Gordon Institute of Business Science
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Decarbonisation in the South African mining industry: A study on strategies, drivers and barriers for Climate Change mitigation

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A research project submitted to the Gordon Institute of Business Science, University of Pretoria, in partial fulfilment of the requirements for the degree of Master of Philosophy (Corporate Strategy).

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Abstract

This qualitative study explores the challenges faced by the South African mining industry in decarbonising. The industry is a significant contributor to the national economy and plays a crucial role in global efforts to mitigate climate change. The study involves interviews with mining professionals and industry experts to comprehensively examine the decarbonisation strategies employed by South African mining companies. The focus is on identifying the key drivers and barriers to reducing greenhouse gas emissions and highlights the importance of the mining sector in achieving climate targets through strategic energy management and the adoption of renewable energy sources.

The study found that the mining industry has made progress in addressing Scope 1 and Scope 2 emissions, but there are limitations in terms of technology maturity and policy frameworks. The study also identified Eskom's energy supply monopoly as a significant barrier to the widespread adoption of renewable energy sources. These insights emphasise the need for a nuanced approach to decarbonisation in South Africa, taking into account the economic significance of the mining sector and the unique challenges it faces. The study provides valuable perspectives on sustainable practices in heavy industries and offers crucial information for stakeholders, policymakers, and industry managers to shape future strategies and policies for a sustainable and low-carbon mining industry in South Africa.

DECLARATION

I declare that this research project is my own work. It is submitted in partial fulfilment ofthe requirements for the degree of Master of Philosophy in Corporate Strategy at the Gordon Institute of Business Science, University of Pretoria. It has not been submitted before for any degree or examination in any other University. I further declare that I have obtained the necessary authorisation and consent to carry out this research.

Name & Surname Signature

Contents

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Business Sustainability

Climate Change

Carbon Emissions

Renewable energy

Chapter 1: Introduction

Greenhouse gases, particularly carbon dioxide (CO_2), are identified as the main drivers of climate change (Caglar et al., 2022). The combustion of fossil fuels plays a role in heat retention, leading to global warming (Omri & Saadaoui, 2023). To reach the Paris Agreement climate targets of keeping the impact of climate change below 2 degrees Celsius, it is necessary to rapidly and continuously reduce greenhouse gas emissions (IPCC, 2021). This requires collective action at all levels of society. One key element to achieve this is decarbonisation, a systematic approach to reducing the amount of carbon in primary energy resources (IPCC, 2023; Omri & Saadaoui, 2023). The reduction in CO2 emissions is a significant factor in mitigating climate change and has been adopted by the Paris Climate Accord as it aligns with the goals of a net-zero target (IPCC, 2023).

Decarbonisation is a crucial goal and process in global sustainability governance. It involves gradually reducing carbon intensity in primary energy, consistent with the Paris Climate Accord's objectives, especially the commitment to limit global warming to less than 2°C. To achieve this goal, net-zero greenhouse gas emissions must be attained between 2060 and 2100, according to Wesseling et al. (2017).

In order to support the global effort to reduce carbon emissions, countries must fulfil their National Determined Commitments (NDCs) by adhering to international conventions, investing in renewable energies, and supporting climate change agreements (King & Van Den Bergh, 2019). These commitments require widespread decarbonisation across various sectors and industries (Delevingne et al., 2020). Companies, which are the primary contributors to CO2 emissions, are under pressure to decarbonise due to societal and political demands (Johnson et al., 2023).Therefore, it requires that energy-intensive industries such as the mining sector must adopt effective strategies to reduce their emissions as part of the broader effort to mitigate climate change (Seroka-Stolka, 2023).

1.1. Global attention to climate change

The decarbonisation concept was formalised by the United Nations framework for climate change convention (UNFCC), enacted in the 2015 Paris climate agreement. The agreement intends to limit global warming to well below 1.5 degrees compared to pre-industrial levels (Delevingne et al., 2020). Prior to this consensus, the 1992 Rio De Janeiro Earth Summit, was the first global discussion that explicitly addressed climate change. The summit agreed that there should be a" stabilisation of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system" (Delbeke et al., 2019; Tollefson & Gilbert, 2012).

This was followed by the 1998 Kyoto Protocol, which took substantial steps by setting binding emission reduction targets. Countries were required to reduce emissions by 5% below 1990 levels (Delbeke et al., 2019). However, the Kyoto Protocol faced numerous challenges, such as low levels of commitment from high-emitting countries like the USA, which did not ratify the agreement. Further, developing countries like China and India, major carbon emitters, were excluded from the treaty as it focused more on developed nations (Delbeke et al., 2019).

These historical developments and progression underscore the global emphasis on reducing carbon emissions and make decarbonisation a conceptual approach and a practice intertwined with international policies and agreements. These agreements require nations to comply with nationally determined contributions (NDCs), which encapsulate the pledges and actions towards cutting greenhouse gas emissions of which decarbonisation strategies play a key and essential role (King & Van Den Bergh, 2019).

While decarbonisation is celebrated as a significant stride towards a sustainable future, there are concerns about its efficacy and practicability. For instance, nations' commitment to the Paris Agreement and the consequent development of nationally determined contributions (NDCs), has not been without criticism. Scholars like Doelle (2019) have criticised the voluntary nature of NDC's, emphasising the absence of strict enforcement to ensure that countries meet set targets.

Morin & Jinnah (2018) argue that these climate agreements are a weak contribution to addressing climate change and are not adopted by the most significant greenhouse gas emitters. The over-reliance on countries' goodwill and self-determination can lead to inconsistencies and inadequate progress in global decarbonisation efforts (King & Van Den Bergh, 2019). The practical implementation of NDCs encounters obstacles, including technical capacity, funding, policy integration, and public and private sector engagement (King & Van Den Bergh, 2019).

Furthermore, there is a general lack of enforcing compliance with emission reduction commitments. There are no stringent penalties for non-compliance, and concerns are expressed over the accuracy and transparency of emissions accounting, monitoring, and reporting. This is underscored by the persistent increase in CO_2 emissions (Doelle, 2019; King & Van Den Bergh, 2019). Figure 1 depicts annual emissions tracked since 1992. To date, the only annual drop recorded was in 2020, and this was a result of measures implemented to slow the spread of the COVID-19 pandemic (Kuramochi et al., 2021; Le Quéré et al., 2021).

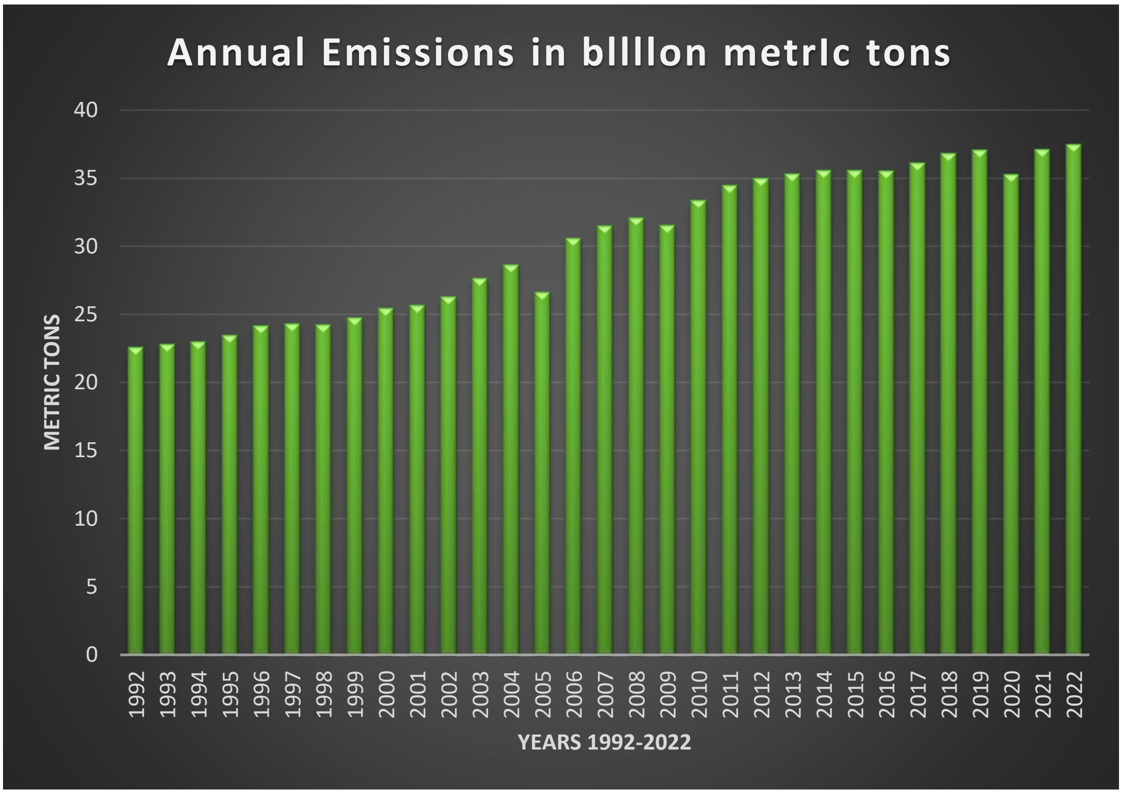


Figure 1: Annual Carbon Emissions; 1992-2022. Graph developed by the author using data from StatsData (2023)

1.2. Decarbonisation in mining

In light of the global agenda towards decarbonisation, understanding the implications for the mining sector is critical. This study delves into specific strategies being shaped by mining companies on the journey to lower carbon emissions from direct and indirect business activities. The exploration not only identifies the range of actions taken but also examines the motivations and challenges behind strategies and approaches being implemented. The study is vital for business as it underscores the need to harmonize environmental sustainability with economic viability.

Globally, the mining sector is a significant contributor to greenhouse gas emissions and thus holds sway in contributing to achieving greenhouse gas reduction goals (Caglar et al., 2022; Immink et al., 2018). This energy transition is poised to reshape energy demands which may potentially lead to a decrease in global mining revenue. To activate the potential impact of sector-wide decarbonisation, mining companies need to incorporate carbon reduction strategies into key portfolios and long-term planning (Delevingne et al., 2020). This approach will drive adaptations that protect the environmental landscape whilst remaining competitive (Seroka-Stolka, 2023).

According to Ivic et al. (2021) sustainability practices provide organisations with competitive edge in terms of cost saving, increased efficiency and improved public perception (Ivic et al., 2021). External pressures can also serve as a catalyst for businesses to adopt sustainability innovations which will lead to improved business performance. Innovation adoption in sustainability practices can be seen as a means of optimising a firm’s performance and improving its competitiveness towards a more sustainable future (Hermundsdottir & Aspelund, 2021). Having adopted this eco-conscious view towards strategic management, companies have voluntarily adopted a range of pertinent actions. The goal is to differentiate by integrating sustainability into processes and procedures along the value chain (Ivic et al., 2021).

1.3. Decarbonisation in South Africa’s mining sector

The mining industry is one of the most significant contributors to South Africa’s economy. In 2022, the industry contributed 493.8 billion to the country's GDP and employed a total of 475,561 people (Minerals Council South Africa, 2023). Furthermore, mining added an estimated R356 billion or 7.3% to the national GDP and accounted for 25% of the country's total export earnings (Minerals Council South Africa, 2023). This highlights the significance of mining and underscores the need for the industry to navigate energy transition interventions effectively.

Like everywhere else, mining in South African is an energy intensive industry and this is further exacerbated by the heavy reliance on coal produced electricity. Additionally, other sources of GHG emissions in the industry include diesel for transportation of ore over increased distances from remote and deep level operations (Immink, Louw, & Brent, 2018). Diesel is the primary energy source for opencast mines, while underground mining relies on grid electricity for the operations as well as for ventilation, cooling and safety systems such as the hoisting of personnel. According to Immink et al. (2018, p. 15), “the decarbonisation of the mining sector is closely linked to energy consumption patterns and energy targets of mining companies”.

Therefore, the South African mining sector is crucial in achieving the climate targets and ensuring a low carbon economy. This is mainly attributed to its significant emission of greenhouse gas (GHG) which accounts to about a total of 7% of South Africa’s total climate change greenhouse gases(Carels et al., 2013). The Carbon Brief Profile of South Africa states that the country is the world's 14th largest emitter of greenhouse gases, and these emissions are as a result of heavy reliance on coal and other fossil fuels (Carbon Brief, 2018).

Just transition and climate pathway study for South Africa states that the decarbonisation in South Africa will primarily be driven by cleaner and renewable energy supply (National Business Initiative, 2021). This would require, for now, a combination of grid and self-generation electricity. Furthermore, mining fleet also present an opportunity to decarbonise, owing to their heavy usage of diesel consumption. Most critically, the decarbonisation project in South Africa needs a well phased out approach, owing to a need to reduce the carbon intensity of South Africa's economy to maintain competitiveness (National Business Initiative, 2021).

There are numerous challenges to decarbonizing the mining industry in South Africa, along with the excessive strength and depth of mining operations, the restricted availability of renewable strength sources, and the excessive capital fees associated with transitioning to low carbon technologies. The decarbonisation process main goal to a net-zero economy in 2050, will have its set of consequences on critical stakeholders, such as labour, communities and supply value chains (Goddard & Farrelly, 2018; Papadis & Tsatsaronis, 2020; Strazzabosco et al., 2022).

A key factor in energy transition lies in the integration and implementation of energy reduction activities in ways that do not compromise operational efficiency or throttle production outputs (Immink et al., 2018). This balance is integral to the industry's broader shift towards decarbonisation. For firms in South Africa, enduring reliance on carbon-based energy sources introduces an additional layer of complexity. Diesel usage is critical for opencast mining while coal-generated electricity is used in underground mines to power production and ensure occupational safety functions such as ventilation and hoisting of personnel (Immink et al., 2018).

Furthermore, adapting to a change in energy patterns is not only of environmental concern but is an aspect of business relevance and competitiveness. In essence, the strategic alignment of decarbonisation goals with operational realities forms the cornerstone of sustainable business practices in mining operations (Immink et al., 2018).

The mining sector is of vital importance in South Africa, playing a significant role in both the economy and pathways to decarbonisation. However, there is a lack of comprehensive literature specifically focusing on decarbonisation strategies within this industry. While existing research primarily concentrates on the transport sector in South Africa, there is a noticeable void in scholarly discourse about decarbonisation in the mining sector. This gap is particularly evident in understanding the drivers, challenges, and specific strategies for decarbonisation in South African mining operations. Given the sector's impact on national economic performance and greenhouse gas emissions, there is a critical need for studies to delve into decarbonisation within the South African mining context.

1.4. Theoretical Relevance

Scholarly attention to decarbonisation within the extractive, energy-intensive and heavy industries such as mining, continues to expand (Buettner, 2022; Johnson et al., 2021). Research in advanced markets such as Sweden and Australian has exposed the role of these industries in reducing global greenhouse emissions. Discussions on how to decarbonise the mining sector revolve around four strategies. These include pivoting towards renewable energy, pursuing energy efficiency measures such as electric-powered machinery, integration of carbon capture and storage technologies and material circularity. These strategies are anchored to address direct and indirect energy-related CO_2 scope emissions (Johnson et al., 2021).

Nurdiawati and Urban (2021) take the debate further by expressing that decarbonisation strategies will be bespoke to countries given the idiosyncrasies pertaining to local policies, availability of technology, costs associated with implementation and location(Nurdiawati & Urban, 2021). This is highlighted by Todd and McCauley (2021) who state that many South African mining companies have initiated various approaches to lowering carbon emissions. However, due to the lack of policy direction, these strategies are vulnerable to failure and may not gain widespread societal acceptance.

This study adds to insight on the relevance and application of decarbonisation strategies in the South African mining sector. In so doing, it exposes the unique technological, economic, and geographical landscape confronting mining firm’s intent on aligning with the global pacts for sustainable change.

1.5. Research Questions

The research questions were guided by scholarly debate in the field. There is consensus that unique insights can be captured from the lived experiences of mining specialists and industry experts, researchers and consultants. The research questions that guided this enquiry stated below and then discussed in depth in Chapter 3 of this report.

RQ1: What are the key aspects of the decarbonisation strategies of the mining sector in South Africa?

Scholars Famiyeh et al., (2021), Ivic et al., (2021) and Nurdiawati and Urban, (2021) argue that there are specific motivations and factors driving the development and implementation of decarbonisation strategies in the mining sector of South Africa. This question contributes to understanding by capturing data that describes the experiences of mining professionals.

RQ2: ***What decarbonisation strategies are being pursued by the mining sector in South Africa?***

This question explores the drivers and barriers to advancement. It pursues a critical analysis of the limitations and issues impeding progress in reducing carbon emissions in the mining industry.

RQ3: What are the barriers to the implementation of decarbonisation strategies in the South African mining industry?

1.6. Research Aim

The research aimed to investigate the different approaches to decarbonisation in various mining settings and provide a broader perspective on the implications throughout the mining value chain. The study was guided by decarbonisation literature, with a focus on the mining sector context. Through this exploration, a better understanding of how South African mining companies are responding to requirements to reduce their carbon footprint through energy management practices was obtained.

Moreover, the study identified the main drivers of decarbonisation efforts, which consist of internal and external pressures or motivations. Additionally, it revealed the barriers that inhibit the successful adoption and implementation of such strategies. The study's findings are expected to offer insights for stakeholders, policymakers, and management in the industry. These insights can be used to inform future strategies, policies, and further research. This will facilitate and accelerate the transition towards a more sustainable and low-carbon mining industry in South Africa. Finally, the researcher aimed to create a conceptual framework that highlights the study's emergent key constructs and themes.

1.7. Research Contribution

The research contributions are divided into two categories: additions to the body of knowledge as well as potential extensions of the body of knowledge

This research enriches the decarbonisation literature by providing context-specific insights into the strategies, pathways, and roadmaps employed within the South African mining industry. It sheds light on the unique challenges and strategic responses that are specific to this sector, thereby enhancing the understanding of how decarbonisation is approached in a critical sector of the South African economy. The study offers a comprehensive view of the complexities and particularities involved in implementing decarbonisation strategies in different economic contexts. Furthermore, it validates the global applicability of decarbonisation strategies while accentuating their unique differences in applicability within the South African context.

The study identifies potential extensions to the existing body of knowledge. It unveils distinct elements of the decarbonisation process in the South African mining industry, which broadens the scope of current literature. Notably, the challenges posed by the energy supply monopoly in South Africa and the industry's responses to these challenges present new dimensions to the decarbonisation narrative. These findings not only serve as extensions of established theories but also encourage further research

1.8. Research Scope

The Scope of the research is delineated within the South African setting, focusing on mining companies operating in the country. The chosen setting is mainly attributed to the access of the researcher, but holds significance given the limited study on decarbonisation strategies in the mining industry. Moreover, focusing on South Africa contributes to the literature by providing perspective from a developing country or emerging market.

The purposive sampling technique was chosen for effectiveness in obtaining a sample representative of the group under study. To this effect, the study focused on the coal, platinum and gold commodity sectors. These sectors are selected due to their significant contribution to South Africa's Gross Domestic Product (GDP) and their economic importance.

1.9. Outline of the report

This chapter outlined the business and theoretical relevance, as well as the research questions, aims and Scope. The rest of the report presents a comprehensive exploration of the decarbonisation strategies in the mining sector as well as the drivers and barriers to those strategies, structured in seven distinct chapters. Chapter 2 lays the conceptual foundation of the study in the form of a literature review focusing on decarbonisation and how it is articulated within the mining sector. This chapter also identifies gaps and opportunities in current research. Chapter 3 outline the specific research questions of the study, guided by the literature review.

Chapter 4 focuses on the research methodology, detailing the research paradigm, approach, population sample selection, level and unit of analysis, research instrument, data collection methods, the data analysis process and, lastly, it acknowledges the limitations of the study. Chapter 5 presents the key findings from the analysis of the data collected from the interview participants, revealing key themes and constructs. Chapter 6 discusses the research findings through a rigorous analysis guided by the literature. The report concludes with a summary of the theoretical conclusions, research contributions made, limitations to the study as well as recommendations for future research, as discussed in chapter 7.

Chapter 2: Literature Review

2.1. Introduction

The opening chapter presented the motivations and specific research questions that were pursued in this study. This chapter presents a review of literature on decarbonisation as a concept; its origins, progression and emerging strategies for energy intensive industries. The section expounds on the current discourse and how it is articulated within the scope of the mining industry. The presentation reveals existing gaps and opportunities that justify the need for further research in the field.

The section begins by framing a conceptual of decarbonisation as a concept. This is followed by an explanation of its development as part of the climate change agenda. Subsequent sections delve into extractive industries with focus on South Africa’s mining industry.

2.2. Search Criteria

The dynamic nature of climate change interventions motivated a primary criterion applied for this review. This pertained to prioritising focus on high currency scholarly debate that reveals advancements in decarbonisation strategies within the mining sector. Searches were conducted in academic journals found in various academic platforms such as Google Scholar, Scite.ai, Semantic Scholar, and the University of Pretoria electronic databases. To ensure the relevance and quality of the retrieved literature, the search criteria employed vital words such as “decarbonisation strategies”, “industrial decarbonisation”, “energy- intensives”, AND “industries”, “mining”, “extractive industries”, “climate change mitigation in industry” as well as “decarbonisation pathways”. These keywords were instrumental in retrieving papers that have insight into the various decarbonisation approaches.

Given the fluidity of the science of climate change and ever-changing policy prescripts, a timeframe was imposed to focus on papers published within the last five years. Therefore, only papers published post-2018 were considered.

While the focus was on the most recent publications, it was deemed necessary to lay the foundational and historical context for decarbonisation within the broader context of the climate change agenda. Essential readings on this included documents and reports from the various climate conferences such as the Earth Summit (1992), Kyoto protocol (1997) and Paris Agreement (2015). Locating decarbonisation within the broader climate change debate underscores the interconnectedness of sector-specific actions towards the broader global net-zero goals.

2.3. Decarbonisation as a concept

Various terms have been used in the academic discourse to articulate a move towards reducing carbon emissions. For instance, Wimbadi & Djalante (2020) note that terms like decarbonisation, low carbon development (LCD), and low carbon transition (LCT) are frequently used interchangeably, highlighting similar aspirations and methodologies. The terms represent efforts to address the impact of climate change and the need to adopt sustainable practices.

Scholars discuss that decarbonisation is a complex and multi-faceted concept with various elements of biophysical and technical issues. This includes multiple levels of analysis and transcends various multi-disciplinary fields of study, such as engineering, environmental sciences (Rizzoli et al., 2021), economics (Semieniuk et al., 2021), public health (Gallagher & Holloway, 2020) and social sciences (Rizzoli et al., 2021). The synergy of diverse disciplines contributes to a holistic understanding of decarbonisation, ensuring that the challenges and opportunities it presents are addressed in an integrated, comprehensive manner (Nielsen et al., 2020; Svensson et al., 2020).

Literature (Nurdiawati & Urban, 2021; Rattle et al., 2023) also positions decarbonisation as a focus on climate change and energy transition frameworks with strong emphasis on strategies and interventions to reduce CO_2 emissions. This suggests and reinforces that CO_2, the primary cause of greenhouse gases, is the main target for decarbonisation efforts (Nurdiawati & Urban, 2021).

In essence, literature underscores decarbonisation as a multifaceted concept articulated through various academic disciplines. The consensus on the definition is centred on denoting the decarbonisation concept as a means to reduce greenhouse gases by transitioning to renewable energy sources. This transition is viewed from a technical lens and as a complex challenge interfacing with social, economic and political considerations. The Lane (2019) argument amplifies this complexity as it posits for unconventional and transformative approaches to tackle the root causes of environmental degradation and climate change.

Lane (2019) points out that “as a process, decarbonisation permeates diverse research fields. Each field contributes nuanced insights, offering specific pathways and articulating tangible measures for curtailing carbon emissions. This diversity in perspective enriches the decarbonisation narrative, infusing it with a multidimensional vibrancy that mirrors the complexity of the climate challenge. Thus, decarbonisation is not confined as a singular, isolated goal but is envisioned as a dynamic, multifaceted journey, marked by the confluence of varied strategies, methodologies, and aspirations, each converging to forge a sustainable, carbon-neutral future”(Lane, 2019, p. 350).

Decarbonisation is posited as a viable solution to reduce greenhouse gas emissions (GHG) and counter the escalating impacts of climate change. However, its feasibility, speed, costs and consequences remain subject to debate (Santos et al., 2022). Although there are costs associated with decarbonisation, Koberle et al. (2021) argues a delay in transitioning will invariably be more costly. Relatedly, Sovacool et al (2019) highlight the impact of energy transitions on communities and societies. In the main, meaningful decarbonisation should be able to address issues of equity and fairness.

Scholars have gravitated towards transitioning to renewable energy as the most efficient way of ensuring target reductions (Papadis & Tsatsaronis, 2020; Wimbadi & Djalante, 2020). This entails changing from fossil fuels, which are the primary sources of carbon emissions, to renewable energy alternatives such as solar, wind and hydropower; and implementing energy efficiency measures (IPCC, 2023; Rizzoli et al., 2021; Wimbadi & Djalante, 2020). However, Lane (2019) introduces a compelling counter-argument in stating that the conventional approaches centred on emission reductions are insufficient to address the magnitude of the environmental challenges confronting humanity. Lane (2019) introduces the discourse of steady-economies and de-growth programs as necessary pathways that transcend the conventional emission-centric paradigm.

De-growth programmes, are a collection of policies and practices specifically tailored to minimise economic growth and consumption. These programmes, rooted in the core of environmental sustainability and social justice, propose that reducing economic growth will lead to diminished environmental impact (Lane, 2019). Steady economies are economic systems that aim to maintain a stable level of resource consumption and waste production over time. In other words, they seek to balance economic growth with environmental sustainability by limiting the use of natural resources and reducing waste. Lane (2019) contends that these two approaches will ensure a reduced and sustained level of consumption and waste generation.

The prevailing narrative contends that human activities, such as burning fossil fuels, are the main drivers for climate change due to the release of greenhouse gas emissions into the atmosphere (Papadis & Tsatsaronis, 2020). Therefore, decarbonising the energy sector by pivoting to renewable energies is regarded the most apparent pathway to reduce greenhouse gases. This can be achieved through implementing low-carbon technologies and energy sources that reduce the amount of greenhouse gas emissions (GHG) released into the atmosphere (Papadis & Tsatsaronis, 2020; Rizzoli et al., 2021; Wimbadi & Djalante, 2020).

2.4. Overview of decarbonisation in the energy-intensive and extractive Industries

As a means to mitigating climate change, the decarbonisation literature underscores the importance of transitioning towards sustainable practices across various industrial sectors. Due to their energy-intensive operations, the heavy and extractive industries significantly contribute to greenhouse gas emissions and climate change (Lèbre et al., 2020; Zheng et al., 2023).

Mining is classified as an energy-intensive, heavy industry and often referred to be part of the extractive sector (Zheng et al., 2023). It is also not uncommon for the mining industry to be included in the literature on hard-to-abate sector, mainly due to its association with technical, environmental and economic complexities (Paltsev et al., 2022).

With energy-intensive operations and heavy reliance on fossil fuel, mining plays a significant role in the quest to reduce greenhouse gas emissions (Johnson et al., 2021; Zheng et al., 2023). Wei et al., (2020) also add that mining and related processes including smelting, contaminate soil and water with heavy metals. These heavy metals are released in the atmosphere through various pathways such as fly ash and vapours. This issue has given impetus to a growing awareness that the goals of the Paris Agreement are strongly aligned with a significant decline in emissions in the extractive and heavy industries (Johnson et al., 2021; Nurdiawati & Urban, 2021).

Further, Zomer &Savaget (2023), note that mining houses or corporate entities do not only embrace decarbonisation as a means to respond to pressure and regulatory demands. Increasingly, compliance is an imperative for sustainable business performance and resilience(Johnson et al., 2021; Zomer & Savaget, 2023).

However, the mining industry faces significant challenges. These stem from the fact that mining houses must grapple with meeting production demands while reducing carbon footprint (Johnson et al., 2021). It should also be noted that decarbonisation in industries such as mining involves a shift in markets (Ciołek et al., 2022), business model changes, infrastructure, and capital costs (Zomer & Savaget, 2023). Furthermore, companies are increasingly required to respond to the political and societal demands to reduce greenhouse emissions (Johnson et al., 2021; Paltsev et al., 2022)

Using a case study of a renewable energy project in Australia, Goddard and Farrelly (2018) highlighted the fact that transition management has been criticised for overlooking political dynamics and injustices for traditional energy regions. The study suggests that transition to renewable energy should embody the principles of social justice and have democratic legitimacy from workers, communities and unions and other stakeholders (Goddard & Farrelly, 2018). Based on the critical sectors of the European economy, Galgóczi (2020) argues that decarbonisation takes places in workplaces that have determined capital-labour relationships and therefore unions are vital in ensuring there is a social dialogue amongst all stakeholders. Climate change plans and addressing broader climate issues will only be successful if the process is just and balanced (Galgóczi, 2020).

Decarbonized operations often translate to reduced operational costs in the long run, enhanced investor appeal due to eco-friendly initiatives, and a reduced risk of future regulatory fines or sanctions (Kalantari et al., 2021).However, there are challenges related to technology, initial investment costs and reliability of renewable energy sources in in supporting energy intensive mining operations (Kalantari et al., 2021)

While the dominant sentiment in the literature suggests that renewable energy sources are the primary means to decarbonise (Rizzoli et al., 2021; Wimbadi & Djalante, 2020), this paper aligns with views that emphasise the significance of delineating emission subsets expressed in literature as Scope 1, 2 and 3. While interconnected, the three scopes require different interventions and guide firms towards framing granular strategies with more focussed outcomes.

2.6.1 Industry Strategies

It is worth noting that in reviewing the literature the interchangeable use of terms like 'pathways', 'roadmaps' was prevalent in describing the strategic plans towards carbon reduction or decarbonisation. This paper adopts 'strategy' as a term encapsulating all the terminologies as mentioned earlier and serves as a holistic term to denote broader plans by industry directed at achieving decarbonisation objectives.

Johnson et al. (2021) state that paths or strategies to decarbonise in energy-intensive industries pivot around four elements: "the transition to decarbonised energy inputs, amplification of energy efficiency, curtailment of process emissions, and the enhancement of material circularity" (Johnson et al., 2021, p. 1). Rissman et al. (2020) agree and go on to delineate between the supply and demand side emphasising that, for more significant impact, the strategies should focus on both the supply and demand sides. Supply-side interventions are measures aimed at reducing greenhouse emissions by changing how energy and materials are produced and supplied to industry (Rissman et al., 2020).

Interventions for the supply side of industry include energy efficiency measures, carbon capture and electrification, as well as using zero-carbon hydrogen as a heat source (Rissman et al., 2020). The demand aspect, referred to as measures that reduce the demand for energy and materials in the industrial process, include circular economy interventions such as product reusability, refurbishment and recyclability, as well as substituting high carbon materials for low carbon materials (Rissman et al., 2020).

The mining industry's decarbonisation is shaped by several core strategies. Key amongst those include a pivot towards renewable energy, energy efficiency measures such as electric-powered machinery and fleet, integration of Carbon Capture and Storage technologies and material circularity. When mapped along the industry value chain as depicted in Figure 2, these strategies span across three scopes of emissions.

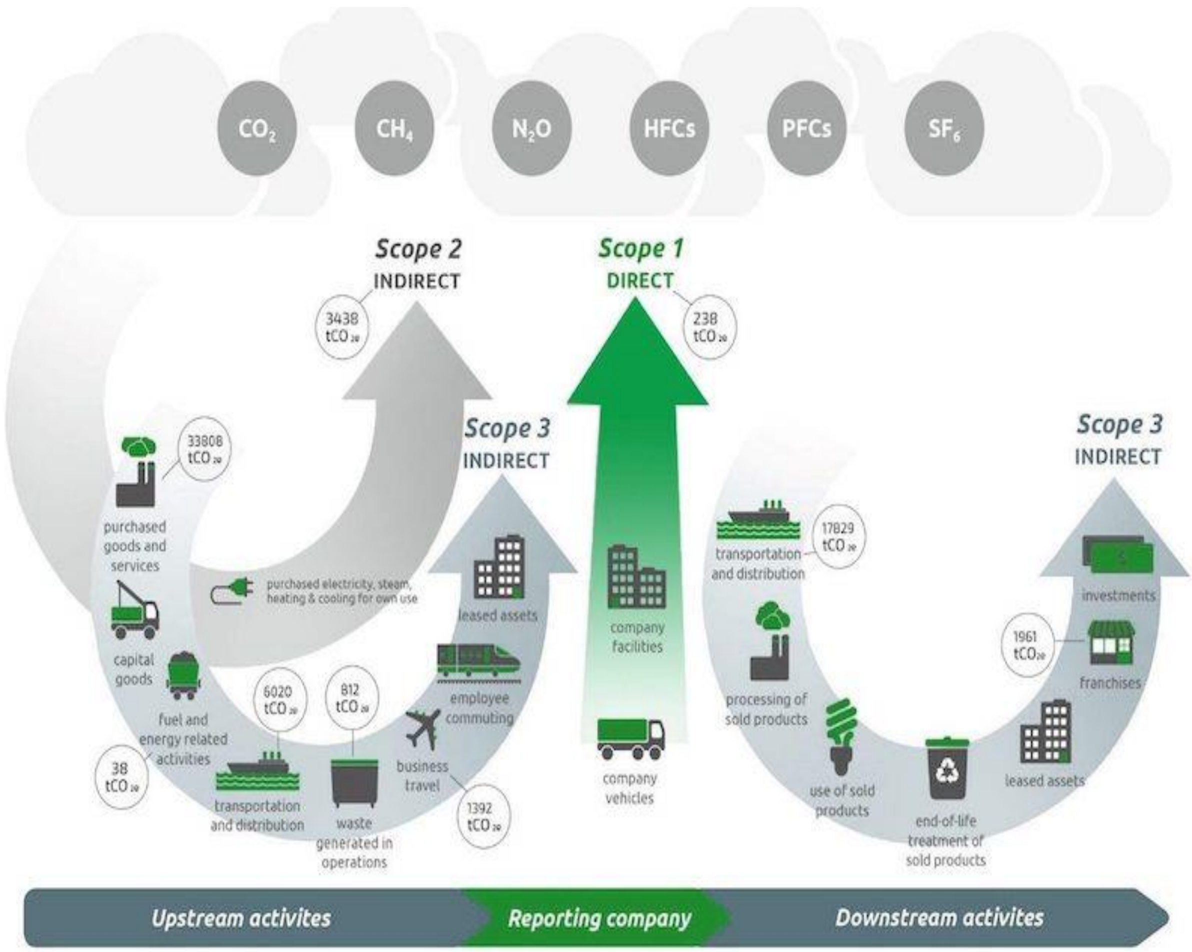


Figure 2: Depiction of Scope 1-3 emissions

Emissions emanating from the entities' facilities and operations, are classified as Scope 1 emissions. These are more likely to be reduced through operational efficiencies and use of technology and innovation (Nurdiawati & Urban, 2021). Johnson et al. (2021) argue that alternative energy sources predominately tackle Scope 2 emission concerns, i.e., those purchased or generated for operational use by an entity. Scope 3 emissions, include a range of indirect effects which the company does not necessarily control. These include carbon impact from the production of purchased goods and services, transportation, and the end-of-life treatment of sold products (Nurdiawati & Urban, 2021).

Transitioning to renewable energy aligns with both Scope 1’s direct emissions from company facilities and the indirect emissions from purchased electricity as per Scope 2. Energy-efficient solutions, such as electric machinery, impact Scope 1 by reducing emissions from company fleet. Scope 1 emissions are tackled at the source by using Carbon Capture and Storage technologies. This paper adopts these four strategies, recognising their significance in addressing all Scope emissions.

Reducing Scope 3 emissions requires collaborative efforts among suppliers, buyers and consumers. These can include utilising low-carbon measure materials, transport route optimisation and waste reduction (Nurdiawati & Urban, 2021). Buettner (2022)argues that Scope 3 emissions are often complex to address as they are not in the company's direct control. This can lead to double counting, as one firm’s count for Scope 3 emissions might be categorised as Scope 1 for another.

Whilst there is universal acceptance that the drive towards low carbon emissions is decarbonisation, the path to achieving it is multifaceted. Each Scope presents its own challenges, and a holistic and collaborative approach is necessary for progress. Companies are finding Scope 2 emissions more accessible to curtail through energy contract optimisation (Buettner, 2022; Figueiredo et al., 2023). In contrast, Scope 1 and 3 targets often trail due to inherent challenges and associated costs.

Scope 1: Emission Reduction Interventions

Scope 1 emissions are tackled at the source by using carbon capture and storage technologies Energy-efficient solutions, such as electric machinery, impact Scope 1 by reducing emissions from company fleet.

In the mining sector, energy consumption, particularly for transportation in open cast mines and underground machinery, is a substantial cost factor. Studies by Gunawan and Monaghan (2022) on Brazilian mining reveal that activities such as moving ore and waste rock and operating heavy machinery account for about 32% of total expenses, largely due to the use of diesel engines. These diesel-powered engines, essential in both underground and open pit mining operations, pose significant environmental concerns due to gas emissions (Figueiredo et al., 2023).

To mitigate these environmental impacts, the mining industry is considering green hydrogen, classified a renewable energy, as a viable alternative. This shift could significantly reduce carbon emissions in mining, contributing to global decarbonisation efforts. However, the transition faces hurdles, including high costs and infrastructural needs for hydrogen production, storage, and transportation (Figueiredo et al., 2023; Nurdiawati & Urban, 2021). Moreover, the energy-intensive nature of hydrogen production poses additional challenges.

Additionally, health and safety risks are particularly pronounced in underground mining adoption of hydrogen. Integrating these fuel cells into mining machinery necessitates careful consideration of regulatory, technical, and cost factors. Despite these concerns, the potential energy efficiency gains of hydrogen fuel cells over diesel engines are significant. These gains could translate into longer operational periods for mining equipment between refueling, offering both environmental and economic advantages (Nurdiawati & Urban, 2021).

The broader transition to green mobility technologies, including hydrogen and electric vehicles, has attracted interdisciplinary research attention. For instance, Ravi and Aziz (2022) provide a technical review of the challenges associated with hydrogen, including safety concerns and the potential of using renewable sources. Feng et al. (2022) point out the current high net cost of hydrogen transport compared to internal combustion. Meanwhile, Xiao and Goulias (2022) suggest that these issues are part of the new technology's acceptance process and eventual adoption.

Nurdiawati and Urban (2021) delve into alternative energy in mining, discussing battery-powered equipment and bio-diesel. They note how policy changes in Sweden encourage bio-diesel use, reducing greenhouse emissions by blending it with traditional fuels. This approach opens avenues for the mining industry to transition to lower carbon energy sources.

Focusing on energy storage, Meander and Meander (2021) state that lithium-ion batteries are prevalent due to their high energy density, low self-discharge rate, and quick recharging. These batteries can power most electric vehicles. However, Feng et al., (2022) points out that lithium-ion batteries are susceptible to thermal runaway, posing safety risks in high temperatures which can lead to auto-ignition.

Despite these concerns, lithium-ion remains the dominant technology for grid-scale energy storage. Addressing the safety issues is vital for the broader application of lithium-ion batteries, especially in electric vehicles, where continuous improvements in energy density are paralleled by an urgent need to enhance safety.

Scope 2: Emission Reduction Interventions

According to Nurdiawati and Urban (2021), reducing carbon emissions needs radical technology innovation and large-scale integration of renewable energy, in the form of solar and wind, into existing power systems. Using the Swedish mining industry as a case study, the authors emphasise that technological innovations should be deployed aimed at more efficient operations. Such interventions include replacing diesel-powered machines with electrical options that reduce total energy and fuel consumption (Nurdiawati & Urban, 2021). Sweden's approach to decarbonisation, although not fully adopted, is centred on the use of fossil-free electricity, hydrogen, and biofuels. Significantly, the Swedish mining sector stands exemplary for other industries globally, given its 90% reliance on renewable energy for mining activities.

Strazzabosco et al. (2022) studied the Australian mining industry to demonstrate that while trends lean towards renewable energy in mining, adoption rates are still relatively low and only account for 7% of existing mines. Although Solar Photovoltaic (PV) seems to be the most preferred source of energy due to its flexibility and scalability, renewable energy adoption is highly dependent on the location of the mine (Strazzabosco et al., 2022). Other strategies in the Australian mining sector include carbon capture, utilisation and storage (CCUS) using mineral carbonation in the coal mining sector (Azadi et al., 2019). Energy-efficiency technologies such as pumps for heating and renewable alternatives to generate steam have also been implemented (Hodgkinson & Smith, 2021).

Scope 3: Emission Reduction Interventions

Scope 3 emissions differ significantly from Scope 1 and 2 emissions in terms of control and mitigation strategies. According to Nurdiawati and Urban (2021), Scope 3 emissions encompass indirect emissions that a company does not control, such as those from the production of purchased goods and services, transportation, and the end-of-life treatment of sold products. Addressing these emissions requires a collaborative approach involving suppliers, buyers, and consumers, and may include strategies like using low-carbon materials, optimizing transport routes and reducing waste.

Buettner (2022) notes the complexity of addressing Scope 3 emissions due to their indirect nature, which can lead to double counting, as one company's Scope 3 emissions might be another's Scope 1 emissions. While companies have found it relatively straightforward to reduce Scope 2 emissions through energy contract optimization, Scope 1 and 3 emissions present more significant challenges and costs. Figueiredo et al. (2023) echo this observation, highlighting that each Scope 3 presents unique challenges and necessitates a holistic and collaborative approach for effective decarbonisation.

Decarbonisation strategies will play out differently in different countries, and this is influenced significantly by local contexts. These strategies are impacted by the availability and pricing of renewable electricity, carbon storage and biomass. Each country's technological, economic and geographical landscapes is a critical determinant in dictating the pace and scale of low carbon alternatives in the industrial or mining industry (Nurdiawati & Urban, 2021). Given this context, Nurdiawati and Urban (2021) underscore the need to explore different strategies and paths, in all countries to mitigate and reduce carbon emissions. It is against this background that this study explores decarbonisation strategies in the mining sector in South Africa.

2.6.2 Drivers

2.6.2.1 Business Sustainability

Sustainability has evolved and transitioned from a generalised concept to being integral in business strategies, which are characterised by business considerations on the environment, social and the economic. Early definition from the sustainable development era stated that “development meets the needs of the present without compromising the ability of future generations to meet their own needs” (WCED, 1987, p. 37), has been expanded. Emerging thought on business sustainability not only encompasses these notions but has been identified as an integral driver of sustainable practices, such as efforts towards low carbon emissions globally (Costa et al., 2022).

At the corporate level, the significance of business sustainability is to foster long-term value. This has become increasingly important for organisations intent on securing future pipeline for products and services (Lazarenko et al., 2021). In addition to the long-term value of the business, sustainability encompasses the capture of opportunities and the management of risks associated with the company’s environmental and social impact (Hedstrom, 2018).

To optimise gains, companies must embed sustainability practices into corporate strategy. In doing so, different levels of attention may be paid to key performance indicators, that promote integration and capture the value generated in the long term (Costa et al., 2022). Lazerenko et al. (2021, p. 4) reiterate the view, stating that “effective integration of long-term strategic priorities related to sustainability into business practices can be used as a basis for implementing a cost leadership strategy which would include efficiency in every aspect of operational activities”.

Lopez-Torres et al. (2022) argue that many firms are reluctant to adopt sustainability practices owing to incremental costs. However, for other firms, sustainability is seen as one of the means to enhance competitiveness. The authors suggest that there should be increased awareness and understanding of sustainability strategies that positively impact outcomes. Liu et al. (2022) studied the link between performance and sustainable management by firms in the Chinese manufacturing sector. The results showed inconsistent trends in ESG (economic, social, governance) implementation and firm financial performance. This was attributed to general neglect of the firm's internal dynamics and external context (Liu et al., 2022).

Moderating factors for sustainability help to balance the impact of sustainability. These factors can include economic, social, environmental and political considerations. "Additionally, other moderating factors are the firm's organisational and technological readiness, regulatory actions, economic model and involvement of all stakeholders" (Lopez-Torres et al., 2022, p. 442). By considering these moderating factors, firms can ensure that sustainability initiatives are adequate and appropriate for particular contexts (Lopez-Torres et al., 2022).

In effect, linking sustainability to business strategy helps organisations identify and capitalise on opportunities for cost reduction and improved efficiency and create a positive environmental impact. Furthermore, companies can improve reputation and attract new customers, which enhances firm competitiveness (Costa et al., 2022; Hedstrom, 2018; Lazarenko et al., 2021).

Mining is an extractive industry and conventional mining practices are often associated with activities that severely impact environmental sustainability. Some scholars have argued that the application of sustainability practices to this industry is an oxymoron. However, the incorporation of sustainable practices, as well as technological advancements continue to expand through exploring sustainable mining practices.

However, sustainability practices in the mining industry remain complex (Li et al., 2023). The challenges are associated with sustainability indicators, which are often not opaque and convoluted. According to Bari et al. (2022, p. 4), "Traditionally, sustainability practices have been driven by regulatory compliance requirements, but recently, businesses have started to focus on corporate sustainability through benchmarking against three key metrics: environmental, social, and governance (ESG)".

2.6.1.2 Sustainability Isomorphism

Ongoing academic debate on drivers of sustainable mining practices provides insights from different contexts (Famiyeh et al., 2021; Ivic et al., 2021). The study by Ivic et.al (2021b) reveals that European mining firms are driven by three isomorphisms: coercive, mimetic and normative. Coercive isomorphism is primarily governed by legal and regulatory pressures exerted by governmental entities. Mimetic isomorphism emerges from companies' tendencies to emulate the sustainability initiatives of industry pacesetters, often motivated by competitive pressures and the aspiration to align with industry standards. On the other hand, normative isomorphism is shaped by international initiatives and stakeholder influences, portraying the role of external pressures and expectations in guiding corporate sustainability actions.

Seroka-Stolka(2023) adds a specific dimension by delving into normative isomorphism, looking at stakeholder pressure and its relationship with CO2-related performance. The study reveals that increased pressure from stakeholders leads companies to adopt advanced or ‘active’ decarbonisation strategies which enhance CO_2 reduction efforts. Famiyeh et al., (2021) highlight the limitations of overemphasising mimetic isomorphism as a single critical driver.

An exploration of 164 mining companies in Ghana aligns with the views of Ivic et al (2021) on the normative (International initiatives and stakeholder pressure) and coercive pressures- from government regulation as the key drivers for sustainability practices. However, the findings suggest that companies that are only reliant on comparisons or benchmarking with competitors often achieve strides in environmental and social spheres but tend to neglect the economic dimension of sustainability. A holistic approach is required in responding to the demands of sustainability, highlighting the importance of scrutiny and an integration of all three isomorphisms.

The below Figure 2 was adopted from Ivic et al (2021) and synthesises the key findings of the study on sustainability practices among European mining companies and their contribution to sustainable development. The figure shows the institutional drivers that influence sustainability practices among European mining companies and the contribution to sustainable development, as presented in sustainability reports. The figure is divided into three types of institutional isomorphism: coercive (regulatory), mimetic (competitive), and normative (market). Coercive isomorphism is influenced by governments and the European Union, while the mimetic stems from industry associations and international initiatives. Meanwhile, normative isomorphism is driven by international initiatives and stakeholders (Ivic et al., 2021).

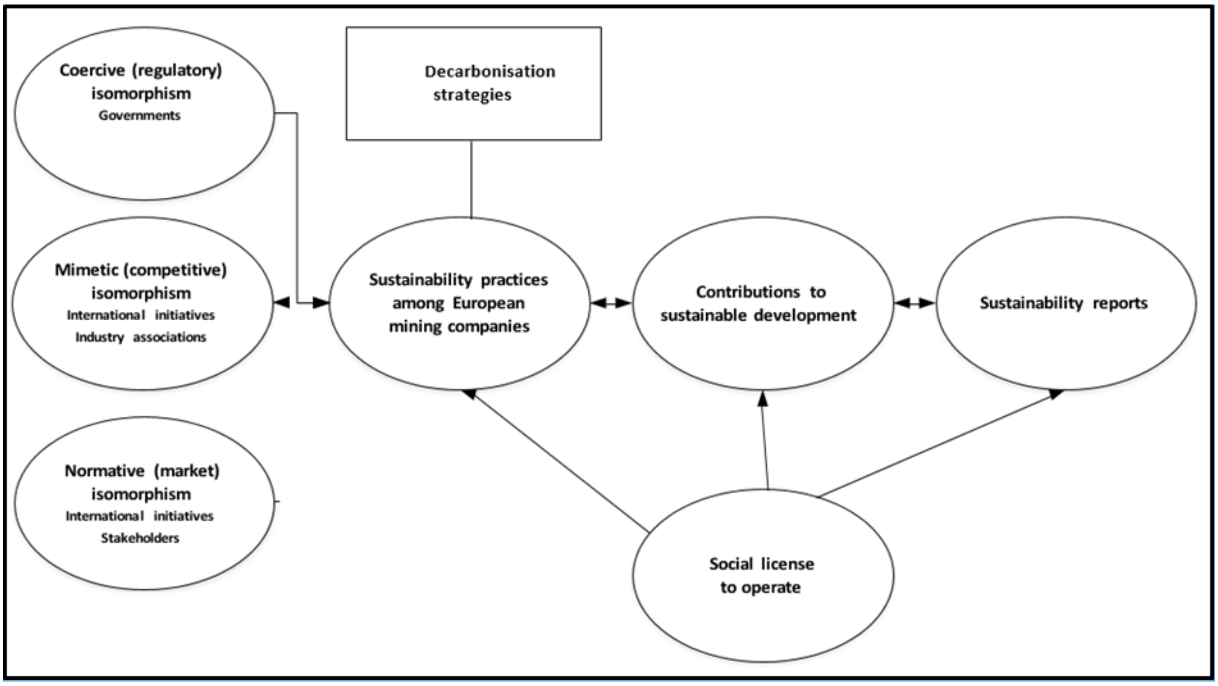


Figure 3: Synthesis of the drivers of Sustainability (Ivic et al., 2021).Additions highlighted (in blue) by author on the integral role of decarbonisation strategies within the broader realm of sustainability practices.

The integration of sustainability practices in business strategy or operations, is driven by normative, coercive and mimetic pressures. Scholars argue that these pressures ensure a holistic approach in business sustainability. Therefore, a reduction of greenhouse gas emissions, as a business sustainability strategy, is not merely a response to regulatory pressure but should be seen as a move to reduce costs and to enhance operational efficiency with a consideration on the environmental, social and the economic dimensions.

2.6.3 Barriers

2.6.3.1 Economic barriers

From an economic point of view, Wesseling (2017) emphasises the challenges associated with high fixed costs of the extractive industry, owing to high-capacity utilisation. These costs need to be earned back despite volatility in prices and profit margins. The cost barrier is more pronounced in heavy industries like metallurgy, where the adoption of technological innovations is seen as both costly and risky (Wesseling: 2017).

Nurdiawati et al. (2021) further contend that although decarbonising the energy-intensive industries is more expensive in the short term, economies of scale resulting from technological advances will reduce costs in the long term. Such is the case in Sweden, where renewable energy has become the most cost-effective energy source. Relatedly, Strazzabosco et al., (2022) also acknowledge a similar trend in the Australian mining sector. They note that the adoption of renewable energy entailed significant upfront investment costs but resulted in lower operational costs. In contrast, the use of diesel or gas plants may be relatively cheaper to set up initially but incurs higher operational costs over time.

Similarly, in Australia, the adoption of renewable energy in the mining sector attracts high investment commitments, but low operational costs. Meanwhile, the use of diesel or gas plants are relatively cheaper to set up but incur high costs in operation (Strazzabosco et al., 2022).

Overall, the implementation of low-carbon technologies such as carbon capture storage (CSS) (Budinis et al., 2018a), fuel-switching (Figueiredo et al., 2023) along with the development of necessary infrastructure require substantial amounts of capital investments. This requirement is a barrier to widespread adoption of decarbonisation strategies.

2.6.3.2 Technical Barriers

According to Nurdiawati et al. (2021) many low-carbon emission technologies are still in the early stages of research, development or pilot. It is anticipated that it will take many years for these technologies to reach maturity. Figuereido et al., (2023) reiterate the same in a study on green hydrogen as an alternative to diesel fuel for powering mining equipment. The authors report that the technology for production, storage and transportation is not fully developed and this invariably poses a barrier to the speed and rate of adoption of hydrogen as a fuel.

Carbon capture usage and storage (CCUS) remains at the forefront of academic discourse and industry discussions as a viable solution for a reduction of carbon emissions. However, due to technical barriers the scale of adoption has been slower than anticipated (Budinis et al., 2018b; Bui et al., 2018). Echoing this sentiment, Nurdiawati el at (2021) contend that large scale deployment of the CCUS needs the necessary supporting infrastructure, such as storage and transport. This is further compounded by the substantial capital requirements for installation and expenses associated with ongoing operations and maintenance (Budinis et al., 2018a; Bui et al., 2018)

As this paper has discussed, a key feature of mining sector decarbonisation is the use of renewable energy. Scholars, (e.g. Igogo et al., 2021; Strazzabosco et al., 2022) articulate significant technical challenges encountered in integrating renewable energy into mining operations. They note that the intermittency of solar PV and wind, due to variability in generation, limits the efficiency of renewable energies for mining operations. This is based on the fact that ”mining operations require significant, high-quality and constant energy supply, often 24 hours a day and seven days a week, that can only be met by few renewable sources such as hydro-electric and geothermal. This requirement poses challenges for implementation and presents a barrier when attempting to integrate large volumes of variable renewable energy. Even technologies such as wind and solar whose co-occurrence may be more favourable could overproduce during peak generation hours; this can lead to complexities associated with the excess energy, some of which may be stored using, e.g., batteries” (Igogo et al., 2021, p. 8).

2.6.3.3 Institutional and Market Barriers

Institutional and market barriers can impede progress towards decarbonisation and the establishment of a circular economy. These barriers, though distinct, often intertwine, magnifying the challenges faced by industries and governments alike.

Nurdiawati and Urban (2021) emphasise the role of institutional barriers to decarbonisation pathways, as identified within the Swedish energy-intensive industry. Lengthy planning cycles and delays in obtaining environmental permits often result in delays in setting up the technological infrastructure and impedes the deployment of cleaner technologies. Furthermore, uncoordinated government efforts exacerbate these barriers. A lack of synergy among various arms of the government can lead to conflicting policies, ambiguities and implementation challenges (Nurdiawati & Urban, 2021). Singh et al. (2020) noted similar challenges in India’s mining industry, where, instead of facilitating, national regulations are impeding the adoption of decarbonisation strategies, such as material circularity.

Despite the existence of technically viable CE solutions, economic and market barriers often hinder practical implementation. This assertion is echoed and emphasized by de Jesus (2018) underscoring a pivotal challenge in the transition towards a sustainable, circular economy. These barriers, ranging from high initial investment costs to uncertainties around evolving markets and consumer behaviours, create a hesitancy among industries to adopt new, albeit necessary, environmental innovations.

These institutional and market barriers are not isolated. They are interdependent and often amplify each other. For instance, a stringent regulatory environment can increase the initial costs of adopting new technologies, exacerbating market barriers. Conversely, market uncertainties can lead to demands for more rigid institutional controls to mitigate perceived risks(de Jesus & Mendonça, 2018; Singh et al., 2020)**.**

2.5. Conclusion

The literature review has outlined the conceptual underpinnings of decarbonisation. The concept appears as complex and multidimensional, cutting across various academic fields of science, engineering, sociology and political science. Central to this discourse is the transition towards reduced carbon emissions through the adoption of renewable energy sources. Other scholars have called for a more transformative approach to decarbonisation and related issues of climate change and sustainability.

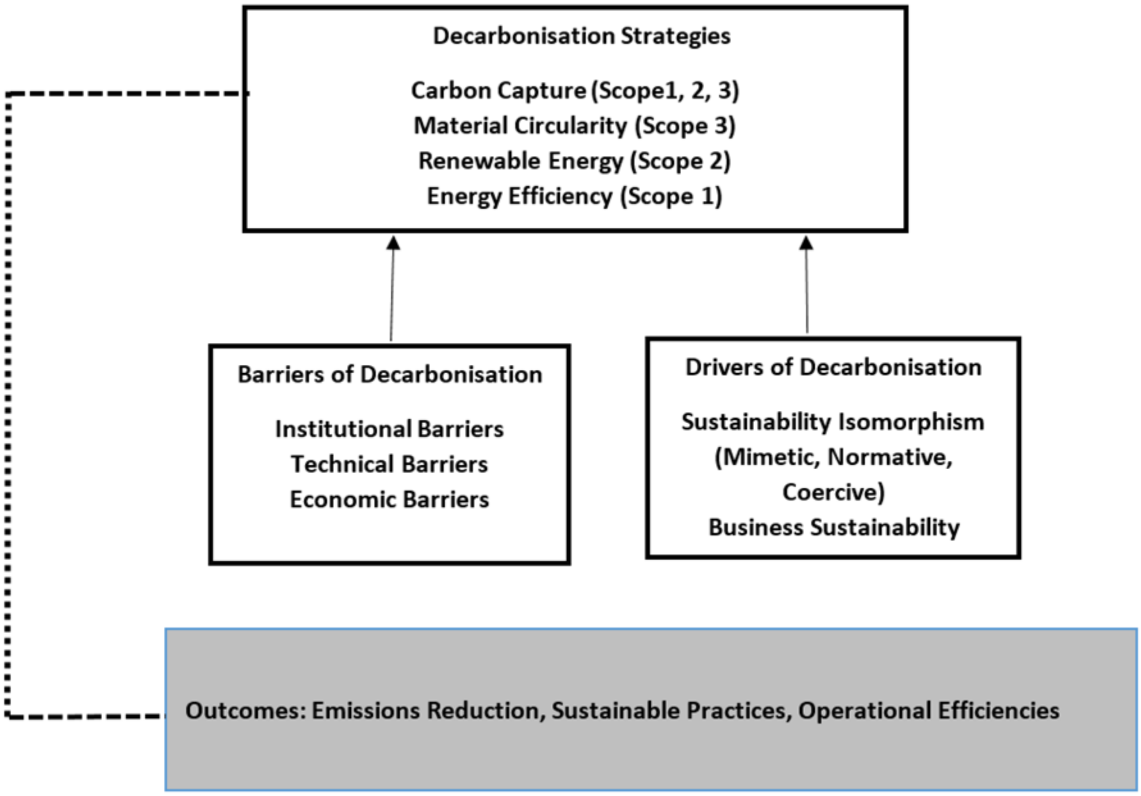
Furthermore, the historical analysis of the concept underscores the global struggle with enforcing emissions reduction commitments, highlighted by the continuous rise in CO2 emissions, only momentarily halted in 2020 due to pandemic-related interventions. The application of decarbonisation strategies is portrayed as context-dependent, influenced by each country's unique technological, economic, and geographical landscapes.

In the extractive industry, the adoption of the four identified decarbonisation strategies; renewable energy, energy efficiency, carbon capture and storage as well as material circularity, are underpinned by an interplay of economic, technical institutional and market barriers. Despite these barriers industries and corporates have shown commitment to aligning with net-zero targets and this is largely driven by regulatory, competitive and other market pressures.

2.6. Conceptual Framework

The literature reviewed in this chapter identified the key constructs and themes that were for the study in order to gain a deeper understanding of what is already known about the topic. The key constructs identified were the following:

- **Decarbonisation Strategies**, which outline the approach organisations take in reducing their carbon footprint.
- **Drivers of decarbonisation**: Push factors motivating organisations towards decarbonisation.
- **Barriers to decarbonisation**: Challenges impeding the implementation of decarbonisation strategies.


Decarbonisation Strategies
Carbon Capture (Scope1, 2, 3)
Material Circularity (Scope 3)
Renewable Energy (Scope 2)
Energy Efficiency (Scope 1)
Barriers of Decarbonisation
Institutional Barriers
Technical Barriers
Economic Barriers
Drivers of Decarbonisation
Sustainability Isomorphism
(Mimetic, Normative,
Coercive)
Business Sustainability
Outcomes: Emissions Reduction, Sustainable Practices, Operational Efficiencies

Chapter 3: Research Questions

This chapter outlines the research questions emanating from the research problem outlined in Chapter 1 and the evaluation of literature in Chapter 2, which shed light on the nexus between decarbonisation and the mining sector. Prominent contributors to the academic discourse have provided in-depth understanding of the intricacies and importance of mining and its role in reducing global greenhouse emissions (Buettner, 2022; Famiyeh et al., 2021; Ivic et al., 2021; Nurdiawati & Urban, 2021). This contribution is based on studies on activities within the extractive industry approaches to reduce greenhouse emissions within a specific setting.

Key amongst this is the work that acknowledges the responses, in the form of strategies, pathways, roadmaps, vary based on the influence by diverse local contexts, technological capabilities, economic landscapes, and geographical settings. Nurdiawati and Urban (2021, p. 2) make the call "that different strategies and paths to reduce emissions in all countries and sectors should be explored". In response to this proposition, this study has refined its lens to concentrate on the mining sector in South Africa.

Therefore, the research question was stated as follows.

3.1 Research question 1: *What are the key aspects of the decarbonisation strategies of the mining sector in South Africa?*

The research question is grounded in the economic, technological, and societal context of South Africa. The study contributes to the broader dialogue on decarbonisation in the mining sector by providing an analysis of the specific methods, practices and innovations tied to decarbonisation strategies. The insights were gained from lived experiences of mining sector specialists, industry researchers, and consultants.

3.2 Research question 2*: What are the drivers for selection of decarbonisation strategies?*

The question was designed to understand the underlying motivations and influences to develop and implement decarbonisation strategies. In the context of the literature review, these drivers are multifaceted, encompassing regulatory compliance, business sustainability, economic viability, and societal expectations. Scholarly work by Ivic et al. (2021) and Famiyeh et al,. (2021) describe these drivers under three broad themes of coercive, normative and mimetic pressures, which providers a holistic view in understanding decarbonisation strategies. The foundation and lens provided by the literature was applied within the South

African context to examine the unique social, economic, regulatory and environmental aspects.

3.3 Research sub-question 3: *What are the barriers to the implementation of decarbonisation strategies in the South African mining industry*?

This question was designed to understand the barriers and limitations for decarbonising the mining sector. The study identified institutional and operational barriers as key barriers to decarbonisation.

In summary, the research question guided the exploration of decarbonisation strategies within the South African mining sector. The next chapter provides a detailed account of the research methodology employed in tackling the research questions.

Chapter 4: Research methodology

4.1. Introduction

This section provides a comprehensive overview of the research methodology used in the study. It outlines the philosophical paradigm, design approach and methods employed. Ethical considerations are discussed and limitations of the study acknowledged. The methodological choices guided the researcher in ensuring validity and reliability of the research process and outcomes.

4.2. Research paradigm and approach

A research paradigm is shaped by the foundational beliefs about ontology and expresses the essence of reality that guided the enquiry (Bell et al., 2019).

Interpretivism, which is primarily concerned with subjective meanings and understanding and holds the view that there are no objective truths to science, was adopted for this study. This approach underscores the importance of context and builds theory from observations and experiences of groups or individuals (Bell et al., 2019). The strength of interpretivist research lies in the ability to access new and richer insight into social phenomenon and contexts.

This approach was particularly relevant given the complexity of interactions within business situations where a group of individuals come together at a specific time (Saunders et al., 2019). Building on this foundation, the stance adopted in this study was instrumental in exploring the ‘how’ and ‘why’ behind the participants' activities and experiences.

Qualitative methodology is most suitable approach for study that reflects on opinions and experiences. Such interaction reveals the multiple perspectives held by different individuals and facilitates exploration of the diversity in perspectives. This is supported by the notion that in qualitative research, there isn’t necessarily a single and ultimate truth to be discovered (Leedy & Ormond, 2013). A qualitative research study is often conducted through interviews, observations, focus groups and content analysis of written material (Bell et al., 2019; Leedy & Ormond, 2013).

Given the above explanation, this paper advanced a qualitative enquiry to access and examine practitioner experiences of decarbonisation strategies within South African mining. Insights from lived-experience are best understood from feedback, perspective and observations within their natural setting.

A qualitative approach is appropriate in pursuing investigation that seeks to capture detailed feedback In supporting the main research question, this approach also ensured a comprehensive understanding of the key drivers behind mining sector towards decarbonisation. This sub-question explored the multifaceted and complex reasons behind the companies' selection of the decarbonisation strategies. The second sub-question identified the barriers and challenges that impeded decarbonisation efforts, offering insights into the operational and institutional constraints of the sector and specific companies.

The study examines the strategies, drivers and barriers to decarbonisation from a perspective of those who have first-hand experience or specialised knowledge in this setting. The population included professionals engaged in energy and sustainability roles across various mining companies as well as researchers and industry experts with an in-depth understanding of the topic.

4.3. Population/Setting

The population for a study of this nature must meet specific criterion to ensure the researcher is able to capture the right information and draw reliable conclusions based on the data collected (Saunders et al., 2019). Further, a target universe can be divided into sub-groups along chosen lines of distinction. The population for this research were professional individuals employed by mining companies in the gold, platinum and coal mining sectors in South Africa. The targeted group was selected based on their areas of specialisation in the fields of energy, climate change and sustainability.

A second grouping consisted of industry experts who, while not directly employed by mining companies, have a proven track record of substantial knowledge on energy transitions within the mining sector, through research and consultancy work. These individuals offered valuable external and independent industry wide perspective on the general practices and challenges related to decarbonisation.

4.4. Sample selection

A non-probability sampling technique in the form of purposive sampling method was used to select participants. This technique enables the researcher to apply subjective judgement based on specific criteria or characteristics (Hennink & Kaiser, 2022; Struwig & Stead, 2013). Using this method, the researcher was able to select an appropriate sample in relation to the phenomenon investigated (Bell et al., 2019).

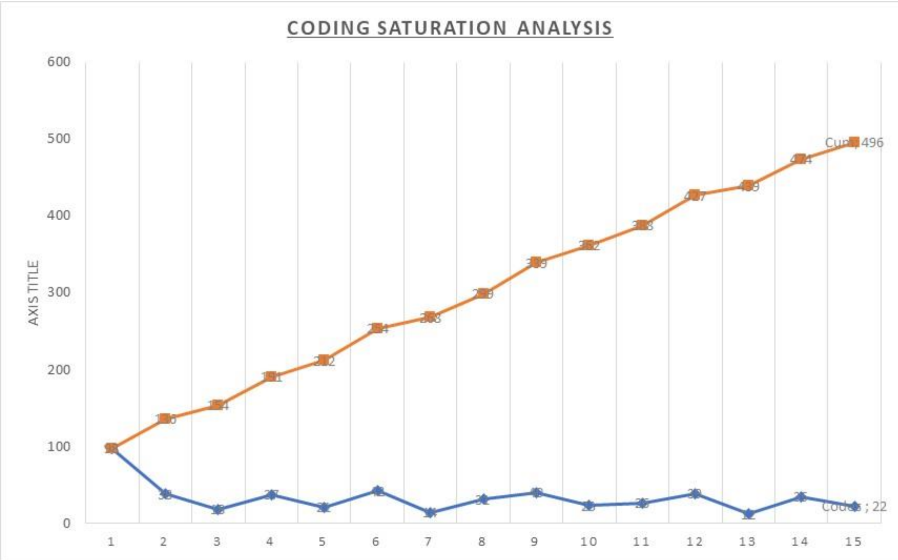
The selected respondents were professionals in the coal, gold and platinum commodity sectors. As described in Chapter 1, these commodity sectors were identified and chosen due to their status as large contributors to the Gross domestic product (GDP), highlighting demand and economic significance in South Africa. The energy-intensive nature of mining operations positions it as significant contributors to greenhouse emissions, and as such central to discussions related to decarbonisation.

Furthermore, the distinct operational processes inherent in the chosen commodity sectors allowed for a diversity of perspectives, insights and approaches. By encompassing the different commodity sectors, the approach ensured sample rigour. This strengthens the validity of the findings within the mining industry and reduces bias that may be in a singular commodity and operational process.

In essence, the diversity ensured by including distinct operational processes heightens the research's rigor, making its findings more reliable, comprehensive, and relevant to the industry.

The researcher conducted a total of 15 interviews and this encompassed participants from the two pools of professionals being mining industry practitioners and industry experts. Selected participants across the diverse commodity groups were able to describe respective company pathways to decarbonisation. This was further reinforced by the industry experts who, shared sentiments to deepen insight. It became evident by the 15th interview that the gathered data was sufficient to inform this study.

Hennick and Kaizer (2022)describe saturation to occur when additional interviewing and data analysis ceases to yield new insights to a study. Achieving this point indicates that an adequate sample size has been reached and ensures rigour in qualitative research work. Guest et al., (2020) suggested that saturation could be reached with as few as 12 interviews, while Hennick and Kaizer (2022) provided a broader range of 9-17 interviews. In this case, the 15 interviews conducted provided ample data to reach saturation and this led the researcher to conclude that the gathered data was sufficient.



Source: Author

4.5. Unit of analysis

According to Kumar (2018), the unit of analysis refers to the person or object that is being studied in business research. The unit of analysis answers the “what” and the “who” in research, which includes the individuals, individuals in organisations or objects (Kumar, 2018). In this study, the unit of analysis were professionals who specialise in climate change intervention and sustainability oversight within mining. These individuals provided insights and experiences in responding to interview questions on decarbonisation strategies, drivers and barriers.

While data was collected from individuals in the form of interviews, the insights provided by were rooted in an organisational context. Therefore, the strategies drivers and barriers described were linked to organisational practices.

4.6. Research instrument

For this study, primary data was collected by using a semi-structured interview guide. The decision to use this particular research instrument was based on the objective of the study which was to gain insights into the strategies, drivers and barriers for mining sector decarbonisation. As guided by Saunders and Lewis (2019), using a discussion guide is appropriate when seeking to balance structure and openness. The open-ended questions ensured that the interview participants were not restricted in expressing responses.

Leedy and Ormond (2013) posit that a good research instrument must pass the validity and reliability test. To achieve this, multiple sources of data are required to support particular argument. To achieve this, the researcher was guided by secondary data analysis of scholarly literature in framing the research questions. In addition, probing respondents during the interviews resulted in additional angles to the discussion and data insights to emerge.

The interview guide aligned with the research question and was consistent with the interpretive and qualitative approach adopted for this study. It enabled the exploration of decarbonisation strategies while maintaining a level of flexibility to capture more insights and nuanced perspective.

4.7. Data collection

Primary data was collected through semi-structured interviews conducted on online platforms such as Zoom, Google Meet and Microsoft Teams. The interviews were recorded using a voice recorder supported by Otter, an artificial intelligence tool which records and transcribes the interview. Participants were required to grant permission for the recording to take place. The average length of the interviews was 35 minutes, with the shortest interview being 22 minutes long and the longest interview 75 minutes. A total of 15 interviews were conducted over an 8-week period.

Turner (2010, p. 754)states that, “interviews provide in-depth information pertaining to participants’ experiences and viewpoints of a particular topic. Often times, interviews are coupled with other forms of data collection in order to provide the researcher with a well-rounded collection of information for analyses”. Babbie (2020) also adds that in interviews, the researcher focuses on the participants’ experiences and perspectives and this allows participants to express themselves in the way they normally speak, think and how they see reality.

This study used semi-structured open-ended interviewing as this approach allowed the researcher to ask fundamental questions of participants (Turner, 2010). The questions were semi-structured inviting open-ended responses. Babbie (2020) emphasises that this type of interviews allows for flexibility. Although the researcher had set out with clear intention to interact as per a set interview guide, the answers from the participants evoked additional questions to seek deeper explanation.

Lastly, the interviewees chose to remain anonymous and in keeping with ethical commitments made, the data collected during the interviews was kept confidential.

4.8. Data analysis

Data analysis entailed systematic interpretation of collected data for the purposes of answering the research questions of the study. The primary aim of data analysis was to generate insight into the questions driving the enquiry (Saunders et al., 2019). The data analysis encompassed two steps: firstly, to synthesise the data so it was easier to manage, and secondly, to categorise the data to detect and identify recurring themes and patterns (Babbie, 2020; Saunders et al., 2019). Coding, was an integral part of the analysis, enabling the organising and categorising of data into the specific themes Babbie (2020).

The process was guided by Castleberry and Nolen (2018) who propose that the analysis of qualitative data should unfold in five definitive steps as outlined in Table 1.

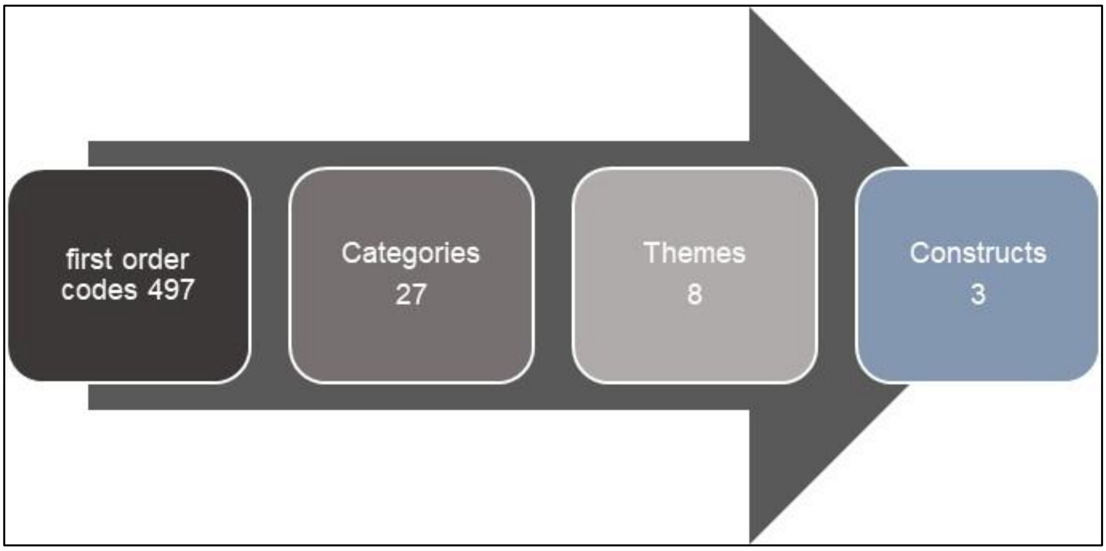
Table 1: Data analysis process (Castleberry & Nolen, 2018)

Steps/Phases	Description of Process
1. Compiling of the data	In this initial step, the researcher began by answering questions, which involved tasks such as transcribing interviews from notes or audio recordings used during the interview process. With all 15 interviews, the researcher used the Otter.ai tool to record and transcribe the data. During this phase, the researcher familiarised themselves with the data.
2. Disassembling:	In this process, the data was separated and organised into meaningful segments. In part, codes were developed based on the research question and sub-questions as started in Chapter 3. This ensured that codes aligned with the objectives of the study. Atlas.ti software was used for this process.
3. Reassembling	This step involved organising codes into themes. These themes were clustered in subgroupings and allocated hierarchies in order of importance to the objectives of the research. This started the process of drawing insight from the data and allowed for clustering of the coded information. Castleberry and Nolan (2018) suggest that this process should be iterative, as this ensures a degree of

Steps/Phases	Description of Process
	reliability and strengthens the researcher’s ability to defend the interpretations and conclusions.
4. Interpreting	In this phase of analytical process the researcher drew conclusions from the categoriesed data. This allowed the researcher to begin focusing on the thematic patterns across the data that were relevant to the research questions.
5. Concluding	Conclusions were made in response to the research questions and purpose of the study. In so doing, the five-step analysis process was able to support the framing of meaningful answers and insights to the study on decarbonisation strategies within the South African mining sector.

The initial phase of the coding process identified 497 distinct codes. These were refine and streamline to ensure all angles of the data were well expressed. Clustering of the codes resulted in 27 categories. These categories were then mapped and analysed as per the theoretical framework in Chapter 2. As part of this process 8 themes and 4 constructs emerged. These constructs represent key insights that were developed from the data.

Figure 7: Data coding process



Source: Author

This revised conceptual framework, which encompasses the 8 themes, is presented in Chapter 5, where the research findings are thoroughly detailed and discussed.

4.9. Limitations to the study

This study was informed by a non-probability purposively selected sample and relied on semi structured interviews with the participants from coal, gold and platinum sectors of the South African mining industry. These boundary conditions on the sample design pose a limitation in that the findings cannot be generalised to other settings and sectors.

Secondly, the emergence of new policies and maturity of technologies affecting decarbonisation strategies is highly fluid and will have an impact on the accuracy and relevance of some of the insights. Meaning the study is time- bound as a temporal dimension.

Thirdly, given the researcher's level of experience in conducting research, especially in the realm of decarbonisation, the study had limitations in the depth of understanding and ability to delve deeper into the technical aspects of decarbonisation in the mining industry. These limitations can, in part, also be attributed to the methodological approach and format of interaction with participants.

Chapter 5: Research Findings

This chapter presents the key findings from the analysis of the data collected from the interview participants. Semi-structured interviews from 15 participants were conducted using an interview protocol. The interview transcripts were subsequently coded using a qualitative research tool. The coding process identified 26 themes and resulted in 4 constructs that provided an in-depth understanding of the experiences of the participants.

The emergent constructs relate to the research questions from the study. From all the identified themes, only nine themes were discussed, and these were selectively considered due to their potential to offer insights and enhance the understanding of the topic. The themes are presented as per the research questions (RQ)

5.1. Constructs and Themes

5.2.1 Research Question 1: What are the key aspects of the decarbonisation strategies of the mining sector in South Africa?

RQ1: Theme one: Renewable energy adoption

The participants highlighted renewable energy as key feature of their decarbonisation strategies. Based on the interviews with mining professionals as well as industry experts, they highlighted that converting their electricity usage, which is currently sourced from fossil fuel, is the easiest way to bring down their carbon emissions targets and they believe this strategy sets them on a path to carbon neutrality by 2050.

Table 1: Evidence of renewable energy as a strategy

Mining Professionals
Par1_Cat1 • "Transition from fossil fuel-based energy sources to renewable energy-based sources as part of the race to net zero. We are aiming to build approximately 520 megawatts of renewable energy sources spread across wind as well as solar by 2040".

Par3_Cat1 • “You know, as we as we look to expand or grow our business, we wouldn't be able to do that in coal, in terms of the decarbonisation itself that we're doing a large part of our strategy sits in renewables replacement of our current sort of Eskom power with renewable power”.
Par6_Cat1 • “We have done that for some of South American operations. We have secured 100% renewable energy and I think in Australia the contract that we've signed will kick off in 2024 [...] in South Africa we are running a renewable energy program to bring three to five gigawatts of renewable energy online”.
Par8_Cat1 “One of the first strategy is to electrify as much as you can in terms of electricity demand make sure that you have renewable energy on the electricity supply side that is the first strategy”.
Industry Experts
Par5_Cat2 • "The starting point that I've seen for most mining companies is they're very much tied with the electricity side of things. So it's, you know, things like installing renewable electricity, solar farms, and those sorts of things. I know like for example, Company X installed a huge solar plant. Company Y is looking at a big, big thing for operations and stuff. So, generally speaking, the starting point for mining companies is some sort of renewable electricity consideration."

Par4_Cat2 • "The easiest thing for most of the mines, which has been well publicized as well, is to tackle Scope 2, which is essentially electricity generation. So regardless of commodity most of the mines are all actively pursuing renewable energy, basically, to make themselves greener and decarbonise."
Par14_Cat2 • "The strategies we discussed were primarily focused on electrification as the most straightforward approach. The rationale is simple: by electrifying operations, you can seamlessly integrate renewable energy sources." • "One was to establish solar farms directly on-site, providing a local and immediate supply of clean energy."

In-Case and Cross-Case analysis of the evidence

The adoption and integration of renewable energy is an approach recognised by both the mining professionals and industry experts. Participants have highlighted that the approach contributes significantly to reducing Scope 2 emissions, which are linked to the purchase of electricity produced from fossil fuels. Apart from addressing decarbonisation and ensuring energy security, the shift also presents a major cost saving opportunity. Notably, this shift to renewable energies is not limited by the type of commodity being mined or the nature of mining operations. The participants emphasised that both under open cast and underground mining operations use this strategy as an alternative to fossil fuels.

As evidenced by the data provided, the transition to renewable energy by the mining industry is multifaceted. Whilst it is clear that the most preferred renewable energy adoption from Solar Photovoltaic (PV) sources, due to availability of abundant solar resources in the country, several participants have indicated that there is a growing trend of companies entering in Power Purchase Agreements (PPAs) for wind energy. The adoption of renewable energy sources by mining companies involves both onsite and off-site solutions.

The major determinate for onsite or off-site operations is considerations of land availability as well as the geographical location. The energy generated from these off-site farms is delivered to the mining operations through a wheeling agreements using the Eskom grid.

Conclusion to theme one

In concluding the theme, the collective insights from mining professionals and industry experts affirm the adoption by the mining sector to transition to renewable energy as an appropriate response to decarbonisation. Although with slight variations, this strategy is the most widely adopted by the mining industry, regardless of the type of commodity being mined and across the various types of mining operations.

RQ1: Theme two: Alternative energy for mining equipment and vehicles

The focus on fuel switching as a vital component of decarbonisation emerged as a significant theme. Participants mentioned that fuel is a critical factor in addressing the Scope 1 emissions, which are directly attributed to the mine's operational processes. In a case of a mining company these operational processes refer to the equipment and vehicles utilised in mining operations. This theme was selected for a detailed discussion because of the wide range of insights and experiences offered by participants.

Table 2: Evidence of alternative energy considerations for mining equipment and fleet

RQ1:Theme 2 :Alternative energy considerations for mining equipment and fleet
Mining Professionals
Par11_Cat1 • "Yes, we are advancing our biofuels and green hydrogen initiatives beyond the pilot phase and into commercialization, scaling up our operations incrementally."
Par6_Cat1 • "So let's start with underground mining. Currently, the trend is to go with battery powered vehicles, lithium style technologies. There are some operations that have been using late base battery systems for many years."

Par9_Cat1 • “On the one on the issue of zero carbon, let's say hydrogen, I mean we do have hydrogen projects that we are currently doing. It's the advancement of the technology, one we are looking at hydrogen for our operations at XXX, we already running using hydrogen. We quiet had advanced in our hydrogens space. The reason why it's called clean hydrogen has nothing to do with that engine, itself has something to do with how you’re powering the conversion. And for us right now, we just feel that renewables we are better off using renewables to actually displace our electricity supply. Than we actually using that hydrogen to push hydrogen molecules. Because at the end, after you have the hydrogen molecules, what do we do with them? Currently, we do think power generation can be one of them”.
Industry Experts
Par4_Cat2 • “Reducing scope one emissions, that becomes a little bit more tricky. Because you're starting to talk about, you know, instead of using diesel, or petrol, what alternatives can we use and what alternative technologies can be used and this is where location type of mining becomes quite important. So let's start with underground mining underground mining. Currently, the trend is to go with battery powered vehicles, lithium style technologies. They are some operations that have been using late base battery systems for many years”,
Par4_Cat2 • “In addition to hydrogen, there are alternative fuels like biofuels and synthetic fuels. These fuels are derived from biological materials or are manufactured using chemical processes that mimic natural processes. The production of biofuels, for instance, typically involves the use of plant matter”

• The big reason why they're going with battery underground at the moment is because it's a technology that is a lot more mature than most other sort of renewable enabling technologies. The other aspect is the alternatives”
Par2_Cat2 • “if you look at what this decarbonisation is not just electricity and then there's the other component are the hard-to-abate sectors within the mining space. This is when you start discussing the hydrogen and the play of hydrogen, right. Some of the mines that we have and actually most of them if not all, they rely on yellow trucks right, you know, fleet. Yeah, currently, they are very much reliant on diesel right one of the fossil fuel input towards that. Now there's a drive to reduce the reliance on diesel and this is what you see Anglo doing with fuel cell type of engines, right. What are those fuel cells there? Obviously, that's the fuel cell. It's a hydrogen technology, right. And we seeing a lot of interest in that space”.
Par14 _Cat2 • “The other aspect is the alternatives. Like hydrogen for example, hydrogen is not necessarily liked as much for underground, because there is some fear of you know, fire explosions, stuff like that, because hydrogen needs to be operated at quite high pressures. And the technology is not as mature from a low pressure soluble organic liquid point of view.”
Par14_Cat 2 • “But look in the interim, utilizing a B50 biodiesel blend, which is 50% renewable and 50% conventional diesel, can be seen as a pragmatic step towards cleaner energy. This approach acknowledges that it may not be feasible to transition to entirely clean energy sources immediately. Instead, it offers a compromise, reducing reliance on traditional diesel in the short term while waiting for more sustainable solutions to mature”.

In-Case and Cross-Case analysis of the evidence

The data gathered from two data groupings reveal a consensus on the adoption of alternative energy sources for mining equipment and mining fleet. This shift primarily aims to tackle Scope 1 emissions by enhancing energy efficiency practices. In this context, alternative sources is said to be a move away from diesel utilisation as a main source of energy for equipment and vehicles. One key insight emphasized by the participants was that cost is a major factor in adopting alternative energy related strategies. The data further shows that there is a growing trend for battery powered equipment for underground mine operations. While, the use of alternative fuels, such as Hydrogen, is slowly gaining traction for utilisation in open cast mining operations, due to its high pressure compatibility. Hydrogen fuel is not recommendable for underground operations as it poses health and safety risks.

Participants also discussed the use of biodiesel and methanol as sources of energy. Interestingly, an expert among the participants suggested a transitional approach, which would blend diesel and biodiesel, as an interim measure while mining companies are awaiting maturity of technology on batteries and alternative fuel production.

Conclusion-theme two

Both mining professionals and industry experts discussed the importance of transitioning to alternative energy sources to improve energy efficiency and to reduce Scope 1 carbon emissions. The move from diesel to alternatives like battery and cleaner fuels is graining traction, however, switching to these alternatives has a cost and safety considerations. Transitional arrangements such as diesel-biodiesel blend, is also being explored as the industry seeks sustainable energy solutions while waiting for the maturity of technology.

RQ1: Theme three: Leveraging strategic partnerships

Participants highlighted that strategic partnerships are a cornerstone in the decarbonisation journey of the mining sector. The data provided insights into how mining companies are leveraging collaborative efforts and partnerships to address their carbon reduction targets and business needs.

These partnerships include collaboration on carbon off-setting projects, establishing Power Purchase Agreements (PPAs) with third parties to set up the infrastructure and operate renewable energy projects and managing suppliers in addressing Scope 3 emissions along the value chain.

Table 3: Evidence of leveraging strategic partnerships

RQ1:Theme 3 :Leveraging strategic partnerships
Mining Professionals
Par12_Cat1 • So 50% on your Scope 3, in reality, I think the biggest thing there is that they are relying on other pressures on, let's say a chemical company, to decarbonize on their own and they just get the benefit. Yeah, sure. So I think Scope 3 is still a big concern that they're not taking the full value chain into effect. • But there is also some companies that create their own plants. So some of them have land, they released the annual reports as well that you can use, so they have different phases, so some of them is PPAs where they get third parties then others have its own generated solar PV plants.
Par12_Cat1 • "So I think scope three is still a big concern that they're not taking the full value chain into effect, but I think the mining sectors almost they don't want to invest in that, especially with South Africa's mines, I think, currently without expansions then the last mine in South Africa will probably be around 2050.So the life of man is a big factor".
Par10_Cat1 • "And so, we've been working on two PPAs. Right. So the two power purchase agreements, right. One was announced last year. September, I think, end of September. That 180 megawatt solar plant in Limpopo. And then we working on a current one, where we we've already got our investment committee approval to sign the PPA, but we just finalizing the legalities of the PPA and we are hoping to try and get that announced in the coming months right. So both projects will take us way beyond our 15% a Carbon abatement targets".

Par7_Cat1 • “The biggest challenge from what I've learned from what we're seeing is you need to find the right partner to build this type of infrastructure. Yeah, solar companies they are looking to build something that will give them money immediately, you need something that's going to sustain”.
Par8_Cat1 • “if you have a project outside of your business and that project contributes to reducing carbon emissions, you are able to claim the reduced emissions as being part of your project. You credit them to your books. So if it was a financial accounting, you'll say all the benefits I created on that project, I am crediting them on my site carbon wise, therefore they are mine. So you are offsetting the emissions somewhere but you claim them as if you are the one who is benefiting from those emissions • “That's why people in businesses are now running away from them, because of those problems or issues. You can't confirm the offsets and it ends up not being credible in the climate in the carbon market. We often say that it's not credible, or it doesn't have environmental integrity.”
Par 9_Cat 1 • “Second part is the Carbon Offset, which we are looking at into future markets, so, you also have to look at all these things in terms of you know, the carbon offsets, but as I said, you are only allowed to do carbon offset when you have written that you have done so much in terms of removing carbon from your own observations using renewables for instance”.
Industry Experts
Par4_Cat2 • “And when I say grow, I mean that the pressure will grow but their supply chains depending on where they come from are well aware of how the world is going. And

those supply chains themselves, those vendors themselves are actively looking to decarbonise themselves, because they don't want their products to attract carbon taxes from other countries”.
Par14_Cat2 • “These wind resources could be harnessed through Power Purchase Agreements (PPAs), where a third-party develops the wind farm and then utilizes the existing Eskom grid to transport the electricity to the mine”.
Par2_Cat2 • “So the mining companies are asking their supply chains, what can they do? They're obviously looking at where can we put in our effort and get the biggest benefits?”
Par6 _Cat2 • “Scope 3, sort of quite limited, and I think they are looking at working with suppliers. The big thing that I think I've recognized or that I've spoken to people about, you know, Scope 3, in some ways, it's easier to address overseas. Yeah, in South Africa, we have all these SMEs and its part of your BEE sort of process. • “That actually kind of makes it a little bit more challenging because you're having to work with so many smaller enterprises. And they don't really have the capacity and capabilities to move in this direction. So Scope 3 in South Africa is just generally speaking, feels like more of a headache as well”.

In-Case and Cross-Case analysis of the evidence

The analysed data indicates that mining companies are not working in isolation but are proactively seeking and establishing strategic partnerships that enable them to address the complex challenges of decarbonisation. Key amongst these partnerships is setting up renewable energy projects through third parties. These sentiments were echoed by both the mining professionals and industry experts. In the main, mining companies establish offsite renewable energy farms through Power Purchase Agreements (PPAs) with third parties.

These third parties are contracted to set up and run the solar or wind farms on behalf of the mine.

The evidence presented indicates that only a few of the mining professionals expressed nuanced views on carbon off-setting. These carbon off-setting projects are normally implemented in partnerships with third parties. Notably, one participant mentioned that there are concerns in their company around the environmental integrity of carbon off-setting, suggesting this scepticism may be why many companies are hesitant to pursue such measures. The discussions on carbon off-setting cut across the industry and were not commodity sector specific. The industry experts made no mention of carbon off-setting as a viable option for the mining industry.

In addressing and managing Scope 3 emissions, the mining professionals highlight their reliance on external partners, however, it also points to a direct over-reliance without direct action by mining companies on Scope 3 emissions. A key point raised by one of the participants is that the life of mine has a significant impact on investments in Scope 3 emissions, particularly in the gold and coal commodity sectors. Mining industry experts also stress the importance of forming strategic partnerships within supply value chain as means to reducing Scope 3 emissions.

Conclusion: RQ1: Theme three

All the groups recognise that the journey towards decarbonisation, somewhat relies on the leveraging and nurturing of strategic partnerships. From the data provided, it is evident that the main focus of these strategic partnerships is on Power Purchase Agreements to set up and operate renewable energy plants. There is also a consensus from both the mining professionals and industry experts that the reduction of Scope 3 emissions requires strategic partnerships within the supply value chain. However, this strategic partnership approach is marked with scrutiny and concerns regarding its efficacy for carbon off-setting.

Conclusion of RQ 1: Themes

The evidence from the participants has lifted the three themes of renewable energy adoption, alternative energy use for machinery and vehicles as well as leveraging strategic partnerships. These themes reflect the mining industry's multifaceted strategies as their road map to decarbonisation. The adoption of renewable energy underscores the shift towards renewable energy sources such as wind and solar as a means to reducing carbon emissions and achieving carbon neutrality. The transition to renewable energy sources is seen as a key strategy for the different types of commodities mined as well as for open cast and underground mining operations. The second theme highlights the industry's transition to alternative energy sources as means to curb costs and reduce Scope 1 emissions. Battery technology and clean fuels such as hydrogen and bio-fuels are considered as alternatives, albeit safety and the maturity of the technology. The third theme reveals a growing reliance on strategic partnerships, especially in establishing renewable energy projects, through Power Purchase Agreements, and managing Scope 3 emissions along the mine's value chain.

5.2. RQ 2: What are the drivers for selection of decarbonisation strategies for the mining industry in South Africa?

RQ 2: Theme 1: Market pressure

Market pressure has been identified as a driver for mining companies to implement their decarbonisation strategies. These market pressures encompass industry peers and global green governance as the two subthemes.

RQ2: Theme 1: Sub theme 1: Industry peers

The evidence provided by some of the participants offered valuable insights on how market pressures from industry peers drive decarbonisation strategies within the mining sector. This sub-theme emerged from the analysis of the data.

Table 3: Evidence of industry peers as a key driver

RQ2:Theme :Market Pressure: Industry Peers
Mining Professionals
Par1_Cat1 • "Obviously, Company XXX is looking at hydrogen protons and things like that. That's not something that we're looking at. We don't have long enough sort of life of mine to warrant that sort of capital investment. Yeah. But yeah, I mean, that they're doing some amazing work.

Par10_Cat1 • “And so, you know, not only do we compete with other industry players, but we also compete internally within the company.
Part12_Cat1 • “However, in terms of broader strategic differentiation, there seems to be limited differences in what companies are doing, as they are all doing the same thing, as most are aligning with industry norms. Everybody's just mimicking everyone else now. So someone's a leader, and the rest are followers”.
Industry Experts
Par2_Cat2 • “Now there's a drive to reduce the reliance on diesel and this is what you see with Anglo American doing with fuel cell type of engines, right”.
Par6_Cat 2 • If we don't start thinking about where we're going to get the market for the ICE your internal combustion engine vehicles outside of the Europe or to the to the east, then that whole industry is gonna die, and if you start looking at the competitors from African context, you know, you've got Morocco, doing very well in that space. So this is to say that whether the local mining or whatever sector that you're talking about is not reacting to the changes that sort of imposed, then we will cease to exist, basically”

In-Case and Cross-Case analysis of the evidence

The mining professionals acknowledged that one of their key drivers towards decarbonisation is benchmarking against industry peers. This is reinforced by one of the industry experts who emphasised that there is now a general trend, amongst mining companies, to move away from the usage of diesel and this follows the path of Anglo American, who have pioneered a move to fuel cell type engines. As such, Participant 12 mentioned that there is no broader differentiation amongst mining companies on their approach to decarbonisation and therefore, in the long run, decarbonisation strategies will no longer be a source of competitive advantage.

The comments by Participant 1 add a layer of depth to the theme by highlighting decision making processes in aligning with industry peers. While the push for decarbonisation is clear, the strategies and pathways are contingent on the financial and operational considerations, especially in the coal mining sector where the life of mine is a key factor for future planning.

RQ2: Theme 1: Sub theme 2: Global green governance

Global green governance, as a subtheme under the broader theme of market pressure, plays a crucial role in driving decarbonisation strategies in the mining sector. This concept encapsulates the influence of international environmental regulations, agreements, and financial market expectations on mining companies, compelling them to adapt their strategies in response to these global standards and pressures**.**

Table 5: Evidence of global green governance

RQ2:Sub theme 2: Global green governance
Mining Professionals
Par13_Cat1 • "We have reported according to the TCFD (task force on climate related financial disclosures) requirements, so that should also improve our standing within the London Stock Exchange, where we are listed. However we haven't really seen advantages yet on that side. But as I said that will start to come in now".
Par1_Cat1 • "And so I think in comparison to mining companies you know, when you at the ratings that the various agencies give from an ESG rating perspective, yeah, certainly we

perform a lot better in that space than some of our peers, particularly in the international arena”.
Par11_Cat1 • “Another factor that demands our attention is the carbon intensity of our products. With the looming presence of the Carbon Border Adjustment Mechanism (CBAM) in regions like the UK and Europe, the way we produce becomes critically important”.
Part10_Cat1 • “So a big part of our company as the second largest mining company globally. You know, we subscribe to the Paris agreement”.
Part8_Cat1 • “Yeah, mainly because they understand the implication of this. They are party to the Paris Agreement. If ever they don't do they work internally, the Paris Agreement is going to kick in and the NDC, which is highly dependent on what companies are doing internally is going to catch up with them. So I think they are trying”.
Industry Experts
Par2_Cat2 • “That is something that is affecting them, but more importantly this introduction of mechanism, Carbon Border Adjustment Mechanism (CBAM), so that we see a lot of mining companies starting to embrace alternative clean energy technologies to circumvent the impact that the CBAM is going to have on their operating businesses,

right. So those are some of the things that we're seeing. So from a global perspective, it's the CBAM”.
Par6_Cat 2 • “And then secondary is desire from investors, and that's where the real drive is coming from. So if you want to have cheap money, number one, you need to be green. If you want to have investors with deep pockets and willing to invest in you so the likes of Blackrock, State Street and so forth. You need to comply with a certain level of ESG**.”**
Par4_Cat 2 • “And then, from a regulation point of view, you are talking about the carbon border adjustment mechanism (CBAM) sitting in Europe, which as of 1 October has officially started in its pilot phase for six commodities, where they're starting to look at a full lifecycle assessment of carbon related to six specific commodities”.
Par5_Cat2 • “I don't know if you know, about CBAM, or the carbon border adjustment mechanism, but yet yeah, so that that whole thing, I think, you know, if two steel companies are exporting to Europe at the same price, but one has a lower embedded carbon than the other, then that means that essentially it's taxed at a lower rate. A company can market it as a green and green as steel, obviously”.

In-Case and Cross-Case analysis of the evidence

The analysed data from mining professionals and industry experts shed light on how global initiatives like the Paris Agreement, the Task Force on Climate-Related Financial Disclosures (TCFD), and the Carbon Border Adjustment Mechanism (CBAM) are shaping the industry's approach to decarbonisation. The looming presence of the CBAM in regions like Europe is a crucial consideration for mining companies, who are concerned with the carbon intensity of their products.

Mining professionals, like Participant 13, acknowledge that international reporting standards like the Task Force on Climate-Related Financial Disclosures enhances their standing in international markets through their Economic, Social and Governance (ESG) ratings. Participants 8 and 10 also highlighted that international agreements like the Paris Agreement is a major and critical consideration in forming their corporate strategies on decarbonisation.

Conclusion on RQ2: Theme 2: Subtheme 1 and 2

The subthemes of industry peers and global green governance were discussed under the main theme on market pressure. The influence of industry peers creates a competitive environment where companies benchmark their decarbonisation strategies against their peers. This peer pressure becomes a key driver but also creates a certain degree of uniformity, creating a scenario where there is little or no differentiation. The second subtheme on global green governance underscores the role of international regulatory frameworks, climate change agreements, expectations from financial markets and investor demands.

RQ2: Theme 2: Energy security

The evidence indicates that energy security is a significant factor in motivating mining companies to pursue decarbonisation strategies. This concern stems from the inability of the national power utility, Eskom, to meet the growing national energy demands, due to its limited capacity to generate electricity.

Table 5: Evidence of energy security as a driver

RQ2:Theme 2 :Energy security
Mining Professionals
Par5_Cat1

• “So I think that's the way I've tried to sort of motivate for it. So it's international pressure, for sure. But yeah, I think load shedding has probably accelerated the need for it”. •
Par11_Cat1 • “Load shedding is definitely one of them, we require a reliable, round-the-clock energy supply, and currently, batteries cannot fulfil this role completely. Thus, Eskom's provision remains a critical component of our operational infrastructure”.
Part5_Cat1 • “Putting your own embedded PV on site can resolve your load shedding or supply of security, but I guess because we'll be putting generation in contributing towards increasing generation in the country. I guess I could say that also. That is one of the drivers. But yeah, climate change goes the load shedding is just accelerating. It over the need to accelerate”.
Part3_Cat1 • “Yes, so for us, it's really and I'm sure for everyone at South African context. First of all, to ensure that we have energy security and energy supply I think the rising energy insecurity posed by loadshedding is really forcing many companies to rethink their approaches around energy”.
Industry Experts
Par2_Cat2 • “But the biggest driver for all this obviously, is your Nationally Determined Commitments (NDC) from the country's perspective, right. The country has

committed to decarbonize, but from a mining perspective, obviously load shedding is the biggest driver for them to move to renewables”.
Par6_Cat 2 • “I don't think I'll be honest, their main motivation for doing it wasn't because of our climate commitments. It was because they realized that there are these projects that are being held up by red tape and if I can get them on board, it reduces the need of the need for these operations on Eskom. So it's been more of an energy security than a decarbonisation kind of perspective”.
Par14_Cat 2 • “Energy security has also emerged as a dominant theme recently, and it's an understandable priority. As an energy efficiency and decarbonisation specialist, I see the value in utilizing our resources responsibly. At the same time, I recognize the need for our country to balance this with economic growth”.

In-Case and Cross-Case analysis of the evidence

The evidence from the analysed data of the participants places a strong emphasis on load shedding as a key driver for alternative energy solutions. The mining professionals acknowledge that energy security is a catalyst for seeking renewable energy solutions and not necessarily climate commitments. This perspective is further reinforced by industry experts who also state that while climate action is a consideration, energy security is more of a pressing issue for South African mining companies. The issue around energy security is not specific to a particular commodity and seems to affect companies across the sector. Participant 14 elaborated on this theme, emphasizing the importance of balancing the responsible use of resources with economic growth considerations.

Conclusion of RQ2: Theme 2

Energy security is a predominant concern and is the major driver towards renewable energy solutions. While international pressures and climate commitments are recognized, the immediate challenges posed by energy supply disruptions, especially due to load shedding, are the more pressing drivers for the change. Issues around energy security have equally highlighted the need to strike a balance between climate goals and economic concerns.

RQ2: Theme 3: Incentives

The participants highlighted incentives as a key factor of their decarbonisation strategies. Based on interviews with mining professionals and industry experts, incentives such as costs, reputation and investor confidence are some of the main drivers for mining companies.

Table 6: Evidence of incentives as a driver

RQ2:Theme 3 :Incentives
Mining Professionals
Par7_Cat1 • **"**But the major thing is to save on our ventilation and diesel costs. Yeah, these are costs. We're not doing it per se to cut on CO_2. CO_2 cutting is just going to be a benefit".
Par1_Cat1 • "So a big component of that is our decarbonisation pathway. So if we meet our targets we've had to analyse targets but if we meet those targets, then all is good. If we don't meet our targets, then we pay a premium on the interest rate".
Part1_Cat1

• "I mean, there's definitely cost saving opportunity and then of course, you know, any efficiency projects are also an absolute no brainers you improve your productivity and you reduce your costs. So, you know, there's only benefit to doing them".
Par10_Cat1 • "Our reputation is quite key".
Industry Experts
Par6_Cat 2 • "Yeah, so it might not be that the perception will take that long. To change. It depends on how well and consistently the company goes about changing that perception. If you look at most of the mining companies in South Africa now, and I don't want to mention too many names. I mean, it's the big ones. They actively advertise the impact that they have on the communities and how much money they put back into the country is what they do. It's not difficult to find. And I think that is part of that narrative and that PR exercise to change the hearts and minds of the general populace".
Par14_Cat2 • "So if you are able to demonstrate you know, that you are on the decarbonisation journey, you give enough sort of what's the word? Investors feel confident enough in terms of what you're doing and that you're all extra on track, that sort of stuff."

In-Case and Cross-Case analysis of the evidence

Incentives have emerged as a theme that drives decarbonisation strategies for mining companies. As presented in the statements from mining professionals and industry experts, incentives are tied to the economic and reputation of the company. Mining professionals predominantly view incentives in terms of direct economic benefits, such as cost savings in ventilation and diesel and avoiding penalties on interest rates for not meeting decarbonisation targets. The emphasis is on efficiency improvements and operational cost reductions as key motivators, with CO_2 reduction often seen as a secondary benefit. Participant 10 highlighted the importance of reputation, suggesting that a company's public image is a significant incentive for pursuing decarbonisation.

Participants 6 and 14, from the industry experts further emphasised the role of public perception and investor confidence in driving decarbonisation efforts. These insights collectively illustrate scenarios where incentives for decarbonisation in the mining sector are not solely driven by a commitment to environmental sustainability, but are also heavily influenced by economic factors, investor confidence, and the need to maintain a positive public image.

Conclusion of RQ2: theme three

In conclusion, the theme of incentives driving decarbonisation strategies in the mining sector highlights that while environmental sustainability remains an important aspect, it is often the cost savings, public image and investor confidence that drives mining companies to a decarbonisation pathway. The tangible benefits are often at the centre of efforts to decarbonise while CO_2 reductions seem to be a beneficial peripheral by-product.

5.3. RQ 3: What are the barriers to the implementation of decarbonisation strategies in the South African mining industry?

A key emergent theme on the barriers to decarbonisation in mining is the government policy framework. Participants expressed that a coherent government policy should be an enabler rather a barrier in the journey towards net-zero carbon. As it stands it presents a variety of challenges that hinder a smoother energy transition.

Table 7: Evidence of government policy framework as a theme

RQ2:Theme 1 :Government policy framework
Mining Professionals

Par9_Cat1 • “So that needs to be improved. The other thing is our planning framework, especially on the electricity as to tie up with the one on energy, because right now, for example, like I said, we can't do our fuel switching because we don't know where governments is in terms of gas”.
Par10_Cat1 • “But there's a lot more government can do to remove a lot of the red tape and to accelerate the processes but I also understand the bureaucracy is really challenging”.
Part12_Cat1 • “Current policy also suffers from misalignments that allow for what might be termed 'smart accounting’, whereby emissions reductions in one area don't necessarily lead to actual change. For example, under the current carbon budgeting approach, companies are allocated budgets for Scope 1 emissions but not for Scope 2. This means a company could switch from a coal boiler to an electric boiler, transferring the emissions from Scope 1 to Scope 2, thus appearing to reduce emissions without making a real impact on overall carbon output”.
Par7_Cat1 • “so because in the end, it boils down to the government space, they are not bringing up a policy that says refineries needs to supply so much diesel that sulphur content free and this is how they as the government will assist that space is not happening as we are not getting these tier 5 engines which have very low carbon emissions because of the quality of the fuel you know that that they use. So there's not I don't think there's enough policy support from the government side on reducing co2 emissions”.

Par5_Cat1 • **“**the only main issue now that is facing the industry being the electricity regulation Amendment Bill**”.**
Par8_Cat1 • “And besides that, there are also some initiatives like your renewable energy benefits, and energy efficiency benefits for instance section 12L, of the income Tax, and they are extending it to make sure that companies are still benefiting in terms if you are if you have an energy efficient initiative. This means that you don't have to pay so much tax. So I think the government is trying”.
Par13_Cat1 • **‘**Well, just to get the climate change bill enacted. That would be the biggest change that we need. They are taking far too long with that. Yeah. And then if there are specific industry related regulations around that, specifically how to do the carbon budgets, and, again, how to incentivise your reductions**”.**
Par12_Cat 1 • “the other part is with carbon tax, rapid increase what they expect and what the government has said the pricing structure will be like, I think the biggest part is currently, that's, let's say, the stick approach, where you're just penalized there isn't a lot of carrots available. So overall incentives, I think they started incentivizing renewables now with this big tax rebate that you can get on renewables. So the expansion on section 12 B of the Income Tax Act, but ultimately, that's only for a year that you can get it and the problem is that was also motivated by load shedding not carbon for South Africa. I think the other challenges is alignment between our legislation, especially now so the climate change bill has been approved only last week, Wednesday”

Par13_Cat1 • “Government has chosen to go the route of stick and not carrots and these adoption of punitive measures rather than incentives has not been particularly well-received within the industry. The carbon tax, thus far, hasn't posed a significant challenge, largely due to the 60% rebate and the exclusion of electricity from its scope. Consequently, the carbon tax hasn't been a major factor in driving change. However, the scenario may shift if scope 2 emissions are included. It's likely that the mining sector would respond more favorably to a system that rewards rather than penalizes, indicating a preference for incentives to foster change”.
Industry Experts
Par2_Cat2 • **“**Another thing important is, you see in law, trying to fast track that whole process of deregulating the electricity market by having their own aggregator model right aggregator for you know, buying electricity in real time from renewable energy sources. So they're creating that portfolio. So that's one thing that is now you're starting to see right as an action towards accelerating that process”.
Par4_Cat 2 • I think would be extremely beneficial because the private market will move and from what I understand, at least in the green hydrogen space, there is actually a policy vacuum from what I understand there isn't really a policy in place with regards to green hydrogen yet, but there's numerous projects that are wanting to start up.
Par6_Cat2 • “So I think there's more that they can do you know, I think National Treasury has got the Carbon Tax Act. I think it's number one, it's set to lower rate. But Treasury's argued that you know, it's in line with other things, but I spoke to some tax people and they said, I think it's in Europe, their, their initial starting point of a carbon tax

was a lot lower, but what European countries did is they ring fenced that they ring fenced that money and sort of feed it back into carbon projects”.
Par14_Cat2 • **“**Policymaking should ideally support a transition to a green economy while also ensuring energy security. In the context of global politics, these decisions resemble a complex game of chess”.

In-Case and Cross-Case analysis of the evidence

The insights from mining professionals reveal a mixed response to the current policy landscape. Key points include challenges in planning frameworks, especially regarding fuel switching and uncertainties in governmental positions on energy sources like gas. Additionally, bureaucratic red tape and government processes are highlighted as barriers to an accelerated decarbonisation efforts. The industry experts also note a lack of support from government in transitioning to a low carbon economy

From the analysed data of the mining professionals, there is a sense that the incentive structure from government structure is not adequate to encourage or drive substantial change. This was raised by Participant 12 and 13.These barriers and obstacles highlight a pressing need for government policies to be reformed and realigned.

Conclusion RQ3: Theme 1

To effectively support decarbonisation strategies by mining companies, there is a need for a more aligned and clear government policy which encourages and incentivises companies to accelerate their decarbonisation efforts. This would benefit government as company emission targets would essentially align with its NDC commitments and targets.

RQ2: Theme 2: Maturity of technology

The theme of technology maturity emerged as a critical barrier in the successful implementation of decarbonisation strategies within the South African mining sector. Both mining professionals and industry experts acknowledged this barrier, citing the limitations of current technologies in meeting the sector's decarbonisation needs**.**

Table 9: Evidence maturity of technology as a theme

RQ2:Theme 2 :Maturity of Technology
Mining Professionals
Par11_Cat1 • **"**While entities like the Industrial Development Corporation (IDC) invest in demonstrated technologies such as green hydrogen, although such investments are subject to stringent conditions and are relatively few"
Par12_Cat1 • "So I would say technology is still a limitation for South Africa's mines as well".
Part13_Cat1 • "Well, if we switch to a battery operated vehicles, yes, that technology is available. In some instances, it's not mature enough. Because we are working underground these type of vehicles prefer above ground operations. So we have seen with the first feasibility study that the technology is not as mature as we thought but by the time that the renewable strategy is in full force, the battery vehicles should be developed to such a state that we will be able to start to implement the fuel switching".
Par8_Cat1 • "It's a mindset change and then for some of the technologies, its maturity of the technologies, specifically when you look at a third strategy where you move away from diesel, most of the technologies to move away from diesel they haven't reached the commercial maturity that can allow it to be done at a pace that is cheaper for

businesses. So the challenge is, firstly mind set change. Why do we have to do this second, costly because the technology hasn't matured”.	
Par5_Cat 1 • “No, the challenge is, I think it's mostly the fact that some of the technology doesn't exist. The fact that we did the hydrogen truck last year. It was a new thing where partnered another company to basically develop because there wasn't a product like that before. And they're not the electrification like obviously, it's the capex that is required in terms of investment. Those are just general challenges. And existing technology, the capex that is required, because you still have working diesel trucks. So those are some of the challenges”.	
Par9_Cat1 • “What I would do with the carbon. Yeah, no carbon capture technology has been there for years. But my argument has been always when you have captured the carbon, what am I going to do with it”?	
Par15_Cat1 • “Quantifying this carbon capture can be challenging, but there are resources available to assist with this. For example, the Restore platform (spelled without an 'e') offers a tool that allows users to explore different habitats, providing details on the carbon sequestration potential associated with each type of restoration”.	
Industry Experts	
Par2_Cat2	

• “So queueing rules is it's sort of putting a damper on this acceleration of renewable energy because traditionally what you have is embedded generators, embedded generators are connected next to the site and there's no need for you to use existing transmission construct or distribution infrastructure right. Now, the queuing rules simply says that if you are being given a place for you to connect for wheeling purposes, the one that gets the first and gets the authorization first would hold on to that, that that connection point, right. • “And what we find is, because there's constraints in certain areas of the network, from from a South African perspective, not all permit holders are able to connect on that specific area because of the constraints, right? So this is purely from the electricity component, right?
Par14_Cat 2 • “One of the technologies being explored to facilitate this partial electrification is known as 'pantograph trolley assist'. It's analogous to how electric trains operate, with an overhead power line providing continuous electric power to the train below. Similarly, trucks can receive power from an overhead system, allowing them to operate electrically for a portion of their journey while maintaining the flexibility to switch back to diesel when necessary. But yeah that’s some of the technical stuff”.
Par14_Cat 2 • **“**The hope is that by 2030, advancements in battery technology will have progressed to the point where battery-electric trucks are a viable option. These would be more compact, allowing for efficient battery swaps”.

In-Case and Cross-Case analysis of the evidence

The theme on the maturity of technology in the South African mining context, poses a barrier to successful implementation of decarbonisation strategies. This is expressed by both the mining professionals and industry experts as a significant challenge. Mining professionals like Participants 11 and 12 acknowledged the potential use of technologies such as green hydrogen but noted their limitations due to lack of full maturity. Industry experts also echoed these sentiments on the maturity of technology and pointed to the challenges around the use of battery operated vehicles for underground use and practical limitations around technologies such as Carbon capture and storage. Participants 2 and 14 also highlighted issues such as queuing rules for electricity connections, battery technologies and the exploration of partial electrification methods like pantograph trolley assist for load and haul trucks.

Conclusion RQ3: theme two

These viewpoints, as analysed from the interview transcripts, paint a picture of a mining sector willing to pursue decarbonisation but hindered by the current maturity level of relevant technologies. This presents a significant barrier to the effective implementation of decarbonisation strategies, necessitating a focus on technological development and innovation to overcome these challenges**.**

RQ3: Theme 3: Energy-supply monopoly

This theme was selected for analysis as it emerged as a significant point of interest in the data collection phase, underscoring its timeliness and relevance in the South African context. Focusing on the monopoly of the power utility, Eskom, provides a critical lens on the challenges to the decarbonisation strategies of the mining sector. Participants offered nuanced and critical insights on the impact of Eskom and the pace which the sector can transition to a low carbon energy supply.

Table 9: Energy-supply monopoly

RQ2:Theme 3 :Energy-supply monopoly
Mining Professionals
Par3_Cat1 • **“**So yeah, we are still dependent also using fossil fuel based energy source, which is mainly coming from Eskom”.

Par10_Cat1 • “Eskom is saying that, you know, they are going to increase the capacity over the next 10 years, but they've been saying that for the last few years as well”.
Part11_Cat1 • “We require a reliable, round-the-clock energy supply, and currently, batteries cannot fulfil this role completely. Thus, Eskom's provision remains a critical component of our operational infrastructure”.
Par12_Cat1 • “A significant portion of the Just Energy Transition Investment Plan (JETIP) funds is directed towards Eskom. This allocation is intended to bolster the utility's capacity and technological capabilities, acknowledging the critical reliance industries have on Eskom's infrastructure and services”.
Par12_Cat 1 • “Yeah, it's a conundrum. I think the biggest thing aspect of this conundrum is the base load. Particularly for operations requiring a reliable base load, is the current uncertainty surrounding sustainable supply”.
Par8_Cat1 • “The only impediment that is appearing as if it's a challenge is when you are at a site that does not have enough capacity to take in the power that you are bringing into the grid. And that is an Eskom challenge.”
Par9_Cat

• So some of the challenges now in South Africa, is the availability of the grid. How are all the projects we trying to procure which are not on site and how we wheel them through the grid
Industry Experts
Par2_Cat2 • **“**I think so Eskom is definitely a problem with the wheeling and I would say technology to provide baseload for this specific operation. So irrespective of Eskom wheeling, how can they create their own baseload?”
Par14_Cat 2 • “So reducing your reliance on Eskom I think it's a big, big consideration for a lot of these guys. And where they've installed the projects. I can't imagine that they haven't seen benefits from that”.
Par14_Cat 2 • “Eskom's current grid capacity is a significant constraint due to high demand from industrial complexes, which have already secured the bulk of available capacity for wheeling energy. This saturation means new players can't easily integrate their own wheeling solutions”.
Par2_Cat2 • So queueing rules is it's sort of putting a damper on this acceleration of renewable energy because traditionally what you have is embedded generators, embedded generators are connected next to the site and there's no need for you to use existing transmission construct or distribution infrastructure right. Now, the queuing rules simply says that if you are being given a place for you to connect for wheeling purposes, the one that gets the first and gets the authorization first would hold on to that, that that connection point, right. And what we find is, because there's constraints in certain areas of the network, from a South African perspective, not all

permit holders are able to connect on that specific area because of the constraints, right? So this is purely from the electricity component, right?”

In-Case and Cross-Case analysis of the evidence

Insights from the data highlights the central role of the power utility, Eskom, in the energy’s energy sector. In the South African mining context, currently there is still a reliance on Eskom due to the necessity of baseload for stable and reliable energy supply. However, mining professional, participants 3, 10, 11, 12 and 8, raise concerns regarding Eskom’s infrastructure and the reliability of energy supply. The concerns are rooted in Eskom’s past performances as well as current technical challenges.

Eskom’s role is said to be critical especially in the face of technological challenges, such as those for battery batteries that are not maturing at a speed that allows for widespread adoption. Where alternatives such as batteries and renewable energy are insufficient Eskom plays a critical role in providing a stable base load for operations. Additionally, the Just Energy Transition Investment Plan (JETIP) in South Africa is seen as a pivotal move towards enhancing Eskom's capacity and technological capabilities, acknowledging the industry's heavy reliance on their services.

Industry experts also emphasise the role of Eskom but focused more on the challenges and the potential solutions. Key issues such grid capacity constraints and the complexities around the wheeling electricity are highlighted owing to the saturation of demand from various industries. The concept of "wheeling”, which is to transfer electricity from an offsite power producer through the grid, emerged as a significant discussion topic. This is regarded, by both mining professionals and experts, as a potential bottleneck. In addition, the queuing rules for connecting to the grid for wheeling purposes are also seen as a barrier to the acceleration of renewable energy projects.

In sum, the cross-case analysis reveals a strong dependency by the mining industry on Eskom as they are the primary energy provider for baseload and renewable energy connected and distributed through the grid. There is a growing concern about its capacity to able to adapt to the integration of renewable energy sources. This concern stems from the limitations on the existing infrastructure as well as regulatory constraints posed by the Electricity Amendment

Bill. Furthermore, Eskom’s monopoly limits flexibility for the procurement of energy sources by mining companies.

Conclusion RQ3: theme 3.

The theme on Eskom's monopoly on energy supply emerges as a critical barrier to the decarbonisation efforts in the South African mining sector. This theme, underscored by both mining professionals and industry experts, highlights the complex interplay between the need for reliable energy, the limitations of current technology, and the challenges posed by the existing regulatory and infrastructure framework

Eskom's energy-supply monopoly represents a double-edged sword for the South African mining industry. On one hand, it provides the essential baseload power necessary for mining operations. On the other hand, it acts as a bottleneck due to its limited capacity, aging infrastructure, and regulatory challenges, all of which hinder the sector's transition to more sustainable energy sources.

5.4. Chapter 5: Conclusion

In conclusion, this chapter has presented the findings emanating from the interviews with 15 participants encompassing mining professionals as well as industry experts. The structure of the chapter followed the logic of the main research questions for this study which allowed for a detailed exploration of the 9 emergent themes. Based on the evidence provided in Chapter 5, it can be concluded that the study found that South African mining sector is pursuing decarbonisation through the adoption of renewable energy, alternative energy sources and strategic partnerships. The findings on the strategies highlighted how the mining industry tackles scope 1, 2, 3 emissions.

Market pressure, and energy security were discussed as the key drivers of decarbonisation while the identified barriers are government policies, energy supply monopoly and technological maturity, which pose as significant challenges for the industry. A comparative analysis of the findings in this chapter as well as the literature, presented in Chapter 2, will be discussed in Chapter 6.

Chapter 6: Discussion

6.1. Introduction

This chapter discusses and aligns the empirical findings from Chapter 5 with the literature presented in Chapter 2. This chapter is structured to mirror the same logic as presented in Chapter 5 and reviews the findings to compare and contrast with the existing literature. This approach yields an analysis of how the study's outcomes expand on the existing body of knowledge on the strategies, drivers and barriers to decarbonisation in the mining sector.

A consistent approach was employed in the comparative analysis to enhance the reliability of the findings. This process was maintained for each of the identified themes and sub-themes. The logic involved a comparison between the identified themes and subthemes with the relevant literature. Similarities and differences are exposed and discussed.

6.2. **Research Question 1**: **What decarbonisation strategies are being pursued by the mining sector in South Africa?**

The categorisation of scope 1, 2 and 3 forms the foundational lens in examining the three key themes of renewable energy adoption, alternative energy use for mining equipment and fleet, and leveraging strategic partnerships. By aligning with the emissions framework, the study dissects how the strategies, as adopted by mining companies, contribute to reducing emissions.

RQ1: Theme 1: Scope 2 Emission Reduction: Renewable energy adoption

Evidence of renewable energy adoption as a decarbonisation strategy

As per the evidence presented in Chapter 5, the mining sector is increasingly adopting renewable energy as a key component of its decarbonisation strategies in addressing scope 2 emissions. Conversations with mining professionals and industry experts revealed consensus over the shift from fossil-fuel-based electricity to renewable sources as a primary method to reduce carbon emissions and strive for carbon neutrality by 2050. This transition significantly impacts scope 2 emissions, which stem from purchased electricity. Besides aiding decarbonisation and enhancing energy security, this shift also offers notable cost savings. The use of renewable energy is not constrained by the type of mining operation or commodity and includes both open cast and underground mining.

The preferred choice for renewable energy in the sector is solar photovoltaic (PV), particularly due to the abundance of solar resources. However, there is also a growing trend towards wind energy, often facilitated through power purchase agreements (PPAs). Renewable energy adoption in mining includes both onsite and offsite solutions, influenced by factors like land availability and geographic location. Off-site energy is typically delivered to mining sites through wheeling agreements using the Eskom grid.

Overall, the mining industry's transition to renewable energy is a widely recognized and implemented strategy across various types of operations and commodities, reflecting its commitment to decarbonisation.

Evidence of renewable energy adoption as a decarbonisation strategy in literature

The literature underscores a significant shift in the mining industry towards renewable energy sources. The adoption of renewable energy sources is identified by Strazzabosco et al., (2022) and Nurdiawati and Urban (2021) as being crucial for decarbonisation of mining operations. The scholars highlight that in a developed country, such as Sweden, the mining sector is reliant on renewable energy for 90% of operations. In contrast, Strazzabosco et al. (2022) describe renewable energy adoption in Australian mining as still in nascency, accounting for only 7% of energy use. Further, there is a clear inclination towards solar photovoltaic (PV) systems due to their flexibility and scalability.

The shift towards renewable energy aligns with efforts to address scope 2 emissions in mining. Studies by Rizzoli et al. (2021) and Wimbadi & Djalante (2020) highlight renewable energy sources as the primary means for decarbonisation, focusing extensively on scope 2 emissions. This perspective is further emphasised by Johnson et al., (2021), who also state that alternative energy sources, in the form of renewable energy, predominantly address scope 2 emissions. This demonstrates the efficacy of renewable energy in reducing the carbon footprint associated with energy consumption.

The literature also emphasizes the influence of local contexts on the adoption of renewable energy. Factors such as land availability, pricing of renewable electricity, and geographical considerations play a pivotal role in determining the extent and nature of renewable energy adoption in different countries (Nurdiawati & Urban, 2021).

Comparative analysis: Evidence vs literature

The findings concur with the literature on renewable energy adoption in the mining sector that there has been a shift towards renewables, particularly solar PV and wind energy, to achieve decarbonisation and cost efficiency. This transition, significantly impacts scope 2 emissions from purchased electricity, is universally applicable, irrespective of the mining operation type or commodity, with both open cast and underground mining adopting these strategies. Strazzabosco et al. (2022) and Nurdiawati and Urban (2021) support these findings, highlighting the growing inclination towards solar PV globally and the heavy reliance on renewable in more developed countries as a means to mitigate carbon emissions. The evidence from the study reveals that South African mining companies also have a preference for solar PV owing to the abundant availability of resources in the country.

Nurdiawati and Urban (2021) delve deeper into the literature on the adoption of renewable energy sources in the mining sector, they discuss land availability, geographic location, and price of renewable energy as factors influencing the adoption of renewable energy. This aspect highlights the context and conditions in shaping renewable energy strategies.

In South Africa, mining companies have adopted both offsite and onsite operations. However, due to constraints related to land availability and geographical location, the adoption of offsite operations seems to be more pronounced. Offsite power generation may be facilitated through purchase arrangements which allow mining companies, through third parties, to generate their power. The electricity from these offsite operators is integrated into the national grid through wheeling agreements with ESKOM. The evidence underscores how local factors influence the adoption of renewable energy strategies.

These arrangements exemplify how local factors, such as land and geographic constraints, can influence the adoption and implementation of renewable energy solutions in the mining sector. It should, however, be emphasised that while mining companies have adopted this approach, many of the renewable energy plants still need to be commissioned. Therefore, there is little proof of concept and testing of the infrastructure.

Conclusion

A comparative analysis of the evidence and the literature shows alignment between the mining sector and the adoption of renewable energy as a key strategy. This theme highlights how the mining sector are tackling the reduction of scope 2 emissions. A critical factor highlighted by the evidence and literature is the influence of local context in adopting these strategies. Furthermore, the analysis enunciates the key role played by Eskom in the provision of baseload electricity and renewable energy generated offsite.

RQ1: Theme 2: Scope 1 Emission Reduction: Alternative energy for mining equipment and fleet.

The data gathered in this study pointed to the growing trend towards the adoption of alternative energy sources for mining equipment and fleets. This shift primarily aims to tackle scope 1 emissions by enhancing energy efficiency practices in mining operations. Alternative sources are pursued to support the move away from using diesel as a main source of energy for equipment and fleet. However, participants emphasised that cost remains a major factor in adopting alternative energy strategies. The data further shows that there is a growing trend for battery-powered equipment for underground mining operations. Additionally, the use of alternative fuels, such as hydrogen, is slowly gaining traction for open-cast mining operations. The high pressure required to operate hydrogen fuel renders it unsuitable for underground operations as it poses health and safety risks.

Participants also discussed the use of biodiesel and methanol as sources of energy. A transitional solution which entails blending diesel and biodiesel was also mooted. Although not carbon neutral, this could serve as a reduced carbon interim measure while mining companies await the maturity of technology on batteries and alternative fuel production.

Alternative energy use for mining equipment and fleet decarbonisation strategy in literature

The mining sector is a significant consumer of energy, particularly for transportation in open-cast mines and underground machinery. There are active efforts to transition towards alternative energy sources that address its substantial energy consumption and environmental footprint, especially focusing on scope 1 carbon emissions. Gunawan and Monaghan (2022) illustrate this in the Brazilian mining context, where activities like moving ore and operating heavy machinery, mostly driven by diesel engines, contribute to about 32% of total operational costs. These diesel engines, indispensable in both underground and open-pit operations, are highlighted by Figueiredo et al. (2023) as major sources of environmental degradation due to high gas emissions.

In response to these environmental concerns, the industry is expanding interest in green hydrogen as a viable alternative. Produced using renewable energy, green hydrogen has the potential to significantly reduce carbon emissions in mining, aiding global decarbonisation efforts. However, this transition is not without its challenges. As pointed out by Figueiredo et al. (2023) and Nurdiawati and Urban (2021), factors such as high costs and the infrastructural needs for hydrogen production, storage, and transportation pose significant hurdles. Additionally, the energy-intensive nature of hydrogen production and the associated health and safety risks, especially in underground mining contexts, require careful consideration. Nevertheless, the potential energy efficiency benefits of hydrogen fuel cells, offering longer operational periods and reduced emissions, are a promising prospect.

Ravi and Aziz ((2022) offer a technical review of hydrogen's challenges and potential, while Feng et al., (2022) point out the current high net costs of hydrogen transport compared to internal combustion engines. Xiao and Goulias (2022) suggest that these issues are part of the technology's acceptance and eventual adoption process. Furthermore, the use of battery-powered equipment and bio-diesel demonstrates a proactive approach to reducing greenhouse emissions (Nurdiawati & Urban, 2021). Lithium-ion batteries, despite their safety concerns (Feng et al., 2022), remain critical in powering electric vehicles and represent a significant step towards energy-efficient mining operations.

In summary, the mining sector's transition to alternative energy sources such as green hydrogen, battery-powered equipment, and bio-diesel represents a concerted effort to tackle scope 1 carbon emissions directly. Despite facing technical and economic challenges, these alternative energy solutions mark a significant stride towards a more sustainable, energy-efficient, and environmentally responsible mining industry.

Comparative Analysis: Evidence vs Literature

The evidence found that a key strategy in addressing Scope 1 emissions by mining companies is transitioning towards alternative energy sources. In the main, the shift is spearheaded by diesel alternatives such as battery-powered equipment, hydrogen fuel and the use of biodiesel. These findings find strong support from the literature where scholars Gunawan and Monaghan (2022) as well as Figueiredo et al, (2023) highlight the environmental and cost implications of diesel usage.

Furthermore, the evidence on insights from the data corroborates the literature that the use of hydrogen is gaining more traction in open cast mining due to potential health and safety risks for underground mining. These sentiments are echoed by Ravi and Aziz (2022) who provide a technical review of the challenges associated with hydrogen usage in mining. Feng et al., (2022) on the other hand, note the challenges regarding the transport and storage of hydrogen. These sentiments are similar to those from the analysed data in which there was mention of high pressure as a requirement for operating hydrogen and as such, this is not ideal for underground mining as there are fears of explosions.

The research findings also indicate that the most preferred alternative energy use for underground machinery or fleets is the use of lithium-powered batteries. However, the findings emphasise that bio-diesel is also a pragmatic step towards cleaner energy. These findings are confirmed in the literature by Nurdiawati and Urban (2022), who discuss battery-powered equipment and bio-diesel as another approach in switching to cleaner alternatives.

Conclusion

For this theme, it can be concluded that the research findings align with the literature on the use of alternative energy sources as a means to reducing scope 1 emissions. The research findings also highlight some of the limitations in adopting some energy efficiency measures. These finding are consistent with literature on decarbonisation strategies in the mining sector.

RQ1: Theme 3: Scope 3 Emission Reduction: Leveraging strategic partnerships

Evidence of leveraging strategic partnerships as a decarbonisation strategy

Mining companies are not working in isolation but are proactively seeking and establishing strategic partnerships that enable them to address the complex challenges of decarbonisation. Key amongst these partnerships is setting up renewable energy projects through third parties. These sentiments were echoed by both the mining professionals and industry experts. In the main, mining companies establish offsite renewable energy farms through power purchase agreements (PPA's) with third parties. These third parties are contracted to set up and run the solar or wind farms on behalf of the mine.

The evidence presented indicates only a few of the mining professionals expressed views on carbon offsetting. These carbon off-setting projects are normally implemented in partnership with third parties. Notably, one participant mentioned that there are concerns over the environmental integrity of carbon offsetting, suggesting this scepticism may be why many companies are hesitant to pursue such measures.

In addressing and managing scope 3 emissions, the mining professionals highlighted a reliance on external partners. A key point raised by one of the participants is that the life of a mine has a significant impact on investments in scope 3 emissions, particularly in the gold and coal commodity sectors. Mining industry experts also stress the importance of forming strategic partnerships within the supply value chain as a means to reduce scope 3 emissions.

Evidence of leveraging strategic partnerships as a decarbonisation strategy literature

The literature review in Chapter 2 emphasizes the complexity of reducing scope 3 emissions, which differ significantly from scope 1 and 2 emissions in terms of control and mitigation strategies. According to Nurdiawati and Urban (2021), scope 3 emissions encompass indirect emissions that a company does not directly control, such as those from the production of purchased goods and services, transportation, and the end-of-life treatment of sold products. Addressing these emissions requires a collaborative approach involving suppliers, buyers, and consumers, and may include strategies like using low-carbon materials, optimizing transport routes, and reducing waste.

Buettner (2022) notes the complexity of addressing scope 3 emissions due to their indirect nature, which can lead to double counting, as one company's scope 3 emissions might be another's scope 1 emissions. While companies have found it relatively straightforward to reduce scope 2 emissions through energy contract optimization, scope 1 and 3 emissions present more significant challenges and costs. Figueiredo et al. (2023) echo this observation, highlighting that scope 3 presents unique challenges and necessitates a holistic and collaborative approach for effective decarbonisation.

Comparative Analysis: Evidence vs Literature

The research findings emphasize that strategic partnerships are crucial in addressing scope 3 emissions in the mining industry. This aligns with the literature, particularly the work of Nurdiawati and Urban (2021), which highlights that scope 3 emissions largely stem from purchased goods and services, areas not directly controlled by the mining company itself.

Among the key strategies identified for mitigating Scope 3 emissions is carbon offsetting. This involves compensating for a company's carbon emissions by investing in projects or initiatives that reduce carbon emissions elsewhere, often through third-party engagements. This strategy is especially relevant for emissions that are challenging to eliminate directly.

The use of power purchase agreements (PPAs) is identified as a form of strategic partnership. Through PPAs, a mining company purchases electricity generated by third parties, often from renewable sources. This practice contributes to reducing the company's scope 3 emissions, as it involves procuring services (in this case, electricity) with a lower carbon footprint. However, it's important to note that the emissions associated with the electricity used directly by the company are classified under scope 2, not scope 3.

While there is agreement in the literature and findings on the importance of partnerships for decarbonisation in the mining industry, there is a divergence regarding the role of these partnerships in the purchased electricity value chain. This highlights the complexities and challenges in accounting for scope 3 emissions, a sentiment echoed by Buettner (2022). Accurately accounting for these emissions is difficult due to their indirect nature and the involvement of multiple external entities in a company's value chain.

Conclusion

The analysis of data and literature underscores the critical role of strategic partnerships in the mining industry's efforts to address the complex challenge of decarbonisation, particularly concerning scope 3 emissions. Mining companies are increasingly not operating in isolation but are proactively engaging in collaborative efforts. While some mining professionals consider carbon offsetting, executed through third-party partnerships, as part of their strategy others express scepticism about its environmental impact. This hesitation is particularly evident where there is no direct mention of carbon offsetting by industry experts as a preferred strategy for the mining sector.

6.3. Research Question 2: *What are the drivers for selection of decarbonisation strategies?*

RQ1: Theme 1: Market Pressure

Evidence of market pressure as a driver of decarbonisation

Industry peers

The recognition by mining professionals that benchmarking against industry peers is a crucial driver towards decarbonisation is a significant trend in the sector. Industry experts emphasise a general movement among mining companies away from diesel usage, following the lead of companies like Anglo-American, which have pioneered the transition to fuel cell-type engines. This trend suggests a convergence in the approach to decarbonisation across different mining companies, indicating that, in the long run, decarbonisation strategies might not serve as a source of competitive advantage.

Further depth is added to this theme by insights into decision-making processes within the industry. While there's a clear push towards decarbonisation, financial and operational considerations heavily influence the specific strategies and pathways adopted. This is particularly notable in the coal mining sector, where factors such as the life expectancy of mines play a crucial role in shaping future planning and decarbonisation efforts. These insights reflect an industry that is increasingly aligning around common environmental goals yet tailoring approaches based on individual operational contexts and economic realities.

Global Green Governance

The analysis of insights from mining professionals and industry experts illuminates the significant influence of global initiatives such as the Paris Agreement, the Task Force on Climate-Related Financial Disclosures (TCFD), and the Carbon Border Adjustment Mechanism (CBAM) on the mining industry's decarbonisation strategies. The CBAM, particularly in European regions, emerges as a critical factor for mining companies, who are increasingly mindful of the carbon intensity of their products.

Furthermore, industry professionals acknowledge the role of international reporting standards like the TCFD in enhancing their standing in global markets. Compliance with such standards is seen as beneficial for improving the economic, social, and governance (ESG) ratings. Similarly, the Paris Agreement is recognized as a major and critical factor influencing corporate strategies towards decarbonisation. These global frameworks and agreements are thus shaping the way mining companies approach environmental sustainability, driving them to align with international standards and considerations in operational and strategic planning.

Evidence of market pressure as a driver in the literature

The literature on sustainable mining practices, particularly the works of Ivic et al. (2021), Famiyeh et al. (2021), and Seroka-Stolka (2023), emphasize three primary drivers of sustainability in the mining industry: coercive, mimetic, and normative isomorphism. Coercive isomorphism involves compliance with legal and regulatory pressures from government entities, while mimetic isomorphism is characterized by companies emulating the sustainability initiatives of industry leaders, driven by competitive pressures. Normative isomorphism, as discussed by Seroka-Stolka (2023), is influenced by external pressures and stakeholder expectations, including international initiatives.

This driver has been linked to enhanced CO2 reduction efforts as companies adopt more active decarbonisation strategies in response to stakeholder pressure. Famiyeh et al. (2021), also point out that companies that are reliant on comparisons or benchmarking with competitors often achieve strides in environmental and social spheres but tend to neglect the economic dimension of sustainability.

Comparative Analysis: Evidence vs Literature

In a comparative analysis of the evidence from mining professionals and industry experts versus the literature on sustainable mining practices, key areas of convergence and divergence emerge. Industry evidence highlights a trend of benchmarking against peers, particularly in shifting from diesel to cleaner technologies like fuel cell engines, aligning with the concept of mimetic isomorphism described by Ivic et al. (2021), which emphasizes emulation of sustainability initiatives by industry leaders.

However, the literature cautions against over-reliance on mimetic isomorphism, wherein Famiyeh et al. (2021), express that companies who mimic industry peers tend not to consider economic sustainability. Evidence from the analysed data suggests divergence from the literature wherein the analysed data from the interviews suggests that for coal mining companies in South Africa, economic sustainability is a mediator to mimetic pressure. The 'life of mine' in the coal sector seems to have a significant influence on the type of decarbonisation strategies.

Additionally, global governance initiatives like the Paris Agreement and TCFD are noted to significantly influence mining companies, aligning with normative isomorphism in the literature, where external pressures shape corporate actions, leading to more active decarbonisation strategies as emphasized by Seroka-Stolka (2023). Furthermore, there is recognition of the influence of regulation, especially with initiatives like the CBAM in Europe, echoing scholarly views on coercive isomorphism, where legal and regulatory pressures compel sustainable practices. This comparison illustrates a multifaceted approach to sustainability in mining, intertwining competitive emulation, regulatory compliance, and response to global environmental standards.

Conclusion

In conclusion, the exploration of market pressure as a driver for decarbonisation strategies in the mining sector, through both industry evidence and academic literature, reveals a nuanced and multifaceted approach to sustainability. The industry's trend towards benchmarking against peers in adopting cleaner technologies, such as the shift from diesel to fuel cell engines, aligns with the concept of mimetic isomorphism. Global initiatives like the Paris Agreement and TCFD hold significant sway over corporate strategies, resonating with the notion of normative isomorphism, where external pressures and stakeholder expectations drive more proactive decarbonisation efforts. Moreover, the industry's recognition of regulatory influences, as seen in initiatives like the CBAM, reflect coercive isomorphism's role in compelling companies towards sustainable practices.

RQ2: Theme 2: Incentives

Evidence of Incentives as a driver

Incentives have emerged as a significant theme driving decarbonisation strategies in the mining industry. The insights from mining professionals and industry experts reveal that these incentives are closely linked to economic benefits, the reputation of companies, public perception as well as investor confidence. Economic benefits are linked to cost savings in ventilation, reduced diesel use, and avoiding penalties on interest rates for not meeting decarbonisation targets.

Furthermore, the decision-making process on the mining companies' decarbonisation strategies is strongly linked to a need to maintain a positive public image in enhancing reputation, which in turn builds investor confidence. These considerations highlight efficiency improvements and operational cost reductions as key drivers, often placing CO2 reduction as a secondary but beneficial outcome.

The need to maintain a positive public image and secure investor trust plays a significant role in the decision-making process of mining companies. This perspective indicates that the incentives for decarbonisation in the sector are multifaceted, encompassing not only a commitment to environmental sustainability but also a strong influence from economic factors and reputational considerations.

Evidence of incentives from the literature

The literature provides substantial evidence on the evolution of business sustainability from a generalized concept to a crucial element in corporate strategies, encompassing environmental, social, and economic considerations. Originally defined in 1987 as meeting current needs without compromising future generations' ability to meet the scope of business sustainability has significantly broadened. Current research, such as Costa et al. (2022), identifies it as a key driver of global low-carbon practices.

The role of business sustainability at the corporate level is increasingly recognized for fostering long-term value, essential for ensuring a future pipeline of products and services (Lazarenko et al., 2021). Hedstrom (2018) expands this view, noting that sustainability is not just about long-term value but also involves seizing opportunities and managing risks related to environmental and social impacts. Companies are advised to embed sustainability into corporate strategies to grasp the broader business picture, using performance indicators to assess and integrate relevant practices for long-term value creation (Costa et al., 2022; Lazarenko et al., 2021).

However, Lopez-Torres et al., (2022) observe a reluctance among many firms to adopt sustainability practices due to perceived incremental costs. Conversely, other firms view sustainability as a means to enhance competitiveness, suggesting a need for greater awareness of sustainability strategies that can positively impact firm performance. Liu et al. (2022) also contribute to this discussion, investigating the link between sustainable management and firm performance in the Chinese manufacturing sector. Their findings reveal inconsistent results regarding the implementation of ESG (economic, social, governance) practices and financial performance, attributed to the often-overlooked internal dynamics and external context of firms.

Moderating factors are crucial in balancing the impact of sustainability, including economic, social, environmental, and political considerations. Lopez-Torres et al. (2022) suggest considering the firm’s organizational and technological readiness, regulatory actions, economic model, and stakeholder involvement to ensure the adequacy and appropriateness of sustainability initiatives.

In summary, integrating sustainability into business strategy is seen as a pathway for organisations to capitalize on opportunities for cost reduction, efficiency improvement, and positive environmental impacts. This integration can also enhance a firm's reputation and competitiveness (Costa et al., 2022; Hedstrom, 2018; Lazarenko et al., 2021). In mining, an extractive and traditionally environmentally impactful sector, the application of sustainability practices remains complex. Bari et al., (2022) acknowledge the complexity, noting the shift from regulatory compliance to a focus on ESG metrics in driving corporate sustainability.

Comparative Analysis: Evidence vs Literature

In a comparative analysis of the evidence from mining professionals and industry experts with the literature on business sustainability, a clear alignment and some differences are observed. Industry evidence indicates that in the mining sector, decarbonisation incentives are closely linked to direct economic benefits, like cost savings and avoiding penalties. Efficiency improvements and operational cost reductions are viewed as primary motivations, while considering CO_2 reduction as a beneficial but secondary outcome.

This perspective is paralleled in the literature, as seen in works by Costa et al., (2022) and Lazarenko et al., (2021), which also recognize the economic dimension of business sustainability and its role in driving long-term value creation through strategic integration for cost and efficiency gains. Additionally, both industry insights and literature emphasize the importance of public perception and investor confidence in driving decarbonisation efforts, underscoring the role of sustainability in enhancing a firm's reputation and competitiveness.

The industry acknowledges the complexity of balancing environmental objectives with economic and reputational considerations, a viewpoint that resonates with scholars like Bari et al. (2022), who note the complex nature of implementing sustainability practices in the mining industry, especially the shift from regulatory compliance to a focus on ESG metrics. This comparative analysis reveals a consensus on the multifaceted nature of sustainability incentives, combining economic, reputational, and environmental factors.

Conclusion

In conclusion, both the mining industry and academic literature consistently emphasize the multifaceted nature of sustainability initiatives, particularly in the context of decarbonisation. The industry's focus largely centres on the direct economic benefits, such as cost savings and avoiding penalties, treating CO2 reduction as a beneficial but secondary outcome. This is in line with scholarly perspectives that highlight the importance of integrating sustainability into business strategies for long-term value creation. Moreover, both the industry and academia acknowledge the critical role of public perception and investor confidence in driving sustainability efforts, further demonstrating the interconnectedness of economic, reputational, and environmental factors in the pursuit of sustainable practices in mining. The consensus points towards a complex, yet cohesive approach to sustainability. Blending regulatory compliance with a broader commitment towards environmental, social, and governance (ESG) metrics will shape a more holistic and balanced path for the future of the mining sector.

6.4. RQ3: *What are the barriers to the implementation of decarbonisation strategies in the South African mining industry*?

RQ3: Theme 1: Maturity of Technology

In the South African mining context, the theme of technological maturity emerges as a significant barrier to the successful implementation of decarbonisation strategies. Mining professionals and industry experts recognise green hydrogen as having a high potential to be a low-carbon substitute for diesel usage. However, there is collective acknowledgement that the option has limitations as the technology to produce, store and transport the product still needs to be developed. Furthermore, it has been emphasised that hydrogen technology is only suitable and applicable for open pit mining operations. This is owing to the heavy load of haulage trucks, which makes battery packs impractical, thereby positioning hydrogen as a more feasible alternative.

The adoption of battery technology for underground mining operations is not without associated challenges. While some mining companies have adopted and embraced battery-powered fleets and equipment, certain practical technicalities exist, such as the size of the battery pack, a result of limitations with the technology. Additionally, battery swapping and the lead time for charging the batteries are some of the impracticalities and concerns that need to be addressed. This shared understanding acknowledges the potential of battery technology in this sector but also highlights the need for improvements to make it more viable for widespread use in underground mining operations.

The technology on carbon capture utilisation and storage (CCUS) in the South African setting is also said to be in a nascent stage of development. Concerns raised revolve around the storage of the carbon post the capture. Additionally, issues such as the queuing rules for electricity and the intermittency of renewable energy as well as the exploration of electrification methods, like the pantograph trolley assist for load and haul trucks, are also highlighted as needing further development. These insights reflect a broader consensus on the need for more advanced and practical technological solutions to drive decarbonisation efforts in the South African mining industry effectively**.**

Evidence of literature on the maturity of technology

The literature presents a comprehensive view of the challenges associated with adopting low-carbon emission technologies in the mining sector. Nurdiawati et al. (2021) emphasise that many such technologies are still in the early stages of development, such as research and pilot phases, indicating that they may take years to reach full maturity. This perspective is supported by Figuereido et al. (2023), who specifically discuss green hydrogen technology, an alternative to diesel fuel with zero carbon emissions. The authors highlight that the technology for its production, storage, and transportation still needs to be fully developed, presenting a significant barrier to its rapid adoption.

In the realm of carbon capture usage and storage (CCUS), scholars point out that despite being at the forefront of academic and industry discussions as a solution for reducing carbon emissions (Budinis et al., 2018; Bui et al., 2018), technical barriers have slowed its adoption rate. Nurdiawati and Urban (2021) also argue that large-scale deployment of CCUS technologies requires substantial supporting infrastructure, including storage and transport facilities. High capital costs and ongoing operational expenses are also a concern.

Scholars (e.g. Igogo et al., 2021; Strazzabosco et al., 2022) identify significant technical challenges regarding renewable energy integration in mining operations. They note the limitations posed by the intermittent nature of solar PV and wind energy, which is a critical issue since mining operations require a consistent, high-quality energy supply, often around the clock. The variability of these renewable sources, particularly an inability to consistently meet the energy demands of mining operations, presents considerable challenges. Even when wind and solar energy are abundant, peak generation periods can lead to complications with excess power, which may require storage solutions like batteries. This complexity in managing and integrating variable renewable energy sources to meet the energy demands of mining operations highlights the ongoing challenges in the sector's transition to more sustainable practices.

Evidence vs literature

South African industry professionals and academic literature consistently acknowledge the challenges posed by the immature state of low-carbon emission technologies as a barrier to successful decarbonisation strategies. Industry experts in South Africa highlight the potential and developmental limitations of technologies like green hydrogen and carbon capture and storage (CCUS). This aligns with perspectives from literature, such as those that emphasise the underdevelopment of green hydrogen technology and the technical and financial barriers to CCUS adoption (Figuereido et al., 2023; Budinis et al. (2018).

Data from this study also revealed the complexities in integrating renewable energy, particularly solar and wind, into mining operations due to intermittency and variability (Igogo et al., 2021; Strazzabosco et al., 2022). The scholars note that the requirement for constant and consistent energy during mining operations poses a significant challenge for mining companies. The technological immaturity of battery technology exacerbates the complexities. These challenges amplify the complexities confronting efforts to integrate renewable energy in energy-intensive industries in South Africa.

Conclusion

The practical insights from the study's findings and the academic literature highlight the challenges related to adopting low-carbon emission technologies in the mining sector. While there is a recognition of the potential to utilise battery-powered equipment and fleet, the technology must be more mature to offer everyday practical solutions for mining operators. Green hydrogen also presents a viable alternative for decarbonising mining operations; however, research, development and investment will need to address its generation, storage and transportation.

RQ3: Theme 2: Government policy framework

Participants thought that government policy is a barrier to driving substantial change related to decarbonisation in the mining industry in the South African context. Government policy on carbon tax is said to need more incentives for real impact. Additionally, excluding electricity emissions from the Act has created unintended consequences. Some study participants highlighted that excluding electricity emissions has resulted in tax avoidance strategies. For instance, the swapping of scope 1 emissions – a coal-powered boiler, for scope 2 emissions – an electricity-powered boiler.

The current approach by the government is seen as primarily punitive rather than incentive-based and acts as a barrier to the industry’s adoption of decarbonisation strategies. Slow governmental action in implementing key reforms, such as the electricity amendment for climate change, further hampers progress. Although there are initiatives like renewable energy benefits, these are often seen as temporary and primarily targeting load shedding instead of focusing on carbon reduction.

Evidence of literature on government policy framework as a barrier

The literature discusses government policy as a barrier to decarbonisation strategies. Nurdiawati et al. (2021) emphasise the role of institutional barriers as challenges to decarbonisation pathways. Lengthy planning cycles and delays in obtaining environmental permits often result in delays in setting up the technological infrastructure and impede the deployment of cleaner technologies. Furthermore, uncoordinated government efforts exacerbate these barriers. A lack of synergy among various arms of the government can lead to conflicting policies, ambiguities and implementation challenges (Nurdiawati & Urban, 2021). Singh et al. (2020) noted similar challenges in India’s mining industry, where governmental policies and regulations, instead of facilitating, impede the adoption of decarbonisation strategies, such as material circularity.

Evidence vs Literature

The evidence indicates that government policies are a barrier to effectively driving decarbonisation in the mining sector. This concern is echoed in the South African mining sector setting and observed by scholars who have studied the mining industry in other countries. Notably, the analysed data shows enduring concern over the finalisation of the anticipated electricity amendment and the climate change bill. Both these policy instruments are considered crucial parts of the decarbonisation pathway for the mining industry. Nurdiawati et al. (2022) express similar concern by pointing out lengthy government planning, lack of intergovernmental coordination as well bureaucratic red tape as significant impediments in driving decarbonisation.

Furthermore, carbon tax legislation remains under scrutiny and is perceived as punitive rather than incentivising decarbonisation. While the carbon tax aims to incentivise, participants allude to the fact that in South Africa, the act lacks sufficient impetus for change. A notable issue with current regulation is its exclusion of scope 2 carbon emissions. This exclusion leads to ‘smart accounting’, where companies may shift their emissions from scope 1 to scope 2, such as switching from a coal-powered boiler to an electric boiler, without reducing the overall carbon footprint. This loophole allows superficial compliance without substantive environmental benefits and reflects a disconnect between the policy's intentions and practice.

Conclusion

While the literature focuses on government policies as barriers to decarbonisation, it needs more specificity on certain policy instruments. However, the findings have highlighted the Carbon Tax Act as a policy instrument that serves as a concrete example of how government policy can hinder progress towards decarbonisation. The findings also reflect a trend in literature where government policies act as a punitive measure rather than incentivise low carbon emissions.

This specific examination of the South African context enriches the broader academic dialogue on decarbonisation by offering detailed insights into how policy instruments and government processes impede the transition to decarbonisation in the mining industry.

RQ3: Theme 3: Energy-supply monopoly

Eskom plays a pivotal role in South Africa’s energy sector. In the context of the mining sector, the power utility is the primary supplier of baseload and offsite renewable energy. The research findings also indicate that the concerns are rooted in Eskom’s past performance and technical challenges.

Eskom’s role is said to be critical, especially in the face of technological challenges, such as those for lithium batteries that are not maturing at a speed that allows for widespread adoption. In a world where alternatives are insufficient, Eskom is critical in providing a stable base load for operations. To acknowledge Eskom’s monopoly, there is emphasis on the significant investment stemming from a just energy transition investment plan (JETIP), which is meant to enhance Eskom’s capacity and alleviate technical challenges.

Key issues such as grid capacity constraints and the complexities around wheeling electricity are highlighted due to the demand saturation from various industries. The concept of ‘wheeling’, the transfer of electricity from an offsite power producer through the grid, emerged as a significant discussion topic. The queuing rules for connecting to the grid for these purposes are seen as a barrier to accelerating renewable energy projects.

6.5. Conclusion

In conclusion, the research findings highlight Eskom's dominant role in South Africa's energy sector, particularly concerning the mining industry. Eskom’s energy supply, especially for base load and renewable energy, is a critical support in the face of technological limitations and slow maturity. The findings underscore Eskom’s limits as a barrier to widespread adoption of renewable energy sources, thereby hampering decarbonisation efforts.

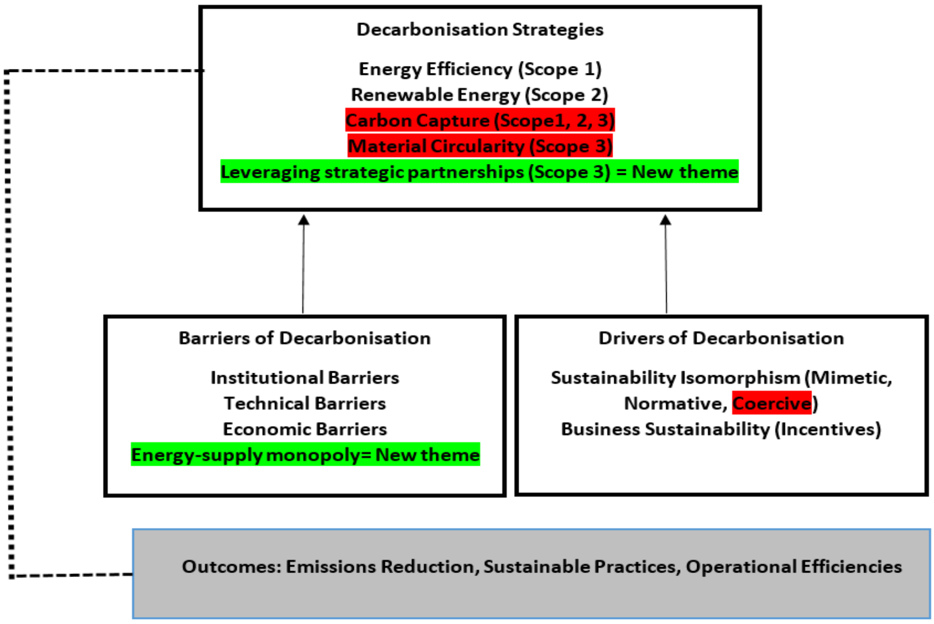
Most notably, academic literature does not provide rich evidence on the theme of energy supply monopoly as a barrier. This indicates a gap in the existing literature. More research is needed to understand the full impact of energy supply monopolies, like Eskom, on the energy transition, particularly in the context of developing countries and their unique challenges.

This chapter provided a detailed comparative analysis of the empirical findings from Chapter 5 and the literature reviewed in Chapter 2, with a focus on decarbonisation strategies, drivers, and barriers in the mining industry. The systematic approach used in this comparative analysis ensured the rigor and external validity of the findings. The key findings of the study are summarized in chapter 7.

6.6 Conceptual Framework

- The study reaffirmed several known themes related to decarbonisation strategies, barriers, drivers, and outcomes, which are consistent with the literature. However, there was no evidence supporting the use of 'Carbon Capture' and 'Material Circularity' as a strategy. This is also true for 'Coercive' measures as drivers of decarbonisation. The three themes are marked in red.

- New themes were identified in the study, which adds to the body of knowledge: energy supply monopoly and leveraging strategic partnerships (these are marked in green).These two new themes provide insights and direction for future research.



Chapter 7: Conclusion

7.1. Introduction

The purpose of this chapter is to present the research outcomes as derived from the comparative analysis discussed in Chapter 6. The comparative analysis was informed by the theoretical framework in Chapter 2 and the empirical findings detailed in Chapter 5. The research set out to explore decarbonisation strategies in the mining industry, as well as examining both the drivers and barriers associated with these strategies. The setting of the study was in the South African mining industry with a particular focus in the areas of coal, platinum and gold. Participants included from the mentioned sectors along with industry experts in the form of consultants and researchers in the energy and decarbonisation spaces.

The chapter also presents the conclusions to each of the three research questions that the study attempted to address. This includes an expansion to the conceptual framework, which was developed using the literature in Chapter 2 and was informed further by the findings of Chapter 5. The framework was then revised in Chapter 6 after a discussion on the similarities and differences between the literature and empirical findings.

This chapter is organised to provide a clear and comprehensive overview of the theoretical conclusions of the research questions, then describes how the study contributes to the existing body of knowledge. This is followed by recommendations for management and other stakeholders. In addition, there is a discussion on the limitations of the study and finally, the chapter is concluded by a suggestion for future studies.

7.2. Principal theoretical Conclusions

Research Question 1: *What are the key aspects of the decarbonisation strategies of the mining sector in South Africa?*

The research question explored the decarbonisation strategies of the mining sector in the South African setting. For this research question, it was concluded that two of the research outcomes were consistent with literature on decarbonisation strategies construct. Renewable energy adoption as well alternative energy use for mining equipment and fleet were the two themes stemming from the research findings and congruent with literature discussed in Chapter 2.

Mining companies are increasingly incorporating renewable energy as a primary strategy for reducing Scope 2 emissions. In this context, Solar Photovoltaic (PV) is preferred due favourable weather conditions. However, the research outcomes also indicate that there is some traction, albeit slow, in the inclination towards wind energy. These findings are consistent with the literature by Strazzabosco et al. (2022) and Nurdiawatti and Urban (2021), who have highlighted that renewable energy is the most preferred source of energy in addressing Scope 2 emissions.

Strazzabosco et al. (2022) highlight the importance of location in choosing renewable energy sources and also emphasises that renewable energy is dependent on the location of the mine but mentions that due to the scalability and flexibility of Solar PV, it is the most preferred. Most importantly, the adoption of renewable energy cuts across the mining industry, regardless of the commodity being mined and the type of operation.

The second emergent outcome from the study indicates that the mining sector is shifting towards alternative energy sources for its mining equipment and fleet. This strategy reduces Scope 2 emissions and enhances energy efficiency. In the main, the outcomes indicate a move towards battery-powered equipment as well as the use of hydrogen energy and bio-diesel. This aligns with the literature by Gunawan and Monaghan (2022) who highlight the prevalence of the use of alternative energy sources as a mitigation for heavy diesel usage in mining operations as diesel is a significant contributor to high carbon emissions and rising operational costs.

Notably, the move to alternative energy sources is marked by an increasing preference for hydrogen energy as identified by Figuereido et al. (2022), who state that hydrogen contributes to the energy transition in the mining industry. This move is becoming widespread due to the lack of technological maturity in relation other alternatives such as lithium batteries. However, the research outcomes also reveal that hydrogen energy use needs to overcome barriers such as storage, production and transportation. Despite these obstacles, the shift to hydrogen energy underscores the industry’s commitment to exploring low carbon alternatives.

According to the study, mining companies face significant difficulties in reducing Scope 3 emissions, such as those resulting from purchased goods and services. Buettner (2022), who emphasises the difficulty in managing Scope 3 emissions due to their indirect nature, echoes this complexity. Some mining companies turn to third-party partnerships for carbon-offsetting projects in response to this challenge. These projects aim to compensate for emissions by investing in environmental initiatives, although their effectiveness in genuinely reducing emissions is a subject of debate (Nurdiawati & Urban, 2021). Furthermore, the nature of the purchased goods and services complicates this strategy. For instance, purchasing electricity through third parties is not typically included under Scope 3 emission reductions. Despite recognising the value of partnerships in addressing the value chain, mining companies have yet to develop clear and defined strategies for effectively managing and reducing Scope 3 emissions.

Conclusion to Research Question 1

The research findings on renewable energy and energy efficiency measures employed by South African mining companies are consistent with the literature on decarbonisation strategies in the industry. The notable differences are centred on material circularity and carbon capture utilisation and storage as these were not part of the outcomes of the study.

Whilst there is clarity and well defined strategies on addressing Scope 1 and Scope 2 emissions, the research reinforced the complexity, as was discussed in the literature, on effectively tackling Scope 3 emissions. This highlights an area where mining companies have yet to develop comprehensive decarbonisation strategies. This study therefore concludes that RQ1, which was stated as: What are the decarbonisation strategies of the mining sector in South Africa? has been answered. The study revealed that the strategies employed by South African coal, platinum and gold mining companies are renewable energy as well as energy efficiency strategies.

Research Question 2: What are drivers of the decarbonisation strategies in the mining industry in South Africa?

The study on decarbonisation strategies in the mining industry highlights two primary drivers that align with existing literature: market pressure in the form of industry peers and global green governance, as well as economic incentives. The mining sector in South Africa is significantly influenced by market pressure, especially from industry peers, which shapes decarbonisation strategies. However, when it comes to coal mining, the strategies are more cautiously adopted, taking into consideration the mine's life and economic sustainability, rather than just mimicking peers. This observation is consistent with Famiyeh et al.'s (2021) findings. Market pressure is driven by global governance initiatives such as the Paris Agreement and frameworks like the Task Force on Climate-related Financial Disclosures. The mining industry is reassessing the carbon intensity of their products due to policies like the Carbon Border Adjustment in Western Europe. This is an example of coercive isomorphism, as described by Seroka-Stolka (2023) and Ivic et al. (2021). Moreover, the research highlights incentives as critical motivators for decarbonisation in mining. These incentives are intrinsically linked to economic benefits such as cost savings and avoiding penalties. The primary motivator for decarbonisation is business sustainability, with CO_2 reduction being a beneficial by-product. This finding is consistent with Lazenko et al.'s (2021) and Hedstrom's (2018) argument that integrating environmental practices like decarbonisation into corporate strategy can create long-term value for businesses.

Conclusion to Research Question 2

The research outcomes on the drivers of decarbonisation were discussed using the lens of mimetic, normative and coercive isomorphism, which revealed similarities and nuances of difference as compared to existing literature. A notable nuance identified was for companies in the coal commodity sector in South Africa, where the life of mine is seen as a critical driver to strategy decisions, as opposed to mimicking industry peers. Given the movement to reduce fossil fuel based energy, the coal sector has adopted a more cautious and individualised approached towards decarbonisation. This study therefore concludes that RQ2, which was stated as: What are the drivers to decarbonisation in the mining sector? has been answered. Such drivers were identified as market pressure as well as economic incentives as highlighted above.

Research Question 3: What are the barriers to the strategies in decarbonising the mining sector?

The research outcomes have identified maturity of technology, government policy and the monopoly on energy supply as barriers to decarbonisation in the mining industry. The main obstacle towards achieving low-carbon emissions is the lack of maturity in technologies that can facilitate it. Although technologies like green hydrogen and carbon capture and storage (CCUS) hold great promise, they are still largely underdeveloped. This challenge has been acknowledged by academic experts, as highlighted in the research conducted by Figuereido et al. (2023) and Budinis et al. (2018). Their studies emphasise the underdevelopment of green hydrogen technology and the technical and financial hurdles to CCUS adoption.

Another major challenge is the integration of renewable energy, particularly solar and wind, into mining operations. The intermittent and variable nature of these energy sources poses a significant challenge, as mining operations require constant and consistent energy. The technological immaturity of battery technology further complicates this issue. Studies by Igogo et al. (2021) and Strazzabosco et al. (2022) highlight these complexities, underscoring the challenges of integrating renewable energy into energy-intensive industries in the context of South Africa.

The role of government policies in hindering effective decarbonisation efforts is also a critical issue. Delays in finalizing essential policy instruments such as the Electricity Amendment and the Climate Change Bills are of concern. Moreover, the Carbon Tax Act, while intended to incentivise decarbonisation, is perceived as punitive and fails to address the loophole of excluding Scope 2 carbon emissions. This exclusion leads to superficial compliance without real environmental benefits, a concern echoed by Nurdiawati and Urban (2022), who also point out the challenges of lengthy government planning and bureaucratic obstacles.

Lastly, the research identifies a significant gap in the existing literature regarding the impact of energy supply monopolies, like Eskom, on the energy transition. Eskom's dominant role in South Africa's energy sector, particularly in base load and renewable energy, presents a critical support and barrier in the face of technological limitations and the slow maturity of battery technology. The monopoly hampers the widespread adoption of renewable energy sources, thus impeding decarbonisation efforts. This indicates a need for further research to understand the full impact of such monopolies on energy transitions, especially in the context of developing countries and their unique challenges.

Conclusion to Research question 3

In summary, the research outcomes identified three primary barriers to decarbonisation in the mining industry in South Africa, thereby answering RQ 3 which was stated as: What are the barriers to the strategies in decarbonising the mining sector? These include the lack of development of low-carbon technologies, ineffective government policies, and the energy supply monopoly. This emphasises the need for further research to effectively address and overcome these challenges in decarbonisation, particularly in understanding the impact of energy supply monopolies.

7.3. Research Contribution

The research contributions are divided into two categories: additions to the body of knowledge as well as potential extensions of the body of knowledge

Additions to the Body of Knowledge

This research enriches the decarbonisation literature by providing context-specific insights into the strategies, pathways, and roadmaps employed within the South African mining industry. It sheds light on the unique challenges and strategic responses that are specific to this sector, thereby enhancing the understanding of how decarbonisation is approached in a critical sector of the South African economy. The study offers a comprehensive view of the complexities and particularities involved in implementing decarbonisation strategies in different economic contexts. Furthermore, it validates the global applicability of decarbonisation strategies while accentuating their unique differences in applicability within the South African context.

Potential Extensions of the Body of Knowledge

The study identifies potential extensions to the existing body of knowledge. It unveils distinct elements of the decarbonisation process in the South African mining industry, which broadens the scope of current literature. Notably, the challenges posed by the energy supply monopoly in South Africa and the industry's responses to these challenges present new dimensions to the decarbonisation narrative. These findings not only serve as extensions of established theories but also encourage further research.

7.4. Recommendations for management

It is recommended that management work towards establishing stronger partnerships within their organisations' supply chain in addressing Scope 3 emissions. This should follow the initial step of clearly defining strategies for Scope 3 emission reduction. These strategies should focus on genuine emission reductions rather than for compliance and reporting.

1. Further, it is important for management to encourage collaboration with technology providers and investing in alternative energy projects to understand their practical implications and scalability.
2. Given the widespread adoption of renewable energy sources by the mining industry, it is essential for mine managers to prioritise research and development for developing new technologies to integrate renewable energy sources and improve energy storage capabilities. This would assist in resolving challenges pertaining to the intermittency of sources such as solar and wind energy Improved energy storage and integration technologies reduce dependence on Eskom.

7.5. Limitations of the research

The study's significant limitation is the exclusion of key stakeholders outside the direct mining industry, such as government policymakers and Eskom. These entities act as drivers and barriers to the mining industry's decarbonisation and provide important insights into the research. Their perspectives and insights could have added essential dimensions to the research, providing a more comprehensive picture of the decarbonisation process.

The inclusion of these stakeholders could have provided a better understanding of the external factors affecting decarbonisation efforts, such as policy implications, regulatory environments, and energy supply dynamics, especially given Eskom's significant role in South Africa's energy landscape. Moreover, the study's investigation into specific decarbonisation strategies is not comprehensive enough. While the study provides an overview and analysis of mining companies' strategies, there is room for further investigation into each strategy. This could include looking into the technical aspects, viability, implementation problems, and possible effects of each strategy in more depth.

Expanding the examination of these aspects might have resulted in more intricate understandings of the efficacy and feasibility of various decarbonisation approaches, thereby providing stakeholders in the mining industry and associated sectors with more practical and relevant data.

7.6. Suggestions for future research

a. Conducting research on policy analysis to evaluate the effectiveness of current policies and proposing recommendations for policy improvements to facilitate decarbonisation in the mining sector.
b. Another fruitful area of research could be investigating the role of emerging technologies and innovation in accelerating decarbonisation in the industry. This may involve studying renewable energy adoption, energy efficiency improvements, and digital transformation in mining operations.
c. To gain insights into how decarbonisation strategies evolve over time and their long-term effectiveness, longitudinal studies could be conducted.
d. Additionally, detailed analysis of individual decarbonisation strategies, including their technical, economic, and operational aspects, could be another focus for further research.

7.7. Conclusion

In conclusion, the study can confirm that all the research questions were answered. Research question 1 on “What are the decarbonisation strategies in the mining sector in South Africa ?” was addressed through key findings on renewable energy adoption in addressing Scope 2 emissions, alternative energy sources for mining equipment for and fleet for tackling Scope 1 emissions leveraging strategic partnerships in addressing Scope 3 was emissions.

On the second research question, “What are drivers of the decarbonisation strategies in the mining industry in South Africa?” the research study indicates that decarbonisation strategies are mainly driven by mimetic (industry peers), normative (global green governance) isomorphism’s as well as economic incentives.

Lastly, the third research question on “What are the barriers to the strategies in decarbonising the mining sector?” was addressed by key findings on lack of maturity of low-carbon technologies, ineffective government policies, and Eskom’s energy supply monopoly.

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Appendix 1: Consistency Matrix

Research questions	Section in Literature Review	Questions on interview guide	Analysis techniques
RQ1: What are the key aspects of the decarbonisation strategies of the mining sector in South Africa?	**2.5 and 2.5.1** • Nurdiawati and Urban (2021) • Rissman et al.,(2020) • Johnson et al (2021) • Buettner (2022)	Question 1 Question 8 Question 9	• First level coding and thematic analysis to develop constructs
RQ2: ***What are the drivers for selection of decarbonisation strategies?***	**2.6,2.6.1** • Lazarenko et al.,(2021) • Costa et al,.(2022) • Famiyeh et al (2021) • Ivic et al.,(2021) • Seroka-Stolka (2023)	Question 3 Question 7 Question 5	• First level coding and thematic analysis to develop constructs
RQ3: ***What are the barriers to the implementation of decarbonisation***	**2.6.3** • Nurdiwati and Urban (2021)	Question 2 Question 4 Question 9	• First level coding and thematic analysis to develop constructs

strategies in the South African mining industry?	• Figueiredo et al (2023)		

Appendix 2: Interview Guide

Possible questions to company representative / sustainability managers in mining companies.

1. Please tell me about the decarbonisation strategy in your company.
2. What are the challenges you face in implementing a decarbonisation strategy?
3. What are the benefits associated with adopting this strategy?
4. What is the impact of your strategy on the company's triple bottom line?
5. How do you measure such an impact?
6. What are the associated costs of the sustainability strategies?
7. To what extent do you believe your strategy aligns or contributes to achieving global net-zero 2050 targets?

Possible questions to mining industry experts with a knowledge base of climate change and decarbonisation.

1. What are some of the decarbonisation strategies used by mining companies?
2. What do you think is the impact of such strategies?
3. In you your experience, what are some of the challenges that the industry experiences in implementing reducing its carbon footprint?
4. What are the potential benefits of decarbonisation for the mining sector?
5. What advice would you give a mining company in reducing its carbon footprint?
6. How can mining companies balance the social, environmental and economic aspects in reducing their carbon footprint?
7. Does successful implementation/progress on decarbonisation strategies translate into competitive advantage?

Appendix 3: Consent form

Informed Consent Form

Gordon Institute of Business Science (GIBS)

Dear Sir/Madam

Title: Towards a just energy transition: Decarbonisation in South Africa's mining sector

You are invited to participate in an MPhil: Corporate Strategy research study titled "Towards a Just Energy Transition: Decarbonisation strategies in South Africa's mining sector." Before you decide whether or not to participate, it is essential that you understand the nature, purpose, and requirements of the study. Please take the time to read this letter carefully and feel free to ask any questions you may have before making your decision.

The purpose of this research study is to explore and analyse the decarbonisation strategies within South Africa's mining sector. By examining the current practices and challenges, we aim to identify potential pathways for a just and sustainable energy transition. The study seeks to contribute to the understanding of sustainable energy practices in the mining industry and their implications for the just energy transition.

During the interview, we will ask questions related to your experiences, perspectives, and insights regarding the energy transition strategies in the mining sector. The interview will be audio-recorded to ensure accuracy in data collection, but your identity will be kept confidential.

Please note your participation in this research is voluntary and should you wish to withdraw, you may do so at any time without any penalty. The interview will be conducted in a semi-structured format and will take between 60-90 minutes. All data will be reported on anonymously and all identifying information like company and people's names will be removed from the report.

Date: 07 Aug 2023

Appendix 4: Code list

Accessing wind energy_requires strategic location of wind farms to access good generation conditions e.g. Western Cape

Advantages of large firms_able to access knowledge sharing across divisions

Advantages of large firms_able to drive decarbonisation investigations centrally at headoffice level

Advantages of large firms_able to invest in multiple project initiatives to align with a basket of measures

Advantages of lithium battery_battery technology is more mature than other renewables

Advantages of lithium battery_five times times smaller in size than lead

Advantages of lithium battery_lithium powered vehicles able to carry bigger loads

Aspects of carbon off setting_a financial accounting measure

Aspects of carbon off setting_claim footprint reduction gains from other project activity towards low or non performing areas

Aspects of carbon off setting_current focus of mines is to establish foundation projects towards decarbonisation

Aspects of carbon off setting_firms only permitted off set claims when own initiatives are also reported

Aspects of carbon off setting_transcations are backed by issue of certificates of attribution

Aspects of decarbonisation_capturing carbon emissions

Aspects of decarbonisation_carbon sequestration

Aspects of decarbonisation_character of required journey depends on multiple factors e.g type of commodity and geo-location

Aspects of decarbonisation_converting coal boilers to steam operated

Aspects of decarbonisation_converting fleets from diesel to electrically powered options

Aspects of decarbonisation_converting fleets from diesel to hydrogen power

Aspects of decarbonisation_energy efficiency tracking

Aspects of decarbonisation_energy efficiency tracking under scope 2 is one of the easiest to tackle

Aspects of decarbonisation_entails a range of components within mining

Aspects of decarbonisation_includes ensuring new aquistions are compliant and support journey to impact reduction goals

Aspects of decarbonisation_increased employ of tech and automation improves energy efficiencies

Aspects of decarbonisation_new energy supply optimisation plans

Aspects of decarbonisation_punitive carbon penalities are increasing and raising risk of companies folding due to non compliance

Aspects of decarbonisation_researched data now available to guide energy efficiency interventions

Aspects of decarbonisation_SA gold mines driving energy usage efficiencies by converting operations of current assets

Aspects of decarbonisation_the journey is still being shaped and benefits yet to be realised

Aspects of decarbonisation_trading of carbon offsets to achieve progression towards targets

Aspects of natural capital_entails ensuring optimal functionality of natural ecosystems

Aspects of natural capital_regarded to be entertwined with climate change mitigation

Aspects of scope 3_applying contract risk penalties on carbon intensive suppliers

Aspects of scope 3_carbon footprint of employees commuting to work

Aspects of scope 3_easier to effect in developed markets with access to advanced tech suppliers to partner with

Aspects of scope 3_engaging network of suppliers for inside out decarbonisation journey alignment

Aspects of scope 3_entails requiring on individual suppliers in value chain to align and commit to compliance targets

Aspects of scope 3_introducing hybrid working arrangements to control indirect environmental impact

Aspects of scope 3_pays more attention to accounting for recorded use

Aspects of scope 3_reduced life of gold and coal mines affecting decision to pursure scope 3 targets

Aspects of scope 3_relevant scope and targets are set and monitored by OECD

Aspects of scope 3_taking longer to define into clear reduction commitments from suppliers

Aspects of solar power usage_generation is capacity dependent on quality of technology employed

Aspects of the broader sustainability agenda_incorporating value creation access for local communities linked to mining project investments

Barriers to decarbonisation efforts_access to technology that is specifically suited to SA conditions

Barriers to decarbonisation efforts_end of life mines cannot remunerate required investment

Barriers to decarbonisation efforts_energy supply monopoly structures

Barriers to decarbonisation efforts_fraud and corruption

Barriers to decarbonisation efforts_full value of ESG has not yet been determined

Barriers to decarbonisation efforts_government support processes require complex decision choices

Barriers to decarbonisation efforts_high cost of biofuels

Barriers to decarbonisation efforts_investment case does not motivate quest for first mover advantage

Barriers to decarbonisation efforts_lack of cohesive government policy push to drive low carbon standards nationally

Barriers to decarbonisation efforts_lack of collaboration across organs of government

Barriers to decarbonisation efforts_legacy systems are not easy to change

Barriers to decarbonisation efforts_multinational response to fraud and corruption is to divest operations

Barriers to decarbonisation efforts_reduction targets being achieved because of loadshedding

Barriers to decarbonisation efforts_technology not advancing fast enough to meet implementation needs

Barriers to decarbonisation efforts_unnecessary red tape and bureaucracy in government

Barriers to employing low carbon solutions_high level of investment required for projects

Benefits of decarbonisation_accessing low cost funding for operations

Benefits of decarbonisation_attracting positive perception and changing public narrative on mining

Benefits of decarbonisation_attracting talent and skills from eco-conscious new age workforce

Benefits of decarbonisation_avoiding heavy tax penalties to retain price competitiveness

Benefits of decarbonisation_building a positive reputation with government and host communities

Benefits of decarbonisation_creating social spillover effects through skills development and intervention planning

Benefits of decarbonisation_creating tangible proof of mining industry transformation

Benefits of decarbonisation_differentiating from competitors

Benefits of decarbonisation_enhancing natural systems in local communities

Benefits of decarbonisation_environmental benefits from reduced emissions

Benefits of decarbonisation_firms can contribute to national power generation

Benefits of decarbonisation_generating new employment opportunities

Benefits of decarbonisation_income tax related benefits

Benefits of decarbonisation_lie in avoiding the negative punishments of non compliance

Benefits of decarbonisation_making mining companies more attractive to shareholders

Benefits of decarbonisation_renewable investments help stabilise energy supplies

Benefits of decarbonisation_securing license to operate and expand operations

Benefits of decarbonisation_softening government attitude to support new investments

Benefits of decarbonisation_there are now opportunities to capture cost benefits from maturing renewables technology

Challenges in defining solutions for open pit_batteries would require several hours to recharge resulting in lost productivity

Challenges of battery operated vehicles_technology is available but not yet mature

Challenges of decarbonisation efforts_backlash from questioning credibility of ESG value

Challenges of decarbonisation efforts_carbon footprint is negatively impacted by negligent disposal of obsolete equipment

Challenges of decarbonisation efforts_carbon footprint tracking must consider full product lifecycle

Challenges of decarbonisation efforts_companies are measured for value chain aspects they have no control over

Challenges of decarbonisation efforts_companies under pressure to implement programs quickly

Challenges of decarbonisation efforts_conversion of machinery must be scoped and tested for each machine type in use

Challenges of decarbonisation efforts_difficult to track if 3rd party wheeled electricity recieved was generated from a renewable source

Challenges of decarbonisation efforts_enduring heavy reliance on diesel powered fleets

Challenges of decarbonisation efforts_firms lack robust strategic clarity to guide implementation initiatives

Challenges of decarbonisation efforts_gas not effective as a long term energy solution in mining

Challenges of decarbonisation efforts_incremental gains of effects reduce with each phase

Challenges of decarbonisation efforts_integrated solutions for renewable energy generation and storage are expensive

Challenges of decarbonisation efforts_navigating complex environmental regulation related to the agenda

Challenges of decarbonisation efforts_not all global markets participate creating gaps in market demand pressure

Challenges of decarbonisation efforts_renewable energy options are intermittent in their supply from source

Challenges of decarbonisation efforts_renewable energy solutions need a connect grid to link source to consumption points

Challenges of decarbonisation efforts_requires long term attentions to capture positive effects

Challenges of decarbonisation efforts_requires long term investment commitments to effect energy usage changes

Challenges of decarbonisation efforts_requires strong internal motivations to change

Challenges of decarbonisation efforts_scope 3 targets are difficult to monitor and track

Challenges of decarbonisation efforts_short term gains fromcarbon trading can delay adjustment of internal mindset to embrace decarbonisation

Challenges of decarbonisation efforts_solution scoping requires consciousness of other aspects of sustainability

Challenges of decarbonisation efforts_some renewable options are not net zero e.g. biodiesel and lithium

Challenges of decarbonisation efforts_some sourcing practises dilute the decarbonised intentions of green products

Challenges of decarbonisation efforts_some sustainability interventions required are not easy to measure

Challenges of decarbonisation efforts_some technologies dilute the decarbonised intentions of green products

Challenges of decarbonisation efforts_sometimes renewable energy options are limited by local constraints

Challenges of decarbonisation efforts_studies showing that scale of renewable materials required to achieve goals is unattainable

Challenges of decarbonisation efforts_within firm tensions between strategic goals and realities faced by operational personnel

Challenges of decarbonisation specific to SA context_enduring heavy reliance on diesel to generate power to supplement power shortages

Challenges of decarbonisation specific to SA context_enduring heavy reliance on Eskom to meet power supply needs

Challenges of defining renewable solutions for open pit_battery systems will require strong management systems to operate large number of batteries required

Challenges of defining renewable solutions for open pit_equipment used is heavier and requires specific solutions

Challenges of defining renewable solutions for open pit_heavy machinery used will require large numbers of battery cells to operate

Challenges of defining renewable solutions for open pit_solutions required are more complexand taking longer to formulate

Challenges specific to SA context_wheeled power cannot be transferred across provinces due to capacity constraints

Challenges with biodiesel_product access has been clouded by fraudulent certification

Challenges with natural gas in SA_only available from Mozambique

Challenges with natural gas in SA_supply from source is projected to runout by 2025

Challenges with natural gas in SA_supply infrastructure is limited and does not extend to remote locations

challenges with offsetting_challenges with credibility dilute environmental impact integrity

challenges with offsetting_no guarantee of permanancy in achievement of claimed reductions

Challenges with renewable energy options_battery retrofit configurations and supporting facilities are costly projects

Challenges with renewable energy options_battery storage solutions are expensive and limited in capacity

Challenges with renewable energy options_energy storage solutions are critical for energy security to be attainable

Challenges with renewable energy options_older mines have aged old tech infrastructure that is difficult to retrofit

Challenges with renewable energy options_solar generation only possible during daylight window

Challenges with renewable energy options_wind generation rate is not consistent

Challenges with renewable energy options_wind vane operations can threaten birdlife

Character of coal mining operations_nature of emissions is predominantly Scope 1 related

Character of coal mining operations_requires greening considerations of outputs as well as product outputs

Character of coal mining operations_solutions required are more complex and taking longer to formulate

Character of gold mining operations_focus is also on implementing energy efficiency projects

Character of gold mining operations_focus is on solar projects to feed in renewable energy

Character of gold mining operations_nature of emissions is 95% related to Scope 2

Character of mining operations_an environment more affiliated with scope 2 targets

Character of mining operations_capture active interests of a wide diversity of stakeholders

Character of mining operations_decarbonisation oversight is broken down into three scopes of oversight -1,2 &3

Character of mining operations_easier to maintain oversight of scope 1 and 2 targets.

Character of mining operations_energy consumption rated biggest contributor to carbon footprint of mining

Character of mining operations_global pricing fluctuations impact the attractiveness of the industry to investors

Character of mining operations_heavily influenced by global commodity price movements for inputs and outputs

Character of mining operations_high demand for energy

Character of mining operations_highly visible operations assumed to have a larger carbon footprint impact than is the case

Character of mining operations_initiating machinery often requires increased surge of power

Character of mining operations_large scale operations

Character of mining operations_long standing operations with important impact on economy

Character of mining operations_multinational firm operations generally smaller than in other global markets

Character of mining operations_multinational firm portfolios create opportunity to implement different interventions in different markets

Character of mining operations_multinational firms have better access to resources for exploring alternative fuels

Character of mining operations_must contend with underground safety issues e.g methane gas and water flows

Character of mining operations_open pit vs underground operations require different decarbonisation agendas

Character of mining operations_operational machinery must operate continously for optimal gains

Character of mining operations_processing plant side of operations is easier to convert to renewable energy

Character of mining operations_requires greening considerations of outputs as well as product outputs

Character of mining operations_significant energy consumption is dedicated to load and haul operations

Character of mining operations_smaller mines tend to focus on internal energy efficiency optimisation options

Character of mining operations_some mines have a short life remaining on existing operations

Character of mining operations_success in meeting ESG goals will require closely integrated response initiatives along value chain

Character of mining operations_there is a circular relationship between industry outputs and inputs from suppliers

Character of platinum mining operations_nature of emissions is 80% related to Scope 2

Community impacting initiatives_creation of community development trust to spread value

Community impacting initiatives_creation of new jobs

Community impacting initiatives_focus requirements and opportunities differ across provinces

Community impacting initiatives_guiding behaviour change toawrds more sustainable practises to meet daily needs

Community impacting initiatives_introducing energy efficient solutions for reduced carbon impact

Community impacting initiatives_running sustainability programs e.g. bursary scheme

Considerations that influence mining leaders choices_acquiring mines for non-fossil fuel minerals and metals to improve footprint impact

Considerations that influence mining leaders choices_deploying landbank assets in mining portfolio for renewable project investsments

Considerations that influence mining leaders choices_when to make necessary decisions to drive actions

Considerations that influence mining leaders' choices_assessing timing of renewable investments to capture cost reductions that come with technology maturity

Considerations that influence mining leaders' choices_ensuring new investments align with sustainability goals and incentives

Considerations that influence mining leaders' choices_establishing a portfolio of mines with different ranges in life of operations

Considerations that influence mining leaders' choices_exaggerated public perception of mining co2 impact demands careful messaging

Considerations that influence mining leaders' choices_identifying lucrative local and international investments to expand portfolios

Considerations that influence mining leaders' choices_internal reward systems now being driven by ESG performance

Considerations that influence mining leaders' choices_managing investor expectations by projecting net-zero pathways

Considerations that influence mining leaders' choices_managing life of mine to determine options for continuity

Considerations that influence mining leaders' choices_monitoring and improving the firm's rating scoring with rating agencies

Considerations that influence mining leaders' choices_need to create a roadmap to establish new good will when transitioning business model

Considerations that influence mining leaders' choices_projecting pace of demise of operations in sustainability unfriendly products

Considerations that influence mining leaders' choices_recognising that product outputs may generte more co2 than process of extractions e.g. coal

Considerations that influence mining leaders' choices_renewables alone may not be enough to run operations

Considerations that influence mining leaders' choices_tracking against ESG goals and necessary disclosures

Considerations that influence mining leaders' choices_transitioning business models to viable options for the future

Considerations that influence mining leaders' choices_working on scope 3 after achievements in scope 1 & 2

Considerations that influence mining leaders' choices_working with Scope 3 partners to ensure downstream targets are met

Decarbonisation efforts_carbon trading arrangements help attainment of reduction goals

Decarbonisation efforts_scope 1 measures are tracked as part of ESG strategies

Decarbonisation efforts_tracking carbon emissions

Decarbonisation efforts_transition into renewable energy solutions

Decarbonisation process_a building phase must unfold to pave way for operational viability

Decarbonisation process_begins with a measured process to think and plan

Decarbonisation process_begins with assessing sources of carbon contribution in the value chain and prioritising approach

Decarbonisation process_begins with attaining environmental impact assessment authorisation before project can proceed

Decarbonisation process_begins with brainstorming caucus to pool ideas and considerations

Decarbonisation process_begins with broad based stakeholder consultations

Decarbonisation process_begins with developing a project scope that aligns with the strategy

Decarbonisation process_begins with developing and launching a pilot implementation

Decarbonisation process_begins with developing business cases for intervention options

Decarbonisation process_begins with establishing dedicated resources to drive the program

Decarbonisation process_begins with establishing market and industry intentions and expectations

Decarbonisation process_begins with fact finding mission to inform range of operational options

Decarbonisation process_begins with formulating a strategic outlook considering external and internal conditions

Decarbonisation process_begins with going out to market to launch request for proposals for program development support

Decarbonisation process_begins with internal search for meaning behind the agenda

Decarbonisation process_begins with partnering with relevant consultants to build detailed context perspective

Decarbonisation process_begins with securing required capital to build assets

Decarbonisation process_begins with short and long range planning to map a way forward

Decarbonisation process_begins with speaking to value chain partners to hear multiple views on implications

Decarbonisation process_is broken into phases of implementation

Decarbonisation process_needs to rely on proven technologies for incremental changes that are sustainable

Decarbonisation process_success requires governemt support to accelerate programs

Decarbonisation strategic scope_encompasses many variables across the value chain

Decarbonisation strategic scope_includes aspects such as hydrogen commercialisation strategy

Decarbonisation strategic scope_includes considerations for responsible asset disposal

Decarbonisation strategic scope_includes integration for group synergies to develop and deploy renewable energy solutions

Decarbonisation strategic scope_ultimately mining output influences the carbon footprint of its inputs

Demand side elements_mining plants

Demand side elements_smelter complex operations

Drivers of change_a thriving growing econmy

Drivers of change_aligning with detailed requirements of legislation

Drivers of change_alignment of industry players under national strategic infrastructure development projects

Drivers of change_building investor confidence

Drivers of change_business continuity now depends on making transitions to more sustainable practises

Drivers of change_capturing cost savings from efficiency projects

Drivers of change_capturing productivity improvements from efficiency projects

Drivers of change_competitive benchmarking against industry peers

Drivers of change_competitive benchmarking against internal peers

Drivers of change_competitive benchmarking of key aspects against international peers

Drivers of change_customer expectations for green products

Drivers of change_easy access to funding to finance plans

Drivers of change_ESG targets and metrics tracked by key stakeholders

Drivers of change_firm level harmonised decarbonisation commitments

Drivers of change_funders now link interest rates to performance against decarbonisation targets

Drivers of change_government incentives to promote change

Drivers of change_government infrastructure development can serve to drive a carbon economy

Drivers of change_high risk for firms and nationally of continuing to rely on fossil fuels

Drivers of change_identfying learnings from other players that help solve problems in hand

Drivers of change_increasing carbon tax

Drivers of change_increasing import tarrifs

Drivers of change_internalised sustainability goals

Drivers of change_international customers

Drivers of change_international sustainability goals

Drivers of change_legislation in support of carbon credits

Drivers of change_mandatory reporting requirements starting to come into effect

Drivers of change_mechanisms to apply penalalties for non compliance with targets

Drivers of change_nationally harmonised decarbonisation commitments

Drivers of change_new international and local carbon command system to commence 2026

Drivers of change_pursuing increased earnings

Drivers of change_regulation on sustainability standards in international markets

Drivers of change_reputation management

Drivers of change_requirement for firms to disclose impact on natural capital

Drivers of change_sense of responsibility towards local community

Drivers of change_sustainability mindset shift in consumers is driving a change in focus from production cost saving to sustainability impact

Drivers of change_sustainability mindset unlocks new opportunities for mutual exchange of value with local communities

Efforts to manage demand_reduction in power consumption

Efforts to manage impact reduction_develop a prioritisation plan to guide focus area selection

Efforts to manage impact reduction_identify most impactful operational areas for carbon reduction

Efforts to manage impact reduction_optimise efficient use of equipment and machinery

Efforts to manage impact reduction_replace equipment with higher efficiency options

Enablers_a government task force empowered to make decisions

Enablers_changes to government policy to align value chain resources

Enablers_clear national government stance to signal intent and commitment

Enablers_creating a national culture of valuing adoption of renewable energy solutions

Enablers_government led processes that suppport industry efforts towards decarbonisation

Enablers_IDC investment into hydrogen technology

Enablers_pursuit of new technology that offer options for electrification of haulage equipment

Energy management process_baseload tracking does not provide refined details of highs and lows

Energy management process_cost of storing of renewables is still high but set to decline with time

Energy management process_driven by quest for energy security

Energy management process_establish power purchase agreements

Energy management process_establishing a wind plant is a lot more tricky than solar so used less in SA

Energy management process_evaluating energy usage patterns across infrastructure and operations

Energy management process_firms must decide whether to invest directly or indirectly into renewables

Energy management process_ideal blend or 'energy trinity' consists of solar, wind and electricity

Energy management process_investigating process efficiencies related to underground ventilation systems

Energy management process_large volumes of power used requires detailed management

Energy management process_power production and management to remain split between Eskom and NERSA

Energy management process_process of wheeling enabling transfer of power from source to cient via hired infrastructure

Energy management process_renewable energy inputs are being wheeled from 3rd party wind and solar producers

Energy management process_SA driving energy reform through electricity wheeling

Energy management process_SA platinum mines driving energy reform through electricity wheeling

Energy management process_solar energy projects are pursued most by mines in SA

Energy management process_sources of renewable energy in SA are geographically dispersed

Energy management process_verification of stability of renewable energy storage tech is still underway

Energy management process_wheeling energy enables accrual of clean energy credits for mines

Energy management process_wheeling is essential and quick to implement ahead of own generation efforts

Energy management process_wheeling is essentially an accounting matrix not a representation of operational reality

Energy management processes_big users have been subject to load curtailment

Energy management processes_buy and sell exchange agreement with Eskom to balance demand fluctuations

Energy management processes_capturing underground gasses to channel into electricity generation

Energy management processes_government moving legal processes to fast track processes to liberalise electricity

Energy management processes_metering, monitoring and verification

Energy management processes_projecting demand over life of mine production plans

Energy management processes_protecting supply in blended generation model requires over subscribing for optimal mix.

Energy management processes_protecting supply requires a blended model of sources

External drivers specific to SA_cost of renewable energy is cheaper than Eskom supplied power

External drivers specific to SA_cost of renewable energy is cheaper than fossil fuel based power

External drivers specific to SA_market opportunity for renewables is significant

External drivers specific to SA_national push for mines to invest in renewable energy own generation capacities

Funding structures in SA_funding mechanism to support Eskom R&D towards energy security

Funding structures in SA_IDC

Funding structures in SA_individual company's own resources

Funding structures in SA_just energy transition investment plan

Government initiatives in SA_allocating funding to build capabilities to support climate change across level of governement

Government initiatives in SA_counsel of geoscience and DMRE piloting carbon capture and storage

Government initiatives in SA_incentivising renewables through big tax rebates

Hydrogen use progress in SA_constrained by complex transportation and handling requirements for truck transported gas

Hydrogen use progress in SA_constrained by high cost of investment required

Hydrogen use progress in SA_constrained by scarcity of supply of hydrogen

Hydrogen use progress in SA_presents high safety risk to operate underground as it needs high pressure

Hydrogen use progress in SA_reliable sources of green hydrogen still need to be confirmed to meet operational demand

Hydrogen use progress in SA_susccessfully trialed on a prototype for heavy open pit equipment

Hydrogen use progress in SA_the technology is still new and under development

Influential regulatory structures in SA_Endangered Wildlife Trust

Influential regulatory structures in SA_JSE

Internal challenges_different pace of embracing sustainability requirements is causing pervasive misalignment

Internal challenges_employee tensions over top-down energy-saving project intensions and onsite operational challenges

Internal challenges_high use of external consultants to define new agendas may be regarded as an imposition

Internal challenges_rescoping of roles to embed new sustainability metrics may be overwhelming

Internal challenges_specialist focus on expert areas may result in loss of insight into other drivers impacting organisational priorities

Internal challenges_top-down impositions invite resistance and high likelihood of reversal to old ways

International industry profile_trend setter as second largest mining company in the world

International policy structures driving sustainability goals_European carbon border adjustment mechanism- CBAM

International policy structures driving sustainability goals_Paris accord

International policy structures driving sustainability goals_task force on climate related financial disclosures (TCFD)

International policy structures driving sustainability goals_taskforce on nature related financial disclosures (TNFD)

International policy structures driving sustainability goals_United Nations

Interventions to reduce power demand_operating at lower furnace capacities

Key stakeholders_activists

Key stakeholders_financing institutions

Key stakeholders_government

Key stakeholders_investors

Key stakeholders_local communities

Key stakeholders_minerals' council

Key stakeholders_municipalities

Key stakeholders_NGOs

Key stakeholders_OECD

Key stakeholders_ratings agencies

Limitations of co2_requires high process safety interventions

Limitations of hydroelectricity_requires hydro processing facilities

Local policy structures driving carbonisation_carbon tax introduced in 2019

Local policy structures driving carbonisation_climate change bill now in effect

Methane gas considerations_difficult to determine volumes that are available underground affecting stability of supply

Methane gas considerations_evaluating option to capture and convert to energy

Natural gas_regarded as a secure option due to ease of availability

Natural gas_rising cost of gas is reducing its viability as a cost effective solution

Nature of scope 1 targets_currently limited by technology alternatives still in trial but not yet confirmed for scale

Nature of scope 1 targets_entails replacing as much coal as possible

Nature of scope 1 targets_entails replacing as much diesel as possible

Nature of scope 1 targets_fewer competitors for underground players than open pit

Nature of scope 1 targets_includes focus on electrification and energy efficiency

Nature of scope 1 targets_more closely related to tax penalties and incentives

Nature of scope 1 targets_more tricky than scope 2 as accessible fuel alternatives must be evaluated

Nature of scope 1 targets_related to emissions directly generated by business operations

Nature of scope 1 targets_underground mines are choosing to convert to lithium battery powered vehicles

Nature of scope 1 targets_underground mining also looking at biodiesel

Nature of scope 1 targets_underground mining conversions are ahead of open pit

Nature of scope 2 targets_related to power sourcing and energy usage across operations

Nature of scope 2_metrics based on agenda to switch to renewable energy sources

Nature of scope 3 targets_play a smaller role in mining as emission contribution to reduction targets is low

Nature of scope 3 targets_related to carbon footprint of indirect emissions e.g. external purchases

Nature of scope 3 targets_relevant remissions for mining originate from Eskom

Nature of scope 3 targets_tracking passive systems for carbon capture e.g. natural capital

Options evaluation_changing energy solutions provided to existing clients from coal to renewables

Options evaluation_closing old mines serves to reduce carbon footprint

Options evaluation_developing hydrogen technology advancements

Options evaluation_exploring carbon capture and storage

Options evaluation_exploring process changes to employ less energy intensive options

Options evaluation_investing in downstream technologies to support customers employ mining outputs sustainably

Options evaluation_mines have access to water waste that can be used for hydrogen power

Options evaluation_mixed views over conversion of waste dumps to energy storage facilities

Options evaluation_recognising progressive loss of market for carbon impacting products e.g. coal

Options evaluation_testing to verify costs and value of alternatives

Options evaluation_use of process byproducts such as co2 gas for energy

Other drivers of operational review_looking for cost containment options

Perspective of leaders_better incentives may be more effective than tax penalties in motivating compliance

Perspective of leaders_carbon tax revenues should be invested into expanding support for carbon reduction efforts

Perspective of leaders_current efforts by SA mines to address emissons are not having significant impact

Perspective of leaders_current policies and taxes are not punitive enough to push compliance

Perspective of leaders_Eskom model needs to change to accommodate a liberal power sector

Perspective of leaders_for sustainable responsible mining attention should be on the entire ecosystem

Perspective of leaders_fragmented state institutions managing power supply not likely to provide required level of responsiveness to corporate

Perspective of leaders_government needs to formulate clear policies to support good intentions

Perspective of leaders_government needs to refine decarbonisation tax incentives to specify impact towards areas needing greater support

Perspective of leaders_government policy needs to create a push and pull effect to drive value for hydrogen investment

Perspective of leaders_in SA the DTI should lead the carbon policy changes for more balance in goal setting

Perspective of leaders_liberalisation will accelerate decarbonisation

Perspective of leaders_need government to balance role of enabler of globally aligned standards as welll as nurturer of competitiveness for local firms

Perspective of leaders_need to motivate sector coupling for comprehensive decision making to drive green economy

Perspective of leaders_online community engagement platforms can be used to inform and invite public participation in sustainability trends and events

Perspective of leaders_SA is leading in driving carbon measures that are effective on business

Perspective of leaders_SA needs to prioritse economic growth agenda over climate change

Perspective of leaders_the national planning framework has to encourage greater speed in implementing solutions

Perspective of leaders_the national planning framework needs to set a strong vision

Positive effects of carbon tracking_reducing demand for electricity and capturing savings

positive impact of decarbonisation efforts_reduction in impact of electricity on cost base

Range of environmental management activities_environmental impact assessment (EIA) authorisation required from ministry to build plants

Range of environmental management activities_rehabilitation of of old mines before disposal

Range of environmental management activities_water treatment processes

Regulatory structures in SA_Minerals Council of South Africa

Renewable energy options considered in SA_hydrogen protons

Renewable energy options considered in SA_natural gas

Renewable energy options considered in SA_solar

Renewable energy options considered in SA_wind

Respondent role_principal for renewable energy ecosystems

Risk of disjointed national value chain_loss of downstream cost competitiveness in international markets

Scoping renewable energy project_requires access to expansive land banks to set up infrastructure

Scoping renewable energy projects_conduct feasibility studies

Scoping renewable energy projects_finalise legalities of the project

Scoping renewable energy projects_greater appetite to invest in green solutions for new mine projects

Scoping renewable energy projects_high energy demands of mining require multiple generation plants

Scoping renewable energy projects_investment committee approvals

Scoping renewable energy projects_negotiate plans and secure sign off

Scoping renewable energy projects_plan on target capacity volume output

Socioeconomic impact of mining in SA_significant contributor to provincial and national fiscus

Socioeconomic impact of mining in SA_significant employment creator

Sources of energy used_biofuels

Sources of energy used_diesel

Sources of energy used_Eskom power supply

Sources of energy used_fuel cells

Sources of energy used_fugitive methane

Sources of energy used_hydrogen protons

Sources of energy used_nuclear

Sources of energy used_solar

Sources of energy used_wind

Strategic value chain partnerships_includes equipment suppliers who must support every phase of the project

Strategic value chain partnerships_includes research institutions supporting investigations into options

Strategic value chain partnerships_includes setting up a community trust that holds stake in any new project investments

Strategic value chain partnerships_includes suppliers who are also working on own decarbonisation goals to avoid penalties

Strategic value chain partnerships_includes technology development global partnerships

Strategic value chain partnerships_includes third party power providers developing and operating wind and solar plants

Strategic value chain partnerships_strategic clients require certain spec of product to meet own ESG goals

Strategic value chain partnerships_uninterrupted electricity supply service relationship agreed with Eskom

Sustainability agenda includes_enhancement of biodiversity and ecosystem funtions

Sustainability agenda includes_focus on re-establishment of native vegetation as part of carbon sequestration

Sustainability agenda includes_focus on rehabilitation, reduction, reuse and recycling

Sustainability agenda includes_repurposing existing infrastructure to avoid new material deployment demands

Threats to stability of SA mining_access to sufficient capital to optimise mines

Type of mining operations_coal

Types of carbon metrics tracked in mining_carbon footprint of executive and staff travel

Types of carbon metrics tracked in mining_carbon footprint of service providers

Usage of biofuels_guided by a blend rating system towards lower emission formats

Usage of biofuels_regarded as an interim solution on the journey to net zero enegry solutions

Usage of biofuels_requires access to feedstock such as hydrogenated vegetable oil

Usage of biofuels_seen as an easier alternative versus complexities of accessing hydrogen

Use of generators_has been stopped by large mines

Use of generators_is not part of long term strategic plan for compliant solutions

Use of generators_recognised to negatively impacts the path to decarbonisation

Use of generators_regarded as a pragmatic solution for mines with short life span remaining

Value chain challenges saffecting mining_financing for equipment purchases comes at a premium from suppliers

Value chain challenges specific to SA_aging electricity infrastructure unable to cope with demand

Value chain challenges specific to SA_BEE regulation compliance promotes SME suppliers which limits capabilities and capacities

Value chain challenges specific to SA_carbon tax revenues currently not being segregated to drive more decarbonisation efforts

Value chain challenges specific to SA_clean diesel efforts are hampered by lack of supply of sulfur free diesel in the country

Value chain challenges specific to SA_concern over value chain viability challenges experienced by mining firms

Value chain challenges specific to SA_concerns over Eskom long term stability and reliability to supply baseload requirements

Value chain challenges specific to SA_concerns over Eskom profitability

Value chain challenges specific to SA_concerns over gaps in Eskom human resource capacities

Value chain challenges specific to SA_cost of Eskom power increasing exponentially

Value chain challenges specific to SA_effecting decarbonisation whilst mitigating negative effects is a difficult balancing act

Value chain challenges specific to SA_electricity supply curtailment structures impact production

Value chain challenges specific to SA_electricity supply curtailment structures impact safety of operations

Value chain challenges specific to SA_enduring fiscal revenue constraints putting pressure on allocation of tax revenues

Value chain challenges specific to SA_Eskom efforts in scope 1 determine mining efforts to attain scope 2

Value chain challenges specific to SA_Eskom emissions are vast and effectively overshadow effect from other sectors

Value chain challenges specific to SA_Eskom inefficiencies are forcing mines to place priority focus on electricity supply issues

Value chain challenges specific to SA_Eskom infrastructure constraints are affecting integration of more wheeling solutions

Value chain challenges specific to SA_Eskom linked projects take a long time to implement due to resource constraints

Value chain challenges specific to SA_Eskom project plan timelines are unreliable

Value chain challenges specific to SA_Eskom projected to pay carbon tax and pass it on to customers through electricity tariff

Value chain challenges specific to SA_firms not able to access external funding for renewables as in other countries

Value chain challenges specific to SA_for sufficient power Eskom supply is critical to supplement renewable sources for mine operations

Value chain challenges specific to SA_funding accessible is limited to specific renewables

Value chain challenges specific to SA_government actions are driven by quest for energy supply security not carbon reduction

Value chain challenges specific to SA_government support processes take too long

Value chain challenges specific to SA_industry starting to push government to effect regulatory reform in power sector

Value chain challenges specific to SA_infrastructure not originally designed to support supply of renewable electrons

Value chain challenges specific to SA_lack of constructive reception of dialogue and input from industry

Value chain challenges specific to SA_lack of investor appetite to invest in old mines

Value chain challenges specific to SA_lack of short term financial capacities to invest into viable value opportunities

Value chain challenges specific to SA_long awaited electricity regulation ammendment bill continues to be delayed affecting progress

Value chain challenges specific to SA_mines are focussing on developing own micro-grids to bypass Eskom grid capacity constraints

Value chain challenges specific to SA_most of Eskom power is generated from fossil fuels

Value chain challenges specific to SA_new queuing rules are affecting access of renewable sources to partcipate in supply arrangements

Value chain challenges specific to SA_positive changes effected on energy supply agreement (ESA) and the Act

Value chain challenges specific to SA_prevailing chronic constraints in government resources limits incentive options

Value chain challenges specific to SA_prioritising deployment of government resourcses is a difficult balancing act

Value chain challenges specific to SA_quest for energy security is a higher priority than decarbonising

Value chain challenges specific to SA_SA does not have pipeline infrastructure to transport hydrogen gas

Value chain challenges specific to SA_some mining conditions are unusually difficult and require bespoke technologies

Value chain challenges specific to SA_steadily increasing cost of electricity

Value chain challenges specific to SA_strategic projects require engagement with multiple levels of government

Value chain challenges specific to SA_use of backup generators to supplement energy curtailment is not environmentally friendly

Value chain challenges specific to SA_water scarcity challenges may hamper ability to employ some renewable technology