Investigation into the South African steel market's preparedness for decarbonization and the purchase of green steel

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A research project submitted to the Faculty of Commerce, Law and Management, University of the Witwatersrand, in partial fulfilment of the requirements for the degree of Master of Business Administration

Johannesburg, 2024

Abstract

The study discusses a South African steel company's effort to integrate sustainability into its business model and strategic planning in response to the Paris Agreement and the global steel industry's goal of achieving net-zero emissions by 2050.

This objective may be attained by: pursuing circular economy and enhancing steel recycling activities via an electric arc furnace coupled with renewable energy sources; retrofitting existing blast furnaces followed with the deployment of carbon capture and usage (CCU) technologies, and the expansion of hydrogen-based direct reduced iron (DRI) production alongside the utilization of renewable energy sources.

However, there are risks that could hinder these goals, such as the continuous load shedding crisis, unfair trade policies and application of economic instruments, supply chain disruptions, and inadequate support for renewable energy. The industry faces financial and environmental pressures, and there is a need for government intervention through fair policies and incentives. Concerns are raised about the government's capabilities and priorities in implementing decarbonization policies and navigating the energy transition.

Collaboration and funding opportunities are crucial for sustainability. The integration of carbon capture usage and storage technology is seen as risky by some experts, and more research and development is needed. This is concerning considering the net-zero timeline.

Currently, there is little demand from industries to purchase green steel, emphasizing the need for product differentiation, improved marketing strategies and consumer awareness. Policymakers should reform policies to align with the net-zero emissions target to prevent the fall of the steel industry and the impact on the South African economy.

Acknowledgements

I would like to express my deepest gratitude to my advisors, Dr Bruce Young, Professor Diane Hildebrandt and Dr Lehlohonolo Tabane for their support, guidance and expertise throughout the research. Their invaluable insights and encouragement have been instrumental in shaping this thesis.

I am grateful to all the participants who generously provided their time and shared their knowledge and experiences, without whom this research would not have been possible.

My sincere appreciation goes to my family and colleagues for their unwavering support and encouragement. Their belief in me and their understanding during the demanding times of this research journey have been a constant motivation.

Finally, I would like to acknowledge my company for the financial support which enabled me to pursue my studies and complete this thesis.

Declaration of generative AI in scientific writing

While preparing this work, the author employed ChatGPT (OpenAI) and Gemini Google to assess and evaluate the paper, highlight areas in need of improvement, and enhance the clarity and coherence by rephrasing and restructuring selected paragraphs, all while preserving the original meaning and context. Subsequently, the author reviewed and edited the content as necessary, bearing full responsibility for the core ideas, research, analysis, conclusions, and overall content of the manuscript.

Keywords

Carbon neutral steel
Decarbonization
Premium steel
Green steel
Sustainable
Electric Arc Furnace
Direct Reduced Iron
Blast Furnace
Fossil fuels
Greenhouse gases

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List of Acronyms

BF - Blast Furnace

BOF – Basic Oxygen Furnace

DRI – Direct Reduced Iron

EAF – Electric Arc Furnace

DR(CH4)/EAF – Direct Reduction of Iron using methane, followed by Electric Arc Furnace

DR(H2)/EAF – Direct Reduction of Iron using Hydrogen, followed by Electric Arc furnace

GDP – Gross Domestic Product

GHG – Greenhouse gas

SDG – Sustainable Development Goals

1. Introduction

1.1 Statement of Purpose

This study is a qualitative analysis aimed at examining the advancements of the South African steel industry in meeting climate action objectives and assessing its preparedness to purchase environmentally sustainable green steel.

1.2 Background

To tackle climate change and amplify measures to reduce carbon emissions, member nations of the United Nations Framework Convention on Climate Change (UNFCCC) collectively ratified the Paris Agreement in 2015 (Falkner, 2016).

This agreement aims to keep the rise in global temperatures below 1.5°C by the year 2050. It anticipates active collaboration among all participating countries to achieve this objective, with developed nations providing support to their developing counterparts (Falkner, 2016).

According to the World Steel Association (2023), the global steel industry was responsible for emitting 7% of the world's anthropogenic greenhouse gases (GHGs) in 2020. The industry is one of the most significant users of coal within the industrial sector, fulfilling approximately 75% of its energy requirements. Coal is used to generate heat and produce coke, which serves as both a fuel and an agent for reducing iron ore in the steel making process (IEA, 2020).

Industry leaders across the steel value chain have formed a collaborative venture known as the Mission Possible Partnership, with a unified commitment to achieving net-zero emissions by the year 2050. To realize this ambitious goal, the partnership acknowledges the need to reduce emissions directly emanating from the steel sector by a substantial 90%, relative to the figures of 2020, by the mid-century mark (OECD, 2023). This considerable challenge indicates the road ahead will require significant effort and indicates that the net-zero emissions objective will be transformative for the steel industry, necessitating a profound and widespread restructuring.

Key environmental considerations driving advancements in the steel industry include the use of scrap steel recycling, the adoption of low-carbon technologies for primary steelmaking, and effective carbon storage strategies, according to the World Steel

Association (WSA, 2023). Steel production can be achieved through one of the following three primary methods:

a) The Blast Furnace-Basic Oxygen Furnace (BF-BOF) process, in which iron ore is transformed into molten iron within a blast furnace. This molten iron is then processed into crude steel in the Basic Oxygen Furnace (BOF). This method accounts for approximately 70% of steel production globally and has an estimated carbon footprint of 2.3 tonnes of carbon for every tonne of crude steel produced (WSA, 2023).

b) The Electric Arc Furnace (EAF) technique, which employs electricity to melt scrap steel. It is responsible for about 25% of steel production globally and produces approximately 0.6 tonnes of carbon per tonne of crude steel (WSA, 2023).

c) The Direct Reduced Iron-Electric Arc Furnace (DRI-EAF) process offers an alternative approach by reducing iron ore without melting it, using a mixture of hydrogen and carbon monoxide derived from natural gas. The output, which is direct reduced iron, is then input into the EAF. Although this route constitutes only 5% of steel production globally, it results in the emission of about 1.4 tonnes of carbon per tonne of crude steel (WSA, 2023).

The shift toward carbon-neutral production methods has increased the requirements of hydrogen, electricity, and natural gas, necessitating the integration of alternatives like sustainable biomass, renewable energy sources, and advanced technologies for carbon capture, transportation, and storage, as depicted in Figure 1.

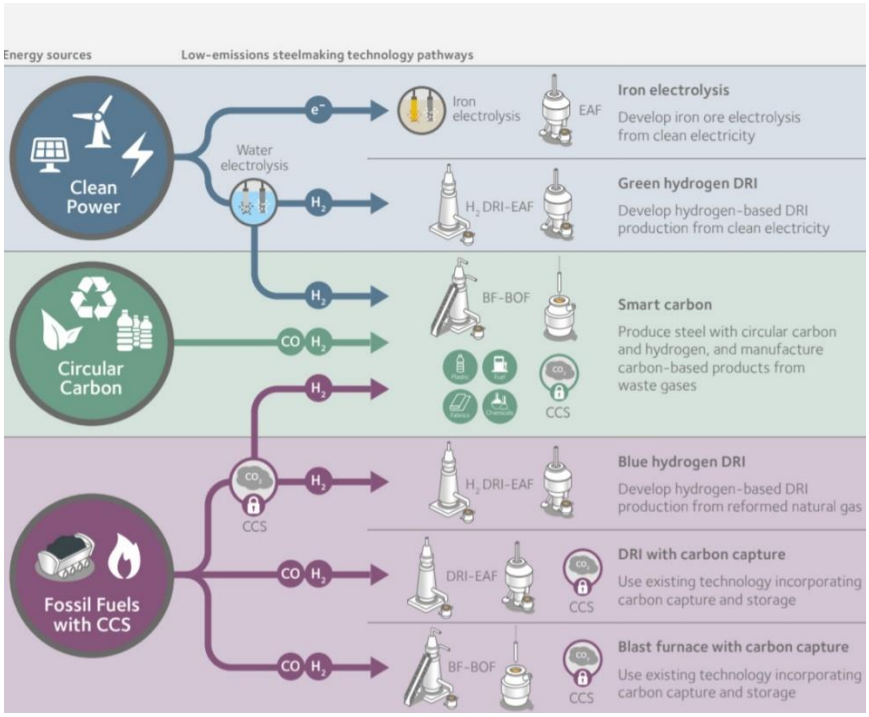


Figure 1: Low emission steelmaking technology pathway. Source: ArcelorMittal Climate Action Report (2019)

Such a transformation entails a substantial capital investment, as noted by Quader, Ahmed, Ghazilla, Ahmed, Dahari. (2015).

The South African economy faces considerable challenges in rebounding from the consequences of the COVID-19 pandemic, fluctuations in exchange rates, disruptions in the global supply chain, surges in commodity prices, natural catastrophes, labour strife, power shortages, water shortages and high unemployment rates. According to the African Development Bank (2024), the economy is expected to achieve a growth rate of 1.7% in 2024, following a modest recovery of 1.5% in 2023 (Automobil, 2024). However, it is predicted that the growth will continue to underperform due to ongoing electricity supply challenges, low business confidence, increasing interest rates and subdued global demand (Automobil, 2024). Data indicates that both South Africa's fiscal deficit and current account deficit are projected to exceed the global average. This indicates the country's necessity for fiscal consolidation, revenue mobilization and external financing.

In addition, the steel industry in South Africa faces numerous obstacles, including high input costs, significant energy price surges, electricity shortages, problems with rail service delivery, internal plant reliability problems, and intense competition (Pelser, 2019). The announced closure of the Long products division by a major steel company in South Africa in November 2023 was primarily influenced by load-shedding, logistics bottlenecks and unfavourable scrap pricing. Consequently, this decision was expected to have a ripple effect on the economy (Arnoldi, 2024).

Major steel producers in South Africa, such as ArcelorMittal South Africa, Columbus Stainless, Unica and Cape Gate are currently facing significant difficulties in maintaining their operations. These companies are urgently appealing to the government for resolution of supply chain constraints and the establishment of a fair-trade policy framework to revive the beleaguered steel industry.

Moreover, the SAISI data (Korombo, 2024) confirms that the local steel demand has experienced a decline in recent years, currently standing at less than 5 million tonnes. This significant decrease has been coupled with a rise in imports and a decrease in

exports. Consequently, the steel industry has been compelled to undergo rationalization and pursue greater levels of diversification.

Another looming economic crisis in South Africa is the supply of natural gas which is expected to reduce dramatically by 2026 (Bloomberg, 2023). Steel industries supplementing by-product fuels with natural gas face a termination of gas supply. Consumers grapple to find alternatives and relook at their business model as it is foreseen to have a huge cost and technology impact.

Therefore, attaining a net-zero status necessitates strong collaborative efforts among the government, financial institutions, and strategic partners or else the target might prove unattainable within the given timeframe.

While a variety of technologies are known, their actual deployment hinges on the availability of capital and reliable experimental work. It also requires accessible resources such as labour, contractors, consultants, infrastructure, equipment, and compliance with trade and environmental regulations (Papadis and Tsatsaronis, 2020). Companies with a solid credit standing may seek funding from financial institutions. These institutions adhere to the Equator Principles (EPs), which are a risk management framework used to fund large-scale infrastructure, mining, and energy projects. This framework is upheld through standards established by the International Finance Corporation (IFC) and a consortium of commercial banks (The World Bank, 2023) to ensure support for social and environmental concerns.

Attaining the status of green steel is undoubtedly a key factor in enhancing sustainability. It is however essential to account for the market's acceptance of and willingness to pay for the higher-priced green steel (Muslemani, Liang, Kaesehage, Ascui, Wilson, 2021). The efficacy of carbon emission reduction in the steel industry hinges on a comprehensive transformation across the entire supply chain.

Sustainability indicators for operational practices can be outlined by measurable decreases in greenhouse gas (GHG) emissions, volatile organic compounds, water

consumption, as well as landfill and hazardous waste generation, coupled with rigorous efforts to conserve natural resources (Strezov et al., 2013).

Achievement of this goal must occur within a framework that ensures continued market competitiveness in terms of cost. As steel is a globally traded commodity that faces intense competition, producers are not only competing with one another but also with other high-emission, intensive products that may be available at lower prices. Consequently, green steel may have to leverage product differentiation as a competitive strategy (Haudi et al., 2020).

Moreover, green steel's appeal may be initially limited to consumers who prioritize environmental considerations. Therefore, steel producers must gain a deep understanding of the evolving values consumers hold in these progressive times. By adopting a strategy that aligns with these values, producers can secure a sustainable competitive advantage (Muslemani et al., 2021).

The study by Muslemani et al. (2021) suggests that the appeal of green steel production could be confined to local markets, due to varying policy landscapes on a global scale. It highlights that for a thriving green steel market, alignment and support among producers, consumers, and governments are essential. Confidence among producers in their competitive edge can lead to differentiation in their products and the optimization of production routes (Muslemani et al., 2021). Nonetheless, such developments are typically driven by existing demand or needs within the market.

The study prompts consideration of the government establishing benchmarks for green steel to boost its market demand. If these standards are implemented, green steel production could become the norm, as manufacturers may find it uneconomical to produce steel through various methods to satisfy different customer requirements. Furthermore, this would intensify competition among steel producers as they strive to achieve recognition for their green steel initiatives (Muslemani et al., 2021). This could be more applicable to the European landscape but fair differently locally.

The research by Muslemani et al. (2021) mentioned also demonstrated that green steel could not only rival conventional 'brown' steel but also potentially displace lower-carbon alternatives such as cement in construction, aluminium in automobile manufacturing, and plastics in packaging. However, if the latter had to adopt environmentally-friendly practices in their industries, it could reduce the overall demand for steel (Larsson and Smith, 2022).

One potential strategy for green steel manufacturers might be to concentrate on a customer base that is unable to replace steel with different materials. To capitalize on environmental conscientiousness, these steel producers might need to position themselves in a specialty market where consumers are willing to pay a higher price for the sustainable attributes of green steel.

1.3 Research Problem

The steel industry faces a critical challenge: achieving net-zero emissions while maintaining business viability in a context of declining demand, potential gas shortages, and uncertain market acceptance for higher-priced green steel. This complex transformation requires significant capital investment and is further hindered by a lack of supportive policies and limited global alignment on climate goals. Given these challenges, it is crucial to investigate the South African steel market's prioritization of climate goals and its adaptation strategies in the face of mandated emission reductions. This analysis is particularly relevant considering the significant economic and industrial constraints faced by the country.

1.4 Research Questions

- How is the steel market in South Africa progressing to meet climate goals set for the global steel industry?
- How do current steel customers perceive value from green steel?
- How can sustainable business models influence future demand of green steel?

1.5 Research Objectives

To evaluate the preparedness of South Africa's steel industry in reaching net-zero emissions, and to ascertain the potential demand for eco-friendly 'green steel,' both immediately and in the future, the following factors must be carefully analysed:

- The strategic management techniques being utilized to facilitate the development of a business model centred on the production of green steel.

- The specific strategies being executed, as well as their congruence with climate action objectives, including the technological solutions to be adopted and the projected timeline for their implementation.

- The perception of consumers regarding the benefits that green steel brings and its implications for their businesses.

1.6 Justification/Rationale of the Study

The steel industry is facing numerous challenges that make achieving net-zero emissions difficult. These challenges include a global recession, electricity shortages, wage strikes, subpar rail service delivery, and high input costs. The volatility of the steel industry also affects the South African economy, as disruptions in the industry can have a domino effect on other sectors. However, there is a lack of understanding about the intentions and necessary support for the local steel industry in achieving climate action objectives. This study aims to explore the strategic management practices of the steel industry and understand customer perspectives for green steel. The findings of this study can inform industry stakeholders and policymakers in working towards a sustainable future for South Africa.

1.7 Delimitations of the Study

This investigation focuses on the usage of steel in the formal steel sectors in South Africa which includes automotive, construction, and infrastructure. The construction and infrastructure sectors have a 52% share of global steel consumption, while the automotive industry also utilizes 12% of total steel (Statista Research Department,

2023). The study will involve conducting interviews with key role players in Strategy, Technology, and Marketing departments to gain insights into their organizations' strategies, business models, and efforts towards decarbonization. The discussions will also explore advancements in the development of eco-friendly 'green' steel.

1.8 Operational Definitions

Blast Furnace	Metallurgical furnace to convert iron ore into liquid iron (World Steel Organization, 2023). 70% of steel is made utilizing the Blast Furnace process. Part of the primary steelmaking route.
Decarbonization	All measures taken by an organization to reduce its carbon footprint, primarily its greenhouse gas emissions to reduce its impact on the environment (Engie, 2021).
Direct Reduced Iron	Process using hydrogen and carbon monoxide to remove oxygen from iron ore (Quader et al., 2015). Generally followed by the EAF.
Electric Arc Furnace	Furnace that heats iron and scrap with high powered electric arc (World Steel Organization, 2023). Estimated 25% of steel production is via this route (Quader et al., 2015). Part of the secondary steel making route.

Green Steel	Steel produced through manufacturing with lower or even zero carbon dioxide emissions (Green Steel World, 2023). There is no standard yet defined for green steel.
Renewable energy	Energy derived from natural resources. Examples include wind, wave and tidal, photovoltaics (PV) and biomass energy (Gross et al., 2003).
Sustainable Steel	Cost efficient steel manufacturing through the reuse of steel (scrap) and via less carbon intensive process (Steel facts: Sustainable Steel, 2023).

1.9 Assumptions

The assumption is that steel customers within the construction and automotive sectors in South Africa align closely with the steel industry's green economy initiatives. Additionally, there is an expectation that the marketing department is proactively engaged in cultivating a market for environmentally-friendly steel. It is also anticipated that the company will demonstrate openness and transparency concerning its strategic plans and the progress toward achieving its milestones.

1.10 Chapter Outline

The project will follow a structured format and begin with an introduction to the research topic, outlining the aims and objectives. A critical review of relevant literature will identify research gaps that the study aims to address. A conceptual framework will be formulated to guide the methodology and research design. Data will be collected and analysed using specific qualitative research methods. The study will conclude with a synthesis of key findings and recommendations.

2. Systematic Review of Literature

2.1 Introduction

The literature review explores the challenges faced by the steel industry in meeting the commitments of the Paris Agreement. It looks at the changes needed in the steel supply chain and assesses the market's readiness for producing eco-friendly steel. It also presents the theoretical foundation for the research.

The global steel industry is moving towards sustainable and low-carbon production methods (AM CAR, 2019). The production of high-quality green steel, which uses low-carbon emission technologies and renewable energy, is seen as an effective way to reduce the sector's carbon footprint. However, there are obstacles preventing the widespread adoption of green steel in the market (Muslemani et al., 2021).

2.2 Empirical Research

Reducing carbon emissions from steel mills can be achieved by decreasing production, enhanced recycling of steel, and technological innovation in steel manufacturing (Quader et al., 2015). However, given the steady growth in steel consumption alongside the shortage of high-quality, cost-effective steel scrap, the development and implementation of ground-breaking carbon dioxide (CO_2) reduction technologies appear to be the only viable option. As per the ArcelorMittal Climate Action Report (2019), steel demand is projected to increase to 2.6 billion tonnes by 2050, up from 1.7 billion tonnes produced in 2018, making it crucial to deploy less emissions-intensive technologies to achieve the targeted reductions by 2050.

Unfortunately, the majority of new or renovated steel facilities still rely on blast furnace-basic oxygen furnace (BF-BOF) method, posing a challenge to decarbonization goals. These facilities are expected to last 20-25 years (Yu et al., 2021). This scenario heightens the danger of creating stranded assets unless Carbon Capture Utilization and Storage (CCUS) technologies are implemented (OECD, 2022). However, Muslemani et al. (2021) emphasizes that these technologies remain undeveloped and

in the research phase. This is further corroborated by GeoEngineering Monitor (StormGeo 2024) describing it as risky and unproven.

According to the International Energy Agency (IEA, 2020), there is a growing emphasis on reducing the demand for steel by exploring alternative materials. In the automotive industry, the demand for steel can be reduced by switching to high-strength, lightweight steel alternatives, which offer the same functionality while using less material. Additionally, steel can be replaced by lighter options such as aluminium, plastics, and, to some extent, carbon-reinforced polymers, according to a report by the International Energy Agency (IEA) in 2020.

However, steel remains the material of choice due to its longevity throughout its lifecycle and its ability to be recycled without diminishing its functionality or quality, as noted by the South African Institute of Steel Construction (SAISI, 2024).

The importance of urgent action to accelerate decarbonization was underscored by the OECD in 2022, highlighting that COP26—the 26th Conference of the Parties to the United Nations Framework Convention on Climate Change (UNFCCC), which convened in 2021— by intensifying calls for the immediate activation of Breakthrough Agenda initiatives. This urgency was reiterated at COP27 to hasten the implementation process. The current decade is pivotal for developing ground-breaking technologies and accomplishing substantial milestones in carbon reduction.

Papadis & Tsatsaronis (2020) argue that achieving total global decarbonization within the twenty-first century appears improbable due to a multitude of barriers. These include the substantial capital investments required and the delay in reaping the associated benefits. Additionally, governments often place a higher priority on a range of social and economic issues over environmental concerns. This can be expected in South Africa.

The inconsistency of environmental policies, combined with the potential for political manoeuvring and corruption, can hinder policy enactment and even roll back advancements made in decarbonization efforts. Furthermore, the authors note that

there is currently a lack of willingness among individuals to change their lifestyles and business practices to reduce energy consumption.

The steel industry has been increasingly committing to net-zero emission targets, as highlighted by a 2022 OECD report. Nevertheless, there is a noticeable disparity between the net-zero ambitions pledged by corporations and those endorsed at a national level. By the conclusion of 2021, firms accounting for 30% of worldwide steel production had established objectives to achieve net-zero emissions—a figure that had grown twofold by 2022. To bridge the gap between high-reaching goals and concrete commitments, it is vital to secure additional pledges.

Despite the challenges, there are encouraging developments in the creation of technologies that approach zero emissions. These initiatives are characterized by their lofty objectives and a nascent degree of industrial maturity, suggesting that substantial technological advancements are crucial. To reach the formidable goal of net-zero emissions by 2050, significant innovations in technology are essential.

The decarbonization strategies of individual companies are influenced by a multitude of elements, such as the age and geographical positioning of steel mills, as well as the innovative drive of their leadership in pioneering new technologies. Additionally, the scale of the steelworks and their capacity for investment play crucial roles in the execution of decarbonization efforts. The convergence of these factors signifies that each company's approach to establishing a low-carbon business model and its corresponding investments is likely distinctive, often managed through a series of gradual initiatives (OECD, 2022). This highlights the necessity of adopting a tailored approach to ensure successful decarbonization.

To meet emission reduction targets and lessen the likelihood of stranded assets, extensive renovations or the premature closure of facilities and infrastructures are necessary. These measures, compounded by the hefty expenses associated with decarbonization, could adversely affect the workforce and the communities surrounding the industry. Given the current configuration of assets, devising tailored strategies for managing existing facilities and infrastructure becomes crucial (OECD,

2022). Additionally, the major elements influencing steel production costs include the method of production and input material expenses, such as coal, iron ore, scrap, and energy, which are estimated to account for 60-80% of the total costs (IEA, 2020).

A European techno economic study was performed to determine the crude steel production costs for the three major production routes and is presented in the below Figure 2.

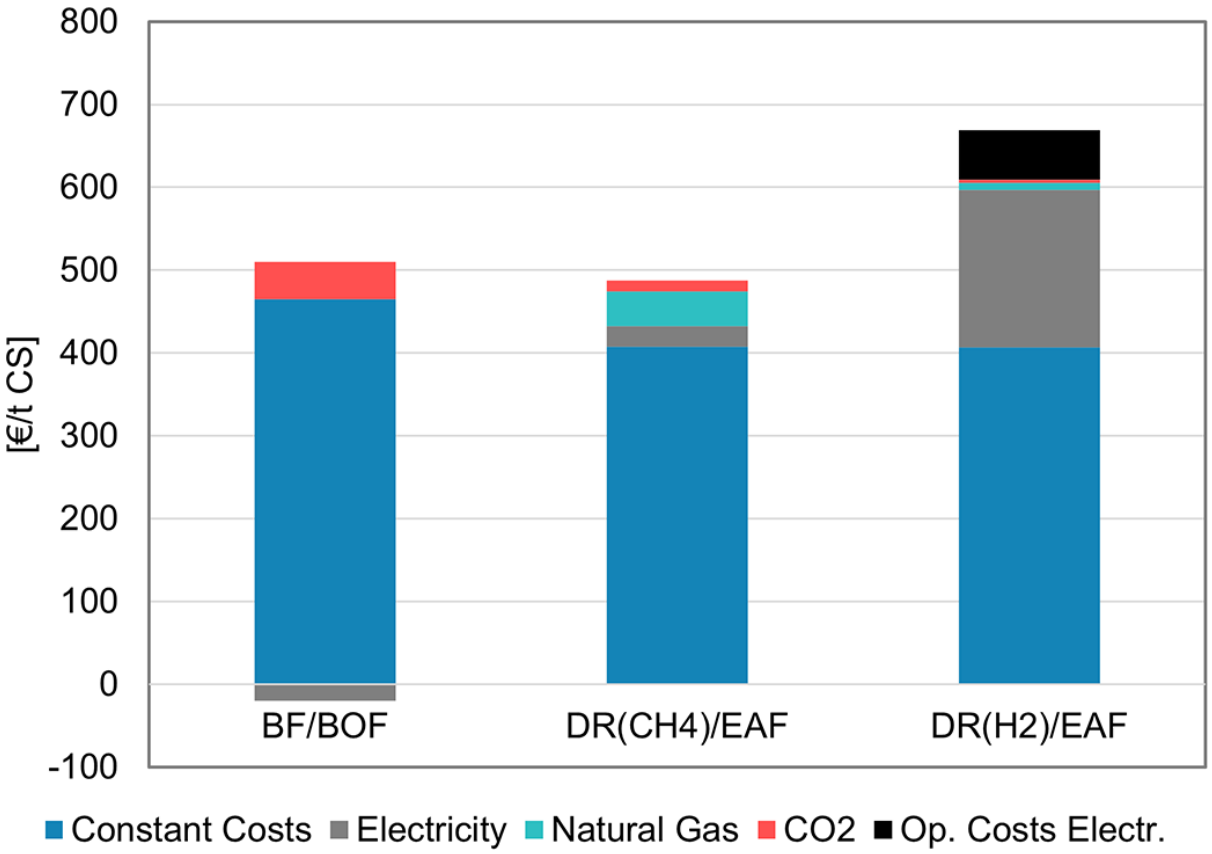


Figure 2: Crude steel cost overview. Source: Materiaux & Techniques (2021)

The research indicates that, within the framework of the existing economic climate, the Basic Oxygen Furnace (BF-BOF) process and the Direct Reduced Iron-Electric Arc Furnace (DRI-EAF) method utilizing natural gas incur roughly equivalent costs when producing crude steel. However, when the DRI/EAF process is powered by green hydrogen, there is a substantial cost increase of approximately 36% over the BF-BOF route. This augmentation is primarily attributed to the high expenses associated with the electricity required for the electrolysis process (Conde, Rechberger, Spanlang,

Wolfmeir, Harris, 2021). It is important to note that these cost analyses do not account for the capital expenditures associated with construction.

According to a 2022 report by the Organisation for Economic Co-operation and Development (OECD), over 60% of cutting-edge low-emission steelmaking projects are designed for industrial-scale operations and have not been implemented yet. The number of project announcements for industrial-scale plants has increased over the past three years, indicating a significant increase in the steel industry's commitment to decarbonisation. However, in a 2023 report, the World Steel Association referenced a roadmap released by the International Energy Agency (IEA) highlighting a potential shortfall in the industry's progress, once again emphasizing the urgent need for accelerated development of pioneering technologies.

For example, in 2018, ArcelorMittal's European division launched the Torero demonstration project in Ghent, Belgium, with an investment of €40 million. This project aims to convert 120,000 tonnes of waste wood into biocoal, which serves as a sustainable alternative to the fossil fuels traditionally used in the reduction of iron ore.

By March 2019, ArcelorMittal began investigating additional iron ore reduction technologies that leverage hydrogen and electrolysis. These methods could achieve considerable carbon emission reductions when powered by renewable energy sources. The company further underscored its commitment to sustainable practices by initiating a €65 million pilot project in Hamburg, Germany. This project is dedicated to testing hydrogen-based steelmaking on an industrial scale and is expected to produce 100,000 tonnes of steel annually, as per the ArcelorMittal Climate Action Report of 2019.

Muslemani et al., (2021) acknowledge that despite investment in research and development, substantial uncertainties persist regarding the economic viability of environmentally friendly steel manufacturing. Essentially, steel produced via low-emission processes is not yet financially competitive and relies on public assistance to be implemented. To address this, a conscientious phase-out strategy is

recommended to ensure that heavily polluting operations do not continue to function parallel to their low-carbon counterparts.
Quader et al., (2021) identify several barriers impeding technology implementation, including investor reluctance due to product uncertainties, prohibitively high innovation costs, limited access to funding, policies that fall short of meeting targets, and a lack of resources required to deploy and sustain technologies. Conejo et al., (in press) endorse low-emission technologies, offering vital information on energy output. However, they express scepticism regarding the presence of environmental policies within industries to back these technologies.

In Europe, ArcelorMittal's Climate Change Report (2019) indicates that the company advocates for the implementation of green border adjustments to ensure a level playing field. These adjustments serve as a policy tool designed to mitigate carbon leakage, a phenomenon where businesses relocate to areas with more lenient environmental law to circumvent higher compliance costs.

The Green Border Adjustment, also known as the Carbon Border Adjustment Mechanism (CBAM), is a form of carbon tariff applied to imported steel products, particularly from countries with less stringent environmental standards than their trading counterparts. This economic policy aims to encourage manufacturers to adopt more eco-friendly practices by equalizing the competition and mitigating the unfair advantage held by firms operating under lax environmental regulations. The income generated from this import duty could potentially fund national climate initiatives or assist developing nations in their efforts to shift towards a lower carbon footprint. According to Muslemani et al., (2021), such carbon adjustment strategies are more feasibly implemented in developed nations rather than developing ones, where imposing them may lead to a shift towards alternative products.

The OECD 2022 report cited the current carbon pricing mechanisms target less than only 20% of the global steel-making capacity and the price levels have not yet reached the threshold necessary to align with a net-zero emission trajectory by the year 2050. Governments have at their disposal several policy tools, including carbon pricing, energy taxes, and subsidies. Modifying these instruments could pave the way for achieving climate objectives. The OECD Taxation Working Paper No. 43 (date

unspecified) emphasizes the importance of communication between key stakeholders in garnering support for carbon pricing. Jakob *et al*, (2016) point out that revenue from carbon pricing could fund vital infrastructure investments — such as those in water, sanitation, electricity, telecommunications, and transport — thus promoting sustainable socio-economic development.

In South Africa, the Carbon Tax Act No. 15 of 2019 came into effect on June 1, 2019. This legislation encompasses two distinct phases. During the first phase, which runs until December 2025, an initial tax rate of R120 per tonne of carbon emissions is imposed, with an annual increase pegged to the Consumer Price Index (CPI) plus an additional 2% through the end of 2022. Afterwards, the rate will continue to rise in line with the annual CPI until the end of 2025, according to KPMG in 2023.

The details of Phase 2, scheduled to span from January 1, 2026, to December 31, 2030, remain unspecified, resulting in a state of uncertainty for businesses planning their future strategies. Dialogues with experts from the local steel industry have highlighted that the carbon tax is already imposing a substantial financial burden on companies.

Steel Market Views

Regarding market necessities, research conducted by Muslemani et al., (2021) revealed that essential elements in the steel supply chain include: government engagement via public procurement, regulatory mandates for major steel users, and the establishment of a verifiable standard for 'green' steel. These measures could facilitate increased demand for environmentally sustainable steel. Industry professionals from manufacturing and supply chain operations suggested that governments can enforce minimum green steel standards for public contract awards. Furthermore, they could impose requirements on certain industries to incorporate a stipulated quantity of green steel, whether applied to entire sectors or targeted at specific private enterprises within those fields, such as construction firms or automotive manufacturers.

Research indicates that steel manufacturers face challenges in absorbing the added expenses associated with transitioning to green steel production. Consumers display ambivalent attitudes towards buying green steel as opposed to its less environmentally

friendly counterpart, which still performs its intended function satisfactorily (Muslemani et al., 2021). This sentiment is in stark contrast to the overarching narrative of contemporary business articles that highlight current trends.
Nonetheless, there are segments within the construction and automotive industries, which are the main consumers of steel, that may show a readiness to incur higher costs for green steel, especially in certain end products.

Steel plays a pivotal role not only as a singular element in the construction of buildings but also in terms of its environmental impact. Consumers often focus on the energy efficiency of green buildings primarily during their operational phase, rather than throughout the construction process (Muslemani et al., 2021). While buildings constitute a modest portion of the broader construction industry, further research is merited to determine if this perspective is widespread.

The automotive sector is increasingly favouring green steel, driven by factors such as the higher ratio of primary steel used in car manufacturing compared to building construction, a simpler supply chain with fewer stakeholders than in the construction industry, and the marginal cost impact on the end product. According to Muslemani et al. (2021), although innovative production methods could raise steel costs by 20-40%, this translates to only a 0.5% increase in the price of a vehicle that typically contains 0.9 tonnes of steel. ArcelorMittal Europe is at the forefront, making strides with its high-strength, lightweight steel created using low-emission technologies tailored for the automotive sector, as highlighted in the ArcelorMittal Climate Action report (2019).
The automotive industry's progress in adopting cleaner technologies positions it at an advantage. Integrating green steel not only enhances its appeal but also boosts its operational efficiency.

2.3 Conclusion of Literature Review

There is a widespread agreement regarding the potential technologies that could be utilized by the steel industry. However, certain proposed technologies like Green Hydrogen production and Carbon Capture and Storage are still in the early stages of development. The availability of literature on the anticipated pricing of green steel is limited, possibly because it has not yet reached an advanced stage of production.

Consequently, only a few studies are able to validate that the steel market is willing to pay a premium for green steel.
The existing research on how the steel industry's transition to more sustainable practices will affect demand for green steel is not sufficient.
The studies highlight the importance of addressing policy shortcomings in achieving comprehensive decarbonization in all sectors, particularly in the steel industry. It emphasizes the need for increased engagement with stakeholders to bridge these gaps and promote sustainability in the industry.

Establishing a market for green steel is important to reduce emissions in steel production. Engaging in dialogue with stakeholders and understanding their concerns and future strategies is crucial. Consumer feedback will help shape policy reform. Data from this feedback will help determine the rate of reducing carbon emissions and the optimal timing and locations for decarbonization tactics. It will also clarify necessary investments and policy adjustments to align the interests of all parties involved.
Given that most research has primarily focused on the international landscape, this study will concentrate on the local steel market. It aims to evaluate their preparedness for transitioning to green steel production and their perception of its value.

2.4 Analytical Framework

2.4.1 Theoretical Framework

The research framework employed in this study will be informed by contemporary business strategies pertinent to the execution of profound transformational changes, specifically focusing on decarbonization initiatives within the steel industry. This framework aims to address the following research questions:

- *How is the steel market in South Africa progressing to meet climate goals set for the global steel industry?*
- *How do current steel customers perceive value from green steel?*
- *How can sustainable business models influence future demand of green steel?*

Various theorists have put forth numerous definitions of strategy. One such definition describes strategy as a “method or plan for the allocation of limited resources to secure a competitive edge, accomplish goals, and exploit perceived opportunities at a

tolerable level of risk” (Omalaga and Eruola, 2011, pp. 59-60). This research will conduct a descriptive case study on a local steel company to investigate its strategic management plans and its compliance with sustainability objectives. The study will aim to identify the primary motivations behind the company's drive for sustainability, analyse the initiatives or projects being undertaken to modify processes and reduce carbon emissions within stringent deadlines, and to understand the dynamics between the company's production of 'green steel' and the market's demand and expectations for such products. Through this research, we anticipate gaining insights into both the company's strategies to ensure a viable market for environmentally friendly steel and the value that consumers seek from such products, thereby assessing their readiness for this sustainable alternative.

Bearing these objectives in mind, the theories of strategic management and sustainability are utilized to establish a framework that aids in the identification, categorization, and examination of prospective business strategies within the local steel industry. Furthermore, market development is delineated and linked to the strategic management theories and frameworks, while the theory of innovation offers valuable perspectives on process transitions both within individual businesses and across the industry at large. This discussion will illustrate the integration of these concepts to forge sustainable business models that are poised to yield competitive advantages in the steel industry.

This study will be carried out through interviews with key role players in the Strategy, Technology and Marketing departments to gain insights into the company's approach to decarbonization. The investigation will evaluate the company's strategic management practices and its detailed decarbonization plan, including key milestones. Dialogue with the Marketing and Strategy departments will reveal the company's initiatives to cultivate new markets and maintain its existing customer base to ensure viability in the shifting environmental landscape.
Subsequently, the research will involve discussions with selected steel consumers in the automotive and construction industries to assess their preparedness for the adoption of premium green steel. The goal is to understand their perceptions regarding the quality of green steel and its value, considering the financial implications and additional advantages it may offer them.

Connection of Theories

The research seeks to provide evidence illustrating the influence of external factors such as the Sustainable Development Goals (SDGs) and the Paris Agreement on prompting businesses to reassess their strategies. It examines how the steel industry can adapt to these external pressures by weaving sustainability into its strategic management practices.

In addition, the study explores the relationship between business innovation and market development, linking them to the principles and frameworks of strategic management. By analysing the concept of innovation, it sheds light on the evolution occurring within the steel sector. Together, these theoretical frameworks offer guidance and foster understanding of how sustainable business models are developed and how they enhance the competitive edge of firms within the steel industry. This is depicted in the Figure 3 below.

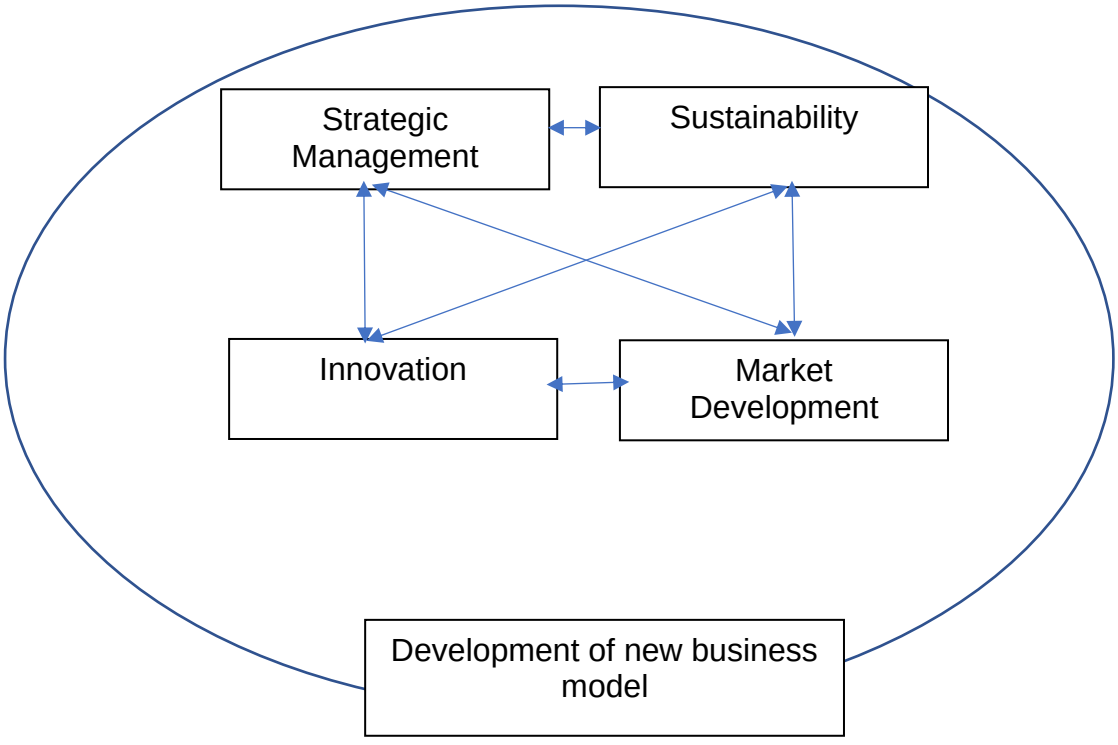


Figure 3: Connection of Theories

Sustainability serves as the cornerstone of this research, which aims to investigate the factors influencing the sustainability of the steel industry. This will be achieved by using

the PESTEL framework, evaluating industry competitiveness through Porter's Five Forces model, and identifying the relevant Sustainable Development Goals (SDGs) that shape the strategic planning and implementation timeline of businesses.
The interconnection of these concepts is crucial for a comprehensive understanding of the ongoing market transition within the steel industry. A detailed discussion of these concepts follows below.

2.4.2 Conceptual Framework

i) Strategic Management and Sustainability

Sustainability is leading to a significant transformation in individual awareness and the collective worldview, and it is becoming an essential consideration for businesses (Galpin & Hebard, 2018). This concept entails a comprehensive approach to decision-making that considers economic, social, and environmental elements with the aim of harmonizing these aspects to secure enduring advantages for both humanity and the environment. Companies striving for sustainability are compelled to undertake strategic alterations and embrace innovative business paradigms. In evaluating the approach to strategic management within the steel industry, guidance will be provided through an analysis within these specific subcategories:

a) Sustainable Development Goals (SDGs)

The 17 Sustainable Development Goals established by the United Nations in 2015 aim to promote sustainability and address various issues such as poverty, environmental protection, and economic growth (The World Bank, 2020). These goals require collaboration from government, private sector, civil society, and individuals to be achieved by 2030.

Businesses play a critical role in achieving the Sustainable Development Goals (SDGs) by driving economic growth, creating jobs, and integrating sustainability into their strategies (Aibar-Guzman and Aibar-Guzman, 2023). This benefits not only shareholders but also employees and customers. Businesses can support the SDGs by implementing sustainable practices, endorsing environmental and social governance, and forming partnerships to address global challenges.
Adhering to the Sustainable Development Goals (SDGs) promises numerous advantages; however, it imposes financial burdens on industries. Companies

endeavour to strike an equilibrium between adherence to these goals and sustaining profitability. While sustainable practices can bolster investor trust, diminished profits can have an adverse impact. Additionally, the lack of comprehensive policies to facilitate compliance can further hinder industries' ability to make decisive choices.

Galpin and Hebard (2018) emphasize that strategy must guide any course of action. Effective strategies might encompass a diverse range of initiatives—from the allocation of resources and structural adjustments within an organization to radical innovation in products or services. They could also stretch to the establishment of partnerships and collaborations or prospects like mergers and acquisitions. These endeavours are key to securing a sustainable competitive edge, augmenting both performance and profitability, and generating value for stakeholders, as delineated by Investopedia (2023). This process is inherently dynamic, necessitating continuous surveillance, appraisal, and refinement of strategies to align with the evolving currents of the business landscape. The diagram that follows Figure 4 presents a conceptual framework for strategic management and sustainability.

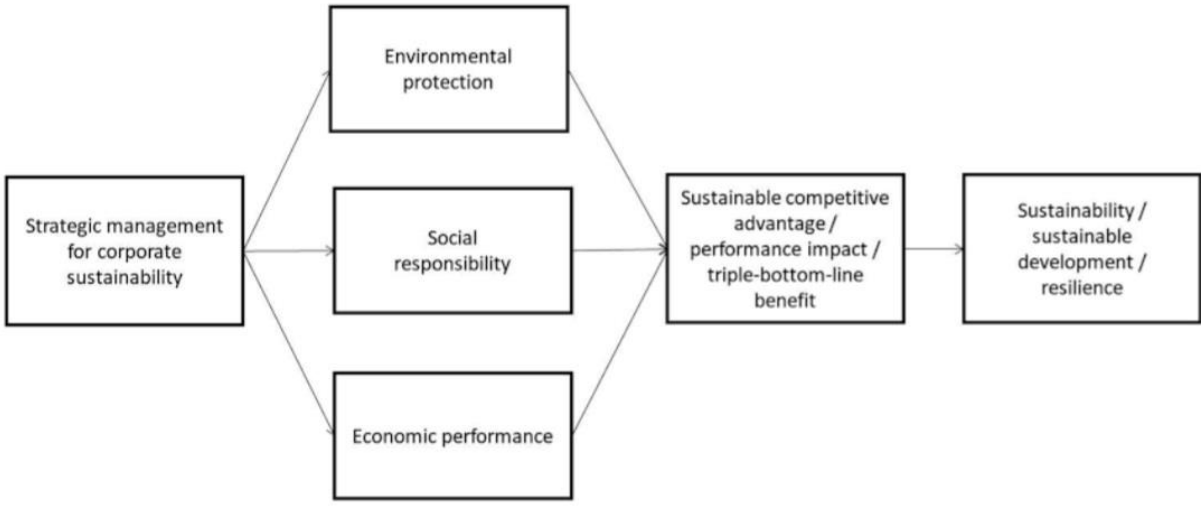


Figure 4: Conceptual Model for Strategic Management and Sustainability

b) **Circular Economy**

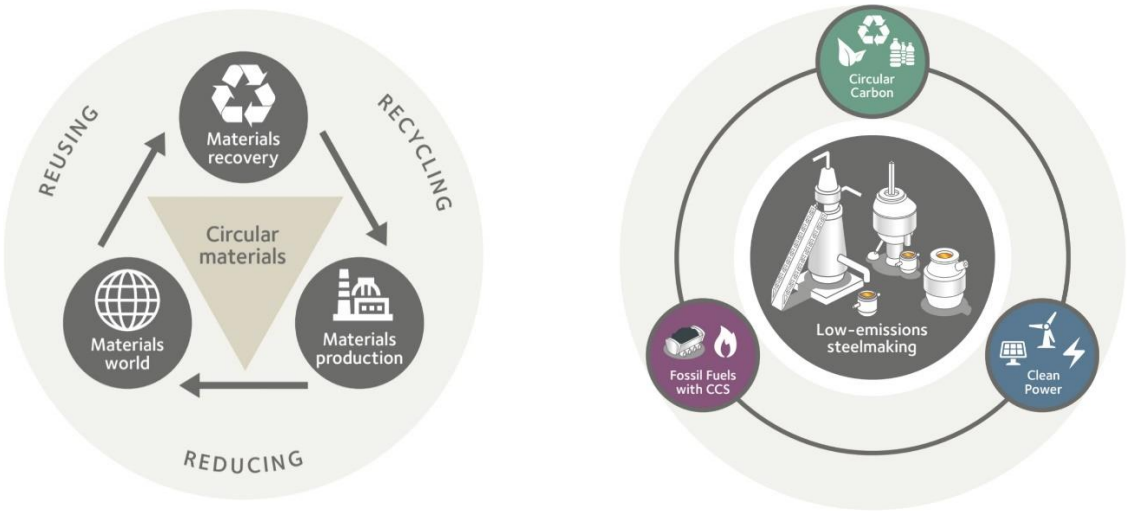
The circular economy is an economic framework that endeavours to maximize the utility of resources by maintaining them in circulation for as long as feasible, thereby minimizing waste and curtailing the use of non-renewable resources. This model plays a pivotal role in decarbonization efforts, as it aids in reducing greenhouse gas

emissions and fosters sustainable production and consumption patterns (Enel Foundation, 2021).

In this sustainable paradigm, product design prioritizes reusability, reparability, and recyclability, transforming waste into a valuable input for new product creation or energy generation. Such practices in a circular economy can significantly lower the carbon footprint associated with production processes and mitigate emissions stemming from waste disposal (Enel Foundation, 2021).

The circular economy can help to diminish the emissions related to raw material production. By encouraging the utilization of recycled materials, companies can lessen their reliance on expensive, unprocessed materials that commonly necessitate considerable energy for extraction and processing.

The circular economy concept garners global support and it is interesting to observe how local steel industries are embracing this paradigm to enhance their operations and achieve cost-effectiveness. Figures 5 below illustrates the significance of the circular economy within the context of the steel production sector.



(a) (b)

Figure 5: (a) Concept of Circular Economy (b) Circular Economy in the steel industry. Source: ArcelorMittal Climate Action Report (2019)

c) Pestel Analysis

In 2019, the World Steel Association placed South Africa as the 27th largest producer of crude steel globally, according to the South African Iron and Steel Institute (SAISI,

2023). The country deals with numerous challenges, including energy supply constraints, logistical issues, and political instability. Such challenges significantly affect the local industries and influence the strategic approaches adopted by businesses. This research aims to explore the difficulties encountered by the South African steel industry, examining how they affect strategic decisions and the industry's capacity to achieve climate objectives.

d) Porters 5 Forces

The Porter's Five Forces framework will be utilized to thoroughly assess the competitive landscape and intensity levels of the company in question (Larsson & Smith, 2022). This analysis helps identify the competitive forces at play and their potential impact on the business, prompting an in-depth evaluation of the company's own competitive strengths and weaknesses. The insights gained from this examination are instrumental in formulating a strategy that protects the business against competitive threats (Porter, 2008). Understanding the competitive forces shaping the local steel industry is crucial as they likely influence the industry's trajectory and progress toward decarbonization.

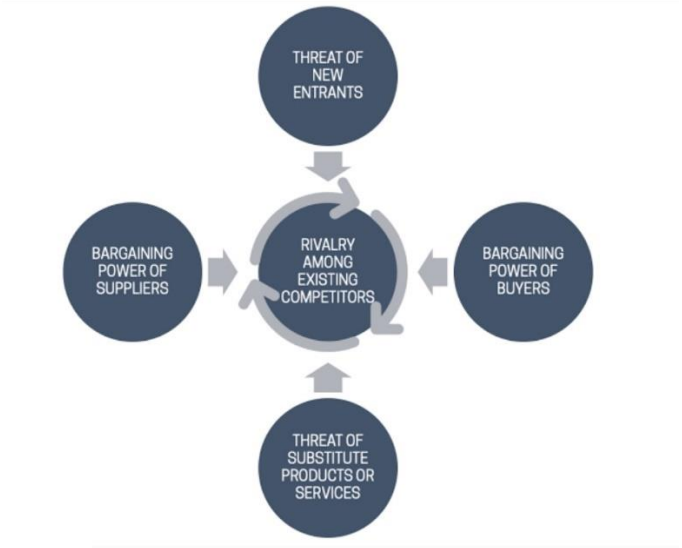


Figure 6: Porter's Five Forces illustrating the state of competition in industry. Source: Porter (2008)

According to the Figure 6 above, the framework contains five competitive forces:

- *the bargaining power of buyers*
- *threat of substitute products or services*
- *bargaining power of supplier=*
- *threat of new entrants*
- *rivalry among existing competitors.*

Many steel companies operate and vie for market share on both local and international fronts. To maintain a competitive edge on a global scale, their strategies must be designed to support their worldwide competitiveness. The South African Iron and Steel Institute (2023) reports that there are six major steel enterprises operating in South Africa, all of which maintain a robust presence in the global steel marketplace. However, following the global financial crisis of 2008, China emerged as a significant challenge to the South African steel industry, posing competitive threats (Author unknown, 2021). This study aims to identify the main competitors that currently impact the strategic direction of a particular steel company, acknowledging their pivotal role in shaping the company's strategic approach.

e) Scopes 1-3 of Carbon emissions

Established in 1998, The Greenhouse Gas Protocol arose from a global partnership involving corporate stakeholders, non-governmental organizations, and governments, and it provides established guidelines to help industries track and manage their greenhouse gas (GHG) emissions. Moreover, the protocol facilitates the identification of emission hotspots throughout the supply chain, promoting collaboration in the pursuit of a sustainable future (Larsson & Smith, 2022). The GHG Protocol addresses emissions from three distinct perspectives — Scope 1, 2, and 3 — each of which is further elucidated and depicted in Figure 7.

Scope 1: Direct emissions

Include direct emissions from the company's owned or controlled sources. Scope 1 emissions encompass process emissions that are released during industrial processes, and on-site manufacturing (eg. Factory fumes, chemicals) (Larsson & Smith, 2022).

Scope 2: Indirect emissions

Represent one of the largest sources of global GHG emissions. Includes indirect GHG emissions from purchased or acquired energy like electricity, steam, heat, cooling that is generated off-site and consumed by the business (Larsson & Smith, 2022).

Scope 3: Indirect value chain emissions

All indirect emissions that occur in the value chain of a reporting company. Reported as "the result of activities from assets not owned or controlled by the reporting

organization, but that the organization indirectly impacts in its value chain." (Larsson & Smith, 2022).

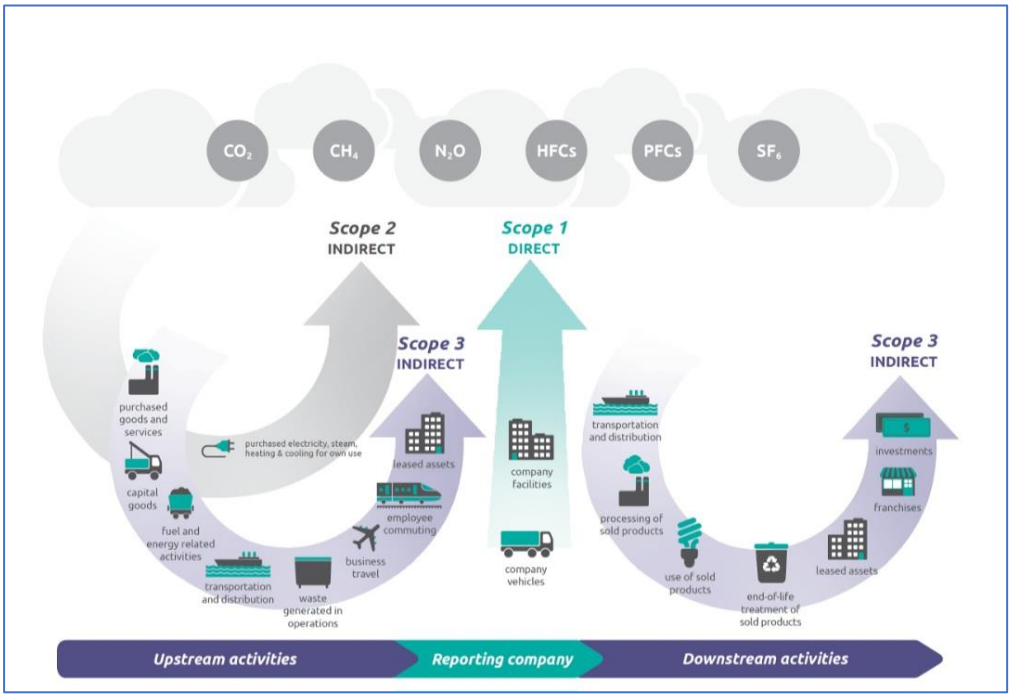


Figure 7: Greenhouse Gas Protocol. Source: ArcelorMittal Climate Action Report (2019).

Understanding the steel company's progress along its decarbonization pathway would be beneficial, as it might consider a phased approach necessary. Furthermore, the company would evaluate its own processes and those of its value chain by employing this protocol.

f) **Economics in the steel industry**

Understanding market readiness for green steel necessitates a thorough examination of the economic principles of demand and supply. The demand for green steel hinges on various determinants, such as the extent of consumer awareness, the perceived quality and cost-effectiveness of the product, as well as prevailing market trends. Conversely, the supply of green steel is contingent upon the availability of necessary resources, the costs associated with its production, and the regulatory framework set forth by government policies. Notably, a substantial portion of the increase in steel demand originates from the construction industry, especially in developing nations that are investing in new buildings and infrastructure, as identified by Muslemani et al., (2021).

As the shift towards renewable energy gains momentum, the demand for steel is set to rise to facilitate the construction of wind turbines and solar energy facilities. Concurrently, the push for reducing plastic waste and the emphasis on recyclable materials are fuelling additional demand within the steel industry. Furthermore, the automotive sector's preference for lightweight steel is gaining traction in today's economy, adding to the overall increase in steel consumption.

ii) Market development

Market development is a business strategy aimed at boosting the market potential of a company that proffers specific products and services (Larsson & Smith, 2022). The objective of this study is to elucidate the transformative impact of innovation for decarbonization on the company, particularly in manufacturing sustainable green steel at a premium. Furthermore, the study examines how the company effectively manages this transition to secure a sustainable competitive advantage (SCA).

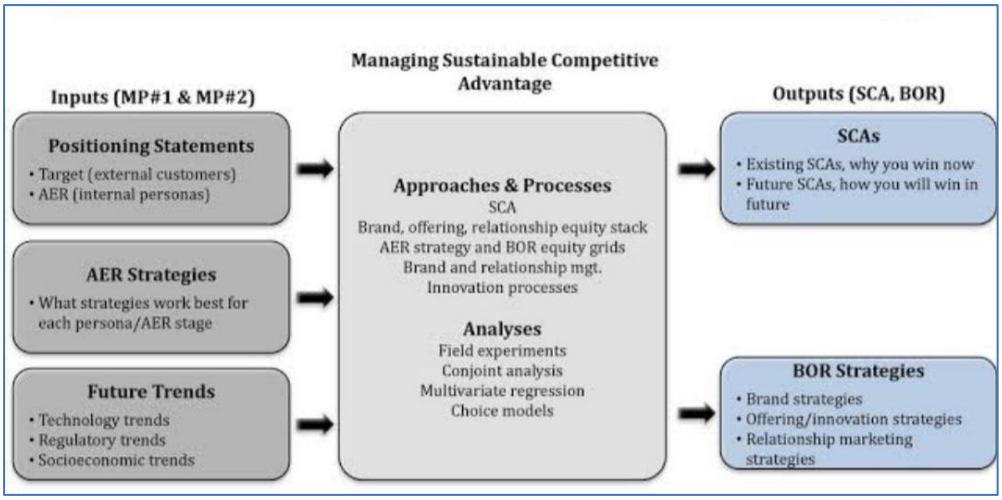


Figure 8: Framework for Managing Sustainable Competitive Advantage Source: Palmatier & Sridhar (2021)

Using the framework for managing SCA, seen in Figure 8, the business must understand the Inputs which can be described as:

- *Who customers are*
- *What set of needs the product or service fulfils*
- *Why this product/service is the best option to satisfy customer needs (relative to competition*

and the Outputs:

- *The firms Sustainable Competitive Advantage (SCA) now and in the future*
- *The detailed Brand, Offering and Relationship (BOR) strategies that combine and adjust each targeted customer segment and qualities according to its needs and effectiveness*

and manage SCA by converting the inputs into outputs through detailed analyses and trials (Palmatier & Sridhar, 2021).

This leads to the business's– brands, offerings and relationships, illustrated in Figure 9.

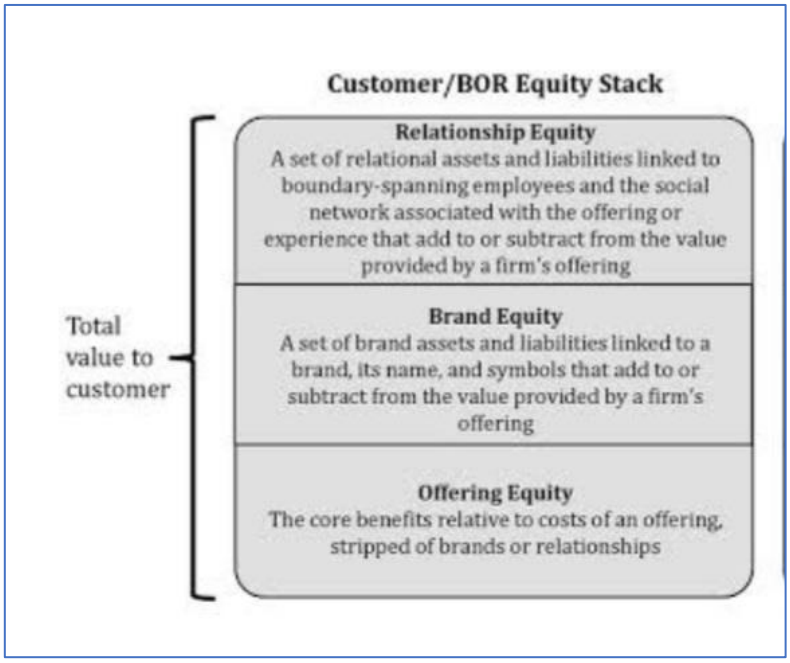


Figure 9: BOR Equity Stack. Source: Palmatier & Sridhar (2021)

Brands

In terms of brand development, companies often allocate resources to advertising, public relations, and celebrity endorsements. These investments are crucial for cultivating brand awareness and crafting brand images that align with their strategic positioning.

Offerings

Innovative products and services, when leveraged as a Sustainable Competitive Advantage (SCA), can profoundly impact and disrupt various market segments. Companies invest significant portions of their budgets into Research and Development (R&D) to craft pioneering products or enhance existing ones, trim production costs, integrate value-added services, or entirely transform the customer experience. An offering that more adeptly fulfills customer needs and introduces sought-after features can give rise to a robust SCA. However, the success of such an offering depends on effectively communicating its benefits to customers, market testing, and tailoring the product to align with customer preferences (Palmatier & Sridhar, 2021).

Relationships

Leveraging relationships as a Strategic Competitive Advantage (SCA) becomes highly effective within the realm of Business-to-Business (B2B) frameworks, particularly in industries that offer services or complex solutions. The strength of the connection between customers and company representatives can create formidable obstacles to customer defection, thereby boosting loyalty and driving superior financial outcomes (Palmatier & Sridhar, 2021). B2B engagements are often intricate, necessitating extensive bidirectional communication and prolonged interactions over time. The development of robust interpersonal relationships fosters a climate of trust, cooperation, and adaptability between buyers and sellers.

Research indicates that investment in marketing is not merely an expense, but a crucial one, as it yields benefits that extend well into the future in terms of building brand equity and cementing customer relationships, thereby establishing significant sustainable competitive advantages (SCAs).

Regardless of how adept a company is at navigating consumer preferences and market dynamics, its competitors will invariably seek to emulate its innovative offerings and business strategies to better fulfill customer needs and desires. Consequently, it is imperative for marketing managers to persistently strive to erect and fortify barriers to competitive encroachment. By developing high-caliber brands, introducing groundbreaking services, and nurturing robust client relationships that cater to specific market segments, managers can secure long-term competitive edges. As highlighted by Palmatier & Sridhar (2021), this proactive marketing strategy is crucial for staying at the forefront of industry competition.

The research is designed to gain insight into how the local steel industry manages its customer relationships and its product offerings, considering the perspectives of both producers and consumers. By adhering to the outlined framework as a point of reference, we aim to garner transparent and informative data through interactions with the Marketing department and through interviews with consumers.

iii) Corporate Entrepreneurship and Innovation

The aim of this discussion is to explore the concept of entrepreneurship as it applies to businesses delivering innovative technology. Corporate Entrepreneurship is regarded as a strategic approach in the business landscape, one that is essential for

companies seeking to enhance their performance and maintain a sustainable, competitive edge.

This strategy entails the development of new products, ventures, and processes, as well as the rejuvenation of existing operations within large organizations. Typically, it is undertaken by employees from dedicated units that operate separately from the core functions of the company. These teams focus on devising and piloting innovative solutions that, upon successful validation, are integrated into the wider operations of the corporation (Neck, Neck and Murray, 2021).

Corporate entrepreneurs are inclined to investigate new opportunities and pursue strategies that leverage the organization's existing framework and procedures to foster innovation. They are adept at recognizing potential, assembling effective teams, and generating valuable outcomes with the aim of bolstering the organization's competitive edge and profitability (Neck et al., 2021).

Organizations exhibiting Corporate Entrepreneurship (CE) are typically perceived as dynamic and flexible, well-equipped to seize emerging business prospects. The entrepreneurial behavior within these organizations is recognized as a key determinant of business evolution, expansion, and overall performance. Current studies have highlighted the pivotal role of CE in promoting innovation, rejuvenating business models, and enhancing productivity. For firms to enhance their capabilities and maintain a lasting competitive edge, innovation is essential (Arfi & Hikkerova, 2019).

Innovation holds a crucial role in addressing climate action and advancing decarbonization efforts. The multifaceted and pressing issue of climate change demands a diverse array of inventive strategies to mitigate greenhouse gas emissions, adapt to climate change effects, and pave the way towards a sustainable and resilient future. Here are examples illustrating the potential of technological innovations to assist the steel industry in meeting its objectives:

1. ***Renewable energy***: Innovation has led to the development and implementation of various renewable energy technologies, including wind turbines and solar panels. These technologies can generate electricity while emitting minimal greenhouse gases, thereby offering a sustainable alternative

to traditional fossil fuel-based electricity generation (ArcelorMittal, Climate Action Report, 2019). ArcelorMittal is actively researching iron ore reduction technologies that utilize hydrogen and electrolysis. When powered by 'clean' electricity sources, these technologies have the potential to achieve substantial reductions in carbon emissions.

2. ***Carbon capture and storage*:** This technology encompasses the process of capturing carbon dioxide emissions from power plants and furnaces and subsequently sequestering them underground or in alternative permanent sites (Kim et al., 2022). Recent advancements in carbon capture and storage (CCS) systems have been pivotal in substantially reducing industrial emissions.
3. ***Circular economy*:** By minimizing waste, repurposing products, and recycling materials, a circular economy can drastically cut emissions and conserve vital resources. Since 2018, ArcelorMittal has been spearheading a project in Germany that transforms 120,000 tonnes of waste wood into bio-coal. This alternative fuel is used for reducing iron ore, presenting a sustainable substitution for fossil fuels. In France, additional initiatives include capturing off-gas from industrial processes and repurposing it for iron ore reduction, as outlined in the ArcelorMittal Climate Action Report of 2019. The company is also innovating in the creation of carbon-based products derived from waste gas by employing circular carbon and hydrogen.

Currently, over half of Europe's renewable energy is generated from circular carbon sources, namely renewable biomass and bio-waste. The steel industry is positioned to become a highly efficient consumer of societal waste, which encompasses construction wood, agricultural and forestry residues, and plastic waste**.**

In summary, the adoption of innovative technologies, the implementation of sustainable practices, and the refinement of processes are crucial steps in reducing greenhouse gas emissions. These measures are pivotal in mitigating the effects of climate change and advancing towards a sustainable future. However, financial limitations linked to emerging technologies could pose a challenge, potentially affecting the steel industry's capacity to achieve climate action goals.

Consequently, it is uncertain how local steel producers will navigate and tackle this challenging endeavour.

Linking Innovation with Strategic Management, management will consider the following matrix in Figure 10 when approaching the market.

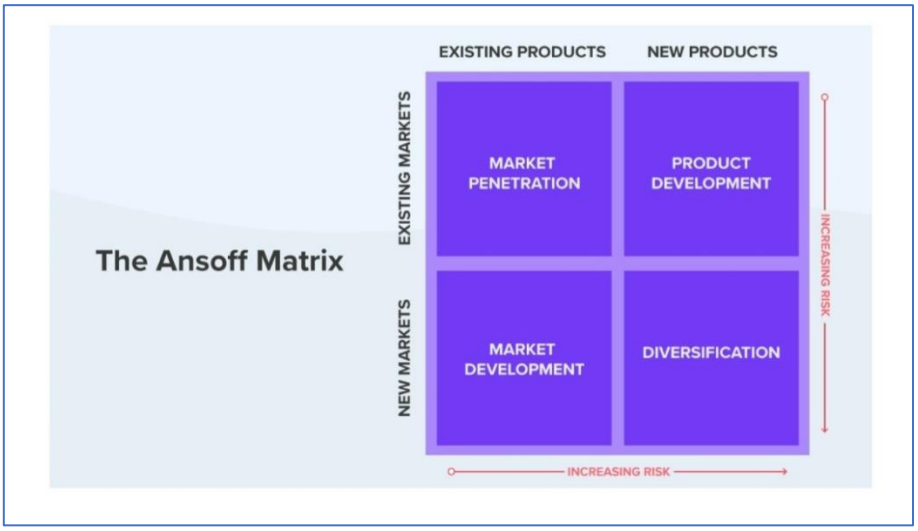


Figure 10: The Ansoff Matrix Source: Igor (2007)

It is an expansion framework that breaks down the relationship between a product/service and the target market and the riskiness of that combination. The four expansion strategies it contains are:

- **Diversification** –introducing a new product/service to a new market
- **Product development/differentiation** – introducing a new product into an existing market
- **Market development** – introducing an existing product into a new market
- **Market penetration** - further selling an existing product into an existing market

Each of these strategies carries varying degrees of risk, with diversification often presenting the highest level of risk and market penetration generally posing less risk (Hussain et al., 2013). Understanding which strategy a business intends to adopt is crucial for determining the allocation of resources required for success.

Consequently, it is essential to examine how the steel company plans to enter the market with its green steel offerings.

Based on the information provided, it is imperative that the research explores the factors prompting change and conducts an in-depth analysis of the strategic management approach that integrates technological advancements as well as market

evolution, alongside an updated business model to ensure ongoing competitiveness. Comprehending these aspects will yield valuable insights into the progress the South African steel industry is making towards achieving the climate goals established for the global steel sector, the future market demand for eco-friendly steel, and the potential benefits that consumers may recognize from utilizing green steel.

Such understanding is essential for government officials, policy makers, and the broader steel industry. It is particularly crucial to grasp how the process of decarbonization impacts the local steel sector, as this will play a significant role in determining the socio-economic viability and sustainability of South Africa's overall economy. The country's future investments, economic growth, and job creation prospects are contingent upon the enduring sustainability of the steel industry.

3. Research Methodology

3.1 Research Process

The research process commenced with an initial examination aimed at gaining an in-depth theoretical understanding of the subject matter. This exploration led to the formulation of pertinent research questions. The study will adopt a descriptive and qualitative methodology to explore the following questions:

- How is the steel market in South Africa progressing to meet climate goals set for the global steel industry?
- How do current steel customers perceive value from green steel?
- How can sustainable business models influence future demand of green steel?

The research adopted a stringent methodology that encompassed an extensive review of academic literature and the implementation of semi-structured interviews for data gathering. In-depth examination of various pertinent topics—including sustainability, steel production, strategic management, marketing, and innovation, alongside current steel industry news and the company's historical context—aided in shaping a well-defined research objective. To gather primary data, semi-structured interviews were conducted, facilitating the collection of first-hand insights.

The study proceeded with a systematic approach, involving the selection of a representative sample and the meticulous collection of data. Subsequently, the data underwent thorough analysis utilizing thematic analysis techniques, with themes emerging from the interview transcripts informing the interpretative process. Upon achieving a comprehensive understanding of the subject matter, the study assessed the market prospects for environmentally friendly 'green' steel. This evaluation was grounded in a theoretical framework, drawing on principles of strategic management, sustainability, marketing, and innovation to inform its conclusions.

3.2 Research Design

The research design establishes a framework for the organization of the study, specifically concerning the collection and analysis of data. A qualitative research methodology was employed to conduct the investigation. Furthermore, the nature of this research project can be characterized as descriptive, involving no manipulation of

variables or exploration of causal relationships. Instead, the focus was on analysing the gathered data to extract insightful interpretations and draw well-founded conclusions (Wikipedia, 2023).

The study involved a thorough analysis of market drivers, business strategies, technology, and resources, which culminated in an examination of market evolution for green steel within a selected South African steel company. A case study methodology was adopted for the research design to rigorously investigate the research question through in-depth exploration of this single case. The case study approach is a commonly employed method in business research and was considered appropriate for this scenario, as it concentrates on a singular entity (Sekaran and Bougie, 2016). The investigation extended to two distinct market segments, specifically targeting the automotive and construction industries, which are principal consumers of the company's products.

An alternative to the case study would be a comparative study, which involves researching and contrasting two distinct steel companies. However, this approach could introduce additional variables like the size and profitability of the companies, potentially influencing the outcomes. In contrast, the case study provided an opportunity for more in-depth analysis, focusing on depth over breadth.

The researcher endeavoured to gather detailed information about a single case, planning to investigate it in its natural setting. This allowed for a thorough examination of the complex web of relationships and processes, with the aim of understanding how they interconnect, rather than attempting to extricate and examine factors in isolation. To gather data, the researcher employed multiple sources and methods. The goal was to create a descriptive case study that would yield a rich and nuanced description of a specific phenomenon – in this case, decarbonization and the adoption of green steel within the steel industry. The study was also characterized by its short-term nature.

3.3 Sampling

For the selection of interview participants, the study employed two types of purposive sampling methods. The first method utilized was judgment sampling, which involves selecting key informants who are likely to possess valuable insights pertinent to the

research topic (Sekaran & Bougie, 2016). This technique involved intentionally identifying not only these critical individuals but also additional stakeholders along the supply chain. Concurrently, snowball sampling was implemented, a technique that leverages existing networks to obtain referrals to new individuals who have relevant expertise on the subject under investigation.

The targeted interviewees were professionals with specialized knowledge in fields such as steel production, strategic planning, technological and market development, as well as sustainability practices within the steel company being studied and their automotive and construction customers. The nature of this research necessitated obtaining information directly from key sources as data acquired through random or quota sampling methods would likely fail to yield the precise and comprehensive information needed for this study.

3.4 Sampling Frame

A non-probability sampling technique was utilized to select individuals closely associated with the specified steel company, including employees. The focus was on engaging participants who possess a thorough understanding of the company's strategic development and corporate governance. Additionally, experts in decarbonization technology and research teams who have a comprehensive grasp of the market dynamics within their industry were included. Market development specialists and customer executives, particularly those from the automotive and construction sectors, were also incorporated into the sample based on the company's recommendations.

3.5 Sampling Size

Owing to the need for subject matter experts, a total of ten individuals were carefully selected for interviews: seven managers from the steel company and three company directors from both the automotive and construction sectors. The interviewees represented a diverse array of departments, each bringing distinct expertise and competence to the conversations. A deliberate choice was made to engage a smaller group of participants, concentrating on management-level personnel, to facilitate more comprehensive and in-depth interviews that could yield richer data. These interviews and meetings were held online using Microsoft Teams, and follow-up communications were conducted via email to ensure thorough and continued engagement.

3.6 Data Collection

Data collection for the study was conducted using a two-pronged approach. Initially, primary data was gathered through semi-structured interviews with key figures in the industry and market. This approach allowed for an in-depth understanding of the subject matter from those with first-hand experience. To enhance the data collected, this information was augmented with secondary sources such as a review of relevant literature, project documentation, and various reports that the interviewees cited. This combined methodology ensured a comprehensive collection of data for the project.

a) Semi-structured interviews

Interviews are commonly utilized in descriptive research for gathering specific information within the realm of business studies (Sekaran & Bougie, 2016). Semi-structured interviews facilitate personalized questioning of individual participants. These interviews comprise broadly framed, open-ended questions, enabling the interviewer to delve deeper through follow-up inquiries as new ideas and questions emerge from the respondent's initial answers (Bell, Bryman, and Harley, 2019).

It is crucial for the integrity and success of the research that interview questions are crafted with care, ensuring clarity, research relevance, optimal scope, and logical connectivity. These criteria help to sustain the interview's high standard and meet its fundamental objectives. Bell, Bryman, and Harley (Ibid) emphasize that the questions must be coherent, precise, appropriately scaled, and well-structured to facilitate a valuable and credible contribution to the study.

In preparation for the interview process, an interview guide was developed and provided to the respondents ahead of time to facilitate their preparation, as detailed in the Appendix A. The semi-structured format of the interview grants the interviewer leeway to diverge from the pre-set questions, offering greater flexibility and freedom compared to a fully structured interview. This adaptability allows the interviewer to uncover additional insights, thereby enriching the depth of the research. Moreover, utilizing video-calling platforms, such as Teams, for interviews enables the researcher to observe non-verbal cues that may influence participant responses and provides an avenue to identify and address critical issues within the study (Sekaran & Bougie, 2016).

b) Literature review

To explore the notions of Sustainable Development Goals (SDGs), decarbonization, and the concept of green steel within the context of steel manufacturing processes, a comprehensive literature review was conducted as the foundation for data collection. This literature review entailed an iterative process that involved extensive reading and gaining an in-depth understanding of the topics at hand. It also required maintaining a critical perspective and assessing the applicability and relevance of various concepts and theories to the project, following the approach suggested by Bell, Bryman, and Harley (2019). The selection of sources drew from a wide range of materials, focusing on the disciplines of strategic management, sustainability, innovation theories, and steel manufacturing. This involved a systematic search for information within relevant journal articles, industry reports, and business news through search engines and databases such as Google, Google Scholar, Google Bing and Sci-Hub.

c) Documentation and Reports

The interviewees frequently cited a range of published materials, including documents and reports pertinent to Climate Action, the Decarbonization Roadmap, Business Strategy, Environment, Social, and Governance (ESG), as well as Integrated Reports and presentations on energy topics.

3.7 The Research Instrument

See Appendix A for Interview Schedule

3.8 Data Analysis & Interpretation

Data was meticulously gathered from primary sources, upon which qualitative analysis was conducted. This analysis was achieved through thematic examination, which was directed by an array of theoretical frameworks and analytical instruments.

Thematic analysis involved:

d) Familiarizing with the data
e) Generating initial codes
f) Searching for themes
g) Reviewing themes
h) Defining and naming themes
i) Producing the report

An alternative method that was considered is narrative analysis. This approach could be employed to validate findings by weaving a story about the business being examined. However, narrative analysis is not typically utilized in business research; it is more often applied to personal narratives. Consequently, thematic analysis was selected. This method enables the researcher to identify and explore the core themes or ideas that surface, their interconnections, and offer a detailed, inductive analysis of the issue being studied (Open AI, 2021).

3.9 Research Quality

To ensure rigor, trustworthiness and credibility of the research and its findings, it is important to use approaches and techniques to reduce partialities, enhance the validity and reliability of the research process and ensure that the research findings accurately reflect the participant's perspectives (Open AI, 2021).

This was achieved by:

- Outlining the research process and design to a transparent level that it was reproducible
- Keeping an audit trail of decisions and actions taken during the study.
- Ensuring the data collection methods were appropriate and provided rich data for analysis from the right participants.
- Ensuring the data obtained was sufficient to analyze and draw a conclusion
- Ensuring the thematic analysis was done correctly and sought expert assistance where necessary
- Engaging with mentor or supervisor to ensure any own biases were removed and render objectivity
- Verifying data with participants to ensure interpretations and conclusions accurately reflect the participants experiences and perspectives
- Sharing the research process, findings and interpretations with trusted colleagues and researchers for critical feedback
- Providing rich data in the research context, participants and findings. This enhanced the credibility and transferability of the research findings by providing enough information for others to evaluate and understand the study

3.10 Limitations of the study

- Geographical locations were an issue when arranging interviews with steel customers, which influenced face to face interview requirements.
- Management and experts were required to be interviewed and therefore researcher had to schedule around their time and availability which were odd hours.
- Participants may have been biased.
- Customer respondents who had limited knowledge on green steel rejected being interviewed.

3.11 Ethics Considerations

- Research process was executed with respect and integrity by following the formal procedures with regards to obtaining consent before conducting any interviews.
- Awaited ethics clearance before conducting interviews and proceeding with the research.
- Established formal business relations with participants.
- Avoided plagiarism during report writing.
- Audio recordings and interview transcripts are safeguarded to maintain confidentiality of information and keep trust of participants.
- Data analysed correctly to avoid misrepresentation of participants.
- Convey gratitude to company, participants for participating in the research.

4. Results

Semi-structured interviews were conducted with key management members from the technology, strategy, marketing departments as well as merchant directors that serve the automotive, construction and infrastructure industries. These interviews were meticulously transcribed, and a thorough thematic analysis was carried out to identify critical insights. Additionally, the interviewees cited documents that are analyzed in this study.

The thematic analysis began with keyword identification using a density tool, seen in the tables 1 - 3.

Table 1: Keyword Density in the interview focused on Strategy

Keyword	Frequency	Density
steel	10	2.28%
world	8	1.83%
future	5	1.14%
people	5	1.14%
skills	5	1.14%
business	5	1.14%
value	4	0.91%
long term	4	0.91%
decarbonization	4	0.91%
material	4	0.91%
long term sustainability	2	0.46%
innovation	2	0.46%
standards corporate responsibility	1	0.23%
makes attractive partner	1	0.23%
new brand promise	1	0.23%
promise smarter steel	1	0.23%
steel people planet	1	0.23%
Planet committed	1	0.23%
Entrepreneurship	1	0.23%

Table 2: Keyword Density in the interview focused on Technology

Keyword	Frequency	Density
carbon	52	1.75%
steel	52	1.75%
EAF	33	1.11%
DRI	26	0.88%
hydrogen	26	0.88%

scrap	24	0.81%
energy	21	0.71%
funding	11	0.37%
hot metal	10	0.34%
carbon tax	9	0.30%
carbon intensity	9	0.30%
electricity	9	0.30%
blast furnace	8	0.27%
carbon footprint	7	0.24%
decarbonization	6	0.20%
natural gas	6	0.20%
South Africa	6	0.20%
reduce carbon	5	0.17%
primary steelmaking	5	0.17%
secondary steelmaking	2	0.07%
solar plant	2	0.07%
banks	2	0.07%

Table 3: Keyword Density in the interview focused on Market Development

Keywords	**Frequency**	**Density**
steel	54	4.62%
green steel	21	1.79%
people	18	1.54%
Europe	16	1.37%
decarbonization	12	1.03%
carbon	11	0.94%
demand	10	0.85%
finances	10	0.85%
Customers	10	0.85%
certification	3	0.26%
carbon tax	3	0.26%
cbam europe	3	0.26%
support customers	3	0.26%
business case	3	0.26%
scope emissions	1	0.09%

After considering their meaning and significance in the context, codes were identified that supported the specific themes to which answers were being sought. This is illustrated in the table 4 below:

Table 4: Codes and Themes generated from all interviews

Technology	Challenges	Strategy	Value Chain	Marketing
• Energy Transition	• Government	• People and Planet	• Customers	• Global warming
• Fossil fuels	• Carbon tax	• New business opportunities	• People	• Climate change
• Efficiency	• Funding	• Goals	• Suppliers	• Initiatives

• Carbon footprint	• Interest rates	• Long term sustainability	• Shareholders	• Decarbonization
• Energy roadmap	• Legislation	• Sustainable business practices		• Sustainability
• Primary steelmaking	• Eskom policies and procedures	• Transformation		• Market perceptions
• Secondary steelmaking	• Hard to abate	• Leadership		• GHG Emissions
• DRI-EAF		• Competitiveness		• Strategy
• BF-BOF		• Corporate and Social Governance		• Branding
• Scrap		• Quality steel		• Steel certification
• Circular economy		• Energy		• Financial position
• Sustainable economy		• Strong financial position		• Green/Eco standards
• Carbon intensity		• Decarbonized steel		• Energy roadmap
• CO2		• Customers		• Customers
• GHG emissions		• Social license to operate		• Circular economy
• Energy		• Automotive		• Innovation fund
• Electricity		• Construction		• CO2
• Renewable energy		• Circular economy		• Scope 1-3 emissions
• Energy roadmap		• Shareholders		• CBAM
• Decarbonization		• Research & Development		• EAF
• Mega trends		• Innovation		• DRI
• Carbon footprint		• Entrepreneurship		• BF-BOF
• Goals				• Scrap
• Low nitrogen				• Legislation
• Hydrogen				• Carbon reporting
				• Green steel demand
				• Business case
				• Carbon tax
				• Competitiveness
				• Subsidies
				• People
				• Customers
				• Premium green steel
				• Automotive
				• Construction
⟸ **Sustainability** ⟹				

5. Analysis and Discussion (from interviews, literature and reports)

Interviews were held with key role players in the Strategy, Technology and Marketing department in the local steel company and supplementary data was found in corporate documentation that was referenced by the company. This was followed by interviews with key customers of the steel company which belong to the formal sector. Guided by the codes and themes under scrutiny, the interview data was analyzed.

5.1 **Strategy and Sustainability**

This study aligns with the global steel industry's pursuit of net-zero emissions and South Africa's commitment to the Paris Agreement. These factors have demonstrably catalyzed a local steel company to integrate sustainability into its strategic planning. The company's commitment to environmental objectives is further underscored by the release of a comprehensive Decarbonization Roadmap in 2023, outlining its planned energy transition from the current state to 2050.

From the engagement with the office of Strategy, the company's intention is to:

"Restructure the organization and business to ensure international cost competitiveness, reposition as the champion of South Africa's backbone of manufacturing and revitalize the balance sheet to improve sustainability, enhance flexibility and agility."

Porter's Five Forces analysis emphasizes that achieving international competitiveness requires cost reduction strategies (Porter,1980) however Ghemwat (2007) and WU et al. (2015) highlight limitations of a singular focus on cost-cutting, as it can hinder innovation. In today's dynamic business environment, resilience and adaptability are essential (Eisenhardt & Martin, 2000). Balancing flexibility and cost-competitiveness requires careful strategic manoeuvring to avoid trade-offs (Wieland, Handley & Rajagopal, 2012).

Examination of the Political, Economic, Social, Technological, Environmental and Legal (PESTEL) factors in the steel environment is relevant throughout the study. While fostering customer loyalty and government support by positioning the company as a champion of South African manufacturing (Luo, 2008) can be beneficial, an overemphasis on national identity might restrict the company's global reach and

market potential (Yip, 2003). Thus, a nuanced approach that considers these potential limitations is crucial for the company to achieve sustainable success.

The strategy office further states that:

"Decarbonization requires a complete overhaul within primary steel making processes," and it is "imperative to demonstrate meaningful value to multiple stakeholders including investors, shareholders, employees, customers, communities, suppliers and government. A strong balance sheet is needed for strategic continuity. Equally important, is securing a suitable funding structure to target growth opportunities and improve the quality of earnings; Maintaining a strong balance sheet provides the financial flexibility critical to ongoing investment in our existing asset base as well as enabling us to take advantage of opportunities to transform for the future, ensuring long-term sustainability and consistent shareholder returns."

The World Steel Association (2023) affirms that decarbonizing the steel industry necessitates a "complete overhaul", reflecting the enormity of this transition. Existing processes heavily rely on fossil fuels, demanding significant technological advancements and infrastructural changes (UNEP, 2021). However, achieving success extends beyond technological innovation. The company rightly emphasizes demonstrating value to a wide range of stakeholders, including investors, employees, and communities (WBCSD, 2021).

Aligning with Environment, Social and Governance (ESG) principles and fostering transparent communication are necessary for securing the social license to operate and attracting investment. Studies by Hahn, Pinkse, Preuss & Figgel. (2015) even suggest a positive correlation between ESG performance and investment returns. Nevertheless, financial constraints present a significant hurdle.

A strong balance sheet is necessary for strategic continuity and investment in new technologies (Agnew & Peat, 2018). Decarbonization projects often require substantial upfront costs, potentially jeopardizing short-term profitability (Morris, 2023). Furthermore, securing suitable funding structures, particularly in developing economies with limited access to green finance (IEA, 2023), and the inherent uncertainty surrounding the long-term viability and economic feasibility of new

technologies (NERC, 2023) pose additional challenges. Striking a balance between financial health, stakeholder needs, and the pursuit of long-term sustainability will be paramount for the company to navigate this complex transition.

The steel company's strategic plan further outlines a multi-pronged approach towards sustainability, including transitioning towards a circular economy. A key element involves optimizing its asset footprint, but details regarding the specific goals and how this aligns with circularity principles are absent (Kirchhoff et al., 2018). The plan prioritizes Electric Arc Furnaces (EAFs) powered by a company-built solar Photovoltaic (PV) plant. This aligns with research advocating for increased EAF adoption for reduced emissions (World Steel Association, 2023). The plan mentions decommissioning two Blast Furnaces while keeping one operational and the future implementation of Carbon Capture and Storage (CCS) technology and a Green Hydrogen Direct Reduced Iron (DRI) facility. These technologies are indeed promising avenues for decarbonization, as evidenced by the Institute for Sustainable Development and International Relations (IDDRI) study (Stockholm Environment Institute, 2021) which draws on a global database of steel technologies.

However, more information on the feasibility study including the technical, financial, and regulatory hurdles associated with such a transition must be considered (Fiorese, Garcia, & Zaharia, 2020). A comprehensive assessment of these aspects is essential to evaluate the plan's achievability and identify potential obstacles during implementation (IEA, 2023).

The Strategy office asserts:

“Our research and development team are relentlessly pushing both process and product innovation frontiers, inventing smarter steels to further enhance our product and service offerings to meet our customers’ evolving needs; And taking advantage of steel’s unique ability to be completely reusable and recyclable, we are developing innovative processes that use less energy, emit less carbon, and reduce costs.”

The steel company's commitment to sustainability is evident in its focus on two key areas: process and product innovation, and embracing circular economy principles for steel. The development of "smarter steels" with enhanced properties aligns with the

industry's trend towards high-performance steels, potentially leading to increased efficiency and reduced material use in customer products (Singh et al., 2023). However, challenges remain. Research and development for breakthrough innovations can be expensive and time-consuming (Agnew & Peat, 2018), and translating these innovations into commercially viable products requires overcoming technological hurdles and gaining market acceptance (Morris, 2023).

The company's recognition of steel's near-infinite recyclability aligns with a circular economy approach, offering significant environmental benefits compared to virgin steel production (World Steel Association,2023). However, implementing a true circular economy for steel requires overcoming obstacles such as limitations in contamination in recycled scrap, the economic viability of recycling compared to virgin steel production (Liu, Lui, Zhang, 2021), supporting policies and the availability of scrap metal.

The strategy office reports:

"Our decarbonization ambition will be dependent on buy-in from multiple private and public sector partners. With supportive policy and backing from partners our journey to net zero can have multiple socio-economic spin offs for communities."

The steel company acknowledges that achieving its decarbonization goals necessitates a collaborative effort. This aligns with the growing recognition of climate change as a systemic challenge requiring multi-stakeholder engagement from both private and public sectors (World Economic Forum, 2023). Collaboration can foster knowledge sharing, resource mobilization, and innovation in decarbonization technologies, accelerating progress towards net-zero emissions (IEA,2023).

Furthermore, the company emphasizes the importance of supportive policy frameworks. Government policies, such as carbon pricing and renewable energy subsidies, can create a market environment that incentivizes investments in clean energy technologies, acting as a crucial driver for decarbonization (Fankhauser & Stern, 2016).

The potential socio-economic benefits of decarbonization efforts are also acknowledged, with the prospect of creating new jobs, improving public health through reduced pollution, and fostering regional economic development (UNEP, 2021).

Navigating the complexities of building effective partnerships that bridge the interests of diverse stakeholders can be challenging (Mullen, 2019). Additionally, securing long-term and consistent policy support can be hampered by political uncertainty (Buchan, 2023). Successfully navigating these challenges will be critical for achieving its decarbonization goals.

5.2 **Progress on Decarbonization initiatives**

Interview with the Office of Technology referred to the Decarbonization roadmap which set plans to achieve a 25% reduction in carbon intensity by 2030. Carbon intensity is measured by the tonne of CO2 emitted per tonne of crude steel produced. The calculated target is 2.16 tCO2 e / t crude steel, based on a 2018 baseline of 2.90 tonnes of carbon dioxide per tonne of crude steel produced. The company aims to further reduce the carbon intensity by 86% to 0.40 tCO2 e/t crude steel by 2050.

The Figure 11 below shows the roadmap with various initiatives to reduce the carbon intensity and by how much.

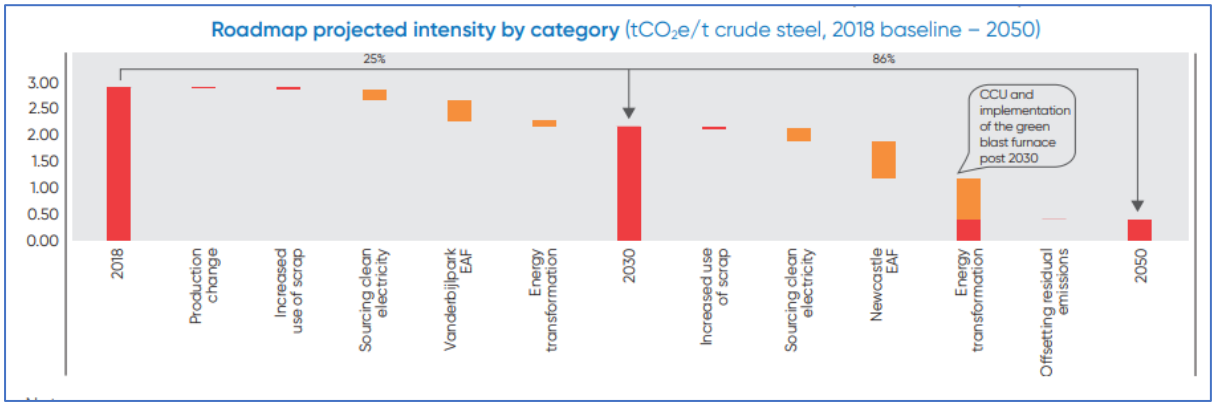


Figure 11: Decarbonization roadmap with projected carbon intensity reduction. Source: ESG Report 2022

Over the past three years, despite asset optimizations and energy and plant improvements, the carbon intensity associated with producing each tonne liquid steel seen in Figure 12, has not shown the anticipated progressive decline, having recorded figures of 2.91, 2.72 and 3.39 tonnes of CO2, respectively. This unexpected increase is attributed to reduced steel output coupled with a rise in electricity purchases due to suboptimal plant reliability and fluctuations in steel demand.

Key sustainability indicator	Unit	Limited Assurance provided for 2022	Year-on-year change	2022	2021	2020	Definitions
Making steel more sustainable							
Percentage of operations certified to the ISO 14001 standard	%		>	100	100	100	ISO 14001 is an international standard for environmental management systems
Greenhouse gases							
Direct carbon dioxide (CO_2) – Scope 1	t/t liquid steel	√	^	2.67	2.09	2.14	Direct CO_2 emissions
Indirect carbon dioxide (CO_2) – Scope 2	t/t liquid steel	√	^	0.72	0.63	0.77	Indirect CO_2 emissions due to electricity consumption
Total greenhouse gas (CO_2 equivalent Scope 1 and Scope 2)	t/t liquid steel	√	^	3.39	2.72	2.91	IPCC methodology as prescribed in National GHG Reporting Regulations used for reporting purposes
Total greenhouse gas (CO_2 equivalent Scope 1 and Scope 2)	Mt	√	v	8.35	8.41	6.71	

Figure 12: Key Sustainability Indicators. Source: ESG report 2022

The company claims to be on track to achieve set targets, with **the office of Technology stating:**

"So 25% by 2030 to answer the question are we on track, yes. But I need to qualify that, on the way there's always disturbances. Disturbances are linked to what efficiencies can you maintain at a given point in time in your business."

However, it is not aligned with their reported 25% emissions reduction target by 2030. The company recognises the potential for "disturbances" is crucial for a realistic assessment of progress (WBCSD, 2023). The identified impact of plant reliability on emissions highlights the importance of operational excellence in emissions reduction strategies, as highlighted by research (IEA, 2023).

Although there is a level of transparency in reporting, the lack of specifics on how the company plans to address these potential disruptions and maintain efficiency. A clear roadmap for addressing such challenges is essential to ensure stakeholder confidence (KPMG, 2023) and ensuring accountability for achieving targets (PwC, 2023).

The company is in progress with their no-regret options and the office of Technology state:

"We are changing our electricity over the fence to renewables and employing Power Purchase Agreements (PPA). We have the approval to build the 200 MW solar plant."

"The pursuit of renewable energy projects has faced obstacles in the form of authorizations and lengthy permissions required. South Africa has good renewable resources but a difficult legislative environment. We are doing our best, need to follow the rules, although it takes a time."

The company's efforts to transition to renewable electricity showcase a commitment to clean energy. Their strategy includes utilizing Power Purchase Agreements (PPAs)

and constructing a 200 MW solar plant, aligning with global trends of adopting renewable energy sources (IEA, 2023). PPAs offer long-term contracts for electricity generated from renewables, accelerating their integration into the grid.

The company however admits to experiencing challenges associated with lengthy permitting processes for renewable energy projects in South Africa. This complex regulatory environment, also highlighted by the World Bank (2023), can be a significant barrier to clean energy adoption. Apart from impacting cost and overall feasibility of renewable energy initiatives (Rogerson, 2019), it can discourage investment and hinder the pace of the energy transition.

The OECD's 2024 report also highlights that, despite the ability of private sectors to develop their own renewable energy facilities, they are often restricted by limited access to the electricity grid. The electricity supplier is similarly struggling with issues faced by the steel industry, including securing financing, supportive policies, and resources.

For a clean energy transition aligned with the Paris Agreement, substantial investment is crucial to enhance grid networks for the system-wide integration of renewable energy sources (IEA, 2023). This investment strategy involves the construction of new transmission lines to connect emerging low-carbon technologies, thereby broadening energy access for consumers. Additionally, it calls for modernizing existing networks to achieve greater grid flexibility, which can be achieved by incorporating automation and digitalization initiatives. These improvements are essential to expedite the adoption of cleaner energy solutions within the steel industry (IRENA, 2023).

There is an opportunity for more research to delve deeper into the reasons behind the absence of established procedures and the implications of these delays on the renewable energy sector. This also includes specific pricing and wheeling mechanisms that create obstacles and potentially propose alternative approaches to facilitate faster implementation. Collaboration with policymakers and streamlining regulations could significantly expedite the transition towards a clean energy future (IEA, 2023).

5.3 **Funding Capabilities**

When questioned on the funding capabilities, the **response from the Technology office was:**

"Government grants are available; however, the value only allows for feasibility studies and not capital for construction."

The company is in discussions with government, including the Industrial Development Corporation (IDC) and other banking institutions to secure preferential funding further stating:

"Borrowing money is also expensive in South Africa, with high interest rates offered by the banks." The inflation rate trend can be observed in Figure 13. The current inflation rate stands at 6%, which is higher than the forecast from 6 months ago.

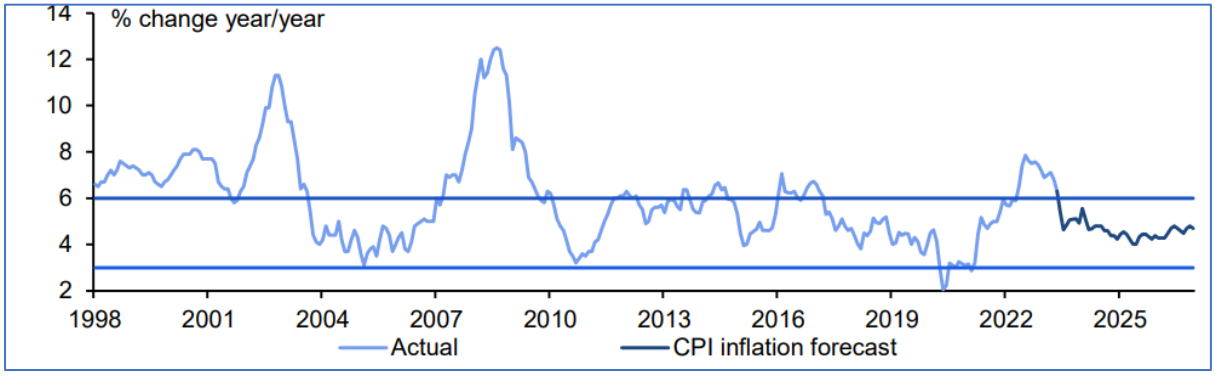


Figure 13: South African consumer inflation: History and Forecast. Source: Stats SA, Investec (2024).

The company's initial statement that government grants solely support feasibility studies in South Africa requires further analysis. While some grants may have limitations in scope, the country offers programs with the potential to fund construction. The Department of Mineral Resources and Energy's (DMRE) Renewable Energy Independent Power Producer Procurement Programme (REIPPPP) provides a combination of grants and loans for qualifying renewable energy projects (Department of Mineral Resources and Energy, n.d.). Similarly, the Department of Environmental Affairs' (DEA) Green Fund offers grants that can be used for project development and investment in green initiatives, potentially including construction costs for renewable energy projects (Department of Environmental Affairs, n.d.).

However, it is important to acknowledge potential limitations associated with government grants. These grants may be restricted in size, potentially falling short of the total project construction cost. Additionally, the availability of these grants might

be limited or subject to high competition, forcing companies to explore alternative funding sources (Rogerson, 2019).

Regarding the high borrowing costs mentioned by the company, South Africa's interest rates can indeed be higher than those in some developed economies (Trading Economics, 2024). However, there are options to mitigate this challenge. A more comprehensive research reveals government initiatives and private lenders offer more favourable terms for renewable energy projects. The Industrial Development Corporation (IDC), for instance, provides preferential loan rates specifically for renewable energy projects (Industrial Development Corporation, n.d.). International Development Finance Institutions (DFIs) like the World Bank's International Finance Corporation (IFC) or the African Development Bank (AfDB) can also offer competitive loan rates for renewable energy projects in developing countries (International Finance Corporation, 2023; African Development Bank, n.d.).

By exploring these options, companies can potentially overcome the limitations of smaller grants and high-interest bank loans, facilitating the transition towards renewable energy.

5.4 **Natural Gas shortage**

South Africa is facing a critical challenge in the form of a projected natural gas supply shortage by 2026. This "gas cliff" scenario arises from the expiration of existing supply contracts coupled with limited domestic production and gas availability (Polity, 2024). The potential consequences for industrial operations are significant, as highlighted by the Industrial Gas Users Association of South Africa (IGUA-SA) who emphasize the importance of immediate collaboration to bridge this supply gap (Engineering News, 2024).

In response to this impending crisis, the company is actively exploring alternative energy sources and pursuing strategies for plant optimization and improved energy efficiency. These efforts align with South Africa's national goals of transitioning towards a clean energy future (OECD, 2024).

Furthermore, collaboration between industry, research institutions, and government is seen as a vital approach. By working together, these entities can accelerate technological advancements in renewable energy and energy efficiency solutions, ultimately mitigating the impact of the gas shortage (OECD-IEA Workshop, 2023).

5.5 **Scrap levy**

South Africa's primary steelmaker faces a challenge due to government policies intended to bolster the domestic steel industry. The company utilizes scrap metal in both the Blast Furnace-Basic Oxygen Furnace (BF-BOF) and Electric Arc Furnace (EAF) routes, aligning with a circular economy approach (Allwood et al., 2019). However, the EAF route, considered more environmentally friendly due to lower carbon emissions (UNEP, 2020), is also employed by local competitors.

The government, through the International Trade Administration Commission of South Africa (ITAC), implemented the Price Preference System (PPS) requiring scrap metal dealers to offer their materials at a discount to local users before export (SARS, 2021). This policy aims to support domestic steel mills and foundries by enhancing their economic competitiveness against imports, ultimately promoting investment, job creation, and industrial growth (DTI, 2019).

Additionally, a scrap export ban was enacted in December 2022 (South African Government, 2022) to curb copper and ferrous metal theft. This further strengthened the market position of secondary steelmakers who rely heavily on scrap. South Africa's steel industry comprises 11 secondary steelmaking businesses compared to just one primary steelmaker (SAISI, 2023).

The combined effect of the PPS and export ban has potentially created an uneven playing field, favouring secondary producers who enjoy a cost advantage due to preferential scrap pricing. While data on the specific cost disadvantage faced by the primary steelmaker is not readily available, industry reports suggest a decrease in production volume due to these policies (SAISI correspondent, personal communication, January 24, 2024).

Furthermore, the scrap export ban may have unintended consequences. While it aims to reduce metal theft, a potential oversupply of scrap within the country could contribute to steel overcapacity. It's crucial to investigate other potential causes of overcapacity, such as a decline in domestic steel demand.

The primary steelmaker needs to address this challenge and create a sustainable competitive advantage. Collaboration with the government to find solutions that balance environmental, economic, and social objectives could be a path forward.

5.6 **Carbon Tax**

The Office of Strategy asserts that carbon tax is being paid however it is not being utilized by the government to encourage decarbonization projects in the industry:
"Carbon tax rates have now been promulgated up to 2030, but uncertainty around tax-free allowances continues. This makes it impossible for us to predict with any certainty our future tax liabilities, especially in the period from 2026."

One major concern is the difficulty businesses face in accurately forecasting costs. Reliable cost forecasts are central for making informed decisions about investments, production levels, and product pricing (Helm, 2020). Uncertainty around tax-free allowances makes it difficult to predict future carbon tax liabilities, hindering long-term planning. This lack of clarity can lead to businesses delaying or even abandoning investments in low-carbon technologies and processes. Without a clear understanding of potential future tax benefits, such as increases in tax-free allowances, businesses may be hesitant to make these necessary investments, ultimately slowing down the transition to a low-carbon economy (Calderón, Duan, Fuller, Gescher & Jotzo, 2019).

There are some factors that can help businesses navigate this new landscape. While the specific details of tax-free allowances might be unclear, the carbon tax rates themselves are already established for the next several years (up to 2030). Businesses can utilize these known tax rates for their core cost calculations, providing a degree of predictability. Additionally, governments often adjust tax-free allowances based on established trends or through policy

announcements. By closely monitoring these trends and announcements, businesses can adjust their forecasts accordingly, reducing the impact of uncertainty (Sterner & Persson, 2008).

The potential impact of the carbon tax on a company's financial sustainability on the other hand depends on several factors, including the company's carbon footprint, the tax rate, and its ability to pass on some of the costs to consumers. Industry reports suggest that some companies might experience reduced profit margins in the short term (SA Chamber of Commerce and Industry, 2023).

In addition, a key aspect of carbon tax policy is the allocation of revenue. While South Africa's carbon tax plan outlines various uses, including social development and economic growth, a dedicated portion could be allocated to incentivize low-carbon projects (National Treasury, Republic of South Africa, 2023). This could include grants for renewable energy infrastructure development, energy efficiency upgrades, or carbon capture and storage technologies. Such incentives could accelerate the transition and provide a clear signal to businesses to invest in low-carbon solutions.

By strategically allocating revenue towards low-carbon projects and fostering collaboration within the supply chain, South Africa can leverage the carbon tax to achieve its decarbonization goals. A holistic approach to reduce Scope 1 and 2 emissions (direct and indirect emissions) requires working with the supply chain partners to adhere to similar environmental standards (SAISI, 2023).

While Europe's decarbonization efforts are significant, a more focused comparison might be relevant. For example, analyzing how specific carbon tax revenue allocation strategies employed in established carbon tax regimes (eg. Sweden) could be adapted to the South African context might be more insightful.

5.7 **Carbon Border Adjustment Mechanism (CABM)**

The EU’s implementation of the Carbon Border Adjustment Mechanism (CBAM) aims to align the carbon pricing of imported goods with that of domestically produced items, upholding the EU’s climate goals without compromise (European Commission,

2023a). Mandatory enforcement beginning in January 2026 will require importers to annually disclose the volume and carbon content of goods brought into the EU from the previous year (EU, 2023a).

The company is poised to thrive amidst this new regulation, having proactively embarked on a decarbonization strategy, positioning themselves advantageously over domestic rivals. The CBAM initiative is anticipated to incentivize local steel consumers to earnestly contemplate decarbonization and the production of environmentally friendly steel (SAISI correspondent, personal communication, January, 24 2024). While it might incentivize consumers to consider lower-carbon steel options, it could also lead to increased import costs.

It creates an inequitable trading environment which has prompted proposed reforms to the World Trade Organization to advocate for a cooperative approach. The suggestion is for developed and developing nations, including the EU and US, to nurture a synergistic trade and environmental framework. This would stimulate and support developing countries in fulfilling their climate mitigation and adaptation commitments, rather than enforcing unilateral regulations like the CBAM (SAISI correspondent, personal communication, January, 24 2024).

5.8 **Market Development**

The company recognizes the importance of marketing and communication in driving awareness and perceptions regarding their efforts to address global warming. The marketing strategy extends beyond the decarbonization program and promotes the company's initiatives to become environmentally friendly and compliant. The Office of **Marketing state:**

"It is important to mention that it is not only decarbonization but its sustainability in the general sense that we are looking at. The perception outside is that steel is a polluting industry, which is true, it is the third or fourth polluting industry in the world, generating about 7 to 8 % GHG emission. People have the wrong perception about it. A lot has not been done to market and improve perceptions so that is why we decided we must change it."

The steel industry faces a critical challenge in addressing its environmental footprint. The company highlights the need to consider not only decarbonization efforts but also public perception of the industry.

There is evidence to support the claim that negative public perception can have a significant impact. Consumers are increasingly making purchasing decisions based on sustainability factors (Brezet and van der Meer, 2008). A negative perception of the steel industry's environmental impact could lead to decreased demand for its products. Furthermore, public perception can influence a company's or industry's "social license to operate" (Moffatt, 2016). Without public support, the steel industry could face stricter regulations or even bans on its activities.

However, a focus solely on improving public perception without concrete actions towards decarbonization shall raise concerns. Regardless of public perception, reducing greenhouse gas emissions remains an essential environmental imperative for mitigating climate change. Focusing solely on perception management strategies without demonstrable progress on decarbonization could be perceived as "greenwashing" (Laufer, 2019).

A successful approach for the company requires a multi-pronged strategy. The steel industry must prioritize reducing its environmental impact through concrete decarbonization efforts. At the same time, proactive communication strategies can improve public understanding of the industry's sustainability initiatives. This approach can help the steel industry navigate the changing landscape and ensure its long-term viability.

5.8.1 **Brand, Offering and Relationship (BOR) Marketing Strategy**

Overall, marketing plays a significant role in steel sales by creating awareness, building trust, positioning the company, nurturing relationships, expanding markets, and gaining a competitive advantage. It helps companies establish a strong presence in the industry, generate leads, and ultimately drive sales and business growth.

The construction industry is experiencing a significant shift towards sustainable practices, with a growing demand for eco-friendly materials like steel (Jeswani, Azapagic & Brent, 2020). Steel producers are responding by developing products with lower environmental footprints and implementing certification programs to verify their sustainability credentials.

One key strategy employed by the company is the use of responsible certification for specific steel products. These certifications involve adhering to established eco-friendly standards and displaying corresponding labels. Certified steel offers a clear benefit to customers pursuing sustainable construction (Aktas and Isık, 2018). By incorporating certified steel into their projects, customers can demonstrate their commitment to environmental responsibility and potentially enhance their green building credentials.

The company aims to capitalize on this growing market demand by providing customers with the means to elevate their sustainable construction practices. However, the company acknowledges that financial constraints have limited their ability to expand their offerings of certified steel products in the past. This highlights the crucial role of financial resources in scaling up responsible certification efforts. Further research could explore potential solutions to overcome these limitations. Options might include forming partnerships with certification bodies, seeking grants or dedicated funding for sustainable steel production, or investigating more cost-effective certification schemes (WBCSD, 2020).

The company's customer support data reveals an interesting trend: inquiries regarding green steel primarily come from clients involved in international projects. This suggests a stronger interest in the recyclable steel content within products from the international construction sector.

To address this growing interest and promote eco-friendly practices, the company has launched a program encompassing an innovation fund, green certifications, and renewable energy initiatives. A more in-depth examination of this program is necessary to fully understand its effectiveness. Transparency regarding the program's specific goals, the actions taken to achieve them, and the resulting outcomes would be valuable. Furthermore, information on accessibility, the terms and conditions of any

financing offered, and the extent to which the program supports diverse decarbonization projects and fosters industry-wide progress would be crucial for a comprehensive evaluation.

Potential marketing strategies for sustainable steel that may be explored by the company include how the company can effectively communicate the environmental benefits of their sustainable steel products to target audiences, such as architects, engineers, and construction companies (Chen & Chen, 2010), educating the industry stakeholders about the importance of using sustainable steel and partner with industry associations or advocacy groups to promote the use of green steel.

According to the Office of Marketing, the perception among local customers is that they are not too concerned about purchasing green steel at this time:
"Locally there is little demand for green steel. It is mostly companies who are exporting or supplying to the industry which are subject to CBAM."

Understanding the specific barriers to local demand for green steel would provide insights into the market dynamics and could inform strategies to increase awareness and promote sustainable practices within the local customer base.

There is an implication that there is a disconnect between local customer priorities and industry trends of regulatory expectations would help the company tailor its approach accordingly. Understanding the specific reasons behind this limited local demand is crucial for developing effective strategies to promote green steel adoption.

Further research is necessary to identify the specific factors hindering local demand for green steel. Potential barriers could include the expectation of paying premium price for green steel, limited understanding of the environmental benefits and long-term cost advantages of green steel and the absence of supportive regulations to incentivize the use of green steel products.

A report by DSS (2024b) highlights the potential effectiveness of forming partnerships with downstream companies to develop pioneering sustainable steel products. This approach offers several advantages including collaborative development of innovative

green steel products can provide a tangible demonstration of the benefits for consumers and collaboration throughout the supply chain can raise awareness of green steel and stimulate demand.

For instance, partnering with a South African car manufacturer to produce vehicles using low-carbon steel could create a unique selling proposition for the automaker. This collaboration would simultaneously promote green steel to a wider audience.

In the realm of steel production, innovating to align products with customer demands is crucial. For instance, ArcelorMittal EU collaborated with the automotive sector to develop a high-strength, lightweight steel known as S-in-motion®. This product delivers benefits such as fuel efficiency, reduced emissions, and enhanced safety, all available at a competitive price (ArcelorMittal Climate Action Report, 2019). This exemplifies the importance of aligning product development with customer needs.

Additional innovations have emerged within the construction industry, such as Steligence®. This offering includes an array of slimmer, more lightweight, and higher-performance steel solutions that effectively lower the embedded carbon footprint of structures (ArcelorMittal Climate Action Report, 2019).

By using the Ansoff Matrix, the South African company should explore market development opportunities such as product development or market penetration. For instance, similar innovation opportunities as mentioned focused on the specific needs and cost sensitivities of the local market, by developing green steel products that address these considerations, the company can bridge the gap between international trends and local customer priorities.

According to the Office of Marketing, the demand for green steel at a local level is negligible to non-existent:

“My thinking is that if we need to ignite a demand for green steel, for green products in general there must be a demand from down up. The person who claims to buy a sheet of steel at the hardware store to build his shack at the township, if he asks for green steel, then a significant change has been achieved.”

The statement suggests that efforts should be made to create demand for green steel. It emphasizes the importance of starting from the grassroots level, with the ordinary person building his own home in the townships. There is a need to explore strategies to raise awareness about the benefits of green steel, engage with local communities and educate customers about the environmental and social advantages. Limited awareness regarding the benefits of green steel is a documented challenge (Khofi, Hanim & Mansor, 2020). Educational initiatives can address this knowledge gap, promoting not only the environmental benefits but also the long-term value proposition of green steel.

Another potential barrier is the perceived cost disparity associated with green steel production (World Steel Association,2020). Exploring innovative pricing models or collaborating with policymakers for incentives could mitigate this concern. For some consumer segments, particularly those focused on basic needs like building a home, affordability and immediate functionality might be prioritized over long-term sustainability (Sutter, 2020). Community outreach programs can be valuable tools to engage with these segments. By educating them about the environmental and social advantages of green steel, such programs can potentially influence purchasing decisions.

The steel industry consensus is that government is expected to take the lead in driving the production of green steel for competitive pricing in the export market (SAISI correspondent, personal communication, January 24, 2024) and these include supporting policies as well as stimulating the demand for green steel. A robust domestic market can justify production scale-up, potentially leading to cost reductions that benefit both local and export customers (WBCSD, 2020). This larger production scale can also enhance the company's global competitiveness.

By addressing the barriers to adoption and creating a robust domestic market, the company can contribute to a win-win situation for itself, the environment, and local communities. This approach aligns with the growing trend of consumer interest in sustainability while also supporting the company's overall business goals.

The Office of Marketing state:

"They will force the change. One reason is for the international commitment that they (government) have, in terms of climate action commitment. Another reason, CBAM – if I am exporting a certain amount of steel to Europe if my steel comes from a legislation where I have not paid any carbon tax or my steel is not green, I will have to pay that in Europe. Now it is like money South Africans are paying to Europe to sell their steel. So why not SA come up with a system whereby anybody wanting to export pays that money here in South Africa."

The previous discussion emphasized the importance of a conducive policy environment for facilitating the transition towards green steel production. The comment regarding government commitment raises a critical question. While international pressure and the Carbon Border Adjustment Mechanism (CBAM) incentivize change, the South African government's commitment and capacity to invest in green technologies and support the steel industry are crucial (European Commission, 2021; UNFCCC, 2015).

South Africa's history of policy pronouncements that lack effective implementation necessitates a clear strategy with concrete actions and timelines (Davis, 2002). This strategy could encompass several key elements:

- **Financial incentives:** Direct subsidies, tax breaks, or loan guarantees could be offered to companies investing in green steel technologies. These incentives can help offset the initial costs associated with transitioning to new production processes.
- **Research and development support:** Funding research institutions and universities can foster the development of innovative green steel production processes. This could involve supporting research into areas like hydrogen reduction or carbon capture technologies.
- **Infrastructure development:** Investing in infrastructure necessary for a green steel industry, such as renewable energy sources, is crucial. A reliable and clean energy supply is essential for powering green steel production processes.

- **Regulatory frameworks:** Developing regulations that promote green steel production and discourage conventional practices with high carbon emissions can be a powerful tool. This could involve implementing carbon pricing mechanisms or setting stricter emissions standards for the steel industry.

This will require a collaborative effort involving the government, the steel industry, and other stakeholders such as environmental NGOs and research institutions. A successful transition will require not only policy pronouncements but also a genuine commitment to implementation and ongoing collaboration between all stakeholders.

5.9 **Customer Perspective**

Customer engagement proved to be challenging, as the majority were hesitant to participate in interviews. This reluctance could stem from a lack of understanding of decarbonization, the concept of green steel, and its implications for their businesses. A leading supplier to the automotive and construction sectors in the South African market, highlights the current low interest from the consumers.

The merchant staunchly asserted that in South Africa, the demand for inexpensive steel takes precedence over the demand for high-quality steel.

Moreover, they argued that the prevailing local economic conditions do not support the production and commercialization of green steel. They advocate for a concerted effort over the next three to five years to educate the steel supply chain on the advantages of green steel. They believe that emphasizing the benefits, which they argue would more than compensate for higher price, will lead to a better alignment within the industry.

"When green steel is available, hopefully the emphasis will be on it benefits and not price. The South African Long steel market is more sensitive to price than quality."

The interview further distinguishes between the formal and informal steel economy, and it will be a long time before the latter accepts the concept of green steel and its consequences. It is expected the formal economy, which includes the automotive and construction sector, will respond more quickly to efforts for green steel.

Net zero emissions cannot be achieved if both sectors do not comply:

“There is a lot of work that needs to be done on the South African market to get to the stage where green steel is sought after. Government needs to exert pressure to facilitate change in the formal sector like mining and automotive. It is doubtful that change would be seen in the informal sector. The formal sector is active globally and once they are aligned, changes in green steel procurement can be expected.”

There is a disparity in acceptance between the formal and informal steel sectors. Factors such as level of awareness, access to information, financial capacity, market pressures that shape the attitudes towards green steel in the two sectors must be understood to be addressed. It is highly likely that the current state of the South African economy, where businesses are struggling to survive, is the reason that decarbonization is not a priority, even for the formal economy of the steel sector. Similarly, government is struggling to provide basic services to South Africans and lack the resources and skills necessary to affect policy coherence. The company is urging the government to foster localization within the industrial sector to decrease reliance on imports and generate increased opportunities for domestic steel manufacturers.

By integrating the theoretical frameworks in the study, the steel company can develop a comprehensive and adaptable strategy for achieving its sustainability goals while navigating the complex business environment.

6. Conclusion

The study supplements existing research indicating the potential for near-complete decarbonization of South Africa's steelmaking industry by 2050. Achieving this goal can be accomplished through incorporation of sustainable practices into a series of strategic approaches. These include retrofitting existing blast furnaces with carbon capture and usage (CCU) technologies, expanding hydrogen-based direct reduced iron (DRI) production, increasing the use of renewable energy sources, promoting circular economy, and enhancing the efficient usage of steel to moderate demand growth.

Despite this potential, there are serious risks that could hinder the realization of decarbonization goals set by the Paris Agreement in South Africa. One such risk is the continuous load shedding crisis, impacting the productivity and profitability of the steel supply chain, making it challenging to invest in decarbonization. Unfair trade policies and economic instruments at local and global levels, such as scrap levies, carbon pricing, and Carbon Border Adjustment Mechanism (CBAM), create an inequitable playing field for the steel industry. Additionally, local and global supply chain disruptions, a weakening currency, and inadequate policies for energy renewables further exacerbate these challenges, leading to downsizing and closures within the industry.

Decarbonization places significant environmental and financial pressure on the industry, especially considering the struggle to sustain operations. While carbon reduction technologies need to be developed urgently to achieve the 2050 net-zero emissions target, generating necessary funds at the required pace is unlikely. There is an urgent appeal to the government to level the playing field by implementing fair policies and incentivizing the steel value chain towards decarbonization through carbon tax application and ring-fenced funding.

Furthermore, concerns are raised about the government's capabilities and expertise in implementing policies and navigating the energy transition, given the history of load shedding in the country. The industry's heavy reliance on natural gas as a replacement or complement for by-product fuels poses a serious challenge when the supply is

depleted in the next two to four years. Identifying collaborative partnerships within the industry is crucial for sustainability and funding opportunities.

The integration of carbon capture and usage (CCU) in the decarbonization plan is seen as risky and uncertain by some technology experts. Further research and development is urgently required to explore breakthrough technologies to reduce carbon intensity. The reliability issues within the industry impact CO_2 emission targets, making capex and plant optimization crucial priorities. Strong governance is necessary to ensure commitments are adhered to.

While the primary steel industry has well-defined decarbonization plans to achieve net-zero emissions by 2050, more government support is required for a smooth transition. Most steel companies, apart from one, have not published their plans, with some believing the use of recycled steel is adequate due to the lack of standard for green steel. This emphasizes the need for clear policies and standards to drive sustainability within the steel industry and its supply chain.

Contrary to expectations, there is currently little demand from the automotive and construction industries in South Africa to purchase green steel at a premium price. These industries prioritize steel with specific quality standards and environmental certifications but have not increased interest in purchasing green steel, demonstrating no perceived value to automotive and construction sector in the short to medium term. The challenges faced by businesses and households in South Africa make decarbonized steel less of a priority at present. Importing green steel becomes a likely option if it is not readily available within the country.

To shape future demand for green steel, the local steel industry needs to improve its marketing strategies by increasing consumer awareness of its decarbonization efforts. Collaboration with research and development functions can contribute to product differentiation initiatives, enticing customers and showcasing the profitability of sustainable practices. Market research should precede product differentiation efforts to align with customer needs and preferences, increase customer value, outperform rivals, and improve sustainable competitive advantage. Investing in marketing should be prioritized, with strategies designed for both the formal and informal steel sectors.

Collectively, these actions can facilitate the wider acceptance of green steel, propelling the South African steel industry towards greater sustainability. Policymakers must take this urgency into account and reform policies to align industries with the net-zero emissions target. Given the steel industry's significant impact on the economy, its fall can result in the collapse of the South African economy.

Further research is needed to understand changing perceptions of green steel among steel customers in South Africa as the economy recovers. This research should also focus on the progress of renewable energy policies, decarbonization plans within the steel supply chain, and the impact of CBAM on South African steel prices. Future analysis of the cost disparity between brown and green steel in price-sensitive markets will provide insights into competitiveness.

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8. Appendices

A. Research Instrument

Interview Schedule

INTERVIEW QUESTIONS

COMPANY	
NAME OF PARTICIPANT	
POSITION TITLE	
DEPARTMENT	
DATE	
INTERVIEWER	

STRATEGY

1. Establish rapport with participant.
2. Kindly explain your role in the company.
3. What are the current challenges (threats) being faced by the company?
4. How does the company manage and prioritize its responses to the challenges?
5. What would you say is the current business strategy and how is the company preparing for it? Kindly explain in the context of company's business model.
6. What is the company's stance on sustainability? How is the company strategy influenced by the sustainable development goals?
7. What do you see the impact of Decarbonization being on the company and how is the company positioning itself for this?
8. Who are the competitors to this company?
9. What is the strategy to remain sustainable and competitive in this industry?

INTERVIEW QUESTIONS

COMPANY	
NAME OF PARTICIPANT	
POSITION TITLE	
DEPARTMENT	
DATE	
INTERVIEWER	

DECARBONIZATION

1. Establish rapport with the participant
2. What is your role in the company?
3. How is the company responding to the climate action targets?
4. What are the different types of technology being explored?
5. What is driving the selection of the technology?
6. Can you take me through your company's decarbonization plan and targets and the motivation behind it.
7. Will there be an impact in the quality of green steel?

INTERVIEW QUESTIONS

COMPANY	
NAME OF PARTICIPANT	
POSITION TITLE	
DEPARTMENT	
DATE	
INTERVIEWER	

MARKET DEVELOPMENT # STRATEGY

1. Establish rapport with the participant.
2. Can you explain the company's current BOR strategy?
3. My interest is to understand how the company is positioning itself in the market with respect to green steel. Kindly tell me what initiatives are in the pipeline for creating a market for green steel.
4. What value is the company attaching to green steel?
5. Has there been any engagement with customers regarding green steel? In your view, what can be expected with regards to customers purchasing green steel?

INTERVIEW QUESTIONS

COMPANY	
NAME OF PARTICIPANT	
POSITION TITLE	
DEPARTMENT	
DATE	
INTERVIEWER	

CUSTOMER

1. Establish rapport with participant.
2. Kindly explain your role in the company.
3. Please provide overview of the business.
4. How regularly are you purchasing steel from company X and at what quantities?
5. Have you given consideration to purchasing green steel for your business and what are your thoughts surrounding this?
6. How will Decarbonization and green steel affect your business?
7. How do you foresee your business reacting to this change?