



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 <sub>2</sub> (t) / crude steel (t)	Direct and Indirect CO <sub>2</sub> (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
	Blast Furnace – Basic Oxygen Furnace (BF-BOF)	1.2	2.2	21.4	22.7	73.2
Primary	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



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.

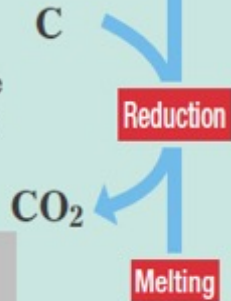


## Reduction with carbon

From iron ore that exists as iron oxides (e.g.,  $\text{Fe}_2\text{O}_3$ ) in nature,



Carbon (C) removes the oxygen (O) (reduction) in the iron ore as carbon is more reactive than iron (Fe).



One ton of steelmaking emits about 2 tons of  $\text{CO}_2$ .

Steel is produced.  
 $\text{Fe}$



## Reduction with hydrogen

From iron ore  
 $\text{Fe}_2\text{O}_3$



Hydrogen deprives oxygen (reduction)



- No  $\text{CO}_2$  generation
- Endothermic reaction

Steel is produced  
 $\text{Fe}$

Due to solid reduction, melting is the next process.

# Direct Reduced Iron Processes

In the DRI process, iron oxide is reduced via carbon monoxide (CO) and hydrogen ( $\text{H}_2$ ) 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.

Source: Nippon Steel



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

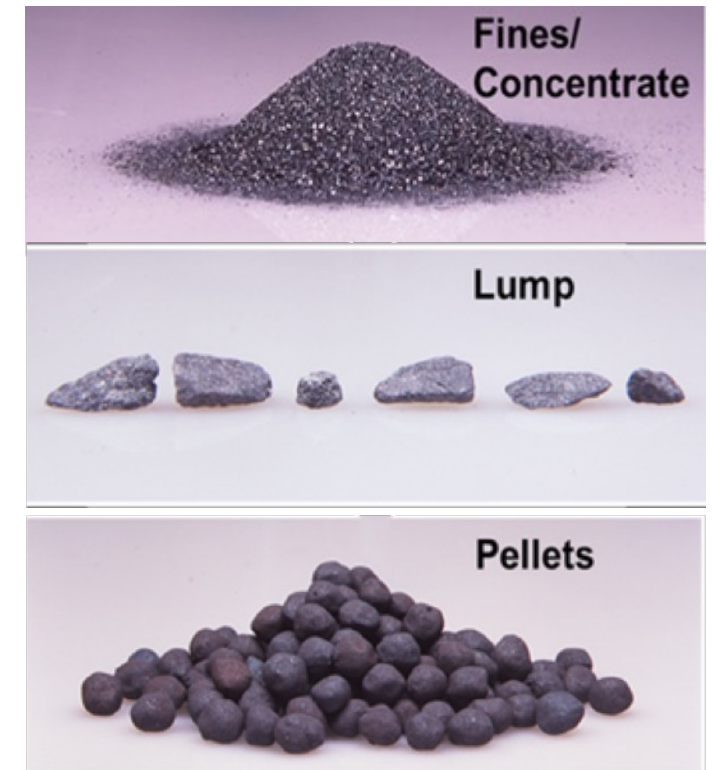


DRI steelmaking requires a higher grade of iron ore than blast furnaces, the dominant global technology. **DR-grade iron ore** ideally has an **iron (Fe) content of 67%** or more and such deposits are scarce -- only a small percentage of global seaborne iron ore comes close to DR-grade.

# 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

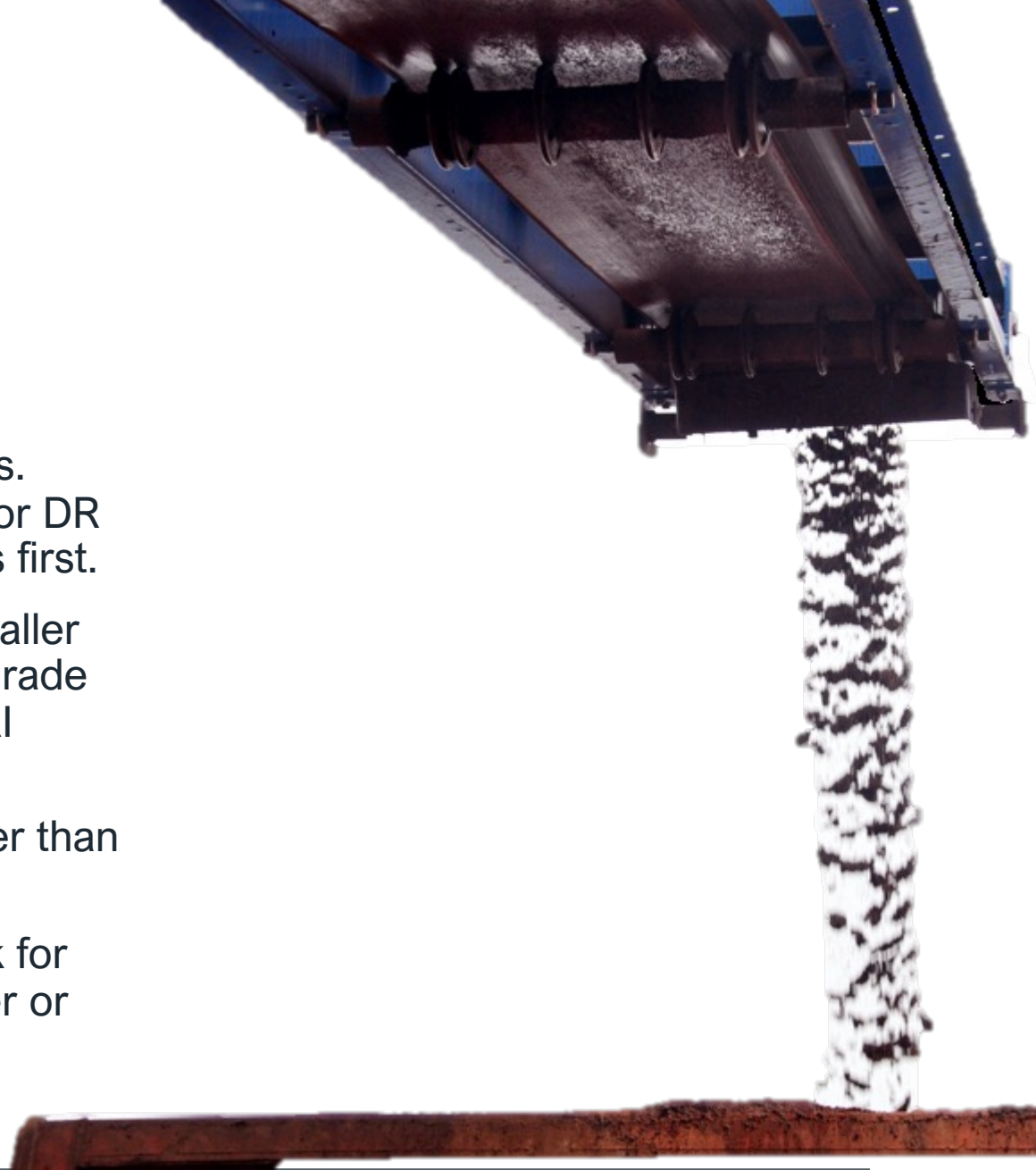
---

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.







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



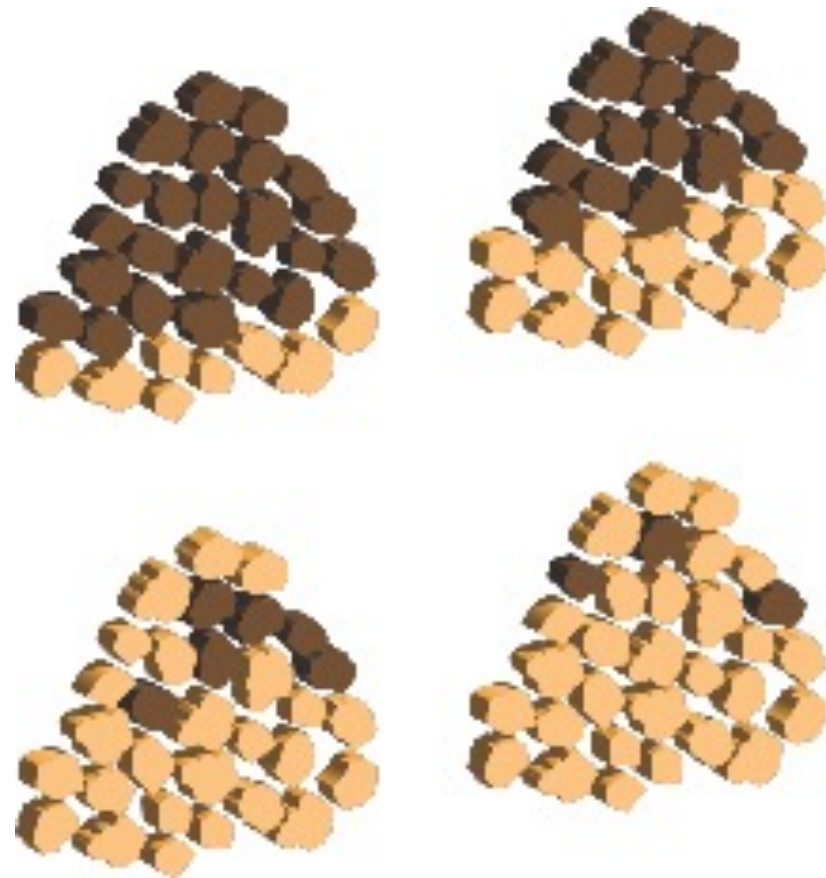
# Iron Ore Quality

---

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

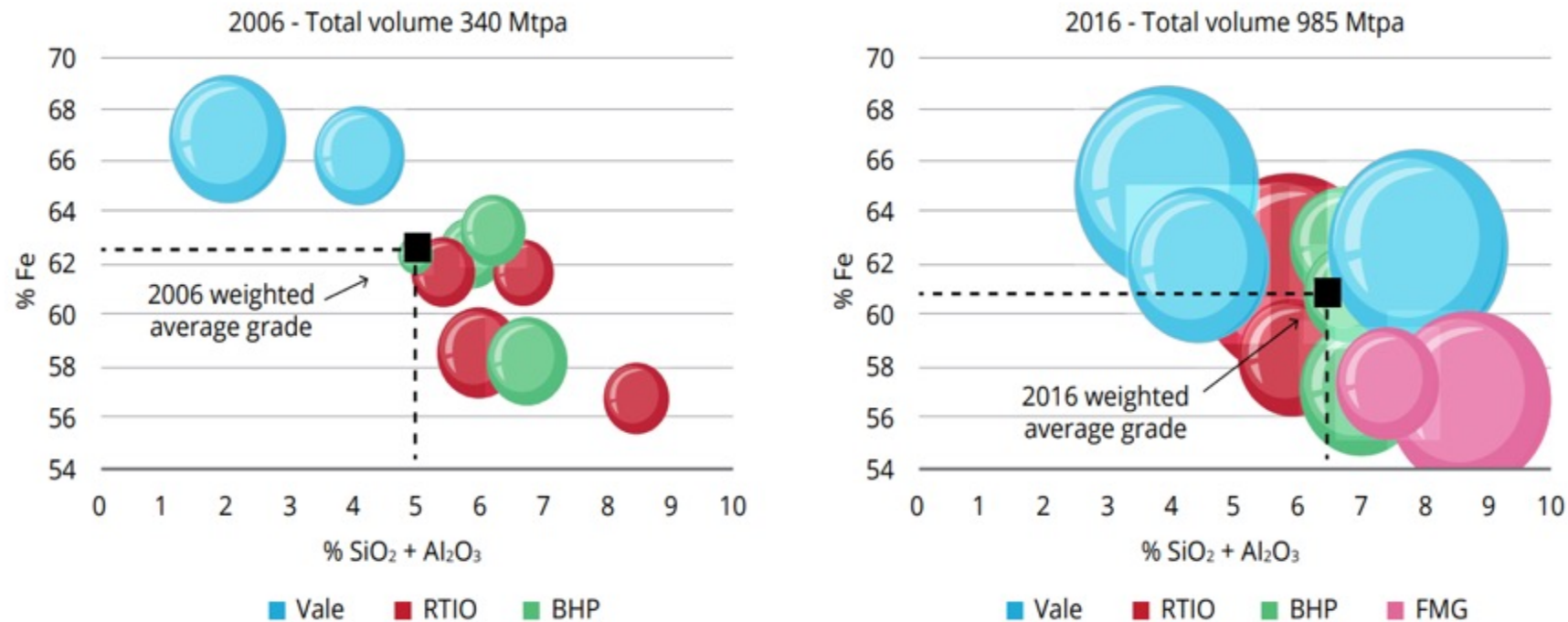
Formerly, the average Fe% was above 62% with 5% impurities (gangue) but by 2016 the respective figures were 61% and 6.5% for the big four mining companies.

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



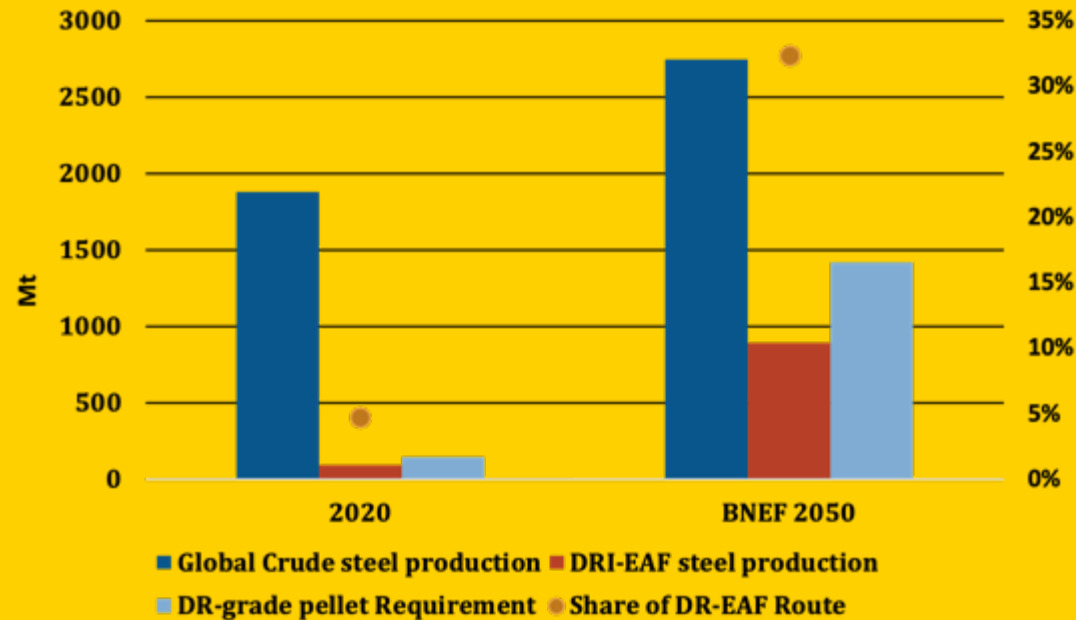


As the DRI process reduces the iron oxide to iron without melting or refining, the **impurities remain** and could be detrimental to the steelmaking process in EAFs.



# 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.

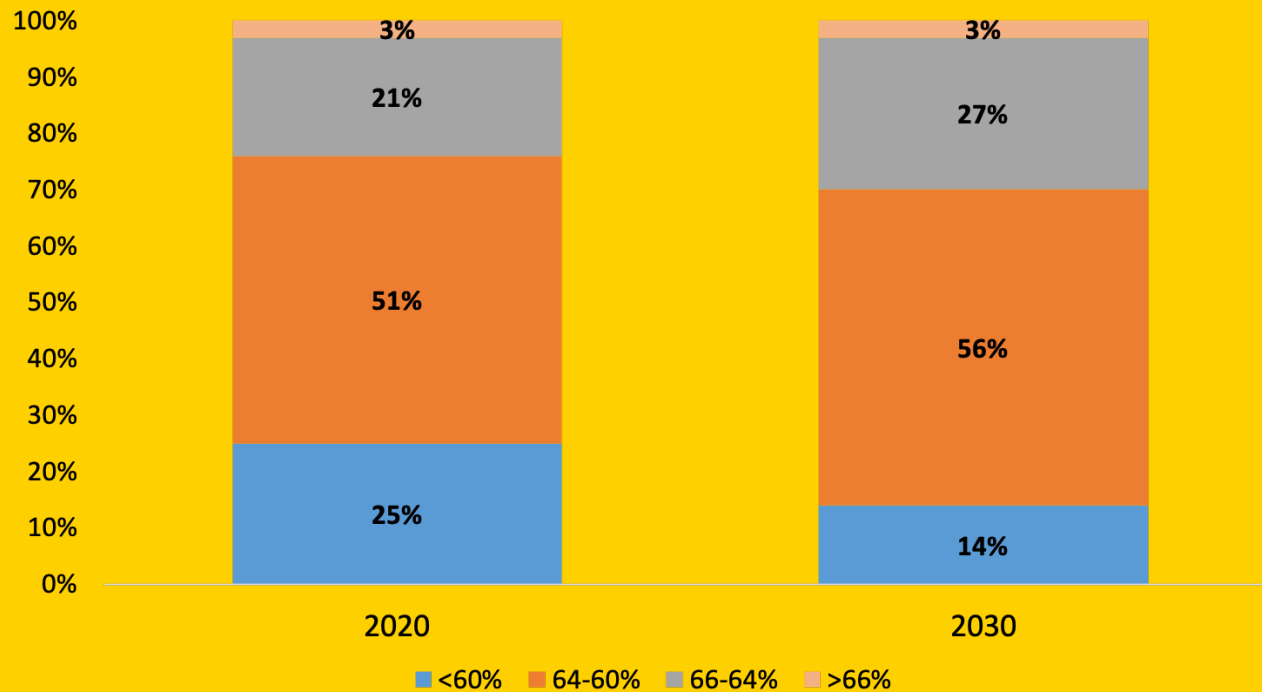
Neither BHP or Rio Tinto have a measurable target to reduce total Scope 3 carbon emissions that occur when its customers use its iron ore and metallurgical coal in steelmaking processes.

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. The 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

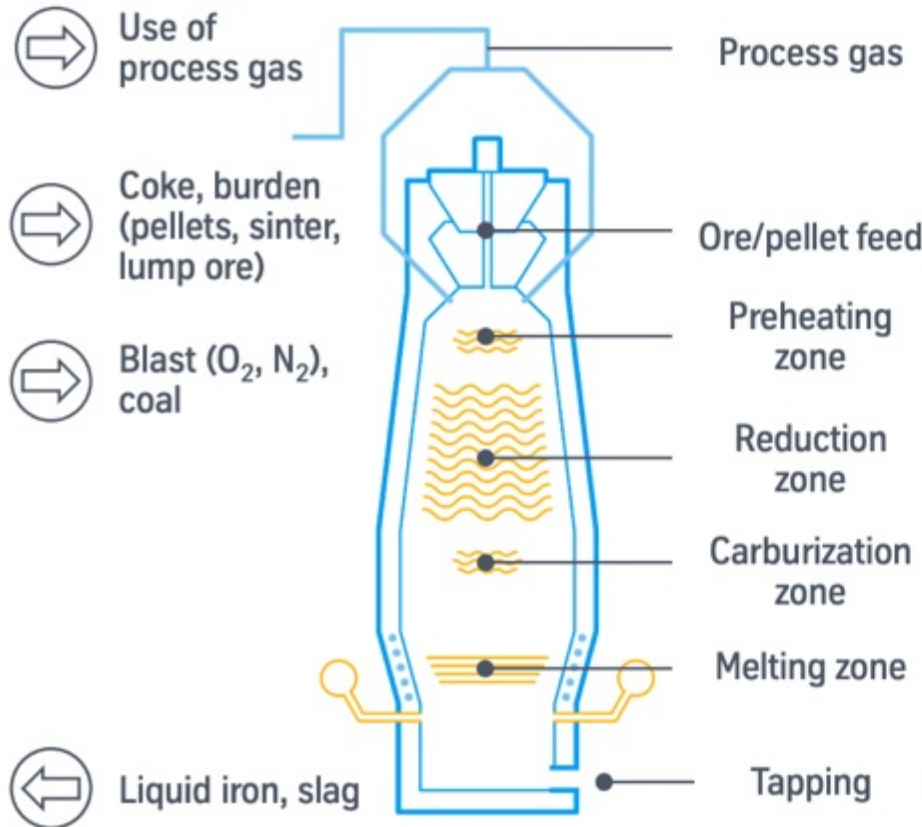
More DRI may need to be made using lower-grade iron ore which will necessitate melting the reduced iron before being charged into a basic oxygen furnace.

- 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.



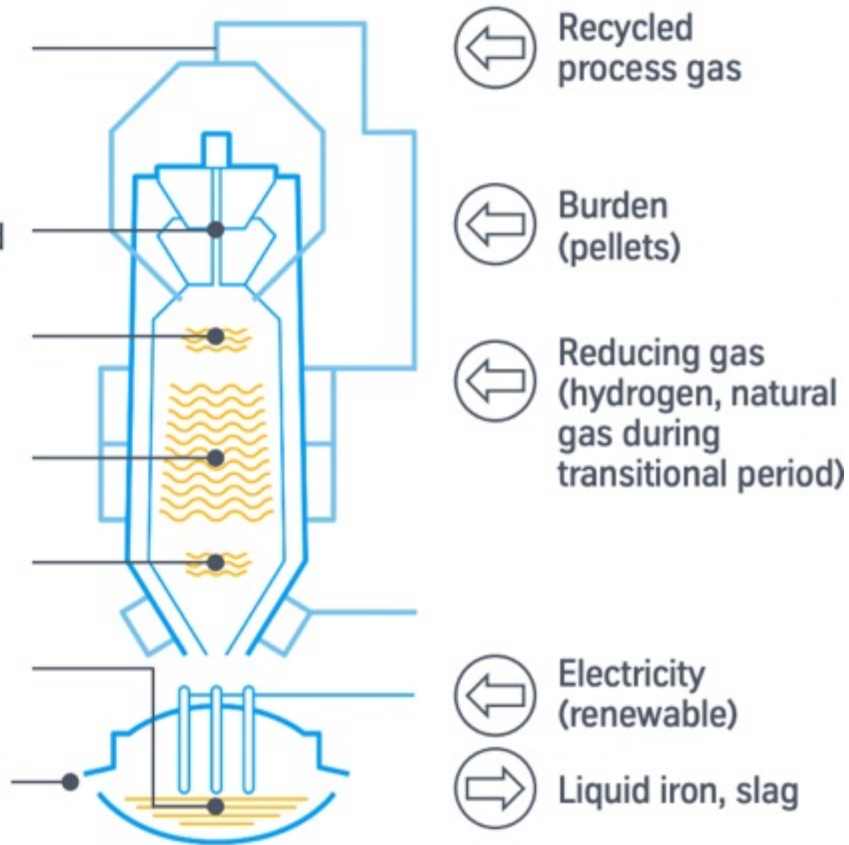
## CONVENTIONAL BLAST FURNACE

Carbon as reducing agent and energy carrier



## DR PLANT WITH MELTING UNIT

Hydrogen as reducing agent in DR plant  
Green electricity as energy carrier in melting unit



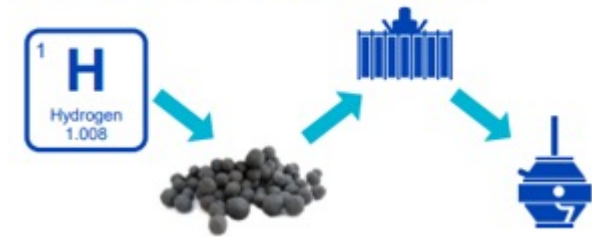
Source: ThyssenKrupp

# 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.

### Hydrogen DRI-Melter-BOF



Source: BlueScope

# Read the full report at IEEFA.org

---

Simon Nicholas [snicholas@ieefa.org](mailto:snicholas@ieefa.org)  
Soroush Basirat [sbasirat@ieefa.org](mailto:sbasirat@ieefa.org)

This report is for information and educational purposes only. The Institute for Energy Economics and Financial Analysis ("IEEFA") does not provide tax, legal, investment, financial product or accounting advice. This report is not intended to provide, and should not be relied on for, tax, legal, investment, financial product or accounting advice. Nothing in this report is intended as investment or financial product advice, as an offer or solicitation of an offer to buy or sell, or as a recommendation, opinion, endorsement, or sponsorship of any financial product, class of financial products, security, company, or fund. IEEFA is not responsible for any investment or other decision made by you. You are responsible for your own investment research and investment decisions. This report is not meant as a general guide to investing, nor as a source of any specific or general recommendation or opinion in relation to any financial products. Unless attributed to others, any opinions expressed are our current opinions only. Certain information presented may have been provided by third-parties. IEEFA believes that such third-party information is reliable, and has checked public records to verify it where possible, but does not guarantee its accuracy, timeliness or completeness; and it is subject to change without notice.



**Institute for Energy Economics  
and Financial Analysis**  
IEEFA.org