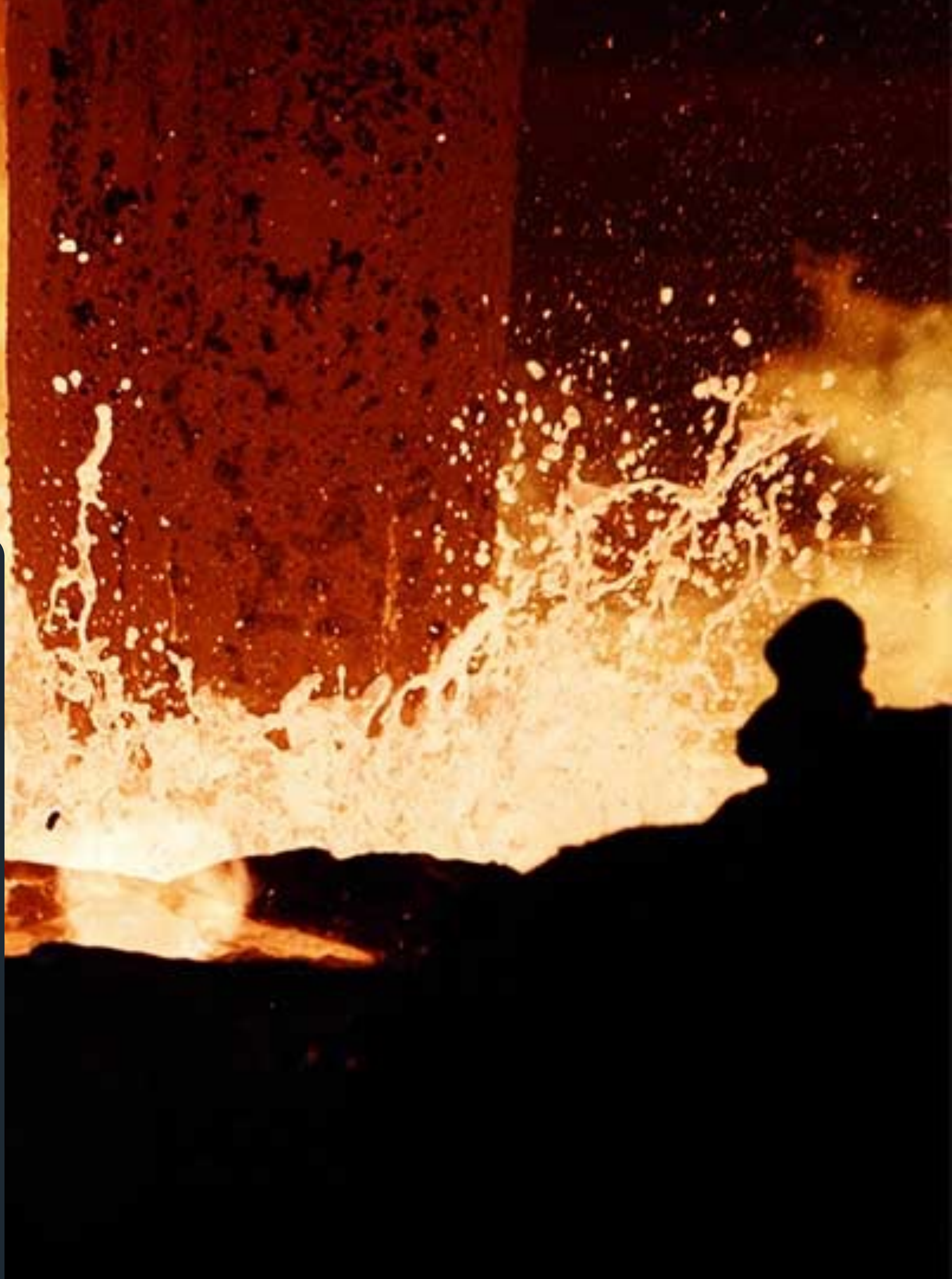

Institute for Energy Economics and Financial Analysis

Iron Ore Quality a Potential Headwind to Green Steelmaking

Technology and Mining Options Are Available to Hit Net-Zero Steel Targets

Simon Nicholas & Soroush Basirat

Steel-Making Technology and Carbon Emissions

Sources	Technology Route	Direct CO_2(t) / crude steel (t)	Direct and Indirect CO_2(t) / crude steel (t)	Energy Consumption (GJ/t)		Share of global steel production (%) 2020
				IEA	Worldsteel	
Secondary	Scrap-Electric Arc Furnace (EAF)	0.04	0.3	2.1	5.2	21.5
Primary	Blast Furnace – Basic Oxygen Furnace (BF-BOF)	1.2	2.2	21.4	22.7	73.2
	Direct Reduced Iron-Electric Arc Furnace (DRI-EAF)	1.0	1.4	17.1	21.8	4.8

Source: IEA, World Steel Association, IEEFA calculation

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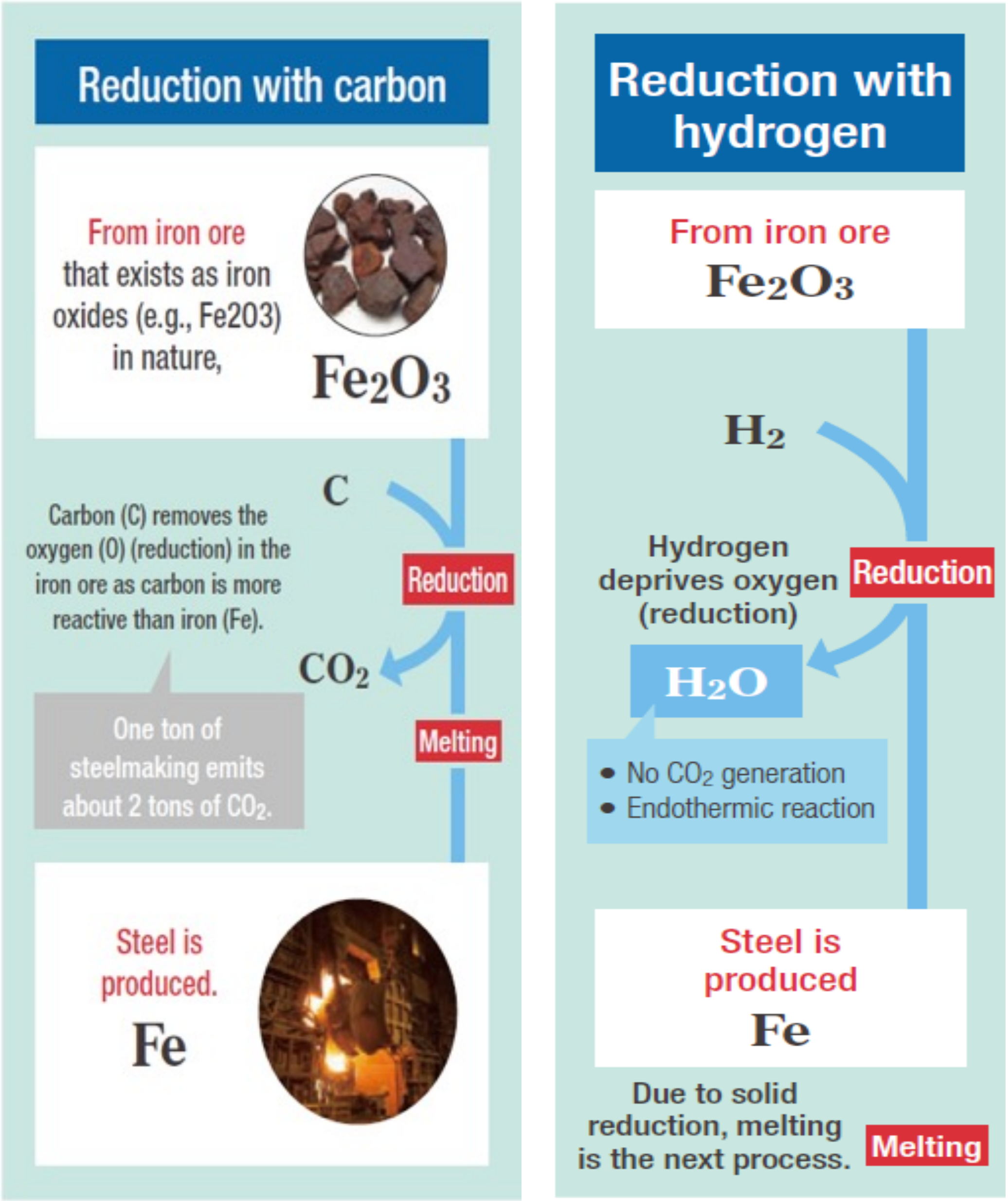
An increasing number of steel companies are seeking to develop technology that uses 100% hydrogen in the DRI-EAF process – potentially zero-carbon green hydrogen produced via renewable energy-powered electrolysis – once this technology becomes cost competitive.



Source: Nippon Steel

Direct Reduced Iron Processes

In the DRI process, iron oxide is reduced via carbon monoxide (CO) and hydrogen (H2) produced from the reforming of natural gas in the shaft furnace route, or via gasified coal in the rotary kiln route.

One of the most promising routes for decarbonisation of the steel industry is to replace these fossil fuel-based gases with green hydrogen produced via the electrolysis of water powered by renewable energy.

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The DRI-EAF route has the potential to be zero emissions if green hydrogen is used and the EAF is powered by renewable energy.

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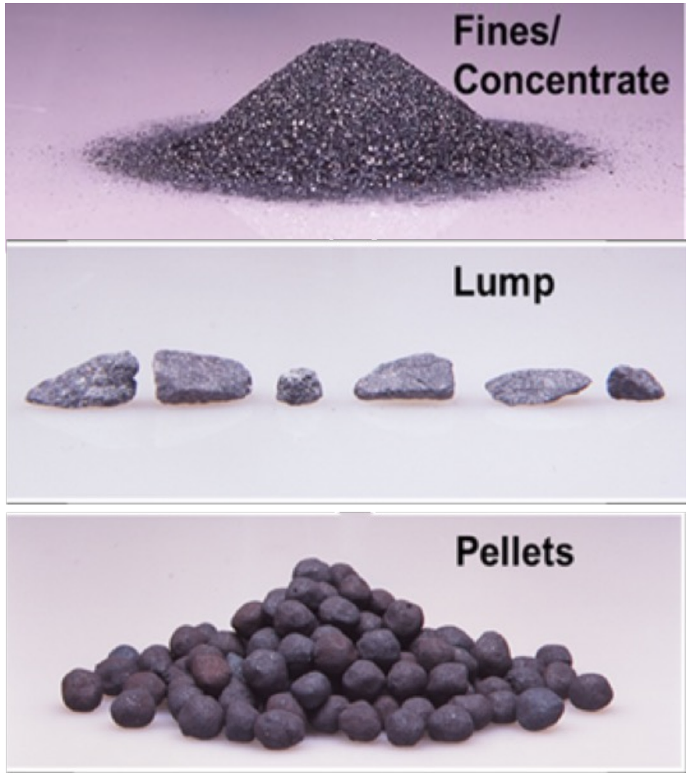
DRI steelmaking requires a higher grade of iron ore than blast furnaces, the dominant global technology. DR-grade iron ore ideally has an iron (Fe) content of 67% or more and such deposits are scarce -- only a small percentage of global seaborne iron ore comes close to DR-grade.

Iron Ore Grades

Description	Size (mm)	Preparation Process	Global Export share
Lump Ore	>6.3	Direct charge in blast furnace	17%
Sinter Fines	<6.3	Agglomeration (Sintering)	70%
Pellet (BF Grade) 65%	9-16	Direct charge in blast furnace following beneficiation and agglomeration (pelletising)	5%
Pellet Feed concentrate	More than 80% is <0.15	Agglomeration (pelletising)	6%
Pellet (DR Grade) 67%	9-16	Direct charge in DR shaft following beneficiation and agglomeration (pelletising)	4%

Source: Fastmarkets, IEEFA



Iron Ore Grades

The majority of iron ore is produced in the form of fines. These cannot be charged directly into a blast furnace or DR shaft but have to be agglomerated into sinter or pellets first.

High-grade (high iron content) pellets form a much smaller part of the market with most pellets used as a higher-grade blast furnace feed and a smaller supply for existing DRI plants.

The Fe content of pellets used in blast furnaces is lower than the DR-grade pellets.

In global iron ore trading, 62% Fe fines is a benchmark for pricing. Premiums or discounts apply to ore with higher or lower Fe content.

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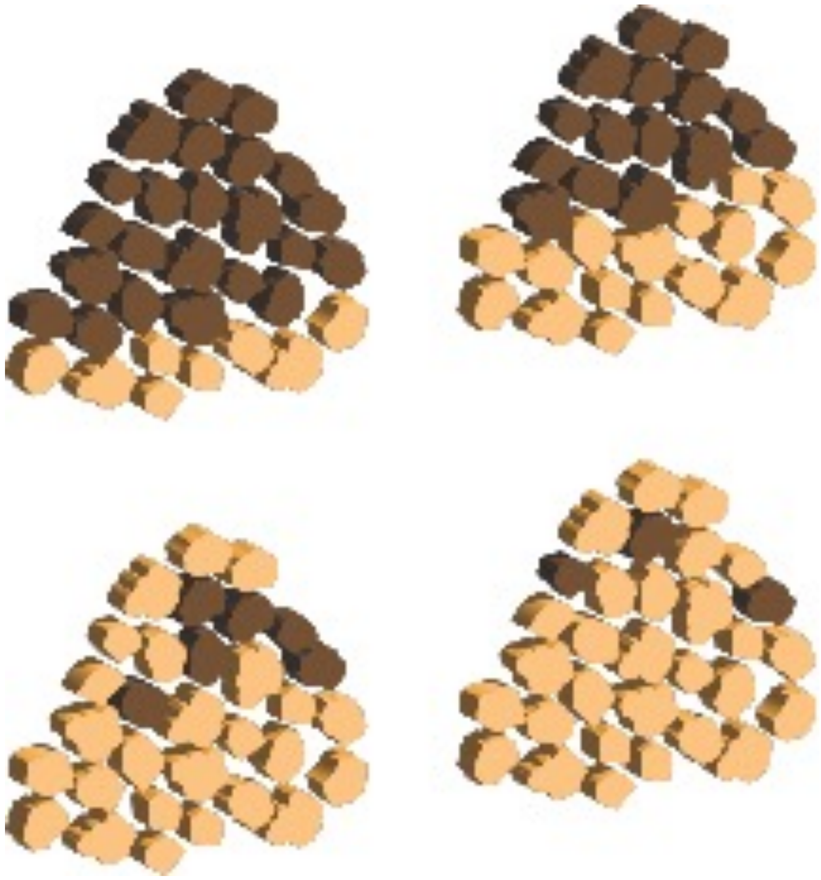
The iron ore market is a mixture of various types of iron ores and products categorized based on physical characteristics and chemistry.

Iron Ore Quality

The average quality of iron ore has been in decline for years.

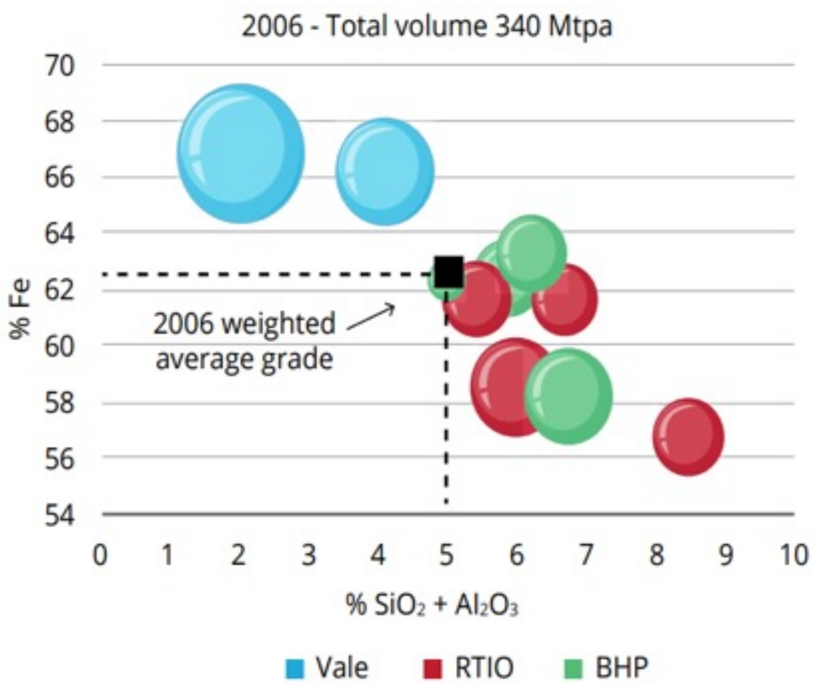
Formerly, the average Fe% was above 62% with 5% impurities (gangue) but by 2016 the respective figures were 61% and 6.5% for the big four mining companies.

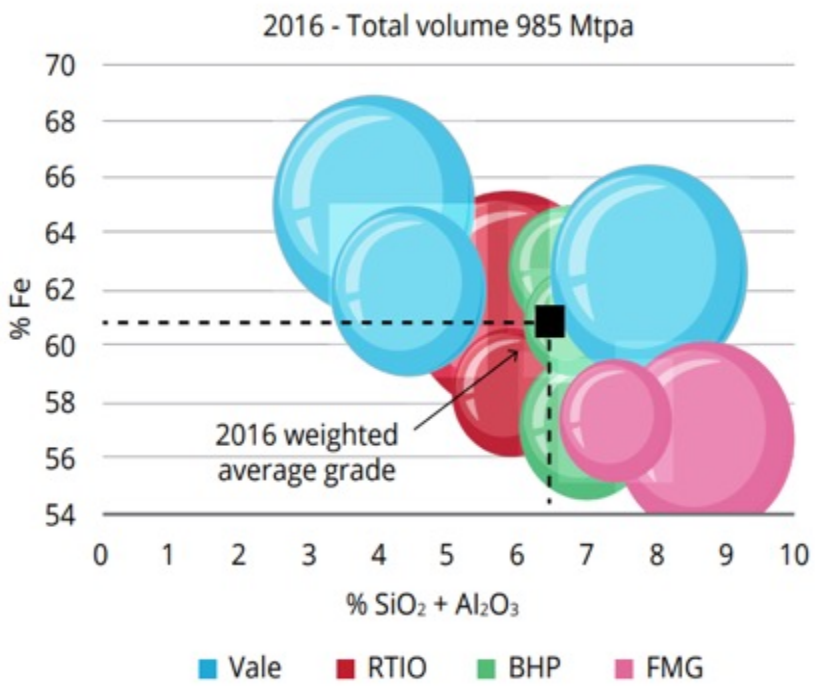
Excessive gangue not only needs more electric power in the EAF but lowers the melting yield, increasing the cost of the liquid steel significantly.



Iron Ore Quality

Big Four Iron Ore Miners Fe% and Acidic Gangue 2006 and 2016





Source: Minerals Council of Australia

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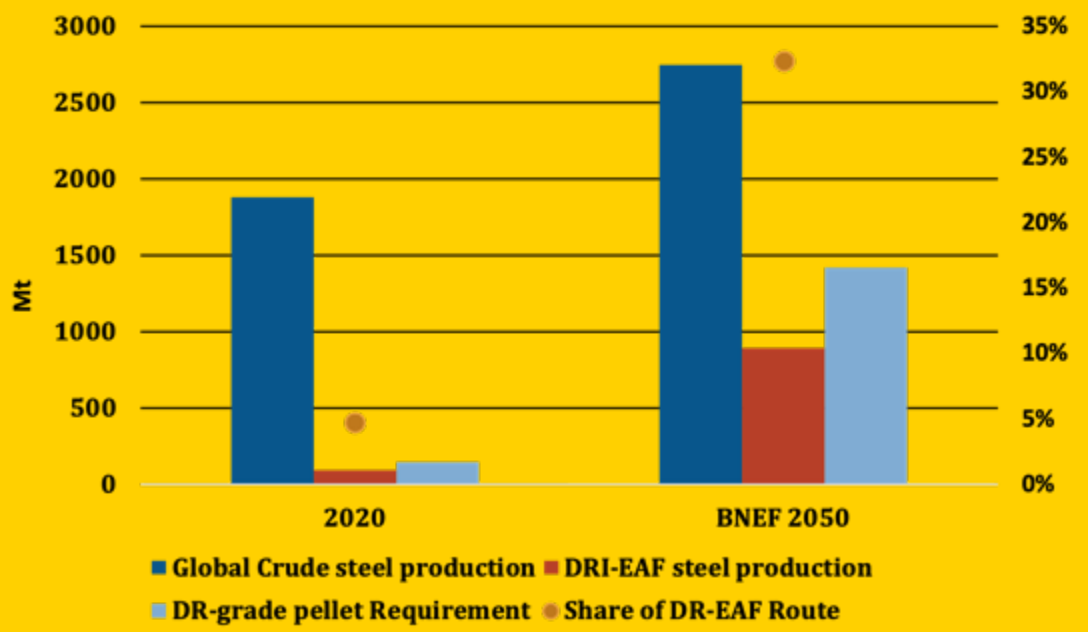
As the DRI process reduces the iron oxide to iron without melting or refining, the impurities remain and could be detrimental to the steelmaking process in EAFs.

DR Grade Demand Set to Increase Significantly in Net Zero Scenarios

DR-Grade Pellet Demand Under BNEF Net Zero Emissions 2050 Scenario (NZE 2050)



Source: BloombergNEF, Worldsteel, Midrex, IEEFA calculations.

Outlook of Major Iron Ore Producers

The big four iron ore producers – Rio Tinto, BHP, Fortescue Metals Group (FMG) and Vale remain largely focused on producing blast furnace-grade ore.

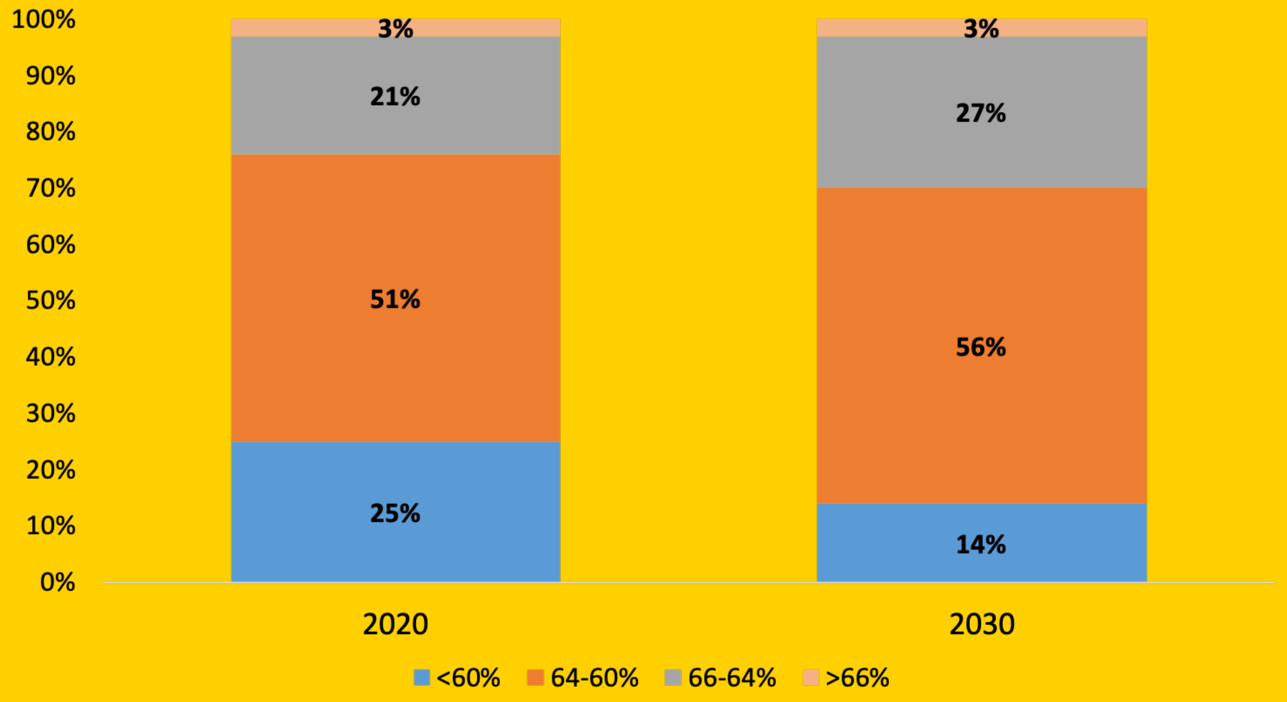
Neither BHP or Rio Tinto have a measurable target to reduce total Scope 3 carbon emissions that occur when its customers use its iron ore and metallurgical coal in steelmaking processes.

Rio is committed to its Simandou project in Guinea. Although this will produce high-grade iron ore, it seems likely that the great majority of output will be blast furnace-grade.

Vale forecasts that, although there will be a shift towards higher quality iron ore over the rest of this decade, there will be no change in the proportion of seaborne iron ore supply over 66% Fe by 2030, remaining at just 3% of the total as it was in 2020.

FMG is committed to developing its magnetite ore reserves at its Iron Bridge project. The project will produce 22MT per annum of high-grade, 67% Fe magnetite concentrate, with the first output scheduled for December 2022. However, FMG has suggested this may be blended with lower-grade ores to produce an improved blast furnace-grade product.

Seaborne Iron Ore Supply by Fe Content (%)



Source: Vale

Main ore bodies available face depletion and beneficiation challenges, thus making it difficult to increase supply of high-grade ores.

Vale

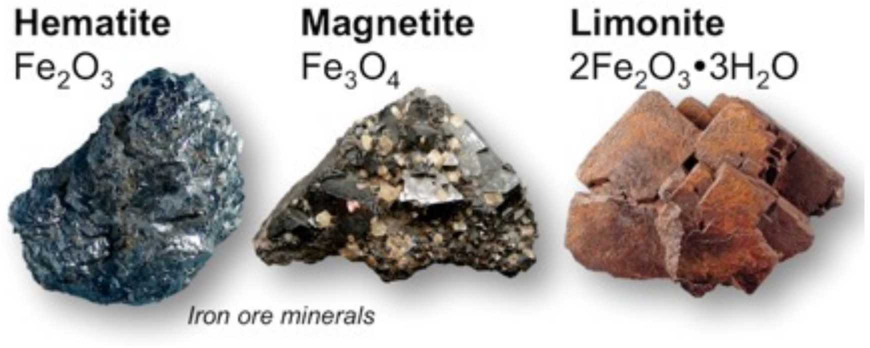
Hydrogen-based steelmaking may still be 20 to 30 years away, in contrast to many more positive views on the rate of steel technology transition, and that steel sector decarbonisation must remain focused on lower emissions from blast furnaces.

Mark Henry BHP CEO

Enabling Global DRI Expansion

Mining Options

- Magnetite iron ores can often be beneficiated to DR-grade and may provide part of the answer to increasing DR-grade iron ore supply going forward. Magnetite ores tend to have a much lower Fe content but are often suitable for significant beneficiation, in part because magnetite is magnetic, which can make separation easier.
- The quality of hematite iron ores could potentially be increased through beneficiation. There extent to which existing Pilbara iron ore could be improved to DR-grade is questionable however.
- Additional pelletising capacity would be required to make increased DR-grade pellet supply ready for DRI operations.

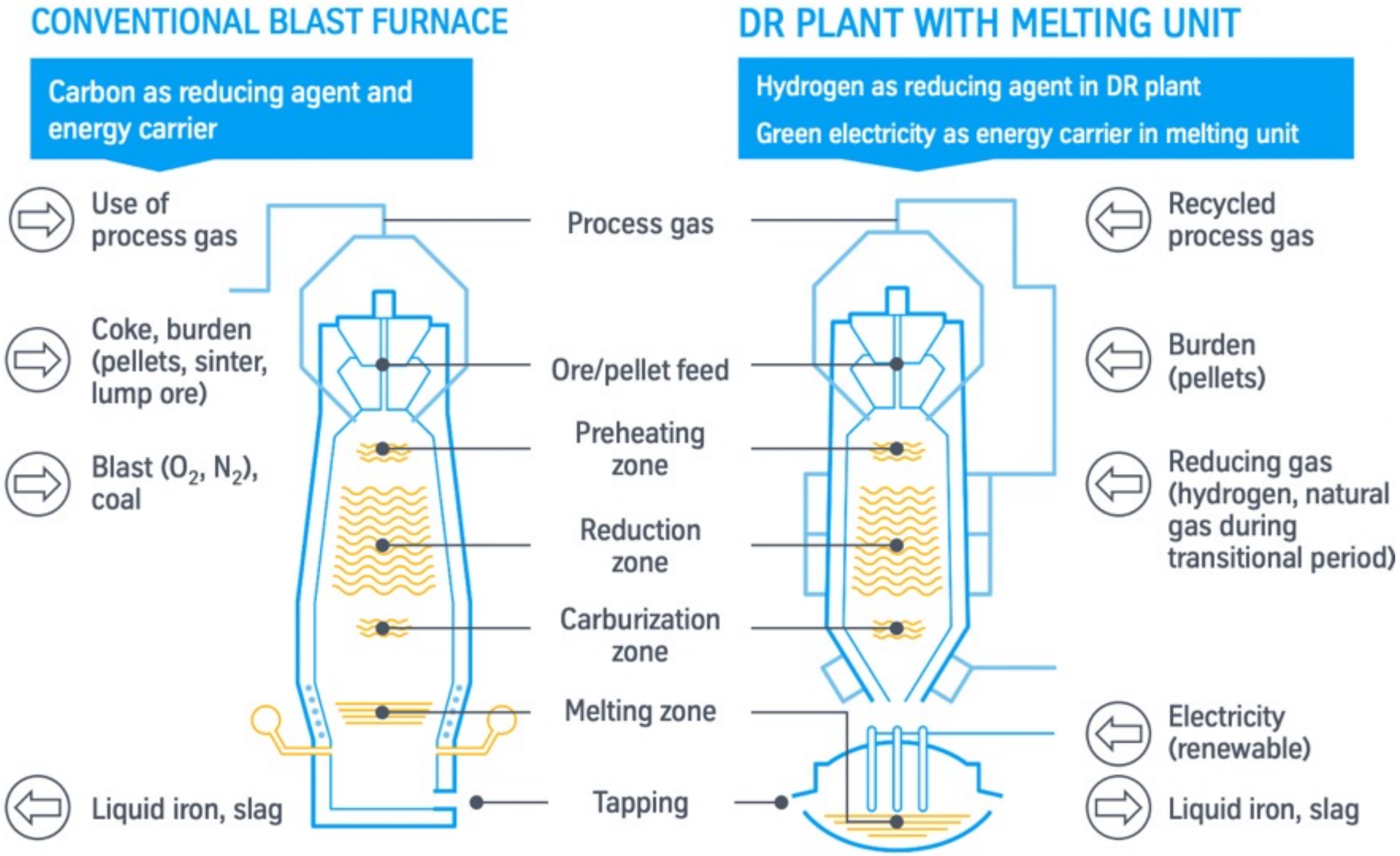


Enabling Global DRI Expansion

Iron and Steel Technology Options

More DRI may need to be made using lower-grade iron ore which will necessitate melting the reduced iron before being charged into a basic oxygen furnace.

- ThyssenKrupp is planning to begin replacing blast furnaces with DRI plants that will combine an integrated melting unit (submerged arc furnace) powered by renewable electricity starting in 2025.
- The liquid iron will then be processed in ThyssenKrupp's existing steelworks.
- This technology combination will enable the company to use blast furnace-grade iron ore in its DRI processes.

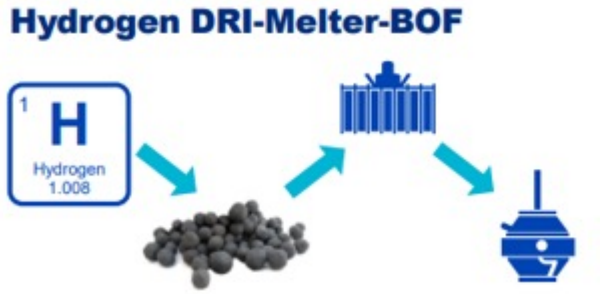


Source: ThyssenKrupp

Enabling Global DRI Expansion

Iron and Steel Technology Options

- ArcelorMittal is also investigating the integration of DRI with a submerged arc furnace melting step which would allow the use of lower grade iron ore.
- BlueScope is working with Rio Tinto on investigating the use of Rio's lower-grade Pilbara iron ore in DRI-based steelmaking. A key area of investigation will be to melt DRI produced from Pilbara iron ore in an electric furnace powered by renewable energy before charging the melted iron into an existing BOF to convert it into steel.
- The melting of the reduced iron allows the removal of the higher quantities of impurities resulting from the use of lower-grade iron ore as a slag.



Source: BlueScope

Read the full report at IEEFA.org

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