vis* H1 2021. Only India challenges the trend with an 8.8% increase *vis-à-vis* H1 2021.

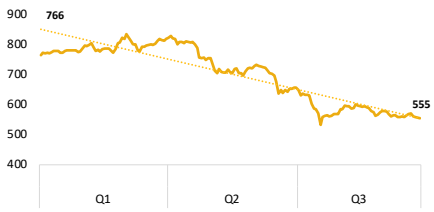


Figure 9 - China Rebar 16-25 mm HBR400 Shanghai market price Q1-Q3 2022 (figures in $USD/tonne)

Chinese Response Amid Stimuli Package Though being the second highest percentual decline among the top ten steel producing economies,[13] Chinese steel mills had production cuts circa 37 mmt in the first half of 2022. Declining reinforced steel bar (Rebar) and hot rolled coil (HCR) steel prices (Figure 9 and Figure 10, respectively) have been pressuring steelmakers, who decided to idle capacity in May as weak rebar margins progressed towards negative territory in mid-June (hitting negative $40.57/mmt in the beginning of July).[14] European sanctions on Russian coal, however, may marginally improve Chinese BOFs' margins entering 2023. As Russia becomes increasingly dependent on exports of coking and thermal coal to China, a paramount strategic partner, local buyers have become able to import cargoes at a deep discount, with an all-time high

[11] World Steel Association Short Range Outlook, April 2022
[12] 116.2 mmt gap, the highest since 2015
[13] Iran's crude steel production declined by 10.8% in H1 2022 when comparing with H1 2021
[14] Source: S&P Global Analysis

Figure 10 - China Hot Rolled Coil 5.5 mm Steel SS400 Shanghai market price Q1-Q3 2022 (figures in $USD/tonne)

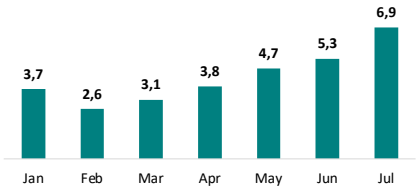


Figure 11 - China's thermal and coking coal imports from Russia Jan-Jul 2022 (figures in mmt)

Figure 12 - Seaborne 65% pellet premium Qingdao index (figures in $USD/tonne)

import in July (Figure 11) at $144/ton on a free on board (FOB) basis [15] (roughly 20.79% below the H1 2022 average market price).[16] Coupling with the unofficial import ban on Australian thermal and coking coal, the share of imports from Russia has increased since the conflict started and is expected to continue in Q1 2023. At the same time, Chinese authorities announced stimuli to boost the country's infrastructure construction and manufacturing, offsetting headwinds to steel demand from the property sector. Most of the fiscal support is expected to be employed in less steel-intensive projects, such as power generation, water conservation and tech-related infrastructure. Steel intensive sectors receive less focus, with investments in highways and railways down by 0.2% and 4.4% on the year.[17] These measures seem to be aimed at preventing further downturn rather than propelling economic growth heading in 2023.

The Russian-Ukrainian Conflict is shaping the European market. Following the EU-imposed restrictions on iron and steel-related imports from Russia, Ukraine became the largest supplier of iron ore concentrates and pellets to the EU in March, accounting for 30% of European needs. Metinvest [18] announced that it would stop operating several mining and processing centers due to the supply chain disruptions caused by the war, with exports from Ukraine falling by 23% in June. Rising iron ore prices and steelmakers' margins pressured by the high energy prices and poor downstream steel demand led some European steel mills to start talks with Vale to accommodate the supply shortage from Eastern Europe. Two-month voyage times from Brazil to Europe, instead of the typical 8 to 14 days from Ukraine though may hinder that possibility.

Other Regional Developments DRI pellets demand from plants located in oil and gas exporting regions, such as the Middle East and North Africa, should be strong in the short-run, as steel production is bounded to regional markets sustained by the escalating oil and gas prices. Solid sales figures in Southeast Asia have also been referred by the company in the Q2 2022 Earnings Call.

Premium Dynamics Despite more favorable steel demand prospects for 2023, with the World Steel Association forecasting a 2.2% global increase in steel demand (reaching 1,881.4 mmt), the short-lived Chinese fiscal stimuli will shape the seaborne iron ore market going from Q4 2022 to Q1 2023. After a 70.82% dip in July, 75% Tangshan BOFs' capacity utilization in September prompts steel production amid possible sintering restrictions throughout the winter months. Carbon emission targets and depressed steelmaking margins will favor direct-charge solutions in Q1 2023 (i.e., lumps and blast-furnace grade pellets).

[15] Source: Bloomberg
[16] Average FOB prices of Newcastle (Australia) and Qinhuangdao (China) thermal coal with 5,500 kcal/kg and 6,000 kcal/kg net calorific value
[17] Source: S&P Global Analysis
[18] International steel and mining group holding most of Ukrainian iron ore reserves

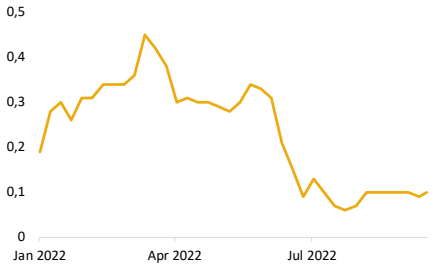


Figure 13 - Seaborne 62.5% lump premium Qingdao index (figures in $USD/tonne)

Nevertheless, suppressed high-grade pellets and lumps' premiums during H1 2022 (Figure 12 and Figure 13, respectively) should persist. Steelmakers must prioritize cost-effective alternatives, seeking products with more impurities (i.e., higher silica and alumina contents) and lower grades while attempting to recover margins. Consequently, Vale's spot sales of medium-to-high silica fines from the Southeastern and Southern Systems have a strong profile over the short-run in detriment of the low-impurity BRBF and high-grade IOCJ products, whose supply has already been limited by the H1 2022 constraints in the Northern System. The company should then privilege its current *value over volume* strategy and place mainstream products at fixed prices with their preferred customers, being able to negotiate at higher premiums than those offered in the seaborne market.[19]

Forecasts

- Revenue Forecasts

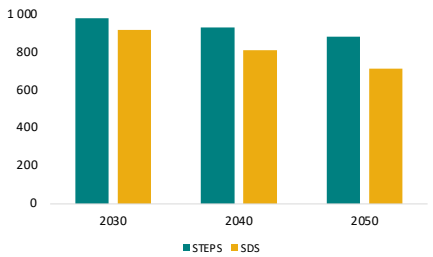


Figure 14 - China nominal crude steel output by scenario (figures in mmt)

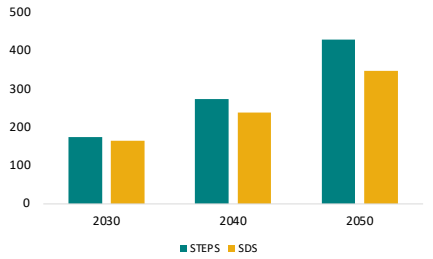


Figure 15 - India nominal crude steel output by scenario (figures in mmt)

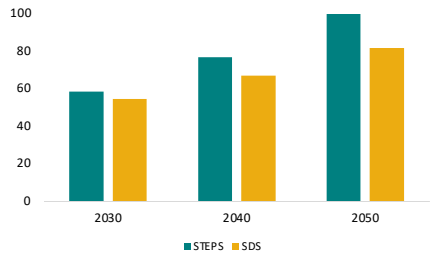


Figure 16 - Middle East nominal crude steel output by scenario (figures in mmt)

Steel Production Scenarios To model global iron ore demand, two pathways for the steel industry, provided by the International Energy Agency (IEA),[20] have been used: the Stated Policies Scenario (STEPS) and the Sustainable Development Scenario (SDS). The STEPS outlines a conservative benchmark for the future, in which governments may not reach all decarbonization and energy-related goals expected to impact the global steel industry. It considers Nationally Determined Contributions under the Paris Agreement and the "Fit for 55" package of measures announced by the European Commission in July 2021.[21] The SDS is based on a surge in clean energy policies and investment that lead to all current net zero pledges being fully achieved.[22]

Under the STEPS, and assuming that global consumption equals production over the long-term, steel production grows from 1,950 mmt in 2021 to 2,535 mmt in 2050 at a CAGR of approximately 1.1%. In the SDS, material efficiency policies ensure that global production equals 2,053 mmt by 2050 (19% reduction *vis-à-vis* the STEPS, increasing at a CAGR of 0.4%). Following the structural changes in the Chinese economy currently being implemented, in both scenarios China's steel production is set to fall (at a CAGR of -1.66% and -1.79%, respectively) and account for 35% of global production by 2050 (nominal crude steel output of 887 mmt and 719 mmt, respectively). India's output will ramp up and compensate the Chinese decline, representing 17% of global crude steel output by 2050 in both scenarios (nominal output of 431 mmt and 349 mmt in the STEPS and the SDS, respectively). Other economies in which production changes may be less

[19] $30/ton higher pellet premiums were negotiated in Q3
[20] *Iron and Steel Technology Roadmap. Towards more sustainable steelmaking (2020)*. International Energy Agency. Paris, France
[21] Provides the foundations for the EU to reach a 55% reduction in emissions by 2030 compared with 1990 levels
[22] Advanced economies reach net zero emissions by 2050, China in 2060 and all other countries by 2070 at least

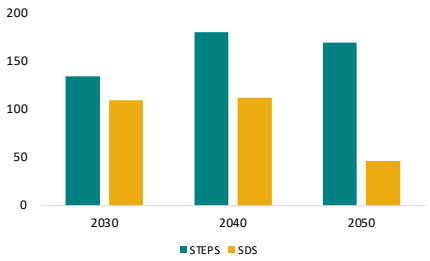
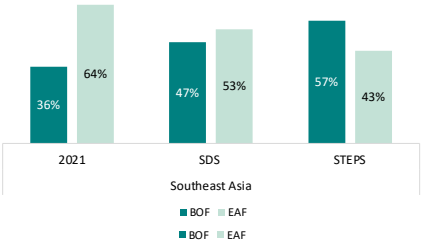


Figure 17 - Southeast Asia nominal crude steel output by scenario (figures in mmt)



penetration rates in 2050 by scenario

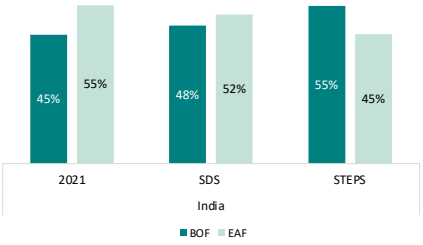


Figure 19 - India BOF and EAF penetration rates in 2050 by scenario

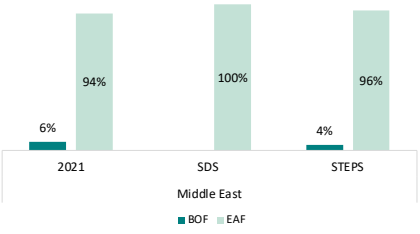


Figure 20 - Middle East BOF and EAF

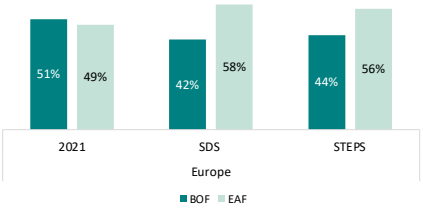


Figure 21 - Southeast Asia BOF and EAF penetration rates in 2050 by scenario

influential in terms of global output will still be regionally significant. The Middle East is expected to account for 4% of global steel production by 2050 in both scenarios, more than doubling its current output in the STEPS (101 mmt). Emerging economies in Latin America, Africa and Southeast Asia, which accounted for 6.6% of global steel production in 2021, will represent a small percentage of global production by 2050 but output will increase between 2 and 4 times in the STEPS. Advanced economies are not expected to make large additions of steelmaking capacity, with Japan, South Korea and the USA maintaining a relatively constant steel output in both scenarios. Europe's output, however, increases up to 266 mmt in the STEPS and 216 mmt in the SDS.

Changing Production Routes Scrap-based EAF and DRI-EAF steel production will dominate by 2050 in the SDS, accounting for 53% of nominal crude steel output. In the STEPS, the increase in production levels relative to steel scrap availability allows BF-BOF to dominate, accounting for 57% of global steel output. Besides scrap inputs, age and size of existing steel mills, local regulatory agendas and energy resources will influence the adoption of the scrap-based EAF route across the world. China, with just a 10.6% share of secondary steel production in 2021, is set to progress to 45% in the STEPS and 47% in the SDS. The transition will be enabled by a large amount of end-of-use steel scrap becoming available very quickly, given the substantial build-up of in-use steel stocks during China's boom period. Given that recent regulation favors the adoption of EAFs to replace older BOFs, a large share of the Chinese installed capacity is in the middle of the typical 25-year investment cycle, meaning the country will be able to experience the rapid transition to secondary steelmaking as the natural phase-out of existing primary production facilities is aligned with increasing scrap availability. India, contrarily to China, is expected to have a strong output growth trajectory in any scenario. Limited availability of scrap inputs relative to overall production levels will coincide with primary steelmaking capacity additions, resulting in lower-than-current shares of secondary steel production by 2050 (45% in the STEPS and 52% in the SDS). The growing hubs of the Middle East, Latin America, Africa, and Southeast Asia will also add substantial amounts of primary steelmaking capacity until 2050. Regions with access to low-cost renewable electricity, such as Africa, will tend to favor the hydrogen-based DRI-EAF route over the long-run, whereas the Middle East and Latin America, regions with low-cost natural gas, will invest in the gas-based DRI-EAF route. In Europe, the predicted constant scrap availability throughout this horizon will limit the replacement of older blast furnaces with scrap-based EAFs.

Metallic Inputs Steelmaking has two main metallic inputs: iron ore and recycled steel scrap. These are consumed in different proportions given the chosen

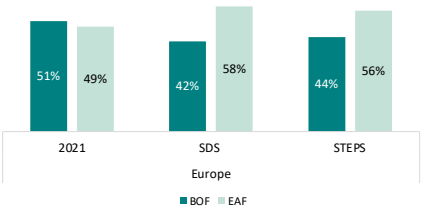


Figure 22 - Europe BOF and EAF penetration rates in 2050 by scenario

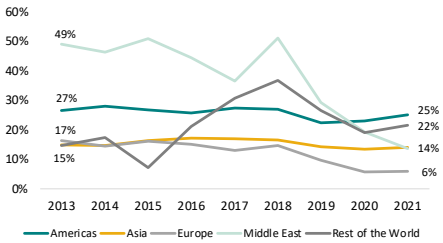


Figure 23 - Vale's market share evolution by region

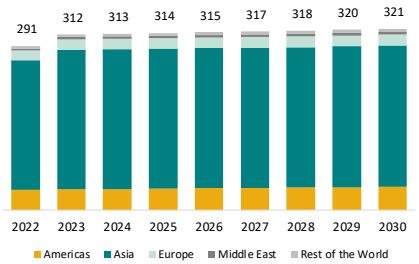


Figure 24 - Attainable demand under the STEPS (figures in mmt)

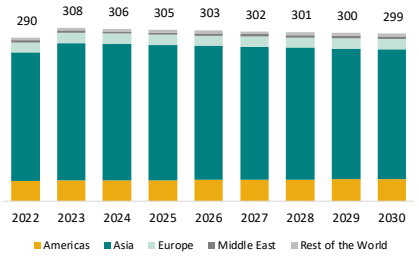


Figure 25 - Attainable demand under the SDS (figures in mmt)

production technology. On average, the EAF route uses 710 kg of recycled steel and 586 kg of iron ore to produce 1,000 kg of crude steel. To obtain the same quantity, the BF-BOF route requires 1,370 kg of iron ore.[23] The increasing adoption of the EAF route implies that iron ore will account for a lower share of metallic inputs' consumption in both scenarios -70.5% in the STEPS and 67.5% in the SDS by 2050.[24] Following the BF-BOF capacity additions discussed, the total amount of iron ore inputs is projected to increase at a CAGR of 0.39% in the STEPS, from an estimated 2,230 mmt iron ore consumption in 2021 to 2,496 mmt by 2050. In the SDS material efficiency and amplified secondary steelmaking implementation ensure that total iron ore inputs consumed decrease at a CAGR of -0.52%, to 1,919 mmt in 2050. The results were obtained assuming that scrap-based EAF adoption is capped by an annual 1,400 mmt and 1,160 mmt steel scrap inventory in the STEPS and SDS, respectively. In neither scenario the pace of secondary steelmaking implementation is affected by this restriction, as annual steel scrap consumption tops at 1,045 mmt and 923 mmt, respectively.

Market Share To complete the top-down approach to the attainable demand in each region, Vale's historical sales and regional iron ore consumption estimates were used to compute the company's market share by region from 2013 to 2021 (Figure 23). The company sustained its market share in the Asian market (averaging 15.5%) and this is expected to continue. Despite higher freight costs compared to Australian producers, Vale secured valuable sales relationships based on a consistent supply of a specific mix of iron ore and pellets at competitive prices, supported by the distribution centres in Malaysia and Oman, and long-term agreements with 19 ports in China that serve as distribution centres. Historical market positioning in the Americas (average market share of 25.9%) is also sustainable. Given the competitive nature of the Brazilian iron ore market,[25] with many small producers and vertically integrated steelmaking companies conducting iron ore mining operations,[26] Vale is likely to have achieved its maximum attainable market share in the region. North America's high adoption of secondary steelmaking (c.69% of total crude steel production in 2021) also hinders growth opportunities. In Europe the market share has been declining since 2018, stabilizing at 6% with the outbreak of the COVID-19 pandemic. The 5.1% sales decline in H1 2022 compared to the homologous period is in line with the 6.2% decrease in crude steel production, suggesting that Vale's market share may bottom at 6% in the next years. In Middle East the most

[23] World Steel Association calculation (2018)
[24] Down from 79.5% as of 2021
[25] By far the most relevant iron ore producer in Latin America: 28.47 mmt of primary iron ore production, followed by Mexico with 8.41 mmt
[26] Arcelor-Mittal and Gerdau S.A, for instance, run both steelmaking and iron ore mining operations in Brazil

recent market share (14%) is the best guidance amid increasing domestic DRI pellet supply.

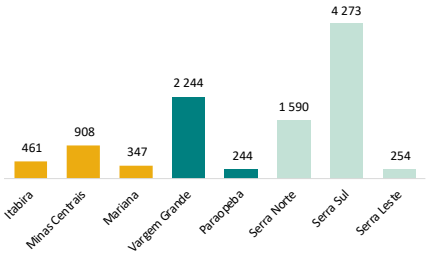


Figure 26 – Marketable iron ore reserves by mining complex (figures in mmt)

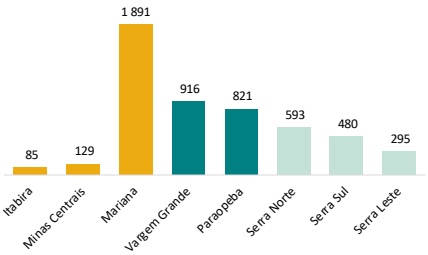


Figure 27 - Marketable (measured) iron ore resources by mining complex (figures in mmt)

Mineral Assets The top-down approach described above, together with the rationale explained in the *Market Overview*, portrait two prospective iron ore demand scenarios for the company (Figure 24 and Figure 25). Existing mineral assets' management under these possible paths, however, is the determinant driving sales volume and the segment's valuation. As of the FY2021, Vale reported [27] iron ore mineral reserves amounting to 12,495.4 mmt,[28] averaging 56.6% Fe content, of which 3,858.9 mmt were proven reserves and 8,636.5 were probable reserves. Although the mining industry only reports 2P reserves (proven and probable) according to SEC guidelines, this may be conservative for valuation purposes. Therefore, 3P reserves (proven, probable and possible) should be used. Despite not reporting possible reserves, Vale conducts mining operations under Brazilian and Canadian jurisdictions, where it is mandatory to report and make a clear distinction between measured (6,871.6 mmt), indicated (7,574.6 mmt) and inferred (8,243.3 mmt) mineral resources. As measured resources have reasonable prospects of eventual economic extraction, they may become a reserve at a future date whenever economic constraints may be fulfilled.[29] For valuation purposes, the average recovery rate per mine [30] was applied to the corresponding 2P reserves and measured resources, reaching a total marketable iron ore tonnage of 15,532.1 mmt. It is then assumed that each mine's measured resources are extracted in their entirety until the corresponding exhaustion date at a fixed yearly rate. From 2020 to 2021, reported mineral reserves decreased by 1,948.8 mmt, though only 459 mmt are justified by the incorporation of new geological information and depletion. The remaining reduction concerns the Mariana complex, where technical and strategic revision of a long-term project to process low grade ores led the company to reclassify a large portion of its mineral reserves as measured mineral resources (Figure 27). Nonetheless, the referred amount is incorporated in the segment's valuation.

Production Capacity Each mine's production capacity was determined based on expected exhaustion dates and expansion projects currently underway. The Capanema Project (Mariana mining complex), with the start-up expected for H2 2023, will bring a net capacity addition of 14 mtpy, ramping total figures up to

[27] For the first time in accordance with the SEC-implemented S-K 1300 regulation
[28] Including moisture and dry iron content
[29] The extraction of mineral resources occurs over a longer period of time compared to the extraction of reserves, and, therefore, conditions allowing the economic extraction of mineral resources may only apply in the future.
[30] According to the company, the reported recovery ranges correspond to the overall metal recovered to point of first material sale. It is then assumed that beneficiation yields are already taken into account (i.e., high-grade iron ore mines from the Northern System have a 100% average recovery rate given that no beneficiation process is required)

c.394 mtpy in 2024.[31] Upon completion of Serra Sul 120 project (Northern System) Vale will surpass the 400 mtpy run-rate capacity goal over the medium term. This consists of increasing the S11D mine capacity by 20 mtpy to a total 120 mtpy. Thus, expected production capacity by 2025 is 414 mtpy.

Sales volume and size of inventory tend to move in opposite directions during times of growth and recession. However, mining companies are unable to navigate the business cycle, failing to adjust production volume in response to changes in demand. Lower capacity utilization during downturns exposes the company to operating inefficiencies, such as higher unit production costs, since a large portion of its cost structure is fixed in the short-term due to the capital intensity of mining operations. Consequently, increasing capacity in Serra Sul is modelled as a buffer, producing to meet sales volume requirements and to build-up inventories according to a long-term averaging holding period trend.[32] Operating efficiency is then ensured for different iron ore demand scenarios.

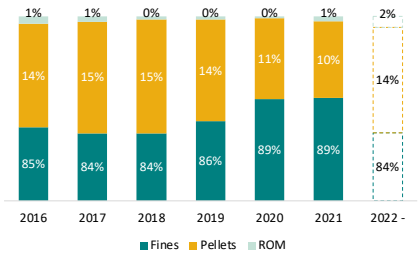


Figure 28 - Historical and forecasted product mix

Product Mix Iron ore revenues are forecasted for 3 different sources: fines, pellets and ROM. The product mix is obtained using historical averages: 84%, 14% and 2%, respectively (Figure 28).[33] Without knowledge of possible changes in steel producers' preferences, the historical average sales mix is the best approach as it accounts for the cyclical marginal changes in the demand for direct feed charges over the business cycle.[34]

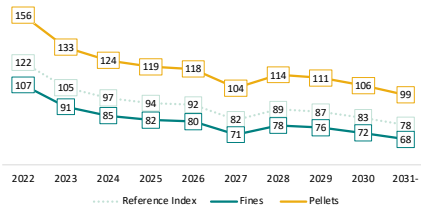


Figure 29 - Fines and pellets' pricing relative to the benchmark index (figures in $USD/ton)

Prices Iron ore fines and pellets' prices are estimated according to historical price realization relative to the 62% Fe CFR China Index forecasts. On average, Vale attained 87.1% of the reference price in its fines sales. As pellets allow steel producers to bypass the sintering stage, those are sold at a premium relative to the same reference index, having averaged a 40.4% premium.[35] Using historical averages is the best approach to estimate each product's discount/premium, as it accounts for the cyclical preference for direct feed inputs over fines and *vice-versa*. The 62% Fe CFR China benchmark forecasts used for valuation purposes (Figure 29) reflect the market consensus that prices should consistently trend downwards, in line with the growing replacement of Chinese BF-BOF capacity and higher iron ore output. Growth is expected to average 2.8% between 2022 and 2026, raising annual production by 367 mmt in 2026, representing more than India, Russia and South Africa's combined output in 2022.[36] Long-term forecast for the 62% Fe CFR China Index is $78/ton, with Vale pricing iron ore fines and pellets at c.$68/ton and c.$99/ton, respectively.

[31] Already accounting for possible delays and the initial production ramp-up
[32] Average holding period of 50 days (days of COGS)
[33] Historical average concerns the period between 2013 and 2019
[34] As already discussed in the *Short-Term Outlook*
[35] Historical averages concern the period between 2013 and 2019
[36] Source: Fitch Solutions

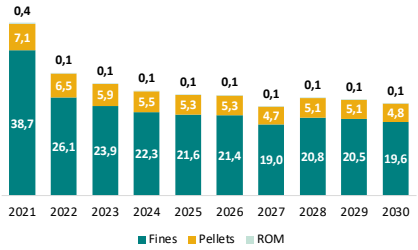


Figure 30 - Ferrous minerals revenues by product in the STEPS (figures in $USD billion)

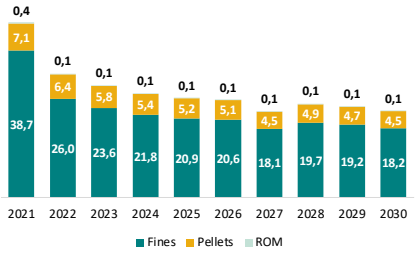


Figure 31 - Ferrous minerals revenues by product in the SDS (figures in $USD billion)

Revenues Revenue forecasts strictly concern the company's sales of its own mineral assets, excluding sales of iron ore fines and pellets obtained from third-party purchases. In the STEPS, revenues are expected to plummet 29.5% *yoy*,[37] from $46.3B in FY2021 to $32.6B in FY2022, with the negative trend still impacting FY2023 sales figures that are forecasted at $29.9B (Figure 30). Both lower realized prices and a negative volume effect driven by lower Chinese steel production justify the results, with fines' sales volume decreasing 12.0% *yoy*, from 276 mmt in FY2021 to 245 mmt in FY2022. Pellets' sales volume is expected to increase by 28.1%, from 32 mmt in FY2021 to 41 mmt in FY2022. Vale's marketable mineral assets will only allow the company to sustain its regional market shares until 2040 in the STEPS and 2042 in the SDS. By then, Vale will have exhausted mineral reserves in the mining complex of Serra Norte under the STEPS,[38] and the mineral reserves of Serra Norte, Itabira and Paraopeba under the SDS.[39] Between FY2022 and FY2027, the segment's revenues are set to decline at a $CAGR_{22\text{-}27}$ of -6.2% in the STEPS and at a $CAGR_{22\text{-}27}$ of -7.0% in the SDS. Under the STEPS, the expected 0.8% annual sales volume growth will not offset the *yoy* realized price decrease. From 2027 until 2040, under the STEPS, the company won't benefit from marginal sales volume increase, with revenues decreasing at the $CAGR_{27\text{-}40}$ of -1.3%. Under the SDS as well, revenues decrease at a $CAGR_{27\text{-}42}$ of -0.6% until 2042. From 2040 and 2042 onwards, under the STEPS and the SDS, respectively, successive mining projects' exhaustions will translate into revenue decreases. Marketable mineral assets by 2089 [40] only ensure $3.340B revenues, decreasing at a $CAGR_{40\text{-}89}$ of -3.9% and a $CAGR_{42\text{-}89}$ of -4.0% in the STEPS and the SDS, respectively.

▪ Operating Expenses

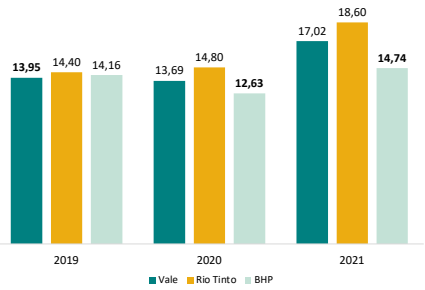


Figure 32 - C1 cash costs among competitors (figures in $USD)

Iron Ore Fines C1 Cash Costs are the standard metric used in mining to represent the unitary cash cost of extracting and processing a company's metal product until it may be delivered to customers.[41] Among the cost drivers, the average ore grade is the most impactful over the long-run. Wet processing is generally used to beneficiate low-grade ores, using water in various stages to remove impurities. Being reliant on dam raisings and a more capital-intensive process by the use of filtration systems to remove ultrathin ore waste mixed in water, dry processing is more cost-effective and a competitive advantage for companies in regions where iron content is high. The blending strategy behind

[37] Year-over-year
[38] 130.5 mtpy output loss
[39] Cumulative 183.5 mtpy output loss
[40] Latest exhaustion date
[41] Net of by-product revenues, as defined by the World Gold Council

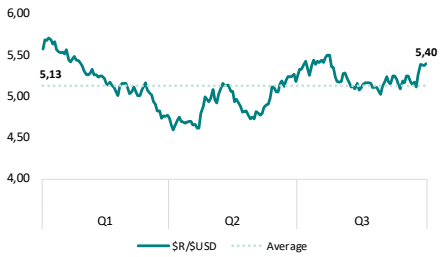


Figure 33 - BRL/USD exchange rate (Q1-Q3 2022)

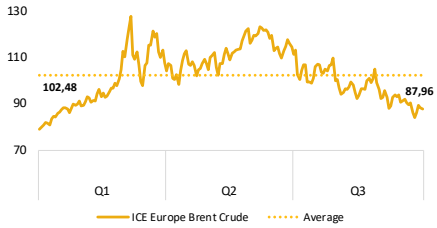


Figure 34 - ICE Europe Brent Crude Energy Future price history (Q1-Q3 2022, figures in USD)

Figure 35 - C1 cash costs forecast for 2022 (figures in $USD)

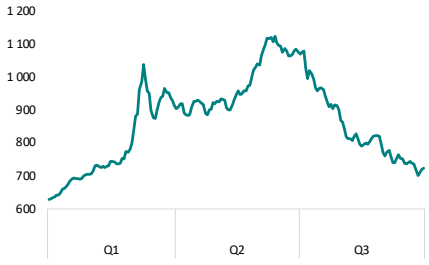


Figure 36 - Price of very low sulfur fuel oil (VLSFO) worldwide in 2022 (figures in $USD)

the BRBF product, mixing low-grade ores from the Southern and Southeastern system with higher-grade ores from the Northern System, allows greater use of dry processing. The continuous promotion of the product allowed the company to reach a 70% share of dry processing production in 2021 compared to 40% in 2014. This will increase to 85% with the completion of capacity increase in Serra Sul and the Capanema project start-up. By adopting more efficient beneficiation methods, Vale's goal of delivering $14 to $15/ton C1 cash costs is attainable over the medium to long-term. However, for conservative reasons, we incorporate C1 cash costs falling in the higher-end of that range from 2023 onwards.[42]

In the short-run, rising fuel prices [43] and appreciation of the Brazilian real [44] were responsible for the immediate $2.2/ton C1 cash cost increase in Q1 2022, that persisted in Q2 2022 given the carryover effect of selling inventories produced at higher costs in the first quarter. Lower production in Q1 2022 (4.1 mmt lower that in Q1 2021) due to halts caused by heavy rains increased pressures. Vale hasn't revised its end-of-year C1 cash cost guidance ($18.5 to $19/ton), based on an exchange rate of R$5/USD (Figure 33) and an average $100/barrel Brent price (Figure 34). Recession fears and expected U.S. Dollar appreciation after interest rate hikes may curb crude oil prices in the last quarter, but markets' focus shifting from recession concerns to tightening oil supply may end up with C1 cash costs falling in the higher-end of the predicted range at $19/ton (Figure 35).

Freight Costs are a key component of total cost, affecting the competitiveness relatively to players more conveniently located.[45] Increases in bunker oil prices during H1 2022 (Figure 36) justified the inflationary pressure on unitary freight costs, which topped at $21.3/ton in Q2 2022. The impact was softened by 70% to 80% of the company's vessel needs being tied to long-term agreements. Given the cyclical nature of the costs, the figure used for valuation purposes is a normalization of pre-pandemic unitary freight costs, averaging $17.9/ton. Following the pandemic, the failures and delays in supply chain led some clients to pass the risk in physical performance of sales contracts to sellers, resulting in an increase in the proportion of sales conducted on a cost and freight (CFR) basis.[46] The pre-pandemic mix of CFR/FOB sales should thus be considered over the forecasting period (76.5% of sales on a CFR basis).

Royalties Vale is required to pay a royalty known as CFEM [47] on revenues from the sale of extracted iron ore. Although the Brazilian National Mining Agency

[42] $15/ton over the entire forecast period
[43] As most of the company costs are denominated in Brazilian reais
[44] Costs of fuel oil, gas and electricity represented 7.6% of total cost of goods sold in 2021
[45] Australian operations conducted by Rio Tinto and BHP
[46] As opposed to those conducted on a FOB basis, in which the buyer has the responsibility to procure the right vessel at the right time, it is the seller that must place the goods on board the vessel
[47] *Compensação Financeira pela Exploração de Recursos Minerais*