Hydrogen Watch Policy Brief 2

PRODUCING GREEN STEEL: AN OPTION TO DECARBONISE ARCELORMITTAL SOUTH AFRICA (AMSA)?

INTRODUCTION

In January 2023, ArcelorMittal South Africa (AMSA) published the company's Decarbonisation Roadmap plans. AMSA intends to reduce greenhouse gas emissions from the operations of its Vanderbijlpark, Saldanha, and Newcastle plants towards a net-zero goal by 2050, and to reduce emissions by 25 % by 2030. The aim is to reduce its direct emissions from coke, iron, and steel production plants, as well as indirect emissions embedded in the electricity that AMSA uses from Eskom fossil-fired generators. The roadmap is in line with AMSA's global plans.

Iron and steelmaking worldwide produce about 8 % of all greenhouse gas emissions. There is scientific agreement that the use of coal, oil, and natural gas are the main cause of global warming. In addition, scientists have found that South Africa is very vulnerable to the effects of climate change. People are already experiencing extreme weather conditions, ranging from devastating floods to protracted droughts. In United Nations (UN) negotiations most countries, including South Africa, have signed agreements to reduce greenhouse gas emissions to net-zero. There is also agreement that each country must do its part. If South Africa does its fair share, the country contributes to the worldwide emissions-reduction effort.

For some time now, environmental and civil-society organisations such as the Vaal Environmental Justice Alliance (VEJA) and the Centre for Environmental Rights (CER) have demanded that AMSA cut emissions from its operations and stop using fossil fuels. They argue that emissions from AMSA's plants affect the health of nearby communities badly, and that greenhouse gases from AMSA's current steel-production process contribute to global warming and climate change. Hydrogen Watch (H2 Watch) asked an independent expert, Hilton Trollip, to provide a non-technical commentary that is accessible and understandable by frontline communities and the NGOs they work with, enabling them to engage with AMSA's roadmap to decarbonise their operations. The commentary in this policy brief reflects the opinion of the independent expert, and not the views of H2 Watch members.

This policy brief assesses AMSA's Decarbonisation Roadmap. It asks questions about the effectiveness and implications of the plans contained in it. It asks whether the steps contained in the roadmap meet the longstanding demands of environmental groups and frontline communities living next to AMSA factories and around the plants and mines from which the steelmaking companies source their supplies. Before answering these questions, the policy brief presents basic technical information on iron and steelmaking as a background to discussing the five main items in AMSA's Decarbonisation Roadmap. Note that, as the costs involved in the plans presented in the Decarbonisation Roadmap are highly uncertain and financial details remain confidential, all costs in this document are rough estimates.

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IRON AND STEELMAKING

Steel is a vital product in society. Its widespread use in buildings, cars, trains, and household appliances makes it central to the 'modern way of living'. Although iron has been used to make tools for thousands of years and is still used today, most iron is now produced to make steel. Steel production involves companies that operate globally rather than just nationally. National governments often shield companies operating in their countries from competition, as well as subsidising steel multinationals. To phase out the use of fossil gas and coal in steelmaking, the global steel industry needs cooperative actions within the industry and between governments; South Africa and individual steel companies cannot take these actions alone.

PRIMARY STEEL PRODUCTION IN SOUTH AFRICA:

Primary steel (i.e., not recycled) is made from primary iron, which comes from iron ore. South Africa has a lot of iron ore and makes most of its primary iron in blast furnaces and some in direct-reduction furnaces (DRI) where coal and iron ore are used as feedstock to make primary iron. This is further processed to make steel.

Although there are several different technologies that can be used to produce iron and steel, this article will focus on the processes used in AMSA's Vanderbijlpark and Saldanha Bay plants. The many processes and plant configurations are immensely complicated. The features outlined below have been selected and simplified to illustrate factors that are relevant to understanding the decarbonisation issues and being able to better engage knowledgeably with AMSA's decarbonisation plans.

Method 1: Blast furnace smelting iron ore reduction ironmaking/basic oxygen furnace (BF/BOF) steelmaking (relevant processes at the Vanderbijlpark works).

This ironmaking process uses coking coal plus iron ore as feedstocks in a blast furnace to produce liquid iron. In the steelmaking step, the liquid iron is fed from the blast furnace to basic oxygen furnaces to make steel, removing carbon and impurities from the iron by blowing oxygen into the basic oxygen furnaces. These plants are used in close combination as the basic oxygen furnaces need to be next to the blast furnace to keep the iron molten. The production of coke in coke ovens, and the CO_2 by-product from iron ore reduction in the blast furnace are the main contributors to greenhouse gas emissions. Smaller amounts of CO_2 are produced in the basic oxygen furnace.

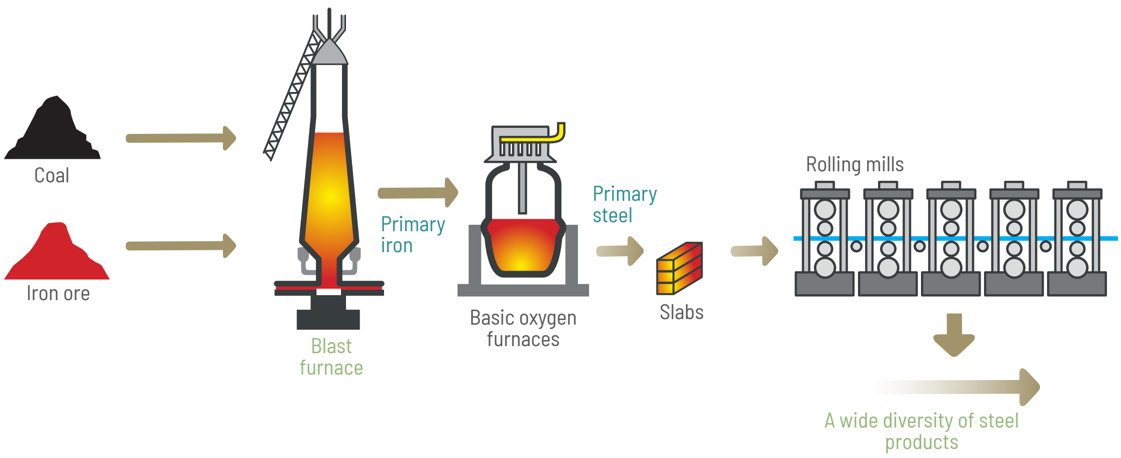

Figure 1a – Basics of primary iron and steelmaking in a combination of blast furnace and basic oxygen furnace

Method 2: Combination of Corex smelting iron ore reduction ironmaking, Midrex direct iron ore reduction ironmaking, and hybrid Conarc/electric arc furnace (EAF) steelmaking (relevant processes at the Saldanha Bay works).

Two ironmaking processes take place in parallel at the Saldanha Bay plant. In one, a Corex furnace uses gas produced from gasifying non-coking coal to reduce iron ore to produce liquid iron. A high value export gas (made up of CO, CO_2, and H_2), referred to as Corex export gas, is also produced. The Midrex furnace then uses the Corex export gas to reduce iron ore feedstock to produce solid iron. The steelmaking involves removing carbon and impurities from a mix of the liquid iron from the Corex furnace and solid iron from the Midrex furnace in a Conarc furnace, which is a hybrid electric arc furnace/basic oxygen furnace (EAF/BOF) to make steel. The ironmaking processes account for most of the CO_2 greenhouse gasses.

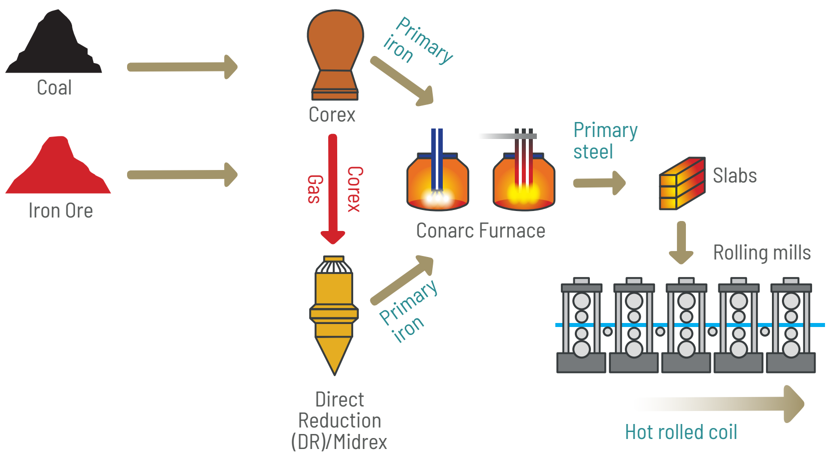

Figure 1b – Basics of primary iron and steelmaking at Saldanha in a combination of Corex furnace, Midrex furnace and Conarc hybrid electric arc furnace/basic oxygen furnace

SECONDARY STEEL PRODUCTION

After steel has been in use, it can be recovered and recycled. It doesn't get used up and, in principle, can be recycled forever, although some contaminants such as copper can make this challenging. Steel scrap is processed in an electric arc furnace to make secondary steel.

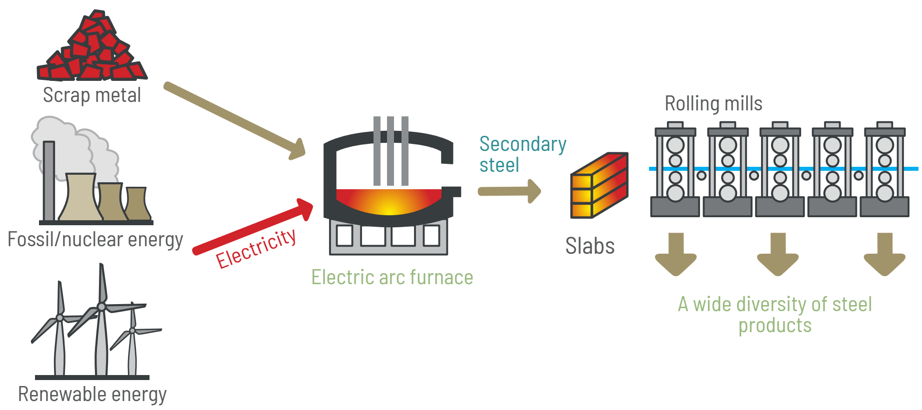

Figure 2 – Basics of electric arc furnace steelmaking

DECARBONISING IRON AND STEEL PRODUCTION

Up until now, making iron from iron ore has relied on fossil-gas or coal feedstock, and most emissions result from these primary ironmaking processes. Coal or gas are not only used as fuel, as the iron-making process needs the carbon in the coal or gas to react with the iron ore to transform it into raw iron. Primary steelmaking has thus been called a 'hard-to-abate' sector – an industry in which it is difficult to eliminate or significantly reduce greenhouse gas emissions. Producing steel has historically emitted a lot of CO_2, about 2.2 tonnes for every tonne of steel.

Green hydrogen can be used instead of coal or fossil gas to make iron from iron ore. When this hydrogen reacts with the iron ore, it produces iron and water, with no CO_2. Green hydrogen is made by using renewable energy to split water into hydrogen and oxygen in an electrolyser. Using renewable energy in the electric arc furnace to produce secondary steel can virtually eliminate CO_2 emissions, as they are mainly from the electricity used. In South Africa these emissions, primarily from burning coal in power stations on the Eskom grid, amount to about 0.5 tonnes of CO_2 per tonne of steel.

Although the technology exists to reduce CO_2 emissions from blast furnaces/basic oxygen furnaces by capturing the CO_2 and either using it in industry or storing it, this technology remains to be proven in industry. Also, as it is not possible to capture all emissions from blast furnaces/basic oxygen furnaces, they cannot be employed for zero-emissions primary steelmaking, whereas DRI furnaces can.

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AMSA PRIMARY AND SECONDARY STEEL DECARBONISATION ROADMAP

This policy brief assesses the five decarbonisation initiatives proposed in AMSA's Decarbonisation Roadmap:

1. Short-term 'no regrets' improvements: simple and immediate changes that offer benefits with no drawbacks.
2. New Electric Arc Furnace to be installed in 2027.
3. Blast Furnace Changes
4. Renewable Energy
5. Upgrade the Saldanha direct reduced iron plant to use green hydrogen (GH2DRI).

1. SHORT-TERM 'NO REGRETS IMPROVEMENTS' - SIMPLE AND IMMEDIATE CHANGES THAT ARE FINANCIALLY BENEFICIAL WITHOUT ANY DRAWBACKS

AMSA Decarbonisation Roadmap plans

These involve small technical improvements, like making operations and energy use more efficient, using more sinter (iron ore mixed with other materials), and increasing the use of scrap metal. These changes will save money, and as an additional benefit, also reduce emissions.

Commentary: Benefits, costs, and risks for frontline communities

Although these initiatives don't have obvious negative impact, they also won't have any significantly positive impact on frontline communities beyond slightly less local pollution.

2. NEW ELECTRIC ARC FURNACE TO BE INSTALLED BY 2027

AMSA Decarbonisation Roadmap plans

- This project is already in progress using established technology.
- Existing Vanderbijlpark electric arc furnaces use iron from coal-DRI kilns, which are prolific polluters. The AMSA roadmap includes increasing these kiln operations to feed the new electric arc furnace.
- Data on the mix of iron from coal-direct reduction furnaces kilns and scrap metal for the existing and new electric arc furnaces is not available, so the ratio of primary to secondary steel production is unknown.

Commentary: Benefits, costs, and risks for frontline communities

Finance: The main cost is the capital investment, an estimated ZAR 10 billion for a 1.7-million-tonne-per-year furnace.

Local jobs/economy: The new electric arc furnace will create new jobs directly at AMSA, and indirectly through increased electricity demand. However, as this electric arc furnace can be seen as replacing one blast furnace, the jobs lost at the blast furnace could potentially result in an overall decrease in jobs at AMSA Vanderbijlpark steel production.

Local and global environment: The electric arc furnace, which can achieve very low pollution levels, will replace a high-pollutant blast furnace, decreasing overall AMSA emissions. However, the pollution from coal-DRI kilns feeding primary iron to the electric arc furnace will remain the same or possibly increase, and the difference in pollution levels between the blast furnace and coal-DRI kilns is not known. The AMSA roadmap states that it will reduce carbon emissions by about 1.2 million tonnes per year, which is equivalent to about 10 % of AMSA's current total emissions.

National economic costs and benefits: Producing primary steel adds more value to the national economy than producing secondary steel. However, as we don't know the proportions of coal-DRI iron and scrap used, the impact on the national economy is unclear. South Africa needs primary steel for basic economic growth, and so maintaining production volumes with the new electric arc furnace at AMSA Vanderbijlpark is important for local and national industrial economies. Consideration of national benefits is included because ultimately these are required for local frontline communities to prosper.

3. BLAST FURNACE CHANGES - CONVERT FURNACE D TO A LOW-CARBON BLAST FURNACE AND CLOSE BLAST FURNACE C

AMSA Decarbonisation Roadmap plans

- Pause blast furnace D in 2027 and convert it to a low-carbon furnace by 2030. This new furnace might use fossil gas and hydrogen, and capture CO_2 for use by Sasol.
- Close blast furnace C in 2030.
- Overall, from 2027–2030, AMSA Vanderbijlpark will replace two old blast furnaces with one low-carbon blast furnace and one electric arc furnace. Steel-production capacity should stay the same or increase slightly.

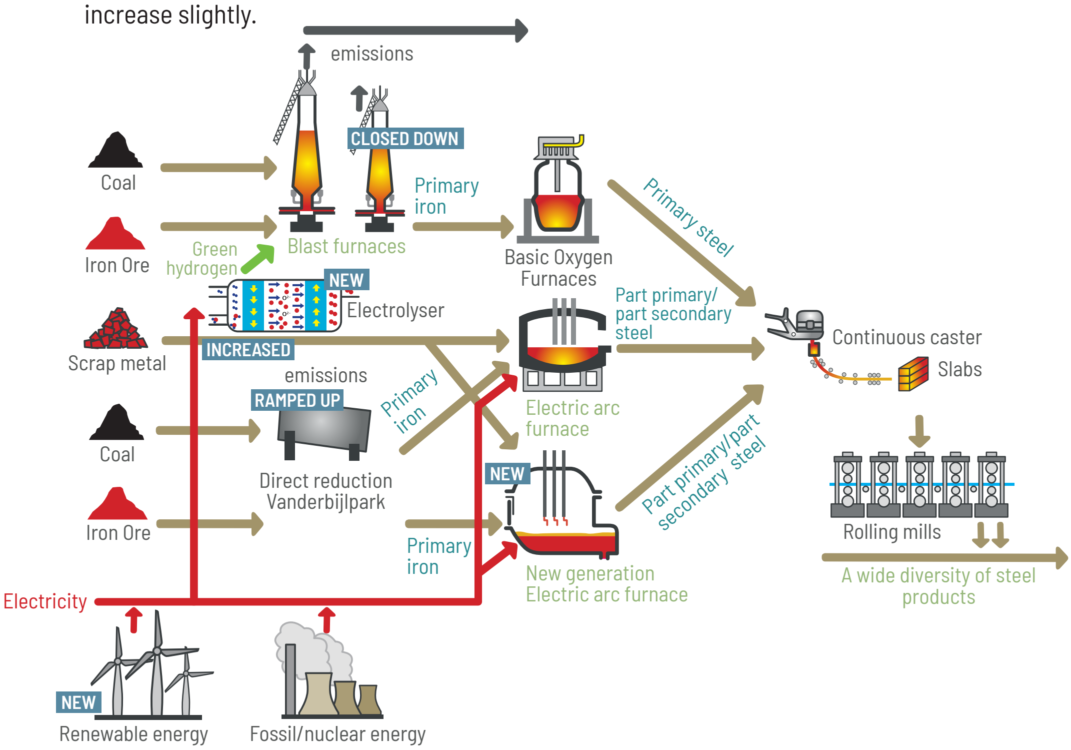

Figure 3 - AMSA Vanderbijlpark coal-DRI, blast furnace, and electric arc furnace configurations before and after 2027-2030 decarbonisation transitions

Commentary: Benefits, costs, and risks for frontline communities

Technology and investment: Low-carbon furnaces are new, untested technologies. Their performance, results, and costs are unknown.

Local industrial economy: Steel production in the local area won't change much. Building the electric arc furnace and converting the blast furnace will create local engineering and construction jobs.

Local operational jobs: While blast furnace D is paused, the number of jobs at both this furnace and related production chains will drop significantly. The job losses will likely exceed the new jobs created by the electric arc furnace. When blast furnace D reopens, blast furnace C will close, meaning that the number of jobs overall will remain lower. There will be overall job losses in the blast furnaces and their supply chains, especially for coal, when the new electric furnace is introduced.

National economy: There will be a shift towards making more secondary steel, which adds less economic value because it doesn't use local iron ore. The exact impact is unknown because the mix of coal-DRI and scrap used in the electric arc furnace is unknown. South Africa doesn't have enough scrap to meet its steel-production needs, so either imports or more local primary ironmaking at Saldanha will be needed.

Local and global environment: Pollution and greenhouse gases from blast furnace D will stop temporarily. When blast furnace C closes and D restarts as a low-carbon furnace, the change in pollution levels will be dependent on the performance of the new, untested technology.

4. RENEWABLE ENERGY

AMSA Decarbonisation Roadmap plans

- Add 250 MW of renewable energy generation soon. This project is already underway. Add another 200 MW after 2030.
- Use power purchase agreements (PPAs) with independent power producers (IPPs) to get more renewable energy.

Commentary: Benefits, costs, and risks for frontline communities

Potential direct economic benefit: Electricity contracts (PPAs) could include partnerships with local communities, possibly sharing extra electricity with, for example, the municipality. AMSA would need to work actively on such initiatives.

Indirect economic benefit: If South Africa makes the equipment for renewable energy projects, the manufacturing process could boost local industry and the economy, benefiting local communities.

Local environment: Using less grid electricity would mean burning less coal, reducing emissions from coal power plants. This would help local communities near coal plants like Lethabo. Less coal use also means less environmental damage caused by coal mining.

Global environment: Emissions will be reduced.

5. CONVERT SALDANHA PLANT DIRECT REDUCED IRON PLANT TO GREEN HYDROGEN

AMSA Decarbonisation Roadmap plans

- AMSA has a mothballed plant at Saldanha that uses iron ore and coal in a Corex furnace and makes iron in a Midrex DRI furnace. These two iron streams are then combined in a Conarc furnace to make steel (Figure 1b). There are two options for this plant.
  - **Option A:** AMSA is looking at converting the Midrex DRI furnace to use fossil gas and hydrogen gas instead of Corex gas. Fossil gas will have lower emissions than Corex, and using only hydrogen gas could make the process almost emission-free.
  - **Option B:** AMSA might restart the original Corex/Midrex plant and gradually introduce carbon capture and fossil gas, followed by green hydrogen gas.
- Decisions have not been made yet about which option to choose or when to implement the chosen option. The timing and degree of process-shift required for carbon capture and green hydrogen are also unknown.

Commentary: Benefits, costs, and risks for frontline communities

Finance: Investment costs required for the various options are very uncertain. A new green iron plant, including DRI furnace, electrolyser, and solar power supply, would cost about US$800 million (ZAR 16 billion), with half of this required for the new solar power supply.

Direct economic benefits: Both options offer substantial benefits to local communities and the Saldanha economy. Restarting the plant could recover about 500 jobs at the Saldanha plant and around 400 contractor jobs lost when it was mothballed. This would boost the local economy and create expansion opportunities.

Indirect economic benefits: Green hydrogen needs renewable energy, which has two potential benefits. Partnering with local communities for renewable energy generation would be beneficial; moreover, if South Africa manufactures equipment for renewable energy, this could boost local industry, especially if industries are located in Saldanha or nearby areas like Atlantis.

National economic benefits: As the world phases out fossil fuels, choosing the full green hydrogen option could lay the foundation for South Africa's green re-industrialisation, leveraging its competitive iron ore and renewable energy resources.

Local environment: The costs, risks, and benefits vary widely depending on the chosen option and the phase-in rates of carbon capture and green hydrogen. If option B (the Corex+Midrex option) is selected and the plant is restarted without initial carbon capture or gas, there will be significant local emissions. Conversely, if the full green hydrogen option (option A) is chosen from the start, there could be minimal emissions, with only iron-oxide dust (red dust) to manage. If using hydrogen, the Midrex furnace can be run on its own to produce solid iron that can be transported long distances before being made into steel, instead of the traditional process of making iron and steel within a single plant.

Water demand: Overall, much less water will be necessary if the green hydrogen option (A) is chosen over the Corex option (B). In this scenario, the highest demand for water (i.e., no recovery/water-recycling) is negligible compared to the present water consumption level. In principle, it is possible to recover all the water produced in the DRI furnace and recycle it back to the electrolyser, enabling an effectively closed cycle and hence close to zero water consumption with no waste water.

Global environment: Green hydrogen direct reduction of iron is supported by the European Union (EU) as the most promising solution for steel sector decarbonisation. Saldanha could become a leading plant in the move to restructuring the global steel industry to achieve the effective and rapid decarbonisation that is required to meet the Paris Agreement goals.

SUMMARY AND ACTION

- It's crucial for economic recovery, re-industrialisation, and the prosperity of frontline communities and South Africa as a whole to recover, maintain, and grow the South African iron and steel industry. Frontline communities need to consider their actions in this overall context.
- Maintaining production at AMSA Vanderbijlpark is very economically beneficial but pollution levels and the potential for full decarbonisation are concerns. If the low-carbon blast furnace doesn't work out, they may need to consider more DRI furnaces at Saldanha and/or electric arc furnaces at both Vanderbijlpark and Saldanha to maintain and increase South African steel production levels.
- Investing in direct reduction of iron, electric arc furnaces, blast furnaces, and renewable energy at the Saldanha and Vanderbijlpark plants can benefit frontline communities. Industries connected to steel production also have the potential to benefit frontline communities significantly. This includes industries making renewable energy equipment and fabricating metals (including structural metals), and the automobile industry. Government needs to integrate industrial policies to enable this.
- For green iron and steel exports, the government must address challenges related to subsidies that benefit green steel producers in other countries and related trade defence measures. South Africa needs to protect local investments from unfair competition.
- Exporting green direct reduced iron has minimal negative impact and offers many benefits for frontline communities.
- The new generation electric arc furnace may result in fewer jobs compared to blast furnaces, but jobs in renewable energy will become more sustainable if components are locally manufactured. Vanderbijlpark and Saldanha are suitable for manufacturing renewable energy equipment. Even if the government doesn't incentivise this, it could be part of AMSA's Just Transition (JT) efforts.
- There will be significant environmental benefits from replacing the blast furnace with an electric arc furnace, both at the blast furnace site and along the coal-supply chain.
- The 'green blast furnace' could still have a negative impact on the upstream coal supply chain and other environmental issues if emissions reductions are low (there is little information and huge uncertainty about this technology), unless the project mitigates these impacts.
- Green hydrogen direct reduction of iron is the most promising technology (with minimal negative impact) for expanding primary iron manufacturing, and hence for primary steel and many linked industries which remain critical for South Africa's development needs.

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