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Barriers to greater adoption of renewable energy by mining companies in South Africa

Takalani Gangazhe

15388477

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Abstract

Mining companies are currently operating in a challenging business environment and are confronted with significant cost pressures in a strained commodity price market which negatively impact on operating margins. Moreover, continuity of electricity supply and escalating electricity costs in South Africa are significant risks facing mining companies today. Notwithstanding the drivers and attractiveness of renewable energy for mining companies, adoption remains low due to the negative impacts of various socio-technical barriers that exist. The aim of this research was to identify barriers to greater adoption of renewable energy by mining companies in South Africa from the perspective of mining companies.

This exploratory study employed qualitative methods to explore barriers to greater adoption of renewable energy by the mining sector in South Africa. The research was conducted through ten semi-structured interviews with decision-makers from various mining companies that represented the major mining sectors in South Africa, using open-ended questions. Both deductive and inductive approaches were used to interpret the findings against existing literature as well as to identify new barriers emerging from the data.

The study identified a number of technical; economic and financial; institutional; and behavioural barriers that contribute to the low penetration of renewable energy in the mining industry in South Africa. The research found that the intermittent nature of renewable energy was a significant barrier that makes it unsuitable for continuous applications, such as mining operations. Mining companies find it difficult to develop a viable business case to invest in renewable energy projects due to the relatively cheap Eskom electricity prices. Other contributing factors to the unfeasible business case include the high capital costs of renewable energy, which translate to long payback times, and a return on investment that is lower than mining companies' expectations. A lack of supportive policy for investment into privately owned renewable energy projects for own consumption (not delivered to the grid) also presents a further challenge. A key finding was that there is an entrenched mindset within mining companies that results in a preference for grid-connected electricity provided by the utility. Mining companies would rather focus on their core business of mining and view renewable energy as supplementary power that does not warrant their attention. Based on the findings, recommendations were made to address the barriers in order to increase the penetration of renewable energy in this industry.

Keywords

Adoption, barriers, renewable energy, mining, penetration

Declaration

I declare that this research project is my own work. It is submitted in partial fulfilment of the requirements for the degree of Master of Business Administration 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: Takalani Gangazhe

Signature: ………………………………..

Date: 7 November 2016

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Chapter 1 Introduction to Research Problem

Despite the optimistic outlook for overall renewable energy uptake in the world, the projections for industry (manufacturing, mining and construction sectors) uptake are poor (Taibi, Gielen & Bazilian, 2012). Projections and scenarios developed by various organisations, such as the International Energy Agency's World Energy Outlook, consistently show that the prospects for renewable energy growth are good, particularly for the power generation sector (Taibi et al., 2012). Notwithstanding the positive outlook for renewable energy, there is still a need for further policy action in order to address both economic and non-economic challenges that hinder the dissemination of renewable energy (International Energy Agency, 2016).

Although the outlook for renewable generation in the electricity sector is positive, the outlook for the transport, heating, and industry sectors is not as encouraging (International Energy Agency, 2015; IRENA, 2016a). The adoption of renewable energy for commercial buildings and for industry has slowed down (IRENA, 2016a). Industry is often overlooked in country strategic plans for renewable energy, resulting in a lack of incentives for renewable energy adoption by industry (IRENA, 2016a). The electricity sector receives the most attention for policy development at the expense of other sectors.

1.1 Research problem

Barriers to the adoption of renewable energy are contextual and evolve over time, thus making them difficult to accurately identify (Verbruggen et al., 2010). Martin and Rice (2012) suggest that even after 14 years of studies being conducted into barriers to renewable energy adoption and dissemination, many financial, infrastructural, technical, regulatory, economic, information, and education barriers still exist in one form or another. Therefore, progress on the development of renewable energy has been restricted with regard to solving socio-technical problems that confront its adoption.

In order to provide favourable conditions to support the adoption of renewable energy sources and technologies it is crucial that the barriers to the dissemination of renewable energy are identified (Liu, 2014). Knowledge of these barriers is particularly useful for energy policymakers to provide long-term conducive policies and regulatory frameworks for overcoming such barriers (Liu, 2014; Yaqoot, Diwan & Kandpal, 2016). Broad and indiscriminate policies that group industry, including mining, with the power generation and building sectors, are unlikely to be effective in addressing the barriers to the adoption of renewable energy (Napp, Gambhir, Hills, Florin & Fennell, 2014). Owing to the diverse nature of industries that can consider use of renewable energy, coupled with issues of international competition, different industries require special attention from policymakers in order to encourage adoption of renewable energy. Successful dissemination of renewable energy will only be achieved when policies are in line with an industry's own goals of minimising energy costs and ensuring competitiveness.

Mining is an industry under pressure, from a sustainability perspective, due to its significant environmental impact, particularly through the substantial requirements and usage of land, water, and energy resources (Visser, 2015). Additionally, mining is currently faced with low and volatile commodity prices that have negatively impacted on mining companies' earnings (Zweig, 2015). In order to thrive and remain competitive in this low commodity price environment, mining companies are focused on cutting operating costs. Energy costs constitute a sizeable proportion of operating costs, up to 40%, for mining companies (Zweig, 2015).

Renewable energy is an attractive solution to address the challenges that mining faces in terms of sustainability and climate change, energy security, and energy price volatility. However, despite the attractiveness of renewable energy, the uptake in mining remains low (Hamilton, 2016). Votteler and Brent (2016) recommended that there is a need for further research to be conducted from the perspective of leaders of mining companies in order to make the knowledge more credible and accessible. The purpose of the research would be to assist leaders of mining companies to better understand the concepts and benefits of renewable energy and how it can address their specific needs and challenges.

Based on the observation that mining companies have been slow to adopt renewable energy as a possible solution to the economic, sustainability, and reputational challenges they face, the research asks the following questions:

- firstly, why have mining companies been slow to adopt renewable energy as a solution to the sustainability, energy price volatility, and energy security challenges they face;
- secondly, what are the barriers to greater adoption of renewable energy by the mining industry;
- thirdly, which specific barriers pose the biggest hurdle for mining companies in their quest to adopt renewable energy; and
- finally, the research seeks to establish which actions (through specific policies, programmes, or measures) by government would address these barriers and provide incentives for mining companies to adopt renewable energy on a larger scale.

1.2 Research motivation

The research aims to address a gap in the literature on the barriers to greater adoption of renewable energy by mining companies in South Africa, as recommended for further research by Votteler and Brent (2016). The research also aims to provide mining companies with an alternative perspective to challenge management assumptions about renewable energy, its benefits, and the role it can play in the long-term viability and sustainability of mining companies. As recommended by Votteler and Brent (2016) the research will be conducted from the perspective of leaders of mining companies in order to make the knowledge more credible and accessible.

In order to address the challenge of sustainability, while still achieving energy security and socio-economic development, the world needs to transform its energy systems from conventional fossil fuel-fired technologies to a broader portfolio of low-carbon (renewable energy) technologies (Strupeit & Palm, 2015). The adoption of renewable energy has accelerated in recent decades due to the increased and focused attention towards sustainable development worldwide (Bhattacharya, Paramati, Ozturk & Bhattacharya (2016). Renewable energy is essential to realise long-term climate change targets, to prevent global temperatures from rising by more than 2°C above preindustrial levels, as agreed in the Paris agreement (IRENA, 2016a).

Furthermore, the highly volatile energy (fossil fuel) prices and the risk of supply, coupled with the geopolitical debate surrounding fossil fuel use, will only serve to accelerate the development and market accessibility for renewable energy by various governments (Bhattacharya et al., 2016). Thus, the mining industry needs to consider the adoption of renewable energy to play its role in addressing the challenges of sustainability, energy security, and socio-economic development. Renewable energy is able to offer lower cost and security of supply, both of which are key considerations for the mining industry when developing new mines that are located in remote areas with under-developed energy infrastructure. Increasing the uptake of renewable energy by users (industry, commercial/buildings, and residential) is critical in growing renewable energy.

1.3 Context of renewable energy

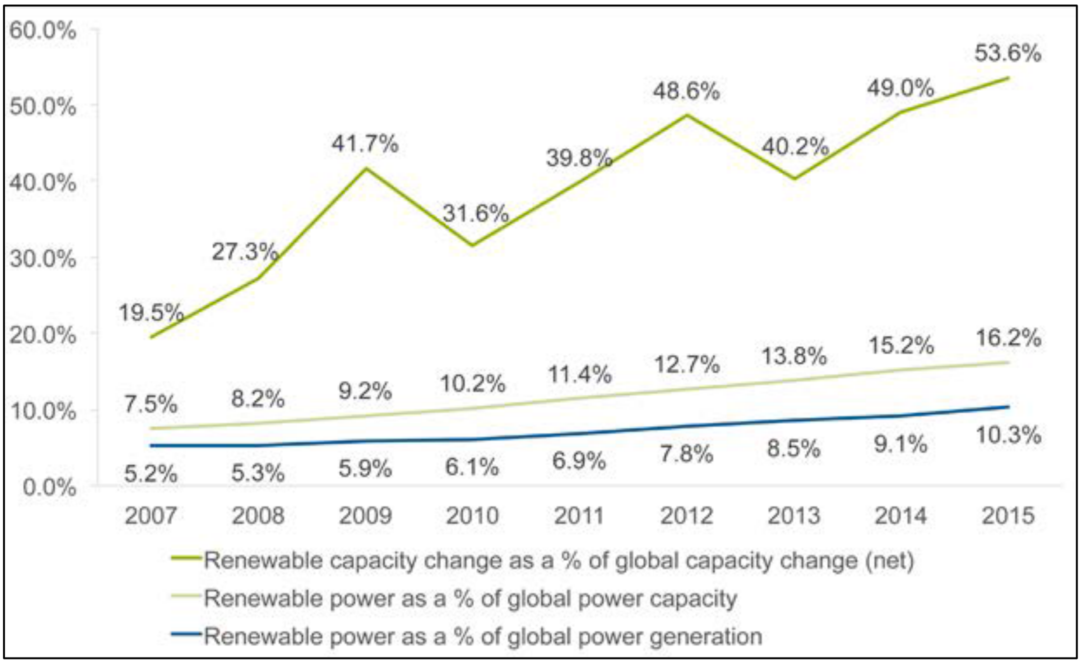
Renewable energy electricity generation capacity grew at its fastest pace (152 gigawatts (GW)) in 2015 (IRENA, 2016b). The accelerated growth was driven by declining costs of renewable energy technologies and supportive policies that seek to address energy security, pollution concerns at a local level, and climate change (International Energy Agency, 2016). The global agreement and pledges that were part of the outcomes of the

United Nations Framework Convention on Climate Change (UNFCCC) 21st Conference of the Parties (COP21), held in Paris in 2015, have resulted in increased optimism on the outlook for renewable energy.

1.3.1 Renewable energy globally

Global investment in renewable energy (excluding large hydroelectric projects) in 2015 reached a record $285.9 billion (McCrone, Moslener, d'Estais, Usher & Grüning, 2016). This record investment was achieved despite the prevailing low fossil fuel (oil, coal, and gas) prices that not only supported investment in fossil fuel-fired generation, but also protected its competitive position. Renewable energy, at 53.6% of installed electricity capacity of all technologies, also constituted the majority of new installed capacity (McCrone et al., 2016). This is the first time that renewable energy has represented the majority of new installed capacity, as shown in Figure 1-1. However, renewable energy technologies only accounted for just over 10% of world electricity in 2015, due to the sheer volume of already existing conventional fossil fuel-fired generation capacity.

Figure 1-1 Renewable power generation and capacity as a share of global power growth (McCrone et al., 2016).



The 8.3% growth in renewable energy generation capacity during 2015 marked the sixth consecutive year in which renewable capacity has grown by at least 8% (IRENA, 2016b). Most of the growth was from the installation of wind and solar energy, with the installed capacity for wind growing by 17% (63 GW of new capacity) and solar by 26% (47 GW of new capacity) (IRENA, 2016b). According to International Energy Agency forecasts, the

leading source of new energy supply capacity from now until 2040 will be renewable energy, with projections showing that renewable energy is likely to surpass thermal coal-fired generation as the largest source of electricity generation by around 2030 (Bouw, 2016). However, industry remains the most overlooked sector for renewable energy integration (IRENA, 2016a).

Declining renewable energy generation costs have made investment in renewable energy attractive, particularly for solar photovoltaic (PV) systems (McCrone et al., 2016). The global average levelised cost of electricity (LCOE) for crystalline silicon PV declined from $143 per megawatt hour (MWh) in the second half of 2014, to $122 per MWh in the second half of 2015. There are specific projects currently in implementation that are priced at tariffs well below $122 per MWh, with the lowest price so far being a 200 MW plant in Dubai being built by ACWA Power International (McCrone et al., 2016). The project was awarded at a contract price, in January 2015, of $58.50 per MWh. Despite the significant drop in fossil fuel prices during 2015, renewable energy remains a cost-competitive option for electricity generation (IRENA, 2016a).

1.3.2 Renewable energy in South Africa

Investment in renewable energy (excluding large hydroelectric installations) in South Africa increased by 329% to $4.5 billion in 2015, placing the country eighth in the world rankings with regards to capital investment in renewable energy (McCrone et al., 2016). A majority of the investment was due to the South African government's Renewable Energy Independent Power Producer Procurement Programme (REIPPPP). The South African government launched the programme to invest in renewable energy because it was considered to be a more attractive option to deliver a rapid solution to the need to invest in much-needed electricity capacity in response to the power shortages experienced in 2008 (Webb, 2016). The REIPPPP is a competitive tender or auction-based-tariff system with clearly defined rounds of bid submission, adjudication, and financial closure (Becker & Fischer, 2013).

The REIPPPP aims to install 17.8 GW of electricity generation from renewable energy sources by 2030 (Walwyn & Brent, 2014). Renewable technologies for the REIPPPP include solar, wind, biogas, biomass, and hydro. By the fourth bid window, the total number of participating independent power producers (IPPs) was 92, and the combined generation capacity that had been procured since the announcement of the first preferred bidders in late 2011 was 6327 MW (Department of Energy, 2015). During the period from January to June 2015, wind and solar PV power plants contributed 2% of the 114.1 TWh (terawatt hours, representing 10^{18} Wh) of electricity sent to the South African national grid (Webb, 2016).

The electricity generation capacity has been procured at competitive prices when compared with grid prices, with the exception of the first bidding round which was characterised by a general lack of competition and high prices (Walwyn & Brent, 2014). By the close of round three of the REIPPPP bid window, the weighted cost of energy had reached a 23% discount to the cost of new coal-based generation and a 28% discount to global renewable energy prices (Walwyn & Brent, 2014). Thus, the weighted average cost of electrical power from renewable energy had declined from $211 per MWh in round one to $84 per MWh in round three (Walwyn & Brent, 2014). Electricity price projections predict that the cost of electricity from the REIPPPP will reach parity with the cost of new coal-based generation by 2016 and thereafter will be lower than the LCOE of either coal or nuclear power (Walwyn & Brent, 2014).

1.3.3 Mining in a global context

The global mining and metals sector is in an extended period of lower and volatile commodity prices due to constrained demand from key markets such as China (Hopwood & Chopra, 2015; Zweig, 2015). To remain competitive and sustainable, mining companies are focused on cost-cutting in order to maximise returns to shareholders. Access to energy is ranked at number eight in a ranking of business risks facing mining and metals companies (Zweig, 2015).

Mining is an energy-intensive industry and energy costs may contribute up to 40% of the company's operating costs (Zweig, 2015). Despite lower oil prices, which have brought some temporary relief, the continued volatility and expected future escalations in energy prices will pose a great risk to mining. Thus, it is crucial that mining addresses access to energy in an integrated manner that ensures energy security in a sustainable, cost-effective, and uninterrupted manner (Zweig, 2015).

It is estimated that the largest mining companies in the world are exposed to external environmental costs of approximately $220 billion, with greenhouse gas (GHG) emissions representing 77% of these (Visser, 2015). The impact of a carbon price at a level of $30 per tonne CO_2 equivalent would represent a 3.3% increase in iron ore costs (Visser, 2015). Investment in renewable energy can help mining companies reduce their exposure to environmental externalities such as carbon prices.

Investment in renewable energy can also help mining companies address energy security challenges, result in cost savings, reduce reliance on fossil fuels, reduce reliance on the national grid, increase predictability in the cost of energy, and also address the sustainability challenge of reducing CO_2 emissions.

1.3.4 Mining in South Africa

Mining is an energy-intensive industry that consumed 14.3% of Eskom's (South African state-owned utility) electricity production in 2015 (Eskom, 2016). One of the factors that determines electricity demand is the type of mining operation. Underground operations require significantly higher amounts of electricity when compared with surface (or opencast) mining, typically 30 to 40% more electricity (Votteler & Brent, 2016). The main contributor to the significant electricity requirements are the hauling requirements, ventilation, water pumping, and other operations within the underground mine. Gold and platinum-group mining are typically underground operations and are indeed among the most electricity-intensive mines.

Owing to low commodity prices and rising input costs, the South African mining industry has been in loss-making position during the last two years, making mining the only loss-making sector in the South African economy (Chamber of Mines of South Africa, 2016). Input and labour costs have risen at a greater rate than inflation and commodity prices have declined, resulting in declining revenues. Labour and electricity are the largest cost drivers in the South African mining industry and both have been increasing (Chamber of Mines of South Africa, 2016).

Despite the success of the REIPPPP, the electricity crisis in South Africa continues to be a major barrier to economic growth, with delays in easing electricity shortages identified as one of the main constraints (Webb, 2016). Electricity tariffs have increased by 348% over the ten-year period from 2007/8 to 2017/18 (Votteler & Brent, 2016; Webb, 2016). The significant tariff increases are a result of the need to invest in new power generation capacity following on years of under-investment in new capacity. The combination of electricity shortages and tariff increases has stifled growth and limited investment in sectors, such as mining, that require secure and cheap electricity supply.

A prospective cost pressure that is likely to impact electricity prices in the near future is the Draft Carbon Tax Bill released for public comment by The National Treasury in November 2015 (Chamber of Mines of South Africa, 2016; Votteler & Brent, 2016; Webb, 2016). The Carbon Tax Bill proposes an initial marginal carbon tax rate of R120 per tonne of CO_2-equivalent emission. The proposed implementation date for the carbon tax was mid-2016, although this has not yet materialised as National Treasury continues with the stakeholder consultation in response to the prevalent resistance to the tax by business. The impact of the carbon tax on electricity tariffs will be significant because around 85% of Eskom's power generation capacity comprises coal-fired power stations (Webb, 2016).

The combination of concern over unreliable and unpredictable power supply, increasing electricity tariffs, and the threat of carbon tax have contributed to limited investments in the mining industry (Chamber of Mines of South Africa, 2016; Hamilton, 2016; Webb, 2016). Power supply uncertainty remains a key challenge for mining companies in South Africa, which makes independently sourced renewable power a particularly attractive option (Staff Writer, 2016).

1.3.5 Renewable energy in mining

It is estimated that the global mining industry consumes about 400 TWh of electricity per year, however renewable energy (excluding large hydropower) only accounts for a meagre 0.1% of total supply (Hamilton, 2016). Most of the renewable energy supply consists of small pilot projects supported by government subsidies. Votteler & Brent (2016) identified 21 operating renewable energy projects supplying mining operations. Chile had the most projects, at 11, followed by Australia and Canada with two projects each. Only one project was identified in South Africa: Cronimet Mining's 1 MW solar-diesel hybrid system at its Thaba mine near Thabazimbi in the Limpopo province (Votteler and Brent, 2016). The majority of the renewable energy projects, 11, use solar PV and eight of the projects employ wind energy. Financing for 12 of the projects was through a power purchase agreement (PPA). Only ten of the projects are connected to the national grid.

Traditionally, the mining industry has relied on fossil fuel sources, such as coal, diesel, and natural gas, to meet its growing demand for energy. As noted, the mining industry currently faces the challenge of volatile energy prices while commodity prices have decreased, which has resulted in the narrowing of operating margins. The mining industry also faces growing pressure from various stakeholders, such as activist shareholders, governments, customers, local communities, and other key stakeholders, to operate in a sustainable manner (Forer & Elliott, 2014). For mines and mining projects located in remote areas, access to the power grid is often unfeasible and reliance on diesel, which has to be trucked in over long distances, is both expensive and exposes the mine to possible supply interruption risks (Staff Writer, 2016). Meeting these demands has an influence on the industry's social license to operate. In response to these challenges, mining companies are exploring the use of renewable energy as a strategic priority. Adoption of renewable energy allows mining to lock in long-term fixed electricity prices, guarantee availability and reliability, while minimising their exposure to regulatory changes, volatile energy price movements, and dependency on external fuel supplies (Forer & Elliott, 2014).

Despite the challenges that mining faces and the perceived strong business case for renewable energy, the scale and pace of renewable adoption in mining has been slower than anticipated (Forer & Elliott, 2014). Some of the reasons for the low uptake include the lack of a clear strategic approach to renewable energy, lack of an energy strategy, the view that renewable energy is a non-core activity with an opportunity cost, and the failure to use third parties to develop, fund, and operate renewable energy projects (Forer & Elliott, 2014). Progress in reducing CO_2 emissions (through adoption of renewable energy) and improving energy efficiency has been made in instances where the mitigation options have fallen in line with industry's own goals of minimising energy costs and ensuring competitiveness (Napp et al., 2014).

Mining companies are beginning to embrace renewable energy. The number and types of mines evaluating renewable energy is growing, with mining companies no longer confining themselves to pilot projects of roughly one or two megawatts but rather considering larger capacity projects that are able to provide most, if not all, of the mine’s required electricity demand (Judd, 2014a). It is forecast that renewable energy will represent between five and eight percent of global mining industry consumption within the next six years (Hamilton, 2016).

Chile is the world leader in integrating renewable power into its mining industry’s electricity make-up (Dube, 2016; Slater, 2016; Votteler & Brent, 2016). The principal drivers for adoption have been energy security concerns, competitive prices, as well as government regulations dictating that 10% of energy be procured from renewable resources. Future targets will require that 20% of Chile’s electricity be derived from renewable energy sources.

Mining companies are focused on finding solutions that reduce their energy costs and improve their energy security and reliability. Renewable energy companies have started to develop an understanding of mining companies’ needs and are offering solutions that address these needs. Renewable energy companies have recognised that mining companies are very slow to change and take time to evaluate projects before approving them (Judd, 2014a, 2014b). One of the reasons is that mining companies view renewable energy projects as capital investments that need to be compared with other potential investments.

Renewable energy companies have also realised that mining companies are not interested in buying renewable energy technology (solar panels and wind turbines, for example) but rather prefer to pay for the energy they need for their operations. Thus, renewable energy companies are developing and funding renewable energy projects themselves and offering PPAs to mining companies with guaranteed security of supply (Judd, 2014b, 2015). PPAs eliminate the need for mining companies to finance renewable energy projects using their balance sheet and thus make it easier for them to adopt renewable energy.

Renewable energy companies have developed innovative solutions to address the perception that renewable energy is intermittent in nature and thus not able to offer a stable power source (Judd, 2014a). Solar–diesel hybrid systems are currently receiving a lot of attention as a potential solution for mining companies. They are considered to be a state-of-the-art solution for micro-grids and off-grid applications that is able to deliver the lowest overall cost of power, while guaranteeing reliable and uninterrupted power supply and at the same time reduces fuel costs by around 25% (Breytenbach, 2016; Votteler & Brent, 2016). Globally, there are some 100 projects that employ the solar–diesel hybrid solution, but in mining there are fewer than ten projects. In Australia, a recently commissioned project integrates a 10.6 MW solar hybrid system with the existing 19 MW diesel-fired power station at Sandfire Resources' DeGrussa mine (Breytenbach, 2016).

1.3.6 Renewable energy in South African mining

BMI Research suggests that South Africa, Chile, and Australia will most likely emerge as global leaders in the mining industry's shift to renewable energy (Staff Writer, 2016). Contributing factors for these countries are favourable climates for renewable energy, the remote locations of their mines, and unreliable power grids.

Cronimet Chrome Mining's Thaba mine employs a solar hybrid system to meet its power requirements. The mine is not connected to the grid and installed a 1 MW PV system (60% penetration ratio) and a 1.6 MVA diesel generator to meets it electricity demand (Votteler & Brent, 2016). The solar PV plant saves the mine approximately 450 000 litres of diesel per year.

Gold Fields have launched a procurement process for 40 MW of solar PV for their South Deeps mine. They have received proposals that indicate that electricity from the solar

PV plant could match Eskom's electricity rates from their first day of operation (Hamilton, 2016). The project proposals assume that the mine would sign a PPA for a minimum duration of at least 20 years.

1.3.7 Barriers

The dissemination of renewable energy faces a variety of barriers. These may be categorised as technical, economic, institutional, socio-cultural (social, cultural, and behavioural), and environmental barriers (Yaqoot et al., 2016). Kennedy and Basu (2013) point out that the barriers that renewable energy faces and the measures to address them will differ significantly among countries. Strupeit and Palm (2015) demonstrate how distinctively different business models in three countries (Germany, USA, and Japan) have managed to overcome many of the commonly observed barriers to solar PV adoption. This contextual dependence implies that business models cannot simply be transferred from one location to another. This shows that context is important in explaining the barriers to adoption of renewable energy.

1.3.8 Barriers in mining

The Carbon War Room's investigation (conducted in 2012) to determine the reasons why there was no growing investment in solar–diesel hybrid systems as a solution to reduce GHG emissions found that there were a number of market hurdles (Hamilton, 2016). These included a perception in the mining industry that renewable energy was unproven technology, capital costs were too high, and financing was too costly (Hamilton, 2016). Another important barrier was that the life of a mine was typically shorter than the payback period and the life of renewable energy projects. Thus, diesel energy generators were preferred because they had a shorter payback period.

Cash constraints, due to the impact of low commodity prices on operating margins, means that mining companies do not have capital (Hillig, n.d.). The requirement for mines to improve their profitability in order to remain competitive means the focus is currently on cost reduction and reduced investment in capital projects. Technical penetration of renewable energy remains low, meaning that the necessary skills and knowledge are not being developed in order to improve the required understanding and expertise. Lack of in-house expertise is also a barrier to the adoption of renewable energy, which leads to the view that energy is not considered a core competency for mining companies; the prevailing attitude is a reliance on suppliers, such as a utility company, for energy requirements (Hamilton, 2016; Hillig, n.d.).

1.4 Research aim and purpose

The purpose of this exploratory study is to identify the barriers to greater adoption of renewable energy by mining companies in South Africa. It will attempt to address the gap in literature by investigating the contributors to the low penetration of renewable energy in mining from the perspective of leaders of mining companies.

The research will contribute to the academic field by extending on the knowledge and understanding about the barriers to the adoption of renewable energy. In particular, the research will add to the understanding of the barriers to the adoption of renewable energy from mining companies' perspectives within a South African context. Understanding of the various contextual barriers that are faced by companies and stakeholder organisations would be informative for researchers and industry practitioners (Martin & Rice, 2012). Thus, the study will ultimately contribute to the global debate on barriers to renewable energy and the contextual perspective of increasing adoption.

In addition, the research will provide guidance to mining companies on how to address barriers that have hindered the adoption of renewable energy. Mining companies will be able to use this information when they engage with policymakers to ensure that appropriate measures are addressed by policies to pave the way for greater adoption of renewable energy. Barriers can be overcome or attenuated by implementation of policies, programmes, or measures to directly address the obstacles that prevent the greater adoption of renewable energy (Verbruggen et al., 2010). Accordingly, the identification of the relevant barriers will enable government and policymakers to tackle the barriers that mining companies face in the adoption of renewable energy. This will enable the enactment of favourable polices that will incentivise mining companies to adopt renewable energy. This is particularly important in the South African context as the government does not currently provide any support for implementation of off-grid industrial electricity generation from renewable energy (Votteler & Brent, 2016).

Chapter 2 Literature Review

This chapter reviews the literature pertaining to barriers to the adoption of renewable energy. The review initially focuses on frameworks, from the literature, that have been used to guide the identification of barriers to the adoption of renewable energy. Building on the identified frameworks, the relevant categories of barriers are identified and defined. The review then discusses barriers to adoption of renewable energy in the power generation sector. The power generation sector was reviewed because this is where renewable energy has achieved the highest penetration and thus a wealth of research exists in this area. The discussion then focuses on the South African context and establishes the barriers that exist within this context and how they may be applicable to the mining sector. The chapter closes off by discussing other potential uses of renewable energy beyond electricity generation.

2.1 Renewable energy sources

Renewable energy is defined as energy that is derived from sources that replenish themselves and thus are essentially inexhaustible (Engelken, Römer, Drescher, Welpe & Picot, 2016). Renewable energy sources include energy derived from solar, wind, hydropower, biomass, geothermal, and ocean resources (Engelken et al., 2016). Renewable energy is widely recognised as the preferred future energy source for the world as it addresses two key risks facing the continued use of conventional fossil fuel sources (Becker & Fischer, 2013). Firstly, conventional fossil fuels are finite resources and will eventually be depleted or reach a point where remaining resources cannot be extracted in an economically viable manner (Becker & Fischer, 2013). Secondly, the negative impact of GHG emissions, released during combustion of fossil fuels and which lead to climate change, is seen as a global challenge that threatens the planet (Abdmouleh, Alammari & Gastli, 2015; Becker & Fischer, 2013). Thus, renewable energy sources should become a major source of energy in the future as they are seen as having a less damaging impact on the environment than fossil fuels.

2.2 Barriers to the adoption of renewable energy

2.2.1 Definitions of barriers

A barrier to renewable energy technology can be defined as any factor that has a negative impact, prevents or hinders action, or impedes progress on the adoption and subsequent utilisation of the technology, with the net result of hindering greater dissemination or achievement of potential (Jarach, 1989; Verbruggen et al., 2010). Within a policy context, barriers are man-made factors that can be intentional or unintentional and thus require targeted actions to address them through policy, programmes, or measures (Verbruggen et al., 2010).

The detailed literature review by Yaqoot et al. (2016) has shown that barriers to the adoption and dissemination of renewable energy have been well researched and studied. Yet, despite several years of studies being conducted, many financial, infrastructural, technical, regulatory, economic, information, and education barriers still exist in one form or another (Martin & Rice, 2012). Up to now, the focus of most of these studies has been on the power generation sector and residential customers, with little attention given to industrial or commercial users of electricity.

Barriers to the adoption of renewable energy are contextual and evolve over time, thus making them difficult to accurately identify (Verbruggen et al., 2010). Barriers that renewable energy faces and the measures to address them will differ significantly among countries (Kennedy & Basu, 2013). Therefore, such barriers will differ for each technology by country, industry, and the prevailing business and economic environments. This contextual dependence implies that policies to address barriers cannot simply be transferred from one context to another. An added complication is the inter-linkage between barriers that results in their mutual reinforcement and thus has a cascading impact on the greater adoption of renewable energy (Liu, 2012; Yaqoot et al., 2016).

It is important to identify the stakeholders whose view is being addressed when identifying barriers because different stakeholders hold different perceptions of barriers and the required policies (Reddy & Painuly, 2004). Stakeholders in the renewable energy industry can be broadly classified into those involved on the supply side and the end users. The supply-side stakeholders include investors, project developers, equipment suppliers, and manufacturers; the end-users group is made up of residential customers (both urban and rural), commercial (buildings), and industry (agriculture, mining, manufacturing).

2.2.2 Frameworks for identifying barriers

In order to guide studies on the barriers to renewable energy, researchers typically establish a framework based on a selected theory base that is appropriate for their research. Table 2-1 provides a list of some of the frameworks that have been used to identify barriers to renewable energy.

Table 2-1 Theoretical frameworks employed by researchers to identify barrier categories

Researchers	Theoretical framework	Barrier categories
Jacobsson & Johnson (2000)	Technology innovations systems and system function approach	i) Market
		ii) Network
		iii) Institutional
Painuly (2001)	Stakeholder approach focused on stakeholder's views	i) Market failure/imperfection
		ii) Market distortions
		iii) Economic and financial
		iv) Institutional
		v) Technical
		vi) Social, cultural and behavioural
		vii) Other Barriers
Richards, Noble & Belcher, (2012)	Systems based approach based on agreement, knowledge, technology, economic, social, or political factors (AKTESP framework)	i) Agreement
		ii) Knowledge
		iii) Technology
		iv) Economic
		v) Social
		vi) Political factors
Viardot (2013)	Information systems theory. Diffusion of Innovation (DOI) using the technology acceptance model (TAM)	i) Technological
		ii) Ontological and social
		iii) Financial and legal
		iv) Physical hindrances
Liu (2014)	Path dependency theory incorporating organisational behaviour and culture.	i) Cultural
		ii) Structural
		iii) Regulatory
		iv) Contextual
Yaqoot, Diwan & Kandpal (2016)	No theoretical framework. Barriers derived from a comprehensive literature review.	i) Technical
		ii) Economic
		iii) Institutional
		iv) Socio-cultural
		v) Environmental

Painuly (2001) advocates for a focus on the relevant stakeholder's view in identifying barriers to renewable energy as perceptions will differ from one stakeholder to another based on their experience and requirements. Richards, Noble and Belcher (2012) argue that understanding the barriers to renewable energy is not a one-dimensional problem that can be identified by focusing on one particular barrier based on stakeholders views.

Richards et al., (2012) criticise the stakeholder approach to identifying barriers, as advocated by Painuly (2001), as limiting in that it narrows down the explanation to any one of technical, social, political, or economic barriers. It is argued that as a consequence of this one-dimensional view, the underlying barriers and the relationships between them are overlooked, which leads to ineffective measures to address the barriers.

Richards et al. (2012) suggested that "a more systems-based approach that integrates investment in renewable energy development with specific mechanisms to identify and address underlying barriers would result in greater penetration of renewable energy in a more cost-effective way" (p. 697). They propose that the agreement, knowledge, technology, economic, social, or political factors (AKTESP) framework is an appropriate multi-dimensional evaluation method. "The AKTESP is based on the notion that all environmental problems, and their potential solutions, are rooted in and can be explained by one or more of the following: agreement, knowledge, technology, economic, social, or political factors" (Richards et al., 2012, p. 692). They stress that it is vital that underlying factors that may be responsible for the perceived barriers are thoroughly explored. However, one of the limitations of this framework is that it is over reliant on knowledge as an underlying barrier and relegates the importance of other barriers.

Jacobsson and Johnson (2000) advocate for technological innovation systems and system functions approaches as an appropriate framework for studying how new technology emerges and is diffused. In contrast, Viardot (2013) used the Technology Acceptance Model (TAM), derived from information systems theory, which models how users come to accept and use a technology. Both approaches draw on the diffusion of technology theories with the major difference being that Jacobsson and Johnson (2000) focused on organisations while Viardot (2013) focused on individuals. As could be expected, the barrier categories identified from these two studies (Table 2-1) are quite different. The drawback of these two approaches is that they focus on the limitations of the technology innovation itself. Hence, the barrier categories identified are generic and fail to identify specific issues that affect the users. The researchers themselves acknowledged that TAM does not fully capture all the characteristics that are specific to the adoption of renewable energy (Viardot, 2013).

In stark contrast to other researchers, Liu (2014) constructed a theoretical framework using path dependency theory incorporating organisational behaviour and culture. The framework specifically focuses on organisational aspects such as ethos, habitual practices, personalities and values present within an organisation. Three of the four barrier categories identified which are not common among other researchers are;

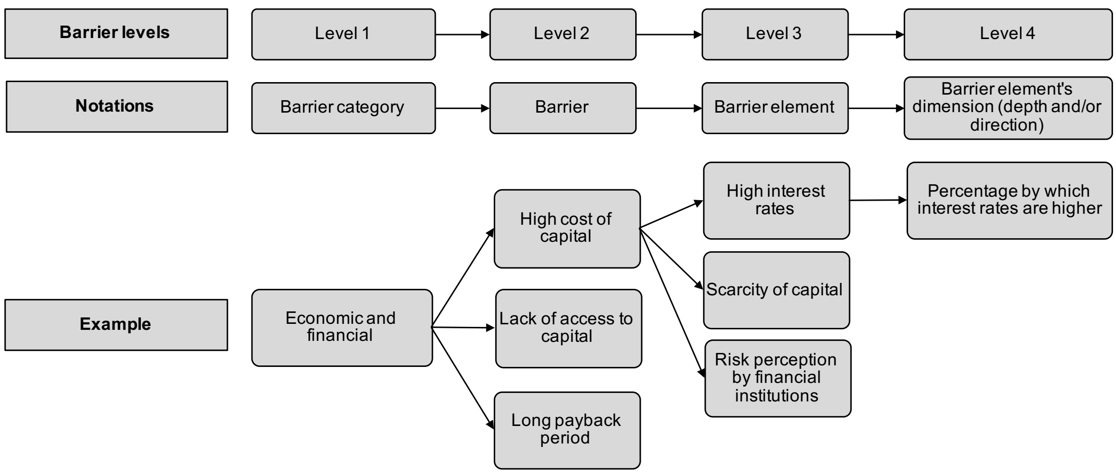
cultural, structural, and contextual barriers. A contextual barrier is described as an operating environment that establishes factors such as structure of the economy, awareness of climate change, and perception of risk (Liu, 2014). Structural barriers are described as the firm's structures and procedures that influence its decision-making process with regard to operations and strategy. Cultural (psychological) barriers are described as the organisational behaviour and culture of the organisation with reference to habitual modes of practice, personalities, and values presented within a firm. Liu's (2014) theoretical framework aims to establish relationships between the different barriers and how they impact the adoption of low carbon production. This framework would have been more relevant if the researchers had included additional factors such as technology, financial and economic as these do impact the decision-makers' perceptions about renewable energy.

There does not appear to be an agreement on the taxonomy of barriers among researchers. Painuly (2001) identified up to seven categories of barriers, whereas Yaqoot et al. (2016) identified five categories based on their extensive literature review. Painuly (2001) identified market failure/imperfection and market distortions as distinct categories of barriers, whereas other researchers see these as falling under the category of an economic barrier. Jacobsson and Johnson's (2000) system approach facilitates the identification of market, network, and institutional barriers. The AKTESP framework recommended by Richards et al. (2012), although it stresses the multidimensional aspect, appears to place an emphasis on knowledge as the underlying barrier that leads to perceived barriers. Liu's (2014) framework appears to focus on the organisation as a unit of analysis and thus the barrier categories are different to those used by other authors. It is evident that to a certain extent, the theoretical framework influences the barrier categories that will be identified. However, there are common barrier categories among the various studies such as technical, institutional and economic/market/financial.

Owing to the fact that the stakeholder framework proposed by Painuly (2001) focuses on stakeholders views makes it appropriate for the objectives of this study. To reiterate, the purpose of the study is to identify the barriers to greater adoption of renewable energy by mining companies in South Africa from the perspective of mining companies. This study adopts the framework developed by Painuly (2001) to identify the barrier categories applicable to mining. On the basis of the extensive literature review conducted by Yaqoot et al. (2016), the following barriers have been identified as relevant to the mining industry: technical, economic and financial, institutional, and socio-cultural behavioural barriers. The rest of the literature review will define these barrier categories and identify the relevant barriers and barriers elements discussed by other researchers. The barrier elements' dimensions will not be covered because these are often context-specific and are thus not widely reported in the literature.

The stakeholder framework developed by Painuly (2001) recommends the exploration of barriers at four levels, as illustrated in Figure 2-1. The objective at the first level is to establish the broad category of barriers. The second level establishes the barriers that fall within specific categories. At the third level, various elements of a specific barrier are identified. Finally, at the fourth level of analysis the dimension (exploring either depth and/or direction) of a barrier element is scrutinised and the details of measures to address the specific barrier can then be determined. Hence, analysis at the fourth level ensures consistency between the recommended measures to overcome the barriers and their dimensions.

Figure 2-1 Stakeholder framework for analysing barriers (Painuly, 2001).



In the example provided in Figure 2-1, the barrier category is "economic and financial". The barriers under this category are: i) high cost of capital; ii) lack of access to capital; and iii) long payback periods. Focusing on the high cost of capital barrier, three barrier elements are associated with this barrier: i) high interest rates; ii) scarcity of capital; and iii) risk perception by financial institutions. The dimension of the high interest rate barrier element is the percentage by which interest rates are higher compared with interest rates for conventional fossil fuel-fired technologies.

2.2.3 Technical barriers

Technical barriers are those attributes of a system that prevent utilisation from reaching its theoretical potential (Yaqoot et al., 2016). Some of the common barriers within this category include: i) resource availability; ii) technical performance, iii) lack of skilled personnel, and iv) a lack of standard codes and certification (Painuly, 2001; Reddy & Painuly, 2004; Yaqoot et al., 2016).

2.2.3.1 Resource availability

Resource availability refers to two characteristics of renewable energy: intermittency and inadequacy (Yaqoot et al., 2016). Renewable energy sources such as solar and wind are intermittent and variable in nature. Solar energy can only be produced when the sun is shining (during the day) and is also dependent on weather conditions (affected by cloud cover and rain). Production of wind energy is affected by daily as well as seasonal variations. The intermittent nature of renewable energy makes it unsuitable for continuous applications such as mining operations (Nalan, Murat & Nuri, 2009).

Inadequacy refers to the lack of a sufficient quantity of renewable energy resources to support capacity utilisation at economical levels (Nalan et al., 2009; Yaqoot et al., 2016). Typically, renewable energy sources such as biomass and biogas may not be available in sufficient quantities to be able to support the requirements of the end user, thus rendering them economically unviable (Yaqoot et al., 2016). Mining operations typically require large amounts of energy continuously in order to keep their operations producing at all times.

To address the intermittent nature of renewable energy sources as well as their lower capacity factor, three technical options can be considered for mining operations (assuming there is no grid connection): renewable energy with battery storage, a hybrid system, and a hybrid system with storage (Votteler & Brent, 2016). A hybrid system incorporates the use of a renewable energy technology with a diesel generator as a backup. The added cost of having a backup, either battery storage or diesel generator, further places renewable energy at a disadvantage compared with conventional fossil fuel-fired technologies. However, hybrid systems offer a possible solution to mining companies because they offer continuous energy supply. This is especially relevant for non-grid connected mines in remote locations.

2.2.3.2 Technical performance

Technical performance relates to the actual performance and unreliability of the technology. A major barrier to the use of renewable energy is the fact that such energy sources typically have a lower energy intensity per unit area compared with fossil fuel sources (Nalan et al., 2009). Consequently, renewable energy technologies require a large footprint when compared with fossil fuel-fired technologies. However, mining operations are typically located in remote areas and thus land should be readily available. The large land requirements, particularly for solar technologies and biomass, do raise a major issue of land availability and competes with other requirements for land use, such as agriculture (Nalan et al., 2009).

Reddy and Painuly (2004) reported that the industrial sector in Maharashtra state in India perceived that technical barriers were the most significant hurdle to the adoption of solar water heaters. The industrial sector was not satisfied with the performance of solar water heaters or the high maintenance costs. Lack of expertise to operate the solar water heaters and the limited size ranges available were also seen as further technical barriers.

2.2.4 Economic and financial barriers

Economic barriers are often classified in the literature as either being cost-related or market-related (Yaqoot et al., 2016). However, Painuly (2001) classifies market failure and market distortions as two distinct categories of barrier. Common barriers within this category include: i) high capital and investment costs; ii) long payback periods; and iii) limited access to credit due to the perception that renewable energy is a high-risk investment which translates to a lack of financial institutions willing to support renewable energy (de Jongh, Ghoorah & Makina, 2014; Krupa & Burch, 2011; Painuly, 2001; Pegels, 2010; Yaqoot et al., 2016).

2.2.4.1 Spending priorities and capital constraints

The current low commodity prices, which result in lower operating margins and lower profits, hinder the widespread adoption of renewable energy in the mining industry (Votteler & Brent, 2016). Decreased profitability of mines and lower fuel prices contribute to the preference to persist with existing energy sources and thus act to maintain barriers to adoption of renewable energy. Additionally, the pressure that mining companies face from investors, to demonstrate that they are responding to the low commodity price environment by showing short-term capital growth, further discourages long-term investment in renewable energy. Thus, mining companies are focused on reducing operating costs and capital investments. Consideration of investment in renewable energy projects for mining companies has to be evaluated against other potential investments, such as production improvement and efficiency projects, which yield much quicker returns.

2.2.4.2 Capital costs of renewable energy

High initial investment costs for renewable energy technologies make this a significant barrier (Engelken et al., 2016; Strupeit & Palm, 2015). The cost of renewable energy technology is relatively high per unit of installed capacity in comparison with conventional fossil fuel-fired technology. Even though renewable energy technologies require no fuel and their operation and maintenance costs are generally low, their high capital cost reduces their attractiveness to mining companies.

2.2.4.3 Financial assessment

Eleftheriadis and Anagnostopoulou (2015) indicate that the financial sector prefers short-term financial products over long-term investments such as renewable energy projects. The perspective of the financial sector is that renewable energy projects have longer payback periods and higher capital costs when compared with conventional fossil fuel-fired technologies. The higher investment risk means that higher returns are required, which then limits the amount of funding made available to invest in renewable energy.

Liu (2014) reported that the most frequently cited barrier to the adoption of low carbon production by Chinese industrial firms was a lack of financial incentives. Reddy and Painuly (2004) found that: i) the high cost of the heater; ii) the high interest rates for loans; and iii) payback periods greater than three years were significant barriers to the adoption of solar water heaters by the industrial sector in Maharashtra state in India.

2.2.4.4 Grid electricity prices and a lack of pricing for externalities

Martin and Rice (2012) reported that the failure to include externalities (pricing the costs of environmental damage) in the price of electricity is seen as a barrier to the adoption of capital-intensive renewable energy technologies. This means that the fundamental benefits of adopting renewable energy are not taken into account in the price of electricity. Owen (2006) calculated that if environmental externalities (costs of damage to health and environment by pollutant emissions and the impact of climate change attributed to GHG emissions) were to be internalised into the price of fossil fuel-generated electricity, then several renewable technologies (specifically wind and some applications of biomass) would become financially competitive. Therefore, it can be argued that in certain instances it is preferable for mining companies to procure relatively cheap and reliable electricity from the grid, in the absence of a carbon tax, than to invest in renewable energy.

2.2.5 Institutional barriers

Institutional barriers refer to the policy and regulatory environment, infrastructure requirements, and institutions that may promote or hinder renewable energy (Jarach, 1989).

2.2.5.1 Policy and regulatory barriers

Abdmouleh et al., (2015) argue that in the absence of a favourable regulatory framework, renewable energy will remain a small niche market. They further point out that strong political support is fundamental to the adoption of renewable energy. Therefore it can be argued that regulatory and policy uncertainty is a substantial barrier to the greater adoption of renewable energy (de Jongh et al., 2014).

Byrnes, Brown, Foster and Wagner (2013) suggest that because of the relative infancy of the renewable energy industry, it is particularly vulnerable to policy shock compared with other industries with more established access to capital and institutional experience. They further point out that two factors are often ignored with regards to existing policy:

i) The existing policy framework for energy tends to ignore the advantages that mature conventional fossil fuel-based energy sources have enjoyed for a period of time.
ii) The effectiveness of existing policy is limited by the focus on developing the current lowest-cost energy options, at the expense of emerging technologies.

Thus, renewable energy technology has to compete with an established technology (conventional fossil fuel-based), placing it at a disadvantage because it has yet to achieve its optimum performance in terms of cost and reliability (Menanteau, Finon, & Lamy, 2003). These arguments highlight the necessity for supportive policy and regulatory frameworks so that renewable energy can be adopted at greater scale and thus allow progress on the development path towards optimum performance.

2.2.5.2 Market structure

Reddy and Painuly (2004) suggested that market distortions arise in the electricity supply industry as the market structure lends itself to being a natural monopoly. The current structure of electricity markets favours investment into large-scale, often fossil fuel-fired, power stations. These factors create distortions in the electricity market through policies that favour conventional technologies by offering incentives such as subsidies, tax rebates, and the inability to internalise externalities (Painuly, 2001). Thus, the existing market structure entrenches mining companies' reliance on grid electricity and acts as a barrier to investment in renewable energy.

2.2.5.3 Administrative and bureaucratic processes

Martin and Rice (2012) reported that firms and stakeholder organizations identified regulatory hurdles as barriers to increased renewable energy supply because they provide an administrative and legal burden to future developments. An example provided is that "a review of the renewable energy project development process in Queensland highlighted three major electricity industry (state and national levels) gateways; three levels of government planning and approvals legislation, including a six-part project development assessment system; separate water and vegetation, environmental, and indigenous culture and heritage testing protocols; and land leasing and/or acquisition procedures" (Martin & Rice, 2012, p.123).

Emphasis has been placed on political support as a key enabler because it ensures that all regulations are simple and the bureaucratic processes are coordinated to facilitate investment in renewable energy (Abdmouleh et al., 2015). A complicated administrative process to obtain approvals for construction of renewable energy projects diverts limited resources away from the core business of mining, which then breeds the negative perception about taking focus away from revenue-generating business to non-core activities.

2.2.6 Social, cultural, and behavioural barriers

Socio-cultural and behavioural barriers may arise as a result of: i) societal structure, norms, and value system; ii) awareness and risk perception (due to a lack of information); iii) behavioural or lifestyle issues (Yaqoot et al., 2016). Mining companies tend to prefer conventional energy sources because these depend on reliable and cheap energy to keep their operations producing on a continuous basis. Owing to dependence on utility companies to provide electricity, resistance to change (consumer inertia) is likely to develop, which impedes the adoption of renewable energy technologies.

2.2.6.1 Industry norms and mindset towards self-energy production

There exists a danger of over-emphasising renewable energy as a solution to the sustainability and economic challenges that mining faces, resulting in the failure to recognise the need for behavioural change on the part of the mining industry (Liu, 2012). To reveal the trues sources of barriers to action requires a focus on deep underlying path-development trajectories (Liu, 2012). Most of the world's current energy systems are based on a centralised generation system owned by large companies (Abdmouleh et al., 2015). Thus, the structure of the electricity market has resulted in a dependency for electricity on such systems. Industry and mining therefore have a preference for grid-connected electricity provided by a utility and have no interest in investments into their own power generation, regardless of the potential benefits.

2.2.6.2 Reputation and image considerations

Mattes, Müller, Jäger, Weidner and Weißfloch, (2014) argue that a company's position in the value chain influences its likelihood of adopting renewable energy technologies. They report that Business-to-consumer companies are more likely to use renewable energy than business-to-business companies. Business-to-consumer organisations are more sensitive to their customers' perceptions of their sustainability image and wary of the reputational damage of not taking action to develop a "green image" (Mattes et al., 2014). In contrast, mining companies (business-to-business) are not as sensitive to their customers' perceptions because, in most instances, they are suppliers of raw or input materials to other industries.

2.3 Barriers to adoption of renewable energy in power generation

2.3.1 Technical barriers

Martin and Rice, (2012) identified two technical barriers that affect the adoption of renewable energy for electricity generation in the state of Queensland, Australia. These were: i) technology intermittency and storage; and ii) lack of a skilled workforce. In contrast, Eleftheriadis and Anagnostopoulou (2015) identified the lack of grid capacity, as a result of an underdeveloped grid, as the only technical barrier in their study of diffusion of wind and solar PV power in the Greek electricity sector.

Richards (2010) identified four technical barriers that affect the development of wind energy in Saskatchewan, Canada: i) wind is limited to locations with sufficient wind regimes; ii) the requirement for storage or immediate consumption as it is produced owing to its intermittency; iii) unreliable energy source which may require that it is used a part of a hybrid system that incorporates other energy types as a back-up; and iv) lower generating capacity than that of conventional fossil fuel-fired technologies.

Researchers have also identified that the requirement to manage the complexity that renewable energy introduces when connected to the grid is a barrier (Byrnes et al., 2013; Luthra, Kumar, Garg & Haleem, 2015; Richards, 2010). The intermittent nature of renewable energy contributes to the congestion of the grid network and also places stress on distribution network as it was not designed to handle bi-directional power flows (Byrnes et al., 2013).

These studies highlight that the intermittent nature of renewable energy is a barrier and consequently storage or a back-up is required to ensure a continuous supply of energy. Additionally, the quantity and quality of renewable energy sources are location dependent which further contributes as a barrier.

2.3.2 Economic and financial barriers

Byrnes et al., (2013) argue that grid connection costs are a barrier as a direct result of a lack of a national standard for grid connection, in Australia. They point out that new electricity generators have to pay the costs of connecting to the grid, which can be substantial, depending on the condition and capacity of the grid network. Martin and Rice, (2012) point out that the feasible solar and wind resources (in the state of Queensland, Australia) are located in remote areas which are very far from the grid network. This presented a further barrier as connecting these renewable energy resources would require significant financial expenditure. Similarly, Eleftheriadis and Anagnostopoulou (2015) identified prohibitive grid connection costs for solar and wind resources located in remote areas.

Luthra et al., (2015) identified high initial costs and the lack of a financing mechanism to be significant barriers to renewable energy technology adoption in India. Whereas, Eleftheriadis and Anagnostopoulou (2015) report that a lack of financial resources was found to be the most important barrier by renewable energy companies in Greece. This result is not surprising as Greece has been adversely impacted by the financial crisis.

Martin and Rice, (2012) identified six economic and financial barriers: i) high capital costs associated with large scale renewable energy projects; ii) the lack of suitable longer term financial incentives such as government and taxation subsidies and renewable energy purchase rebate schemes; iii) the existing contracting fiscal climate; iv) inability to negotiate profitable long-term PPAs with government businesses and private power companies; v) the abundant fossil fuel resources; and vi) cheap electricity prices from coal-fired power.

Collectively, the studies discussed in this section highlight the critical aspect of developing a viable business case for renewable energy. The significant barriers are the high capital costs which translate to long payback periods. Additionally, there has been a lack financing mechanisms. Owing to the remote location of renewable energy projects, grid connection costs are also a concern.

2.3.3 Institutional barriers

Byrnes et al. (2013) assert that Australian policies are largely to blame for the limited investment in renewable energy in general. The policy framework is described as unbalanced because it ignores the bias towards existing fossil fuel technologies. The policy framework is said to favour lower cost and more mature renewable technologies (such as onshore wind) and fossil (gas) fuelled technologies, thus limiting the development of emerging technology. Furthermore, the preferential tax treatments of some fossil fuels, which create inherent distortions in the energy market in Australia, are downplayed in the policy framework.

Luthra et al., (2015) reported that a lack of political commitment was the top barrier to renewable energy technology adoption in India. In addition, the lack of adequate government policies was ranked fourth. It is surprising that institutional barriers are prominent in India, given that it is the only country in the world with a with a separate ministry dedicated to renewable energy (Ministry of New and Renewable Energy) (Luthra et al., 2015). However, given the fact that the lack of political commitment is the top barrier, this may indicate the failure of the ministry to adequately address barriers to adoption of renewable energy.

Eleftheriadis and Anagnostopoulou (2015) found that the lack of a stable energy policy contributed to the perception that renewable energy is a high risk investment. Additionally, they report that the lack of integrated spatial planning and delays in the issuance of building permits also barriers. Eleftheriadis and Anagnostopoulou (2015) report that until recently, Greece did not have an institutional framework nor political support to promote the adoption renewable energy for electricity production. Martin and Rice, (2012) identified three regulatory barriers: i) complex zoning and planning ii) multi-tiered government approvals; and iv) land access and use.

Taken together, the studies discussed in this section highlight the importance of political support to ensure an enabling regulatory environment exists that supports renewable energy and addresses any potential barriers.

2.3.4 Behavioural barriers

Richards et al., (2012) reported that risk aversion by power suppliers may be a barrier to investment in wind energy technology as they are often more likely to prefer simpler and proven energy technologies where the option exists. Similarly, Byrnes et al., (2013) report that businesses are more likely to remain loyal to technologies and skills with which they are familiar (coal- and gas-fired electricity generation) than to transition to renewable energy.

These studies highlight that organisations are often risk averse and would rather remain faithful to simple and proven technologies. As such, it can be concluded that there is resistance to change.

2.3.5 Limitations in prior research

Eleftheriadis and Anagnostopoulou (2015) acknowledged that their study focused on suppliers of solar and wind power technologies so provided a view of only one of the stakeholders. Therefore, the study was limited in that it did not incorporate the views of other stakeholders in the renewable energy system.

A weakness of the results reported by Luthra et al. (2015) is that they are based on a literature review of the Indian market with some additions of literature from similar, developing markets. Ranking of the barriers was based on expert opinions (selected from academia and industry) and a multi-criteria decision-making model. Therefore, their study does not fully represent the stakeholders in the renewable energy industry.

The reliance of the AKTESP framework employed by Richards (2010) on knowledge and agreement as underlying barriers relegates the importance of other barriers. Therefore, the impact of the other barriers is not thoroughly scrutinised.

2.4 South African context

South Africa has recently been faced with an electricity crisis due to capacity constraints as a result of years of underinvestment in new generation capacity (Pollet, Staffell & Adamson, 2015). Pollet et al., (2015) attribute the failure to invest in generation capacity to two main reasons: i) Eskom and the South African government underestimated the rate at which demand for electricity would increase and ignored warning signs about the imminent capacity shortages; and ii) the South African government denied Eskom's request for funds to invest in new generation capacity. Government had planned to open the electricity market and allow the entry of IPPs.

Consequently, electricity prices have increased at a pace much higher than inflation in order to fund investment into new generation capacity and to also address the historic under-investment in generation capacity (Pollet et al., 2015; Votteler & Brent, 2016). Electricity costs, as a percentage of operating costs for mines, have increased from an average of 7% in 2007 to 20% in 2014 (Votteler & Brent, 2016). The decreased reliability of Eskom's grid, together with increasing electricity tariffs, represents a major risk for the global competiveness of South African mines. These risks, together with low commodity prices, have encouraged mining companies to investigate self-generation of electricity using renewable energy. Recent technological and economic development of renewable energy has increased its attractiveness as a possible option for mining companies in South Africa as it offers lower electricity costs, reduced reliance on the national grid, and reduced carbon footprint of operations.

A prospective cost pressure that is likely to impact electricity prices in the near future is the Draft Carbon Tax Bill released for public comment by The National Treasury in November 2015 (Votteler & Brent, 2016). A carbon tax should act to strengthen the business case for investing in renewable energy.

2.4.1 South African electricity sector

The South African electricity sector is dominated by Eskom, a state-owned enterprise that produces virtually all (95%) of the electricity consumed in the country (Baker, 2015; Krupa & Burch, 2011; Pegels, 2010). Eskom is a vertically integrated monopoly that also owns and operates the national transmission grid (Pegels, 2010) and 60% of the distribution network (Baker, 2015). The balance of the distribution network is owned by municipalities (Krupa & Burch, 2011), which essentially means that the South African electricity sector is owned, controlled, and operated by the government.

Because electricity forms the foundation of any stable economy, the electricity sector is typically subjected to political intervention by government as a way of ensuring stability within the economy (Krupa & Burch, 2011). Thus, the structure of the South African electricity sector, a natural monopoly dominated by Eskom, inherently lends itself to a combination of barriers. Firstly, economic barriers are expected to exist through market distortions (Reddy & Painuly, 2004) on the basis that Eskom and government will act to protect their own interests in most instances. Secondly, institutional barriers will also be present through policies that favour conventional technologies by offering incentives such as subsidies, tax rebates, and the inability to internalise externalities (Painuly, 2001).

2.4.2 Renewable energy in South Africa

The REIPPPP was introduced by the South African government in order to address three challenges arising from the 2008 electricity crisis (Walwyn & Brent, 2014; Pollet et al., 2015): i) the lack of adequate electricity supply capacity; ii) the large amount of capital required by Eskom to invest in generation capacity; and iii) Eskom's dependence on low quality coal, which results in a high GHG emissions intensity. The REIPPPP aims to install 17.8 GW of electricity generation from renewable energy sources by 2030. The technologies considered for the REIPPPP include solar, wind, biogas, biomass, and hydro. The REIPPPP is described as a competitive tender or auction-based-tariff system with clearly defined rounds of bid submission, adjudication, and financial closure (Becker & Fischer, 2013).

The REIPPPP has been described as being successful in that it was a more rapid response to the need to invest in much-needed electricity capacity, in response to the power shortages, than would have otherwise been possible (Walwyn & Brent, 2014). The electricity has been procured at competitive prices when compared with grid prices, with the exception of the first bidding round which was characterised by a general lack of competition and high prices (Minnaar, 2016; Walwyn & Brent, 2014). Walwyn & Brent (2014) predicted that the cost of electricity from the REIPPPP will reach parity with the cost of new coal-based generation by 2016 and thereafter will be lower than the LCOE of either coal or nuclear power.

2.4.3 Barriers to adoption of renewable energy in South Africa

2.4.3.1 Technical barriers

Researchers have identified technical barriers to be present in South Africa. Pegels (2010) contends that investment in research and development in the energy field is dominated by Eskom and Sasol, with both companies reliant on coal as the source of energy. Traditionally, these companies have dominated sponsorship of academic research to the extent that limited investment was made in research into renewable energy technology, and thus limited progress was made on developing renewable energy (Pegels, 2010). As a consequence of underinvestment in research and development, prices for renewable energy technologies have remained high. The financing costs of renewable energy technology also remained high because the technology was considered to be in its infancy and, as such, untested, thus attracting higher risk (Pegels, 2010).

Votteler and Brent (2016) identified the intermittency of renewable energy sources as a barrier but suggested that the most feasible solution is to use a hybrid system incorporating a renewable energy source and diesel. They point out that batteries for storage are still too expensive to be a viable solution. Joubert, Hess and Van Niekerk (2016) found that the technical complexity of solar thermal technology was a key barrier to the adoption of the technology. They contend that solar thermal technology for industrial and commercial applications requires expertise on large-scale systems, process engineering, and energy efficiency. Thus, there is lack of experience for optimal design, simulation, and implementation of industrial and commercial-scale solar thermal systems.

Internationally, the renewable energy market started to rapidly evolve only in 2011 and, as such, global experience is still limited (Votteler & Brent, 2016). Correspondingly, the South African renewable energy industry is considered to be still in its infancy and so relevant skills and expertise are still scarce (de Jongh et al., 2014).

Overall, the studies discussed in this section have highlighted the presence of technical barriers in other sectors in South Africa. Therefore, it can be expected that technical barriers will feature in the mining industry.

2.4.3.2 Economic and financial barriers

Economic and financial barriers have been found to be prevalent in South Africa. Access to credit from financial institutions has been identified as a barrier (Pegels, 2010; Krupa & Burch, 2011). The economics of renewable technologies entails high risk and cost factors due to the perceived technology risk of infant and as-yet untested technology (Pegels, 2010). Financial institutions factor these risks in their credit assessment, resulting in a higher cost of capital when compared with established technologies (de Jongh et al., 2014). Consequently, project developers for renewable energy projects have found it difficult to obtain funding due to lack of experience and the reluctance of financial institutions to explore new endeavours. Additionally, the global financial community has treated South Africa as an emerging market and third-world country and thus made access to credit for renewable energy entrepreneurs difficult (Krupa & Burch, 2011).

The relatively low cost of electricity (predominantly from coal-fired power) at the time of writing was also cited as a factor that led to renewable energy not being commercially attractive (Krupa & Burch, 2011). However, Votteler and Brent (2016) point out that tariffs for several renewable energy sources are half the levelised costs of diesel generators and are close to parity with Eskom tariffs. The forecast future price changes for renewable energy sources indicate that renewable energy will be cheaper than Eskom tariffs.

Joubert et al. (2016) identified the low cost of conventional energy sources, such as coal, the dominant fuel for heating, and electricity as the key barrier in the adoption of solar thermal systems. Long payback times and high initial investment costs were also identified as key barriers to increased market diffusion (Joubert et al., 2016; Votteler & Brent, 2016).

Financial viability, which includes a combination of the identified barriers of capital and operating costs, market, selling price, and foreign currency risks, was identified as a barrier, with specific reference to an investor's perspective (de Jongh et al., 2014). These barriers are used as a basis to compare conventional fossil fuel-fired technologies and renewable energy technologies. The traditional methods for financial assessment fail to take into account the fact that investment in renewable energy is a long-term commitment that represents a shift from current operating costs to high initial capital costs (Votteler & Brent, 2016).

Collectively, the studies discussed in this section highlight the critical aspect of developing a viable business case for renewable energy. Therefore, economic and financial barriers are expected to be a prominent feature in the mining industry, especially given the prevailing low commodity price environment that has affected the industry's profitability.

2.4.3.3 Institutional barriers

Institutional barriers identified to be present in South Africa include regulatory uncertainty (Krupa & Burch, 2011). This was said to be a result of a power struggle arising from key players in the South African energy landscape driven by corruption, a lack of transparency, and nepotism. The lack of clear regulations, misalignment in state policies, and non-existent government support have been identified as barriers to investment in renewable energy (de Jongh et al., 2014). It is advocated that there is a need for clarity from government to ensure that there is alignment of the political objective and its various instruments (de Jongh et al., 2014). In the absence of this clarity, it was argued that investment in renewable energy technologies will remain low.

The lack of government support for off-grid renewable energy applications, be it through incentives or political support of financing schemes like energy service contracting and subsidies, was also identified as a barrier (Joubert et al., 2016; Votteler & Brent, 2016). Another barrier is the lack of net metering, which is not formally supported by the current regulatory framework (Votteler & Brent, 2016). Net metering would allow the sale of excess electricity back into the national grid, thus reducing the reliance of the IPP on a single client, which would have a positive impact on the business case for investing in a renewable energy project.

Votteler and Brent (2016) indicate that wheeling, which is the ability to use the grid to transfer electricity from one point to another, is not an attractive option in South Africa as additional costs could add a further 18% increase to the renewable energy tariff. Therefore, the cost of wheeling electricity is seen as a barrier to the adoption of renewable energy.

The barriers identified contribute to the lack of transformation in the electricity sector because the key players are more interested in protecting their vested interests in perpetuating the status quo that relies on coal. Eskom, as the monopoly electricity provider, has used its power and dominance to influence and protect the electricity market's features that suit its core competencies (Baker, 2015). Pegels (2010) contends that, for as long as Eskom's dominance in the electricity sector remains unchanged and it continues to influence regulations, then IPPs will find it difficult to enter the market and supply significant amounts of renewable energy. Therefore, the market structure in South Africa continues to be a barrier to wider renewable energy adoption beyond utility-scale, due to political inertia.

Taken together, the studies discussed in this section support the notion that political support is critical, particularly for investment in privately owned renewable energy projects. The institutional barriers identified are likely to be a prominent feature in the mining industry.

2.4.3.4 Behavioural barriers

Poverty was identified to be a South African-specific barrier that prevents the development of a renewable energy market (de Jongh et al., 2014). Renewable energy is a more expensive alternative to the relatively cheap electricity. Thus, for domestic purposes, poor households will always opt for cheaper alternatives such as paraffin.

Votteler and Brent (2016) suggest that the shift from conventional energy sources (electricity and diesel) to renewable energy sources, representing a shift from operating costs (Eskom electricity or diesel costs) to capital costs (investment in renewable energy projects), poses some key challenges for mining companies. The first challenge is the need to build trust between IPPs and mining companies so that projects based on PPAs may be realised. Secondly, the lack of experience with renewable energy and the business and financial models required for their acceptance necessitate further education of decision makers in mining companies so that they are able to fully appreciate and understand the benefits of renewable energy (Votteler & Brent, 2016).

Joubert et al. (2016) also identified a lack of awareness and trust in the solar thermal technology as a barrier. This is due to the poor dissemination of appropriate information to decision makers. Jongh et al. (2014) identified a lack of sufficient education as a barrier to the adoption of renewable energy by society. Insufficient education results in a lack of social awareness and people are thus not able to grasp the complex environmental issues associated with the use of fossil fuels and the role of renewable energy in addressing sustainability challenges.

Owing to its maturity, the mining industry is often described as being conservative and risk averse. Consequently, behavioural barriers are expected to be present in the mining industry.

2.5 Role of policy in addressing barriers to renewable energy

Greater adoption of renewable energy can only be achieved by addressing the various barriers that exist. The extent to which penetration of renewable energy technology will be successful will be determined by the association of benefits from supportive, aligned, and coordinated measures enacted in a country to address the barriers that exist (Abdmouleh et al., 2015). However, it is worth noting that barriers do not function in isolation, but rather they are part of a complex, intertwined system that impacts the greater adoption of renewable energy (Liu, 2012). Thus, no one measure can be singled out to have a significant positive impact on renewable energy penetration. In other words, there is no 'one size fits all' policy that will be successful in promoting greater adoption of renewable energy (Becker & Fischer, 2013). Rather, the success of a policy will depend on the effectiveness of other complimentary policies (Abdmouleh et al., 2015).

Barriers to the adoption of renewable energy can be addressed through a conducive policy environment, an enabling and supportive regulatory framework, and suitable institutional measures (Yaqoot et al., 2016). The policy design has to address the specific barriers that exist within each barrier category and be relevant to the specific country context and technology (Becker & Fischer, 2013). Thus, policy design and fit are essential for success. Although it is generally agreed that a policy mix consisting of complementary instruments is required to address barriers to the adoption of renewable energy, there is no consensus on what the design criteria are or what might comprise this optimal policy mix (Polzin, Migendt, Täube & von Flotow, 2015).

The establishment of a reliable framework with a clear vision and long-term policy objectives regarding renewable energy capacities to be installed in the future are important in supporting electricity generation from renewable energy sources (Polzin et al., 2015). Political support is a key enabler because it ensures that all regulations are simple and the bureaucratic processes are coordinated to facilitate investment in renewable energy (Abdmouleh et al., 2015).

Policy strategies that have been employed to address economic and financial barriers include: financial incentives (through capital subsidies and soft loans), fiscal incentives (tax incentives for investment, environmental taxes, and tax holidays on generation income), legislative support or market-based incentives (feed-in tariffs, auction-based tendering, net metering programmes, and green certificates) (Abdmouleh et al., 2015; González & Lacal-Arántegui, 2016). Feed-in tariffs are an essential measure because they provide a more reliable and long-term signal for potential investors when compared with grants and subsidies that are dependent on the government budget (Polzin et al., 2015). Market-based incentives (such as carbon emission trading systems) can also have a strong influence on the perception of investments by institutional investors (Polzin et al., 2015).

In addition, supportive regulatory measures such as codes and standards are required to accelerate the dissemination of renewable energy technologies and assist in further reducing technological and regulatory risk associated with investments in renewable energy projects (Polzin et al., 2015). Technology support is also required in the form of research and development grants that allow technology improvements and the construction of demonstration facilities (Abdmouleh et al., 2015).

2.6 Renewable energy applications in mining

A common misconception is that renewable energy is only applicable for power generation. The review below highlights other potential applications of renewable energy technologies that could increase their adoption.

Napp et al. (2014) reviewed energy-efficient and low carbon technologies for achieving energy and GHG emissions savings in the industrial sector. The focus of their study was on three main sectors within industry: i) iron and steel; ii) cement; and iii) refineries; as well as iv) crosscutting technology options (for example, motor and steam systems and combined heat and power). They reported that the industrial sector comprises a diverse range of processes and product manufacturing, which makes it a challenge to focus on one single technology. The recommended fuel switching to low carbon energy and renewable energy sources as one of the key actions required to significantly reduce industrial emissions beyond energy-efficiency improvements.

Taibi et al. (2012) analysed the potential for renewable energy use primarily in four areas: i) biomass for process heat; ii) biomass for petrochemical feedstocks; iii) solar thermal systems for process heat; and iv) heat pumps for process heat. They established that it is technically possible to substitute half of industrial fossil energy and feedstock requirement usages with renewable sources. They also suggest that the possibility exists to switch from heat produced by fossil fuels to electricity from renewables. Suggested solutions for the iron-making industry are: charcoal or similar products could replace fossil fuels, while medium-temperature steam could be co-generated in concentrated solar power (CSP) plants. They found that, although refrigeration and freezing using solar heat is currently not attractive, these applications could piggy-back on solar cooling systems for buildings. The use of heat pumps has been identified as an important option but this is only feasible if breakthroughs in technology development are made that will meet temperature levels required by industry.

An important aspect that Taibi et al. (2012) raised is the need for policymakers to engage in dialogue with industrial energy users and equipment suppliers. This was seen as essential in order to agree on feasible pathways for the adoption of renewable energy technologies by industry.

Eglinton, Hinkley, Beath and Dell'Amico (2013) studied potential applications of concentrated solar thermal (CST) energy in the Australian minerals processing and extractive metallurgical industries. They indicated that the drivers for implementing renewable energy in this industry are economic as well as environmental. They suggested that CST technologies can be used for moderate temperature heating, electricity production, and steam generation, all of which are useful processes that could be used in the Australian minerals processing and metallurgical industries.

Replacing expensive fossil fuels, even partially, has the potential to generate large savings and, where applicable, reduce carbon tax liability (Eglinton et al., 2013). Opportunities for the applications were identified as mines and beneficiation plants located in remote locations where fuel costs are much more significant than in urban areas. Solar energy could replace the diesel generators that are used by many mine facilities not connected to the grid. They also identify various process technologies in development phases that are based on solar energy; namely, solar kiln, solar thermal heating of air, solar gas process to produce syngas, and a solar carbothermic reduction process. However, Eglinton et al. (2013) established that there are several challenges that still need to be overcome to achieve development and scale-up. These include: i) acquiring the large land area required; ii) acquiring the capital cost that may be involved; and iii) encouraging confidence in these new technologies in well-established industries.

Overall, the studies discussed in this section have highlighted that there are other potential applications of renewable energy technologies beyond power generation. These applications focus on delivering other types of energy required in mining such as process steam and heat. However, all these technologies are still in development and have not yet achieved commercial operation.

2.7 Conclusion

The literature review has shown that barriers to the adoption of renewable energy have been widely researched with specific focus on the power generation sector and residential customers (both rural and urban). However, there is limited academic research available on the barriers to the adoption of renewable energy in the mining industry. Votteler and Brent (2016) highlighted that there is a need to educate decision-making leaders of mining companies to better understand the concepts and benefits of renewable energy and how it can address their specific needs and challenges. Votteler and Brent (2016) recommended that there is a need for further research to be conducted from the perspective of leaders of mining companies in order to make the knowledge more credible and accessible. Therefore, the lack of research in the mining industry suggests that there is both an academic and business need for research.

The literature review has shown that various frameworks have been developed by researchers to identify barriers to renewable energy penetration. Frameworks based on a stakeholder approach (Jarach, 1989; Painuly, 2001) identify barriers by focusing on the identified stakeholder's perception of barriers that exist to the adoption of renewable energy. In contrast, other researchers use a systems approach based on technology innovation models and theories (Jacobsson & Johnson, 2000; Richards et al., 2012; Viardot, 2013). These frameworks are more customer-orientated and proceed by identifying factors that influence the willingness to use new technology. These factors include perceived usefulness and ease of use, which can lead to barriers to adoption if not aligned with the customer's needs. However, regardless of the framework employed and the debate on the taxonomy of barriers, the researchers identify similar barrier categories with minor disagreement on some categories. The stakeholder framework proposed by Painuly (2001) is better aligned with the objective of this study as it focuses on stakeholders views, in this case mining companies perspectives on barriers to the adoption of renewable energy.

The four most commonly identified barrier categories in the literature are: technical, economic and financial, institutional, and socio-cultural behavioural barriers. Those characterised under the “other” category include environmental and contextual barriers. This study concentrates on the four commonly cited categories of technical, economic and financial, institutional, and behavioural barriers. These common categories are more likely to be present within a mining context.

Technical barriers prevent renewable energy from reaching its theoretical potential. Barriers identified within the technical category include resource availability and technical performance. In particular, the intermittent nature of renewable energy has been identified as a significant barrier, especially for applications that require continuous electricity supply, such as a mining operation.

Economic and financial barriers are the most prevalent; these represent the cost, market, and financial aspects that inhibit greater dissemination of renewable energy. Barriers within this category include: high capital and investment costs, long payback periods, low electricity prices, and the exclusion of environmental externalities in the pricing of fossil fuel sources. The perception that renewable energy is a high-risk investment leads to a reluctance by financial institutions to support renewable energy, which then limits the amount of credit available to fund such projects. Additionally, renewable energy projects attract high finance costs due to this perception. Given the current global economic downturn, investors have found it difficult to motivate for high capital investment in long-term renewable energy projects, which makes the high initial investment and capital costs a significant barrier.

Institutional barriers refer to the policy and regulatory environment, infrastructure requirements, and institutions that may promote or hinder renewable energy penetration. The existing policy and regulatory framework for electricity markets favours investment into large-scale, often fossil fuel-fired, power stations. Renewable energy technology has to compete with established fossil fuel technologies that have benefited, and continue to benefit from, incentives such as subsidies, tax rebates, and the inability to internalise externalities. In the absence of a favourable regulatory framework, renewable energy would not be able to compete with conventional energy sources.

Behavioural barriers are mainly due to the influence of accepted norms within society and industry in particular. This results in certain behavioural aspects due to lack of information and awareness. This manifests in certain perceptions and preferences, such as the reliance and dependence on grid electricity even in situations when faced with unreliable grids and increasing electricity prices.

Barriers to the adoption of renewable energy can be addressed through a conducive policy environment, an enabling and supportive regulatory framework, and suitable institutional measures. However, it is worth noting that barriers do not function in isolation, but rather they are interlinked in a complex way that results in a cascading impact on the greater adoption of renewable energy (Liu, 2012). A policy mix consisting of complementary instruments is required to address barriers to the adoption of renewable energy, although the literature highlights that there is no consensus in what the design criteria are or what would comprise an optimal policy mix. The essential aspect to be considered, so that the policy delivers the desired objectives, is to ensure that the policy design fits the country context and technology.

To answer the questions posed in Chapter 1, research propositions are postulated in Chapter 3. The basis of the propositions are the four barrier categories identified in the literature, taking into account the context of the mining industry in South Africa (discussed in Chapter 1).

Chapter 3 Research Propositions

The literature review shows that barriers to the adoption of renewable energy have been widely researched in the power generation sector. The search within the literature for studies focused on the mining sector yielded few results. Consequently, there is a gap that exists in informing mining leaders' decision-making with regards to the role and benefits of renewable energy for the mining industry.

Building on the stakeholder framework (Painuly, 2001) for identifying barriers and the knowledge of barriers in the power generation sector, the researcher has postulated the following propositions to answer the research question. The propositions are structured into the four main categories of barriers that were identified in the literature review. The proposed barriers contained within each category seek to provide an answer as to which factors influence or impact mining companies' perceptions regarding renewable energy. It is these negative perceptions that ultimately translate into the barriers that have negatively impacted the adoption of renewable energy by mining companies in South Africa.

3.1 Proposition 1: Technical barriers

Renewable energy technologies are not technically feasible for mining applications due to their intermittent nature and variability as well as dependence on location. Other than power generation, there are no applications for renewable energy in mining.

Proposition 1.1 Intermittent nature of renewable energy – the intermittent nature of renewable energy means that it is not able to continuously supply base-load power required by mines.

Proposition 1.2 Inadequacy of supply and location of mines – the areas where mining operations are located does not contain sufficient quantities of renewable energy resources to support capacity utilisation at economical levels. The location of mines also plays a role because the quantity and quality of renewable energy resources is dependent on location.

Proposition 1.3 Technology maturity – storage technology is not yet commercially proven and still very expensive.

3.2 Proposition 2: Economic and financial barriers

The current capital constraints in mining mean that there is no room to consider investment in capital-intensive projects such as renewables that do not improve productivity/efficiencies.

Proposition 2.1 Capital constraints – spending priorities on production and efficiency-related projects means that renewable energy is not able to compete with the limited capital available for stay-in-business projects.

Proposition 2.2 Business case – high capital costs of renewable energy and the long payback periods makes them not feasible for mining operations.

Proposition 2.3 Risk perception – the perception that renewable energy is a high-risk investment, requiring a higher rate of return, when compared with other capital projects, makes it unattractive for mining operations.

Proposition 2.4 Electricity pricing – electricity prices from Eskom are lower than renewable energy prices, even in instances where IPPs are used.

3.3 Proposition 3: Institutional barriers

There are no policies or regulations in place that incentivise mining companies to invest in renewable energy.

Proposition 3.1 Lack of supportive policy – there is no explicit national policy or regulation that encourages renewable energy use in mining.

Proposition 3.2 Lack of a framework to allow feeding into the grid – the current policy and regulatory framework does not allow for the sale of excess electricity back into the grid.

Proposition 3.3 Inability to use the grid – current policy does not encourage the wheeling of electricity from one point to another.

Proposition 3.4 Grid-connection costs – costs to connect to the grid are prohibitive.

Proposition 3.5 Administrative – bureaucratic processes such as the environmental impact assessment (EIA) process create an administrative burden that ties up valuable resources.

3.4 Proposition 4: Behavioural

The norm within the mining industry is to focus on mining and leave the provision of power to the utility and grid. Renewable energy is only applicable to power generation and has no other role in mining as an energy source.

Proposition 4.1 Entrenched mindset – mining companies prefer grid-connected power and thus the mindset is that power generation does not form part of the core business of mining companies.

Proposition 4.2 Lack of information – there are no other possible applications of renewable energy technologies in mining.

Chapter 4 Research Methodology

The aim of the study was to identify the barriers to greater adoption of renewable energy within the mining industry in South Africa. This chapter provides details on the research design chosen for the study and provides justification for its suitability to answer the research question. The sampling parameters for the study are outlined, followed by descriptions of the data collection process and the analytical method employed. The chapter concludes with a discussion of the research limitations.

4.1 Research design

4.1.1 Research philosophy

Research philosophy refers to the underlying assumptions or beliefs that are held by the researcher which underpin the research strategy and data collection methods that are likely to be chosen as part of the research design (Creswell, 2013). The researcher in this study strongly favours the positivism philosophy, given the fact that the researcher's background is from a scientific-based field, namely engineering. The positivism philosophy entails the use of highly structured methods to facilitate the replication of studies that lead to the development of law-like generalisations (Saunders & Lewis, 2012). This philosophy is consistent with research undertaken in the physical and natural sciences disciplines (Creswell, 2013). However, despite the researcher's preference for a positivism philosophy, the researcher had to adopt a pragmatic position. The pragmatism philosophy is guided by what is possible and thus the pragmatic position suggests that the research philosophy chosen is largely determined by the research questions and objectives (Creswell, 2013). The pragmatic approach allows for the use of various research tools that allow both deductive and inductive evidence to be used in the findings (Creswell, 2013). In this regard, the researcher's decisions were guided by the literature review presented in Chapter 2, the propositions formulated in Chapter 3, as well as the methodologies employed by other researchers.

4.1.2 Research approach

The literature review in Chapter 2 yielded a wealth of information on barriers to the adoption of renewable energy, with particular focus on the power generation sector and residential users. However, there are limited studies that focused on barriers affecting the adoption of renewable energy by mining companies in South Africa. To answer the research question, propositions have been postulated building on the existing body of knowledge concerning barriers to the adoption of renewable energy in the power generation sector. Thus, the research made use of existing theory and frameworks for identifying barriers to explore and determine the barriers to the adoption of renewable energy by mining companies in South Africa. The process followed is defined as the deductive approach, which clarifies the theory, framework, or model at the inception of the study and then proceeds to test the theoretical proposition based on the earlier identified theory, framework, or model (Saunders & Lewis, 2012). Although the deductive approach was followed, the researcher kept an open mind to new themes and issues that may arise during the study. The reason for this was that interest in the research problem developed from the identification of the fact that a gap existed in existing theory and research (Edmondson & McManus, 2007); namely, the lack of research into the barriers to greater penetration of renewable energy in the mining sector in South Africa. Thus, ultimately both deductive and inductive approaches were employed in the research.

Deductive research is depicted as proceeding in five sequential stages (Saunders & Lewis, 2012):

i. Defining research questions from existing general theory;
ii. Defining the way in which the questions may be answered;
iii. Seeking answers to the questions defined in stage i;
iv. Analysing the results of the study to determine whether they support the theory or suggest the need to modify the theory;
v. Confirmation of the initial general theory or modifying it on the basis of the findings.

The first two stages of the deductive research process are fulfilled in Chapters 2 and 3. Chapters 5 to 7 serve to complete the rest of the deductive research process.

4.1.3 Research type

Despite the existence of a wealth of literature on barriers to the adoption of renewable energy, the focus of previous research was mainly on the power generation sector and residential users. Consequently, the study of barriers affecting mining companies in South Africa can be considered to be new territory as it seeks to address a gap in existing theory (Edmondson & McManus, 2007). The study aims to establish the mining industry’s perceptions of the barriers it faces in adopting renewable energy. Therefore, this study lends itself to exploratory research. Saunders and Lewis (2012) describe exploratory studies as being suitable to discover general information about a topic that is not understood clearly by the researcher.

4.1.4 Research method

Saunders and Lewis (2012) suggest that the three most common ways to conduct exploratory research are: i) searching the academic literature; ii) interviewing experts in the subject; iii) conducting interviews. Edmondson and McManus (2007) suggest that the selection of a suitable research methodology is dependent on the state of prior knowledge. They indicate that intermediate theory research draws on prior knowledge from separate bodies of literature to propose new ideas. These types of studies are said to often combine qualitative and quantitative data in order to establish the external validity and construct validity of new measures through triangulation (Edmondson & McManus, 2007). They further argue that, despite the debate about the correctness of combining qualitative and quantitative data, the two methods can be successfully combined in instances where the objective is “to generate greater understanding of the mechanisms underlying quantitative results in at least partially new territory” (p. 1157).

As already emphasised in the literature review in Chapter 2, context is important in understanding the impact of barriers on the adoption of renewable energy technology. Owing to the fact that there is limited information available on the barriers affecting the adoption of renewable energy by mining companies in South Africa, rich and detailed data are required to identify the barriers (Edmondson & McManus, 2007). Therefore, it is appropriate to collect qualitative data for the research study. The data collected using this method provides valuable insights into the barriers to adoption of renewable energy by the mining industry (Saunders & Lewis, 2012). The hybrid approach (qualitative and quantitative) was considered but was discounted as the risk exists that the quantitative measure may yield an ambiguous relationship to the phenomenon being studied (Edmondson & McManus, 2007). This would have adversely impacted the study by limiting the researcher’s openness to new ideas and issues.

Accordingly, interviews based on open-ended questions were identified as the ideal method for collecting the rich and detailed data that are required to shed light on barriers that have prevented greater penetration of renewable energy in the mining sector in South Africa (Edmondson & McManus, 2007). Thus, the aim was “…to gather views from a medium sample of people likely to have different perspectives and experiences…” (Easterby-Smith, Thorpe & Jackson, 2015 p.67). The collection of qualitative data enabled the researcher to establish which barriers are significant factors to the mining industry, consistent with the level 2 barriers as suggested by Painuly (2001). The collection of qualitative data also allowed for a deeper interrogation of the barrier elements (level 3 barriers), which assisted in the determination of measures that can be recommended in order to address the various barriers (Painuly, 2001). In addition, the literature illustrated that previous researchers studying a more mature phenomenon – the adoption of renewable energy in the power generation sector – had also employed qualitative methods (Eleftheriadis & Anagnostopoulou, 2015; Luthra et al., 2015; Martin & Rice, 2012; Pegels, 2010; Richards et al., 2012).

Thus, this exploratory study employed qualitative methods (in the form of semi-structured interviews) to explore the barriers to greater adoption of renewable energy by the mining sector in South Africa, using a deductive approach guided by the pragmatic philosophy.

4.2 Population

The population is defined as the whole set of entities that have some common set of characteristics (Easterby-Smith et al., 2015). The population of relevance encompasses all individuals currently employed by mining companies that have operations in South Africa. The individuals of interest within the mining companies are those who exert some form of influence on the investment decisions relating to renewable energy technology and projects, such as project, engineering, and sustainability managers and executives. This will include both mining companies that are interested in adopting renewable energy for their mining operations and those that are not considering renewable energy.

4.3 Unit of analysis

The unit of analysis is defined as the entity that will form the basis of any sample (Easterby-Smith et al., 2015). The importance of providing clarity about the unit of analysis in advance is that it forms the basis for collating data that will subsequently be analysed, and thus it provides initial guidance for analysis.

The unit of analysis for this research was the individual's perception of the barriers to adoption of renewable energy by the mining sector in South Africa. The individuals of interest within the mining companies are those who are involved or exert some form of influence on the investment decisions of renewable energy technology such as project, engineering, and sustainability managers. As part of their daily tasks, these individuals are normally tasked with dealing with the following aspects on energy: energy security, energy costs, energy efficiency, sustainability, carbon or GHG emission management, and alternative energy considerations.

4.4 Sampling

4.4.1 Method

A sampling frame is defined as the complete list of all members of the population (Saunders & Lewis, 2012). Although it was deemed possible that a list of the mining companies operating in South Africa could be obtained from a combination of public institutions (such as the Department of Minerals and Resources) and industry representative bodies (such as the Chamber of Mines), it was reasoned that using this list to perform probability sampling would be time-consuming and further complicate the research process. A further complication would have been the process to be used in identifying the relevant individuals eligible to participate in the study based on this list. Thus, given the time constraints and complexity of accessing eligible individuals, the researcher chose to employ non-probability sampling techniques.

A combination of purposive and convenience sampling was used to identify potential candidates to interview. Purposive sampling is based on the researcher's judgment to choose respondents who are eligible to participate in the study and are able to help answer the research questions and meet the objectives of the research study (Easterby-Smith et al., 2015). The researcher approached the Energy Intensive User Group (EIUG) and asked the council members that represent the mining companies to participate in the research. The EIUG is a non-profit organisation whose members are energy-intensive consumers – of which 16 of the 33 member are mining companies (Energy Intensive User Group, 2015). The basis of choosing the EIUG members is that they meet the criteria of relevant people as defined in Section 4.3. Although the EIUG primarily deals with energy security and costs aspects, the members of the council are broadly involved in and exposed to renewable energy. A total of 18 council members were identified as having met the eligibility criteria to participate in the research.

Purposive sampling is used when a researcher needs to understand what is happening so that logical generalisation can be made (Saunders & Lewis, 2012). By approaching the mining representatives of the EIUG council, the researcher was hoping to obtain a homogeneous sample group within the purposive sampling technique. The reason for a homogeneous group is that it would consist of one particular subgroup, which will provide minimum variation in the data collected (Saunders & Lewis, 2012). This allowed the researcher to explore characteristics in greater depth and to easily identify minor differences. Thus, purposive sampling is appropriate for the study because it is aligned with the research objective of determining and developing a deep understanding of the barriers to greater adoption of renewable energy in the mining sector in South Africa.

As the study proceeded, it became necessary to obtain more candidates to interview as the initial response was low. Thus, convenience sampling was employed to identify potential candidates. Convenience sampling involves the selection of respondents on the basis of the ease of access to eligible respondents (Easterby-Smith et al., 2015). The researcher used his own network as well as those of his supervisor to identify other potential candidates to participate in the research. However, the researcher still ensured that the potential candidates met the eligibility criteria provided in Section 4.3.

4.4.2 Sample size

The actual sample size from which a researcher needs to collect data is dependent on the nature of the study's population (Saunders & Lewis, 2012). It is recommended that, for homogeneous populations (such as the one sought in this study), the non-probability sample size is likely to be approximately ten (Saunders & Lewis, 2012). Therefore, a sample size of around ten participants would be sufficient for this study. However, the goal for qualitative research is to reach data saturation. Data saturation is the stage where additional interviews provide few, if any, new insights into the research questions and objectives. Given the deliberate choice to have a homogenous sample, it was believed that data saturation should be achieved within six to eight interviews. Therefore, the study aimed to interview eight respondents.

A total of ten interviews were conducted with individuals who worked for mining companies and had an influence on or were involved in their company's consideration of investment in renewable energy technologies. Additionally, these individuals are normally tasked with dealing with the following aspects of energy: energy security, energy costs, energy efficiency, sustainability, carbon or GHG emission management, and alternative energy considerations.

4.5 Data collection

Data were collected by conducting semi-structured interviews, using a guiding questionnaire, in order to elicit the participants' views on the underlying barriers and the measures to overcome them. Interviews were set-up with the selected participants and the consent form, together with a brief introduction to the research, was sent to the participants. Where participants gave permission, the interviews were recorded and notes were also taken during the interview. The audio recordings from the interviews were submitted to a transcription service for them to be transcribed. The transcripts were validated by the researcher against the audio recording to ensure their accuracy.

4.5.1 Design of the interview guide

The interview guide was based on elements of the framework developed by Painuly, (2001), as discussed in Chapter 2, Section 2.2.2. The structure of the interview guide was developed based on the interview guide developed by Richards (2010), which uses the AKTESP framework. The interview guide was divided into five sections as detailed below. An example of the interview guide questionnaire is provided in Appendix A: Interview Guide. The consent form is included in Appendix B: Consent Form for the Study. The consent form made it clear to participants that participation was voluntary and that they could withdraw from the study at any time with no penalty.

- Section 1 – General information. The first section was designed to obtain general information about the respondent, their experience with renewable energy, and to ensure that they met the eligibility criteria (as describe in Section 4.3). In addition, the respondent's views on renewable energy and its applicability in mining was sought.
- Section 2 – Technical barriers. This section was designed to assess the respondent's views on barriers that fall under the technical barriers category.
- Section 3 – Economic and financial barriers. This section was designed to assess the respondent's views on barriers that fall under the economic and financial barriers category.
- Section 4 – Institutional barriers. This section was designed to assess the respondent's views on barriers that fall under the institutional barriers category.
- Section 5 – Social, cultural, and behavioural barriers. This section was designed to assess the respondent's views on barriers that fall under the social, cultural and behavioural barriers category.

The interview was based on open-ended questions and the respondent's answers were used to build on further discussion through targeted questions. With the targeted questions, the interviewer would first define the barrier category and then ask the respondent to identify barriers that could be applicable in the mining sector. In instances where the respondent could not identify any barriers falling under a particular category, the interviewer would suggest barriers that had been identified from the literature and that could be applicable to mining.

4.5.2 Pretesting of the interview guide

The interview guide was piloted using one respondent who matched the eligibility criteria with the exception that she did not work for a mining company. The respondent's suitability was based on their involvement in assessing renewable energy projects that participated in the government REIPPPP process with a view that the respondent's employer would provide funding to the project developers. Thus, the respondent was familiar with the research topic and was a good candidate on which to test the interview guide.

The pilot-test interview allowed the researcher to check that the questions would be understood, they would not be leading, and would provide the required data. Based on feedback from the respondent, the interview guide was further simplified and two open-ended questions were included at the opening. The opening questions allowed the interviewer to get insight into the respondent's view on renewable energy and its applicability to mining. The final interview guide is provided in Appendix A: Interview Guide.

4.6 Data analysis

Data analysis was performed through content analysis, which is not too different to quantitative analysis. Content analysis is a research method that identifies words or phrases and makes inferences based on their presence or repetition (Babbie & Mouton, 2001). This choice relates back to the researcher's preferred philosophy of positivism, which translates to the preference of structured methods. The coding scheme was developed deductively, based on the theory from the literature review in Chapter 2, by identifying the barriers (as per the propositions in Chapter 3) as the coding categories. This approach is referred to as directed content analysis because the goal is to validate or conceptually extend a theoretical framework or theory (Hsieh & Shannon, 2005).

The interview transcripts were analysed using *ATLAS.ti* software, which is a computer-aided qualitative data analysis software (CAQDAS) program. Because the goal of the research was to identify and categorise all instances of when a barrier was mentioned, the strategy followed for coding was to read the transcripts and highlight all the text that on first impression that appeared to represent barriers (Hsieh & Shannon, 2005). The highlighted text was then allocated to the predetermined codes (barriers). During the process of coding the transcripts, the researcher picked up on new barriers that were not identified in the literature review. The newly identified barriers were allocated a new code and categorised in successive reviews and coding of the transcripts. Thus, an inductive approach was also employed, which is consistent with the pragmatism philosophy.

The level of analysis used for the coding ranged from a key phrase to a string of words, and, at times, whole paragraphs (Babbie & Mouton, 2001). The reason for this choice of level of analysis was that barriers were denoted by a number of barrier elements (as shown in Figure 2-1). Thus, a participant in the research may use a whole paragraph to describe a barrier with the barrier elements contained within that paragraph. As discussed in Section 2.2.2 of the literature review, it is important to identify the barrier elements because they are the underlying issues that need to be addressed.

The coding was done to allow for both the reporting of whether the code (barrier) did in fact occur and also the frequency (number of times) that the barrier was mentioned (Babbie & Mouton, 2001). In addition, the number of participants associated with the code (who raised the barrier) is reported. The combination of these three measures allows the researcher to determine if there is consensus among the respondents about the existence of such a barrier in the mining industry.

4.7 Transcript coding and analysis

The transcribed transcripts were analysed using *ATLAS.ti* software, a CAQDAS program. A detailed account of the analysis process is provided below.

4.7.1 Accuracy and validity of data collection and transcription

All the audio recordings from the interviews were transcribed by a transcription service. As each transcript was received from the transcription service, the researcher reviewed the transcripts by listening to the audio recordings while simultaneously reviewing the transcripts. During this review process, the researcher corrected any spelling mistakes, words, abbreviations, and jargon that were inaccurately transcribed. In instances where parts of the interview were marked as inaudible by the transcriber, the researcher listened to the inaudible section several times and based on memory and context of the interview, an attempt was made to transcribe the section. However, there remained some sections of the interviews that could not be transcribed; these were marked as inaudible in the transcript.

4.7.2 Transcript coding

All the reviewed and verified transcripts were imported into *ATLAS.ti*. The naming convention of the transcripts was “Respondent #”, with the transcripts simply numbered from 1 to 10. The process of coding the transcripts was as follows:

- The researcher developed a coding scheme based on the literature. Each of the barriers identified in Chapter 3, as part of the propositions, was used as code. The initial list of codes is provided Table C - 1 in Appendix C. The researcher then reviewed each transcript and highlighted relevant quotations and assigned them to the code (barrier). It should be noted that the words "code" and "barrier" are used interchangeably in the context of this research.
- During the initial coding process, new barriers were identified and assigned a code name. At this stage, the researcher decided to colour code the barriers according to the barrier categories to make it easier for the researcher to review the table code while working.
- A further coding process was performed by reviewing each transcript and assigning relevant quotations to the barriers. During this process, the researcher also looked for the occurrence of both new codes (barriers) and proposed barriers from the initial list of codes.
- The table code was then reviewed and new codes were defined based on quotations that had been assigned to them. The researcher also ensured that none of the new codes overlapped and, where possible, codes were merged together. The new codes with a low occurrence were scrutinised to determine if they were indeed individual codes (barriers). A final list of codes was developed as provided in Table C - 2 in Appendix C.
- The researcher then reviewed the transcripts one final time based on the final list of codes. During this review, the researcher also looked for evidence that contradicted the theory or where the respondents contradicted each other's views. This was an attempt to remove any confirmation bias that the researcher may have developed over the course of the interviews and during the coding process. In addition, the researcher also looked for insights into potential solutions to the barriers that had been identified.
- The coded quotations were reviewed to ensure that there was a level of consistency between the definitions of the barrier (code) and the quotations that were assigned. The researcher also looked for consistency of the quotations across the interviews.
- During the review and analysis of the quotes associated with the barriers (codes), the researcher realised that the various arguments that were being raised as part of the justification of how barriers influenced their perception of renewable energy

were actually the barrier elements, as explained by the stakeholder framework developed by Painuly (2001).

- Finally, the researcher then grouped the codes into what is referred to as code families in *ATLAS.ti*. This is the equivalent of grouping the barriers into their barrier categories (for example, technical barriers as per Chapter 3).

4.7.3 Analysis in *ATLAS.ti*

The coded transcripts were analysed using *ATLAS.ti* software, a CAQDAS program. The software has a range of tools that allows the researcher to analyse the coded transcripts. As discussed in Section 4.6, the researcher settled on the following measures to use as evidence to determine whether the data from the interview supported the propositions:

- The number of respondents who mentioned the barrier (code). The reason for this measure is that it gives the researcher the ability to determine if there is consensus among the respondents on the existence of a barrier.
- The frequency (number of times) the barrier was mentioned during the interview by the respondents is presented as code occurrence. Code occurrence refers to the number of quotations allocated to each separate code or, in this case, each barrier.
- In addition, the researcher determined the “share of voice”, which is a count of the number of words contained in quotations that a code had been allocated to relative to the total number of words contained in the interview by the interviewee (this excludes the words by the interviewer during the interview). This can be used as a proxy to illustrate the amount of time a respondent spent speaking about a barrier and therefore can be inferred to relate to the importance they attach to that particular barrier. The share of voice is reported as “relative count (%)” in the findings presented in Chapter 5.

4.7.4 Criteria used to identify significant barriers

The average share of voice for all the barriers identified in Table 5-4 was calculated to be 1.39%. The following criteria was used to determine if the barrier was perceived to be significant and if there was general consensus among the respondents on its importance:

i) The barrier must have a share of voice greater than the average share of voice of 1.39%, and
ii) The barrier must have been identified by at least five respondents.

The barrier has to meet both criteria above to be considered to be significant. The rationale for the two criteria is that when the barrier meets the two threshold levels then it evidently must be important as the respondents have: i) spent more time speaking about the barrier than the average time they spoke about the other barriers; and ii) at least half the respondents who participated in the study have identified it as being significant.

4.8 Limitations

There are certain limitations to this study. Firstly, given that the researcher focused the research on South African mining companies, the generalisability to other industries both in other sectors within South Africa or global mining companies is limited. The findings from this study, however, would provide a good platform for further research in the aforementioned areas. In addition, the use of purposive sampling, a non-probability sampling technique, means that the sample is not be representative of the population and consequently results cannot be generalised (Saunders & Lewis, 2012).

Given that the research includes qualitative elements, there is potential for subjectivity in the research outcomes. Saunders & Lewis (2012) suggest that exploratory research is subjective and may reflect the perspectives of the researcher. This potentially introduces researcher bias into the research study. Nonetheless, exploratory research is deemed the best fit to the research objective.

There may be elements of bias due to the following reasons: i) the fact that the researcher has predominantly worked in the mining industry during his career; ii) the researcher is also familiar with some of the participants in the research, having worked with them or interacted with them in various contexts; iii) the reliance on theory and the use of the deductive approach and directed content analysis in the research. Based on the three reasons above, there is a risk that the researcher may be more likely to find evidence that supports the theory and framework, rather than evidence that does not support the theory.

The researcher has focused on isolating specific barriers and their impact on the penetration of renewable energy. The researcher did not try to study and elaborate on linkages that exist within the various barriers. Inter-linkage between barriers reinforces the impact of the barriers and makes it difficult to study them.

Finally, past research has assessed several more categories of barriers than the four selected for review in this study. The researcher has opted to focus the research on four categories based on the appropriateness to the mining context, and only briefly acknowledged other categories in the literature review.

4.9 Ethical considerations

The process of ethical clearance as prescribed by the Research Ethics Committee of GIBS was followed and approval was obtained before proceeding with the research study. Measures were taken to ensure the protection of research participants from harm or exploitation as prescribed by the ethical clearance process.

A consent form (Appendix B: Consent Form for the Study) was made available to each participant at the start of the interview, or sent ahead of time in the case of the telephonic interview. The consent form made it clear to participants that participation was voluntary and that they could withdraw from the study at any time with no penalty.

All the interview transcripts have been anonymised by removing all references to names, companies and any other name that could be associated with the respondent. Similarly, the results have also been anonymised. In some instances, the transcripts were sent to the participants for them to give approval of the transcript.

Chapter 5 Results

This chapter presents the results of the research and the data analysis from the interviews with respondents from various mining companies. The chapter starts by providing a summary of the interviews conducted, together with details of the participants. The rest of the chapter is structured as per the research propositions outlined in Chapter 3. The research propositions (barriers) were developed following a deductive process based on the literature review. However, additional barriers were identified during the interviews, coding, and analysis phases and these are highlighted were applicable. The researcher assigned the identified additional barriers within the existing categories identified in the Chapter 3. In instances where the barriers do not fit under the identified categories, these barriers are placed under the “other” category.

5.1 Sample description

5.1.1 Summary of interviews

Table 5-1 provided information regarding the respondents interviewed and the mining sectors they represent. A total of ten interviews were conducted. The interviews ranged in duration from 22 minutes to 73 minutes. The total duration of the audio recordings from interviews conducted during research was 459 minutes and the resulting transcripts had a total of 61 418 words. The interviewees’ total word count from the interviews was 41 655 words, which represents over two thirds of the total word count. The average interview was approximately 46 minutes long with the average transcript length of 6142 words. This length of time allowed the respondents to go into depth about their perspective on the barriers to renewable energy in the mining industry.

Nine of the interviews were conducted in person, in a boardroom, at the interviewees’ work places; one of the interviews was conducted telephonically. All interviews were recorded using a digital voice recorder. Brief notes were taken during the interview relating to the barriers or challenges that the interviewees were identifying. The researcher would then get the interviewees to expand on these barriers to get more detailed information on the underlying challenges.

Table 5-1 Respondents and interview statistics

Respondent	Sector	Interview total word count	Interviewee word count	Duration (minutes)
Respondent 1	Gold	3844	2967	27.95
Respondent 2	Platinum	8558	6018	58.62
Respondent 3	Diamonds	7145	4494	71.02
Respondent 4	Diversified	4896	3704	34.55
Respondent 5	Coal	9262	6008	66.93
Respondent 6	Diversified	11079	7247	73.38
Respondent 7	Iron Ore	5780	4761	39.78
Respondent 8	Diversified	3157	1995	22.80
Respondent 9	Gold	3590	1841	27.92
Respondent 10	Diversified	4107	2620	36.00
	Total	**61 418**	**41 655**	**459**
	Average	**6142**	**4166**	**45.9**

5.1.2 Characteristics of respondents interviewed

Table 5-2 provides a summary of characteristics of the respondents who were part of the sample interviewed. Specific details such as the company name, job designation, and location of mining operations have been excluded as they may affect the anonymity of the individuals. All respondents interviewed had an engineering background, with seven having an electrical engineering qualification, three had a mechanical engineering qualification, and one had studied engineering geology. The number of years' experience working in the mining industry varied from five to 40 years. The average number of years' experience for the sample was 21.4 years. Seven respondents indicated that they had been involved with renewable energy projects in previous roles.

Based on the characteristics of the sample, the respondents are suitable to contribute to the research study. Owing to the homogeneity of the group, data saturation should be achieved.

Table 5-2 Summary of respondents' qualification, mining experience, and experience with renewable energy

Qualification	Number of years' experience in mining	Previous experience with renewable energy
Electrical engineer	40	Yes
Electrical engineer	36	Yes
Mechanical engineer	31	Yes
Electrical engineer	30	No
Engineering geology	26	Yes
Electrical engineer	15	No
Mechanical engineer	15	Yes
Electrical engineer	10	Yes
Electrical engineer	6	Yes
Mechanical engineer	5	No

The respondents were from mining companies that produce various minerals, such as gold, platinum, diamonds, coal, iron ore, as well as some diversified mining companies, as shown in Figure 5-1. The diversified mining companies own a varied portfolio of mining operations and do not concentrate on a single commodity. The data shows that the respondents represent the major mining sectors in South Africa.

Figure 5-1 Mining sectors represented by the respondents

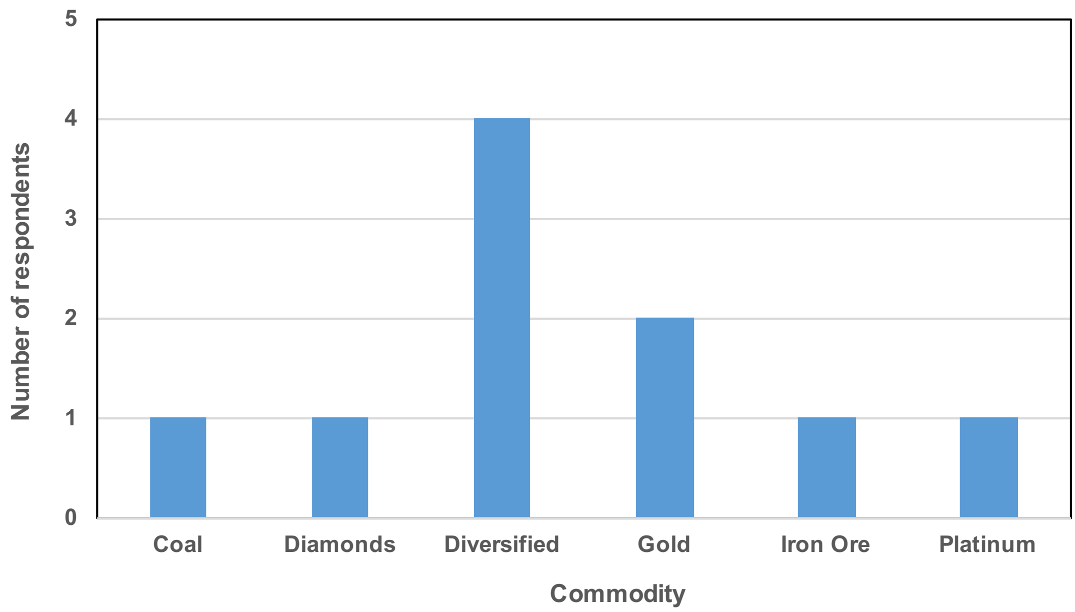


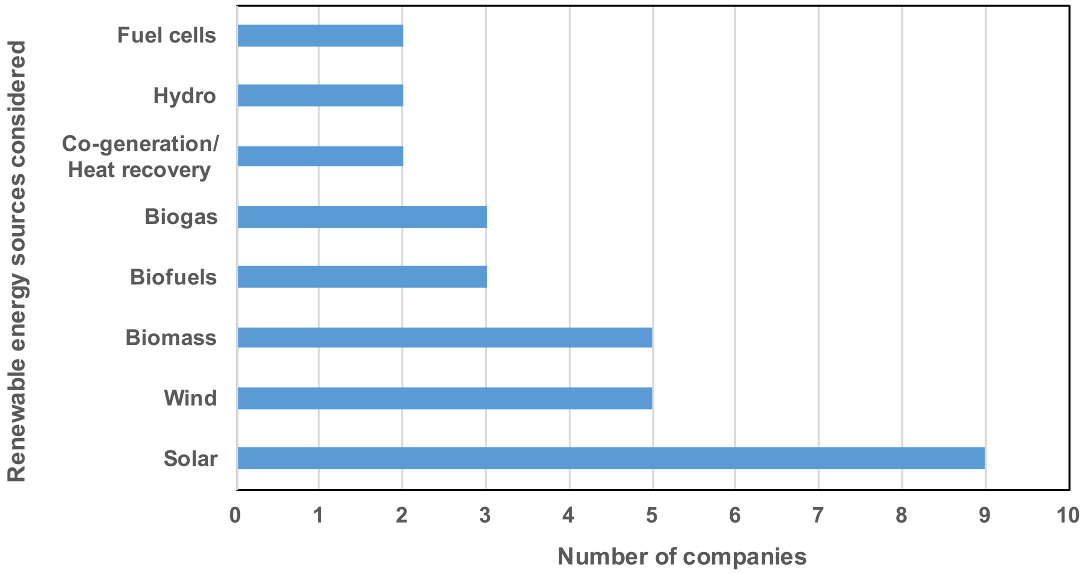
Table 5-3 provides a summary of the past considerations of investing in renewable energy as well as future intentions. All ten respondents indicated that the mining companies they worked for had considered investment in renewable energy technologies. Nine of the respondents reported that the mining companies they work for are currently considering plans to implement renewable energy projects. One of the respondents indicated that it was not clear whether the company they worked for would still consider renewable energy projects in the future. Based on the data in Table 5-3, it is apparent that the sample contains respondents who work for mining companies that are considering adopting renewable energy sources. Therefore, the respondents are suitable to provide informed views on the perception of barriers to renewable energy adoption, based on past and current experience.

Table 5-3 Summary of the respondents' companies past and future considerations of investment in renewable energy

Respondent	Company considered implementing renewable energy in the past?	Future plans to implement renewable energy
Respondent 1	Yes	Yes
Respondent 2	Yes	Yes
Respondent 3	Yes	Yes
Respondent 4	Yes	Yes
Respondent 5	Yes	Yes
Respondent 6	Yes	Yes
Respondent 7	Yes	Maybe
Respondent 8	Yes	Yes
Respondent 9	Yes	Yes
Respondent 10	Yes	Yes

The renewable energy technologies that the respondents or their companies have considered and are considering future implementation are shown in Figure 5-2. Solar energy has been considered by nine companies, with most of the respondents indicating that they had considered using solar PV, CSP, and solar water heating. Five companies indicated that they had considered wind and biomass renewable energy sources for implementation. The remaining renewable energy sources had been considered by three or less companies. In summary, Figure 5-2 shows that mining companies have considered a wide variety of renewable energy technologies, with an overwhelming focus on solar energy.

Figure 5-2 Renewable energy sources that have been considered by the respondents' mining companies



5.1.3 Suitability of sample

The following conclusion can be drawn based on the characteristics of the respondents:

i) The sample represents a fairly homogenous group as they all have an engineering background.

ii) The sample contains an experienced mining group with previous experience in renewable energy.

iii) The sample contains respondents from the major mining sectors in South Africa.

iv) The mining companies represented by the respondents have considered renewable energy in the past and are still considering it for future implementation.

v) The mining companies represented by the respondents have considered a variety of renewable energy technologies.

Based on the characteristics provided of the respondents, it is evident that the sample contained respondents who met the eligibility criteria specified in Section 4.3. In addition, when the respondents were asked about their view on renewable energy (in the opening question), all ten respondents indicated a positive attitude towards renewable energy. Thus, the individuals' perspectives on the barriers to renewable energy are likely to be informed by their experiences in assessing and implementing renewable energy projects for their companies.

5.2 Significant barriers

5.2.1 Significant barriers based on analysis of evidence from the interview

Table 5-4 provides a list of all the barriers that were identified during this research ranked by share of voice from highest to lowest. The number of respondents who identified the barrier and its occurrence during interviews are also provided.

Table 5-4 Share of voice for all the barriers identified during the interviews – ordered by relative count

Barrier	Relative count (%)	Number of respondents	Number of quotations
Intermittent nature of renewable energy	4.61	10	37
Electricity pricing	4.09	9	27
Entrenched mindset	3.28	10	30
Lack of supportive policy	2.84	9	20
Business case	2.51	10	22
Political and regulatory uncertainty	2.09	6	11
Monopolistic market and Eskom influence	1.97	6	14
Inability to use the grid	1.85	5	11
Accounting standards	1.60	6	15
Risk aversion	1.52	7	11
Inability to meet maximum demand	1.46	5	8
Lack of information	1.34	2	7
Capital constraint	1.32	6	10
Lack of knowledge and skills	1.26	6	8
Lack of focus on energy challenges	1.20	3	12
Preference to invest in energy efficiency projects	0.96	3	5
Technology maturity	0.90	6	9
Lack of framework to allow feeding into the grid	0.81	3	3
Life of mine	0.81	5	8
Administrative	0.69	4	5
Inadequacy of supply and location of mines	0.68	5	6
Industry and regulatory standards	0.65	2	4
Security costs	0.62	2	5
Duration of the PPA contract	0.60	4	5
Risk perception	0.51	3	5
Resources to manage the project	0.48	2	2
Land availability	0.39	3	6
External factors affecting performance	0.20	2	2
Age of grid infrastructure	0.19	1	1
Grid connection costs	0.00	0	0
Average	**1.39**		

Based on the criteria described in Section 4.7.4, the following 11 barriers were determined to have a significant impact on the adoption of renewable energy: i) intermittent nature of renewable energy; ii) electricity pricing; iii) entrenched mindset; iv) lack of supportive policy; v) lack of a viable business case; vi) political and regulatory uncertainty; vii) monopolistic market and Eskom influence; viii) inability to use the grid; ix) accounting standards; x) risk aversion; and xi) inability to meet maximum demand. These barriers will be discussed in detail in the rest of the Chapter 5.

5.2.2 Significant barriers as identified by the respondents

The final question of the interview requested the respondents to list up to three barriers that they consider to be the most significant in the mining industry. The request was not for the respondent to rank the barriers. It should be noted that in some instances, the respondents only provided two barriers while others identified four barriers. Table 5-5 provides the significant barriers as identified by respondents ranked by barrier occurrence. None of the barriers had more than five respondents identifying them as significant.

Table 5-5 Significant barriers as identified by respondents – ranked by occurrence

Barrier	Occurrence
Business case	5
Intermittent nature of renewable energy	5
Accounting standards	3
Political and regulatory uncertainty	3
Electricity pricing	2
Lack of focus on energy challenges	2
Entrenched mindset	2
Monopolistic market and Eskom influence	2
Industry and regulatory standards	1
Capital constraints	1
Lack of supportive policy	1
Land availability	1
Life of mine	1
Inadequacy of supply and location of mines	1
Resources to manage the project	1
Time period of the PPA contract	1

The top two barriers, each identified by five respondents, are: i) business case barrier and; ii) Intermittent nature of renewable energy. The results in Table 5-5 suggest that there is no agreement among the respondents on what the significant barriers are that contribute to the low penetration of renewable energy in mining. A possible explanation for this difference is that the mining companies are faced with different challenges which again emphasises the importance of context.

5.3 Proposition 1: Technical barriers

The results for the three technical barriers are presented below.

5.3.1 Proposition 1.1 Intermittent nature of renewable energy

The following proposition was tested:

Proposition 1.1 Intermittent nature of renewable energy – the intermittent nature of renewable energy means that it is not able to continuously supply base-load power required by mines.

The code occurrence for the barrier "intermittent nature of renewable energy" is shown in Table 5-6, ordered from highest to lowest. In total, 37 quotes were coded under the barrier "intermittent nature of renewable energy". Interestingly, all ten respondents identified the intermittent nature of renewable energy as a barrier. The results indicate that six of the respondents had four or more quotes attributed to the intermittent nature of renewable energy.

Table 5-6 "Intermittent nature of renewable energy" code occurrence – ordered by occurrence

Respondent	**3**	**6**	**2**	**4**	**7**	**9**	**10**	**1**	**5**	**8**	**Total**
Intermittent nature of renewable energy	8	5	4	4	4	4	3	2	2	1	37

Table 5-7 shows the share of voice of quotes for the barrier "intermittent nature of renewable energy" for each respondent, ordered from highest to lowest. All ten respondents gave the "intermittent nature of renewable energy" barrier a share of voice of greater than 2% during the interviews, which is greater than the average of 1.39% for all the barriers. Over the course of the interviews conducted during the research, the intermittent nature of renewable energy barrier was given a share of voice of 4.6% by the respondents, which is the highest of all the interviews (as shown in Table 5-4). On the basis of the criteria (barrier must be identified by at least five respondents and have a share of voice of at least 1.39%) described in Section 4.7.4, the findings suggest that the respondents view the intermittent nature of renewable energy as a significant barrier.

Table 5-7 "Intermittent nature of renewable energy" code by share of voice – ordered by relative count

Respondent	9	3	10	8	6	7	1	5	2	4	Total
Intermittent nature of renewable energy – word count	223	361	175	131	338	191	110	177	134	82	1922
Interviewee word count	1841	4494	2620	1995	7247	4761	2967	6008	6018	3704	41655
Relative count (%)	12.1	8.0	6.7	6.6	4.7	4.0	3.7	2.9	2.2	2.2	4.6

Three main themes (barrier elements) emerged around Proposition 1.1 from the interviews, namely: i) availability of renewable energy; ii) the inability of renewable energy to provide base-load power; and iii) the inability of renewable energy to provide security of supply. Quotes that provide evidence of the three themes (barrier elements) identified are provided in Sections 5.3.1.1 to 5.3.1.3.

5.3.1.1 Availability of renewable energy

The first barrier element relates to the availability and volatility of renewable energy. Respondent 2 illustrated the issue with solar PV by expressing the following (emphasis added by researcher is shown **in bold** in this and all subsequent quotes): "***PV is great but it only works when the sun shines*** *and you probably only get 24% to 25% harvesting in general, over the whole cycle of it.*"

Respondent 3 expressed similar views, stating the following: "*I would have thought probably solar must constitute the biggest opportunity but I guess* ***its biggest drawback is that it is time- or day-dependent and that makes it useful only for energy [at those times]****.*"

Respondent 7 suggested that neither solar or wind energy are sustainable solutions for mining due to their intermittent nature: "*The other thing, if you look at the technical aspect…****the sun only shines for 8 hours a day, the wind blows whenever it wants to, so wind and solar [are] not sustainable renewable energy sources for a mine****,"* further adding that: *"****Because, you don't want to mine and then suddenly the wind stops blowing or it is night time and then you don't have power anymore****."*

5.3.1.2 Renewable energy does not provide mining with base-load power

The second barrier element raised by the respondents was that renewable energy is not able to provide base-load power due to its intermittent nature. The respondents explained that base-load power requirement refers to the minimum amount of electricity that a mining operation needs. The quotes below from the interviews provide evidence of this concern:

Respondent 2 had the following to say about renewable energy: "***So the whole problem with renewables in general is the fact that it is not dependable power. It is not base-load power, ever, and that to me is the issue.***"

Respondent 3 further suggested that, although renewable energy technologies do work, the concern is primarily its inability to supply base load: "***I mean these things [renewable energy] can work but you are never going to get away from having base-load something.***"

Respondent 4 emphasised the importance of base-load power to mining companies in the following two quotes: "*I think I am actually pro renewable but the cost must be right and* ***there must be a base-load solution because…mining is not a stop–start process****.*"

Respondent 9 suggested that, due to the intermittent nature of renewable energy, the mining operations would always have to rely on a utility for their power supply, with renewable energy acting only as a supplement: "***That is the main thing about renewable: [it is] intermittent. It is not base-load power.*** *We will never get away from being dependent from Eskom.* ***Renewable will only be supplemental****.*"

Respondent 6 made reference to a report by the Council for Scientific and Industrial Research (CSIR) on the potential for renewable energy penetration in South Africa. Respondent 6 suggested that the CSIR report acknowledges that renewable energy does not offer base load: *"Their analysis suggests that you can get to the 34% renewables by 2030 in South Africa but then there is a funny thing at the bottom of it which says,* ***but to run this economy you still need base load and its either going to come from coal and nuclear or gas. So that context doesn't just apply to the whole of South Africa, it applies to companies that have significant base-load demand****."*

5.3.1.3 Renewable energy does not provide security of supply

The third challenge raised by the respondents was that renewable energy does not guarantee security of supply due to its intermittent nature. Respondent explained that security of supply refers to the fact that mining operations want the guarantee that they will have electricity when they need it and in the quantities that they require for their operations. The following quotes from the interviews provide evidence of this concern:

Respondent 6 further expressed doubt about renewable energy: *"So to my mind, to be honest with you,* ***I don't think renewables, on their own, are a solution for security of supply****."*

Respondent 10 stressed the importance of having secure and reliable power supply in order to ensure the safety and security of people working in underground mines: *"…also, if you look at the safety barriers and the legislation that we are creating, one of the constraints in investing in those kinds of renewable energy is exactly that.* ***The assurance and the availability of electricity in case of emergency is very important and that is a constraint****."*

In addition, two respondents suggested that they only see the role of renewable energy as supplementary power. Respondent 10: *"So, yes,* ***intermittency is a bigger problem and you can only supplement with renewables*** *and the only reason for supplementing will be because it is cheaper and now it is not yet cheaper."*

Respondent 3 also implied that renewable energy may only be supplemental power: *"So … we don't really have a technology challenge, so …* ***the constraint is going to be availability of the renewable and the suitability of that as a…supplement****."*

Interestingly, two respondents contradicted the others regarding their views that the intermittent nature of renewable energy was a barrier. While they acknowledged that intermittency was a challenge for adopting renewable energy, they suggested that this was not insurmountable. Respondent 1 suggested that the intermittency of renewable energy should no longer be a major challenge because it can now be managed in the same manner as any other business risk that mining faces: "*But what* ***we have also come to learn is that resource intermittency does not equate to unpredictability, so now we can actually better predict that intermittency****..."*

Respondent 1 further added that: *"**So as much as it [renewable energy] is intermittent, you come to accept that intermittency can be predicted. It is like risk and uncertainty. It will always be there: you just need to be able to predict the uncertainty and come within reasonable prediction accuracy and live with it**."*

Respondent 8 (in response to the opening question on whether there was any potential for renewable energy to play a role in terms of providing energy to the mining industry) insinuated that it was possible to combine various renewable energy sources to address challenges posed by the intermittent nature of renewable energy: *"Yes and no. The reason I say yes is I think technically it is absolutely the right solution. My personal opinion in mining* ***is because mining normally needs quite a constant supply of energy. So we need to combine, I would say at least three technologies in supplying the mining industry****. Everywhere in the world and specifically in Africa and it is wind and it is solar and it's biomass to electricity and* ***if you combine those three you can utilise your daytime supply from PV, your late evening, your early morning, depending on your wind profile of where you are with wind and then make up the balance of that with typical biomass to biogas to electricity and/or heat or steam if you need that for a process****."*

5.3.1.4 Conclusion for Proposition 1.1

The findings support the proposition that the intermittent nature of renewable energy is a barrier that contributes to the low penetration of renewable energy in the mining industry. This barrier is possibly the most significant contributor to the low penetration of renewable energy in the mining industry. There are three barrier elements that can be attributed to the intermittent nature of renewable energy:

i) The periodic availability of renewable energy means that it does not provide a continuous supply of power, which is essential for mining operations.
ii) Renewable energy is not able to supply the base load, the minimum amount of energy that is required by mines for their operations.
iii) Renewable energy is not able to guarantee mining operations security of supply, the assurance and availability of electricity in adequate quantities when required.

Consequently, mining companies view the role of renewable energy as supplementary power.

5.3.2 Proposition 1.2: Inadequacy of supply and location of mines

The following proposition was tested:

Proposition 1.2 Inadequacy of supply and location of mines – the areas where mining operations are located does not contain sufficient quantities of renewable energy resources to support capacity utilisation at economical levels. The location of mines also plays a role because the quantity and quality of renewable energy resources is dependent on location.

The code occurrence for the barrier "inadequacy of supply and location of mines" is shown in Table 5-8, ordered from highest to lowest. In total, there were six quotes that were coded under the code "inadequacy of supply and location of mines". The results show that only five respondents indicated that inadequacy of supply and the location of mines was a barrier to renewable energy penetration.

Table 5-8 "Inadequacy of supply and location of mines" code occurrence – ordered by occurrence

Respondent	2	1	4	7	9	3	5	6	8	10	Total
Inadequacy of supply and location of mines	2	1	1	1	1	0	0	0	0	0	6

Table 5-9 shows the share of voice of quotes for the barrier "inadequacy of supply and location of mines" for each respondent, ordered from highest to lowest. Over the course of the interviews, the inadequacy of supply and location of mines barrier was given a share of voice of 0.7% by the respondents, which is lower than the average of 1.39% for all the barriers. On the basis of the criteria described in Section 4.7.4, the findings suggest that the respondents do not consider the inadequacy of supply and location of mines to be a significant barrier.

Table 5-9 "Inadequacy of supply and location of mines" code by share of voice – ordered by relative count

Respondent	4	2	7	1	9	3	5	6	8	10	Total
Inadequacy of supply and location of mines – word count	66	92	66	41	20	0	0	0	0	0	285
Interviewee word count	3704	6018	4761	2967	1841	4494	6008	7247	1995	2620	41655
Relative count (%)	1.8	1.5	1.4	1.4	1.1	0.0	0.0	0.0	0.0	0.0	0.7

Three main themes (barrier elements) emerged around Proposition 1.2 from the interviews, namely: i) inadequate amounts of biomass and biogas; and ii) the location of mines. Quotes that provide evidence of the two themes (barrier elements) identified are provided in Sections 5.3.2.1 and 5.3.2.2.

5.3.2.1 Inadequate quantities of biomass and biogas

The first barrier element relates to the lack of adequate quantities of biomass and biogas. Respondent 2 reported that there was not enough biomass available to use it as a sustainable source of energy for their mining operations, stating that: *“**The problem is in South Africa, the amount of biomass available is simply not enough**.”*

Respondent 7 also remarked that, when his company considered biogas, they found that it was not viable because there were insufficient input materials: *“In terms of other renewable technologies, let's say **biogas which is something we considered for a small biogas [project]**, when we did some calculations we said, ok, we have enough stock to do this for a certain time but **thereafter we need a sustainable input of x amount and I think those sustainable inputs we have available is just not big enough yet to make a difference**.”*

5.3.2.2 Location of mining operations

The second barrier element relates to the observation made by the respondents that mining operations are not necessarily located in areas with the best renewable energy resources. The respondents pointed out that wind energy, which is considered the more mature renewable energy technology, is mostly only available in the coastal areas in South Africa. Most mines are located inland, which thus discounts wind as an option. Even when considering solar PV, the respondents suggested that mining operations are not necessarily located in the best areas with respect to solar insolation.

Respondent 4 hinted that mining operations are not necessarily located in areas that have the best renewable energy sources: *“I think it’s **the ability to put the best renewable in the best place which might not be on your site**. So I don’t know if you know, Company X [company name removed for anonymity], for example, are looking hard to put solar onto its sites. **My own view is that’s hardly the right place. The sun is not necessarily the best but the barrier is wheeling from A to B**.”*

Respondent 1 also commented on the locations of mines relative to those of renewable energy sources: *“**The solar parks that are being built in the Northern Cape,** they still have to be injected into the grid, see… **so to a miner you have not really taken away the issue of transmission line reliability to mine because they are not very close to the mines over there**.”*

Two of the respondents spoke about the suitability of wind as a renewable energy source for mining. Respondent 1 suggested that wind is located in the coastal areas relative to the location of their operations: “***Wind has its problems of resource constraints in that it is available mostly in South Africa on the coast, coastal areas.** This is large-scale wind, so one constraint…that we have to jump over is the resource mapping.”*

Respondent 9 simply expressed the view that wind is not viable in the area where their mines are located: *"We have considered wind, solar, biomass. We have got turbines running, that is renewable energy.* ***Wind doesn't make sense here****."*

5.3.2.3 Conclusion for Proposition 1.2

The findings support the proposition that the inadequacy of supply and location of mines are barriers that contribute to the low penetration of renewable energy in the mining industry. However, the findings in this study could not conclusively identify this barrier as being significant. Two barrier elements were identified that can be attributed to the inadequacy of supply and location of mines:

i) The quantities of biomass available are not sufficient to make it a viable energy source for mining operations.
ii) Mining operations are not located in the areas with the best renewable energy resources.

5.3.3 Proposition 1.3: Technology maturity

The following proposition was tested:

Proposition 1.3 Technology maturity – storage technology is not yet commercially proven and still very expensive.

The code occurrence for the barrier "technology maturity" is shown in Table 5-10, ordered from highest to lowest. In total, nine quotes were coded for "technology maturity". Only six respondents indicated that technology maturity of mines was a barrier to renewable energy penetration.

Table 5-10 "Technology maturity" code occurrence – ordered by occurrence

Respondent	6	2	3	5	7	9	1	4	8	10	Total
Technology maturity	4	1	1	1	1	1	0	0	0	0	9

Table 5-11 shows the share of voice of quotes for the barrier "technology maturity" for each respondent, ordered from highest to lowest. Over the course of the interviews, this barrier was given a share of voice of below 0.9%, which is lower than the average of 1.39% for all the barriers. On the basis of the criteria described in Section 4.7.4, the findings suggest that the respondents do not consider technology maturity to be a significant barrier.

Table 5-11 "Technology maturity" code by share of voice – ordered by relative count

Respondent	**9**	**7**	**6**	**3**	**5**	**2**	**1**	**4**	**8**	**10**	**Total**
Technology maturity – word count	66	89	127	31	34	27	0	0	0	0	374
Interviewee word count	1841	4761	7247	4494	6008	6018	2967	3704	1995	2620	41655
Relative count (%)	3.6	1.9	1.8	0.7	0.6	0.4	0.0	0.0	0.0	0.0	0.9

Two main themes (barrier elements) emerged around Proposition 1.3 from the interviews: i) battery technology not yet mature and expensive; and ii) small improvements in solar PV conversion efficiency. Quotes that provide evidence of these two barrier elements are provided in Sections 5.3.3.1 and 5.3.3.2.

5.3.3.1 Battery storage technology not yet mature and expensive

Three of the respondents pointed out that battery storage technology is still too expensive. Respondent 3 explained that they considered storage for a mine and the associated mine village located in a remote with no access to the grid: *"…you would battle to store sufficient energy* ***even … with battery storage to run the village at night. When we went down that road, it just became very costly.****"*

Respondent 5 pointed out that, although there were advances in battery technology, the costs were still too high: *"I* ***mean battery storage has also come a long way****…****I think technically it's there, but it's not economical currently how it operates****."*

Respondent 9 raised a similar point in pointing out the inability to store enough energy using batter storage technology: *"You can't be completely independent from Eskom just because of the amount of energy you use. Actually, I checked a while back,* ***the biggest plant currently in the world that is currently being put up in Dubai will not be sufficient to supply our mining operations*** *[located in one mining complex]* ***with that. [Even] if you had battery storage in[stalled], it will not be sufficient to supply the whole of the mining complex****."*

5.3.3.2 Small improvements in solar photovoltaic technology conversion efficiency

Two respondents pointed out that the conversion efficiency of solar PV panels had not improved significantly. Respondent 6 pointed out the incremental progress on conversion efficiency: *"The bit that hasn't quite shifted with PV, and I am just harping on*

PV, is the conversion, ***the conversion of sunlight into electrical energy: five years ago it was maybe 10%, now it's only maybe 22%. It hasn't been phenomenal****."*

Respondent 7 suggested that, at some stage, renewable energy technologies are due for a disruptive innovation that will improve the conversion efficiency: *"But what I also think is, you get these little advancements in renewables. You know panels are becoming a bit more efficient but at some stage somebody will come with a disruptive innovation that is going to transform not necessarily solar, not necessarily wind, not necessarily biogas or whatever, but one of those technologies or maybe more of them and we are going to jump* ***from a 20% efficiency instead of going 20, 20.5, 22, 24 and hanging around there,*** *we may go to 40 or 60 or whatever."*

5.3.3.3 Conclusion for Proposition 1.3

The findings support the proposition that the inadequacy of supply and location of mines are barriers that contribute to the low penetration of renewable energy in the mining industry. However, the findings in this study could not conclusively identify this barrier as being significant. Two barrier elements were identified that can be attributed to technology maturity:

i) Battery storage technology has not yet matured and is still too expensive.
ii) Small improvements in solar PV conversion efficiency.

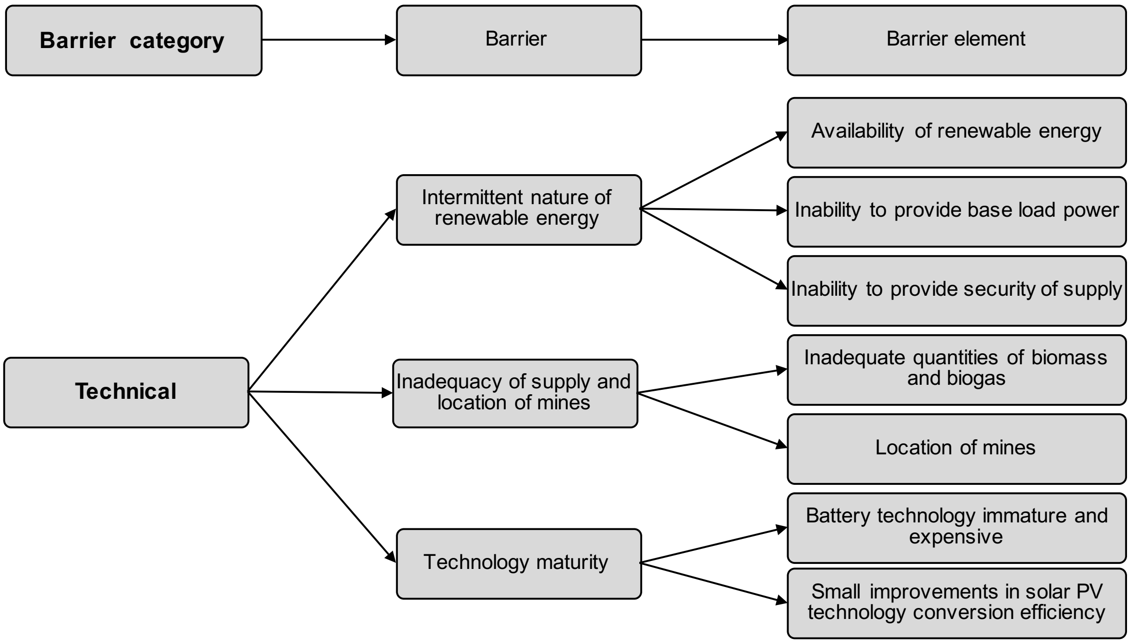
The added cost of installing battery storage technology further places a barrier on the adoption of renewable energy.

5.3.4 Conclusion on technical barriers

The results presented in Sections 5.3.1 to 5.3.3 show that renewable energy faces technical barriers within the mining industry. The technical barriers and the barrier elements from the results are shown in Figure 5-3 Technical barriers and the associated barrier elements for mining. As a consequence of the technical barriers that have been identified, mining companies view the role of renewable energy as supplementary power.

The biggest challenge renewable energy faces in mining is that it is intermittent in nature. It is not able to provide mining with continuous supply of power, which is essential for mining operations that operate on a continuous basis. Mining companies are reluctant to adopt renewable energy as it is not able to supply mining with base-load power nor offer security of supply. The added cost of installing battery storage technology, as a solution to intermittency, further places a barrier on the adoption of renewable energy.

Figure 5-3 Technical barriers and the associated barrier elements for mining



Turning to inadequacy of supply and location of mines, there is insufficient quantities of biomass and biogas to make it a viable energy source for mining operations. The fact that mining operations are not located in the areas with the best renewable energy resources further contributes to the low penetration of renewable energy.

5.4 Proposition 2: Economic and financial barriers

The results for the four economic and financial barriers are presented below.

5.4.1 Proposition 2.1: Capital constraints

The following proposition was tested:

Proposition 2.1 Capital constraints – spending priorities on production and efficiency-related projects means that renewable energy is not able to compete with the limited capital available for stay-in-business projects.

The code occurrence for the code “capital constraints” is shown in Table 5-12, ordered from highest to lowest. In total, ten quotes were coded under the barrier “capital constraints”. Only six of the respondents identified “capital constraints” as a barrier.

Table 5-12 "Capital constraints" code occurrence – ordered by occurrence

Respondent	7	4	9	2	5	8	1	3	6	10	Total
Capital constraints	3	2	2	1	1	1	0	0	0	0	10

Table 5-13 shows the share of voice of quotes for the barrier "capital constraints" for each respondent, ordered from highest to lowest. Over the course of the interviews, the capital constraints barrier was given a share of voice of 1.32%, which is lower than the average of 1.39% for all the barriers. On the basis of the criteria described in Section 4.7.4, the findings suggest that the respondents do not consider capital constraints to be a significant barrier.

Table 5-13 "Capital constraints" code by share of voice – ordered by relative count

Respondent	8	7	9	2	4	5	1	3	6	10	Total
Capital constraint –word count	101	231	79	71	30	39	0	0	0	0	551
Interviewee word count	1995	4761	1841	6018	3704	6008	2967	4494	7247	2620	41655
Relative count (%)	5.1	4.9	4.3	1.2	0.8	0.6	0.0	0.0	0.0	0.0	1.3

Two main themes (barrier elements) emerged around Proposition 2.1 from the interviews, namely: i) prioritisation of capital for projects related to the core business; and ii) the impact of low commodity prices on capital allocation. Quotes that provide evidence of the two themes (barrier elements) identified are provide Sections 5.4.1.1 and 5.4.1.2.

5.4.1.1 Prioritisation of capital for projects related to core business

The respondents suggested that mining companies would prioritise the allocation of capital to projects that addressed the requirements of their core (mining) business, such as production- and efficiency-related projects. These provide a better return on investment than renewable energy projects and improve the mining company's production volumes. Thus, renewable energy projects are not able to compete with these projects. The following quotes provide evidence of this:

Respondent 5: *"…**from a mining company perspective, your capital is competing with your other capital projects and generally the renewable energy project has a much lower IRR [internal rate of return] and a longer payback so it might not be considered feasible for the company.**"*

Respondent 9: "...*that upfront cost is just such that if you want to put up a significant plant…,* ***the company will never spend that capital on a solar plant. There is other stuff, production and just keeping places running, that will take up that capital****."*

Respondent 7 provided a summary of why the company directors had chosen not to invest in a renewable energy project they had developed: *"**The reason why we didn't invest, according to the directors (**the response they gave to me when I did the presentation) was: we have a certain amount of capital we can invest.* ***If we invest that capital in a renewable energy project, we get a certain return****.* ***And there is certain risks there.*** *If we invest it in a mining project, the right mining project, we have a certain return and a certain risk. Now in their opinion at that stage, it is the same choices you make when you take money. Do you put it in the bank at 4% interest, do you invest it in equities and maybe you can get 20%? It's the same thing.* ***They said they can take the amount of capital that we had and rather invest it in a mining project and get better returns on that than investing it in a renewable project****."*

5.4.1.2 Impact of low commodity prices on capital allocation

Three respondents further suggested that, as a consequence of the current low commodity prices, capital was even more constrained and thus renewable energy projects are not even considered. The following quotes provide evidence of this: Respondent 4: *"**I think the current downturn in resources has meant it is way out of everyone's mind to spend money on renewables**."*

Respondent 7 further emphasised the impact of the low commodity prices with the following two quotes: "*It is going tough in the mining industry at the moment. There is no spare capital around. Not even in iron ore when we did very well for a long time." and "****...in the past it was difficult to motivate or impossible to motivate a renewable [energy project] to the company when we actually had money. Now we don't have money. Income stream is less so we are trying to save more money so it is just a further barrier****."*

Respondent 9: *"**I believe that the commodity price, if it goes down, more focus will be placed on capital that will be spent towards production…Capital just gets more constrained**."*

Respondent 8 contradicted the other respondents, instead suggesting that the economic downturn may actually have a positive influence on the penetration of renewable energy as mining companies look for cheaper alternative sources of energy: *"**I think the downturn actually started opening people's eyes because if you are a conservative***

***mining executive and you are making a lot of money, you think you are already doing well and why change the recipe**. While where we are now where iron ore is not profitable anymore, it was one of the best commodities five years ago, coal and many other things, it becomes a challenge to say do I have a sustainable business. So **I think the downturn really started opening some thought processes and eyes in terms of all these disruptive technologies** and where things are going."*

5.4.1.3 Conclusion for Proposition 2.1

The findings support the proposition that capital constraints are a barrier that contributes to the low penetration of renewable energy in the mining industry. However, the findings in this study could not conclusively identify this barrier as being significant. Two barrier elements were identified that can be attributed to technology maturity:

i) Prioritisation of capital for projects related to the core business.
ii) The impact of low commodity prices on capital allocation.

Renewable energy projects are not able to compete for capital with production- and efficiency-related projects as these projects have better returns, with the added benefit of increasing the mining company's production volumes. Furthermore, as a consequence of the current low commodity prices, capital was even more constrained and thus renewable energy projects are pushed lower in the allocation process or not even considered at all.

5.4.2 Proposition 2.2: Business case

The following proposition was tested:

Proposition 2.2 Business case – high capital costs of renewable energy and the long payback periods makes them not feasible for mining operations.

The code occurrence for the code "business case" is shown in Table 5-14, ordered from highest to lowest. In total, 22 quotes were coded under the barrier "business case". Significantly, all ten respondents identified "business case" as a barrier. Six respondents had two or more attributed quotes while the other four had one quote each.

Table 5-14 "Business case" code occurrence – ordered by occurrence

Respondent	7	9	2	3	5	6	1	4	8	10	Total
Business case	7	3	2	2	2	2	1	1	1	1	22

Table 5-15 shows the share of voice of quotes for the barrier "business case" for each respondent, ordered from highest to lowest. Eight respondents gave the "business case" barrier a share of voice of at least 1% during the interviews. Over the course of the interviews conducted, the business case barrier was given a share of voice of 2.5%, which is the fifth highest of all the interviews (as shown in Table 5-4). On the basis of the criteria described in Section 4.7.4, the findings suggest that this is a significant barrier.

Table 5-15 "Business case" code by share of voice – ordered by relative count

Respondent	9	8	7	1	10	5	6	2	3	4	Total
Business case – word count	122	132	266	85	46	103	121	97	47	27	1046
Interviewee word count	1841	1995	4761	2967	2620	6008	7247	6018	4494	3704	41655
Relative count (%)	6.6	6.6	5.6	2.9	1.8	1.7	1.7	1.6	1.0	0.7	2.5

5.4.2.1 Lack of a compelling business case

In offering the business case proposition, the barrier elements already identified were: i) high capital cost; ii) long payback periods; and iii) low return on investment. Therefore, when respondents mentioned any of these barrier elements as challenges, it was taken that they were referring to the business case proposition (in part or wholly). The following quotations provide evidence of the difficulty to develop a viable business case for renewable energy in mining.

Respondent 2 identified the long payback period and hurdle rate (the required minimum return for projects by the company) as challenges in motivating renewable energy projects: *"Coupled with that … **the long payment period is an issue**. The fact that a typical power project is an eight-year period or something at this stage, it's very unattractive. **It doesn't meet the hurdle rate**."*

Similarly, Respondent 6 identified payback period, hurdle rates, as well as net present value (NPV) as challenges in motivating for renewable energy: *"If I had to think about what is the barrier to implementing a project, I think **the first thing is it has to make business sense**. So, what is the payback, what hurdle rates can you use, and on a levelised cost of electricity basis, taking in [to account] the intermittency in supply over the life of that project, I am actually going to save money and it is going to give me a positive NPV."*

Respondent 3 explained that the two studies they undertook to investigate renewable energy projects did not yield a compelling business case: *"…**the NPV was just not particularly good** and it is because of the tariffs that they charge."* and *"**So I think the biggest single barrier is the right financial regime** or if I say regime, model that's going to either suggest that it is viable or isn't viable."*

Respondent 7 stated that the business case was not yet compelling when compared with Eskom electricity prices: *"So in my opinion, **the business case is just not solid enough** because to assume that Eskom will give you a 20% increase year-on-year and …yes, they apply for it, but they never get it…"*

Respondent 7 then proceeded to make the link between high capital costs and other aspects of the business case that make it difficult to justify renewable energy: *"So the capital. I mean yes, it is great, the fuel source is for free and all that, **but for some reason renewables are just capital-intensive in the beginning and I don't think people want to take the risk yet of putting the capital there: the capital must come down**."* Respondent 7 then further explained that mining companies prefer short payback periods: *"**Capital, high capital cost. With that, goes long payback periods.** Some people will say to you, well maybe its three years. **In the mining environment they want to pay something back in six months and then make money, lots of it**."*

Respondent 8 succinctly explained that mining companies expect a high IRR from their investments, which renewable energy cannot offer: *"**So I think the real golden rule in mining is, don't start any new operation if you cannot be in the bottom quartile of the cost curve of your specific commodity. That leads to a thinking where mining companies want to have typically 25% nominal after tax IRR's for a mining operation. You don't get that out of a renewable energy project. You typically get a 14 to 16% return.***

5.4.2.2 Conclusion for Proposition 2.2

The findings support the proposition that mining companies are not able to develop a viable business case for renewable energy. The lack of a viable business case is a significant contributor to the low penetration of renewable energy in the mining industry. The factors that contribute to the difficulty in developing a viable business case are:

i) The high capital costs of renewable energy projects.

ii) Long payback periods as a result of the high capital costs.

iii) Renewable energy projects have a lower return on investment when compared to other alternative investments for mining companies, such as production and efficiency projects.

These factors do not meet mining companies' expectations and thus make renewable energy projects unattractive for mining companies.

5.4.3 Proposition 2.3: Risk perception

The following proposition was tested:

Proposition 2.3 Risk perception – the perception that renewable energy is a high-risk investment, requiring a higher rate of return, when compared with other capital projects, makes it unattractive for mining operations.

The code occurrence for the code "risk perception" is shown in Table 5-16, ordered from highest to lowest. In total, five quotes were coded under the barrier "risk perception". Only three respondents identified "risk perception" as a barrier.

Table 5-16 "Risk perception" code occurrence – ordered by occurrence

Respondent	7	2	8	1	3	4	5	6	9	10	Total
Risk perception	3	1	1	0	0	0	0	0	0	0	5

Table 5-17 shows the share of voice of quotes for the barrier "risk perception" for each respondent, ordered from highest to lowest. Over the course of the interviews conducted, the share of voice for the risk perception barrier was only 0.5%, which is lower than the average of 1.39% for all the barriers. On the basis of the criteria described in Section 4.7.4, the findings suggest that the respondents do not consider risk perception to be a significant barrier.

Table 5-17 "Risk perception" code by share of voice – ordered by relative count

Respondent	7	8	2	1	3	4	5	6	9	10	Total
Risk perception – word count	164	34	15	0	0	0	0	0	0	0	213
Interviewee word count	4761	1995	6018	2967	4494	3704	6008	7247	1841	2620	41655
Relative count (%)	3.4	1.7	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5

5.4.3.1 Risks associated with investments in renewable energy

The respondents offered varying reasons for why renewable energy projects are perceived as high risk. The high capital cost was frequently mentioned as the underlying reason. Respondent 2 believes that a lack of knowledge leads to the misconception that because renewable energy is expensive it must also be high risk "…***it's largely knowledge-based that people think it's expensive; people think it's a high risk***."

Respondent 7 implied that renewable energy is high risk and mining could not afford to invest significant amounts of capital in a high-risk investment: *"I mean, yes, it is great the fuel source is for free and all that, but for some reason renewables are just capital-intensive in the beginning and* ***I don't think people want to take the risk yet of putting the capital there: the capital must come down****."* Respondent 7 further emphasised that: *"**So the risk versus the cost I have to incur, is just not there yet**."*

5.4.3.2 Conclusion for Proposition 2.3

The findings support the proposition that risk perception is a barrier that contributes to the low penetration of renewable energy in the mining industry. However, the findings in this study could not conclusively identify this barrier as being significant. The high capital cost of renewable energy is what leads to the perception that it is a risky investment.

5.4.4 Proposition 2.4: Electricity pricing

The following proposition was tested:

Proposition 2.4 Electricity pricing – electricity prices from Eskom are lower than renewable energy prices, even in instances where IPPs are used.

The code occurrence for the code "electricity pricing" is shown in Table 5-18, ordered from highest to lowest. In total, 27 quotes were coded under the barrier "electricity pricing". Nine of the ten respondents identified "electricity pricing" as a barrier.

Table 5-18 "Electricity pricing" code occurrence – ordered by occurrence

Respondent	9	7	6	3	5	10	1	2	8	4	Total
Electricity pricing	8	5	4	3	2	2	1	1	1	0	27

Table 5-19 shows the share of voice of quotes for the barrier "electricity pricing" for each respondent, ordered from highest to lowest. Over the course of the interviews conducted, the electricity pricing barrier was given a share of voice of 4.1%, which is the second highest of all the interviews (as shown in Table 5-4). On the basis of the criteria described in Section 4.7.4, the findings suggest that this is a significant barrier.

Table 5-19 "Electricity pricing" code by share of voice – ordered by relative count

Respondent	9	7	8	10	1	6	5	3	2	4	Total
Electricity pricing – word count	355	332	117	116	117	255	189	125	97	0	1703
Interviewee word count	1841	4761	1995	2620	2967	7247	6008	4494	6018	3704	41655
Relative count (%)	19.3	7.0	5.9	4.4	3.9	3.5	3.1	2.8	1.6	0.0	4.1

Two main themes (barrier elements) emerged around Proposition 2.4 from the interviews, namely: i) utility electricity prices are currently cheaper than renewable energy; and ii) uncertainty in predicting when renewable energy tariffs will reach grid parity. Quotes that provide evidence of the three themes (barrier elements) identified are provided in Sections 5.4.4.1 and 5.4.4.2.

5.4.4.1 Utility electricity prices are currently cheaper than renewable energy

The respondents stated that the current Eskom prices are cheaper than tariffs from renewable energy projects. This makes it impossible to motivate a business case for investing in renewable energy projects. The following quotes provide evidence of this:

Respondent 2: *"There is another factor that is very important in mining specifically.* ***[It] is that we still have…relatively cheap Eskom utility electricity and simply from a business point of view, if we can buy electricity from Eskom at 70 cents a kilowatt/hour there is a very poor business case of buying renewable power at 75, 80, 85, 90 cents whatever. It simply costs more, why do it.*** *We would be wasting our shareholder's money if we use anything else than Eskom."*

Respondent 3 explained that the two studies they conducted with two renewable energy suppliers both concluded that the Eskom tariff was still cheaper: *"So, I mean that is what both, in fact all, of the projects have been looking at and* ***the conclusion that they have come to has been similar. You will not necessarily do it now but you will do it when the tariff gets to the right value.****"* Respondent 3 further added: *"****But both exercises, the one done by Supplier A and the one done by Supplier B*** *[company names removed to maintain anonymity]* ***said that the tariff still wasn't at the right level to go for it right now. You don't want to be losing money necessarily to start with.****"*

Respondent 5: *"Firstly, if we are talking about grid-connected mines that are connected to Eskom,* ***Eskom power is still cheap****. If you work out your levelised costs. I mean even solar PV, you can't work on an average cost because you supply power during standard time so you don't even bring in the peak times into that calculation. So to really make PV work, you have to look at the standard tariff which it struggles to maintain. So it's the cost, you know your actual levelised cost of energy that you will be paying. Although it gives you something predictable* ***I think until we reach that point where we can say, well now this is cheaper than Eskom during this time, only then it will maybe be enough incentive to really look at it****."*

Respondent 7: "*…****that is your first major challenge, is why would I buy power at R1.80 per kilowatt hour, let's say for some PV solution if I can get it at 64 cents per kilowatt hour*** *especially if I have that 64 cents per kilowatt hour grid connection available, fairly stable, yes, I have to cut back 10% now and then but it is still, you know, for now almost seven months we haven't seen load shedding or load curtailment."*

5.4.4.2 Uncertainty in predicting when grid parity will be reached

The respondents further indicated that there was a great degree of uncertainty in predicting when renewable energy tariffs will reach grid parity. In particular, the respondents raised concerns about the assumptions that are often used in projecting future Eskom prices. This uncertainty makes it difficult to build a business case for investment in renewable energy projects. The following quotes provide evidence of this.

Respondent 5: *"****The thing that makes it difficult as well is we don't have a clear price path in terms of where Eskom is going.*** *I mean we estimate it's going to be CPI [consumer price index] plus 3 or 4% for the next 10 years probably but I mean* ***there is no certainty in that****.*"

Respondent 6 argued that the fact that there is political interference when the regulator determines the electricity price to ensure that the ordinary consumer is protected from unaffordable prices made it difficult to predict future prices: "*When you look at levelised cost of electricity and if you are talking South Africa, then the fuzzy area is what is the Eskom price." "So I think the levelised cost of electricity is an issue and* ***the issue is not so much with the price of renewables, it's the issue with the insertion of a political intervention on the pricing.****"*

Respondent 7 indicated that management would wait until renewable energy reached grid parity before they take action: *"So you know what, I think it is still a matter of let's wait and see because at this stage the cost is not* ***to assume that it will cut each other***

***in … three years' time and then they will start paying less, that assumption I don't think the big brass is willing to take that risk yet**.”* Respondent 7 concluded that: *“**The problem is at this stage it is projections and when we think so they don't want to take the risk but I think once that time has come and it's here people will more easily invest in renewables**.”*

Respondent 9 raised a concern about the unrealistic projection of future Eskom prices presented by suppliers: “*… **they make the Eskom projections unrealistically high just to show saving** and then I put my own projections of the Eskom price and then see the lines never cross. These guys, some got different models than some.”*

Respondent 8 contradicted the other respondents and suggested that mining companies have not done their due diligence to understand renewable energy projects: *“my personal opinion, is that most mining executives and non-executive directors of mining companies in South Africa has moved through life with closed eyes and has not followed their fiduciary duty in really looking at what is happening. **It is very clear that wind and solar in South Africa is cheaper than new coal and it is already cheaper than grid parity prices. For some reason they just don't see it.** But they lend their ears out to Eskom or politicians or whoever else, without really doing the work to understand what is happening and therefore continues to make the wrong decisions. And by the time they wake up, they have missed the window of opportunity.”*

5.4.4.3 Conclusion for Proposition 2.4

The findings support the proposition that the low electricity price is a barrier that contributes to the low penetration of renewable energy in the mining industry. The low electricity price is a significant contributor to the low penetration of renewable energy in the mining industry. There are two barrier elements that can be attributed to the intermittent nature of renewable energy:

i) Utility electricity prices are currently cheaper than renewable energy.
ii) Uncertainty in predicting when renewable energy tariffs will reach grid parity.

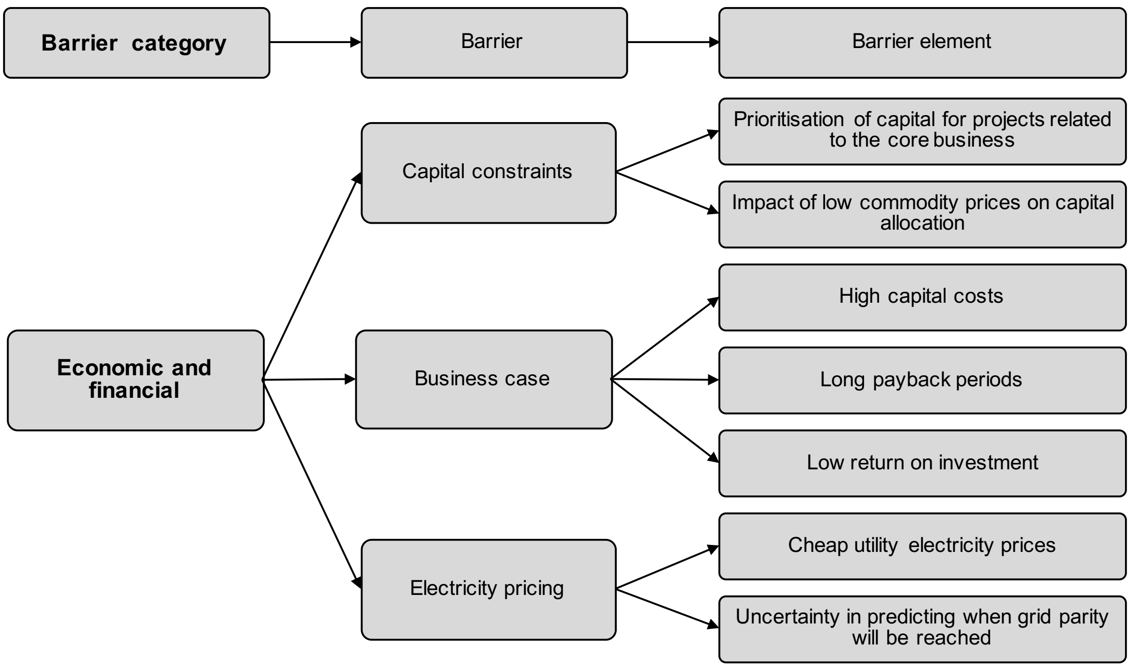
Eskom prices are currently lower than the tariffs offered by renewable energy projects and mining companies are not willing to pay a higher price for electricity. Ambiguity in projecting future Eskom prices makes it difficult to determine when renewable energy tariffs would reach grid parity. Consequently, mining companies are not willing to invest in renewable energy projects, and will rather wait, until prices reach grid parity. These two barrier elements make it difficult to motivate the business case to invest in renewable energy projects.

5.4.5 Conclusion on economic and financial barriers

The results presented in Sections 5.4.1 to 5.4.4 show that renewable energy does face economic and financial barriers within the mining industry. The economic and financial barriers and the associated barrier elements are shown in Figure 5-4. Owing to the high capital costs of renewable energy and the associated long payback periods and a low return on investment, mining companies find it difficult to develop a compelling business case for renewable energy projects. A further contributing factor to the unfeasible business case is the Eskom tariffs for electricity which are currently lower than those offered by renewable energy projects. A complicating factor in the consideration of renewable energy is that there is ambiguity in projecting future Eskom prices, which makes it difficult to determine when renewable energy tariffs would reach grid parity. Consequently, mining companies are not willing to invest in renewable energy projects, and will rather wait, until prices reach grid parity.

Turning to the capital constraints barrier, renewable energy projects are not able to compete for capital with production- and efficiency-related projects as these projects have better returns. These projects have the added benefit of increasing the mining company's production volumes. As a result of the current low commodity prices, the availability of capital is even more constrained, so renewable energy projects are pushed lower in the allocation process or not even considered at all.

Figure 5-4 Economic and financial barriers and the associated barrier elements for mining



5.5 Proposition 3: Institutional barriers

The results for the five institutional barriers are presented below.

5.5.1 Proposition 3.1: Lack of supportive policy

The following proposition was tested:

Proposition 3.1 Lack of supportive policy – there is no explicit national policy or regulation that encourages renewable energy use in mining.

The code occurrence for the code "lack of supportive policy" is shown in Table 5-20, ordered from highest to lowest. In total, 20 quotes were coded under this barrier. Nine respondents identified "lack of supportive policy" as a barrier.

Table 5-20 "Lack of supportive policy" code occurrence – ordered by occurrence

Respondent	**4**	**5**	**6**	**1**	**2**	**7**	**8**	**10**	**9**	**3**	**Total**
Lack of supportive policy	3	3	3	2	2	2	2	2	1	0	20

Table 5-21 shows the share of voice of quotes for the barrier "lack of supportive policy" for each respondent, ordered from highest to lowest. Over the course of the interviews conducted during the research, the intermittent nature of renewable energy barrier was given a share of voice of 2.8% by the respondents, which is the fourth highest of all the interviews (as shown in Table 5-4). On the basis of the criteria described in Section 4.7.4, the findings suggest that this is a significant barrier.

Table 5-21 "Lack of supportive policy" code by share of voice – ordered by relative count

Respondent	**8**	**4**	**9**	**5**	**10**	**1**	**6**	**7**	**2**	**3**	**Total**
Lack of supportive policy – word count	150	182	89	249	83	86	203	113	27	0	1182
Interviewee word count	1995	3704	1841	6008	2620	2967	7247	4761	6018	4494	41655
Relative count (%)	7.5	4.9	4.8	4.1	3.2	2.9	2.8	2.4	0.4	0.0	2.8

Three main themes (barrier elements) emerged around Proposition 3.1 from the interviews, namely: i) lack of government support; ii) lack of incentives; and iii) carbon tax. Quotes that provide evidence of the three themes (barrier elements) identified are provided in Sections 5.5.1.1 to 5.5.1.3.

5.5.1.1 Lack of government support

The respondents suggested that there is an apparent lack of willingness from government to support investment in privately owned (and own consumption) renewable energy projects. The respondents said this was evident though the absence of a coherent policy and regulatory environment. The following quotes provide evidence of this:

Respondent 4: *"**There is government support for [state-]owned renewables but not necessarily non-state renewables, if I can use those words**."* Respondent 4 further stated: *"**I think the government is not falling over to encourage it because they potentially but not necessarily lose taxes that are levied on transmission lines.** So, like funding for the indigent electrification for the poor and so on and so on, **I don't think we have a specifically strong enabling environment for renewables but it is certainly not impossible, it has been done.**"*

Respondent 4 further added that a challenge may arise in the event that a company wanted to build their own renewable energy project because they would need approval from the regulator, National Energy Regulator of South Africa (NERSA), and the Minister of Energy: *"I don't know if the DOE [Department of Energy] is supportive … in the IRP process. **In theory, if you want to build your own renewables you have to get the Minister's approval. I personally asked NERSA, is that going to be a problem and they replied no. But when it happens let's see what happens.** So I suspect there is a mental barrier there because people don't know when they apply, will they get it. I think it has become a perception that it will be difficult to get approvals for own generation. On site it probably is not a problem."*

Respondent 7: "*I think government has no clue what they are doing. I think they did try and get it going through the REFIT [Renewable Energy Feed-In Tariff] process and now we have got some guys going but, yes, there are people that have generation and wheeling arrangements … but they haven't facilitated this properly."* Respondent 7 further added that: *"So although they think they have stimulated the market and I think in the short term it was a good thing, **in the long term, the bigger picture is not there yet. To get private investors to come and do this, we need a whole different regulatory environment, a whole different way the country operates its electricity grid. It needs to change dramatically**."*

Respondent 8 pointed out that the confusion created by political infighting within government is an issue: *"…in South Africa specifically, we have got a massive challenge where the* ***Department of Energy has done excellent work in combination with National Treasury in setting up the IPP office*** *and according to the…1998 White Paper****,*** **[government]** ***is really promoting independent power producers. So we have got a lot of megawatts online that is cheaper than new coal, new nuclear, all of those things, but now it is hung up in a political fight between Treasury, Eskom, the DOE, and the Presidency…****"*

5.5.1.2 Lack of incentives

The respondents noted that there was a lack of incentives from government to encourage mining companies to adopt renewable energy. The following quotes provide evidence of this: Respondent 2: "*There is no incentive, at this stage, from the likes of NERSA."* Respondent 2 further pointed out that: *"**the whole tax/incentive regime for manufacturing and enabling these renewable power doesn't exist yet**."*

Respondent 5: *"**I think for renewables what is lacking is more incentive on implementing it**. I mean there is the tax rebates. We have accelerated depreciation over the three years for the capital equipment but I think mine capital, everything is over a year anyway or under a year. So I think there must be* ***a little bit more of incentive just to breach the gap between where Eskom is and where the renewable price is****. So just* ***a little bit of incentive just to make it viable to do something now****."*

Respondent 10: *"There are some incentives available for mining houses but it is very one-directional.* ***It is not incentive-enough for the mining house to invest because of the other factors that they are facing****."*

5.5.1.3 Carbon tax

Two respondents indicated that they believe that an introduction of a carbon tax will encourage mining companies to consider renewable energy. The following quotes provide evidence of this.

Respondent 5: *"There is no incentive to do that for us. So those are the kind of things that make it difficult to sell these things because a lot of the time it is just better to do nothing because then there is no risk and there is no money spent and* ***I think as soon as carbon tax is implemented there will be a lot more…bigger focus, especially when the first six months comes up and you have to pay provisional tax on your emissions.****"*

Respondent 9: *"**The carbon tax is pushing us more towards, well, that is just making renewable more competitive**…So those things do assist, yes…"*

Respondent 6 contradicted the other respondents and suggested that carbon tax would not be an effective mechanism to support adoption of renewable energy: *"**The carbon price will give you that signal but the amount of volatility in the carbon price and to say that is a deterrent, you know I don't think it is a deterrent**…But to say, the fact that we don't have a carbon price is a deterrent, **I would argue that places that have a carbon price, it has been so volatile [that] to say that they have really benefitted because there was a carbon price and they have implemented technology because of the carbon price, I don't know.**"*

5.5.1.4 Conclusion for Proposition 3.1

The findings support the proposition that the lack of supportive policy is a barrier that contributes to the low penetration of renewable energy in the mining industry. The lack of supportive policy is a significant contributor to the low penetration of renewable energy in the mining industry. There are three barrier elements that can be attributed to the lack of supportive policy:

i) Lack of government support.
ii) Lack of incentives.
iii) Carbon tax.

It appears as if the South African government is unwilling to support investment into privately owned renewable energy projects for own consumption (not delivered to the grid). Consequently, there are no incentives in place to encourage the adoption of renewable energy projects by mining. The introduction of carbon tax is likely to encourage mining to consider investing in renewable energy.

5.5.2 Proposition 3.2: Lack of a framework to allow feeding into the grid

The following proposition was tested:

Proposition 3.2 Lack of a framework to allow feeding into the grid – current policy and regulatory framework does not allow for the sale of excess electricity back into the grid.

The code occurrence for the code "lack of a framework to allow feeding into the grid" is shown in Table 5-22, ordered from highest to lowest. In total, only three quotes were coded under this barrier. Only three respondents identified "lack of a framework to allow feeding into the grid" as a barrier.

Table 5-22 "Lack of a framework to allow feeding into the grid" code occurrence – ordered by occurrence

Respondent	1	2	10	3	4	5	6	7	8	9	Total
Lack of framework to allow feeding into the grid	1	1	1	0	0	0	0	0	0	0	3

Table 5-23 shows the share of voice of quotes for the barrier "lack of a framework to allow feeding into the grid" for each respondent, ordered from highest to lowest. Over the course of the interviews, the lack of a framework to allow feeding into the grid barrier was given a share of voice of 0.8%, which is lower than the average of 1.39% for all the barriers. On the basis of the criteria described in Section 4.7.4, the findings suggest that the respondents do not consider the lack of framework to allow feeding into the grid to be a significant barrier.

Table 5-23 "Lack of a framework to allow feeding into the grid" code by share of voice – ordered by relative count

Respondent	1	10	2	3	4	5	6	7	8	9	Total
Lack of framework to allow feeding into the grid	230	69	39	0	0	0	0	0	0	0	338
Interviewee word count	2967	2620	6018	4494	3704	6008	7247	4761	1995	1841	41655
Relative count (%)	7.8	2.6	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.8

5.5.2.1 Inability to sell excess electricity into the grid

The following quotes provide evidence of the respondents' views on the inability to sell excess electricity into the grid and its impact on adoption renewable energy.

Respondent 1: *"So in the case of a captive PPA, as we call it, which is a private PPA, you have to be thinking differently because we are not a reseller of – we are not going to resell the electricity, we are going to use it.* ***What happens when we don't use it and your product as an IPP cannot be rejected on our side****…You start looking at net metering and wheeling arrangements and then you start bringing the Eskom grid into the discussion.* ***You start looking for back-up power purchase agreements with other clients, you start looking for energy banking,*** *Eskom calls it energy banking so you* *supply back to Eskom but they don't necessarily pay you, you accumulate credits for that and they run a recon in a year or so for that component.* ***So those…because they are policy issues and they are systematic in the industry, they will take a very, very long time, so what people tend to do is they tend to size their private assets (as in the power plants) to be within what they can consume at all times****."*

Respondent 2: *"In fact it's an institutional barrier and in South Africa it's a regulatory barrier still****. I can't generate electricity and sell it to you legally, I just can't. The industry doesn't allow it, well the law doesn't allow it****."*

Respondent 10: *"****The few cons that I would refer to is, the negative side of the ability to generate energy and if you are not in a position to utilise it yourself, there is only one player who will buy it and that is a parastatal. That is a definitive negative aspect because Eskom are trying to be a player and the referee in this game. That is a significant constraint.****"*

5.5.2.2 Conclusion for Proposition 3.2

The findings support the proposition that the lack of a framework to allow feeding into the grid is a barrier that contributes to the low penetration of renewable energy in the mining industry. However, the findings in this study could not conclusively identify this barrier as being significant. The risk of having excess electricity that cannot be consumed or sold into the grid, but yet mining companies are liable to pay for it as PPAs are on a take-or-pay basis, is a barrier that contributes to the low penetration of renewable energy in mining.

5.5.3 Proposition 3.3: Inability to use the grid

The following proposition was tested:

Proposition 3.3 Inability to use the grid – current policy does not encourage the wheeling of electricity from one point to another.

The code occurrence for the code "ability to use the grid" is shown in Table 5-24, ordered from highest to lowest. In total, there were 11 quotes coded under this barrier. Five respondents identified "ability to use the grid" as a barrier.

Table 5-24 "Inability to use the grid" code occurrence – ordered by occurrence

Respondent	4	1	9	7	10	2	3	5	6	8	Total
Inability to use the grid	5	2	2	1	1	0	0	0	0	0	11

Table 5-25 shows the share of voice of quotes for the barrier "ability to use the grid" for each respondent, ordered from highest to lowest. Over the course of the interviews, the capital constraints barrier was given a share of voice of 1.9%, which is higher than the average of 1.39% for all the barriers. On the basis of the criteria described in Section 4.7.4, the findings suggest that the respondents view this as a significant barrier.

Table 5-25 "Inability to use the grid" code by share of voice – ordered by relative count

Respondent	1	9	4	10	7	2	3	5	6	8	Total
Inability to use the grid – word	308	174	230	35	25	0	0	0	0	0	772
Interviewee word count	2967	1841	3704	2620	4761	6018	4494	6008	7247	1995	41 655
Relative count (%)	10.4	9.5	6.2	1.3	0.5	0.0	0.0	0.0	0.0	0.0	1.9

Two main themes (barrier elements) emerged around Proposition 3.3 from the interviews, namely: i) the cost of wheeling; and ii) the complexity and long times required to negotiate wheeling arrangements. Quotes that provide evidence of the three themes (barrier elements) identified are provided in Sections 5.5.3.1 and 5.5.3.2.

5.5.3.1 Costs of wheeling electricity

The respondents explained that the ability to use the grid to transfer electricity from one point to another (referred to as wheeling) would mean that mining companies would be able to wheel electricity from an IPP or renewable energy power plant that is located in another area to the point where they want use the electricity. This would mean that mining companies could invest in renewable energy projects that are located in areas with the best resources, or they could wheel excess electricity from one sister mine to another or to another party who can use it at the times that they are not able to use it. The following quotes provide evidence of the respondents' views on the costs of wheeling power and its impact on the penetration of renewable energy.

Respondent 1: *"…the solar parks that are being built in the Northern Cape, they still have to be injected into the grid see, so to a miner you have not really taken away the issue of transmission line reliability to mine because they are not very close to the mines over there and* ***you have not taken fully the issue of costs because there are system use costs which Eskom does not want us to say they are wheeling costs.****"*

Respondent 4: *"I would take you on a different road and say **the biggest technical barrier is wheeling power from A to B and that's actually not a technical barrier, it's more an accounting barrier and a need to use someone else's hardware**.*"

Respondent 4: *"The bigger barrier is wheeling Eskom through [municipality] to Eskom. Unlikely in an ABC Company [company name removed to maintain anonymity] situation but not impossible, but the unreliability of, unreliability is the wrong word. **The unknown of what will we get charged, what's the escalation.** They are currently escalating generation, transmission, and distribution tariffs equally and we are suggesting that's wrong. **So if you are wheeling, you get lumped with the same escalation as everyone else**."*

Respondent 9: "*We have had proposals or apparently some guys has managed to get it right where your solar farm is put up somewhere in Eastern Cape and you are basically buying that power so everything they put on the grid you pay them for it and it is basically credited by Eskom. They say there is stuff like that. **But then the price is not competitive because you are paying wheeling charges.**"*

5.5.3.2 Complexity and long times required to negotiate wheeling arrangements

Respondents also suggested that an additional challenge with trying to wheel electricity from one point to another is the complexity of the process as well as the time it takes to negotiate the wheeling arrangements with Eskom. The following quotes provide evidence of this. Respondent 4: *"I think NERSA are generally supportive of free access to the grid so I think the policy, government-wise, it actually exists but **I don't think it is that well implemented right now**,*" further adding that: *"**I think the complication is, we can access the grid, but there is this huge sort of time scale involved.**"*

Respondent 4: *"So **Eskom, as you know, will quote you 16 months to connect to the grid. So that's 16 months before you can start anything. 16 months, sometimes 18 months, two years just to get a quote. That in my mind is a huge barrier** for someone who wants to open a little coal mine, a pit, a little diamond mine, obviously not a deep level shaft because that's 10 years in the making."*

Respondent 7: *"**It still takes years to negotiate wheeling arrangements with Eskom. So although the mechanisms have been put in place, it has not been made easy**."*

Respondent 9: *"I believe if you want to put up a plant offsite and wheel it, it will never fly through. Not only because of the cost **but I think where Eskom will be involved and I***

don't think there is a procedure or framework in place for wheeling to yourself. That stuff has been going on for years and they don't really get to a point."

5.5.3.3 Conclusion for Proposition 3.3

The findings support the proposition that the inability to use the grid is a barrier that contributes to the low penetration of renewable energy in the mining industry. The inability to use the grid is a significant contributor to the low penetration of renewable energy in the mining industry. Two barrier elements were identified that can be attributed to technology maturity:

i) The cost of wheeling.

ii) The complexity and long times required to negotiate wheeling arrangements.

The costs associated with wheeling power are negatively impacting on considerations to invest in renewable energy projects. A further complication is the complex and protracted negotiation process with Eskom in order to conclude wheeling arrangements

5.5.4 Proposition 3.4: Grid connection costs

The following proposition was tested:

Proposition 3.4 Grid-connection costs – costs to connect to the grid are prohibitive.

None of the respondents interviewed identified "grid connection costs" as a barrier. The likely reason for this is that current mining operations already have a connection point to the grid. Any costs associated with upgrading the connection to connect renewable energy projects would not be as expensive as a new connection.

5.5.5 Proposition 3.5: Administrative processes

The following proposition was tested:

Proposition 3.5 Administrative – bureaucratic processes such as the environmental impact assessment (EIA) process create an administrative burden that ties up valuable resources.

The code occurrence for the code "administrative" is shown in Table 5-26, ordered from highest to lowest. In total, five quotes were coded under this barrier; four respondents identified "administrative" as a barrier.

Table 5-26 "Administrative" code occurrence – ordered by occurrence

Respondent	9	2	5	7	1	3	4	6	8	10	Total
Administrative	2	1	1	1	0	0	0	0	0	0	5

Over the course of the interviews, the capital constraints barrier was given a share of voice of 0.7%, which is lower than the average of 1.39% for all the barriers. On the basis of the criteria described in Section 4.7.4, the findings suggest that the respondents do not consider administrative processes to be a significant barrier.

Table 5-27 shows the share of voice of quotes for the barrier "administrative" for each respondent, ordered from highest to lowest. Over the course of the interviews, the capital constraints barrier was given a share of voice of 0.7%, which is lower than the average of 1.39% for all the barriers. On the basis of the criteria described in Section 4.7.4, the findings suggest that the respondents do not consider administrative processes to be a significant barrier.

Table 5-27 "Administrative" code by share of voice – ordered by relative count

Respondent	7	9	5	2	1	3	4	6	8	10	Total
Administrative – word count	140	34	73	39	0	0	0	0	0	0	286
Interviewee word count	4761	1841	6008	6018	2967	4494	3704	7247	1995	2620	41655
Relative count (%)	2.9	1.8	1.2	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.7

5.5.5.1 Time involved

The respondents were more concerned with time it takes to complete the EIA process, as evidenced by the following quotes: Respondent 2: *"…**if you have to do an EIA** for more than a 10 MW plant at this stage, **it will probably take you two years and that is just crazy**. You know, I think we are over-regulated."*

Respondent 5: *"**The thing that is kind of holding back is the time frame involved** because it does take a long time to do it and I mean, I think for us as a mining company and that, it's not something new so it might just be an amendment to our current EIA which we have or even if we have to go through the process, I don't think it's too foreign for us."*

Respondent 7: *"I don't think it will hinder as such. **I think it will just be another time-consuming** **[item].** So I think it will get done eventually, I think most renewable energy project get their environmental approvals but because government and **government institutions operate so inefficiently at this stage, everything takes longer**. If I just* *take how long it took the solar project to get to financial close because of environmental things that weren't in place here, not in place but I mean the applications are in but then they take three months to sign some agreement and then this and that.* ***Ultimately, it will get there but your project will be late. There is no way you can estimate their timelines accurately.*** *You will have to make provision for that, you will have to have enough money available for that."*

Respondent 9: *"**But with the time it takes for EIAs** and these things, now is the time to start."*

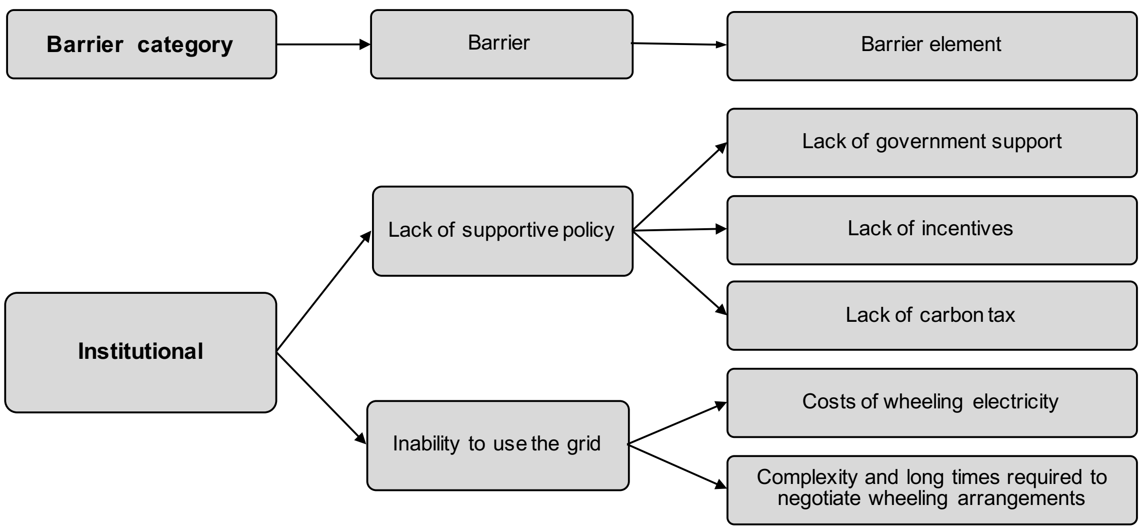
5.5.5.2 Conclusion on Proposition 3.5

The findings support the proposition that administrative processes are a barrier that contributes to the low penetration of renewable energy in the mining industry. However, the findings in this study could not conclusively identify this barrier as being significant. The time it takes to complete, and approve, the EIA process is a concern for mining companies and can discourage the investigation of the feasibility of renewable energy projects.

5.5.6 Conclusion on institutional barriers

The results presented in Sections 5.5.1 to 5.5.5 show that renewable energy does face institutional barriers within the mining industry. The institutional barriers and the associated barrier elements are shown in Figure 5-5.

Figure 5-5 Institutional barriers and the associated barrier elements for mining



The lack of a supportive policy is a significant barrier that contributes to the low penetration of renewable energy in the mining industry. It is apparent that there is a reluctance by the South African government to support investment into privately owned renewable energy projects that are for own consumption (not delivered to the grid). Furthermore, there are no incentives to encourage the adoption of renewable energy projects by mining. The delays in implementing the carbon tax is possibly hampering the investment in renewable energy projects.

The lack of access to the grid is a significant barrier. The real issue is that, the prohibitive wheeling costs impact negatively on considerations of investing in renewable energy projects. In addition, negotiating wheeling arrangements with Eskom is a complex process, which takes a long time to conclude agreements.

5.6 Proposition 4: Behavioural barriers

The results for the two behavioural barriers are presented below.

5.6.1 Proposition 4.1: Entrenched mindset

The following proposition was tested:

Proposition 4.1 Entrenched mindset – mining companies prefer grid-connected power and thus the mindset is that power generation does not form part of the core business of mining companies.

The code occurrence for the code “entrenched mindset” is shown in Table 5-28, ordered from highest to lowest. In total, 30 quotes were coded under this barrier. Interestingly, all ten respondents identified “entrenched mindset” as a barrier.

Table 5-28 “Entrenched mindset” code occurrence – ordered by occurrence

Respondent	4	3	5	8	6	7	9	10	1	2	Total
Behavioural	10	4	3	3	2	2	2	2	1	1	30

Table 5-29 shows the share of voice of quotes for the barrier “entrenched mindset” for each respondent, ordered from highest to lowest. Over the course of the interviews conducted during the research, the intermittent nature of renewable energy barrier was given a share of voice of 3.3% by the respondents, which is the third highest of all the interviews (as shown in Table 5-4). On the basis of the criteria described in Section 4.7.4, the findings suggest that this is a significant barrier.

Table 5-29 "Entrenched mindset" code by share of voice – ordered by relative count for each respondent

Respondent	8	4	9	10	5	7	3	6	1	2	Total
Behavioural	278	355	132	136	180	103	95	55	18	15	1367
Interviewee word count	1995	3704	1841	2620	6008	4761	4494	7247	2967	6018	41655
Relative count (%)	13.9	9.6	7.2	5.2	3.0	2.2	2.1	0.8	0.6	0.2	3.3

Three main themes (barrier elements) emerged around Proposition 1.1 from the interviews, namely: i) preference to connect to the grid; ii) focus on core business; and iii) the lack of innovation. Quotes that provide evidence of the three themes (barrier elements) identified are provided in Sections 5.6.1.1 to 5.6.1.3.

5.6.1.1 Preference for grid connection

Respondents indicated that mining companies prefer to obtain their electricity from the grid. The following quotes provide evidence of this entrenched mindset.

Respondent 1: *"…**in South Africa, I think if you have the grid, you don't want to disconnect from the grid**"*

Respondent 2: *"You will still have to be connected to the grid or you must have storage."*

Respondent 3 suggested that industry will always rely on the grid: *"So I don't think that you can frankly do without the utility"*, further adding that "*The **industry will never manage on anything other than a grid. Well, I don't think so**."* Respondent 3 further suggested that mining would never voluntarily generate their own electricity as long as there was a grid available: "***I don't think we would voluntarily generate our own power when it just depends on where you are but, if there is a utility there, then you know one would get connected to it** because generally those rates are cheaper than what you can do it yourself."*

Respondent 4 stated upfront that he has a bias towards the grid: "***So my thinking is all coloured grid first, everything else second.*** Respondent 4 indicated that he is not convinced that a renewable energy only source for energy is viable for mining: *"There is grid base versus localised* [in reference to a micro-grid based on renewable energy]*. **I am not persuaded that local power for big heavy mining projects is viable.**"* Respondent 4 further added that as long the utility company is state-owned, then the perception will remain that the utility will never fail: *"The boss I worked for 20 years ago told me Eskom will never let us down. That barrier, I think, is gone but I can tell you that* *perception pervades boardrooms and I am not talking South Africa, I am talking* ***generally companies will rely on state companies to never go bankrupt because the state never goes bankrupt****, it just borrows more."*

Respondent 9: ***"You can't be completely independent from Eskom just because of the amount of energy you use."***

5.6.1.2 Focus on core business

Respondents indicated that mining companies would rather focus on their core business of mining than invest in renewable energy projects. The prevailing mindset is that mining companies would rather obtain their electricity from the utility. The following quotes provide evidence of this mindset.

Respondent 4: *"I think…****this continued thought that many mining companies are not power companies therefore they won't touch this thing****. They want to buy power at the fence and that's the model that is in everyone's head."* Respondent 4 further added: *"On our side, or inside companies, I think* ***the biggest barrier is that we have persuaded ourselves that we do not, we are not, in power generation and therefore we will buy at the fence****."*

Respondent 5: "*But I think one of the barriers is just the mindset change of, you know,* ***we are a mining company and we mine****. Everything else is kind of auxiliary things so I think still getting that change, say well we have rehab[ilitated] land, there is huge benefits of utilising that land and you know, having it as an asset and not a liability especially when you look at mine closure. So I think still to get across that mind-set change is one of the barriers."*

Respondent 6: "***I always go back to, what we are, a mining company. We are not a power generating industry. We really shouldn't be in the power generation space and that's fine****."* Respondent 6 further adds that: ***"When I said that power generation is not our business, that is a fact. We don't have the skills to add value to power generation."***

Respondent 10: *"So in a certain sense, the* ***mining houses are clearly focusing on their core business and they see power generation as a secondary aspect****. If there are any benefits for them for investing and utilising the existing incentive schemes, they would rather outsource and buy that electricity without investing further investment and especially not to maintain and operate."*

5.6.1.3 Lack of innovative thinking

Three respondents suggested that there was generally a lack of innovative thinking or breaking away from historical mindset: The following quotes provide evidence of this.

Respondent 5: *"Well, I think it's the mind set change but also just the kind of day-to-day thing. This is how we have been doing things in the past 20 years."*

Respondent 7: *"So **I think that is maybe also a bit of a different thinking that we must put on us.** Renewable energy is not just about using a renewable source to generate electricity. It is about using renewable source to generate stored fuels, heat, steam, refrigeration, whatever form we use energy in."*

Respondent 8: *"I think one thing that is more of a philosophical thing and that is, **mining executive's ability to think out of the box and to see or to actually design their desired future**. **They have got much more of a conservative approach of looking into history and saying what worked. Now, if we don't get mining executives to start thinking about the future and how disruptive technology has become, just that mind set will withhold them.** I don't know whether that is technical but that is a definite mind set, a barrier to this."*

5.6.1.4 Conclusion to Proposition 4.1

The findings support the proposition that the intermittent nature of renewable energy is a barrier that contributes to the low penetration of renewable energy in the mining industry. The presence of an entrenched mindset, and consequently the resistance to change, is a significant contributor to the low penetration of renewable energy in the mining industry. There are three barrier elements that can be attributed to the entrenched mindset:

i) Preference to connect to the grid.
ii) Focus on core business.
iii) The lack of innovation

Mining companies prefer to connect to the grid and will not voluntarily generate their own electricity as long as there is a grid available. Mining companies are adamant that they would rather focus on their core business of mining and not venture into power generation projects such as renewable energy. Furthermore, it appears that there is a lack of innovative thinking or breaking with conventional thinking around energy. These three barrier elements suggest that there is a resistance to change by the mining industry. The mining industry has not fully come to terms with the transition to renewable energy that is happening in the rest of the world.

5.6.2 Proposition 4.2: Lack of information

Proposition 4.2 Lack of information – there are no other possible applications of renewable energy technologies in mining.

The code occurrence for the code "lack of information" is shown in Table 5-30, ordered from highest to lowest. In total, there were only seven quotes coded under the barrier "lack of information". Only two respondents identified "lack of information" as a barrier.

Table 5-30 "Lack of information" code occurrence – ordered by occurrence

Respondent	7	8	1	2	3	4	5	6	9	10	Total
Lack of information	6	1	0	0	0	0	0	0	0	0	7

Table 5-31 shows the share of voice of quotes for the barrier "lack of information" for each respondent, ordered from highest to lowest. Over the course of the interviews, the capital constraints barrier was given a share of voice of 1.3%, which is lower than the average of 1.39% for all the barriers. On the basis of the criteria described in Section 4.7.4, the findings suggest that the respondents do not consider the lack of information to be a significant barrier.

Table 5-31 "Lack of information" code by share of voice – ordered by relative count

Respondent	7	8	1	2	3	4	5	6	9	10	Total
Lack of information	480	79	0	0	0	0	0	0	0	0	559
Interviewee word count	4761	1995	2967	6018	4494	3704	6008	7247	1841	2620	41655
Relative count (%)	10.1	4.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.3

5.6.2.1 Lack of information

The following quotes from Respondent 7 illustrate that mining companies are not considering or even aware of other applications of renewable energy technologies:

*"**Because people think renewable energy, ok, I use something renewable to generate power. Energy is not just power. In mining, energy is refrigeration. In other processes, it may be steam. Energy is different forms and renewable energy means we may need some biogas…reactor to make gas, to burn to get steam.** And*

leave the electricity, buy the electricity cheap off the grid and we make steam cheap from…whatever.”

*“**Renewable energy is not just about using a renewable source to generate electricity. It is about using renewable source to generate stored fuels, heat, steam, refrigeration, whatever form we use energy in**...”*

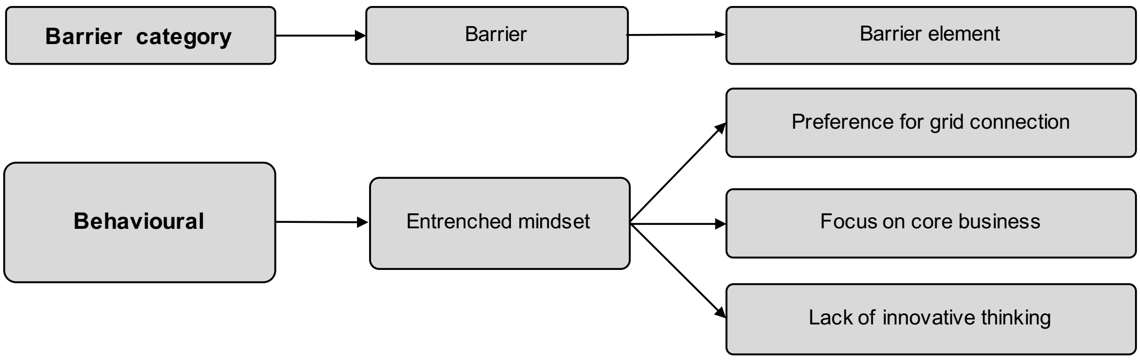
5.6.2.2 Conclusion for Proposition 4.2

The findings support the proposition that the lack of information is a barrier that contributes to the low penetration of renewable energy in the mining industry. However, the findings in this study could not conclusively identify this barrier as being significant. Mining companies are not thinking of alternative uses of renewable energy technologies to supply the form of energy they require for their operations. Therefore, they limit renewable energy applications to power generation which contributes to the low penetration of renewable energy.

5.6.3 Conclusion on behavioural barriers

The results presented in Sections 5.6.1 and 5.6.2 show that renewable energy does face behavioural barriers within the mining industry. The behavioural barriers and the associated barrier elements from the results are shown in Figure 5-6. An entrenched mindset within the industry causes mining companies to focus solely on their core business. The existence of this mindset explains mining companies' reluctance to voluntarily invest in generating their own electricity and rather preferring to be connected to the national grid. Additionally, this mindset contributes to the lack of innovative thinking or breaking with conventional thinking around energy.

Figure 5-6 Behavioural barriers and the associated barrier elements for mining



5.7 Emerging themes – additional barriers

During the coding process, the researcher identified new codes or barriers that were not part of the propositions in Chapter 3. In total, 16 additional barriers were identified from the interviews. These barriers are summarised in Table 5-32, ordered from highest to lowest based on total share of voice over the duration of all the interviews.

Eight of the 16 additional barriers are discussed further in Sections 5.7.1 to 5.7.5. The barriers chosen for further discussion were selected on the basis that they either had a share of voice of equal to or greater than 1% or were identified by at least five respondents. Where possible, the barriers were classified under the main categories of technical, economic and financial, institutional and behavioural. Barriers that did not fall under the four categories were classifies as "other" barriers.

Table 5-32 Share of voice for additional barriers identified during the interviews – ordered by relative count

Barrier	Relative count (%)	Number of respondents	Number of quotations
Political and regulatory uncertainty	2.09	6	11
Monopolistic market and Eskom influence	1.97	6	14
Accounting standards	1.60	6	15
Risk aversion	1.52	7	11
Inability to meet maximum demand	1.46	5	8
Lack of knowledge and skills	1.26	6	8
Lack of focus on energy challenges	1.20	3	12
Preference to invest in energy-efficiency projects	0.96	3	5
Life of mine	0.81	5	8
Industry and regulatory standards	0.65	2	4
Security costs	0.62	2	5
Duration of the PPA contract	0.60	4	5
Resources to manage the project	0.48	2	2
Land availability	0.39	3	6
External factors affecting performance	0.20	2	2
Age of grid infrastructure	0.19	1	1

5.7.1 Emerging themes – additional technical barriers

An additional four barriers were identified from the interviews that were categorised as technical barriers. These are:

- External factors affecting performance – this relates to the aspect of dust, which primarily affects solar PV panels and reduces their performance. This challenge is relevant to open-cast mining operations.
- Inability to meet maximum demand – this relates to the fact that renewable energy projects are often not large enough to meet the peak energy demand required to start-up large mining equipment. This is especially true when the mine has to simultaneously start up a number of large electricity-consuming items of equipment after a shutdown.
- Lack of knowledge and skills – this barrier focuses on the lack of technical knowledge and skills. Two particular challenges were raised by respondents: the lack of technical expertise to implement solar PV solutions that will perform for the 20 to 25 years' duration for which they are designed; a lack of understanding of the mining business by suppliers that offer renewable energy solutions that do not meet the needs of mining operations.
- Preference to invest in energy-efficiency projects – this barrier relates to the fact that mining companies would rather invest in energy-efficiency related projects because these projects reduce their actual energy consumption and deliver cost savings. Mining companies prefer energy-efficiency projects because they are more familiar and address challenges in their operations.

5.7.1.1 Inability to meet maximum demand

The barrier "inability to meet maximum demand" was identified by six respondents and received a share of voice of 1.46%. The following quotes provide evidence of the concerns raised by the respondents that renewable energy sources may not be able to provide the peak demand requirements of mining operations:

Respondent 2: *"If you use, you know, the typical mining environment,* ***you can't use PVs to start the motors and the big compressors or whatever else because that's a huge MDP*** *[maximum demand peak] but it can give you the loading to keep it running."*

Respondent 3: *"**You are not going to start megawatt motors. In fact, I am not sure, what sort of motors you are going to start and particularly when you come to a process plant**. You know we are not talking about soft starting something. This bloody thing is jammed up with whatever or the conveyer belt has got whatever it has on it. You just not going to manage to do it unless you have a very much larger PV array."*

Respondent 4: *"I am not persuaded that local power for big heavy mining projects is viable. It is certainly viable for your house to run off-grid. It's certainly viable to run a small* *factory off-grid. You can run a farm off-grid.* ***Can you run a 20, 40, 50, 100 megawatts mine off grid? Not easily.*** *Technically [it is] not impossible. You need a whole infrastructure just, if it's diesel, just to fuel it, to maintain it, back it up."*

Respondent 9: ***"Maximum demand will also still remain because that day or night where there is no solar, you reach a maximum demand and that's what you pay for****. So it doesn't cover that cost and it is just more charges. So 85% of your total tariff is what you are competing with."*

5.7.1.2 Lack of knowledge and skills

The barrier "lack of knowledge and skills" was identified by six respondents and received a share of voice of 1.26%. The following quotes provide evidence of the lack of understanding that persists and which leads to use of inappropriate motivators:

Respondent 2: "***Knowledge, understanding, just to understand all of this. People don't know and that, to me, is a significant barrier****. You can have as much money as you want and as much vigour and all the rest of the other things that you are talking about* ***but if you don't have the knowledge to do it then you do the wrong things and it gets a bad name****."*

Respondent 5: *"I think in certain technologies there is, I mean just in South Africa on PV, I think a lot of companies are offering it.* ***There is probably only a small portion [of these companies] that…has the technical ability to do it properly. Lots of people can do it but not necessarily in a sustainable way, because at the end of the day, that farm PV or rooftop PV needs to last 20 or 25 years, so I am not sure everybody is necessarily competent for that****. And then also just in terms of maintenance, PV not so much, but I think other things,* ***maintenance is also an issue in terms of skills****."*

Respondent 9: *"Our power is not unreliable so lots of times,* ***solar guys, they come here and they jump on this load shedding and it's going to solve, we don't have load shedding we have got curtailment. You are not going to solve it for us****. If I have got solar, my baseline just changes. I still have to cut 10% or 20% for curtailment. So we don't have that problem so you don't solve that."*

5.7.1.3 Conclusion on additional technical barriers

Two additional technical barriers have been identified:

i) Renewable energy power plants are not large enough to be able to meet the maximum demand that mining operations need to simultaneously start up large items of equipment.

ii) Mining companies are being offered renewable energy solutions that do not address the challenges they are facing.

5.7.2 Emerging themes – additional economic and financial barriers

An additional three barriers were identified from the interviews that were categorised as economic and financial barriers. These are:

- Accounting standards – this barrier relates to current accounting standards that dictate that if a mining company signs a long-term off-take agreement as part of a PPA, then the PPA becomes a contingent liability on its balance sheet. This is not desirable for companies that are under pressure to reduce their debt and strengthen their balance sheet in a low commodity price environment. Thus, mining companies are not able to use IPPs to invest in renewable energy.
- Duration of the PPA contract– PPAs are typically signed for a duration of 20 to 25 years on a take-or-pay basis. Mining companies are reluctant to sign such a long-term contract due to the inherent risk presented by the volatility of commodity prices.
- Security costs – this barrier relates to the experiences of some respondents who indicated that rooftop solar panels have been stolen from their mines and mine staff accommodation. The companies concerned have incurred extra costs relating to additional security measures to prevent the theft of PV panels.

5.7.2.1 Accounting standards

The barrier "accounting standards" was identified by six respondents and received a share of voice of 1.6%. The following quotes provide evidence of the concerns raised by the respondents about the impact of the accounting standards on the penetration of renewable energy in mining.

Respondent 2: *"…**the biggest issue is the balance sheet thing**. To have a commitment**. Even if you enter into PPA, you have to take or carry a long-term commitment on your balance sheet and if you have to do that …, there is a risk in closing down the business or selling the business or whatever you want to do**. So that ownership/balance sheet thing is an issue."*

Respondent 4: *"So once again, we have an opportunity to have owned renewable power. Bluntly we are not grabbing it because* ***we don't have balance sheet capacity****." "**I think the real problem is that we don't have capital on our balance sheet so whether it was a R10 renewable or a R1000 renewable, we will not get capital as a general***

***remark**.” “We have said it before and **I think the next biggest barrier, if not the biggest, is the lack of access to balance sheet**. So right now, this balance sheet word is a dirty word. It is worse in some companies.”*

Respondent 5: *“…and then when you look at other options, such as power purchase agreements, **if you are still the sole off-taker, you take that on your balance sheet. For most companies trying to reduce debt, that is not a good thing to add**. So even if we don’t actually finance it, if it is on a power purchase agreement and we are the only off-taker, it is still a risk.”*

Respondent 8: *“The reason why I say no is **I think IFRS** [International Financial Reporting Standards]**, the whole financial accounting standard worldwide that is being used, it creates barriers to entry** because an IPP wants to sign a long-term off-take agreement with, let's say, a mine and then **that off-take agreement or the power purchase agreement becomes a contingent liability on the balance sheet of the company**.”*

However, Respondent 1 did contradict the other respondents, suggesting that the IFRS issue can be overcome: “*The rest of the other IFRS accounting, whether it is off or on balance sheet, whether it is a financial lease or an operating lease: that can be solved – it is not a train smash.”*

Respondent 4 confirmed that it is possible to overcome the IFRS issue by having multiple off-takers: *“So I have challenged every person I have ever spoken to, to find, build the renewables, sell it to us without balance sheet issue. Apparently it can be done. If you have multiple off-takers, then you get into another complexity of contracting and risk sharing and if this company goes bankrupt or that company goes bankrupt…”*

5.7.2.2 Conclusion on additional economic and financial barriers

The barrier “accounting standards” is a real challenge that is preventing mining companies from being able to use IPPs to invest in renewable energy without diverting focus from their core business of mining. The situation is exacerbated by the current economic downturn, in which mining companies are focused on reducing their debt in order to preserve their balance sheet for future investments.

5.7.3 Emerging themes – additional institutional barriers

An additional three barriers were identified from the interviews that were categorised as institutional barriers. These are:

- Industry and regulatory standards – this relates to the onerous requirements of the complying with the grid code. This is relevant when a renewable energy project has to establish a new connection to access the grid.
- Monopolistic market and Eskom influence – this relates to the monopolistic structure of the electricity sector and the undue influence of Eskom. This creates an unconducive environment for investing in renewable energy.
- Political and regulatory uncertainty – this relates to the current political and legislative environment in South Africa. Mining companies are reluctant to invest capital in renewable energy projects in an environment where there is no clarity on direction of future policy for mining companies.

5.7.3.1 Monopolistic market and Eskom influence

The barrier "monopolistic market and Eskom influence" was identified by six respondents and received a share of voice of 1.97%. Several respondents suggested that the monopolistic structure of the electricity sector and the undue influence of Eskom has created an unconducive environment to invest in renewable energy. The following quotes provide evidence of this.

Respondent 2: *"There is another thing which is just from a technical, electrical point of view: grid code compliance. We have a certain grid, or laws, associated laws,* ***the Eskom laws and they are man-made laws in terms of requirements and stuff and you have to conform to that****. Now I can understand that you have to manage things like, unwanted distortion, power quality issues and things like that* ***but it is making it so difficult****."*

Respondent 3: *"Now the problem here is that some of our utilities have forced the more recent contracts (and that's* ***specifically Eskom) to include a clause which says that you are not allowed to buy energy from a third party unless it is agreed to by Eskom*** *and we had a big fat fight about this when we went from 20 MVA to 40 MVA as an NMD [Notified Maximum Demand]."* Respondent 3 further added that: *"…****it's the legal complications of one's supply contracts. So that can be a hindrance and might require negotiation with Eskom which is probably, at this point, unlikely to be successful****."*

Respondent 4: "*…****the Eskom barriers…are issues,****"* further adding that: *"****I think the barrier is, I don't know that Eskom want any of us to do this so they just, whether it is consciously or not, it just takes time****."*

Respondent 8: "***The challenge lies with Eskom and Eskom is playing politics*** *while their own ship is burning and sinking and the reality is* ***they try to put a spanner in the works and stop the whole IPP thing because that is a massive, massive challenge to their business case****."* Respondent 8 further added (in response to the question to name three significant barriers): *"**I think the whole vertically integrated monopolistic Eskom, elephant in the room, and that is South African based**."*

Respondent 10: *"… **there is only one player who will buy it and that is a parastatal. That is a definitive negative aspect because Eskom are trying to be a player and the referee in this game. That is a significant constraint**."*

5.7.3.2 Political and regulatory uncertainty

The barrier "political and regulatory uncertainty" was identified by six respondents and received a share of voice of 2.09%. Respondents pointed out that one of the barriers that limits investment by mining companies, not only in renewable energy projects but also mining projects, was the political environment in South Africa. In particular, there is a concern about the uncertainty in government policy, political infighting, and the perception that government wants to have more involvement in mining as a shareholder. The following quotes provide evidence of this.

Respondent 2*: "**It's mostly regulatory. We simply don't allow that at the moment because the regulations all scream against it**. If you have true free enterprise where you can harvest the sun because it's for free but in South Africa, I promise you once we start doing that, they will even tax the sun and to me that's not great. That is what is impeding it."* Respondent 2 further added that: *"**In South Africa, we sort of haul rocks into the road to kind of stop progress, impede progress instead of rolling them out of the road, filling the potholes and smoothing the road so that we can go forward faster and that's the point we seem to miss.**"*

Respondent 4: *"This government, once again I am hearing they are wanting more cut of the pie. **The minute you hear that, in any context, renewable purchases just fly out the window**."* Respondent 4 further added that: *"**I suspect politics, as much as we are not allowed to say it, is a fairly strong barrier. People do not want to spend money when they don't know where the licence is coming from tomorrow**…."*

Respondent 5: *"…**there must be some clear guidance from government saying this is the policy, these are the regulations, this is how it all fits together, these are the incentives** and the companies can take that, build it into their company vision and objectives and then, …according to that, work further."*

Respondent 8: *"…So we have got a lot of megawatts online that is cheaper than new coal, new nuclear, all of those things* ***but now it is hung up in a political fight between Treasury, Eskom, the DOE, the presidency…."***

Respondent 10*: "****The social political situation in the country has scared off a lot of investors. Mining houses are busy reducing and clamping on costs because of the uncertainty, the potential of state-owned properties, and the labour in South African context is in turmoil, and that actually contribute[s] to the financial constraints and the lack of further development****."*

5.7.3.3 Conclusion on additional institutional barriers

The political environment in South Africa is a great concern that not only limits investment in renewable energy by mining companies, but also affects investment into mining projects in general. Additionally, the monopolistic structure of the electricity sector and the undue influence of Eskom creates an unconducive environment to invest in renewable energy. The respondents believe that Eskom is using its position to ensure that companies continue to rely on it for electricity.

5.7.4 Emerging themes - additional behavioural barriers

An additional two barriers were identified from the interviews that were categorised under behavioural barriers. These are:

- Lack of focus on energy challenges – this relates to the challenge that the mining industry faces due to the low commodity prices. Thus, mining companies are in a survival mode mindset and the focus is on conserving cash rather than investing capital in new projects (neither renewable nor mining).
- Risk aversion – this barrier relates to the fact that mining companies tend to be conservative and risk-averse. Thus, mining companies are not likely to invest in renewable energy until they are convinced that the risk is well understood and can be managed.

5.7.4.1 Lack of focus on energy challenges

The barrier "lack of focus on energy challenges" was identified by three respondents and received a share of voice of 1.20%. Several respondents suggested that, due to the low commodity prices, mining companies are more focused on survival by conserving cash rather than investing capital in new projects (neither renewable nor mining). The following quotes provide evidence of this survival mode mindset.

Respondent 4: *"Once again, this company doesn't want to see it because **I think most guys at the top are focused on surviving the next board meeting or the next shareholder meeting.**"*

*"I think also with companies starting to downsize, resell, move on, change what they mine, I think there is this big brick wall against putting up infrastructure that you might sell and I don't think a lot of people think about it that way…**So that's a huge barrier now which you are just not going to get approval to build, to spend capex when you are trying to sell something. That barrier has not been thought about much before so it's a new dynamic for this country**."*

*"So value systems, I think, as the older guys were more entrenched with the Eskom thinking have left, probably that is not that pervasive but there is a view that I always say, **boardrooms have got 9 to 10% to worry about power cost and 90% about something else. What do they worry about? Not the 9 to 10%. So engineering worries about power, does anyone else, no. It must just be at the fence**."*

*"**I think we are so focused on short-term survival that we will not consider renewables because renewables are a 20- to 30-year option**." "…this company is still in survival mode so I think right on top of your list is: we are in survival mode; we don't spend money. Although for the dumb electrical engineer, no power equals no mine. So for us, we think survive means [to] have power."*

Respondent 5: "*Well, I think at this stage, just internally, just looking at the company for now is**, I think with all the restructuring and changes there is not a lot of focus on energy and carbon emissions in general**…but I think until…the restructuring is complete, only after then, there will be renewed focus because I don't see that we have a clear strategy in terms of [where] we are going for renewables." "I think a lot of times the guys are just too caught up with the day-to-day things or if the markets are going to be depressed for the next year or two, you know **the focus is kind of trying to survive and not really focussing on long-term things**."*

Respondent 10 explained that mining companies are so focused on addressing labour issues and government requirements to beneficiate minerals that energy is not considered a priority: *"…the social labour plan constraints and the expectation of beneficiation is a definite constraint on mining houses to take on the option of renewable energy."*

5.7.4.2 Risk aversion

Respondents suggested that mining companies tend to be conservative and risk-averse. Thus, mining companies are not likely to invest in renewable energy until they are convinced that the risk is well understood and can be managed. The following quotes provide evidence of this risk aversion.

Respondent 2: *"Even if you enter into PPA, you have to take or carry a long-term commitment on your balance sheet and if you have to do that you know,* ***there is a risk in closing down the business or selling the business*** *or whatever you want to do."*

Respondent 5: *"I think there is more and more options on what you can do with it but is it worth the risk at the end of the day? So mining is all about risk management, as you know."* Respondent 5 further added that: *"So those are the kind of things that make it difficult to sell these things because a lot of the time* ***it is just better to do nothing because then there is no risk and there is no money spent****…*"

Respondent 7: "*I think it is still a matter of let's wait and see because, at this stage, the cost is not to assume that it will cut each other in 3 months' time, or 3 years' time and then they will start paying less, that assumption* ***I don't think the big brass is willing to take that risk yet****."*

*"****The problem is at this stage it is projections and … they don't want to take the risk*** *but I think once that time has come and it's here, people will more easily invest in renewables. Even though it will then still take them two years or whatever to actually get a project up,* ***the risk will just be so much lower****."*

5.7.4.3 Conclusion on additional behavioural barriers

Owing to the low commodity prices, mining companies are in a survival mode mindset and the focus is on reducing debt and preserving the balance sheet. Therefore, mining companies are reluctant to invest capital in new projects, neither renewable nor mining projects. The respondents also insinuated that mining companies are conservative and risk-averse. Thus, mining companies are not likely to invest in renewable energy until they are convinced that the risk is well understood and can be managed.

5.7.5 Emerging themes – other barriers

An additional four barriers were identified from the interviews that were categorised as behavioural barriers. These are:

- Age of grid infrastructure – this relates to the fact some of the grid infrastructure and equipment (protection relays and meters) are outdated and may not able to cope with transferring energy in both directions.
- Land availability – this relates to the fact that renewable energy requires a large amount of land. In addition, in instances where land is available, the constraint is that it may already be classified for a different use (such as mineral rights or agricultural use). The process of changing the land classification to allow renewable energy projects to be constructed is a long bureaucratic process.
- Life of mine – this relates to the fact that the life of mine (number of year before the mine's mineral resource is depleted) for current operations is shorter than the duration of the PPA agreement or the payback period. Thus, it is not feasible for the mine to invest in renewable energy because the mine will close down before the end of the PPA agreement or before the renewable energy project has reached its payback period.
- Resources to manage the project – this relates to the fact mining companies may not have the human resources to manage renewable energy projects because they have been downsizing to counter the low commodity prices.

5.7.5.1 Life of mine

The following quotes provide evidence of concerns raised by the respondents that renewable energy may not be viable for mines that do not have a life of mine that is in excess of the duration of the PPA agreement.

Respondent 1: *"…**the second most important part that makes or break a deal is life of mine**."* Respondent 1 further added that: *"…when you look at how long you have to go to make a fundable business case – whether it is an IPP model whether you buy the equipment yourself – **it fails if you don't have life of mine** and the reason being that your bankers will be looking to recover their money if they invest within about 10 years if you [are] lucky (7 years is like the standard time) and then you looking at the developer having to make profit and typically a minimum 15-year PPA on an IPP model is what will typically be a good start."*

Respondent 3: *"You know, if you were to do something like a PV array, the question would be what do you do with it **when you come to closing the mine**. … we come to that whole process of cleaning up our mess."*

Respondent 5: *"…even if they go that way, you [are] **looking at a long-term investment, 20 or25 years, then your life-of-mine plan becomes important.** If the* *mine is only going to be there for 15 years, that's already an issue, because what happens after that?"*

Respondent 7: "*… that is* ***life of mine in terms of mining****." "… often for these projects to be viable we need 20-year off-take agreements.* ***Then they want to come and sell it to a mine which only has 10 years' life of mine left or five years life of mine left. I think that is the other challenge****. So for me, if you want to invest or you want to get renewables into mining, you have to go to new mining projects."*

Respondent 9: *"It is the other thing…* ***which is a barrier to it [implementation of renewable energy] is just the life of mines.****"*

5.7.5.2 Conclusion on additional constraints barriers

Life of mine is a key consideration for number of existing mining operations. These mines are likely to close down within a few years as they reach the end of their productive life. In some scenarios, the remaining productive years (life of mine) is shorter than the duration of PPAs or the payback periods. As a consequence of the long payback periods or the long duration of PPAs, the life of mine is a barrier for current operations.

5.7.6 Increasing penetration of renewable energy

During the interviews, various themes emerged that are not barriers but provide guidance on how to increase the penetration of renewable energy in mining. Two respondents argued that the best way to increase penetration of renewable energy in mining was to target new (greenfields) projects in mining.

Respondent 6: *"****But it may make sense to us to get into that field in new greenfields in remote locations. It gives us a competitive advantage****. It lowers the cost to doing business but, even in that context, there is going to be a community and so to the extent that you can provide on a basis where, even if you had to come out there, you will leave a sustainable energy [and] water infrastructure for that community…* ***The only difference for a mining company is…if you are in a greenfields situation, you can take a 20- or 30-year view over the life of mine and you can capitalise it differently and you can start to look at renewable penetration in a different order of magnitude.****"*

Respondent 7: "*…for these projects to be viable, we need 20-year off-take agreements…* ***So,…if you want to invest or you want to get renewables into mining, you have to go to new mining projects****….* ***And retrofits will always come at a cost but I think new developments is where we stand the biggest chance to get this*** *[renewable energy]."*

Chapter 6 Discussion of Results

Chapter 6 discusses the findings from Chapter 5 in terms of existing support for existing literature (Chapter 2) and new contribution to the existing academic and business contexts. light of the propositions postulated in Chapter 3 by interrogating the existing literature reviewed in Chapter 2. This chapter is structured as per the research propositions outlined in Chapter 3.

6.1 Proposition 1: Technical barriers

6.1.1 Proposition 1.1: Intermittent nature of renewable energy

In contrast to the findings in the power generation sector, the technical barriers in the mining industry centre around resource availability – intermittency and inadequacy of supply – (Yaqoot et al., 2016) whereas the power generation sector is primarily focused on the maturity of technology and the lack of availability of a skilled workforce (Martin & Rice, 2012). This difference in focus can possibly be explained by the business motivation that these sectors have for adopting renewable energy. The power generation sector is in the business of generating and selling electricity whereas mining is a consumer of electricity. Unsurprisingly, mining's main concern would be around the continuous supply of energy whereas the lower generation sector has the flexibility of including other energy sources.

The results in Section 5.3.1.1 to 5.3.1.4 provide evidence that the intermittent nature of renewable energy is a barrier. In addition, the findings in Table 5-4 suggest that it is in fact the most significant barrier for mining companies. This finding is aligned with the literature in the following areas.

This finding is consistent with other research which has found that the intermittent nature of renewable energy, as well as the variability, makes it unsuitable for continuous applications such as mining operations (Nalan et al., 2009; Votteler & Brent, 2016). This concern arises owing to the fact that mining operations are energy-intensive and energy is a key input into the mining process (Votteler & Brent, 2016). Without a continuous supply of energy, mining operations would have to cease operating. It is therefore not surprising that all ten respondents expressed concerned about the intermittent nature of renewable energy.

However, as noted in Section 5.3.1.3, two respondents contradicted the generally accepted view that the intermittent nature of renewable energy was a barrier. While they acknowledged that intermittency was a challenge for adopting renewable energy, they suggested that this was not insurmountable. A possible explanation for this contradiction is that these respondents have a more optimistic and innovative view of how renewable energy can be integrated into mining operations. For example, a hybrid system which incorporates the use of a renewable energy technology with a diesel generator as a backup (Votteler & Brent, 2016). This is evidenced by the fact that the companies that employ these two respondents are proceeding with implementing renewable energy projects at their operations and have set targets of achieving a certain percentage of renewable energy penetration.

The current study identified three main challenges (or barrier elements) that impact mining's view on renewable energy, due to its intermittency (as shown in Figure 5-3). Firstly, the periodic availability of renewable energy means that it is not a reliable source of energy (Section 5.3.1.1). This is consistent with the observation that solar energy can only be produced when the sun is shining (during the day) and is also dependent on prevailing weather conditions (affected by cloud cover and rain), whereas wind energy is affected by daily variations as well as seasonal variations (Yaqoot et al., 2016).

Secondly, respondents are concerned that renewable energy is not able to provide mining operations with base-load power (Section 5.3.1.2). Consequently, mining companies have developed the view that the role of renewable energy may be limited to providing supplementary power. Thirdly, respondents are not convinced that renewable energy will be able to guarantee security of supply (Section 5.3.1.3). These two barrier elements reinforce the view of unsuitability of renewable energy for mining operations due to the inability to provide a continuous supply of energy (Nalan et al., 2009; Votteler & Brent, 2016).

The proposition that the intermittent nature of renewable energy contributes to the low penetration in the mining industry is supported both by the literature and the findings in this research. Therefore, the intermittent nature of renewable energy is a barrier to greater adoption of renewable energy in mining.

6.1.2 Proposition 1.2: Inadequacy of supply and location of mines

The availability, quantity, and quality of renewable energy sources to support mining operations' energy requirements is a key consideration in evaluating the viability renewable energy resources. The lack of sufficient quantities of biomass and biogas to support capacity utilisation at economical levels presents a barrier to the adoption of renewable energy (Nalan et al., 2009; Yaqoot et al., 2016). The results in Section 5.3.2.1 provide evidence that mining companies have found that there are insufficient quantities of biomass and biogas to be able to support the requirements of their mining operations. This renders these renewable energy sources economically unviable for mining operations.

Another aspect related to inadequacy is the quality of renewable energy sources, such as wind and solar, in the areas where mining operations are located. The findings in Section 5.3.2.2 show that wind energy, which is considered a more mature renewable energy technology compared with other renewable energy sources, is mostly only available in the coastal areas in South Africa. Owing to the fact that most mines are located inland, this disqualifies wind as a feasible option. Even when considering solar PV, the findings (Section 5.3.2.2) suggested that mining operations are not necessarily located in the areas with the best renewable energy sources.

It has been suggested by Martin and Rice (2012) that renewable energy sources located in remote areas require enabling mechanisms to be able to transfer the power in to the grid. The evidence provided in Section 5.3.2.2 suggests that mining companies consider the inability to wheel power from areas with the best renewable energy sources to their mines is a contributing factor. This is in line with the assertion made by Martin and Rice (2012).

The proposition that the inadequacy of supply and the location of mines contributes to the low penetration in the mining industry is supported both by the literature and the findings in this research. Therefore, the inadequacy of supply and the location of mines is a barrier to greater adoption of renewable energy in mining.

6.1.3 Proposition 1.3: Technology maturity

Storage technology is deemed to be an important aspect as it will allow for the storage of excess energy that can then be used when the renewable energy source is not available (Nalan et al., 2009). Consequently, storage technology will assist in addressing the intermittent nature of renewable energy. However, battery technology is currently still too expensive and further places renewable energy at a disadvantage (Votteler & Brent, 2016). Battery storage technology is yet to achieve its optimum performance in terms of cost, performance, and reliability (Menanteau et al., 2003; Votteler & Brent, 2016). The results presented in Section 5.3.3.1 support previous findings that battery storage technology has not yet matured and is still too expensive.

The findings presented in Section 5.3.3.2 suggest that mining companies are of the opinion that the lack of a radical improvement in the efficiency of solar PV technologies means that the technology has not yet matured. This implies that solar PV technology is yet to achieve its optimum performance in terms of cost, performance, and reliability (Menanteau et al., 2003). The implication of this finding is that mining companies may be deliberately choosing not to invest in renewable energy technology until such time that the technology reaches its optimum performance.

The proposition that technology maturity contributes to the low penetration of renewable energy in the mining industry is supported both by the literature and the findings in this research. Therefore, technology maturity is a barrier to greater adoption of renewable energy in mining.

6.1.4 Emerging themes – additional technical barriers

The following additional technical barriers were identified during the interviews that were not part of the propositions in Chapter 3. These barriers will be briefly discussed because they were identified as probably having a significant impact on the penetration of renewable energy in mining, based on the share of voice and the number of respondents who identified the barriers (Section 5.7).

6.1.4.1 Inability to meet maximum demand

The findings in Section 5.7.1.1 suggest that respondents are of the opinion that renewable energy power plants do not have the capacity to be able to provide the peak demand requirements of mining operations. The concern is focused on situations when mines have to simultaneously start up several items of large electricity-consuming equipment. In this scenario, mining operations would probably require a maximum demand that exceeds the generating capacity of the available generating capacity. Under current circumstances, when mining operations exceed their maximum demand, Eskom levies a penalty charge on the mining operations for exceeding their agreed maximum demand with Eskom.

This barrier appears to be a new finding as it has not been identified in the academic literature. Therefore, further research is required to determine its significance in the context of the adoption of renewable energy in mining. The implication of this barrier is that renewable energy suppliers and mining companies have to find an appropriate solution to overcome this challenge.

6.1.4.2 Lack of knowledge and skills

The literature indicates that, because the South African renewable energy industry is considered to be in its infancy, the relevant skills and expertise are still scarce (de Jongh et al., 2014). Furthermore, Joubert et al., (2016) asserted that there is generally a lack of experience for optimal design and implementation of industrial and commercial-scale solar thermal systems. The findings presented in Section 5.7.1.2 support the literature in terms of the lack of knowledge and skills being barriers to the adoption of renewable energy. Respondents highlighted that people lacked the knowledge and expertise to design and install the appropriate renewable energy solutions which resulted in unacceptable solutions being implemented.

Additionally, respondents highlighted that they were concerned that mining companies were being offered renewable energy solutions that do not address the challenges they are facing. A possible explanation for this is that in the past, renewable energy companies based their motivation on the electricity crisis and the load shedding events at that stage. The findings in Section 5.7.1.2 provide evidence that mining companies did not face load shedding during the electricity crisis, instead they were required to curtail their overall consumption by a certain percentage.

6.2 Proposition 2: Economic and financial barriers

6.2.1 Proposition 2.1: Capital constraints

Prior studies in the power generation sector have noted that the relative infancy of the renewable energy industry has meant that there has been reluctance by financial institutions to fund renewable energy projects due to the perception that renewable energy is a high risk investment (de Jongh et al., 2014; Krupa & Burch, 2011; Painuly, 2001). Consequently, access and availability to credit to fund renewable energy projects is limited (Krupa & Burch, 2011; Pegels, 2010). The results discussed in Section 5.4.1.1 confirm that mining companies have a limited amount of capital to invest in projects on their operations. Owing to the limited capital available, mining companies prioritise the allocation of capital to projects that address the requirements of their core (mining) business, such as production- and efficiency-related projects. These projects provide a better return on investment than renewable energy projects and improve the mining company's production volumes. Renewable energy projects are not able to compete with these projects.

The results discussed in Section 5.4.1.2 confirm that as a consequence of the current low commodity prices, capital was even more constrained and thus renewable energy projects are not even considered. This finding is further supports the observation made by Votteler and Brent (2016) that the current low commodity prices, which result in lower operating margins and lower profits, are hindering the widespread adoption of renewable energy in the mining industry. However, one of the respondents contradicted this observation, instead suggesting that the economic downturn may actually have a positive influence on the penetration of renewable energy because it may stimulate mining companies to look for cheaper alternative sources of energy.

The proposition that capital constraints contribute to the low penetration of renewable energy in the mining industry is supported both by the literature and the findings in this research. Therefore, capital constraints are a barrier to greater adoption of renewable energy in mining.

6.2.2 Proposition 2.2: Business case

The results reported in Section 5.4.2.1 suggest that mining companies find it difficult to develop a viable business case for renewable energy. The primary concern is the high capital costs associated with renewable energy projects. A contributing factor is the current capital constrained environment in which mining finds itself, as a consequence of the lower commodity prices. This relates back to Proposition 2.1 which is discussed in Section 6.2.1. These results seem to be consistent with previous research which found that renewable energy projects have high capital costs which results in long payback periods and lower returns, which makes them unattractive for mining companies (Engelken et al., 2016; Strupeit & Palm, 2015). The findings in Section 5.4.2.1 further suggest that the return on investment for renewable energy does not meet mining companies' expectations. As one of the respondents pointed out, mining companies typically expect an IRR of 25% from their investments, whereas renewable energy projects typically had returns of 14 to 16%.

Previous studies have reported that long payback times and high initial investment costs were identified as key barriers to increased market diffusion of renewable energy technologies (de Jongh et al., 2014; Joubert et al., 2016; Votteler & Brent, 2016). The findings in Section 5.4.2.1 further suggest that mining companies expect payback periods of six months for projects implemented on existing mining operations. This is in line with literature, which indicates that there is preference for short-term over long-term investments, such as renewable energy projects (Eleftheriadis & Anagnostopoulou, 2015). A possible explanation for the preferred short payback period is that mining companies are concerned about the cyclical nature of commodity prices as well as the life of mine. A decrease in commodity prices may result in a project becoming unfeasible in a relatively short period of time.

The proposition that mining companies are not able to develop a viable business case for renewable energy is a barrier that contributes to the low penetration in the mining industry is supported both by the literature and the findings in this research. Therefore, the lack of a compelling business case is a barrier to greater adoption of renewable energy in mining.

6.2.3 Proposition 2.3: Risk perception

Owing to the relative infancy of the renewable energy industry, there is a perception that it is a high-risk investment (Menanteau et al., 2003; Pegels, 2010). Contrary to expectations, this study found that it was the the high capital cost of renewable energy that made it a risky investment, from a mining perspective and not the maturity of the industry (Section 5.4.3.1). As discussed in Section 6.2.1, mining companies are not willing to commit significant amounts of capital to projects (such as renewable energy) that do not improve their core business of mining. This contradicts literature that associated the perception that renewable energy is a high risk to the infancy of the renewable energy industry and the perception that there is technology risk due to investing in untested technology (Pegels, 2010; de Jongh et al., 2014). The findings suggest that there is a linkage between the risk perception barrier and the capital constraints barrier (Proposition 2.1 discussed in Section 6.2.1). A possible explanation why mining companies do not consider that renewable energy projects are a high risk investment is due to the success of the REIPPPP (Walwyn & Brent, 2014), government's renewable programme, which may have had a positive influence on how mining companies perceive renewable energy projects.

The proposition that risk perception contributes to the low penetration of renewable energy in the mining industry is supported both by the literature and the findings in this research. Therefore, risk perception is a barrier to greater adoption of renewable energy in mining.

6.2.4 Proposition 2.4: Electricity pricing

The results in Section 5.4.4.1 show that Eskom prices are currently lower than tariffs offered by renewable energy projects. It is highly unlikely that mining companies will be willing to pay higher prices than what they pay for electricity from Eskom. This makes it impossible to motivate a business case for investing in renewable energy projects because the price for electricity is a significant determinant in their evaluation. This result is in agreement with the findings by Joubert et al., (2016) which identified the low cost of electricity as a key barrier.

Furthermore, the results in Section 5.4.4.2 suggest that mining companies are concerned about the great degree of uncertainty in predicting when renewable energy tariffs will reach grid parity. In particular, the respondents raised concerns about the assumptions that are often used in projecting future Eskom prices. This uncertainty makes it difficult to build a business case for investment in renewable energy projects. Even with the possibility of future savings, mining companies are not willing to invest in renewable energy until prices reach grid parity. This finding is contrary to previous studies which have suggested that projections of future Eskom tariffs show that renewable energy tariffs are close to parity with those of Eskom (Votteler & Brent, 2016) and are predicted to reach parity in 2016 (Walwyn & Brent, 2014) and, thereafter, renewable energy tariffs should be cheaper. A possible explanation for this contradiction is that assumptions used by various researchers differ and thus result in different prices projections. In addition, there is political influence (the political and regulatory uncertainty barrier discussed in Section 6.3.6.1) in the process of setting electricity prices in South Africa, which is often done to keep prices at affordable levels for the poor. These factors contribute to the uncertainty in prediction future Eskom tariffs.

The proposition that electricity pricing contributes to low penetration of renewable energy in the mining industry is supported both by the literature and the findings in this research. Therefore, the relatively cheaper Eskom tariff is a barrier to greater adoption of renewable energy in mining.

6.2.5 Emerging themes – additional economic and financial barriers

The following additional economic and financial barrier was identified during the interviews and was not part of the propositions in Chapter 3. This barrier will be briefly discussed because it was identified as probably having a significant impact on the penetration of renewable energy in mining, based on the share of voice and the number of respondents who identified the barrier (Section 5.7).

6.2.5.1 Accounting standards

The findings in Section 5.7.2.1 confirm that respondents are concerned about the accounting standards and the constraints they place on financing renewable energy projects using the company's balance sheet. This creates a barrier to investment in renewable energy. As one of the respondents explained, the IFRS (International Financial Reporting Standards) accounting standards dictate that long-term off-take agreements that are signed as part of a PPA then become a contingent liability on the balance sheet. This is not desirable for mining companies that are under pressure to reduce their debt and strengthen their balance sheet in a low commodity price environment. PPAs are typically on a take-or-pay basis which means that mining companies are liable to pay for electricity from the IPP, regardless of whether they are able to consume it or not.

This barrier appears to be a new finding as it has not been identified in the academic literature. Therefore, further research is required to determine its significance in the context of the adoption of renewable energy in mining.

6.3 Proposition 3: Institutional barriers

6.3.1 Proposition 3.1: Lack of supportive policy

Abdmouleh et al. (2015) assert that political support is a key enabler because it ensures that all regulations are simple and the bureaucratic processes are coordinated to facilitate investment in renewable energy. Polzin et al. (2015) argue that the establishment of a reliable framework with a clear vision and long-term policy objectives regarding renewable energy capacities to be installed in the future have been essential in supporting electricity generation from renewable energy sources.

The results in Section 5.5.1.1 indicate that mining companies believe that the South African government appears unwilling to support investment into privately owned renewable energy projects for own consumption (not delivered to the grid). This finding confirms the observation made by Votteler and Brent (2016) that the South African government does not presently support the adoption of off-grid industrial electricity generation from renewable sources.

A further finding, discussed in Section 5.5.1.2, is that there is a lack of incentives to encourage the adoption of renewable energy projects by mining companies. This result is in line with previous results that found that the lack of incentives acts as a barrier (Liu, 2012; Joubert et al., 2016; Votteler & Brent, 2016). Incentives are necessary because renewable energy is disadvantaged by competing with established technologies that have reached or are close to their optimum performance in terms of cost and reliability (Menanteau et al., 2003). As previously discussed in Section 6.1.3, mining companies may be deliberately choosing not to invest in renewable energy technology until such time that the technology reaches its optimum performance. This makes incentives a necessity to overcome this barrier.

A final finding from the discussion in Section 5.5.1.3 is that mining companies indicated that they believe that an introduction of a carbon tax will encourage mining companies to consider renewable energy. This result is in line with previous findings in the literature which argues that the failure to include externalities (pricing the costs of environmental damage through a carbon tax) in the price of electricity is a barrier to the adoption of capital-intensive renewable energy technology (Owen, 2006; Martin & Rice, 2012). The introduction of a carbon tax is seen as likely to strengthen the business case for investing in renewable energy (Votteler & Brent, 2016).

However, one respondent argued that the carbon tax would not be an effective mechanism to support adoption of renewable energy, stating that countries that had introduced such a carbon tax had not necessarily seen renewable energy adoption increase due to the volatility in the carbon price. The findings in Section 5.7.4.2 relating to the risk aversion barrier offer a possible explanation to this view. As one of the respondents pointed out, mining companies may weigh up the risk of investing significant capital in a presumably immature technology versus paying a penalty in the form of a carbon tax and choose to rather pay the penalty. Another possible explanation for this alternative view is that carbon tax on its own as a policy may not have a significant positive impact on renewable energy penetration (Liu, 2012). Rather, the success of a policy will depend on the effectiveness of other complimentary policies (Abdmouleh et al., 2015).

The proposition that the lack a supportive policy contributes to the low penetration of renewable energy in the mining industry is supported both by the literature and the findings in this research. Therefore, the lack of supportive policy from government is a barrier to greater adoption of renewable energy in mining.

6.3.2 Proposition 3.2: Lack of a framework to allow feeding into the grid

The findings in Section 5.5.2.1 suggest that the lack of a framework to allow for the sale of excess electricity back into the grid (also referred to as net metering) is a barrier to the adoption of renewable energy in mining. This finding is in agreement with the finding by Votteler and Brent (2016) that net metering is currently not formally supported by the regulatory framework in South Africa. Net metering allows the sale of excess electricity back into the national grid (Votteler & Brent, 2016). This has a positive impact on the adoption of renewable energy in that it addresses three specific challenges. Firstly, it reduces the reliance of the IPP on a single client, (Votteler & Brent, 2016). Secondly, it ensures that electricity is not wasted during times that the mine is not able to use the electricity, typically during breakdowns or maintenance periods (as discussed in Section 5.5.2.1). Finally, it ensures that the mine would not be liable for electricity it is not able to consume as the PPA is typically on a take-or-pay basis.

One of the respondents pointed out an interesting implication of this finding. As a consequence of a lack of regulatory framework, mining companies would choose to design renewable energy projects to have generation capacity that a mining operation can consume at all times (Section 5.5.2.1). This implies that mining companies will not design an optimal renewable energy project in terms of generation capacity, but will rather ensure that it is smaller than the true potential capacity that the available resource allows for. This is done to avoid the second and third challenges mentioned above. Therefore, renewable energy penetration is limited by the design of lower generation capacity plants.

The proposition that the lack of a framework to allow feeding into the grid contributes to the low penetration of renewable energy in the mining industry is supported both by the literature and the findings in this research. Therefore, the lack of a framework to allow feeding into the grid is a barrier to greater adoption of renewable energy in mining.

6.3.3 Proposition 3.3: Inability to use the grid

The ability to use the grid to transfer electricity from one point to another (referred to as wheeling) would mean that mining companies would be able to wheel electricity from an IPP or renewable energy power plant located in one area to another area where they want use the electricity. The findings in Section 5.5.3.1 confirm that the respondents are concerned about the costs associated with wheeling. This is in line with the observation made by Votteler and Brent (2016) that the costs of wheeling power in South Africa are prohibitive because they can add a further 18% increase in the tariff for renewable energy projects.

An additional challenge highlighted in the findings (Section 5.5.3.2) is that negotiating wheeling arrangements with Eskom is a complex process that takes a long time to conclude. This discourages mining companies from considering investing in renewable energy projects that are not located in areas in close proximity to mines. This finding further reinforces the finding discussed in Section 6.1.2 regarding the fact that mining operations are not necessarily located in areas with the best renewable energy sources. Therefore, a combination of the inability to use the grid to wheel power and mining operations not being located in areas with the best renewable energy sources contributes to the low penetration of renewable energy in mining.

The proposition that the inability to use the grid contributes to the low penetration of renewable energy in the mining industry is supported both by the literature and the findings in this research. Therefore, the inability to use the grid is a barrier to greater adoption of renewable energy in mining.

6.3.4 Proposition 3.4: Grid-connection costs

Prior studies have noted that new electricity generators have to pay the costs of connecting to the grid, which can be substantial, depending on the condition and capacity of the grid network (Byrnes et al., 2013). Martin and Rice (2012) point out that this barrier is exacerbated by the fact that current grid infrastructure does not have sufficient capacity to connect numerous renewable energy projects and often the grid is not in close proximity to renewable energy projects. Therefore, substantial financial expenditure would be required to connect the renewable energy projects to the grid.

In contrast to previous studies, however, no evidence was found to support the proposition that grid connection costs are a barrier in mining. A possible explanation for this might be that current mining operations already have a connection point to the grid: any costs associated with upgrading the connection to connect renewable energy projects would not be as expensive as a new connection. Therefore, grid connections costs are not a barrier in the mining industry, specifically for existing operations.

6.3.5 Proposition 3.5: Administrative

Regulatory hurdles have been identified as barriers to increased renewable energy adoption because they provide an administrative and legal burden (Martin & Rice, 2012). Additionally, political support has been identified as a key enabler because it ensures that all regulations are simple and the bureaucratic processes are coordinated to facilitate investment in renewable energy (Abdmouleh et al., 2015). A complicated administrative process to get approvals for construction of renewable energy projects diverts limited resources away from the core business of mining, which then breeds the negative perception about taking focus away from revenue-generating business to non-core activities. The findings discussed in Section 5.5.5.1 show that mining companies are particularly concerned about the time involved in completing and obtaining the approvals of an EIA study.

The proposition that administrative processes contribute to the low penetration of renewable energy in the mining industry is supported both by the literature and the findings in this research. Therefore, the administrative process is a barrier to greater adoption of renewable energy in mining.

6.3.6 Emerging themes – additional institutional barriers

The following additional institutional barriers was identified during the interviews that were not part of the propositions in Chapter 3. These barriers will be briefly discussed because they were identified as probably having a significant impact on the penetration of renewable energy in mining, based on the share of voice and the number of respondents who identified the barriers (Section 5.7).

6.3.6.1 Political and regulatory uncertainty

The political environment in South Africa has been described as being not conducive to investment (de Jongh et al., 2014). This is apparent in the lack of clear regulations and government support, particularly for private, non-grid-connected renewable energy projects. The findings in Section 5.7.3.2 support the literature, with respondents voicing concerns about the uncertainty in government policy, political infighting, and the perception that government wants to have more involvement in mining as a shareholder. The findings suggest that this political and regulatory uncertainty not only affects the decision to invest in renewable energy, but has also had an impact on decisions about new investments in mining projects.

6.3.6.2 Monopolistic market and Eskom influence

The structure of the South African electricity sector is a natural monopoly dominated by Eskom, which inherently lends itself to a combination of barriers (Krupa & Burch, 2011). Consequently, economic barriers are expected to exist through market distortions (Reddy & Painuly, 2004) on the basis that Eskom and government will act to protect the parastatal's interest in most instances. Pegels (2010) contends that as long as Eskom's dominance in the electricity sector remains unchanged and it continues to influence regulations, then IPPs will find it difficult to enter the market and supply significant amounts of renewable energy. The findings in Section 5.7.3.1 provide support for the literature, with respondents identifying various instances where Eskom is using its influence to ensure that it maintains its position.

This finding also provides further evidence for the barrier discussed in Section 6.3.1, which identified that the South African government appears unwilling to support investment into privately owned renewable energy projects for own consumption. The South African government is the sole shareholder of Eskom and as a result is unlikely to support activities that will negatively impact Eskom's business.

6.4 Proposition 4: Behavioural barriers

6.4.1 Proposition 4.1: Entrenched mindset

The findings in Section 5.6.1.1 confirm that mining companies prefer to obtain their electricity from the grid and will not voluntarily generate their own electricity as long as there is a grid available. This finding supports the research by Richards et al., (2012) which found that complacency and a preference for the status quo are underlying barriers to the adoption of renewable energy. It can be further argued that the mining industry has developed a dependency on traditional electricity systems, which is the status quo, that are based on the existence of a centralised generation system with a national grid (Abdmouleh et al., 2015). Thus, mining companies have a preference for grid-connected electricity provided by the utility and are not keen to invest in their own power-generation plants, regardless of the potential benefits.

A further finding, discussed in Section 5.6.1.2, shows that mining companies would rather focus on their core business than invest in renewable energy projects. Respondents were adamant that mining companies would rather focus on their core business of mining and view renewable energy as supplementary power that does not warrant their attention. In addition, the findings in Section 5.6.1.3 show that some of the respondents believe that there is generally a lack of innovative thinking or breaking away from historical mindset. The three barrier elements identified in Figure 5-6 indicate that there is possibly a resistance to change by the mining industry. This would suggest that the mining industry has not fully come to terms with the transition to renewable energy that is happening in the rest of the world. Consequently, mining companies will more readily find a justification to maintain the status quo to use grid connected electricity rather than consider the best possible way to integrate renewable energy.

The proposition that an entrenched mindset in mining contributes to the low penetration in the mining industry is supported both by the literature and the findings in this research. Therefore, an entrenched mindset is a barrier to greater adoption of renewable energy in mining.

6.4.2 Proposition 4.2: Lack of information

Literature suggests that poor dissemination of information to decision makers has contributed to the low penetration of renewable energy (Joubert et al., 2016). Other researchers have pointed out that mining companies are not aware of CST technologies that would allow them to switch from using heat produced by fossil fuels to heat from renewable energy (Taibi et al., 2012; Eglinton et al., 2013). The findings in Section

5.6.2.1 show that mining companies believe that there is a poor dissemination of information which means mining companies are not considering alternative uses of renewable energy technologies to supply the form of energy they require for their operations.

The proposition that a lack of information contributes to the low penetration of renewable energy in the mining industry is supported both by the literature and the findings in this research. Therefore, the lack of information is a barrier to greater adoption of renewable energy in mining.

6.4.3 Emerging themes - additional behavioural barriers

The following additional behavioural barriers were identified during the interviews and were not part of the propositions in Chapter 3. These barriers will be briefly discussed because they were identified as probably having a significant impact on the penetration of renewable energy in mining, based on the share of voice and the number of respondents who identified the barriers (Section 5.7).

6.4.3.1 Lack of focus on energy challenges

The findings presented in Section 5.7.4.1 show that the respondents believe that a further impact of the low commodity prices is that mining companies are not focused on energy challenges. Respondents indicated that mining companies are in survival mode and the focus is on reducing debt and preserving the balance sheet. Therefore, renewable energy is not an important consideration in the current low commodity price environment.

This barrier appears to be a new finding as it has not been identified in the academic literature. Therefore, further research is required to determine its significance in the context of the adoption of renewable energy in mining. A possible explanation for this is that this barrier is unique to the current low commodity price environment which has had a significant impact on mining companies.

6.4.3.2 Risk aversion

The findings in Section 5.7.2.1 confirm respondents' views that mining companies tend to be conservative and risk-averse. Respondents suggest that mining companies are not likely to invest in renewable energy until they are convinced that the risk is well understood and can be managed.

This barrier appears to be a new finding as it has not been identified in the academic literature. Therefore, further research is required to determine its significance in the context of the adoption of renewable energy in mining.

6.5 Emerging themes – constraints barriers

The following additional barrier was identified during the interviews that was not part of the propositions in Chapter 3. This barrier will be briefly discussed because it was identified as probably having a significant impact on the penetration of renewable energy in mining, based on the share of voice and the number of respondents who identified the barrier (Section 5.7).

6.5.1 Life of mine

The academic literature does not make specific mention of life of mine being a barrier. The closest the literature come to identifying this barrier is in discussing the risks of an IPP being dependent on a single client (Votteler & Brent, 2016); however, the literature do refer to mine closures due to low commodity prices being a major risk for IPPs. The findings presented in Section 5.7.5.1 specifically refer to the fact that a mine has a finite number of years during which it can economically extract minerals. The life of mine for current operations can be shorter than the duration of the PPA agreement or the payback period.

The discussion on the life of mine raised an interesting point. Two respondents argued that the best way to increase penetration of renewable energy in mining was to target new (greenfields) projects in mining. They argued that the retrofitting of renewable energy solutions on current mining operations is expensive and does not make business sense. They suggest that a greenfields project could be designed to incorporate renewable energy, not only for electricity generation, but to also meet other energy requirements for the mine, such as process steam.

6.6 Significant barriers and measures to address them

The findings for the significant barriers are presented in Table 5-5 (as identified by respondents) and Table 5-4 (based on share of voice from all the interviews). When comparing the top five barriers from both tables, it can be observed that there are some commonalities. These include: intermittent nature of renewable energy, electricity pricing, entrenched mindset, and business case. The barriers that are not common on both tables are: accounting standards, lack of focus on energy challenges, monopolistic market and Eskom influence, political and regulatory uncertainty, and lack of supportive policy. However, the barriers of political and regulatory uncertainty and lack of supportive policy are closely linked because they relate to government and political support.

The following barriers are discussed in brief, with the focus on establishing actions that need to be taken by either government, mining companies, suppliers of renewable energy technology, IPPs, or the relevant stakeholder. These actions aim to address the barriers.

6.6.1 Intermittent nature of renewable energy

The discussion in Section 6.1.1 highlighted the following barrier elements due to the intermittent nature of renewable energy: i) availability of renewable energy; ii) the inability of renewable energy to provide base-load power; and iii) the inability of renewable energy to provide security of supply.

Votteler and Brent (2016) advocate three technical solutions for mining operations to address the intermittent nature of renewables: battery storage, hybrid systems, and hybrid systems with storage. However, they also point out that these options would only be considered in circumstances where there is no grid connection. The discussion in Section 6.4.1 highlighted that mining companies will always prefer grid connection. The grid is able to offer mining operations base-load power and security of supply, both of which are key for continuous operation of mines. Therefore, it can be argued that it is challenging to motivate for a retrofitted renewable energy solution for current operations that are grid-connected, as highlighted in the discussion in Section 6.5.1. Retrofitting a renewable energy solution on current mining operations that are grid connected is expensive and does not make business sense.

The life of mine of current mining operations is also a factor that has to be considered, given the long payback periods or long durations for PPA agreements. One of the scenarios under which current operations would most likely invest in renewable energy projects is in instances where Eskom tariffs are excessively higher than renewable energy tariffs. However, even in such instances, it is likely that mining companies may only consider renewable energy as supplementary power.

The ideal solution to increasing the penetration of renewable energy in mining would be to follow the advice provided in Section 6.5.1, to target new (greenfields) mining projects and that provided by Respondent 8 of combining various sources of renewable energy to provide a continuous supply. The following quote explains this solution:

"So we need to combine, I would say at least three technologies in supplying the mining industry. Everywhere in the world and specifically in Africa and it is wind and it is solar and it's biomass to electricity and, if you combine those three, you can utilise your daytime supply from PV, your late evening, your early morning, depending on your wind profile of where you are with wind and then make up the balance of that with typical biomass to biogas to electricity and/or heat or steam if you need that for a process" (Respondent 8).

It is therefore recommended that for new (greenfield) mining projects that are not able to connect to the grid, mining companies should consider the three options of renewable energy with battery storage, a hybrid system, and a hybrid system with storage. In addition, mining companies must take a holistic approach to designing and addressing the energy requirements of a new mine by considering the use of a combination of renewable energy sources to meet the energy requirements, as outlined in the quote above.

In the case of current operations, it is recommended that mining companies continue to monitor the Eskom tariff as well as looking for opportunities where they can use renewable energy as supplementary energy. In particular, they should also focus on other forms of energy, such as steam and heat, rather than on electricity.

6.6.2 Electricity pricing

The discussion in Section 6.2.4 highlighted the following barrier elements due to electricity pricing: i) Eskom electricity prices are currently lower than those of renewable energy; and ii) uncertainty exists in predicting when renewable energy prices will reach grid parity.

It is an accepted fact that, currently, Eskom tariffs are cheaper than those offered by renewable energy projects (Joubert et al., 2016), as discussed in Section 6.2.4. The findings in Section 6.2.4 further highlight the concern around the ambiguity and uncertainty in the projection of future Eskom tariffs and this makes it difficult for them to motivate for future investment in renewable energy projects. In most instances, the respondents indicated that the assumptions used in the projections were unrealistic.

Two additional barriers act to exacerbate this issue. Firstly, there is political influence (the political and regulatory uncertainty barrier discussed in Section 6.3.6.1) in the process of setting electricity prices in South Africa, which is often done to keep prices at affordable levels for the poor. Secondly, the risk aversion barrier (Section 6.4.3.2) has shown that mining companies are conservative and will not take unnecessary risk in a situation where there is uncertainty about future Eskom prices. The following quote explains this issue:

"When you look at levelised cost of electricity and if you are talking South Africa, then the fuzzy area is: what is the Eskom price? So I think the levelised cost of electricity is an issue and the issue is not so much with the price of renewables, it's the issue with the insertion of a political intervention on the pricing" (Respondent 6).

It is clear from this discussion that the underlying issue that needs to be addressed is the requirement for clarity with regards to the future prices of Eskom electricity. Mining companies are not engaging in feasibility studies for investing in renewable energy projects because they are not confident about when renewable energy prices will reach grid parity. They also indicate that they do not have confidence in projections that have been made.

It is recommended that NERSA and government provide clarity regarding the electricity price-setting process. Mining companies need clarity on what the grid price will be in the future so that they are able to make a comparison with renewable energy tariffs.

6.6.3 Entrenched mindset

The discussion in Section 6.4.1 highlighted the following barrier elements due to an entrenched mindset within mining: i) preference to connect to the grid; ii) focus on core business; and iii) lack of innovation.

The mining industry has developed a dependency on traditional electricity systems that are based on the existence of a centralised generation system with a national grid (Abdmouleh et al., 2015). It is clear from the discussion in Section 6.4.1 that there is a preference for the status quo by mining companies (Richards et al., 2012). The discussion in Section 6.1.4.2 further illustrates that leaders in mining companies do not fully appreciate the benefits of renewable energy and how it can address their specific needs and challenges. This is a direct result of a lack of knowledge and the conservative nature of mining, as discussed in Section 6.4.3.2. Additionally, mining companies appear to be lacking in innovation and do not comprehend other possible applications of renewable energy technology.

It is apparent that there is a need to change the mindset within mining. Mining companies need to realise that there is an ongoing worldwide transition from traditional electricity systems that are dependent on a national grid to decentralised electricity systems based on a micro-grid. It is recommended that mining companies become more proactive in acquiring information and knowledge about this transition so they can understand how this will impact their operations. Mining companies can use the acquired knowledge to develop strategies about the role they will play in the future with regards to energy. It is also recommended that IPPs and renewable energy suppliers engage mining companies in providing them with information and knowledge.

6.6.4 Lack of supportive policy

The discussion in Section 6.3.1 highlighted the following barrier elements due to a lack of supportive policy: i) lack of government support; ii) lack of incentives; and iii) the imminent carbon tax.

Political support is a key enabler because it ensures that all regulations are simple and the bureaucratic processes are coordinated to facilitate investment in renewable energy (Abdmouleh et al., 2015). Polzin et al. (2015) argued that the establishment of a reliable framework with a clear vision and long-term policy objectives regarding renewable energy capacities to be installed in the future have been essential in supporting electricity generation from renewable energy sources. The discussion in Section 6.3.1 clearly shows that mining companies believe that government is not willing to support the adoption of off-grid industrial electricity generation from renewable sources (Votteler & Brent, 2016). The quote below highlights this point:

"So although they [government] think they have stimulated the market and I think in the short term it was a good thing, in the long term, the bigger picture is not there yet. To get private investors to come and do this, we need a whole different regulatory environment, a whole different way the country operates its electricity grid. It needs to change dramatically" (Respondent 7).

The discussion in Section 6.3.6.2 clearly establishes that the real reason why there is a lack of supportive policy is that the government is still committed to ensuring that the electricity sector remains a monopoly. This allows Eskom to influence regulations and use their dominance to protect their business while creating barriers for IPPs and the adoption of renewable energy (Pegels, 2010).

The issue that needs to be addressed is changing the structure of the electricity sector from a monopoly to an open market with an independent system operator that purchases electricity from various generators. It is therefore recommended that government needs to provide clarity on the future state of the electricity sector. The government needs to clearly articulate whether it will keep the electricity sector as a monopoly or whether it intends to reform the sector into an open market. This clarity will allow mining companies and other stakeholders to make an informed decision on their future roles in this sector.

6.6.5 Lack of a viable business case

The discussion in Section 6.2.2 highlighted that mining companies are not able to develop a viable business case for renewable energy projects due to the high capital costs, long payback periods, and low returns. The discussion in Section 6.2.1 further highlights that mining companies would rather invest the limited capital available in mining-related projects, which have better returns than renewable energy projects. This situation is exacerbated by the current low commodity prices, which have further limited the amount of capital available. An additional impact of the low commodity prices is that mining companies are in survival mode and the focus is on reducing debt and preserving the balance sheet (Section 6.4.3.1). Therefore, renewable energy projects are not even considered.

An important factor in developing the business case for renewable energy is the electricity prices from alternative sources. The discussion in Section 6.2.4 highlights that Eskom tariffs are currently lower than tariffs offered by renewable energy projects. A further challenge raised is the ambiguity and uncertainty in projecting future Eskom tariffs. The following quote demonstrated the importance of electricity price:

"You have to make a business case and a business case is one that says pricing must at least have grid parity. If the price that you gonna give me by the time you finish building is higher than the grid price, [then] you have to convince me how many more years do I have to take that. Is it just one year, then maybe that is acceptable? With a view of the long term, it becomes more predictable [when] it [will become] lower than the grid."

In order to address the business case for renewable energy projects, it is recommended that mining companies primarily evaluate the business case for mines that are not able to connect to the grid. It is also recommended that mining companies take a pragmatic and holistic approach in considering renewable energy by factoring in aspects such as environmental externalities, reputational value, and the future ability of Eskom to supply power.

6.6.6 Accounting standards

The discussion in Section 6.2.5.1 highlights the constraints that current accounting standards place on mining companies' ability to use IPPs as a mechanism to invest in renewable energy projects. The accounting standards dictate that long-term off-take agreements that are signed as part of a PPA then become a contingent liability on the balance sheet. This is not desirable for mining companies that are under pressure to reduce their debt and strengthen their balance sheet in a low commodity price environment. Respondent 4 indicated a possible solution to this issue by having multiple off-takers:

"So I have challenged every person I have ever spoken to, to find, build the renewables, sell it to us without balance sheet issue. Apparently it can be done, [but] if you have multiple off-takers, then you get into another complexity of contracting and risk sharing and if this company goes bankrupt or that company goes bankrupt…"

However, having multiple off-takers also introduces a limitation because mines will only obtain a portion of the electricity they require instead of investing in their own optimally designed renewable energy project to meet their requirements.

Chapter 7 Conclusions

This chapter consolidates the findings presented in Chapter 5 and the discussions in Chapter 6 into key outcomes based on the research problem as formulated in Chapter 1. The chapter highlights implications for various stakeholders, limitations of the research, and recommends focus areas for future research.

7.1 Research background and objectives

The aim of the study was to determine the barriers to greater adoption of renewable energy within the mining industry in South Africa. The study followed on the recommendation made by Votteler and Brent (2016) that a need existed to conduct research from the perspective of mining leaders in order to assist these leaders to better understand the concept of renewable energy and how it can address their specific needs and challenges. The research set out to determine the reasons for the low penetration of renewable energy in mining by establishing what barriers exist within the mining context in South Africa. The research also set out to determine the most significant barriers that need to be addressed in order to increase the penetration of renewable energy in this industry.

7.2 Principal findings

A number of propositions were formulated, based on related prior findings in the literature, to explain the low penetration of renewable energy in the mining industry in South Africa. The research has shown that there are a number of technical, economic and financial, institutional, and behavioural barriers that contribute to the low penetration of renewable energy in the mining industry in South Africa. The study identified 30 barriers that contribute to the low penetration of renewable energy in the mining industry as provided in Table 5-4. The findings suggest that the following 11 barriers have a significant impact on the adoption of renewable energy: i) intermittent nature of renewable energy; ii) electricity pricing; iii) entrenched mindset; iv) lack of supportive policy; v) lack of a viable business case; vi) political and regulatory uncertainty; vii) monopolistic market and Eskom influence; viii) inability to use the grid; ix) accounting standards; x) risk aversion; and xi) inability to meet maximum demand.

Four barriers were identified that appear to be mining-specific: i) inability to meet maximum demand; ii) accounting standards; iii) lack of focus on energy challenges; and iv) life of mine. Further research is required to determine their significance in the context of barriers to the adoption of renewable energy in mining.

7.2.1 Barriers to adoption of renewable energy

The following barriers were found to have significant impact and have prevented renewable energy from achieving its true potential.

7.2.1.1 Intermittent nature of renewable energy

The intermittent nature of renewable energy was identified as the most significant barrier. Mining operations are energy-intensive and require a reliable, guaranteed, and continuous supply of energy at sufficient capacity in order to be able to produce at their targeted production rates. The intermittent nature of renewable energy, as well its variability, makes it unsuitable for continuous applications, such as mining operations. The current study identified three main challenges (or barrier elements) associated with intermittency that influence mining's view on renewable energy:

i) The periodic availability of renewable energy (when the sun shines or the wind blows, for example) means that it is not a reliable source of energy since it does not provide a continuous supply of energy, which is essential for mining operations.
ii) Mining companies are concerned that renewable energy is not able to provide mining operations with base-load power. Consequently, mining companies are of the opinion that the role of renewable energy may be limited to providing supplementary power.
iii) Mining companies are not convinced that renewable energy will be able to guarantee security of supply. The assurance and availability of electricity in adequate quantities, when required, is an essential requirement for continuous mining operations.

7.2.1.2 Relatively cheap Eskom electricity prices

The relatively cheap price for Eskom electricity was identified as the second most significant barrier. The research findings confirmed that Eskom tariffs are currently cheaper than the tariffs offered by renewable energy projects. This explains the low penetration to date because mining companies are not willing to pay a higher price than that offered by Eskom. Low Eskom tariffs also account for the fact that mining companies struggle to develop a feasible business case for renewable energy.

The research found that an additional factor that currently impacts the potential for future adoption of renewable energy by mining companies is the inability to confidently predict when renewable energy tariffs will reach grid parity. The research shows that mining companies do not have confidence in future projections of Eskom tariffs. Mining companies indicated that the assumptions used in the electricity price projections were ambiguous and created uncertainty. Owing to the conservative nature of mining companies (which relates to the risk-aversion barrier, an additional behavioural barrier that has been identified in this research), mining companies are not willing to take any risk and invest in renewable energy projects. The findings from the study suggest that mining companies will rather wait until such time that when Eskom prices are higher than renewable energy tariffs before they consider investing.

7.2.1.3 Entrenched mindset

An entrenched mindset barrier was identified to be the third most significant barrier. The research has found that there is an entrenched mindset within mining companies that results in a preference for grid-connected electricity provided by the utility. The mining industry has developed a dependency on traditional electricity systems that are based on the existence of a centralised generation system with a national grid. Consequently, mining companies are not keen to invest in their own power generation, regardless of the potential benefits. The current study identified three main challenges (or barrier elements) due to the entrenched mindset:

i) Mining companies have a preference to connect their mining operations to the grid as it offers a reliable, guaranteed, and continuous supply of energy.

ii) Mining companies would rather focus on their core business of mining and view renewable energy as supplementary power that does not warrant their attention. As long as there is a grid available, there is a general reluctance to voluntarily invest in renewable energy projects

iii) A lack of innovation inhibits mining companies from thinking of alternative uses of renewable energy technologies to supply other types of energy (such as process steam) required for their operations.

As a consequence of this entrenched mindset, mining companies fail to appreciate the potential benefits of renewable energy and how it can address their specific needs and challenges.

7.2.1.4 Lack of supportive policy

The lack of supportive policy was identified as the fourth most significant barrier. Government support and incentives are necessary because renewable energy is disadvantaged by competing with established technologies (such as fossil fuel-fired power stations) that have reached or are close to their optimum performance in terms of cost and reliability. The study identified three main challenges (or barrier elements) due to a lack of supportive policy:

i) Mining companies believe that the South African government appears unwilling to support investment into privately owned renewable energy projects for own consumption (not delivered to the grid).

ii) There is a lack of incentives to encourage the adoption of renewable energy projects by mining companies.

iii) The lack of a carbon tax provides an advantage for Eskom electricity prices, thus creating a barrier for renewable energy.

7.2.1.5 Lack of a viable business case

The lack of a viable business case was identified as the fifth most significant barrier. Mining companies have found it difficult to develop a compelling business case to invest in renewable energy projects. The research found that high capital costs and the long payback times were key barrier elements (challenges). In addition, the return on investment for renewable energy does not meet mining companies' expectations. Mining companies prioritise the allocation of capital to projects that address the requirements of their core (mining) business, such as production- and efficiency-related projects. These projects provide a better return on investment than renewable energy projects and improve the mining company's production volumes. Owing to the cyclical nature of commodity prices, mining companies prefer to invest in short-term projects for existing mining operations rather than long-term projects such as renewable energy.

7.2.1.6 Political and regulatory uncertainty

The political and regulatory uncertainty barrier raises a significant concern as it emphasises that the political environment in South Africa is not conducive to investment. Concerns were raised about the uncertainty in government policy, political infighting, and the perception that government wants to have more involvement in mining as a shareholder. This not only affects investment in renewable energy, but also highlights that investors are reluctant to invest capital in the country under the current political environment.

7.2.1.7 Accounting standards

Current accounting standards place a constraint on mining companies' ability to use IPPs as a mechanism to invest in renewable energy projects. The current IFRS accounting standards dictate that long-term off-take agreements that are signed as part of a PPA become a contingent liability on the balance sheet of the company. This is not desirable for mining companies that are under pressure to reduce their debt and strengthen their balance sheet in a low commodity price environment. This discourages mining companies from adopting renewable energy. The accounting standards barrier warrants further investigation.

7.2.1.8 Life of mine

The research found a significant constraint when considering renewable energy for existing mining operations: the life of mine of current mining operations. This refers to the finite number of years during which a mine can economically extract minerals. The life of mine for current operations may be shorter than the duration of the PPA agreement (typically 20 to 25 years) or the payback period for renewable energy projects. This makes the life of mine a barrier for current mining operations.

Discussion on the life of mine barrier led to an additional finding for this research. The respondents argued that the best way to increase penetration of renewable energy in mining was to target new (greenfields) projects in mining. They argued that the retrofitting of renewable energy solutions to current mining operations was expensive and does not make business sense. The suggestion is that greenfields projects offer an opportunity to optimally design the incorporation of renewable energy, not only for electricity generation, but to also meet other energy requirements for the mine, such as process steam and heat.

7.2.2 Contribution to the literature

This research has made two major contributions to the literature on barriers to the adoption of renewable energy, particularly because research in the mining context in South Africa is relatively new and the related literature is limited.

Firstly, this research identified the barriers that contribute to the low penetration of renewable energy from the perspective of mining companies. Therefore, the research has extended the knowledge on the barriers to renewable energy beyond the traditional sectors researched in the literature (such as the power generation sector, commercial buildings, and residential customers) to include the mining industry, which is a significant user of energy. Although some researchers have identified barriers in their studies on the potential of renewable electricity sources for mining operations in South Africa (Votteler & Brent, 2016), their findings were based on a conceptual literature review; they relied on conceptual knowledge to develop a better understanding of barriers. The current research contributes to the understanding of barriers from a mining perspective.

Secondly, the research has enhanced understanding of the impact of the barriers in a different context: the mining industry in South Africa. Additionally, the research has identified the main challenges (barrier elements) associated with the barriers. As a result, findings from the research should enhance the understanding of the issues that need to be addressed, from a consumer perspective (privately owned renewable energy projects), compared with the supplier perspective. The actions (through specific policy, programmes, or measures) required to address the barriers for energy consumers are different to those of the power-generation sector. Therefore, the research provides knowledge that contributes to the design of effective and complementary policies that specifically target addressing barriers within mining. This is in line with the observation made in literature that broad and indiscriminate policies that group mining with the power-generation and commercial-buildings sectors, are unlikely to be effective in addressing the barriers to the adoption of renewable energy (Napp et al., 2014).

7.3 Implications for management

The findings of this research have several practical implications for various stakeholders in the renewable energy space. It is quite clear that, unless the significant barriers are addressed through specific actions, it is unlikely that mining companies will invest in renewable energy. However, all stakeholders have a role in addressing the current barriers that prevent the adoption of renewable energy in mining. Implications for mining and policymakers are provided in the following sections.

7.3.1 Energy and sustainability managers

Energy and sustainability managers formed the majority of the participants in this study. Their role in the adoption of renewable energy in mining is quite important because they are responsible for developing the business case for investing in renewable energy. They can be viewed as ambassadors for renewable energy. The findings from this research should provide such managers with an understanding of the barriers they need to overcome in order to introduce renewable energy in the mining industry.

The energy and sustainability managers need to educate and provide information about the benefits of renewable energy and the role it can play in addressing the needs and challenges of their organisations. They should target mining executives in order to influence their thinking so that the entrenched mindset barrier can be addressed, with a particular focus on reducing reliance on the grid.

There is also a need for energy and sustainability managers to educate IPPs and equipment suppliers about the specific needs of mining. They should point out that the crucial requirements for mining companies are base-load power, security of supply, and predictable tariffs that are lower than grid prices. By clearly articulating these requirements, the stakeholders can work towards finding innovative solutions that address these key barriers.

7.3.2 Mining executives

A key finding from this research is the behavioural barrier of an entrenched mindset that was identified within mining companies. This barrier raises three key challenges. Firstly, mining companies have a preference for grid-connected electricity provided by the utility and will not voluntarily generate their own electricity as long as there is a grid available. Secondly, mining companies are adamant that they would rather focus on their core business of mining and not venture into power-generation projects such as renewable energy. Thirdly, as a consequence of these two attitudes, mining companies are not able to see the potential benefits of renewable energy and how it can address their specific needs and challenges. Thus, there is a lack of innovation.

This research has also revealed that mining companies are risk-averse and conservative in nature, which is a barrier to the adoption of renewable energy. In light of these findings, this would suggest that there is a need to change this prevailing mindset in the industry. Mining executives can play a role here because they are able to influence the cultures of their organisations. Therefore, mining executives need to consider emphasising renewable energy as part of the organisational transformation of transitioning mining companies, and the industry in general, into more environmentally friendly and sustainable businesses.

Mining executives also have a key role to play in motivating their employees, who are responsible for energy, to produce innovative solutions for mining operations' energy requirements that integrate renewable energy. The findings also show that mining companies need to lobby government and policymakers to establish policy and regulations that allow for privately owned renewable energy power stations.

7.3.3 Government and policymakers

Government and policymakers are key stakeholders; other researchers (Abdmouleh et al., 2015) have shown that political support is a key enabler to facilitate investment in renewable energy. Polzin et al. (2015) argued that the establishment of a reliable framework with a clear vision and long-term policy objectives regarding renewable energy capacities to be installed in the future is essential in supporting investment in renewable energy sources.

The findings of this research have shown that mining companies believe that the South African government is not willing to support investment into privately owned off-grid renewable energy projects. In addition, mining companies have also pointed out that there is little clarity about the electricity price-setting process and often it appears as if there is political intervention in the process. This creates ambiguity and uncertainty about future Eskom tariffs. Mining companies are not able to develop business cases for renewable energy because they are unable to determine when renewable energy tariffs will reach grid parity.

Government and policymakers need to clearly articulate their policy position on the future of the South African electricity sector. In addition, government must provide clarity on whether it supports privately owned off-grid renewable energy projects. Provided that there is clarity, mining companies and other stakeholders will be able to make informed decisions on their future roles in the electricity sector.

7.4 Limitations of the research

There are certain limitations to this study. These are restated here, as previously provided in Section 4.8. Firstly, given that the researcher focused on South African mining companies, the generalisability to other industries, both to other sectors within South Africa or global mining companies, is limited. The findings from this study, however, would provide a good platform for further research in the aforementioned areas. In addition, the use of purposive sampling, a non-probability sampling technique, means that the sample is not representative of the population (Saunders & Lewis, 2012).

Given that the research includes qualitative elements, there is potential for subjectivity in the research outcomes. Saunders and Lewis (2012) suggest that exploratory research is subjective and may reflect the perspectives of the researcher. This potentially introduces researcher bias into the research study. Nonetheless, exploratory research was deemed the best fit to the research objective.

There may be elements of bias due to the following reasons: i) the fact that the researcher has predominantly worked in the mining industry during his career; ii) the researcher is familiar with some of the participants in the research; having worked with them or previously interacted with them in various fora; iii) the reliance on theory and the use of the deductive approach and directed content analysis in the research. Based on the three reasons above, there is a risk that the researcher is more likely to find evidence that supports the theory and framework, rather than evidence that does not support the theory.

The researcher focused on isolating specific barriers and their impact on the penetration of renewable energy. The researcher did not try to study and elaborate on the linkages that exist within the various barriers. The inter-linkage between barriers reinforces the impact of the barriers and makes it difficult to study them.

Finally, prior research has assessed several more categories of barriers than the four selected for review in this study. The researcher chose to focus the research on four categories based on their appropriateness to the mining context, and only briefly acknowledged other categories in the literature review.

7.5 Suggestions for future research

The current study broadly looked at all renewable energy sources so as not to limit information on the most applicable source for mining. Future studies should concentrate on solar PV and hybrid solar–diesel systems as the energy sources having the greatest potential.

One of the findings of this research was that, to increase penetration of renewable energy, mining companies should target new (greenfield) mining projects. Future studies should separate the context between current (brownfield) operations and greenfield projects. The studies should focus on barriers that may exist to adoption of renewable energy for greenfield projects that do not have access to a stable and reliable grid. This is where the greatest potential and opportunity for greater penetration of renewable energy lies.

Future studies should concentrate on the barrier elements to allow for the design and recommendation of suitable policy and programmes to address the barriers.

Future studies should focus on understanding the significant barriers that were identified in this study. The electricity price, in particular, should be investigated because, once grid parity is reached, it is possible that mining could experience a significant uptake of renewable energy. Increased uptake will affect national energy planning and strategy.

7.6 Conclusion

The research was motivated by the observed low penetration of renewable energy in the mining sector. Mining is an industry under pressure, from a sustainability perspective, due to its significant environmental impact, particularly through the substantial requirements and usage of land, water, and energy resources. Additionally, the mining industry is currently faced with low and volatile commodity prices that have negatively impacted on mining companies' earnings. Moreover, continuity of electricity supply and escalating electricity costs in South Africa are significant risks facing mining companies today. Despite the strong evidence of renewable energy as a sustainable and cost-effective source of energy when compared with conventional fossil fuel-based sources, uptake has remained low.

The objective of the study was to identify the barriers to greater adoption of renewable energy in the mining industry in South Africa. The study also sought to identify specific barriers that pose the biggest hurdle to mining companies adopting renewable energy.

The study identified a number of technical, economic and financial, institutional, and behavioural barriers that contribute to the low penetration of renewable energy in the mining industry in South Africa. The study identified 30 barriers that contribute to the low penetration of renewable energy in the mining industry, with 11 of these barriers considered to have a significant impact: i) intermittent nature of renewable energy; ii) electricity pricing; iii) entrenched mindset; iv) lack of supportive policy; v) lack of a viable business case; vi) political and regulatory uncertainty; vii) monopolistic market and Eskom influence; viii) inability to use the grid; ix) accounting standards; x) risk aversion; and xi) inability to meet maximum demand. Recommendations have been made to address the barriers to the main stakeholders.

This study provides a foundational basis for future research on barriers in mining and other industry sectors in South Africa, as well as globally.

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Appendix A: Interview Guide

Interview guide – Barriers to greater adoption of renewable energy by mining companies in South Africa

Section 1: General

This section seeks to gather some general information about the respondent.

Question 1:

1.1. Position/role in the company:

1.2. Education/Qualification

1.3. Number of years' experience in mining:

1.4. Do you have any previous experience or exposure to the use of renewable energy in your previous positions/roles??

a) Yes

b) No

1.5. Has your company considered or implemented renewable energy in the past?

c) Yes

d) No

1.6. Is your company considering the implementation of renewable energy in future?

a) Yes

b) No

1.7. Which renewable technologies have you considered/are being considered by your organisation?

Opening questions

Utility scale renewable energy (REIPPPP) in South Africa has been lauded as a great success. However, this optimism on renewable energy has not transferred to residential, commercial and industrial sectors.

1. What is your view (in general) about renewable energy?
    a. *Probe:* Why do you think it is good/bad?
    b. *Probe:* What informs your view? Experience
2. Would you say renewable energy is applicable for the mining industry?
    a. *Probe:* Which renewable energy technologies do you consider to be the most appropriate? Why? Informed by experience/technical information/case studies/demo plants?
3. What are the pros and cons for renewable energy in mining?
4. What is your opinion on the uptake of renewable energy by the mining industry?
    a. *Probe:* Do you think the uptake is high or low? Why do you think uptake has been high or low?
    b. *Probe:* Does the level of uptake in any manner reflect mining's view/assessment of renewable energy?
    c. *Probe:* What factors are driving/contributing to this level of uptake?
5. In general, what is required to improve the level of uptake of renewable energy by mining companies?

The next set of questions are going to be dealing with four main themes regarding barriers to the adoption of renewable energy. These are technical, economic and financial, institutional barriers and behavioural barriers. We define barriers as factors that negatively affect the adoption and utilisation of renewable energy and thus limit widespread diffusion.

If you look at a programme like the government's REIPPPP; the challenges that IPPs face relate to development costs. These development cost can contribute 2 to 2.5% of the investment and include:

a) Land acquisition
b) Grid connection
c) Legal costs
d) Environmental specialist

The advantage that mines have over IPPs is that most of these challenges are to certain extent mitigated.

Section 2 Technical barriers

Technical barriers to renewable energy generally include factors such as the availability of the resource, technological applications and the availability of skilled people to implement renewable energy technologies. These factors prevent the utilisation from reaching its full potential.

1. What technical challenges or barriers do renewable energy technologies face in the mining industry?
    a. Probe: Do any specific examples come to mind?
    b. Probe: How do these barriers affect the level of uptake of renewable energy by mining?
    - Potential technical barriers include:
        i. Intermittent nature of renewable energy
        ii. Mines not located in favourable areas for renewable energy
        iii. Storage costs/hybrid systems too expensive

Section 3 Economic and financial barriers

This section of the interview investigates the influence of economic and financial factors on the adoption of renewable energy. It considers the impact of global and macro-economic (commodity prices) conditions, financial evaluation of renewable energy.

1. What financial challenges or barriers do renewable energy technologies face in the mining industry?
    a. Probe: Do any specific examples come to mind?
    b. Probe: How do these barriers affect the level of uptake of renewable energy by mining?
2. Which aspect of the financial assessment is the greatest hurdle for the evaluation of renewable energy in your organisation (i.e. a) high capital cost b) long payback period c) high rate of return compared to other capital projects due to perceived high risk)?
3. How have the current economic conditions (low metal prices, slow economic growth etc.) affected the decisions to invest in renewable energy? Explain
4. Do you think renewable energy projects are a higher risk investment compared to other capital projects? Why?
5. Do you think renewable energy is cost-competitive with other energy options (for example Eskom/grid electricity tariffs)? Please explain.

Section 4 Institutional barriers

Institutional barriers refer to the policy and regulatory environment, infrastructure requirements and institutions that may promote or hinder renewable energy.

1. What institutional/policy/regulatory challenges or barriers do renewable energy technologies face in the mining industry?
    a. Probe: Do any specific examples come to mind?
    b. Probe: How do these barriers affect the level of uptake of renewable energy by mining?
2. How do the current policy measures and government programmes (i.e. Renewable energy independent power producer programme) affect the adoption of renewable energy in mining?
3. Do you think there is political/regulatory will to encourage mining companies to adopt renewable energy? Explain
    a. Probe: What should be done to address this?
4. Does the nature of the electricity market (Eskom as a monopoly and state controlled) affect (facilitate or constrain) the adoption of renewable energy in mining? Explain?
    a. What needs to be done to address this?
5. Do bureaucratic processes such as the environmental impact assessment (EIA) process have an impact on evaluating the feasibility of renewable energy? Explain

Section 5 Social, cultural and behavioural

Socio-cultural and behavioural barriers may arise as a result of i) industry (both mining and energy industries) structure, norms and value system; ii) awareness and risk perception (due to a lack of information); iii) behavioural, negative perceptions and resistance to change.

1. Do you think that the past reliance on Eskom as the sole provider of electricity has an impact on considerations of adopting renewable energy (i.e. energy does not form part of the core business of mining companies)? Explain

Concluding questions and remarks

1. Which are the three most significant barriers (poses the greatest threat) to renewable energy adoption in mining that should first be addressed? Or perhaps, what are the combination of barriers that prevent adoption of renewable energy by mining companies?
    a. Explain. What should be done to address these?

2. In order for investment in renewable energy by the mining industry to increase, what changes do you think should happen? In other words, what do you envision as an ideal/enabling environment?
3. Which area is the most progress being made in? Explain.
4. Do you have any final comments or questions?

Appendix B: Consent Form for the Study

CONSENT FORM

Dear Participant,

As part of the MBA programme at the University of Pretoria's Gordon Institute of Business Science (GIBS), I am conducting a study on the barriers to the adoption of renewable energy by the mining industry. The study seeks to determine and understand the underlying causes for the barriers to the adoption of renewable energy by the mining industry. It is anticipated that the interview should last for one hour.

Your participation is voluntary and you can withdraw at any time without penalty. Of course, all data will be kept confidential. The results of this study will be presented in aggregate and individuals will not be associated with findings or views expressed. If you have any concerns, please contact me or my supervisor. Our details are provided below.

Researcher name: Takalani Gangazhe

Email:takalani.gangazhe@gmail.com

Phone: 083 962 4812

Supervisor: Patsy Hime

Email: patsyhime@gmail.com

Phone: 082 528 1045

Name of participant: ______________________________

Signature of participant: ______________________________

Date: ______________________________

Signature of researcher: ______________________________

Date: ______________________________

Permission to record the interview granted.

1. Yes
2. No

Appendix C: Coding scheme

Table C - 1 Initial coding scheme

Colour	Name	Occurrence
Orange	Access to infrastructure	2
	Accounting standards	14
Orange	Administrative	5
Yellow	Behavioural	28
Red	Business case	20
Red	Capital constraint	10
	Complex regulatory environment	5
	Current operations compared to greenfields	6
Red	Electricity pricing	26
	External factors affecting performance	1
	Financial guarantees	2
	Industry and regulatory standards	2
	Lack of focus on energy challenges	12
Orange	Lack of framework for grid usage	10
Orange	Lack of framework to allow feeding into the grid	2
Yellow	Lack of information	7
	Lack of knowledge	5
	Lack of skills	2
Orange	Lack of supportive policy	20
	Land availability	6
	Life of mine	7
	Monopoly abuse and influence	13
Dark Green	Resource availability - location of mines	1
Dark Green	Resource availability - nature of renewable energy	38
	Resources to manage the project	1
Red	Risk perception	2
	Security costs	5
	Size limited to what you are able to consume	1
Dark Green	Technology maturity	10
	Time duration of processes	7
	Time period of the PPA contract	4
	Unable to meet maximum demand peaks	7
	Uncertainty in mining policy	4
	Wasting of energy	5

Dark Green	Technical barriers
Red	Economic and financial barriers
Orange	Institutional barriers
Yellow	Behavioural barriers
	Additional barriers

Table C - 2 Final coding scheme

Colour	Name	Occurrence
Orange	Inability to use the grid	11
Purple	Accounting standards	15
Orange	Administrative	5
Purple	Age of grid infrastructure	1
Red	Business case	22
Red	Capital constraint	10
Purple	Current operations compared to greenfields	8
Purple	Duration of the PPA contract	5
Red	Electricity pricing	27
Yellow	Entrenched mindset	30
Purple	External factors affecting performance	2
Orange	Grid connection costs	0
Purple	Inability to meet maximum demand peaks	8
Dark Green	Inadequacy of supply and location of mines	6
Purple	Industry and regulatory standards	4
Dark Green	Intermittent nature of renewable energy	37
Purple	Lack of focus on energy challenges	12
Orange	Lack of framework to allow feeding into the grid	3
Yellow	Lack of information	7
Purple	Lack of knowledge and skills	8
Orange	Lack of supportive policy	20
Purple	Land availability	6
Purple	Life of mine	8
Purple	Monopolistic market and Eskom influence	14
Purple	Political and regulatory uncertainty	11
Purple	Preference to invest in energy efficiency projects	5
Purple	Resources to manage the project	2
Purple	Risk aversion	11
Red	Risk perception	5
Purple	Security costs	5
Dark Green	Technology maturity	9

Dark Green	Technical barriers
Red	Economic and financial barriers
Orange	Institutional barriers
Yellow	Behavioural barriers
Purple	Additional barriers