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Driving Steel Decarbonisation Together: BHP’s Progress and Partnerships

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Steel decarbonisation program overview

Building strategic customer partnerships and leveraging research to propagate and share knowledge across the industry

We are supporting decarbonisation of the steel sector

CY2030 goal

Support industry to develop steel production technology capable of 30 per cent lower GHG emissions intensity relative to conventional blast furnace steelmaking, with widespread adoption expected post-CY2030.

CY2050 goal

Net zero Scope 3 GHG emission by CY2050. Achievement of this goal is uncertain, particularly given the challenges of a net zero pathway for our customers in steelmaking, and we cannot ensure the outcome alone.

We are progressing delivery of our strategy to support reduction of Scope 3 GHG emissions in our value chain

Customers | Research | Ventures | Ecosystems

BHP Steel Decarbonisation Program

Modified Blast Furnace	DRI to ESF/EAF	Electrochemical Reduction
Demonstrate staged abatements to the Blast Furnace (BF) process route	Demonstrate and optimise the use of BHP's Pilbara iron ores	Support emerging technology to test the use of BHP's Pilbara iron ores

Our Aims

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Potential routes to near zero emission steel[1]

These pathways offer the greatest potential for steel decarbonisation with sufficient flexibility, scalability and efficiency

	Raw materials flexibility	Current State		End State	
		Primary Reductant	Emissions[2,3] (t-CO_2/t-steel)	Primary Reductant	Emissions[3] (t-CO_2/t-steel)
1 Modified Blast Furnace (BF)					
BF – BOF Pathway	*very high*	Carbon	*2.2*	Carbon	*0.4*
2 Direct Reduced Iron (DRI) - Electric Steel Making					
DRI – ESF Pathway	*high*	Carbon (NG)	*1.2*	Hydrogen	*0.4*
DRI – EAF Pathway	*very low*	Carbon (NG)	*1.3*	Hydrogen	*0.3*
3 Electrochemical Reduction (ER)					
Electrolysis Pathway	*high*	Electricity	*2.6*	Renewable Electricity	*<0.1*

(1) "Near-zero emission steel" is 0.40 t-CO_2/t-steel for 100% ore-based production (no scrap), as defined by the IEA and implemented in ResponsibleSteel International Standard V2.0 ('near zero' performance level 4 threshold). IEA (2022), Achieving Net Zero Heavy Industry Sectors in G7 Members, IEA, Paris, License: CC BY 4.0.
(2) Using Pilbara-type iron ores, natural gas for direct reduction and typical global grid electricity emissions intensity
(3) Estimated practical minimum from laboratory testing and conceptual engineering designs for full scale plant – process route is not yet commercialised

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We are progressing abatement projects across multiple pathways

Delivering emissions reductions today while strengthening our customer relationships and insights to shape our portfolio for the future

2020 — 2026 — 2030 — 2050

Modified Blast Furnace

Demonstrate staged abatements to the Blast Furnace process route

BF/BOF

- **Optimisation** Lump screen
- **Optimisation** Sintering Natural Gas Injection
- **Optimisation** Lump dryer
- **Carbon Substitution** H_2 BF Injection
- **BF CCUS demonstrations**
- >30%
- **Demonstration: Modified BF** Commercial scale trials Target commissioning CY28/29

Retrofit, modification & optimisation

DRI-Electric Furnaces

Demonstrate and optimise the use of BHP's iron ores

DRI

- **Pilbara Pellets** Laboratory testing **50-100% Pilbara ores**
- **Pilbara Pellets & DRI Trials** Commercial production **15-30% Pilbara ores**
- **Pilbara Pellets & DRI Trials** Commercial production **50% and above Pilbara ores**
- **Alternate H2 DRI production** Fines based DRI **100% Pilbara ores**

ESF

- **DRI – ESF Concept Study** with Hatch
- **Laboratory-scale ESF trials** University of Newcastle + others
- **NeoSmelt FID** 2026
- >30%
- **Demonstration: NeoSmelt** Commissioning

Scale-up & optimisation with Pilbara ores

Electrochemical Reduction (ER)

Support emerging technology to optimise the use of BHP's iron ores

ECR

- **Boston Metals** Ventures Investment
- **Electra** Ventures Investment
- **Lab Scale Trials** with BHP iron ores
- **Boston Metal pilot-scale trials** with BHP iron ores
- **Electra pilot-scale trials** with BHP iron ores
- >30%
- **Demonstration:** Possible demo or commercial plant trials

Development & scale up of emerging technology

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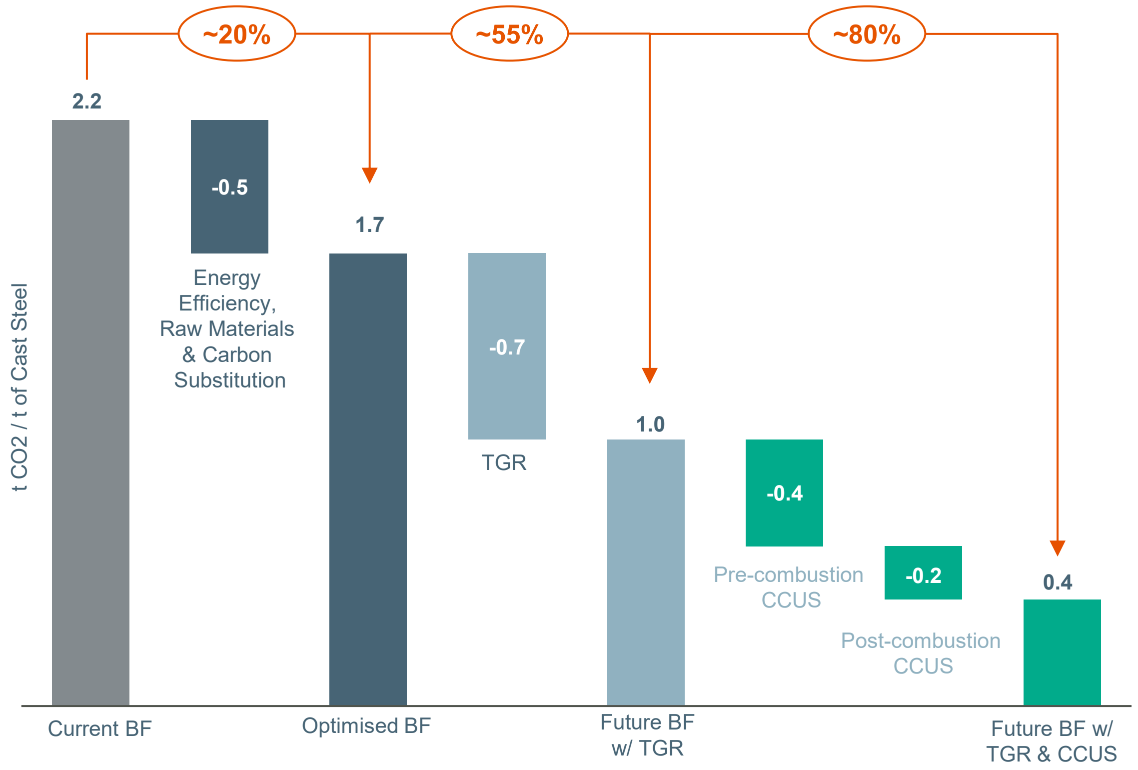
Modified Blast Furnace Pathway

A Scalable Route to Near-Zero Emissions Steelmaking

Significant GHG emission reduction potential of Modified BF Pathway

Modified BF pathway with carbon recycling and CCUS requires technology development and demonstration to near-zero CO_2 emissions steel from the BF process

Potential CO_2 Abatement of the Blast Furnace to Near Zero CO_2 intensity



Modified BF has 80% reduction potential with combined abatements including CCUS

(Steel intensity in t CO_2 / t crude steel)

Potential Enablers

Increase use of high-quality raw materials

Higher quality coke to support lower fuel rates
Low GHG ferrous, like lump / pellets

Substitute, recycle and capture carbon

Biogenic or low carbon fuels
Electric heating, Byproduct gas recycle,
Capture /separation technology

Utilise, transport and store

Carbon utilisation technologies
Transport and storage value chains

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Understanding the use of hydrogen in the blast furnace

Multi-Scale Insights on Hydrogen Use in Blast Furnaces

Modelling

THE UNIVERSITY OF NEWCASTLE AUSTRALIA

- Developing and extending models to assess the use of hydrogen rich gases[1]
- Understanding theoretical limits and operational constraints

Materials Research

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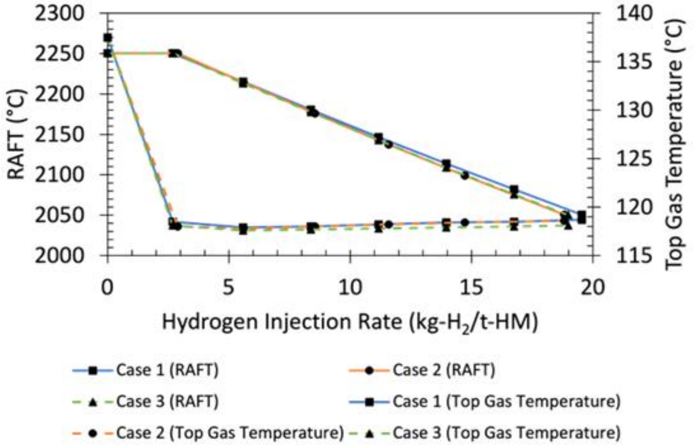
- Assessing ferrous and coke impacts
- Observing that high CSR coke better withstands hydrogen[2]
- Hydrogen use increases ferrous cracking and increases ultra-fines generation, particularly in pellet[3]

Demonstration

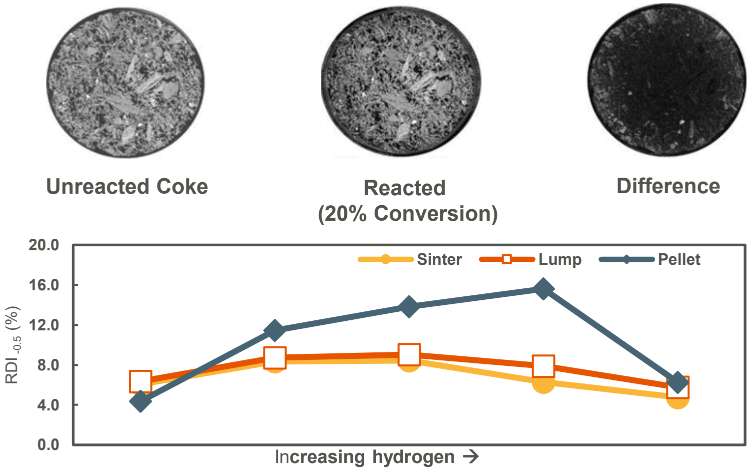
ZENITH 中天钢铁

- H_2 rich gas (COG) injection trials
- Demonstration at scale in BF
- Completion of two trial campaigns after commissioning

Modelling of H2 BF injection rates



Micro CT images of H2-reacted coke and ferrous burden RDI testing



Blast Furnaces at Nantong for COG injection trials

(1) Barrett, N., et. al; *Assessment of Blast Furnace Operational Constraints in the Presence of Hydrogen Injection,* ISIJ International, Vol 62, Issue 6, pp 1168-117 (2022)
(2) Wang, A., et. al; *Coke microstructure evolution during CO2 and H2O gasification*, Asia Steel Conference, Changsha, China (2024)
(3) Barustan, M., et. al; *Reduction Degradation of Sinter and Lump under CO and H2 Gas Mixtures,* METEC & 6th ESTAD, Dusseldorf (2023) Unpublished for Pellet

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Case Study

Hydrogen-rich COG injection trials

A low-carbon blast furnace modification designed to reduce carbon emissions and improve fuel efficiency in ironmaking

Project Objectives

- Target GHG emission intensity reduction of 5-10% with COG injection at Zenith Nantong base
- Optimise COG injection and BF operation
- Review Pilbara iron ore as lump and pellets in BF performance with COG injection

Recent Activities

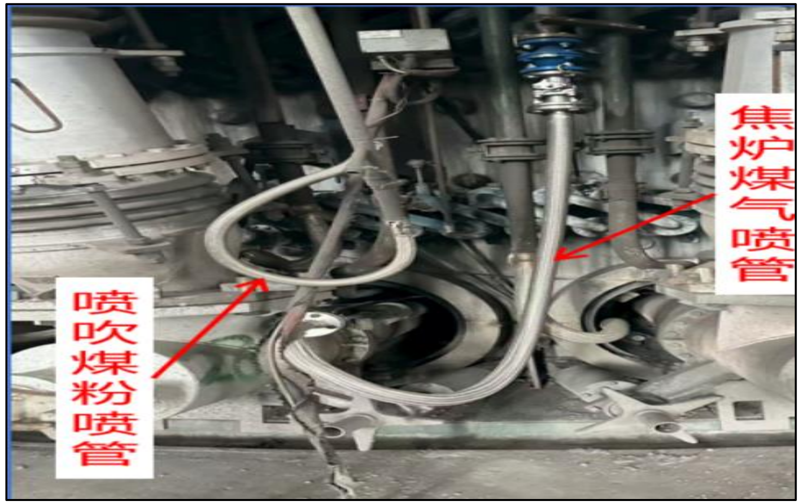
- Initial trials are promising:
  - ↓ Fuel ratio reduced by 11 kg/t HM
  - ↑ Coke replacement ratio reached 0.46kg/m3
  - ↓ CO_2 emission intensity reduced by 37kg/tHM

Next Steps

- Further modifications and trials to improve fuel rate reductions

COG compressor

PCI and COG injection lines



COG distribution and control system

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Supporting carbon capture development for steel

Pilot trials across technology types and increasing scale to assess performance and improvement options

100 tpa

ArcelorMittal, BHP, Mitsubishi Heavy Industries, Mitsubishi Development

- MHI commercial amine capture system
- Pilot operating on BF gas through 2024/25,
- Plan to test hot strip mill emissions next

1,000 tpa

BHP, HBIS Group

- Pressure Swing Adsorption system
- Pilot commissioned for testing blast furnace gas

100,000 tpa

BHP, carbon clean, JSW Steel

- CycloneCC rotating packed bed technology
- Engineering design study

CCUS Hub Study

BHP, AM/NS India, JSW Steel, Hyundai Steel, Chevron, Mitsui & Co.

- First independent industry-led study of its kind in Asia
- Seeks to leverage shared infrastructure and economies of scale to explore CO_2 applications or storage sites

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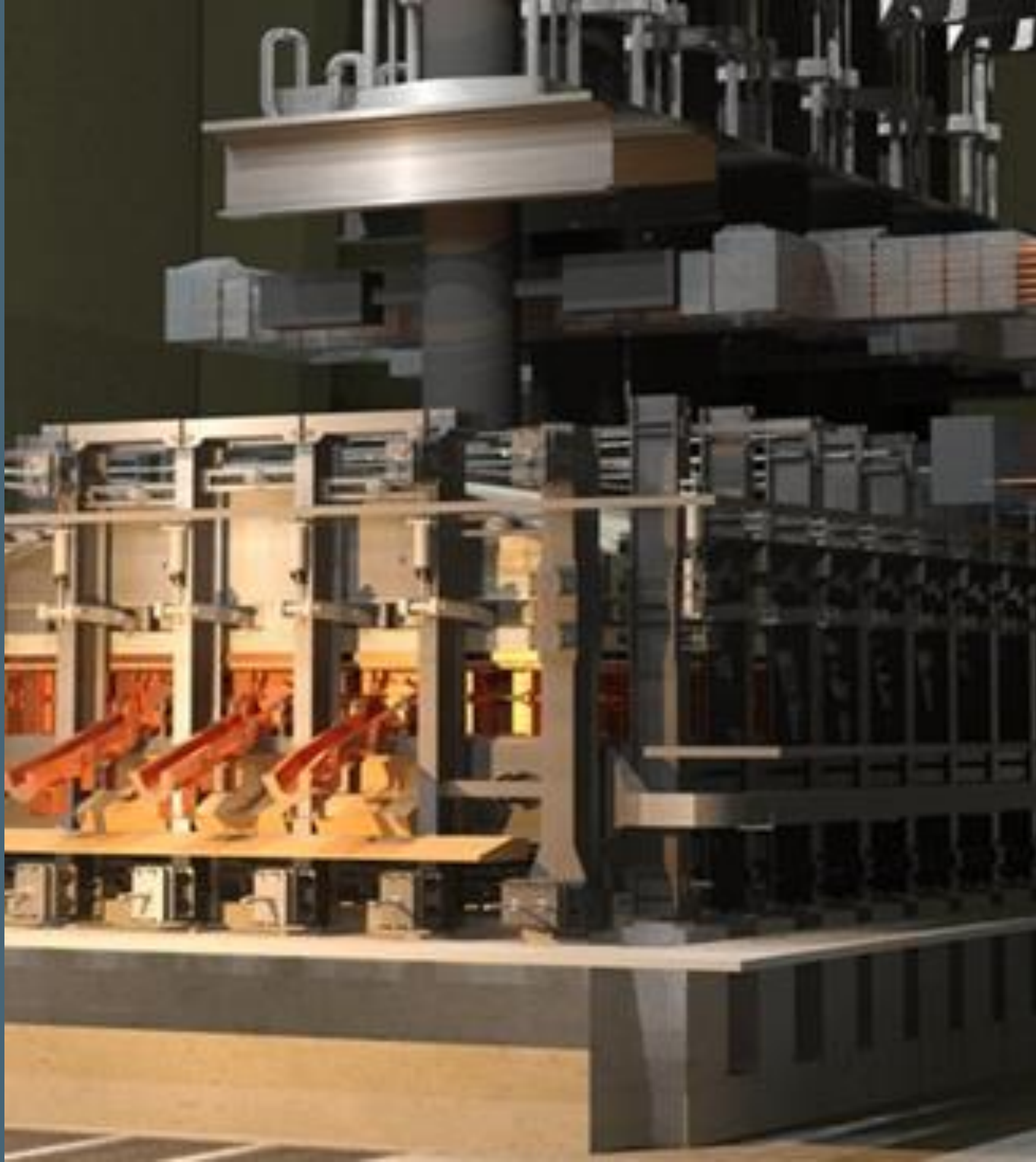
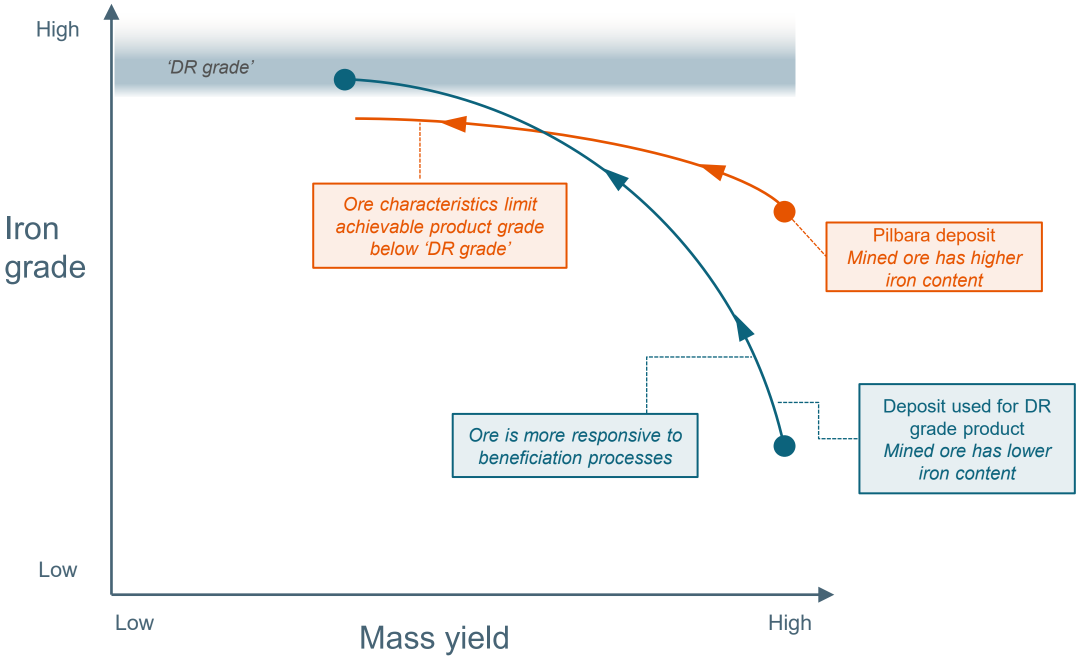
New potential pathways for Pilbara ores

Demonstrate and support optimisation of BHP Pilbara iron ores in new technologies



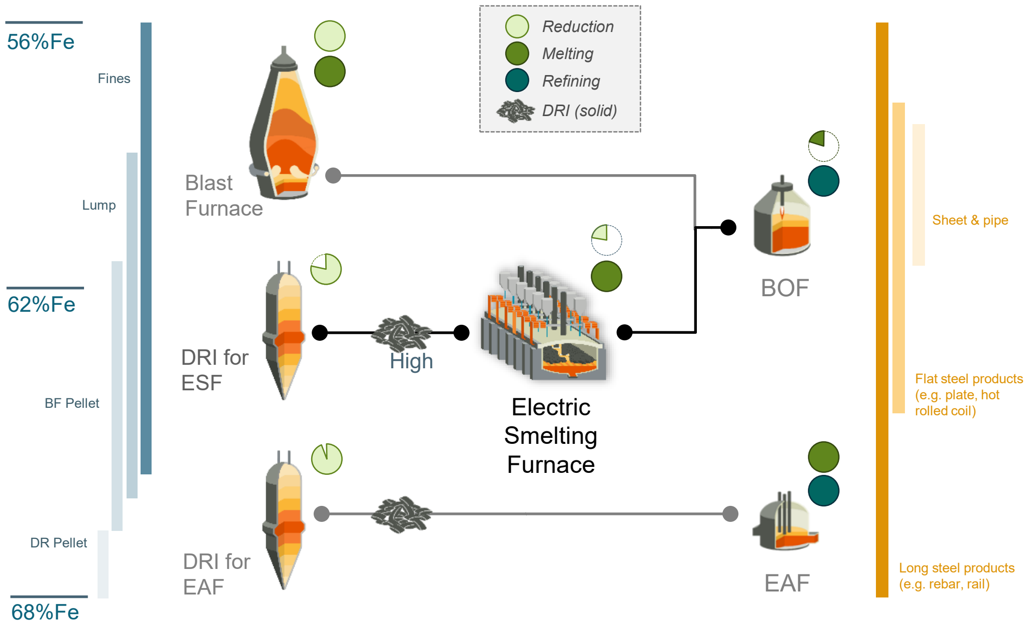
Potential ESF pathway offers raw material & product flexibility

The beneficiation challenge



- Indicative mass recovery curves for the beneficiation of a Pilbara deposit and a deposit that currently produces DR grade product
- Arrows indicate the direction along the curve that the mined ore follows during beneficiation.

Combining DRI with ESF can offer greater flexibility



Notes:

(1) The DRI, scrap, flux and carbon charge rates shown are illustrative, considered typical of efficient furnace operation with DRI produced from Pilbara-type ores. The EAF has greatest flexibility in scrap ratio, with some of the key performance trade-offs discussed in the text of this article.

(2) "Liquid steel" tapped from an EAF is usually ready to cast. "Hot metal" tapped from an ESF, like BF hot metal, requires refining to liquid steel before casting. This is typically performed in a Basic Oxygen Furnace (BOF) but can also be performed in an EAF.

(3) Most of the iron losses to electric furnace slag are re-oxidised iron (FeO), with smaller losses as metallic iron droplets suspended in the slag.

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Pelletising BHP Pilbara ores to enable DRI

Aiming to provide our customers flexibility through a wide range of blend testing across operational ranges and scales

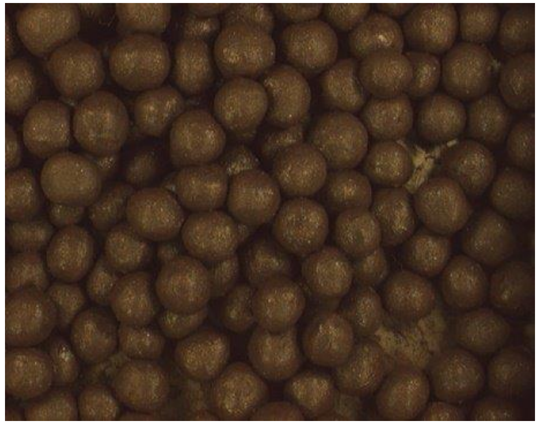
There is growing use of 10-40% BHP Pilbara ores as BF pellet feed in China, supporting lower BF CO_2 intensity and production flexibility

Learnings and tactics:

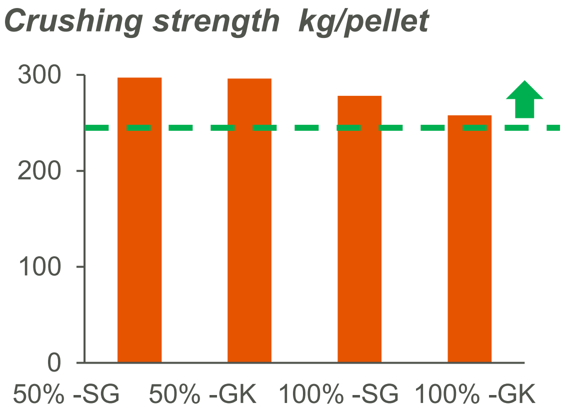
- Pellet Fe content increases to 63-64%
- Great grinding and green balling performance
- Lower binder consumption
- Induration profile optimisation is critical
- Flux addition can further enhance the quality

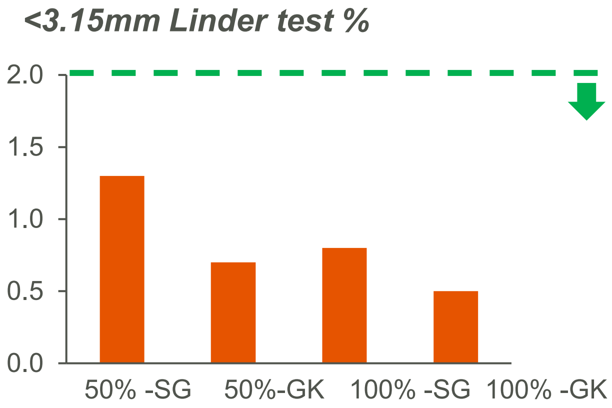
Good DRI shaft performance may be achieved by blending BHP Pilbara ores

- DR grade pellet quality and EAF performance could be maintained with 10-20% BHP Pilbara ores
- Up to 30% successfully validated at commercial scale for DRI shaft use
- 50-100% tested at pilot scale and DRI bag tests



Green Pellets with different binders (bentonite and organic)





50% and 100% BHP ore pellet quality, SG – straight grate; GK – grate kiln

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Case Study

DRI production using BHP's Pilbara ores

We are aiming to demonstrate the application of BHP Pilbara iron ores in DRI production across multiple process routes and scales

Project Objectives

- Demonstrate commercial scale production of pellet and shaft DRI using BHP Pilbara ores
- Demonstrate the CO_2 abatement potential

Recent Activities

- Multiple trials at 1Mtpa DRI Plant
    - ~70% H2 in reducing gas
    - ~2 week operation for each trial
- Achieved stable DRI shaft operation and acceptable DRI quality

Next Steps

- Continue pellet-shaft DRI trials at higher Pilbara ore ratios
- Explore options for fines-based H2 DRI trials

DRI Shaft

Product DRI sample

Ongoing collaboration with our customers

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Case Study

Scaling Pilbara Ores in DRI-ESF Technology

Scaling DRI-ESF is critical to enable near-zero CO_2 steelmaking for a wide range of iron ores

Project Objectives

- Optimise hydrogen reduction and electric smelting processes & technology
- Evaluate and optimise performance for Pilbara iron ores
- Collaborate with steel industry to accelerate scale up and commercialisation

Recent Activities

- Lab scale work to investigate ESF process metallurgy
- Development of thermo-chemical and process models
- Kicked off feasibility study for pilot DRI-ESF in the Neosmelt partnership in West Australia
- Joined HILT CRC in Australia to help promote the ESF pathway

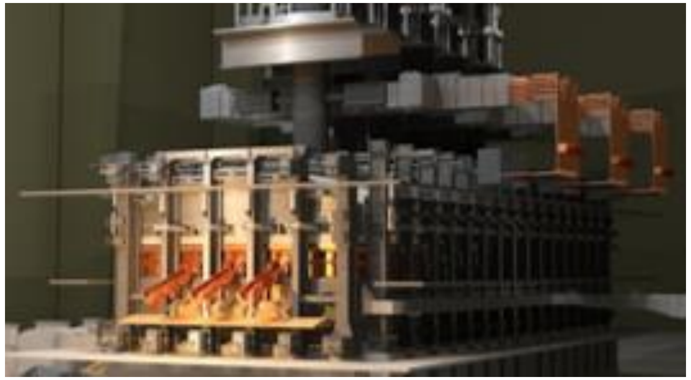
Next Steps

- Progress Neosmelt pilot DRI-ESF project to FID
- Continue lab and intermediate scale research to inform pilot operation and future commercialisation
- Work closely with industry partners to share learnings and accelerate development of the ESF pathway

5 kg-scale ESF testing at the University of Newcastle (left). Tapping the 100 kg-scale ESF at University of Duisburg-Essen, Germany (right).

BHP iron ore fines (left), H2 DRI from BHP fines (right), and iron produced by electric smelting of BHP DRI (centre).

Render of an Electric Smelting Furnace (Hatch)



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Case Study

Electrochemical Reduction

BHP's Ventures investments in Boston Metal and Electra are enabling transformative steelmaking using Pilbara ores

Project Objectives

- Explore scale up of different of electrolysis systems for near zero CO_2 steel production
- Test performance of Pilbara iron ores

Recent Activities

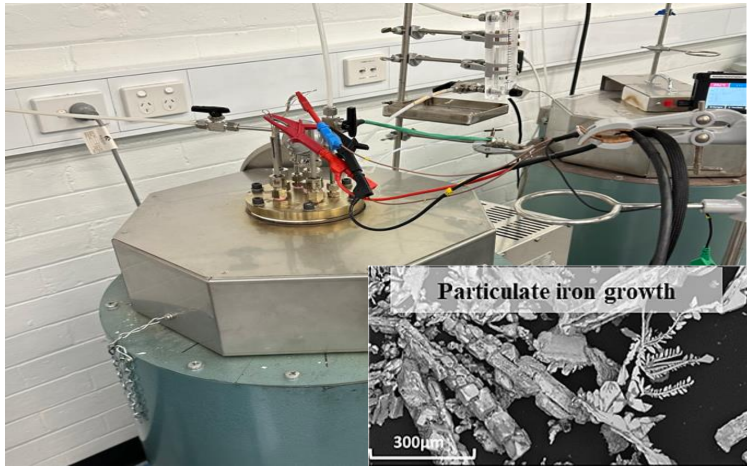
- Lab testing of multiple systems and components and testing BHP Pilbara ores
- Construction and commissioning of pilot plants, with trials using BHP iron ores for low temp electrolysis and MOE

Next Steps

- Continue laboratory and pilot scale trials and testing the impacts Pilbara ores
- Explore scale up opportunities

Low temperature - Electra pilot plant facility

Molten Salt – lab scale testing at Uni of Newcastle Aus



High temperature – Bosten Metal MOE metal tapping

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Conclusions

Partnering is critical to progressing steelmaking decarbonisation

Multiple potential pathways to support steelmaking decarbonisation

We are demonstrating potential enablers for decarbonising the blast furnace with our partners

We are demonstrating and supporting optimisation of BHP Pilbara ores in new technologies

Working with partners is critical to develop, demonstrate, and derisk

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