Saldanha Hydrogen Direct Reduced Iron Project

November 2023

Aldrich Louis

ArcelorMittal

Saldanha Hydrogen DRI

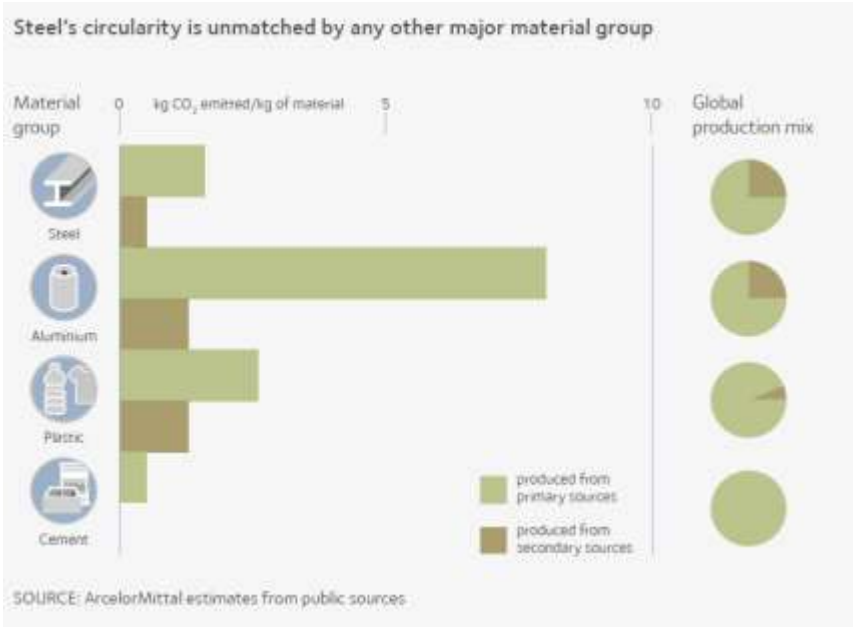
Introduction: Steel is an important circular material that must be decarbonised

Decarbonisation Impact

- Steel industry contributes 7% of global emissions or 2.6 Gt of CO2
- Coal provides 75% of steelmaking energy demand currently
- Need to replace coal in the conversion of iron ore into steel or the replacement of natural gas
- ArcelorMittal South Africa has its own decarbonisation ambition
  - 25% reduction by 2030
  - Net zero by 2050

Direct Reduced Iron (DRI) as an important decarbonisation steelmaking input

- Not all steel grades can be produced using scrap steel (tramp elements)
- Demand for DRI expected to increase as the industry transforms to Electric Arc Furnace (EAF) technology away from BF/BOF
- Early mover advantage can be gained by meeting the demand for DRI in the EU and East



85-90% of steel is recycled

Source

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Terminology

IRON

STEEL

IRON ORE

Iron oxide is the natural form that most Iron exists in nature, usually Fe_2O_3 Hematite. Various qualities in the market with different levels of gangue. Fine ore can also be agglomerated or pelletized for the market – also known as virgin iron

HOT METAL / LIQUID IRON

Molten iron product of the blast furnace (BF) with the gangue material removed. Tapped at 1500ºC

DIRECT REDUCED IRON (DRI)

Iron ore with the oxygen removed. It is still in solid state with gangue material attached and containing with 2% carbon. Also known as sponge iron

PIG IRON

BF hot metal that was cooled and shaped in a mold or casted in nuggets.

Also known as merchant pig iron when traded

STEEL SCRAP

Recycled material left over from manufacturing and consumption, such as vehicle parts and appliances reaching end of life and which can be recovered for its Fe content and reused in the steel production process

LIQUID STEEL

Molten product of the steel making processes EAF or BOF. Tapped at >1600ºC with a low carbon content.

BF Blast furnace
DRP Direct reduction plant
BOF Basic Oxygen Furnace
EAF Electric arc furnace
CCS Carbon capture storage
CCU Carbon capture usage
RE Renewable energy
HBI Hot briquetted iron
Fe Iron

Flat Steel Products

STEEL SLABS

Product of a slab caster used for flat steel products

CRUDE STEEL

Long Steel Products

STEEL BILLETS

Product of a billet caster used for long steel products

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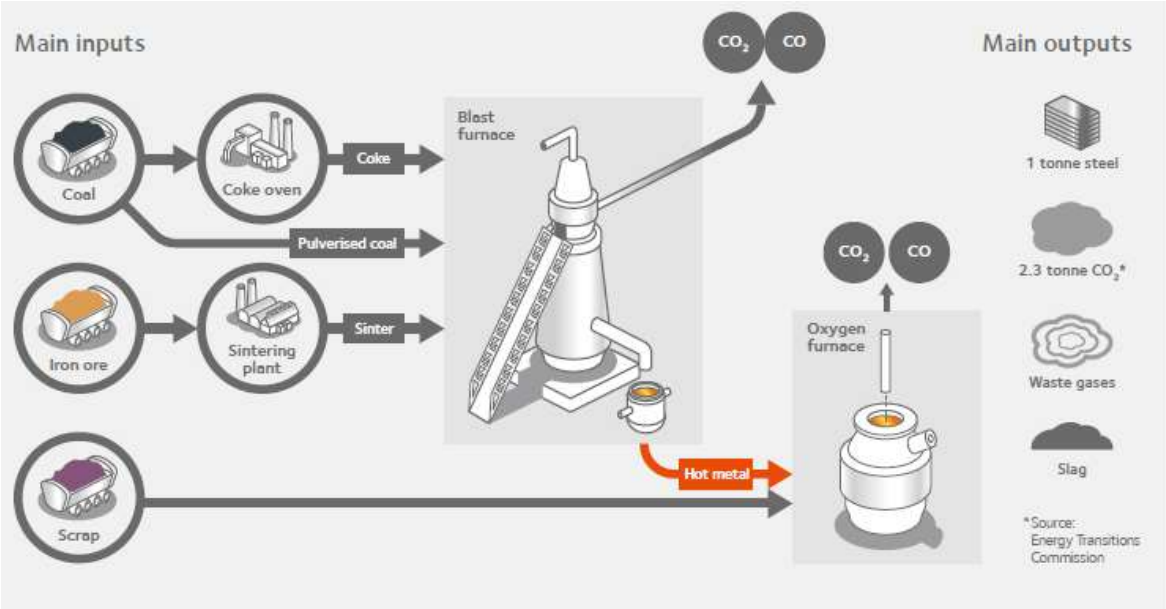
Conventional steelmaking technologies is highly reliant on coal for energy

- Steel today is produced using mostly primary sources (Iron Ore)
- Up to 20% of primary sources can be replaced using secondary sources (scrap) which has a decarbonisation impact, without a technology change (added to the Oxygen furnace mix)
- 18-22 GJ/ton of energy required per ton steel produced
- By products include slag which is a cement replacement (250kg slag/ton steel)
- Opportunities to decarbonise include the capture and storage of CO2 or its conversion into fuels and chemicals or;
- The replacement of coal with sustainable carbon



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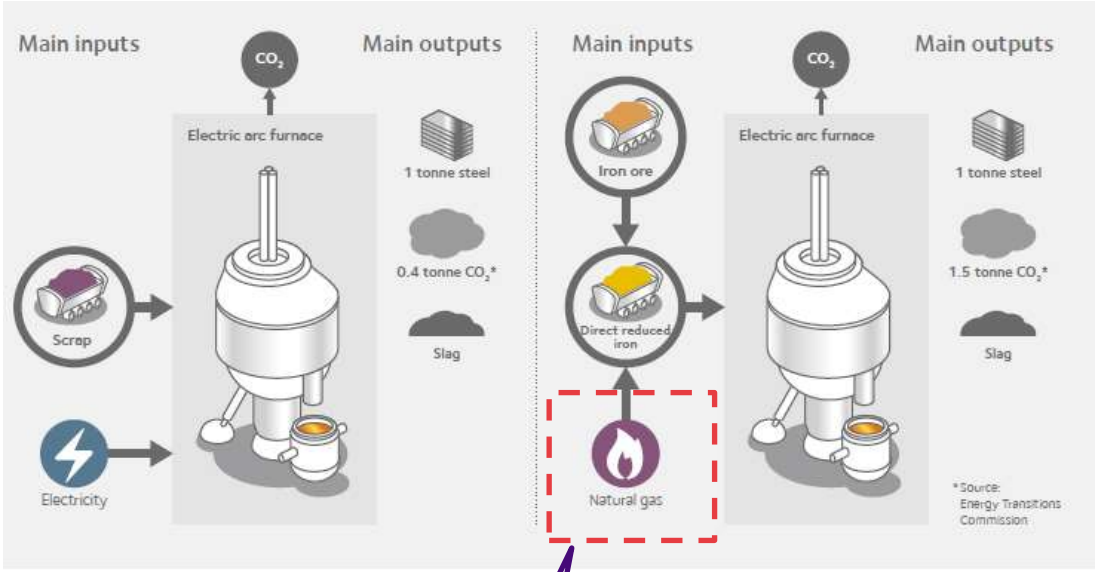
Steelmaking transformation offers a solution for decarbonisation but requires H2

- Electric Arc furnaces can use scrap, pool iron and DRI (NG or H2 as reductant) as input
- However primary inputs (Iron Ore based) is essential to supply full steel demand, since quality scrap is available in insufficient volumes
- Closure of blast furnaces are expected to impact pool iron and scrap availability
- Primary virgin inputs are also essential in producing certain grades (automotive)
- Energy requirement of 5-7 GJ/ton steel for a EAF process produced when operating on a pure scrap
- Possible to achieve 0.1t CO2/ton steel for pure EAF with green electricity

Process flow for Electric Arc Furnace (EAF) with scrap as input

Process flow for Electric Arc Furnace (EAF) with scrap and DRI as input



Possible to achieve 0.1t CO_2/ton Steel when using green energy

Possible to achieve 0.6t CO_2/ton Steel when using green electricity

Natural gas to be replaced with green H2

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Technical review of the conventional Midrex process

- Reduction using CO and H2 from reforming process using steam and natural gas
- Scope 1 intensity of ca 0.5-ton CO2/ton DRI
- Carbon in the DRI makes important contribution to electricity consumption at the EAF ca. 150 kWh/ton (23%)

Reduction (removal of oxygen from iron ore)

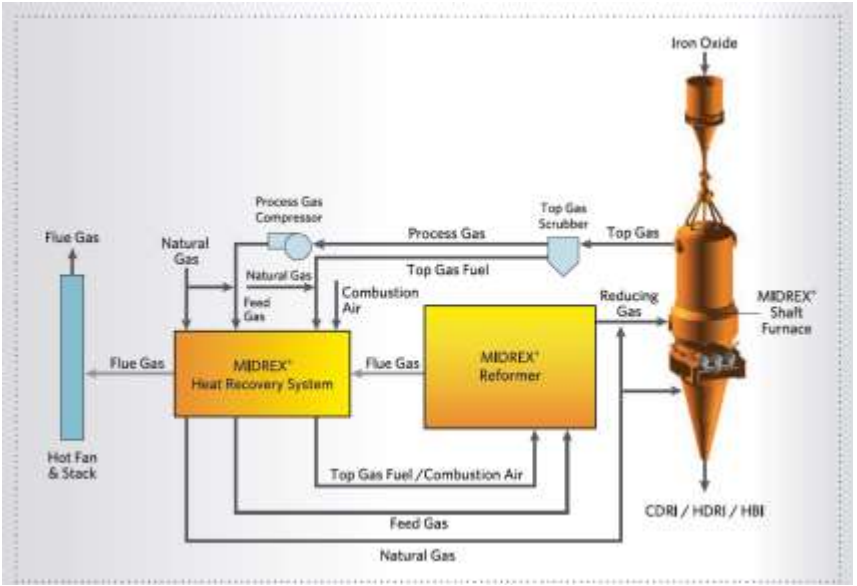
1. $Fe_2O_3 + 3H_2 \longrightarrow 2Fe + 3H_2O$ (endothermic)
2. $Fe_2O_3 + 3CO \longrightarrow 2Fe + 3CO_2$ (exothermic)

Carburization (addition of carbon to iron)

3. $3Fe + CO + H_2 \longrightarrow Fe_3C + H_2O$
4. $3Fe + CH_4 \longrightarrow Fe_3C + 2H_2$
5. $3Fe + 2CO \longrightarrow Fe_3C + CO_2$

Reforming (conversion of CH_4 to CO and H_2)

6. $CH_4 + CO_2 \longrightarrow 2CO + 2H_2$
7. $CH_4 + H_2O \longrightarrow CO + 3H_2$



Source: Midrex

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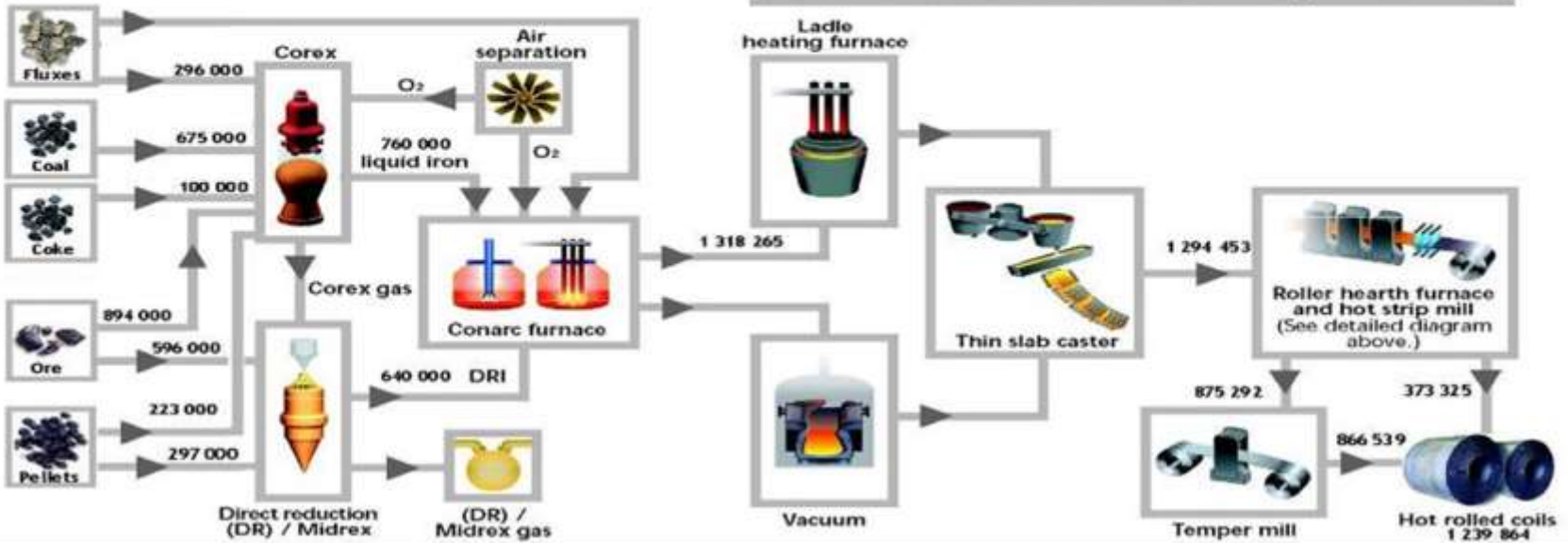
ArcelorMittal Saldanha Works contains an existing Midrex direct reduction facility and an installed EAF

Saldanha Works mass and process flow
Unit: tons per annum



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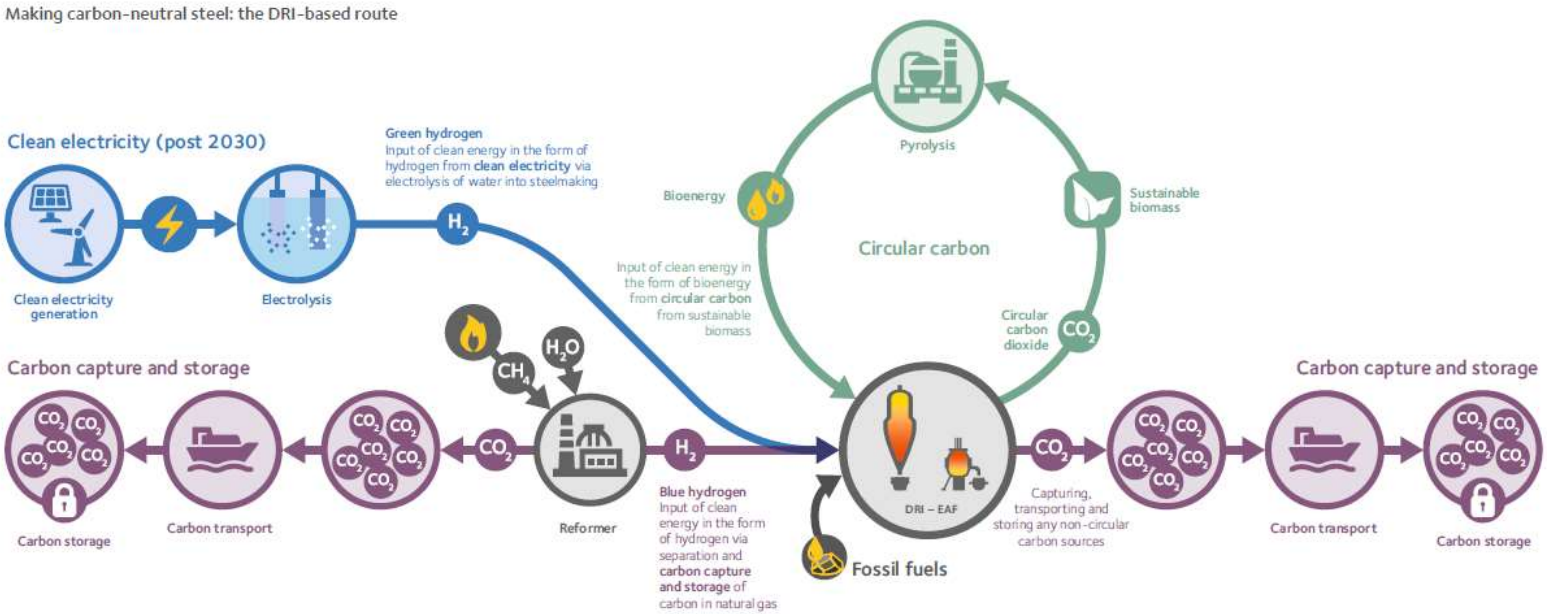
Steelmaking Transformation: Making green steel the DRI based route



https://corporate-media.arcelormittal.com/media/ob3lpdom/car_2.pdf

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Midrex process making use of green hydrogen

- Full replacement of natural gas with green hydrogen
- Reformer not required
- Solution for industrial level CO2 free heating is being considered

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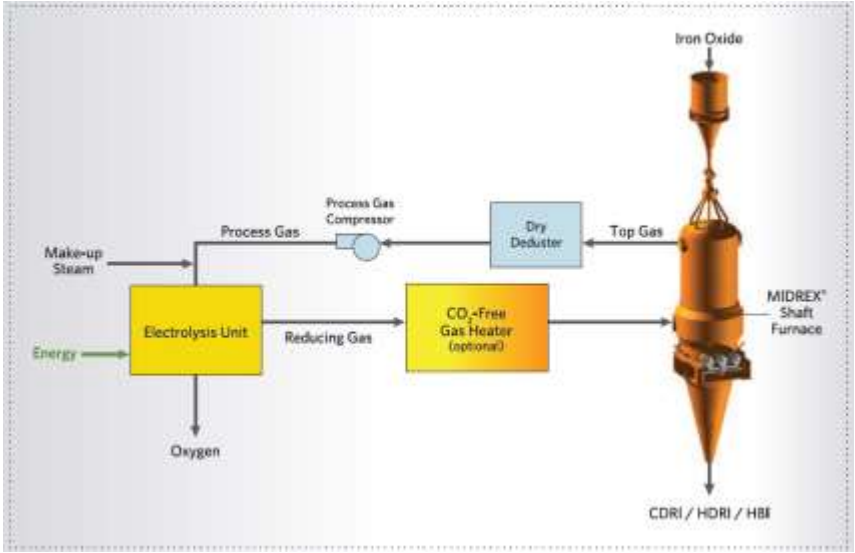

Source: Midrex

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Saldanha is well positioned to produce 1.2 Mt/y Green H_2 Direct Reduced Iron …

Project description

ArcelorMittal South Africa is **investigating the opportunity of producing up to 1.2 Mt of H_2 Direct Reduced Iron (DRI)** at its Saldanha Works plant for**:**

- Local consumption
- Export to EU and other countries

- ArcelorMittal South Africa has signed a non-binding agreement with **SASOL and with Mainstream Renewable Power for the supply of hydrogen and RE** and agreements with the **IDC for development funding**
- Aim is to **start DRI production in 2027 / 2028** ramping up to 1.2 Mt in a phased manner

Project Status and Key Findings

Saldanha Works: **A plant in an advanced state of readiness to produce hydrogen-based DRI and finally Green steel**

- **Pre-feasibility study** to produce H_2 DRI commenced early 2023 and will be **completed Q4 2023**
- The plant can act as an important catalytic project for the **establishment of a hydrogen hub in the Saldanha area**
- For the opportunity to be feasible the project will require access to:
  - A **stable supply of competitively priced H_2**
  - **Competitively priced iron ore**

Saldanha's Strengths

The Saldanha asset lends itself to the production of Green H_2 DRI and steel due to:

- AM Group is the largest producer of DRI in the world
- Saldanha Midrex is the best positioned plant in the group to transition to H_2 DRI due to its existing setup
  - The plant contains an existing Midrex direct reduction facility and installed EAF
  - Well developed infrastructure (port, roads, rail, electricity transmission)
  - ArcelorMittal owns vacant land adjacent to the facility
  - Attractive renewable resource endowment

Project need

H_2 DRI is an important steelmaking input to decarbonise the steelmaking process

- Demand for DRI is expected to increase as the industry transforms to Electric Arc Furnace technology
- Limited scrap availability and the fact that not all steel grades can be produced using 100% scrap will create a high demand for DRI

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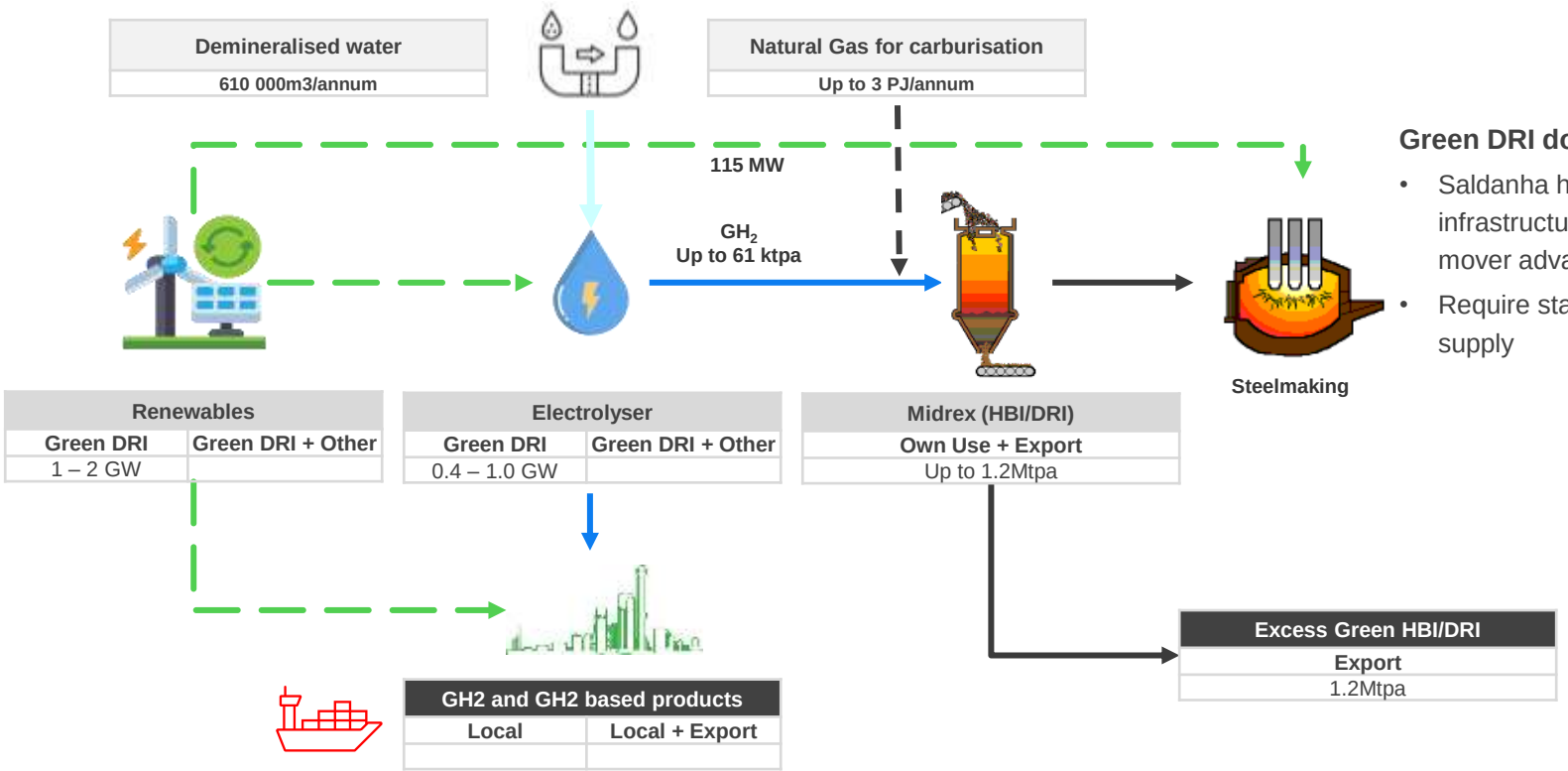
Envisioned technical layout of the facility



Green DRI domestic use

- Saldanha has installed infrastructure to enable first mover advantage
- Require stable hydrogen supply

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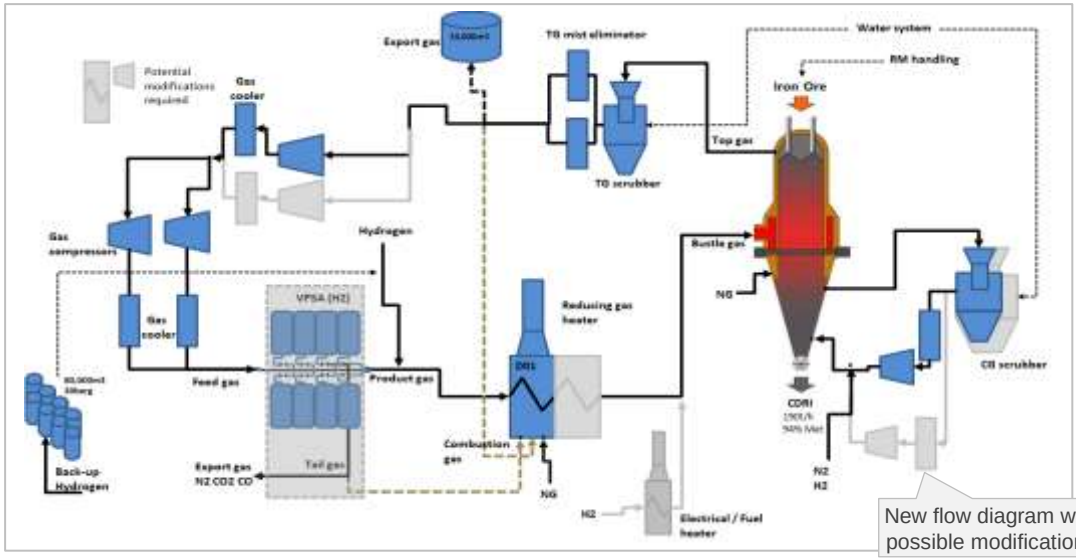
Minor modifications are needed for Saldanha to be hydrogen ready

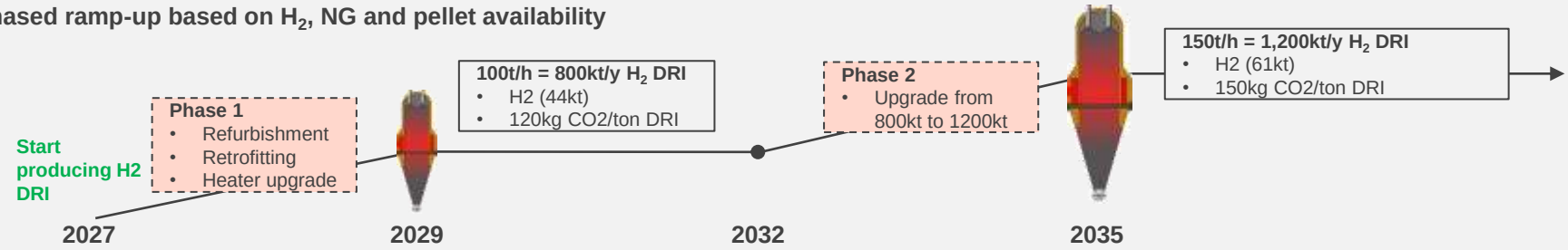
Initial technical assessment

- Well positioned for hydrogen DRI production
- Will require certain adaptation
- Can be first in the group to operate on high percentages of hydrogen



New flow diagram with possible modifications

Phased ramp-up based on H_2, NG and pellet availability



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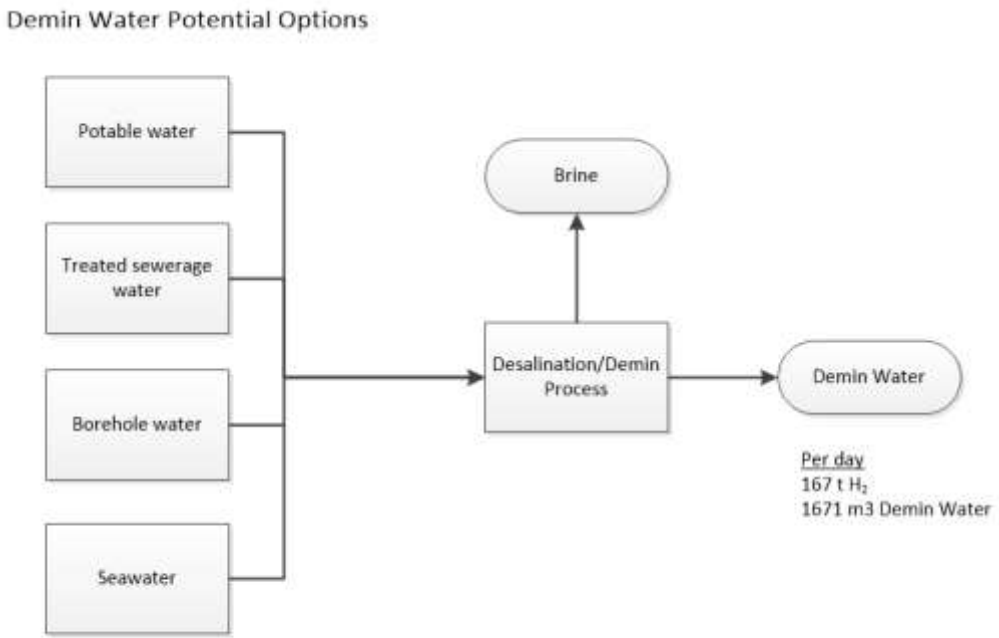
Demineralised water production is an important project consideration



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Competitive GH_2 and green DRI project drivers

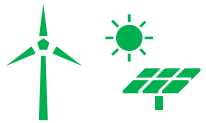
Iron Ore Pelletisation

- South Africa has a significant iron ore endowment
- Iron ore pelletisation locally could have an important enabling impact

Partnerships

- Partnerships identified to develop, potentially fund GH_2 production and de-risk the project due to their individual unique enablers
- Important to take all stakeholders along (government, NGO's, SOE's communities,)

Renewable Resources



- Low-cost renewable energy largely determines the price of green hydrogen
- Significant renewable potential in South Africa
- Capacity factors are critical
- Land and grid capacity availability will be important

Existing Midrex Plant

- Existing Midrex plant located in Saldanha
- Conversion to 100% hydrogen-based production possible
- Existing Midrex to be used

Deep Water Port

- Existing deep-water port located in Saldanha
- Significant GH_2 offtake potential - bunker fuel
- Export terminal for green DRI
- Reduced need for local on-land transport
- Infrastructure to be developed for GH_2 and Natural Gas

Transport Routes

- Access to Europe through established shipping routes
- Existing deep-water port located in Saldanha
- Export terminal for green DRI
- Well-established trade routes

Land Availability

- Significant land availability for renewable power generation
- Co-location with the electrolyser and Midrex plant

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End

ArcelorMittal South Africa Decarbonisation Roadmap (January 2023) (2).pdf (arcelormittalsa.com)

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