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DETERMINANTS THAT INFLUENCE RENEWABLE ENERGY INVESTMENTS

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A Research Report submitted to the Faculty of Science, University of the Witwatersrand, Johannesburg, in partial fulfilment of the requirements for the degree of Master of Science.

02 November 2018

Declaration

I declare that this research report is my own, unaided work. It is being submitted for the Degree of Masters of Science at the University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination at any other University.



(Signature of candidate)

2nd day of November 2018 in Johannesburg

Abstract

The Kyoto Protocol, Global Climate Change Agenda and imperative to reduce greenhouse gas emissions has gained significant traction recently as decision makers attempt to mitigate the impacts of climate change. Energy that is produced from non-renewable energy sources, such as fossil fuels, is a significant contributor to greenhouse gas emissions, and by displacing non-renewable energy production and consumption with renewable energy production, greenhouse gas emissions can be reduced. This is particularly relevant to the mining industry, which is a significant consumer of energy, particularly energy from non-renewable fossil fuel sources. Consumption of renewable energy for mining related activities presents a cost saving opportunity for the industry and could support mitigating the effects of climate change. This research aimed to identify the main determinants that influence decisions in energy investment projects, and specifically, to determine the most influential determinant in energy investment decisions, particularly in the mining industry. Through interviews of subject matter experts in the mining industry, sustainable development, renewable energy and renewable energy project investment and finance, the results suggest that Life of Operation, i.e. life of mining asset or operation, was the most influential determinant in making energy investment decisions. Security of Energy Supply in which cost, reliability and availability are secured through the energy investment closely follows as the second most influential determinant.

The Global Climate Change Agenda may create an enabling environment for renewable energy investments, however the key drivers in such decisions are the financial aspects of the investment.

Keywords: renewable energy, greenhouse gas emissions, mining, life of operations, security of energy supply, base load energy requirements, Global Climate Change Agenda, financial investment

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Nomenclature

CDM	Clean Development Mechanisms
COP21	Conference of the Parties of 1992 United Nations Framework Convention on Climate Change, COP21 was the 21st conference in Paris
CSP	Concentrated Solar Power
EPC	Engineer, Procure, Construct
ESG	Environment, Social, Governance
GHG	Greenhouse Gas
GWh	Gigawatt Hour
IPCC	Intergovernmental Panel on Climate
IPP	Independent Power Producer
IRR	Internal Rate of Return
MW	Mega Watts
NPV	Net Present Value
PPA	Power Purchase Agreement
PV	Photovoltaic
REIPPP	Renewable Energy Independent Power Producer Projects
REN21	Renewable Energy Policy Network for the 21st Century
UNFCCC	United Nations Framework Convention on Climate Change
US$	United States Dollars
WEF	World Economic Forum
WWF	World Wide Fund for Nature

Chapter 1: Introduction

Renewable energy sources are being driven as the solution for energy supply challenges globally, pushed by considerations such as ‘cleaner’ energy and reduction in greenhouse gas (GHG) emissions as part of the ‘Global Climate Change Agenda’ (Akuru, Onukwube, Okoro, and Obe, 2017; Mohammed, Mustafa, Bashir, and Ibrahem, 2017). Renewable energy sources also present practical solutions for remote areas where grid supply may be challenging, or as a potential cost savings opportunity (Sonnenschein, 2016). On a large commercial and industrial scale, renewable energy may be supported by a non-renewable power supply to ensure operational continuity for power supply security, when renewable energy storage is not viable, or fully available (Kempton and Tomić, 2005; Evans, Strezov, and Evans, 2009).

Investment in renewable energy is increasing, albeit it at a slow pace, and can achieve objectives such as reduction in GHG emissions, cost savings through the use of a non-depletable source of energy and contribute towards economic growth (Soberanis, Alnaggar, and Mérida, 2015; Can Şener, Sharp, and Anctil, 2017). Investment in non-renewable energy supply however also continues (Kahia, Aïssa, and Lanouar, 2017). It is speculated that this may be due to cost, Security of Energy Supply, renewable resources availability (such as sunshine, wind) or limited availability of effective energy storage options. Paradoxically, non-renewable energy supply and continued investment in existing supplies may also be an important requirement to successfully invest in and grow renewable energy supply (The Economist, 2017).

The African mining industry is often cited as a significant consumer of fossil fuels, and therefore significant emitter of GHGs (Holmberg, Kivikytö-Reponen, Härkisaari, Valtonen, and Erdemir, 2017). Mining typically utilises significant amounts of energy to access the ore body of the material being mined, particularly in ventilation, cooling and materials movement in deep underground mining and/or materials movement, utilising heavy earth moving equipment or

facilities (Holmberg *et al.*, 2017; Vyhmeister, Aleixendri, Bermúdez, Pina, Fúnez, Rodríguez, Reyes-Bozo, 2017). Associated infrastructure, services and mineral processing also require energy, all of which has traditionally been provided by non-renewable sources (Limanskiy and Vasilyeva, 2016). As a significant consumer of energy and emitter of GHGs, the mining sector potentially has significant opportunities in the reduction of GHG emissions with renewable energy sources. However, the resource investment, particularly capital investment, is likely to be significant for the conversion to, or utilisation of, renewable energy sources (Vyhmeister *et al*., 2017), particularly in remote areas or countries with already limited energy and/or renewable energy generation and supply opportunities. The intense 'base load' energy demands of the mining sector also present an energy security challenge, particularly when considering renewable energy (Bajpai and Dash, 2012; McLellan, Corder, Giurco, and Ishihara, 2012). Investment in energy generation from non-renewable sources continues, such as the South African national utility (Eskom) investment in the 4,764MW Medupi and 4,800MW Kusile coal-fired stations (Eskom, 2017). However, opportunities for renewable energy use exist and are being implemented, for example the 82.5MW Paleisheuwel Concentrated Solar Power (CSP) Project and 10MW Enel Upington photovoltaic power plant situated in the Northern Cape (Africa News Agency, 2016). Whilst these schemes may not compare in size with the coal fired power stations, they demonstrate that large scale renewable energy production is possible.

So, what is influencing renewable energy investments? Conversely, what is influencing the investment in non-renewable energy when renewable options may be available?

1. 1 Aim and Objectives of the Study

The aim of this study was to identify the most influential determinant in an energy investment project decision, and determine the amount of influence the remaining determinants have on a decision. This, in turn may identify why non-renewable

energy investments continue, despite the apparent global drive for cleaner energy production and the benefits of renewable energy investments.

The objectives of the study were to:

- identify the most applicable drivers or determinants of energy investment decisions;
- ascertain the most influential determinant or driver of investment decisions through interviews with subject matter experts in energy generation, renewable energy investment, financial and commercial considerations in energy investment, sustainability and the mining industry;
- determine the influence the remaining determinants have in an energy investment decision;
- assess the suitability of objective criteria of the determinants that influence investment decisions, once again through the interview of subject matter experts, and
- where appropriate, identify enablers for renewable energy investments.

1.2 Layout of Research Report

The chapters of this report are designed to follow the aims and objectives of the report, and present data in the chronology in which it was obtained. Chapter 1 includes an introduction to the study as well as the aim and objectives of the research. Chapter 2 provides a literature review, giving insights in the energy challenges of the mining industry, the challenges and opportunities associated with renewable energy and an investigation in the determinants identified to influence decision-making with regards to renewable energy. Chapter 3 summarises the methodology used for this research and Chapter 4 presents the results obtained. Chapter 5 closes with a discussion of the findings and the implications of the insights gained for the future of renewable energy in the mining sector. A reference list follows this last chapter, and appendices are found at the end of this research report. Figures and tables and numbered consecutively throughout the report.

Chapter 2: Literature Review

It is widely accepted that anthropogenic climate change and associated greenhouse gas (GHG) emissions are affected by energy consumption, through energy production (Weisser, 2007; Evans *et al.,* 2009; Ou, Xiaoyu, and Zhang, 2011). Converting energy from a non-renewable fossil fuel to a renewable form may therefore have a significant impact on the reduction of the GHG emissions footprint. There is a global climate change drive, most recognisably through the Intergovernmental Panel on Climate (IPCC) and United Nations Framework Convention on Climate Change (UNFCCC). The IPCC represents a body of international scientists whose research and assessments are consolidated and interpreted to provide governments. This includes policy makers, with scientific information on climate change, risks, impacts and possible mitigation and management measures to address these impacts. This information is intended to inform decision making, policy, and importantly, the UN Climate Conferences (Osorio-Arce *et al*., 1988).

The objective of the UNFCCC is to ensure the "stabilisation of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system" (UNFCC, 1992, page 9). This should be ensured in a manner that allows ecosystems to adapt naturally, protects food security and ensures that economic development is not compromised. The Kyoto Protocol, an international treaty negotiated in 1997, enacted in 2005 and extended to 2020, is a binding agreement in which industrialised countries have set reduction targets for their collective GHG emissions (Kyoto Protocol, 1997). The UNFCCC has further initiated the setting of reduction targets and associated mitigation strategies, including strategies in the energy sector for developing nations (Amrutha, Balachandra, Mathirajan, 2017).

The 'Paris Agreement', which was negotiated by the UNFCCC Conference of Parties (COP) in December 2015 and enacted in November 2016, specifically

addresses the mitigation of GHG emissions, adaptation to the effects of climate change as well as the financing mechanisms for these aspects (UNFCCC, 2017a). As a means of achieving the commitments set out in the Paris Agreement, there is an imperative for a significant and fast transformation in the energy generation space (Clemencon, 2016).

Countries that participate in the Paris Agreement are required to mitigate climate change by determining their contribution to climate change (their GHG emissions footprint), provide plans to address these and report on the progress in mitigating climate change in a manner that exceeds previous targets (UNFCCC, 2017b). Ultimately, these interventions are aimed at preventing the predicted temperature increase going beyond 2^{o}C and, where possible, work towards a 1.5^{o}C increase limit to reduce the effects of climate change (Rohit, Devi, and Rangnekar, 2017). Countries are also required to improve their ability to adapt to climate change effects in a sustainable manner (UNFCCC, 2017b). The Paris Agreement - recognises that mitigation and adaptation need to be complemented with an enabling financial environment that contributes to reduced GHG emissions and climate resilience (Reboredo, Quintela, and Otero, 2017). Arguably, an enabling financial environment can unlock mitigation and adaptation initiatives and provide a real driver for managing climate change. This enabling driver presents an opportunity for growing and technologically advancing developed and developing economies. As the demand for energy grows, GHG emissions from energy generation can be mitigated through mechanisms of energy savings, efficient consumption and / or increased use of renewable energy sources (Tezer, Yaman, and Yaman, 2017). This can be optimised or fast tracked through a financially enabling environment.

The World Economic Forum (WEF) maintains that, to ensure equitable and sustainable economic growth particularly in developing countries, a transition to “green growth” economic development is required. This includes investment in renewable energy technology in developing countries to reduce GHG emissions. They have however identified slow and inadequate progress as investment in

fossil fuel energy generation continued to exceed investment in renewable energy generation in 2013 (World Economic Forum, 2013). A World Wide Fund for Nature (WWF) report re-iterates, after reviewing European investor practices, that whilst financial regulators and investors are increasing their commitment and investment decisions to achieve a reduction in GHG emissions in line with the Paris Agreement, the rate of and extent to which this is achieved is not sufficient (Godinot and Vandermosten, 2017). Therefore, the reason or cause for the pace at which this is achieved is in question.

2.1 Non-Renewable and Renewable Energy

Energy exists in many forms on Earth and humankind has utilised this energy in its different forms and sources over time. Some of the forms in which energy exists includes solar energy, thermal energy, and kinetic energy.

The energy sources available have not materially changed over time, but man's ability to harness this energy in an efficient manner or on a large scale and continuous manner has changed over time. These energy sources consist of non-renewable and renewable sources with non-renewable energy supply being the dominant source of energy supply for electricity generation, for distribution and use in the United States of America in 2016 (U.S. Energy Information Administration, 2016), as data for 2006 to 2015 illustrate in Table 1 below.

Table 1: Electricity generation by source (non-renewable and renewable), in thousand megawatt hours, in the United States in 2016. (Source: U.S. Energy Information Administration, 2016. p15)

Period	Renewable Total	Renewable % of Total	Non-Renewable Total	Non-Renewable % of Total	Total Generation at Utility Scale Facilities
2006	392,188	10%	3,672,514	90%	4,064,702
2007	358,083	9%	3,798,663	91%	4,156,745
2008	386,448	9%	3,732,939	91%	4,119,388
2009	425,025	11%	3,525,306	89%	3,950,331
2010	434,730	11%	3,690,329	89%	4,125,060
2011	521,069	13%	3,579,071	87%	4,100,141

Period	Renewable Total	Renewable % of Total	Non-Renewable Total	Non-Renewable % of Total	Total Generation at Utility Scale Facilities
2012	503,410	12%	3,544,356	88%	4,047,765
2013	530,980	13%	3,534,984	87%	4,065,964
2014	545,867	13%	3,547,738	87%	4,093,606
2015	557,671	14%	3,529,709	86%	4,087,381

The information provided above illustrates the large dependence on non-renewable energy sources for power generation and distribution, primarily using natural gas, coal and nuclear fuel sources for electricity. In 2015 3.5million GWh of electricity were generated at utility scale from non-renewable sources whilst 0.6million GWh of electricity were generated at utility scale from renewable sources (Source: U.S. Energy Information Administration, 2016. p15).

Fossil fuel energy supply is the primary fuel source used globally for non-renewable electricity generation and consists of five types of fossil fuels: coal, petroleum coke, petroleum liquids, natural and other gas. These along with nuclear fuels typically make up the fossil fuel source for energy generation and / or are ‘non-renewable’ (International Energy Agency, 2016). Thermal generation utilises these energy sources in generating electricity (International Energy Agency, 2016).

Renewable energy has undeniably undergone a radical transformation over the last decade. The Renewable Energy Policy Network for the 21st Century (REN21) attributes this largely to changes in policy, financing opportunities, improvements in renewable energy supply, security and the Global Climate Change Agenda demanding cleaner energy (REN21, 2016). REN21 (2016) also recognises developing and emerging economies’ demand for energy increase, thus driving the renewable energy market from another demand perspective. Whilst renewable energy is not the majority contributor to power generation and supply, the use of renewable energy on a utility generation scale has increased by more than 40% in the last 10 years, in the United States of America, as shown in Table 1 above. The predominant forms of renewable energy include solar and

solar photovoltaic (PV), concentrated solar power (CSP), hydropower from flowing water, wind power, bioenergy (such as fuel generated from plant matter, for example sugarcane), geothermal power (REN21, 2016) and hydrogen fuel (Renewable Energy World, 2016).

The sun's energy can be used directly and indirectly in many ways to harness its energy, and in some instances generate power or electricity. Solar energy or direct heat from the sun is perhaps the simplest form of harnessing the sun's energy, but is mostly useful for heating. The sun's energy, when it is available during the day, needs to be converted into a useable from of energy supply such as solar thermal power or solar PV before it can be used commercially (Mills, 2004).

Solar PV utilises the energy (photons) from the sun and converts it to direct electricity using specialist semi-conductors (Eskom, 2014). The PV effect utilises photons of light or light energy to excite electrons contained in specialist semi-conductor material which in turn converts them to charge carriers for an electric current, essentially creating a direct current of electricity (Eskom, 2014). This electric current can be used directly as electricity or to charge a battery storage system which will store energy, or electricity, when the sun is not shining. The cost of these batteries, and low efficiencies or short lifespan, make this option very expensive on a commercial scale (Vyhmeister *et al*., 2017). Battery technology, for the purpose of renewable energy storage, is evolving rapidly (Olabi, 2017; Caldera and Breyer 2018).

CSP utilises various methods to capture or concentrate solar energy to a central collection point in which heat energy is used to heat a heat-transfer-fluid or system. This in turn is utilised to generate electricity through a turbine and the Faraday process. Two main types of CSP generation are utilised, one of which allows for a thermal storage solution through the use of thermal storage material, such as molten salt, in order to retain thermal energy captured during the day for extended use when the sun is no longer shining (Hussain, Arif, and Aslam, 2017). This increases the capacity factor of CSP. Capacity factor is the ratio of the actual

energy generated for use from a facility to the potential energy that could be generated from a facility, with the higher the capacity factor the better for efficient energy generation and use (Jha and Puppala, 2017). CSP is a relatively new and expensive technology with limited large-scale applications. The land requirements for such a project are also likely to be significant (Lilliestam, Bielicki, and Patt, 2012).

Hydropower utilises kinetic energy, the energy in moving water, such as a river, to drive a turbine, which in turns generates electricity. The energy supply, or river, needs to have sufficient all year flow in order to ensure full generation potential is met, and the river should preferably not be sensitive to seasonal fluctuations in water flow. Modifications to the existing river hydrology are likely to be required in order to install the power generation system and to protect the aquatic ecology, where possible. Modifications and alterations to the hydrological flow may have long lasting impacts on the aquatic ecology. Given the constant flow of water in a river and through a turbine, the capacity factor of hydropower is generally high (Bartle, 2002).

Hydropower pump and store power generation utilises two dams and a river (or pathway). Water is captured in the first dam, which is situated high enough to generate energy through turbines when water is released from this dam and reports to the lower second dam. Here it is contained, and pumped back up to the first dam at an appropriate time. The appropriate time is normally during non-peak energy use conditions with low electricity costs, where the water is stored before release again (Tran and Smith, 2017). These pump and store schemes are ideally suited to provide peak flow of electricity. This method comes at a high cost in that energy (electricity) is required to pump the water back to the storage scheme and the overall electricity consumption for pumping can exceed the electricity production from the scheme (U.S. Energy Information Administration, 2016). This form of power is therefore only viable to provide peak supply.

Wind power is a long established, yet relatively inefficient (Olabi, 2017), method of generating electricity, or harnessing energy. It uses large wind turbines (blades) which turn in the correct wind conditions and generate electricity, or drive a shaft system to perform work. Modern wind turbines are able to generate electricity when the wind is blowing, which can be modelled and predicted to some extent. Wind is not constant, which means that the capacity factor of this form of power generation is low, and power is not always available or predictable (Munguia, 2016). Wind turbines may also create unintended environmental impacts, particularly related to birds and bats.

Bioenergy essentially utilises biological material in order to generate energy. The most common application of this is biofuels, which utilise plant material to feed combustion, heat generation or other processes. Whilst biofuels may be a renewable energy source, and a cleaner form of energy production, there are many inherent environmental and social risks associated with it. These could be changes to biodiversity in the biofuel growing area, conflict over land use, specifically around land used for food production, risk to small scale farmers who invest fully in a single crop which may fail, and the farming of the biofuels may rely on non-renewable fuel (Fischer, Hizsnyik, Prieler, Shah, and Van Velthuizen, 2009).

Geothermal energy is natural energy that is derived from fluid (water or steam) heated by the earth's core and / or in some instances molten lava reserves in close proximity, which are under pressure and can be easily harnessed to generate power from the heated fluid through a conventional electricity generation process (Energy.gov, 2016).

Hydrogen can be used to generate a fuel, or fuel cell, which in turn can generate power. This occurs when a chemical reaction (not combustion) converts a hydrogen atom into heat and water, thus generating energy for use (Energy.gov, 2016).

Renewable energy technology poses a range of options that could be used to generate cleaner energy and complement or displace existing non-renewable energy generation, although with less availability then many forms on non-renewable energy. Renewable energy technologies are not appropriate in all situations, as some have advantages and disadvantages in different operating circumstances. For example, hydropower is dependent on an appropriate water source that delivers appropriate flow conditions all year round, which is readily available (Bartle, 2002). The source of power (hydrology) may not necessarily be close to the demand and as such, additional transmission infrastructure may be required. CSP is able to generate renewable energy and provide a form of storage that can extend power generation duration during the day. The sun, infrastructure and space requirements may once again pose a limiting factor to where the demand is required as significant generational schemes are likely to be located in desert-like conditions. CSP may also require significant infrastructure capital investment (Lilliestam *et al.*, 2012). Other renewable energy sources such as wind power may only be able to provide a small percentage of renewable energy requirements based on the availability of wind, and as such this may need to be supplemented, in most cases, with other renewable (or non-renewable) sources (Sharifzadeh, Lubiano-Walochik, and Shah, 2017) such as PV or thermal generation. Renewable energy solutions are therefore unique to each energy demand situation and should be configured accordingly. This is particularly applicable for costing and financial investment around the renewable source, as the energy source needs to be sustainable and affordable.

Niesten, Jolink, and Chappin (2017) researched renewable energy wind investment in the active Dutch onshore wind renewable energy sector. Niesten *et al.* (2017) determined that financial considerations were informed by elements such as renewable energy investment experience, industrial and energy generation experience. These all play a significant role in influencing energy investment, despite the established nature of this sector of renewable energy.

2.2 Energy Investment Determinants

Renewable energy generation solutions are available and in many instances exist as proven technology (Dincer, 2000; Elabban, Abu-rub, and Blaabjerg, 2014).

The determinants that can influence the choice of energy generation solution have been identified in a number studies. Zharan and Bongaerts (2017) have identified a series of mining renewable energy investment project case studies that have been implemented through arrangements such as a Power Purchase Agreement (PPA) with a service provider or the use of an Independent Power Producer (IPP). Importantly, a key consideration in the case studies presented by Zharan and Bongaerts (2017) was the mine life effect, i.e. the life of the mining operations are a key consideration in an energy investment.

An analysis into completed or established renewable energy investments in Europe, undertaken by Papież, Śmiech, and Frodyma (2018), modelled four determinants for energy investment. This first determinant is the environment, which considers the impact of energy consumption, specifically GHG emissions, and high levels of carbon dioxide emissions associated with non-renewable energy generation. Essentially, this determinant refers to environmental impact, or conversely, the determinant is to avoid environmental impact (Global Climate Change Agenda aspirations). This determinant is a common feature in literature regarding renewable energy investments and is often proposed as a reason or motivation for renewable energy investment (Christensen and Hain, 2017; Zeng, Liu, Liu, and Nan, 2017; Surroop and Raghoo, 2018).

The second determinant identified by Papież *et al.* (2018) is Security of Energy Supply, where energy self-sufficiency, renewable or non-renewable mix, and ability to fully access and utilise the available energy influence the energy investment approach. This is further supported by volume and cost of importing energy to meet a project or country's demand and this volume and cost consideration is evaluated against the country's renewable energy supply in the energy mix: GDP per capita Papież *et al.'s* (2018) consideration of the third determinant, economic influences related largely to the local economic

development status of the country. It considers the country's GDP, energy consumption both per capita relative to GDP, and the proportion and cost of renewable energy consumption. Another component of economics or costs is subsidies as recognised by Moriarty and Honnery (2007). Moriarty and Honnery (2007) caution against using costs for comparative purposes as the subsidies are not always easily recognisable or transparent and may incorrectly impact on assessment outcomes.
Lastly, Papież *et al.* (2018) identifies political influences in energy investments as the fourth determinant, although this was restricted to consideration of EU Membership of the countries that invest in renewable energy.

Gómez-Navarro and Ribó-Pérez (2018) identified further influences in energy and potential renewable energy investments, which are divided into three main categories: technical, social and economic. The technical elements identified by Gómez-Navarro and Ribó-Pérez (2018) include security of energy supply in the form of lack of grid connectivity and therefore transmission challenges, tariff challenges (pricing) and insufficient understanding of the potential of renewable resources and options. Gómez-Navarro and Ribó-Pérez (2018) identified the social influences related to lack of planning from a regulatory environment perspective, poor public-private organisation and insecurity related to regional civil unrest and potential armed attacks. Finally, Gómez-Navarro and Ribó-Pérez (2018) identified the economic influences as high capital or investment costs in renewable energy, inability to fully internalise environmental costs of non-renewable energy generation, competing subsidies offered to non-renewable energy sources and tariffs that do not differentiate between renewable and non-renewable energy generation.

Energy requirements, from a mining perspective, cannot be considered without ensuring that minimum operating requirements, or base load requirements, are met through the energy investment approach (Moriarty and Honnery, 2007). Where these requirements cannot be secured through a renewable energy

generation source, energy storage will be a critical consideration Hadjipaschalis, Poullikkas, and Efthimiou, 2009)

Lastly additional determinants could include environmental and social pressures and expectations (Phadke, 2018) which include environmental permitting requirements and social acceptance of renewable energy initiations, or social rejection of non-renewable energy generation. Land access is also an important consideration for renewable energy investment, particularly in instances where there is competition for land (Fischer, Hizsnyik, Prieler, Shah, and Van Velthuizen, 2009) and potential unintended environmental impacts such as biodiversity impacts (Moriarty and Honnery, 2007). Selosse, Garabedian, Ricci and Maïzi (2018) identified the need for a favourable regulatory and policy environment for renewable energy investment to occur, as well as secure legislation in the energy sector (Kamara, 2016).

From the determinants identified above, available renewable energy options or potential options, were not considered further. The type of renewable energy solution available does not necessarily influence whether or not a renewable energy solution is possible or desired. Rather it is likely to determine whether more work is required, or what *type* of renewable energy source is utilised and the opportunities and limitations for that solution (Tezer *et al*., 2017). This determinant was therefore considered unlikely to assist in determining why a decision is taken to invest, or not invest, in renewable energy, given the site specific context of options available.

Dependence on non-renewable energy options from a subsidy, tariff, cost of capital or cost of financing perspective was considered to be an unlikely scenario to influence a decision as it could be equally applicable to renewable energy options (Kahia *et al.*, 2017). Given the global response to the climate agenda and evolving financing and regulatory environments, this determinant was seen as likely to be moot.

The determinants of environmental permitting requirements, biodiversity impacts social opportunities or challenges, political influences, security and land access opportunities or challenges may be grouped together from a 'sustainable development' classification or perspective, which is a common grouping in the mining industry (Hilson and Murck, 2000; Azapagic, 2003). This determinant is unique to individual site contexts in terms of what may be applicable and required. It is also common to individual site contexts in that it needs to be considered for any energy investment (World Economic Forum, 2013; Waite, 2017). It is therefore equally unique yet equally applicable at each site, and it is difficult to determine their influence, if any, on the investment decision. They were therefore not considered further.

Government subsidies were not considered further due to the complex opportunities and constraints that may exist for renewable and non-renewable options and that which may have been negotiated, but not publicised, between mining companies, suppliers, service providers and government (Xie, Li, Xia, Liang, and Zhang, 2017). This determinant was therefore not considered any further, It was, however, was indirectly considered as part of pricing or Security of Energy Supply and was therefore noted where applicable. Security of Energy Supply also considers the tariff as a determinant and the security or predictability associated with that.

Financial considerations, government subsidies, costs of energy generation and supply, technical constraints around Security of Energy Supply, evolution of the in-country electricity generation and supply, etc. are determinants that were grouped together. This was included for further research and analysis as they are likely to materially influence decision making from the perspective of Security of Energy Supply, and were therefore considered as part of the consolidated determinant "Security of Energy Supply (reliability and pricing)".

“Life of Operation Assumptions” was identified as an important and relevant determinant as the investment life span is directly influenced by this, and therefore a key determinant in the investment decision.
“Mining Demand Side Requirements” could determine whether a proposed renewable energy investment can be supported in continued mining operations and as such is a key determinant.

Broader environment, social, governance, and sustainability considerations, climate change and GHG emissions response, government policy, enabling regulatory environment, policies or policy interventions, are determinants that were grouped together to be addressed as part of the Global Climate Change Agenda. These are likely to include policy and legislative drivers in investment decisions (Elum and Momodu, 2017). This group is referred to “Global Drive towards GHG emission Reduction” and is considered further.

Therefore, to establish a set of determinants and associated criteria for influencing the renewable energy investment decision, the following determinants, in no order of importance, were used:

- **Global Drive towards GHG emission Reduction:** Global and country response to climate change and high levels of GHGs in the atmosphere;
- **Security of Energy Supply (reliability and pricing):** Reliability, continuity and certainty of electricity supply, and affordability, certainty and predictability in the pricing and associated increases, for electricity;
- **Life of Operation Assumptions:** The remaining, profitable, life of an operation or mine, on which business planning decisions and commitments can be made; and
- **Mining Demand Side Requirements:** Activity specific requirements of the operations from an electricity supply perspective e.g. unique base load or start-up requirements.

2.3 Investment Approaches

Companies with established investment systems and processes typically follow a complex process when considering an investment for the business. Various drivers may be present in determining the need for an investment, such as business continuity, business improvement, strategic investment, reputational management, etc. However, a systematic approach is applied to understand the need for the investment, the options available to the investment, the financial implications of the investment, and how the investment will be executed (Strantzali and Aravossis, 2016).

Systematic approaches could include a life-cycle analysis, cost-benefit analysis or multi-criteria decision aids (Strantzali and Aravossis, 2016). These are usually combined with an investment model for a project, or investment in which alternatives, options, risks, uncertainties can be modelled and compared in financial terms for a project decision to be taken (Focacci, 2017). The investment model considers, where appropriate, the current status quo, baseline conditions or base case and it is against this that alternatives or options can be measured. The base case for an energy investment model could be the current energy supply, inclusions and exclusions. The investment model is then used to develop scenarios much like scenario planning, in which the outcomes of technical, risk, financial and other processes can be modelled (Soberanis *et al*., 2015).

At the start of an investment, a company or project will have a certain set of criteria against which decisions must be made. These criteria could typically include legal compliance, technical reliance (although 'proven technology' may not necessarily be a requirement), environmental, social and governance considerations as part of good corporate governance and / or impact management (King, 2016). Furthermore impact on business, for example losses or gains should the project be implemented, cash flow risk and requirements, capital investment requirements, operating cost requirements, and maintenance costs are important criteria against which a decision is also likely to be made (Kamara, 2016). This enables total cost of energy, return on the investment from net present value (NPV) and internal rate of return (IRR) of the investment (Ye,

Zhang, Jiang, Miao, and Li, 2017) to be determined. NPV is the value of a project, in today's terms, after considering the cash inflows and outflows over its life. The cash inflows may be determined by, for example, cash generated by the sale of a mining product, like platinum, and the outflows influenced by the cost of electricity (Percoco and Borgonova, 2012). IRR is a method, utilising certain assumption, that is used to calculate return on, or profitability of, an investment (Percoco and Borgonova, 2012). These criteria may also become 'hurdles', which the investment case must overcome for it to have a positive outcome. Overcoming hurdles in investment modelling is important as projects and initiatives compete for capital. Capital is not freely available and comes at a cost to a business or project, regardless of whether a company is able to 'self- fund' or attract external investment. Ultimately, the preferred outcome of investment modelling should ensure that the company's internal requirements are met and the investment returns are in line with the company requirements (Christensen and Hain, 2017).

In the case of an energy investment project, alternative supply options should be modelled including existing supply, renewable options, non-renewable options, hybrid options etc. The investment modelling should also consider funding options and the cost of those over the life of the investment (Christensen and Hain, 2017). These costs include the cost of funding and the cost of cash flow and are likely to trade off against each other, for example, higher upfront capital investment against a lower operating costs, or vice versa. Whilst the trade-offs themselves may show suitable outcomes for all options, when compared against the hurdles, the preferred trade-off may become immediately apparent (Vyhmeister *et al*., 2017).

Financiers or lenders often drive a 'greener' agenda and a trend is emerging in which major lenders are shifting to cleaner energy investments or energy investments with a renewable energy component (Schwerhoff and Sy, 2017). Together with this, volatile commodity prices, a changing energy generation and supply landscape, investment modelling hurdles, climate agenda drivers and

requirements, society demands and business operating requirements play a key role in investment decisions which are complex with multiple dependencies and interrelationships (Cunico, Flores, and Vecchietti, 2017).

Ming, Ximei, Yulong, and Lilin (2014) have evaluated China's renewable energy investment, which has undergone rapid growth attributable to China's policies that support such investment. Whilst China has had considerable investment in wind and PV renewable energy initiatives, the financing aspect has significantly influenced the investment approaches, particularly through the investment environment, organisations and bodies that can finance the required renewable energy investments and have the means to do so, source of the investment funds and expectations on returns of those funds (Ming *et al.,* 2014). This evaluation demonstrates the importance of financing mechanisms and arrangements despite a regulatory environment and available renewable energy resources that easily support renewable energy investments.

Chapter 3: Methodology

3.1 Identification of Key Determinants

From the determinants, in no order of importance, identified in the Literature Review in Chapter 2, the following determinants were determined to be relevant factors in influencing energy project decision making:

- **Global Drive towards GHG emission Reduction:** Global and country response to climate change and high levels of GHGs in the atmosphere;
- **Security of Energy Supply (reliability and pricing):** Reliability, continuity and certainty of electricity supply, and affordability, certainty and predictability in the pricing and associated increases, for electricity;
- **Life of Operation Assumptions:** The remaining, profitable, life of an operation or mine, on which business planning decisions and commitment can be made; and
- **Mining Demand Side Requirements:** Activity specific requirements of the operations from an electricity supply perspective e.g. unique base load or start-up requirements.

In order to determine which of these is the most influential in influencing energy investment decisions, and to determine how the remaining determinants influence the decisions, they were evaluated in interviews with subject matter experts. In order to support these interviews and ensure an element of rigor and repeatability, the determinants were further elaborated on using five criteria specific to each. These criteria, which are presented in Table 2, are specifically related to the determinants and were used to assess the determinants and their contribution to energy investment decision making. These criteria were identified from the literature review and used for the development of the key determinants for the study (Chapter 2) and are summarised below.

Table 2: Criteria for Determinants

Global Drive towards GHG emission Reduction	Security of Energy Supply (reliability and pricing)	Life of Operation Assumptions	Mining Demand Side Requirements
Legal or regulatory requirements to reduce GHG emissions (e.g. Country Paris Agreement commitments)	Rising increases in cost of current energy supply	Life of Mine is shorter than investor payback period	Base load considerations fully exclude renewable energy as an option
Corporate strategy for climate / GHG emissions reduction	Unpredictable increases in cost of current energy supply Instability in pricing	Life of Mine is shorter than renewable energy investment payback period	Base load considerations cannot be adequately met by renewable energy requirements
Corporate strategy to invest in renewable energy	Inability to secure a 'development' or 'stability' agreement for energy pricing and control	Life of Mine is incompatible with incentive (e.g. government) period	Renewable energy generation constraints are incompatible with operational requirements
Investor or external ESG influences to reduce GHG emissions or invest in renewable energy	Unreliable, and therefore interrupted, supply of electricity due to generation constraints	Life of Mine assumptions did not allow for adaptive management to energy investment (changing landscape)	Renewable energy storage solution is inadequate
Current CDM Investment Project(s) within organisation	Unreliable, and therefore interrupted, supply of electricity due to transmission constraints	Investment or utilisation of renewable energy investment does not extend beyond life of mine	Renewable energy storage solution is cost prohibitive

3.2 Evaluation Criteria

To ensure that the determinants were considered in the most objective way possible, the determinants for influencing the investment decisions were rated on a scale of 1 to 5, with 1 being the least likely influence on the investment decision, and 5 being the most likely influence on the investment decision. The determinants were assessed during interviews, with highest rating representing the key driver for the investment decision as discussed in more detail.

To support the analysis of the determinants and further enhance the consideration of the determinants and applicability to energy investment

decisions, each of the criteria identified in Table 2 were assessed in a binary manner, i.e. yes or no, with regards to their relevance to the determinant for assessment purposes. This enabled the determinants to be considered in further detail, without compromising the primary objective of comparing the four determinants against each other in order to determine that which is most applicable the energy investment decisions.

3.3 Interviews

Interviews were identified as a means to assess the most influential determinants in the decision process for energy investments. In order for targeted and useful interviews to be concluded, industry subject matter experts as well as representatives from renewable energy projects and investment financing, were identified as potential interviewees for the study.

A questionnaire for the interviews was developed in such a way that both qualitative and quantitative, or easily measurable and comparable information was gathered. Context could be set, structured questions could be answered in a way in which determinants could be ranked, and less structured questions were developed in order to facilitate discussion, and identify any potential gaps in the approach to the determinants or decision making process. The questionnaire is presented in Appendix A. Ethics Clearance was obtained from the University of the Witwatersrand's Human (non-medical) Ethics Committee (clearance number HA1808).

The interviewees were contacted telephonically or via email in order to request an interview, and subject to their approval, a Participant Information Letter, Consent Form and copy of the questionnaire were provided. Interviews were undertaken during normal business hours, in a place of business or public place (such as coffee shop) and in line with the questionnaire.

In total, four people were interviewed:

- Interviewee 1: Current mining industry experience, non-renewable and renewable energy expertise in both technologies and energy, decision making for project experience and sustainability subject matter expert. Works in

private sector mining and renewable energy. Recent energy investment experience (2017 / 2018).

- Interviewee 2: Current mining industry experience, and renewable energy subject matter expert, sub-Saharan African investment, geopolitical and sustainable development expert. Works in private sector mining and renewable energy. Recent energy investment experience (2017 / 2018).
- Interviewee 3: Subject matter expert on non-renewable and renewable energy, subject matter in energy investments (technology, finance and sustainable development) and sustainability expert. Works in private sector mining, in sustainable development in climate, carbon and energy areas. Recent energy investment experience (2017 / 2018).
- Interviewee 4: Subject matter expert on renewable and non-renewable energy, renewable and non-renewable energy investments (technology, finance, commercial, legal, sustainable development and project management), commercial or investment modeller and implementer, mining experience. Works in the private sector for mining and 'energy' clients (such as funders, suppliers, energy producers, energy users etc.).

The data from the interviews were noted, summarised and categorised according to the determinants, criteria and additional considerations. Data from all four interviews were then compared in order to identify common themes, common determinants and ranking of the determinants and criteria. During the interviews, it was apparent that the criteria for the determinants could not necessarily be considered in a binary manner, some criteria were mutually exclusive, and other criteria were mutually inclusive. Similarly, the determinants were not necessarily mutually exclusive but could be complementary in a chronological manner. For example, the key determinant allowing the investment process to begin was identified, and was further complemented by secondary and tertiary determinants or considerations. The determinants could also be ranked in order of influence or importance, thus achieving the objective.

The scores for each determinant by each interviewee was plotted to determine if there was any relationship between the determinants, or any pattern in the how the determinants were related to each other. This could be considered for each determinant or each interviewee's response.

3.4 Research Limitations

The research and interviews were based on understanding the most influential determinants related to energy investment decisions in the private sector, specifically the mining industry. The subject matter experts as such have considerable mining and renewable energy experience. Other private sectors such a manufacturing were not considered as part of the scope. Broader scope may influence the determinants that are considered for investment decisions, or even the outcome of the most influential determinant.

Furthermore, only four subject matter experts were interviewed, and a wider range of experts may have yielded a more diversified outcome.

Chapter 4: Results

This study has focussed on determinants most likely to influence energy investment decisions related to the mining industry, and determine which of these are the most influential in energy investment decisions. Whilst the Global Climate Change Agenda and supporting international and intergovernmental protocols and policies create an enabling environment for renewable energy investment, the determinants considered in this study relate to mining aspects of project decision making processes, in the private sector. These determinants are analysed through the views of mining, sustainability and renewable energy investment experts who are able to assess the most influential determinants based on experience in their field of expertise.

As part of the interviews, interviewees rated those determinants, on a scale of 1-5, where 1 is the least likely to influence investment decisions for an energy investment, and 5 is the most likely to influence an investment decision. The consolidated outcome of the interviews is presented in Table 3. Interviewee 1 and Interviewee 4 rated Life of Operation Assumptions as 5, which is the determinant most likely to influence energy investment decisions. Interviewee 2 and 3 rated Security of Energy Supply as 5, or the determinant most likely to influence energy investment decisions. Global Drive towards GHG emission reduction had the lowest overall score of 8 or 40%, and is therefore the least likely determinant to influence an energy investment decisions. Security of Energy Supply has the second highest score of 16 or 80%, and Life of Operation Assumptions had the highest score of 17 or 85%, which confirms that this is the determinant most likely to influence renewable energy investment decisions.

Table 3: Summary of interview outcomes in assessing the influence of determinants on investment decision

Determinant	Interview 1 Mining & Sustainability Expert	Interview 2 Mining & Renewable Expert	Interview 3 Renewable & Sustainability Expert	Interview 4 Renewable Expert	Score
Global Drive towards GHG emission Reduction	2	3	2	1	8 40%
Security of Energy Supply (reliability and pricing)	3	5	5	3	16 80%
Life of Operation Assumptions	5	4	3	5	17 85%
Mining Demand Side Requirements	4	2	4	4	14 70%

Mining Demand Side Requirements were found to play a part in influencing investment decisions, although it was not the primary or secondary determinant. The combination of the Life of Operation Assumptions, Security of Energy Supply and Mining Demand Side Requirements suggests that each investment decision is determined by bespoke or specific elements. This includes the duration, location and type of operation or project.

4.1 Life of Operation Assumptions

Life of Operation Assumptions were collectively, and in two instances, the most influential determinant in energy investment decisions (Table 3). From the interviews it emerged that these assumptions are the most critical. They determine whether or not there is sufficient time for investment capital and financing costs to be recovered through the reduced energy generation costs or cost savings. The guaranteed life of an operation or facility determines the bankability of the energy investment. Similarly, the longer operational life of a facility, the better the returns of the investment may to be. From a renewable energy perspective, a financed project such a Power Purchase Agreement (PPA), or even an owner Engineer, Procure Construct (EPC) Project, which the interviewees identified as being less common, a capital investment for project will have a certain period of time in which the capital and other financing costs will be

recovered. After the cost recovery period, savings in energy generation from, for example, a solar PV project, which are most common in the interviewees' experience, delivers a financial return on the investment. In a PPA arrangement, the costs of capital, finance and generation will be evenly spread over the life of the renewable energy investment, which will be the same as the guaranteed life of the operation, in the form of a tariff. The interviewees agreed, with the exception of one, that EPC Project energy generation contracts, particularly for renewable energy, are generally not very popular or common.

Interviewee 1 explained that a guaranteed life of operation, in mining terms, is generally accepted as being the resource determination. This refers to the resource that has been declared within a prescribed and industry accepted deterministic limit of certainty. Whilst mining operations may have identified more ore reserves that have not been included in the resource calculation, these reserves, inferred reserves, or in some instance 'blue sky' reserves are known to exist. They have also been tested for their availability to within a prescribed and industry accepted, lower, deterministic limit of certainty. Reserves, inferred reserves and blue sky reserves do not have sufficient certainty regarding their availability, mine-ability or processing ability for the mining operation to guarantee performance or delivery. As such, planners and financiers are not prepared to make significant financial commitments or accept guarantees on reserves, inferred and / or blue sky reserves. This in turn does not allow PPA or EPC Project contracts to be established on potential life of mine. This is a limiting factor in financing energy investments.

Interviewee 1 and 4 elaborated that non-renewable energy investments can be structured in such a way that smaller thermal generators or modular components are deployed for the life of operation. These can be upgraded, added on, or removed to another site should life of mine operations extend. The non-renewable energy investment sector is well established and many options and iterations are available for energy generation along this operating configuration. As such, almost any configuration or arrangement can be accommodated.

Renewable energy investments generally have a minimum generation capacity, which three of the four interviewees agreed was around 20MW (although this could be as low at 10MW). Economy of scale is important, in order to ensure a viable investment proposition. This is not an absolute requirement, and is dependent on other variables but can be used as guideline. In order for a successful renewable energy investment agreement to be established, using a PPA for example, the Life of Operation Assumptions would need to be a minimum of 7 to 10 years. Interviewees were in general agreement around this, and once again, other variables could influence this period and it is therefore not absolute, but rather a useful guideline. Lastly, one interviewee indicated that currently, the size and life of the project would also likely need to trigger an investment value of US$30million or more. This will secure an acceptable return on investment to meet the investment criteria relative to the cost of capital and finance.

The interviewees indicated that the bankability of an energy investment, particularly a renewable energy investment, may seem to be driven by financing. However, they indicated that financing is not the driver, it is rather an enabler, or a risk modifier. As such, financing should not be considered as a determinant to energy investment but rather a tool that can be utilised in different ways to influence an energy investment, particularly a renewable energy investment. This presents an opportunity in the renewable energy investment space, particularly private investment projects. All interviewees agreed that the financing component of the Paris Agreement supports renewable energy investment in the public investment space, but not necessarily the private investment space...

In summary the Life of Operation Assumptions is the primary determinant or influencer in energy investment decisions. Once secured, Life of Operation Assumptions will determine tariff, which means that a longer life of mine will secure a lower tariff for energy generation over the life of the project. The life of operation will influence the tariff but not determine the viability of the project (beyond certain underlying assumptions of bankability or revenue). This view was supported by two different interviewees' perspectives.

If a Life of Operation Assumption is too short to meet, for example, the requirements of a bankable renewable energy investment, the project will not be discarded. Rather, the proponent will still consider the energy investment, particularly if it is a necessity for the operation or business, but simply re-evaluate or select a different technology. As mentioned previously, this could be a non-renewable choice or a variation of a hybrid approach. This illustrates that Life of Operation Assumptions need to provide certainty for the investment, and that this will in turn influence the technology, which may be renewable energy.

Lastly, if Life of Operation Assumptions have established a viable investment, the technology and Security of Energy Supply can be modified as required and delivered. Nevertheless, remote and captive mining operations that may be very sensitive to the cost of energy and have a short, guaranteed, life of operation. They may be challenged to achieve security in the form of affordability, and may also need to rely on thermal generation to secure an investment. No examples or instances were identified or discussed by the interviewees where an energy solution, and therefore investment, could not be secured. Whilst this does not mean that such projects do not exist, it does indicate that their occurrence may be limited, and more importantly other factors may play a key role in the investment decision. Mining projects generally need significant capital investment for infrastructure and requirements upfront, and generally need a suitable life of operation to fund this, which in turn should be able to provide a significant amount of time for an energy investment return.

4.2 Security of Energy Supply

Whilst the interviews focused on reliability and affordability, it became evident from an interviewee that Security of Energy Supply consists of three main components, i.e. reliability, affordability *and* availability. This was not captured as such prior to the interviews, and was an important gap or incomplete consideration of this component. All three components are required to ensure Security of Energy Supply, and is best illustrated in Figure 1 below.

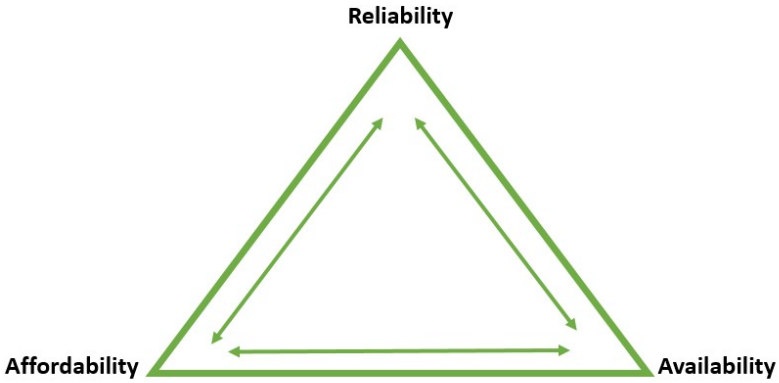


Figure 1: Energy Security Triangle (based on interview results)

The following points have been summarised from the interview in order to fully explain Security of Energy Supply. Reliability involves a consistent, predictable supply of energy. This is illustrated through a utility that may supply a consumer, for example a mining operation, with electricity, and that supply is not interrupted, unpredictable or does not fluctuate. This ensures that the consumer can utilise this energy in a planned predictable manner that meets their requirement on a consistent and reliable basis.

Affordability refers to the pricing or cost of energy for consumption. Affordability includes the actual tariff for generation, and where required transmission cost and predictability in price increases. The affordability or cost of energy is likely to be a key consideration for the viability of a particular energy supply and in some instances may be too expensive, or unaffordable, for the energy to be utilised. This is particularly relevant where other forms of energy are available that may be more cost effective.

Availability considers the energy available to meet a consumer's demand, for example the generation available from a utility is sufficient to be able to supply to the consumer. This refers to the sufficiency or availability of the required energy. It is important to note that renewable energy availability could be effected by available sun or wind (which determines Capacity Factor) or events such as

droughts affecting hydropower availability. From a renewable energy perspective it could also refer to the availability of the natural resource for generation purposes. For example, sufficient solar radiation or sufficient wind energy or hydrological components to meet the requirements. Availability also considers the ability, where required, to transmit the energy to the consumer. Security in availability would therefore typically mean that there is sufficient electricity available for use, and it can be transmitted, if required, for use.

These considerations do not exist in isolation but need to be considered together in order to ensure Security of Energy Supply, as shown in the Energy Security Triangle, in Figure 1 above.

Interviewee 4 supported considerations of the Energy Security Triangle, through a non-renewable example. Thermal coal energy generation, with a reliable or predicable source of coal, is an established and effective manner to secure energy supply. This provides a typical example of where a non-renewable energy source such as this may be selected over a renewable source for energy supply, particularly for large-scale generation. Thermal (coal) generators can ensure available energy when it is required at any time of day and during peak demand, with a predictable cost and reliably. Security of Energy Supply in non-renewable energy investment, using thermal coal power, may therefore determine the outcome of an energy investment. Security of Energy Supply is not restricted to non-renewable energy. A renewable energy source, for example solar PV, can be modelled for reliability, affordability and predictable availability. This could displace a portion of non-renewable energy generation, thereby presenting a hybrid type approach which may reduce energy generation costs and meet the Security of Energy Supply requirements, as discussed by the interviewee.

Security of Energy Supply was an important determinant for all interviewees and whilst not all agreed that this is the most influential determinant, all agreed that it is influential in investment decisions.

The two interviewees that rated Life of Operation Assumptions as being more influential than Security of Energy Supply agreed that once a bankable investment is secured, Security of Energy Supply could be considered, and achieved, through technology choices such as PV and wind. The two interviewees that rated Security of Energy Supply as being more influential than Life of Operations Assumptions provided directly opposing views to each other. Interviewee 2 stated that once the technical requirements of an investment can be secured, the client and investor financial requirements can be secured. Interviewee 3 determined the second most influential consideration to the Mining Demand Side Requirements, which perhaps also 'dilutes' the view that Security of Energy Supply is the most influential determinant. In summary, Security of Energy Supply was scored as the second most important determinant in influencing an energy investment decision. This view was supported by two different interviewee perspectives.

Life of Operations Assumptions and Security of Energy Supply each had two interviewees rating them as the as the most influential determinants in energy investment decisions.

4.3 Mining Demand Side Requirements

Mining Demand Side Requirements are an important influencer in energy investment decisions and with the exception of one interviewee was rated as the second most influential determinant. However, the overall score did not fully support this, and it was determined to be the third most influential determinant. It supports the discussion above that the determinants that are influential in decision-making are related to the unique nature of the mining operations, jurisdictional setting and mining activities. All interviewees consistently and firmly agreed that Mining Demand Side Requirements related to base load cannot be met solely through renewable energy supply without storage.

This energy demand cannot be achieved by renewable energy without storage, such as battery storage of solar PV, or as it was hypothesised, hydropower with

storage, although that in itself may not be secure. As such, there was consensus amongst the interviewees that mining operations need an alternative non-renewable energy supply to meet base load requirements, as solar PV storage is currently not economically viable for mining operations. It is therefore evident that base load power requirements need to be met for an energy investment decision, through whatever means, and that this cannot be provided by renewable energy. Renewable energy rather displaces the potential non-renewable energy supply to other operational requirements, when it is available. This means that a non-renewable or hybrid renewable energy solution can be implemented, with variable configurations.

4.4 Global Drive towards GHG Emissions Reduction

Ironically, the Global Drive towards GHG Emissions Reduction, loosely referred to as the Global Climate Change Agenda, is one of the key triggers of renewable energy growth, and a driver to reduce GHG emissions., However when considering the investment case for energy including renewable energy, this was found to be least influential.

All interviewees confirmed that this is least likely to influence investment decisions. Two interviewees confirmed that a company directive to invest in renewable energy achieves better outcomes than those companies that do not have such directives or strategies. It was suggested that these companies also have a less risk-averse view on renewable energy investment, that which favours investment and has more enabling views, for example on new technologies, funding models, commercial arrangements for power supply etc. Activists, lobbyists, non-governmental organisations were also identified as being a low driver or influencer of investment decisions. Essentially the interviewees recognised that the Global Climate Change Agenda is driven through business, where government policies are driving renewable energy investment in accordance with targets set for and by the Global Climate Change Agenda such as the Paris Agreement or COP 21.

Whilst interviewees agreed that there are significant jurisdictional differences, developed and developing country governments are driving renewable energy across the private and public sectors. Developing countries have a strong focus on renewable energy investments, and in many instances the private sector is able to catalyse much needed growth in the energy sector.

Despite business objectives, government influences and Global Climate Change Agenda opportunities for renewable energy investment, consensus maintained that the decision to invest in renewable energy would only be taken if there were a financial advantage when compared with the status quo. Carbon credits are not an advantage or driver. The market drivers for carbon credits, as indicated by an interviewee, do not exist and therefore this is currently regarded as a potential upside with possible future value, although not bankable.

One interviewee suggested, anecdotally, that there seems to be a lot of 'green agenda' money for investment, although not enough renewable energy opportunities exist. This is partly attributable to investors not wanting to work with the private mining sector due to legacy and reputational issues. Another interviewee suggested that in this line of thinking, private mining companies present catalytic opportunities to develop energy investment opportunities for communities. Although, where private mining companies can be enablers, some country legislation does not necessarily allow for these opportunities to be realised. Rigid investment models may also not recognise potential returns beyond certain operating assumptions, which are limited to the mining aspects such as life of mine. Furthermore, technological improvements may be required to support growth in community related renewable energy investment. An incentive programme or procurement initiative such as South Africa's Renewable Energy Independent Power Producer Project (REIPP), which has the potential to be very successful enabler and other African countries beyond South African, may benefit from such an initiative.

Interviewees were asked to identify any possible gaps in the determinants that were material to the decision-making process for energy investments. The interviewer identified legal or regulatory requirements as possibly being such a gap, which was identified upfront in the first interview, and considered in all subsequent interviews. Whilst all interviewees discussed and considered legal and regulatory requirements, it was consistently reported that this did not influence investment decisions in this context. Some interviewees recognised the importance of legal and regulatory requirements, but they were not determined to be enablers. Reasons for this include legislation that is focused on public investment, legislation that is aspirational in Global Climate Change Agenda targets but immature in development, and utility protectionism in some instances. As such, this has not been identified as a determinant, and not useful for further consideration.

Based on the outcomes of the interviews, and the drivers of the investment decision, a Hierarchy of Determinants Influencing Investment Decisions has been developed and is presented below in Figure 2.

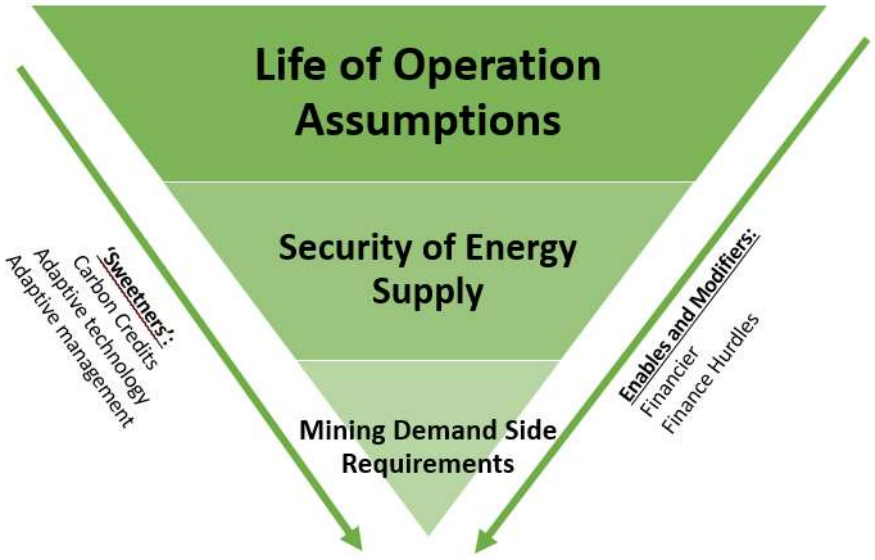


Figure 2. Hierarchy of investment decision influencers (based on the outcome of the interviews)

In support of this hierarchy, and a consistent outcome of each interview, is the variability between project, location and jurisdictions for energy investment projects. This extends to how this variability is a likely to be key factor in the determinants that influence the investment decision. As part of the interviews, it was therefore reiterated that the scope and boundary of the study was limited to private energy investments (not public), mining sector energy investments and a South African and African (continent) context, recognising that these two are materially different. Jurisdiction considerations, specifically in Africa (in general, but excluding South Africa) and South Africa became very evident in all interviews and discussions.

The outcomes of the interviews are presented plotted below in Figure 3 which identifies the pattern of investment decision determinants. This presents the most influential determinants as those that are bespoke to the energy investment projects and its needs. This representation also confirms the important influence that Mining Demand Side requirements have on the investment decision, and whilst this was not the most important influence for investment decisions, it re-iterates the bespoke nature and / or requirements being keep factors in decision-making processes.

For completeness, Regulatory Framework was included in this illustration, although, like Global Climate Change Agenda, it is clear that these determinants do not influence an energy investment decision and plot to the left of the illustration. This is perhaps supported by the apparent pattern of determinants likely to influence decisions being those that are unique and specific to each project, e.g. Life of Operation Assumptions is unique for each project which in turn determines the technology choice (renewable or non-renewable, followed by tariff or cost of that investment). The same project, located in a different jurisdiction, for example, may have a different outcome.

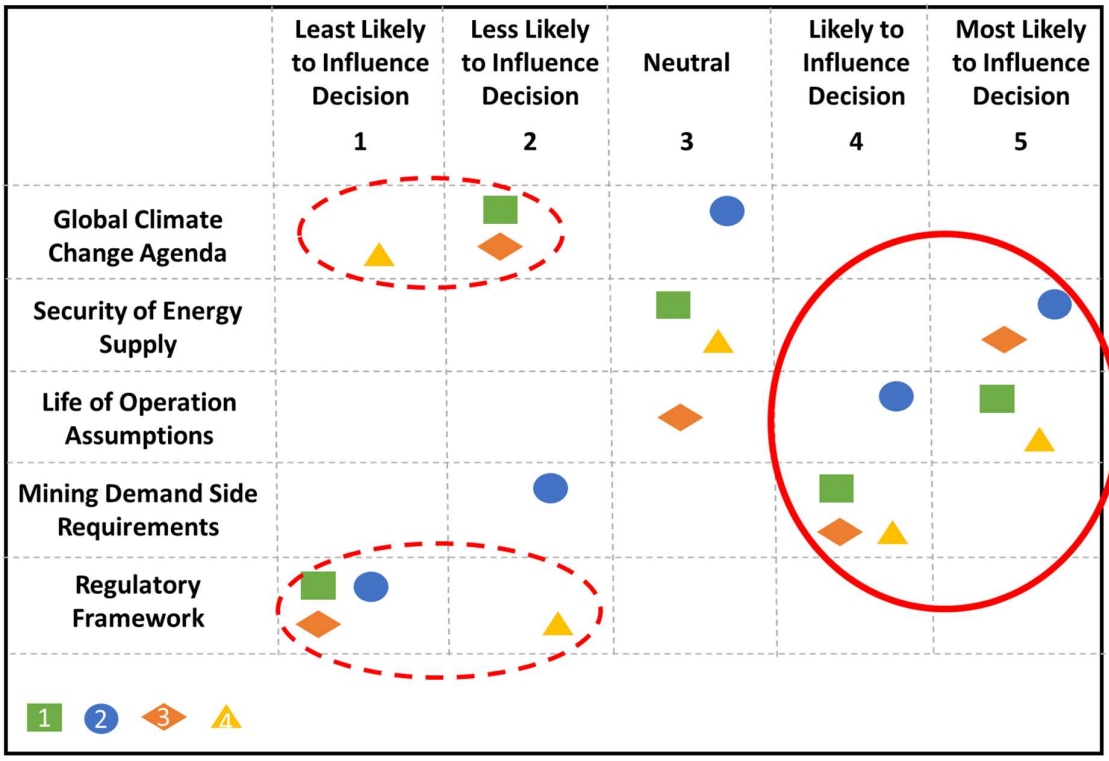


Figure 3: Pattern of influence of key determinants on investment decisions

4.5 Objectively Assessing the Determinants

In order to fully understand the interviewees' perspective on the identified key determinants, and ensure an element of objectivity and repeatability, detailed criteria were assessed with the interviewees. These criteria were assessed in a binary fashion in order to determine how they contributed to the determinant. It was expected that all criteria would not necessarily be relevant to the determinant. Generally speaking, there was a large degree of consistency in the interviewees' considerations of the criteria, although there were some exceptions (see Table 4). Notably, of the five criteria presented for Mining Demand Side Requirements, only one criterion was applicable to the determinant, in the context of this report and the energy investment scope and boundaries. This criterion was related to base load, which is essential for mining operations and energy investments cannot be considered without base load. Interviewees were fully aligned on this.

Although this determinant was deemed to be the least likely to influence an energy investment, the interviewees were mostly in agreement that corporate strategies to reduce emissions, or to invest in renewable energy initiatives were the most relevant and supportive of this determinant. Interviewees were split on the ESG investment pressure and legal or regulatory requirements, with half agreeing that this is relevant to this determinants influence, and half not. Consensus was largely achieved for clean development mechanisms (CDM) or carbon credit opportunities as being irrelevant to the determinant.

Table 4: Criteria for global climate change agenda

Determinant: Global Climate Change Agenda **Criteria**	**Interview 1 Mining & Sustainability Expert**	**Interview 2 Mining & Renewable Expert**	**Interview 3 Renewable & Sustainability Expert**	**Interview 4 Renewable Expert**	**Score**
Legal or regulatory requirements to reduce GHG emissions (e.g. Country Paris Agreement commitments)	Y	Y	N	N	Y = 2 N = 2 N/A = 0
Corporate strategy for climate / GHG emissions reduction	N	Y	Y	Y	Y = 3 N = 1 N/A = 0
Corporate strategy to invest in renewable energy	N	Y	Y	Y	Y = 3 N = 1 N/A = 0
Investor or external ESG influences to reduce GHG emissions or invest in renewable energy	N	Y	Y	N	Y = 2 N = 2 N/A = 0
Current CDM Investment Project(s) within organisation	N	N	Y	N	Y = 1 N = 3 N/A = 0

Interviewees were generally in alignment that the main contributors to Security of Energy Supply were security of affordability, which includes rising costs or unpredictability in costs (Table 5).

In terms of the criteria for Life of Operation Assumptions, interviewees were largely aligned on the applicability of these criteria with the exception of the last criterion (Table 6). Outcomes of the interview focused on guaranteed Life of

Operation Assumptions, i.e. proven resources in order to secure the bankability of the investment. Agreement was unanimous on the requirement of the payback period of an investment or of a renewable energy investment being the applicable criterion for the investment decision. There was mostly agreement on adaptive energy opportunities. Lastly, interviewees were divided on the applicability of criteria related to an investment that could be realised within the life of mine.

Table 5: Criteria to security of energy supply

Determinant: Security of Energy Supply **Criteria**	**Interview 1 Mining & Sustainability Expert**	**Interview 2 Mining & Renewable Expert**	**Interview 3 Renewable & Sustainability Expert**	**Interview 4 Renewable Expert**	**Score**
Rising increases in cost of current energy supply	Y	Y	Y	Y	Y = 4 N = 0 N/A = 0
Unpredictable increases in cost of current energy supply Instability in pricing	N	Y	Y	Y	Y = 3 N = 1 N/A = 0
Inability to secure a 'development' or 'stability' agreement for energy pricing and control	N	Y	N/A	Y	Y = 2 N = 1 N/A = 1
Unreliable, and therefore interrupted, supply of electricity due to generation constraints	Y	Y	Y	Y	Y = 4 N = 0 N/A = 0
Unreliable, and therefore interrupted, supply of electricity due to transmission constraints	N	Y	Y	Y	Y = 3 N = 1 N/A = 0

The interviewees were unanimous in the consideration of the criteria related to Mining Demand Side Requirements, asserting that base load energy must be available for mining operations as presented in the context of this study (Table 7). Should base load requirements not be met, the investment is not viable. In support of this, renewable energy solutions, without storage, will not be able to meet base load requirements, and as such, a non-renewable or hybrid solution is required.

Table 6: Criteria for life of operation assumptions

Determinant: Life of Operation Assumptions Criteria	Interview 1 Mining & Sustainability Expert	Interview 2 Mining & Renewable Expert	Interview 3 Renewable & Sustainability Expert	Interview 4 Renewable Expert	Score
Life of Mine is shorter than investor payback period	Y	Y	Y	Y	Y = 4 N = 0 N/A = 0
Life of Mine is shorter than renewable energy investment payback period	Y	Y	Y	Y	Y = 4 N = 0 N/A = 0
Life of Mine is incompatible with incentive (e.g. government) period	N/A	N	N/A	N	Y = 0 N = 2 N/A = 2
Life of Mine assumptions did not allow for adaptive management to energy investment (changing landscape)	N/A	N	N	N	Y = 0 N = 3 N/A = 1
Investment or utilisation of renewable energy investment does not extend beyond life of mine	Y	N/A	N	Y	Y = 2 N = 1 N/A = 1

Table 7: Criteria to mining demand side requirements

Determinant: Mining Demand Side Requirements Criteria	Interview 1 Mining & Sustainability Expert	Interview 2 Mining & Renewable Expert	Interview 3 Renewable & Sustainability Expert	Interview 4 Renewable Expert	Score
Base load considerations fully exclude renewable energy as an option	Y	Y	Y	Y	Y = 4 N = 0 N/A = 0
Base load considerations cannot be adequately met by renewable energy requirements	N/A	N/A	N/A	N/A	Y = 0 N = 0 N/A = 4
Renewable energy generation constraints are incompatible with operational requirements	N/A	N/A	N/A	N/A	Y = 0 N = 0 N/A = 4
Renewable energy storage solution is inadequate	N/A	N/A	N/A	N/A	Y = 0 N = 0 N/A = 4
Renewable energy storage solution is cost prohibitive	N/A	N/A	N/A	N/A	Y = 0 N = 0 N/A = 4

Chapter 5: Discussion

With recognition of the climate agenda and the importance of reducing greenhouse gas (GHG) emissions, renewable energy investments present an opportunity to replace, displace or supplement non-renewable energy generation (Wüstenhagen and Menichetti, 2012.; Mostert, 2014.). The decision to invest in energy projects, and specifically renewable energy projects, seems to be consistently influenced by the financial aspects of a project, as identified by Wüstenhagen and Menichetti (2012). Wüstenhagen and Menichetti (2012) report that when considering renewable energy investments for which there is a Global Climate Change Agenda imperative to investment, and in many instances an enabling policy environment for investment in renewable energy, it is the economics associated with the financial investment that determine the rate at which renewable energy investments are made. Traditional risk and return metrics that are considered as part of the financial modelling and considerations for investments are the drivers for the investment. Risk and return are usually unique to the energy investment scenario and aim at reducing risk and maximising return (Wüstenhagen and Menichetti, 2012). This can be achieved through determinants such as those identified in this study. This is further supported by a Nordic renewable energy investment study in which Boomsma, Meade, and Fleten (2012) identified financial aspects of an investment decision being influenced by the return on the investment, and the ability to enhance the return through increased Security of Energy Supply. This can be done through utilising improved pricing or a higher, secure tariff for the investment. Boomsma *et al.* (2012) found that improved security of cost supports an earlier initiation of renewable investments. Furthermore, this can be supplemented through additional financial support, such as subsidies, or a larger investment capital. Project investment decisions, in the context of this study, are clearly dependent on the outcome of the financial model and financial metrics that need to be met. Key to this is that a successful investment decision outcome assumes that for a replacement, or renewable energy displacement project, the investment must be more cost effective than the status quo. It is highly unlikely that an investment

that cost more than the status quo will be made. This is generally not materially influenced by the Global Climate Change Agenda or supported by appropriate regulatory requirements.

The most applicable drivers of energy investment decisions, along with criteria that can be used to objectively measure them, were identified in this report through interviews with subject matter experts. With the mining industry as context, the four determinants in energy investment decisions were analysed to determine which is the most influential. Enablers to further renewable energy investments were identified through discussion with interviewees. Interestingly, no interviewees had the exact same ranking of determinants for investment decisions. It is likely that this is a reflection of the bespoke nature of each energy solution or project. More importantly, the most influential determinants were consistently those that influence the financial viability of a project or investment decision. The imperative to reduce GHG emissions and the Global Climate Change Agenda, which are least likely to influence the financial model of an investment, was also the least likely determinant to influence an investment decision.

Life of Operation Assumptions was identified to be the most influential determinant, followed by Security of Energy Supply assumptions. Mining Demand Side Requirements were also influential in the investment decision, but not a primary influencer. The uniqueness of a project, and location seem to drive the influencers in the investment decision, which ultimately related to the financial viability of the investment (Masini and Menichetti, 2012). The results demonstrated that the life of the project is key to determining the viability of the project. Once the viability has been established, the technology choice will be made in a manner that ensures Security of Energy Supply. The results have clarified that Security of Energy Supply consists of three components, i.e. reliability, affordability and availability, and as such all analyses should ensure that all there components are considered.

Risk-averse investment assumptions or companies with a significant focus on core business and / or more conservative or traditional approaches to investment may not readily consider a hybrid model for energy supply. In this instance, if the Global Climate Change Agenda does not enable them to adjust their investment approach, other drivers such as corporate climate change strategies, corporate renewable energy performance indicators and possibly even shareholder pressure could enable a shift to renewable energy investments. This however, is unlikely to drive the investment. Mostert (2014) proposed that, when considering a renewable energy investment, a broader consideration of the financial aspects should be made. This includes environmental, social and human aspects of an investment. Should Mosterts' (2014) approach be successfully applied, one could possibly improve the financial aspects of an investment decision by internalising the Global Climate Change Agenda, reducing GHG emissions and enhancing possible social benefits of renewable energy investments. This would also be consistent with Mosterts' (2014) recommendation of utilising a sustainable development approach towards energy investments.

When evaluating financial models utilised for renewable energy investment projects in Brazil, China, India and South Africa, Kamara (2016) noted the differences in approach, context and jurisdictional context was acute and evident in the investment models used for those countries. Furthermore, where similarities in some countries' financial models or economic context may exist, Kamara (2016) reported that similar financial models would not necessarily work, but rather a unique approach is required for each context. Jurisdictional comparisons are therefore important considerations when evaluating projects and energy investment decisions. The scope and context of the study, which is the mining industry in an African context, is a critical fact that needs to be considered. This includes distinguishing between Africa and South Africa from an African perspective, as the South African context is markedly different to the remaining African context. South Africa is currently experiencing considerable renewable energy investment (Kamara, 2016) which, identified by some interviewees, may be attributable to an innovative renewable energy procurement

programme. Furthermore, country governance and risk are key considerations in financing an investment, and as such the industry, country context and risk profile, infrastructure, credit worthiness, tax incentives etc. related to an energy investment could be hugely variable between different industries and countries. Komendantova, Patt, Barras, and Battaglini, (2012) identify significant renewable energy generation opportunities in North Africa that could benefit both North Africa and Europe. In order to harness this potential, substantial private foreign direct investment would be required, however, geopolitical risk such as regulatory challenges, political instability and terrorism influence the investment risk and financial hurdles for investment (Komendantova *et al.*, 2012).

Adaptive technology could influence the investment models and determinants in that they could materially change the underlying assumptions. Hadjipaschalis *et al.* (2009) recognise the benefits of renewable energy sources such as cleaner energy production and continual improvements in technology. In some instances, however, renewable power generation can only compete with non-renewable power generation sources where the supply is supplemented with storage of the renewable energy in order to increase reliability. This is currently not occurring on a large, commercially viable scale. In the context of this study, renewable energy storage could significantly influence the Life of Operation Assumptions due to the cost of the capital required for storage, or alternatively, a reduction in capital costs for non-renewable infrastructure. Similarly, re-deployable solar PV panels could significantly influence the Life of Operation Assumptions in that the PV panels could be utilised for a short life of operation mine or project and then redeployed to another, resulting in the capital or investment burden return being significantly lower. This may result in a viable or lower tariff for renewable energy on a project that has demand for less than seven to 10 years or an available US$30M for investment. Technological changes could again disrupt the energy investment space, and improve project outcomes for renewable energy investment.

In conclusion, the Global Climate Change Agenda and imperative to reduce GHG emissions creates an enabling environment for renewable energy investment which aims to mitigate the impact of climate change (Elum and Momodu, 2017). This enabling environment is widely supported at an intergovernmental and international level with many governments developing policies to achieve the desired outcomes (Huenteler, Niebuhr, and Schmidt, 2016). Investment in energy projects is not restricted to renewable energy projects, and in some instances non-renewable energy investments continue. This is largely driven by the financial aspects of the energy investment and associated return on investment (Kamara, 2016). The factors that influence the return on investment, as shown in this research, tend to be unique to the investment project and mining industry. They support the outcome of certain financial investment hurdles beings met or achieved, primarily related to risk and reward. Incentivising renewable energy investments would be successful if they influence the return on the investment. The study identified that the changing renewable energy landscape, in the form of adaptive technology related to energy storage, could materially influence the outcome of investment modelling, and drive additional renewable energy investments (Hadjipaschalis *et al.*, 2009). Adaptive technologies should therefore be continually pursued when considering energy investment initiatives.

Limitations to the Study

The research and interviews were based on determining and understanding the most influential determinants related to energy investment decisions in the private sector and mining industry. The nature of the determinants and the most influential determinant in investment decisions reflects this, along with the project and mining specific nature of the investment decisions. Should the scope of the study be broadened to additional industries, additional determinants may be identified and those with the most influence on an investment decision may also be different. Similarly, only four subject matter experts were interviewed, and had more experts been interviewed, a wider base of information may have been available to trend the determinants that were most influential on the investment decision.

Mining case studies for renewable energy investment decisions were considered at the onset of the research. The case studies were not used in the analysis of the determinants due to sensitivities in the financial modelling components of the projects, and regulatory delays in project authorisations, which resulted in restricted publically available information to be used in the research.

Lastly, whilst the determinant of base load requirements is applicable to the mining industry, it is likely to be applicable to other industrial processes too. .

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Appendices

Appendix 1: Interviewee Questionnaire

Determinants that influence renewable energy investments.
Survey Interview Questionnaire

Context

Renewable energy sources are being driven as the solution for energy supply challenges globally. Investment in renewable energy is increasing, however investment in non-renewable energy supply continues. As such, this research will aim to identify key influencers in renewable or non-renewable energy investment decisions when renewable options may be available. The following determinants will be considered when evaluating the influences in the investments decision:

- **Global drive towards GHG emissions reductions:** Global and country response to climate change and high levels of GHGs in the atmosphere.
- **Security of Energy Supply (reliability and pricing):** Reliability, continuity and certainty of electricity supply; and affordability, certainty and predictability in the pricing and associated increases, for electricity.
- **Life of Operation Assumptions:** The remaining, profitable, life of an operation or mine, on which business planning decisions and commitment can be made.
- **Mining Demand Side Requirements:** Activity specific requirements of the operations from an electricity supply perspective e.g. unique base load or start-up requirements.

Participation is the survey is voluntary and will remain anonymous and confidential. Information obtained during the survey will not be communicated in a way that identifies participant or participant's company. Participants may opt out of answering any of the questions and are under no obligation to share any information that may compromise the participant or participant's organisation.

Interview Questionnaire

A: Case Study Participants:

1. Please briefly describe your renewable energy investment project
2. Please describe the status of the investment project e.g. feasibility, execution and construction, operational etc.
3. Please will you share (if you are prepared to do so) the overall investment cost of the energy investment project

B: All Participants:

1. Please may you comment on the following drivers or determinants, in your experience, in influencing energy investment projects you have worked on (renewable or non-renewable):
   - Global drive towards GHG emissions reductions
   - Security of Energy Supply (reliability and pricing)
   - Life of Operation Assumptions
   - Mining Demand Side Requirements
2. Are there other drivers, or determinants, that you feel are material in investment project decisions that have not been considered above?
3. Please may you rate these determinants (question B1 above), including any you have identified, in influencing investment decisions as follows:

   1 = Least Influential: Immaterial determinant – not considered

   2 = Unimportant determinant: does not influence decisions

   3 = Neutral determinant: does not influence decision in either direction, but is considered

   4 = Important determinant: can influence decisions

   5 = Most Influential: Material determinant - can ‘make or break’ decisions
4. Please may you elaborate on any noteworthy points in the rating process or decision making process
5. In order to try and objectively analyse the determinants identified in question B1, please rate the following criteria identified for each determinant as being applicable or not in the investment decision (i.e. yes or no):

5.1 Global drive towards GHG emissions reductions

a. Legal or regulatory requirements to reduce GHG emissions (e.g. Country Paris Agreement commitments)
b. Corporate strategy for climate / GHG emissions reduction
c. Corporate strategy to invest in renewable energy
d. Investor or external ESG influences to reduce GHG emissions or invest in renewable energy
e. Current CDM Investment Project(s) within organisation

5.2 Security of Energy Supply (reliability and pricing)

a. Rising increases in cost of current energy supply Unpredictable increases in cost of current energy supply Instability in pricing
b. Unpredictable increases in cost of current energy supply Instability in pricing
c. Inability to secure a 'development' or 'stability' agreement for energy pricing and control
d. Unreliable, and therefore interrupted, supply of electricity due to generation constraints
e. Unreliable, and therefore interrupted, supply of electricity due to transmission constraints

5.3 Life of Operation Assumptions

a. Life of Mine is shorter than investor payback period
b. Life of Mine is shorter than renewable energy investment payback period
c. Life of Mine is incompatible with incentive (e.g. government) period
d. Life of Mine assumptions did not allow for adaptive management to energy investment (changing landscape)
e. Investment or utilisation of renewable energy investment does not extend beyond life of mine

5.4 Mining Demand Side Requirements

a. Base load considerations fully exclude renewable energy as an option

b. Base load considerations cannot be adequately met by renewable energy requirements
c. Renewable energy generation constraints are incompatible with operational requirements
d. Renewable energy storage solution is inadequate
e. Renewable energy storage solution is cost prohibitive

6. Are there other criteria for these four determinants (B5) that you feel are material in investment project decisions that have not been, and should be, considered?
7. Do you have any recommendations for determinants that governments or regulators, investors or financiers, project proponents, and / or stakeholders should take into consideration in *renewable energy investments* in order to streamline or incentivise further investment?
8. Do you have any recommendations for determinants that governments or regulators, investors or financiers, project proponents, and / or stakeholders should take into consideration in *non-renewable energy investments* in order to improve or dis-incentivise further investment?
9. Do you wish to add any additional considerations for renewable energy investment projects?
10. Do you have any comments you would like to provide on the survey process?

Thank you

DETERMINANTS THAT INFLUENCE RENEWABLE ENERGY INVESTMENTS

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A Research Report submitted to the Faculty of Science, University of the Witwatersrand, Johannesburg, in partial fulfilment of the requirements for the degree of Master of Science.

02 November 2018

Declaration

I declare that this research report is my own, unaided work. It is being submitted for the Degree of Masters of Science at the University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination at any other University.



(Signature of candidate)

2nd day of November 2018 in Johannesburg

Abstract

The Kyoto Protocol, Global Climate Change Agenda and imperative to reduce greenhouse gas emissions has gained significant traction recently as decision makers attempt to mitigate the impacts of climate change. Energy that is produced from non-renewable energy sources, such as fossil fuels, is a significant contributor to greenhouse gas emissions, and by displacing non-renewable energy production and consumption with renewable energy production, greenhouse gas emissions can be reduced. This is particularly relevant to the mining industry, which is a significant consumer of energy, particularly energy from non-renewable fossil fuel sources. Consumption of renewable energy for mining related activities presents a cost saving opportunity for the industry and could support mitigating the effects of climate change. This research aimed to identify the main determinants that influence decisions in energy investment projects, and specifically, to determine the most influential determinant in energy investment decisions, particularly in the mining industry. Through interviews of subject matter experts in the mining industry, sustainable development, renewable energy and renewable energy project investment and finance, the results suggest that Life of Operation, i.e. life of mining asset or operation, was the most influential determinant in making energy investment decisions. Security of Energy Supply in which cost, reliability and availability are secured through the energy investment closely follows as the second most influential determinant.

The Global Climate Change Agenda may create an enabling environment for renewable energy investments, however the key drivers in such decisions are the financial aspects of the investment.

Keywords: renewable energy, greenhouse gas emissions, mining, life of operations, security of energy supply, base load energy requirements, Global Climate Change Agenda, financial investment

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Nomenclature

CDM	Clean Development Mechanisms
COP21	Conference of the Parties of 1992 United Nations Framework Convention on Climate Change, COP21 was the 21st conference in Paris
CSP	Concentrated Solar Power
EPC	Engineer, Procure, Construct
ESG	Environment, Social, Governance
GHG	Greenhouse Gas
GWh	Gigawatt Hour
IPCC	Intergovernmental Panel on Climate
IPP	Independent Power Producer
IRR	Internal Rate of Return
MW	Mega Watts
NPV	Net Present Value
PPA	Power Purchase Agreement
PV	Photovoltaic
REIPPP	Renewable Energy Independent Power Producer Projects
REN21	Renewable Energy Policy Network for the 21st Century
UNFCCC	United Nations Framework Convention on Climate Change
US$	United States Dollars
WEF	World Economic Forum
WWF	World Wide Fund for Nature

Chapter 1: Introduction

Renewable energy sources are being driven as the solution for energy supply challenges globally, pushed by considerations such as ‘cleaner’ energy and reduction in greenhouse gas (GHG) emissions as part of the ‘Global Climate Change Agenda’ (Akuru, Onukwube, Okoro, and Obe, 2017; Mohammed, Mustafa, Bashir, and Ibrahem, 2017). Renewable energy sources also present practical solutions for remote areas where grid supply may be challenging, or as a potential cost savings opportunity (Sonnenschein, 2016). On a large commercial and industrial scale, renewable energy may be supported by a non-renewable power supply to ensure operational continuity for power supply security, when renewable energy storage is not viable, or fully available (Kempton and Tomić, 2005; Evans, Strezov, and Evans, 2009).

Investment in renewable energy is increasing, albeit it at a slow pace, and can achieve objectives such as reduction in GHG emissions, cost savings through the use of a non-depletable source of energy and contribute towards economic growth (Soberanis, Alnaggar, and Mérida, 2015; Can Şener, Sharp, and Anctil, 2017). Investment in non-renewable energy supply however also continues (Kahia, Aïssa, and Lanouar, 2017). It is speculated that this may be due to cost, Security of Energy Supply, renewable resources availability (such as sunshine, wind) or limited availability of effective energy storage options. Paradoxically, non-renewable energy supply and continued investment in existing supplies may also be an important requirement to successfully invest in and grow renewable energy supply (The Economist, 2017).

The African mining industry is often cited as a significant consumer of fossil fuels, and therefore significant emitter of GHGs (Holmberg, Kivikytö-Reponen, Härkisaari, Valtonen, and Erdemir, 2017). Mining typically utilises significant amounts of energy to access the ore body of the material being mined, particularly in ventilation, cooling and materials movement in deep underground mining and/or materials movement, utilising heavy earth moving equipment or

facilities (Holmberg *et al.*, 2017; Vyhmeister, Aleixendri, Bermúdez, Pina, Fúnez, Rodríguez, Reyes-Bozo, 2017). Associated infrastructure, services and mineral processing also require energy, all of which has traditionally been provided by non-renewable sources (Limanskiy and Vasilyeva, 2016). As a significant consumer of energy and emitter of GHGs, the mining sector potentially has significant opportunities in the reduction of GHG emissions with renewable energy sources. However, the resource investment, particularly capital investment, is likely to be significant for the conversion to, or utilisation of, renewable energy sources (Vyhmeister *et al*., 2017), particularly in remote areas or countries with already limited energy and/or renewable energy generation and supply opportunities. The intense 'base load' energy demands of the mining sector also present an energy security challenge, particularly when considering renewable energy (Bajpai and Dash, 2012; McLellan, Corder, Giurco, and Ishihara, 2012). Investment in energy generation from non-renewable sources continues, such as the South African national utility (Eskom) investment in the 4,764MW Medupi and 4,800MW Kusile coal-fired stations (Eskom, 2017). However, opportunities for renewable energy use exist and are being implemented, for example the 82.5MW Paleisheuwel Concentrated Solar Power (CSP) Project and 10MW Enel Upington photovoltaic power plant situated in the Northern Cape (Africa News Agency, 2016). Whilst these schemes may not compare in size with the coal fired power stations, they demonstrate that large scale renewable energy production is possible.

So, what is influencing renewable energy investments? Conversely, what is influencing the investment in non-renewable energy when renewable options may be available?

1. 1 Aim and Objectives of the Study

The aim of this study was to identify the most influential determinant in an energy investment project decision, and determine the amount of influence the remaining determinants have on a decision. This, in turn may identify why non-renewable

energy investments continue, despite the apparent global drive for cleaner energy production and the benefits of renewable energy investments.

The objectives of the study were to:

- identify the most applicable drivers or determinants of energy investment decisions;
- ascertain the most influential determinant or driver of investment decisions through interviews with subject matter experts in energy generation, renewable energy investment, financial and commercial considerations in energy investment, sustainability and the mining industry;
- determine the influence the remaining determinants have in an energy investment decision;
- assess the suitability of objective criteria of the determinants that influence investment decisions, once again through the interview of subject matter experts, and
- where appropriate, identify enablers for renewable energy investments.

1.2 Layout of Research Report

The chapters of this report are designed to follow the aims and objectives of the report, and present data in the chronology in which it was obtained. Chapter 1 includes an introduction to the study as well as the aim and objectives of the research. Chapter 2 provides a literature review, giving insights in the energy challenges of the mining industry, the challenges and opportunities associated with renewable energy and an investigation in the determinants identified to influence decision-making with regards to renewable energy. Chapter 3 summarises the methodology used for this research and Chapter 4 presents the results obtained. Chapter 5 closes with a discussion of the findings and the implications of the insights gained for the future of renewable energy in the mining sector. A reference list follows this last chapter, and appendices are found at the end of this research report. Figures and tables and numbered consecutively throughout the report.

Chapter 2: Literature Review

It is widely accepted that anthropogenic climate change and associated greenhouse gas (GHG) emissions are affected by energy consumption, through energy production (Weisser, 2007; Evans *et al.,* 2009; Ou, Xiaoyu, and Zhang, 2011). Converting energy from a non-renewable fossil fuel to a renewable form may therefore have a significant impact on the reduction of the GHG emissions footprint. There is a global climate change drive, most recognisably through the Intergovernmental Panel on Climate (IPCC) and United Nations Framework Convention on Climate Change (UNFCCC). The IPCC represents a body of international scientists whose research and assessments are consolidated and interpreted to provide governments. This includes policy makers, with scientific information on climate change, risks, impacts and possible mitigation and management measures to address these impacts. This information is intended to inform decision making, policy, and importantly, the UN Climate Conferences (Osorio-Arce *et al*., 1988).

The objective of the UNFCCC is to ensure the "stabilisation of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system" (UNFCC, 1992, page 9). This should be ensured in a manner that allows ecosystems to adapt naturally, protects food security and ensures that economic development is not compromised. The Kyoto Protocol, an international treaty negotiated in 1997, enacted in 2005 and extended to 2020, is a binding agreement in which industrialised countries have set reduction targets for their collective GHG emissions (Kyoto Protocol, 1997). The UNFCCC has further initiated the setting of reduction targets and associated mitigation strategies, including strategies in the energy sector for developing nations (Amrutha, Balachandra, Mathirajan, 2017).

The 'Paris Agreement', which was negotiated by the UNFCCC Conference of Parties (COP) in December 2015 and enacted in November 2016, specifically

addresses the mitigation of GHG emissions, adaptation to the effects of climate change as well as the financing mechanisms for these aspects (UNFCCC, 2017a). As a means of achieving the commitments set out in the Paris Agreement, there is an imperative for a significant and fast transformation in the energy generation space (Clemencon, 2016).

Countries that participate in the Paris Agreement are required to mitigate climate change by determining their contribution to climate change (their GHG emissions footprint), provide plans to address these and report on the progress in mitigating climate change in a manner that exceeds previous targets (UNFCCC, 2017b). Ultimately, these interventions are aimed at preventing the predicted temperature increase going beyond 2^{o}C and, where possible, work towards a 1.5^{o}C increase limit to reduce the effects of climate change (Rohit, Devi, and Rangnekar, 2017). Countries are also required to improve their ability to adapt to climate change effects in a sustainable manner (UNFCCC, 2017b). The Paris Agreement - recognises that mitigation and adaptation need to be complemented with an enabling financial environment that contributes to reduced GHG emissions and climate resilience (Reboredo, Quintela, and Otero, 2017). Arguably, an enabling financial environment can unlock mitigation and adaptation initiatives and provide a real driver for managing climate change. This enabling driver presents an opportunity for growing and technologically advancing developed and developing economies. As the demand for energy grows, GHG emissions from energy generation can be mitigated through mechanisms of energy savings, efficient consumption and / or increased use of renewable energy sources (Tezer, Yaman, and Yaman, 2017). This can be optimised or fast tracked through a financially enabling environment.

The World Economic Forum (WEF) maintains that, to ensure equitable and sustainable economic growth particularly in developing countries, a transition to “green growth” economic development is required. This includes investment in renewable energy technology in developing countries to reduce GHG emissions. They have however identified slow and inadequate progress as investment in

fossil fuel energy generation continued to exceed investment in renewable energy generation in 2013 (World Economic Forum, 2013). A World Wide Fund for Nature (WWF) report re-iterates, after reviewing European investor practices, that whilst financial regulators and investors are increasing their commitment and investment decisions to achieve a reduction in GHG emissions in line with the Paris Agreement, the rate of and extent to which this is achieved is not sufficient (Godinot and Vandermosten, 2017). Therefore, the reason or cause for the pace at which this is achieved is in question.

2.1 Non-Renewable and Renewable Energy

Energy exists in many forms on Earth and humankind has utilised this energy in its different forms and sources over time. Some of the forms in which energy exists includes solar energy, thermal energy, and kinetic energy.

The energy sources available have not materially changed over time, but man's ability to harness this energy in an efficient manner or on a large scale and continuous manner has changed over time. These energy sources consist of non-renewable and renewable sources with non-renewable energy supply being the dominant source of energy supply for electricity generation, for distribution and use in the United States of America in 2016 (U.S. Energy Information Administration, 2016), as data for 2006 to 2015 illustrate in Table 1 below.

Table 1: Electricity generation by source (non-renewable and renewable), in thousand megawatt hours, in the United States in 2016. (Source: U.S. Energy Information Administration, 2016. p15)

Period	Renewable Total	Renewable % of Total	Non-Renewable Total	Non-Renewable % of Total	Total Generation at Utility Scale Facilities
2006	392,188	10%	3,672,514	90%	4,064,702
2007	358,083	9%	3,798,663	91%	4,156,745
2008	386,448	9%	3,732,939	91%	4,119,388
2009	425,025	11%	3,525,306	89%	3,950,331
2010	434,730	11%	3,690,329	89%	4,125,060
2011	521,069	13%	3,579,071	87%	4,100,141

Period	Renewable Total	Renewable % of Total	Non-Renewable Total	Non-Renewable % of Total	Total Generation at Utility Scale Facilities
2012	503,410	12%	3,544,356	88%	4,047,765
2013	530,980	13%	3,534,984	87%	4,065,964
2014	545,867	13%	3,547,738	87%	4,093,606
2015	557,671	14%	3,529,709	86%	4,087,381

The information provided above illustrates the large dependence on non-renewable energy sources for power generation and distribution, primarily using natural gas, coal and nuclear fuel sources for electricity. In 2015 3.5million GWh of electricity were generated at utility scale from non-renewable sources whilst 0.6million GWh of electricity were generated at utility scale from renewable sources (Source: U.S. Energy Information Administration, 2016. p15).

Fossil fuel energy supply is the primary fuel source used globally for non-renewable electricity generation and consists of five types of fossil fuels: coal, petroleum coke, petroleum liquids, natural and other gas. These along with nuclear fuels typically make up the fossil fuel source for energy generation and / or are ‘non-renewable’ (International Energy Agency, 2016). Thermal generation utilises these energy sources in generating electricity (International Energy Agency, 2016).

Renewable energy has undeniably undergone a radical transformation over the last decade. The Renewable Energy Policy Network for the 21st Century (REN21) attributes this largely to changes in policy, financing opportunities, improvements in renewable energy supply, security and the Global Climate Change Agenda demanding cleaner energy (REN21, 2016). REN21 (2016) also recognises developing and emerging economies’ demand for energy increase, thus driving the renewable energy market from another demand perspective. Whilst renewable energy is not the majority contributor to power generation and supply, the use of renewable energy on a utility generation scale has increased by more than 40% in the last 10 years, in the United States of America, as shown in Table 1 above. The predominant forms of renewable energy include solar and

solar photovoltaic (PV), concentrated solar power (CSP), hydropower from flowing water, wind power, bioenergy (such as fuel generated from plant matter, for example sugarcane), geothermal power (REN21, 2016) and hydrogen fuel (Renewable Energy World, 2016).

The sun's energy can be used directly and indirectly in many ways to harness its energy, and in some instances generate power or electricity. Solar energy or direct heat from the sun is perhaps the simplest form of harnessing the sun's energy, but is mostly useful for heating. The sun's energy, when it is available during the day, needs to be converted into a useable from of energy supply such as solar thermal power or solar PV before it can be used commercially (Mills, 2004).

Solar PV utilises the energy (photons) from the sun and converts it to direct electricity using specialist semi-conductors (Eskom, 2014). The PV effect utilises photons of light or light energy to excite electrons contained in specialist semi-conductor material which in turn converts them to charge carriers for an electric current, essentially creating a direct current of electricity (Eskom, 2014). This electric current can be used directly as electricity or to charge a battery storage system which will store energy, or electricity, when the sun is not shining. The cost of these batteries, and low efficiencies or short lifespan, make this option very expensive on a commercial scale (Vyhmeister *et al*., 2017). Battery technology, for the purpose of renewable energy storage, is evolving rapidly (Olabi, 2017; Caldera and Breyer 2018).

CSP utilises various methods to capture or concentrate solar energy to a central collection point in which heat energy is used to heat a heat-transfer-fluid or system. This in turn is utilised to generate electricity through a turbine and the Faraday process. Two main types of CSP generation are utilised, one of which allows for a thermal storage solution through the use of thermal storage material, such as molten salt, in order to retain thermal energy captured during the day for extended use when the sun is no longer shining (Hussain, Arif, and Aslam, 2017). This increases the capacity factor of CSP. Capacity factor is the ratio of the actual

energy generated for use from a facility to the potential energy that could be generated from a facility, with the higher the capacity factor the better for efficient energy generation and use (Jha and Puppala, 2017). CSP is a relatively new and expensive technology with limited large-scale applications. The land requirements for such a project are also likely to be significant (Lilliestam, Bielicki, and Patt, 2012).

Hydropower utilises kinetic energy, the energy in moving water, such as a river, to drive a turbine, which in turns generates electricity. The energy supply, or river, needs to have sufficient all year flow in order to ensure full generation potential is met, and the river should preferably not be sensitive to seasonal fluctuations in water flow. Modifications to the existing river hydrology are likely to be required in order to install the power generation system and to protect the aquatic ecology, where possible. Modifications and alterations to the hydrological flow may have long lasting impacts on the aquatic ecology. Given the constant flow of water in a river and through a turbine, the capacity factor of hydropower is generally high (Bartle, 2002).

Hydropower pump and store power generation utilises two dams and a river (or pathway). Water is captured in the first dam, which is situated high enough to generate energy through turbines when water is released from this dam and reports to the lower second dam. Here it is contained, and pumped back up to the first dam at an appropriate time. The appropriate time is normally during non-peak energy use conditions with low electricity costs, where the water is stored before release again (Tran and Smith, 2017). These pump and store schemes are ideally suited to provide peak flow of electricity. This method comes at a high cost in that energy (electricity) is required to pump the water back to the storage scheme and the overall electricity consumption for pumping can exceed the electricity production from the scheme (U.S. Energy Information Administration, 2016). This form of power is therefore only viable to provide peak supply.

Wind power is a long established, yet relatively inefficient (Olabi, 2017), method of generating electricity, or harnessing energy. It uses large wind turbines (blades) which turn in the correct wind conditions and generate electricity, or drive a shaft system to perform work. Modern wind turbines are able to generate electricity when the wind is blowing, which can be modelled and predicted to some extent. Wind is not constant, which means that the capacity factor of this form of power generation is low, and power is not always available or predictable (Munguia, 2016). Wind turbines may also create unintended environmental impacts, particularly related to birds and bats.

Bioenergy essentially utilises biological material in order to generate energy. The most common application of this is biofuels, which utilise plant material to feed combustion, heat generation or other processes. Whilst biofuels may be a renewable energy source, and a cleaner form of energy production, there are many inherent environmental and social risks associated with it. These could be changes to biodiversity in the biofuel growing area, conflict over land use, specifically around land used for food production, risk to small scale farmers who invest fully in a single crop which may fail, and the farming of the biofuels may rely on non-renewable fuel (Fischer, Hizsnyik, Prieler, Shah, and Van Velthuizen, 2009).

Geothermal energy is natural energy that is derived from fluid (water or steam) heated by the earth's core and / or in some instances molten lava reserves in close proximity, which are under pressure and can be easily harnessed to generate power from the heated fluid through a conventional electricity generation process (Energy.gov, 2016).

Hydrogen can be used to generate a fuel, or fuel cell, which in turn can generate power. This occurs when a chemical reaction (not combustion) converts a hydrogen atom into heat and water, thus generating energy for use (Energy.gov, 2016).

Renewable energy technology poses a range of options that could be used to generate cleaner energy and complement or displace existing non-renewable energy generation, although with less availability then many forms on non-renewable energy. Renewable energy technologies are not appropriate in all situations, as some have advantages and disadvantages in different operating circumstances. For example, hydropower is dependent on an appropriate water source that delivers appropriate flow conditions all year round, which is readily available (Bartle, 2002). The source of power (hydrology) may not necessarily be close to the demand and as such, additional transmission infrastructure may be required. CSP is able to generate renewable energy and provide a form of storage that can extend power generation duration during the day. The sun, infrastructure and space requirements may once again pose a limiting factor to where the demand is required as significant generational schemes are likely to be located in desert-like conditions. CSP may also require significant infrastructure capital investment (Lilliestam *et al.*, 2012). Other renewable energy sources such as wind power may only be able to provide a small percentage of renewable energy requirements based on the availability of wind, and as such this may need to be supplemented, in most cases, with other renewable (or non-renewable) sources (Sharifzadeh, Lubiano-Walochik, and Shah, 2017) such as PV or thermal generation. Renewable energy solutions are therefore unique to each energy demand situation and should be configured accordingly. This is particularly applicable for costing and financial investment around the renewable source, as the energy source needs to be sustainable and affordable.

Niesten, Jolink, and Chappin (2017) researched renewable energy wind investment in the active Dutch onshore wind renewable energy sector. Niesten *et al.* (2017) determined that financial considerations were informed by elements such as renewable energy investment experience, industrial and energy generation experience. These all play a significant role in influencing energy investment, despite the established nature of this sector of renewable energy.

2.2 Energy Investment Determinants

Renewable energy generation solutions are available and in many instances exist as proven technology (Dincer, 2000; Elabban, Abu-rub, and Blaabjerg, 2014).

The determinants that can influence the choice of energy generation solution have been identified in a number studies. Zharan and Bongaerts (2017) have identified a series of mining renewable energy investment project case studies that have been implemented through arrangements such as a Power Purchase Agreement (PPA) with a service provider or the use of an Independent Power Producer (IPP). Importantly, a key consideration in the case studies presented by Zharan and Bongaerts (2017) was the mine life effect, i.e. the life of the mining operations are a key consideration in an energy investment.

An analysis into completed or established renewable energy investments in Europe, undertaken by Papież, Śmiech, and Frodyma (2018), modelled four determinants for energy investment. This first determinant is the environment, which considers the impact of energy consumption, specifically GHG emissions, and high levels of carbon dioxide emissions associated with non-renewable energy generation. Essentially, this determinant refers to environmental impact, or conversely, the determinant is to avoid environmental impact (Global Climate Change Agenda aspirations). This determinant is a common feature in literature regarding renewable energy investments and is often proposed as a reason or motivation for renewable energy investment (Christensen and Hain, 2017; Zeng, Liu, Liu, and Nan, 2017; Surroop and Raghoo, 2018).

The second determinant identified by Papież *et al.* (2018) is Security of Energy Supply, where energy self-sufficiency, renewable or non-renewable mix, and ability to fully access and utilise the available energy influence the energy investment approach. This is further supported by volume and cost of importing energy to meet a project or country's demand and this volume and cost consideration is evaluated against the country's renewable energy supply in the energy mix: GDP per capita Papież *et al.'s* (2018) consideration of the third determinant, economic influences related largely to the local economic

development status of the country. It considers the country's GDP, energy consumption both per capita relative to GDP, and the proportion and cost of renewable energy consumption. Another component of economics or costs is subsidies as recognised by Moriarty and Honnery (2007). Moriarty and Honnery (2007) caution against using costs for comparative purposes as the subsidies are not always easily recognisable or transparent and may incorrectly impact on assessment outcomes.
Lastly, Papież *et al.* (2018) identifies political influences in energy investments as the fourth determinant, although this was restricted to consideration of EU Membership of the countries that invest in renewable energy.

Gómez-Navarro and Ribó-Pérez (2018) identified further influences in energy and potential renewable energy investments, which are divided into three main categories: technical, social and economic. The technical elements identified by Gómez-Navarro and Ribó-Pérez (2018) include security of energy supply in the form of lack of grid connectivity and therefore transmission challenges, tariff challenges (pricing) and insufficient understanding of the potential of renewable resources and options. Gómez-Navarro and Ribó-Pérez (2018) identified the social influences related to lack of planning from a regulatory environment perspective, poor public-private organisation and insecurity related to regional civil unrest and potential armed attacks. Finally, Gómez-Navarro and Ribó-Pérez (2018) identified the economic influences as high capital or investment costs in renewable energy, inability to fully internalise environmental costs of non-renewable energy generation, competing subsidies offered to non-renewable energy sources and tariffs that do not differentiate between renewable and non-renewable energy generation.

Energy requirements, from a mining perspective, cannot be considered without ensuring that minimum operating requirements, or base load requirements, are met through the energy investment approach (Moriarty and Honnery, 2007). Where these requirements cannot be secured through a renewable energy

generation source, energy storage will be a critical consideration Hadjipaschalis, Poullikkas, and Efthimiou, 2009)

Lastly additional determinants could include environmental and social pressures and expectations (Phadke, 2018) which include environmental permitting requirements and social acceptance of renewable energy initiations, or social rejection of non-renewable energy generation. Land access is also an important consideration for renewable energy investment, particularly in instances where there is competition for land (Fischer, Hizsnyik, Prieler, Shah, and Van Velthuizen, 2009) and potential unintended environmental impacts such as biodiversity impacts (Moriarty and Honnery, 2007). Selosse, Garabedian, Ricci and Maïzi (2018) identified the need for a favourable regulatory and policy environment for renewable energy investment to occur, as well as secure legislation in the energy sector (Kamara, 2016).

From the determinants identified above, available renewable energy options or potential options, were not considered further. The type of renewable energy solution available does not necessarily influence whether or not a renewable energy solution is possible or desired. Rather it is likely to determine whether more work is required, or what *type* of renewable energy source is utilised and the opportunities and limitations for that solution (Tezer *et al*., 2017). This determinant was therefore considered unlikely to assist in determining why a decision is taken to invest, or not invest, in renewable energy, given the site specific context of options available.

Dependence on non-renewable energy options from a subsidy, tariff, cost of capital or cost of financing perspective was considered to be an unlikely scenario to influence a decision as it could be equally applicable to renewable energy options (Kahia *et al.*, 2017). Given the global response to the climate agenda and evolving financing and regulatory environments, this determinant was seen as likely to be moot.

The determinants of environmental permitting requirements, biodiversity impacts social opportunities or challenges, political influences, security and land access opportunities or challenges may be grouped together from a 'sustainable development' classification or perspective, which is a common grouping in the mining industry (Hilson and Murck, 2000; Azapagic, 2003). This determinant is unique to individual site contexts in terms of what may be applicable and required. It is also common to individual site contexts in that it needs to be considered for any energy investment (World Economic Forum, 2013; Waite, 2017). It is therefore equally unique yet equally applicable at each site, and it is difficult to determine their influence, if any, on the investment decision. They were therefore not considered further.

Government subsidies were not considered further due to the complex opportunities and constraints that may exist for renewable and non-renewable options and that which may have been negotiated, but not publicised, between mining companies, suppliers, service providers and government (Xie, Li, Xia, Liang, and Zhang, 2017). This determinant was therefore not considered any further, It was, however, was indirectly considered as part of pricing or Security of Energy Supply and was therefore noted where applicable. Security of Energy Supply also considers the tariff as a determinant and the security or predictability associated with that.

Financial considerations, government subsidies, costs of energy generation and supply, technical constraints around Security of Energy Supply, evolution of the in-country electricity generation and supply, etc. are determinants that were grouped together. This was included for further research and analysis as they are likely to materially influence decision making from the perspective of Security of Energy Supply, and were therefore considered as part of the consolidated determinant "Security of Energy Supply (reliability and pricing)".

“Life of Operation Assumptions” was identified as an important and relevant determinant as the investment life span is directly influenced by this, and therefore a key determinant in the investment decision.
“Mining Demand Side Requirements” could determine whether a proposed renewable energy investment can be supported in continued mining operations and as such is a key determinant.

Broader environment, social, governance, and sustainability considerations, climate change and GHG emissions response, government policy, enabling regulatory environment, policies or policy interventions, are determinants that were grouped together to be addressed as part of the Global Climate Change Agenda. These are likely to include policy and legislative drivers in investment decisions (Elum and Momodu, 2017). This group is referred to “Global Drive towards GHG emission Reduction” and is considered further.

Therefore, to establish a set of determinants and associated criteria for influencing the renewable energy investment decision, the following determinants, in no order of importance, were used:

- **Global Drive towards GHG emission Reduction:** Global and country response to climate change and high levels of GHGs in the atmosphere;
- **Security of Energy Supply (reliability and pricing):** Reliability, continuity and certainty of electricity supply, and affordability, certainty and predictability in the pricing and associated increases, for electricity;
- **Life of Operation Assumptions:** The remaining, profitable, life of an operation or mine, on which business planning decisions and commitments can be made; and
- **Mining Demand Side Requirements:** Activity specific requirements of the operations from an electricity supply perspective e.g. unique base load or start-up requirements.

2.3 Investment Approaches

Companies with established investment systems and processes typically follow a complex process when considering an investment for the business. Various drivers may be present in determining the need for an investment, such as business continuity, business improvement, strategic investment, reputational management, etc. However, a systematic approach is applied to understand the need for the investment, the options available to the investment, the financial implications of the investment, and how the investment will be executed (Strantzali and Aravossis, 2016).

Systematic approaches could include a life-cycle analysis, cost-benefit analysis or multi-criteria decision aids (Strantzali and Aravossis, 2016). These are usually combined with an investment model for a project, or investment in which alternatives, options, risks, uncertainties can be modelled and compared in financial terms for a project decision to be taken (Focacci, 2017). The investment model considers, where appropriate, the current status quo, baseline conditions or base case and it is against this that alternatives or options can be measured. The base case for an energy investment model could be the current energy supply, inclusions and exclusions. The investment model is then used to develop scenarios much like scenario planning, in which the outcomes of technical, risk, financial and other processes can be modelled (Soberanis *et al*., 2015).

At the start of an investment, a company or project will have a certain set of criteria against which decisions must be made. These criteria could typically include legal compliance, technical reliance (although 'proven technology' may not necessarily be a requirement), environmental, social and governance considerations as part of good corporate governance and / or impact management (King, 2016). Furthermore impact on business, for example losses or gains should the project be implemented, cash flow risk and requirements, capital investment requirements, operating cost requirements, and maintenance costs are important criteria against which a decision is also likely to be made (Kamara, 2016). This enables total cost of energy, return on the investment from net present value (NPV) and internal rate of return (IRR) of the investment (Ye,

Zhang, Jiang, Miao, and Li, 2017) to be determined. NPV is the value of a project, in today's terms, after considering the cash inflows and outflows over its life. The cash inflows may be determined by, for example, cash generated by the sale of a mining product, like platinum, and the outflows influenced by the cost of electricity (Percoco and Borgonova, 2012). IRR is a method, utilising certain assumption, that is used to calculate return on, or profitability of, an investment (Percoco and Borgonova, 2012). These criteria may also become 'hurdles', which the investment case must overcome for it to have a positive outcome. Overcoming hurdles in investment modelling is important as projects and initiatives compete for capital. Capital is not freely available and comes at a cost to a business or project, regardless of whether a company is able to 'self- fund' or attract external investment. Ultimately, the preferred outcome of investment modelling should ensure that the company's internal requirements are met and the investment returns are in line with the company requirements (Christensen and Hain, 2017).

In the case of an energy investment project, alternative supply options should be modelled including existing supply, renewable options, non-renewable options, hybrid options etc. The investment modelling should also consider funding options and the cost of those over the life of the investment (Christensen and Hain, 2017). These costs include the cost of funding and the cost of cash flow and are likely to trade off against each other, for example, higher upfront capital investment against a lower operating costs, or vice versa. Whilst the trade-offs themselves may show suitable outcomes for all options, when compared against the hurdles, the preferred trade-off may become immediately apparent (Vyhmeister *et al*., 2017).

Financiers or lenders often drive a 'greener' agenda and a trend is emerging in which major lenders are shifting to cleaner energy investments or energy investments with a renewable energy component (Schwerhoff and Sy, 2017). Together with this, volatile commodity prices, a changing energy generation and supply landscape, investment modelling hurdles, climate agenda drivers and

requirements, society demands and business operating requirements play a key role in investment decisions which are complex with multiple dependencies and interrelationships (Cunico, Flores, and Vecchietti, 2017).

Ming, Ximei, Yulong, and Lilin (2014) have evaluated China's renewable energy investment, which has undergone rapid growth attributable to China's policies that support such investment. Whilst China has had considerable investment in wind and PV renewable energy initiatives, the financing aspect has significantly influenced the investment approaches, particularly through the investment environment, organisations and bodies that can finance the required renewable energy investments and have the means to do so, source of the investment funds and expectations on returns of those funds (Ming *et al.,* 2014). This evaluation demonstrates the importance of financing mechanisms and arrangements despite a regulatory environment and available renewable energy resources that easily support renewable energy investments.

Chapter 3: Methodology

3.1 Identification of Key Determinants

From the determinants, in no order of importance, identified in the Literature Review in Chapter 2, the following determinants were determined to be relevant factors in influencing energy project decision making:

- **Global Drive towards GHG emission Reduction:** Global and country response to climate change and high levels of GHGs in the atmosphere;
- **Security of Energy Supply (reliability and pricing):** Reliability, continuity and certainty of electricity supply, and affordability, certainty and predictability in the pricing and associated increases, for electricity;
- **Life of Operation Assumptions:** The remaining, profitable, life of an operation or mine, on which business planning decisions and commitment can be made; and
- **Mining Demand Side Requirements:** Activity specific requirements of the operations from an electricity supply perspective e.g. unique base load or start-up requirements.

In order to determine which of these is the most influential in influencing energy investment decisions, and to determine how the remaining determinants influence the decisions, they were evaluated in interviews with subject matter experts. In order to support these interviews and ensure an element of rigor and repeatability, the determinants were further elaborated on using five criteria specific to each. These criteria, which are presented in Table 2, are specifically related to the determinants and were used to assess the determinants and their contribution to energy investment decision making. These criteria were identified from the literature review and used for the development of the key determinants for the study (Chapter 2) and are summarised below.

Table 2: Criteria for Determinants

Global Drive towards GHG emission Reduction	Security of Energy Supply (reliability and pricing)	Life of Operation Assumptions	Mining Demand Side Requirements
Legal or regulatory requirements to reduce GHG emissions (e.g. Country Paris Agreement commitments)	Rising increases in cost of current energy supply	Life of Mine is shorter than investor payback period	Base load considerations fully exclude renewable energy as an option
Corporate strategy for climate / GHG emissions reduction	Unpredictable increases in cost of current energy supply Instability in pricing	Life of Mine is shorter than renewable energy investment payback period	Base load considerations cannot be adequately met by renewable energy requirements
Corporate strategy to invest in renewable energy	Inability to secure a 'development' or 'stability' agreement for energy pricing and control	Life of Mine is incompatible with incentive (e.g. government) period	Renewable energy generation constraints are incompatible with operational requirements
Investor or external ESG influences to reduce GHG emissions or invest in renewable energy	Unreliable, and therefore interrupted, supply of electricity due to generation constraints	Life of Mine assumptions did not allow for adaptive management to energy investment (changing landscape)	Renewable energy storage solution is inadequate
Current CDM Investment Project(s) within organisation	Unreliable, and therefore interrupted, supply of electricity due to transmission constraints	Investment or utilisation of renewable energy investment does not extend beyond life of mine	Renewable energy storage solution is cost prohibitive

3.2 Evaluation Criteria

To ensure that the determinants were considered in the most objective way possible, the determinants for influencing the investment decisions were rated on a scale of 1 to 5, with 1 being the least likely influence on the investment decision, and 5 being the most likely influence on the investment decision. The determinants were assessed during interviews, with highest rating representing the key driver for the investment decision as discussed in more detail.

To support the analysis of the determinants and further enhance the consideration of the determinants and applicability to energy investment

decisions, each of the criteria identified in Table 2 were assessed in a binary manner, i.e. yes or no, with regards to their relevance to the determinant for assessment purposes. This enabled the determinants to be considered in further detail, without compromising the primary objective of comparing the four determinants against each other in order to determine that which is most applicable the energy investment decisions.

3.3 Interviews

Interviews were identified as a means to assess the most influential determinants in the decision process for energy investments. In order for targeted and useful interviews to be concluded, industry subject matter experts as well as representatives from renewable energy projects and investment financing, were identified as potential interviewees for the study.

A questionnaire for the interviews was developed in such a way that both qualitative and quantitative, or easily measurable and comparable information was gathered. Context could be set, structured questions could be answered in a way in which determinants could be ranked, and less structured questions were developed in order to facilitate discussion, and identify any potential gaps in the approach to the determinants or decision making process. The questionnaire is presented in Appendix A. Ethics Clearance was obtained from the University of the Witwatersrand's Human (non-medical) Ethics Committee (clearance number HA1808).

The interviewees were contacted telephonically or via email in order to request an interview, and subject to their approval, a Participant Information Letter, Consent Form and copy of the questionnaire were provided. Interviews were undertaken during normal business hours, in a place of business or public place (such as coffee shop) and in line with the questionnaire.

In total, four people were interviewed:

- Interviewee 1: Current mining industry experience, non-renewable and renewable energy expertise in both technologies and energy, decision making for project experience and sustainability subject matter expert. Works in

private sector mining and renewable energy. Recent energy investment experience (2017 / 2018).

- Interviewee 2: Current mining industry experience, and renewable energy subject matter expert, sub-Saharan African investment, geopolitical and sustainable development expert. Works in private sector mining and renewable energy. Recent energy investment experience (2017 / 2018).
- Interviewee 3: Subject matter expert on non-renewable and renewable energy, subject matter in energy investments (technology, finance and sustainable development) and sustainability expert. Works in private sector mining, in sustainable development in climate, carbon and energy areas. Recent energy investment experience (2017 / 2018).
- Interviewee 4: Subject matter expert on renewable and non-renewable energy, renewable and non-renewable energy investments (technology, finance, commercial, legal, sustainable development and project management), commercial or investment modeller and implementer, mining experience. Works in the private sector for mining and 'energy' clients (such as funders, suppliers, energy producers, energy users etc.).

The data from the interviews were noted, summarised and categorised according to the determinants, criteria and additional considerations. Data from all four interviews were then compared in order to identify common themes, common determinants and ranking of the determinants and criteria. During the interviews, it was apparent that the criteria for the determinants could not necessarily be considered in a binary manner, some criteria were mutually exclusive, and other criteria were mutually inclusive. Similarly, the determinants were not necessarily mutually exclusive but could be complementary in a chronological manner. For example, the key determinant allowing the investment process to begin was identified, and was further complemented by secondary and tertiary determinants or considerations. The determinants could also be ranked in order of influence or importance, thus achieving the objective.

The scores for each determinant by each interviewee was plotted to determine if there was any relationship between the determinants, or any pattern in the how the determinants were related to each other. This could be considered for each determinant or each interviewee's response.

3.4 Research Limitations

The research and interviews were based on understanding the most influential determinants related to energy investment decisions in the private sector, specifically the mining industry. The subject matter experts as such have considerable mining and renewable energy experience. Other private sectors such a manufacturing were not considered as part of the scope. Broader scope may influence the determinants that are considered for investment decisions, or even the outcome of the most influential determinant.

Furthermore, only four subject matter experts were interviewed, and a wider range of experts may have yielded a more diversified outcome.

Chapter 4: Results

This study has focussed on determinants most likely to influence energy investment decisions related to the mining industry, and determine which of these are the most influential in energy investment decisions. Whilst the Global Climate Change Agenda and supporting international and intergovernmental protocols and policies create an enabling environment for renewable energy investment, the determinants considered in this study relate to mining aspects of project decision making processes, in the private sector. These determinants are analysed through the views of mining, sustainability and renewable energy investment experts who are able to assess the most influential determinants based on experience in their field of expertise.

As part of the interviews, interviewees rated those determinants, on a scale of 1-5, where 1 is the least likely to influence investment decisions for an energy investment, and 5 is the most likely to influence an investment decision. The consolidated outcome of the interviews is presented in Table 3. Interviewee 1 and Interviewee 4 rated Life of Operation Assumptions as 5, which is the determinant most likely to influence energy investment decisions. Interviewee 2 and 3 rated Security of Energy Supply as 5, or the determinant most likely to influence energy investment decisions. Global Drive towards GHG emission reduction had the lowest overall score of 8 or 40%, and is therefore the least likely determinant to influence an energy investment decisions. Security of Energy Supply has the second highest score of 16 or 80%, and Life of Operation Assumptions had the highest score of 17 or 85%, which confirms that this is the determinant most likely to influence renewable energy investment decisions.

Table 3: Summary of interview outcomes in assessing the influence of determinants on investment decision

Determinant	Interview 1 Mining & Sustainability Expert	Interview 2 Mining & Renewable Expert	Interview 3 Renewable & Sustainability Expert	Interview 4 Renewable Expert	Score
Global Drive towards GHG emission Reduction	2	3	2	1	8 40%
Security of Energy Supply (reliability and pricing)	3	5	5	3	16 80%
Life of Operation Assumptions	5	4	3	5	17 85%
Mining Demand Side Requirements	4	2	4	4	14 70%

Mining Demand Side Requirements were found to play a part in influencing investment decisions, although it was not the primary or secondary determinant. The combination of the Life of Operation Assumptions, Security of Energy Supply and Mining Demand Side Requirements suggests that each investment decision is determined by bespoke or specific elements. This includes the duration, location and type of operation or project.

4.1 Life of Operation Assumptions

Life of Operation Assumptions were collectively, and in two instances, the most influential determinant in energy investment decisions (Table 3). From the interviews it emerged that these assumptions are the most critical. They determine whether or not there is sufficient time for investment capital and financing costs to be recovered through the reduced energy generation costs or cost savings. The guaranteed life of an operation or facility determines the bankability of the energy investment. Similarly, the longer operational life of a facility, the better the returns of the investment may to be. From a renewable energy perspective, a financed project such a Power Purchase Agreement (PPA), or even an owner Engineer, Procure Construct (EPC) Project, which the interviewees identified as being less common, a capital investment for project will have a certain period of time in which the capital and other financing costs will be

recovered. After the cost recovery period, savings in energy generation from, for example, a solar PV project, which are most common in the interviewees' experience, delivers a financial return on the investment. In a PPA arrangement, the costs of capital, finance and generation will be evenly spread over the life of the renewable energy investment, which will be the same as the guaranteed life of the operation, in the form of a tariff. The interviewees agreed, with the exception of one, that EPC Project energy generation contracts, particularly for renewable energy, are generally not very popular or common.

Interviewee 1 explained that a guaranteed life of operation, in mining terms, is generally accepted as being the resource determination. This refers to the resource that has been declared within a prescribed and industry accepted deterministic limit of certainty. Whilst mining operations may have identified more ore reserves that have not been included in the resource calculation, these reserves, inferred reserves, or in some instance 'blue sky' reserves are known to exist. They have also been tested for their availability to within a prescribed and industry accepted, lower, deterministic limit of certainty. Reserves, inferred reserves and blue sky reserves do not have sufficient certainty regarding their availability, mine-ability or processing ability for the mining operation to guarantee performance or delivery. As such, planners and financiers are not prepared to make significant financial commitments or accept guarantees on reserves, inferred and / or blue sky reserves. This in turn does not allow PPA or EPC Project contracts to be established on potential life of mine. This is a limiting factor in financing energy investments.

Interviewee 1 and 4 elaborated that non-renewable energy investments can be structured in such a way that smaller thermal generators or modular components are deployed for the life of operation. These can be upgraded, added on, or removed to another site should life of mine operations extend. The non-renewable energy investment sector is well established and many options and iterations are available for energy generation along this operating configuration. As such, almost any configuration or arrangement can be accommodated.

Renewable energy investments generally have a minimum generation capacity, which three of the four interviewees agreed was around 20MW (although this could be as low at 10MW). Economy of scale is important, in order to ensure a viable investment proposition. This is not an absolute requirement, and is dependent on other variables but can be used as guideline. In order for a successful renewable energy investment agreement to be established, using a PPA for example, the Life of Operation Assumptions would need to be a minimum of 7 to 10 years. Interviewees were in general agreement around this, and once again, other variables could influence this period and it is therefore not absolute, but rather a useful guideline. Lastly, one interviewee indicated that currently, the size and life of the project would also likely need to trigger an investment value of US$30million or more. This will secure an acceptable return on investment to meet the investment criteria relative to the cost of capital and finance.

The interviewees indicated that the bankability of an energy investment, particularly a renewable energy investment, may seem to be driven by financing. However, they indicated that financing is not the driver, it is rather an enabler, or a risk modifier. As such, financing should not be considered as a determinant to energy investment but rather a tool that can be utilised in different ways to influence an energy investment, particularly a renewable energy investment. This presents an opportunity in the renewable energy investment space, particularly private investment projects. All interviewees agreed that the financing component of the Paris Agreement supports renewable energy investment in the public investment space, but not necessarily the private investment space...

In summary the Life of Operation Assumptions is the primary determinant or influencer in energy investment decisions. Once secured, Life of Operation Assumptions will determine tariff, which means that a longer life of mine will secure a lower tariff for energy generation over the life of the project. The life of operation will influence the tariff but not determine the viability of the project (beyond certain underlying assumptions of bankability or revenue). This view was supported by two different interviewees' perspectives.

If a Life of Operation Assumption is too short to meet, for example, the requirements of a bankable renewable energy investment, the project will not be discarded. Rather, the proponent will still consider the energy investment, particularly if it is a necessity for the operation or business, but simply re-evaluate or select a different technology. As mentioned previously, this could be a non-renewable choice or a variation of a hybrid approach. This illustrates that Life of Operation Assumptions need to provide certainty for the investment, and that this will in turn influence the technology, which may be renewable energy.

Lastly, if Life of Operation Assumptions have established a viable investment, the technology and Security of Energy Supply can be modified as required and delivered. Nevertheless, remote and captive mining operations that may be very sensitive to the cost of energy and have a short, guaranteed, life of operation. They may be challenged to achieve security in the form of affordability, and may also need to rely on thermal generation to secure an investment. No examples or instances were identified or discussed by the interviewees where an energy solution, and therefore investment, could not be secured. Whilst this does not mean that such projects do not exist, it does indicate that their occurrence may be limited, and more importantly other factors may play a key role in the investment decision. Mining projects generally need significant capital investment for infrastructure and requirements upfront, and generally need a suitable life of operation to fund this, which in turn should be able to provide a significant amount of time for an energy investment return.

4.2 Security of Energy Supply

Whilst the interviews focused on reliability and affordability, it became evident from an interviewee that Security of Energy Supply consists of three main components, i.e. reliability, affordability *and* availability. This was not captured as such prior to the interviews, and was an important gap or incomplete consideration of this component. All three components are required to ensure Security of Energy Supply, and is best illustrated in Figure 1 below.

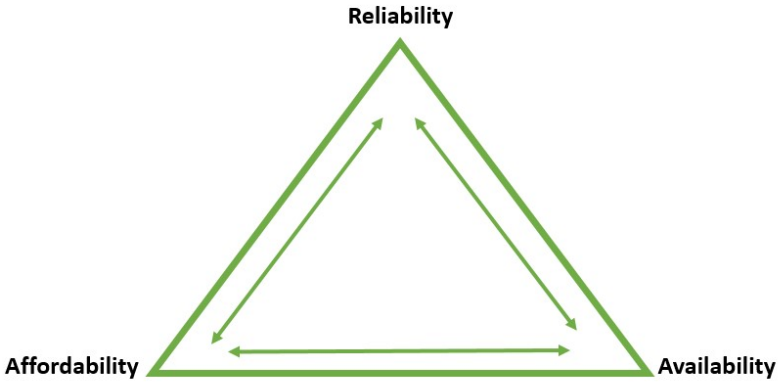


Figure 1: Energy Security Triangle (based on interview results)

The following points have been summarised from the interview in order to fully explain Security of Energy Supply. Reliability involves a consistent, predictable supply of energy. This is illustrated through a utility that may supply a consumer, for example a mining operation, with electricity, and that supply is not interrupted, unpredictable or does not fluctuate. This ensures that the consumer can utilise this energy in a planned predictable manner that meets their requirement on a consistent and reliable basis.

Affordability refers to the pricing or cost of energy for consumption. Affordability includes the actual tariff for generation, and where required transmission cost and predictability in price increases. The affordability or cost of energy is likely to be a key consideration for the viability of a particular energy supply and in some instances may be too expensive, or unaffordable, for the energy to be utilised. This is particularly relevant where other forms of energy are available that may be more cost effective.

Availability considers the energy available to meet a consumer's demand, for example the generation available from a utility is sufficient to be able to supply to the consumer. This refers to the sufficiency or availability of the required energy. It is important to note that renewable energy availability could be effected by available sun or wind (which determines Capacity Factor) or events such as

droughts affecting hydropower availability. From a renewable energy perspective it could also refer to the availability of the natural resource for generation purposes. For example, sufficient solar radiation or sufficient wind energy or hydrological components to meet the requirements. Availability also considers the ability, where required, to transmit the energy to the consumer. Security in availability would therefore typically mean that there is sufficient electricity available for use, and it can be transmitted, if required, for use.

These considerations do not exist in isolation but need to be considered together in order to ensure Security of Energy Supply, as shown in the Energy Security Triangle, in Figure 1 above.

Interviewee 4 supported considerations of the Energy Security Triangle, through a non-renewable example. Thermal coal energy generation, with a reliable or predicable source of coal, is an established and effective manner to secure energy supply. This provides a typical example of where a non-renewable energy source such as this may be selected over a renewable source for energy supply, particularly for large-scale generation. Thermal (coal) generators can ensure available energy when it is required at any time of day and during peak demand, with a predictable cost and reliably. Security of Energy Supply in non-renewable energy investment, using thermal coal power, may therefore determine the outcome of an energy investment. Security of Energy Supply is not restricted to non-renewable energy. A renewable energy source, for example solar PV, can be modelled for reliability, affordability and predictable availability. This could displace a portion of non-renewable energy generation, thereby presenting a hybrid type approach which may reduce energy generation costs and meet the Security of Energy Supply requirements, as discussed by the interviewee.

Security of Energy Supply was an important determinant for all interviewees and whilst not all agreed that this is the most influential determinant, all agreed that it is influential in investment decisions.

The two interviewees that rated Life of Operation Assumptions as being more influential than Security of Energy Supply agreed that once a bankable investment is secured, Security of Energy Supply could be considered, and achieved, through technology choices such as PV and wind. The two interviewees that rated Security of Energy Supply as being more influential than Life of Operations Assumptions provided directly opposing views to each other. Interviewee 2 stated that once the technical requirements of an investment can be secured, the client and investor financial requirements can be secured. Interviewee 3 determined the second most influential consideration to the Mining Demand Side Requirements, which perhaps also 'dilutes' the view that Security of Energy Supply is the most influential determinant. In summary, Security of Energy Supply was scored as the second most important determinant in influencing an energy investment decision. This view was supported by two different interviewee perspectives.

Life of Operations Assumptions and Security of Energy Supply each had two interviewees rating them as the as the most influential determinants in energy investment decisions.

4.3 Mining Demand Side Requirements

Mining Demand Side Requirements are an important influencer in energy investment decisions and with the exception of one interviewee was rated as the second most influential determinant. However, the overall score did not fully support this, and it was determined to be the third most influential determinant. It supports the discussion above that the determinants that are influential in decision-making are related to the unique nature of the mining operations, jurisdictional setting and mining activities. All interviewees consistently and firmly agreed that Mining Demand Side Requirements related to base load cannot be met solely through renewable energy supply without storage.

This energy demand cannot be achieved by renewable energy without storage, such as battery storage of solar PV, or as it was hypothesised, hydropower with

storage, although that in itself may not be secure. As such, there was consensus amongst the interviewees that mining operations need an alternative non-renewable energy supply to meet base load requirements, as solar PV storage is currently not economically viable for mining operations. It is therefore evident that base load power requirements need to be met for an energy investment decision, through whatever means, and that this cannot be provided by renewable energy. Renewable energy rather displaces the potential non-renewable energy supply to other operational requirements, when it is available. This means that a non-renewable or hybrid renewable energy solution can be implemented, with variable configurations.

4.4 Global Drive towards GHG Emissions Reduction

Ironically, the Global Drive towards GHG Emissions Reduction, loosely referred to as the Global Climate Change Agenda, is one of the key triggers of renewable energy growth, and a driver to reduce GHG emissions., However when considering the investment case for energy including renewable energy, this was found to be least influential.

All interviewees confirmed that this is least likely to influence investment decisions. Two interviewees confirmed that a company directive to invest in renewable energy achieves better outcomes than those companies that do not have such directives or strategies. It was suggested that these companies also have a less risk-averse view on renewable energy investment, that which favours investment and has more enabling views, for example on new technologies, funding models, commercial arrangements for power supply etc. Activists, lobbyists, non-governmental organisations were also identified as being a low driver or influencer of investment decisions. Essentially the interviewees recognised that the Global Climate Change Agenda is driven through business, where government policies are driving renewable energy investment in accordance with targets set for and by the Global Climate Change Agenda such as the Paris Agreement or COP 21.

Whilst interviewees agreed that there are significant jurisdictional differences, developed and developing country governments are driving renewable energy across the private and public sectors. Developing countries have a strong focus on renewable energy investments, and in many instances the private sector is able to catalyse much needed growth in the energy sector.

Despite business objectives, government influences and Global Climate Change Agenda opportunities for renewable energy investment, consensus maintained that the decision to invest in renewable energy would only be taken if there were a financial advantage when compared with the status quo. Carbon credits are not an advantage or driver. The market drivers for carbon credits, as indicated by an interviewee, do not exist and therefore this is currently regarded as a potential upside with possible future value, although not bankable.

One interviewee suggested, anecdotally, that there seems to be a lot of 'green agenda' money for investment, although not enough renewable energy opportunities exist. This is partly attributable to investors not wanting to work with the private mining sector due to legacy and reputational issues. Another interviewee suggested that in this line of thinking, private mining companies present catalytic opportunities to develop energy investment opportunities for communities. Although, where private mining companies can be enablers, some country legislation does not necessarily allow for these opportunities to be realised. Rigid investment models may also not recognise potential returns beyond certain operating assumptions, which are limited to the mining aspects such as life of mine. Furthermore, technological improvements may be required to support growth in community related renewable energy investment. An incentive programme or procurement initiative such as South Africa's Renewable Energy Independent Power Producer Project (REIPP), which has the potential to be very successful enabler and other African countries beyond South African, may benefit from such an initiative.

Interviewees were asked to identify any possible gaps in the determinants that were material to the decision-making process for energy investments. The interviewer identified legal or regulatory requirements as possibly being such a gap, which was identified upfront in the first interview, and considered in all subsequent interviews. Whilst all interviewees discussed and considered legal and regulatory requirements, it was consistently reported that this did not influence investment decisions in this context. Some interviewees recognised the importance of legal and regulatory requirements, but they were not determined to be enablers. Reasons for this include legislation that is focused on public investment, legislation that is aspirational in Global Climate Change Agenda targets but immature in development, and utility protectionism in some instances. As such, this has not been identified as a determinant, and not useful for further consideration.

Based on the outcomes of the interviews, and the drivers of the investment decision, a Hierarchy of Determinants Influencing Investment Decisions has been developed and is presented below in Figure 2.

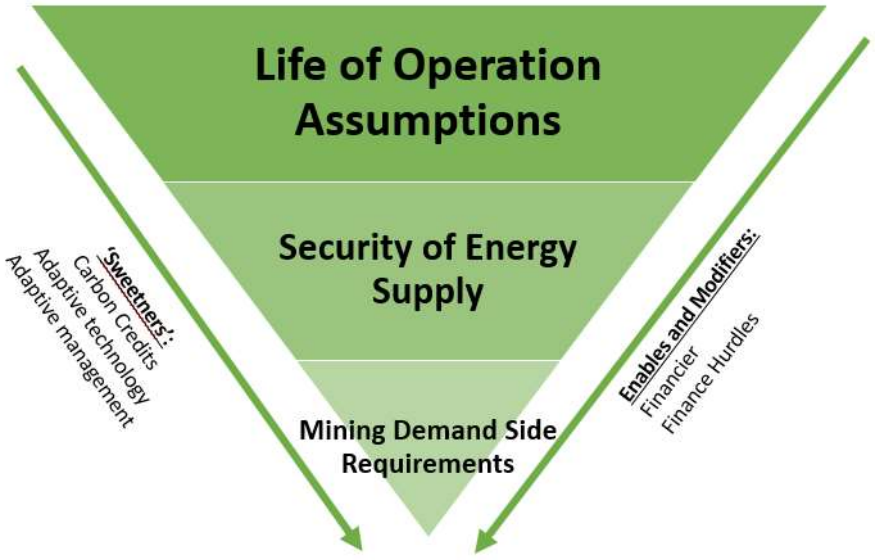


Figure 2. Hierarchy of investment decision influencers (based on the outcome of the interviews)

In support of this hierarchy, and a consistent outcome of each interview, is the variability between project, location and jurisdictions for energy investment projects. This extends to how this variability is a likely to be key factor in the determinants that influence the investment decision. As part of the interviews, it was therefore reiterated that the scope and boundary of the study was limited to private energy investments (not public), mining sector energy investments and a South African and African (continent) context, recognising that these two are materially different. Jurisdiction considerations, specifically in Africa (in general, but excluding South Africa) and South Africa became very evident in all interviews and discussions.

The outcomes of the interviews are presented plotted below in Figure 3 which identifies the pattern of investment decision determinants. This presents the most influential determinants as those that are bespoke to the energy investment projects and its needs. This representation also confirms the important influence that Mining Demand Side requirements have on the investment decision, and whilst this was not the most important influence for investment decisions, it re-iterates the bespoke nature and / or requirements being keep factors in decision-making processes.

For completeness, Regulatory Framework was included in this illustration, although, like Global Climate Change Agenda, it is clear that these determinants do not influence an energy investment decision and plot to the left of the illustration. This is perhaps supported by the apparent pattern of determinants likely to influence decisions being those that are unique and specific to each project, e.g. Life of Operation Assumptions is unique for each project which in turn determines the technology choice (renewable or non-renewable, followed by tariff or cost of that investment). The same project, located in a different jurisdiction, for example, may have a different outcome.

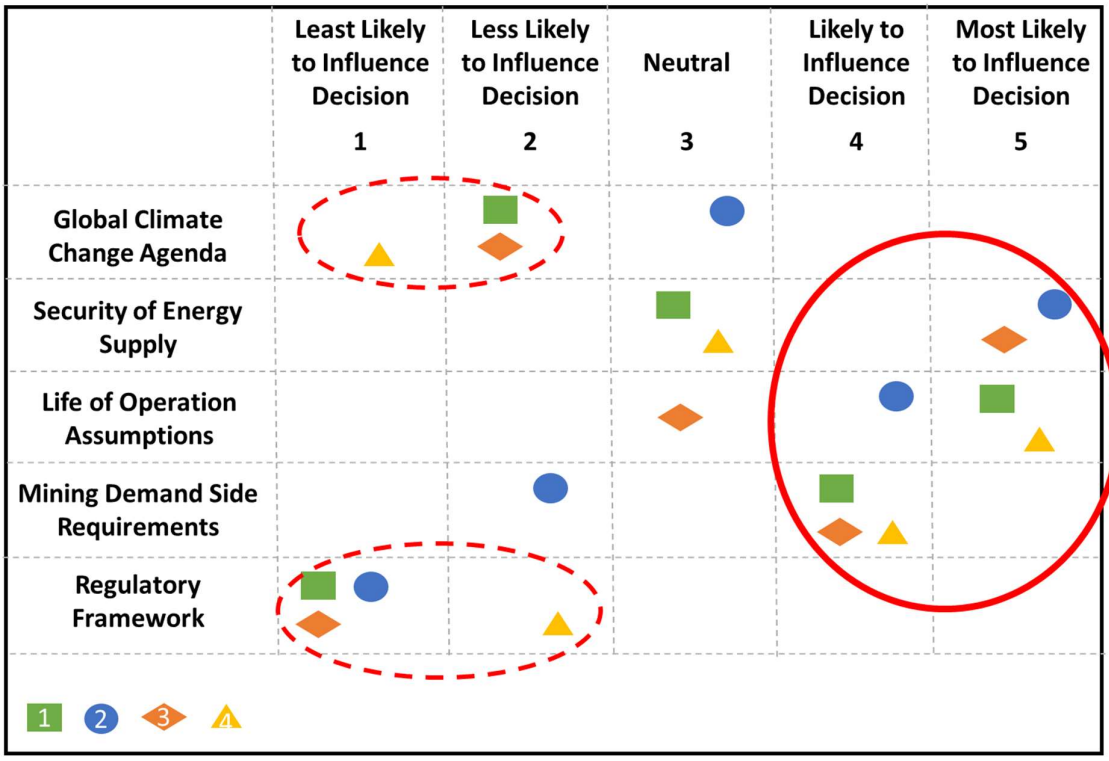


Figure 3: Pattern of influence of key determinants on investment decisions

4.5 Objectively Assessing the Determinants

In order to fully understand the interviewees' perspective on the identified key determinants, and ensure an element of objectivity and repeatability, detailed criteria were assessed with the interviewees. These criteria were assessed in a binary fashion in order to determine how they contributed to the determinant. It was expected that all criteria would not necessarily be relevant to the determinant. Generally speaking, there was a large degree of consistency in the interviewees' considerations of the criteria, although there were some exceptions (see Table 4). Notably, of the five criteria presented for Mining Demand Side Requirements, only one criterion was applicable to the determinant, in the context of this report and the energy investment scope and boundaries. This criterion was related to base load, which is essential for mining operations and energy investments cannot be considered without base load. Interviewees were fully aligned on this.

Although this determinant was deemed to be the least likely to influence an energy investment, the interviewees were mostly in agreement that corporate strategies to reduce emissions, or to invest in renewable energy initiatives were the most relevant and supportive of this determinant. Interviewees were split on the ESG investment pressure and legal or regulatory requirements, with half agreeing that this is relevant to this determinants influence, and half not. Consensus was largely achieved for clean development mechanisms (CDM) or carbon credit opportunities as being irrelevant to the determinant.

Table 4: Criteria for global climate change agenda

Determinant: Global Climate Change Agenda **Criteria**	**Interview 1 Mining & Sustainability Expert**	**Interview 2 Mining & Renewable Expert**	**Interview 3 Renewable & Sustainability Expert**	**Interview 4 Renewable Expert**	**Score**
Legal or regulatory requirements to reduce GHG emissions (e.g. Country Paris Agreement commitments)	Y	Y	N	N	Y = 2 N = 2 N/A = 0
Corporate strategy for climate / GHG emissions reduction	N	Y	Y	Y	Y = 3 N = 1 N/A = 0
Corporate strategy to invest in renewable energy	N	Y	Y	Y	Y = 3 N = 1 N/A = 0
Investor or external ESG influences to reduce GHG emissions or invest in renewable energy	N	Y	Y	N	Y = 2 N = 2 N/A = 0
Current CDM Investment Project(s) within organisation	N	N	Y	N	Y = 1 N = 3 N/A = 0

Interviewees were generally in alignment that the main contributors to Security of Energy Supply were security of affordability, which includes rising costs or unpredictability in costs (Table 5).

In terms of the criteria for Life of Operation Assumptions, interviewees were largely aligned on the applicability of these criteria with the exception of the last criterion (Table 6). Outcomes of the interview focused on guaranteed Life of

Operation Assumptions, i.e. proven resources in order to secure the bankability of the investment. Agreement was unanimous on the requirement of the payback period of an investment or of a renewable energy investment being the applicable criterion for the investment decision. There was mostly agreement on adaptive energy opportunities. Lastly, interviewees were divided on the applicability of criteria related to an investment that could be realised within the life of mine.

Table 5: Criteria to security of energy supply

Determinant: Security of Energy Supply **Criteria**	**Interview 1 Mining & Sustainability Expert**	**Interview 2 Mining & Renewable Expert**	**Interview 3 Renewable & Sustainability Expert**	**Interview 4 Renewable Expert**	**Score**
Rising increases in cost of current energy supply	Y	Y	Y	Y	Y = 4 N = 0 N/A = 0
Unpredictable increases in cost of current energy supply Instability in pricing	N	Y	Y	Y	Y = 3 N = 1 N/A = 0
Inability to secure a 'development' or 'stability' agreement for energy pricing and control	N	Y	N/A	Y	Y = 2 N = 1 N/A = 1
Unreliable, and therefore interrupted, supply of electricity due to generation constraints	Y	Y	Y	Y	Y = 4 N = 0 N/A = 0
Unreliable, and therefore interrupted, supply of electricity due to transmission constraints	N	Y	Y	Y	Y = 3 N = 1 N/A = 0

The interviewees were unanimous in the consideration of the criteria related to Mining Demand Side Requirements, asserting that base load energy must be available for mining operations as presented in the context of this study (Table 7). Should base load requirements not be met, the investment is not viable. In support of this, renewable energy solutions, without storage, will not be able to meet base load requirements, and as such, a non-renewable or hybrid solution is required.

Table 6: Criteria for life of operation assumptions

Determinant: Life of Operation Assumptions Criteria	Interview 1 Mining & Sustainability Expert	Interview 2 Mining & Renewable Expert	Interview 3 Renewable & Sustainability Expert	Interview 4 Renewable Expert	Score
Life of Mine is shorter than investor payback period	Y	Y	Y	Y	Y = 4 N = 0 N/A = 0
Life of Mine is shorter than renewable energy investment payback period	Y	Y	Y	Y	Y = 4 N = 0 N/A = 0
Life of Mine is incompatible with incentive (e.g. government) period	N/A	N	N/A	N	Y = 0 N = 2 N/A = 2
Life of Mine assumptions did not allow for adaptive management to energy investment (changing landscape)	N/A	N	N	N	Y = 0 N = 3 N/A = 1
Investment or utilisation of renewable energy investment does not extend beyond life of mine	Y	N/A	N	Y	Y = 2 N = 1 N/A = 1

Table 7: Criteria to mining demand side requirements

Determinant: Mining Demand Side Requirements Criteria	Interview 1 Mining & Sustainability Expert	Interview 2 Mining & Renewable Expert	Interview 3 Renewable & Sustainability Expert	Interview 4 Renewable Expert	Score
Base load considerations fully exclude renewable energy as an option	Y	Y	Y	Y	Y = 4 N = 0 N/A = 0
Base load considerations cannot be adequately met by renewable energy requirements	N/A	N/A	N/A	N/A	Y = 0 N = 0 N/A = 4
Renewable energy generation constraints are incompatible with operational requirements	N/A	N/A	N/A	N/A	Y = 0 N = 0 N/A = 4
Renewable energy storage solution is inadequate	N/A	N/A	N/A	N/A	Y = 0 N = 0 N/A = 4
Renewable energy storage solution is cost prohibitive	N/A	N/A	N/A	N/A	Y = 0 N = 0 N/A = 4

Chapter 5: Discussion

With recognition of the climate agenda and the importance of reducing greenhouse gas (GHG) emissions, renewable energy investments present an opportunity to replace, displace or supplement non-renewable energy generation (Wüstenhagen and Menichetti, 2012.; Mostert, 2014.). The decision to invest in energy projects, and specifically renewable energy projects, seems to be consistently influenced by the financial aspects of a project, as identified by Wüstenhagen and Menichetti (2012). Wüstenhagen and Menichetti (2012) report that when considering renewable energy investments for which there is a Global Climate Change Agenda imperative to investment, and in many instances an enabling policy environment for investment in renewable energy, it is the economics associated with the financial investment that determine the rate at which renewable energy investments are made. Traditional risk and return metrics that are considered as part of the financial modelling and considerations for investments are the drivers for the investment. Risk and return are usually unique to the energy investment scenario and aim at reducing risk and maximising return (Wüstenhagen and Menichetti, 2012). This can be achieved through determinants such as those identified in this study. This is further supported by a Nordic renewable energy investment study in which Boomsma, Meade, and Fleten (2012) identified financial aspects of an investment decision being influenced by the return on the investment, and the ability to enhance the return through increased Security of Energy Supply. This can be done through utilising improved pricing or a higher, secure tariff for the investment. Boomsma *et al.* (2012) found that improved security of cost supports an earlier initiation of renewable investments. Furthermore, this can be supplemented through additional financial support, such as subsidies, or a larger investment capital. Project investment decisions, in the context of this study, are clearly dependent on the outcome of the financial model and financial metrics that need to be met. Key to this is that a successful investment decision outcome assumes that for a replacement, or renewable energy displacement project, the investment must be more cost effective than the status quo. It is highly unlikely that an investment

that cost more than the status quo will be made. This is generally not materially influenced by the Global Climate Change Agenda or supported by appropriate regulatory requirements.

The most applicable drivers of energy investment decisions, along with criteria that can be used to objectively measure them, were identified in this report through interviews with subject matter experts. With the mining industry as context, the four determinants in energy investment decisions were analysed to determine which is the most influential. Enablers to further renewable energy investments were identified through discussion with interviewees. Interestingly, no interviewees had the exact same ranking of determinants for investment decisions. It is likely that this is a reflection of the bespoke nature of each energy solution or project. More importantly, the most influential determinants were consistently those that influence the financial viability of a project or investment decision. The imperative to reduce GHG emissions and the Global Climate Change Agenda, which are least likely to influence the financial model of an investment, was also the least likely determinant to influence an investment decision.

Life of Operation Assumptions was identified to be the most influential determinant, followed by Security of Energy Supply assumptions. Mining Demand Side Requirements were also influential in the investment decision, but not a primary influencer. The uniqueness of a project, and location seem to drive the influencers in the investment decision, which ultimately related to the financial viability of the investment (Masini and Menichetti, 2012). The results demonstrated that the life of the project is key to determining the viability of the project. Once the viability has been established, the technology choice will be made in a manner that ensures Security of Energy Supply. The results have clarified that Security of Energy Supply consists of three components, i.e. reliability, affordability and availability, and as such all analyses should ensure that all there components are considered.

Risk-averse investment assumptions or companies with a significant focus on core business and / or more conservative or traditional approaches to investment may not readily consider a hybrid model for energy supply. In this instance, if the Global Climate Change Agenda does not enable them to adjust their investment approach, other drivers such as corporate climate change strategies, corporate renewable energy performance indicators and possibly even shareholder pressure could enable a shift to renewable energy investments. This however, is unlikely to drive the investment. Mostert (2014) proposed that, when considering a renewable energy investment, a broader consideration of the financial aspects should be made. This includes environmental, social and human aspects of an investment. Should Mosterts' (2014) approach be successfully applied, one could possibly improve the financial aspects of an investment decision by internalising the Global Climate Change Agenda, reducing GHG emissions and enhancing possible social benefits of renewable energy investments. This would also be consistent with Mosterts' (2014) recommendation of utilising a sustainable development approach towards energy investments.

When evaluating financial models utilised for renewable energy investment projects in Brazil, China, India and South Africa, Kamara (2016) noted the differences in approach, context and jurisdictional context was acute and evident in the investment models used for those countries. Furthermore, where similarities in some countries' financial models or economic context may exist, Kamara (2016) reported that similar financial models would not necessarily work, but rather a unique approach is required for each context. Jurisdictional comparisons are therefore important considerations when evaluating projects and energy investment decisions. The scope and context of the study, which is the mining industry in an African context, is a critical fact that needs to be considered. This includes distinguishing between Africa and South Africa from an African perspective, as the South African context is markedly different to the remaining African context. South Africa is currently experiencing considerable renewable energy investment (Kamara, 2016) which, identified by some interviewees, may be attributable to an innovative renewable energy procurement

programme. Furthermore, country governance and risk are key considerations in financing an investment, and as such the industry, country context and risk profile, infrastructure, credit worthiness, tax incentives etc. related to an energy investment could be hugely variable between different industries and countries. Komendantova, Patt, Barras, and Battaglini, (2012) identify significant renewable energy generation opportunities in North Africa that could benefit both North Africa and Europe. In order to harness this potential, substantial private foreign direct investment would be required, however, geopolitical risk such as regulatory challenges, political instability and terrorism influence the investment risk and financial hurdles for investment (Komendantova *et al.*, 2012).

Adaptive technology could influence the investment models and determinants in that they could materially change the underlying assumptions. Hadjipaschalis *et al.* (2009) recognise the benefits of renewable energy sources such as cleaner energy production and continual improvements in technology. In some instances, however, renewable power generation can only compete with non-renewable power generation sources where the supply is supplemented with storage of the renewable energy in order to increase reliability. This is currently not occurring on a large, commercially viable scale. In the context of this study, renewable energy storage could significantly influence the Life of Operation Assumptions due to the cost of the capital required for storage, or alternatively, a reduction in capital costs for non-renewable infrastructure. Similarly, re-deployable solar PV panels could significantly influence the Life of Operation Assumptions in that the PV panels could be utilised for a short life of operation mine or project and then redeployed to another, resulting in the capital or investment burden return being significantly lower. This may result in a viable or lower tariff for renewable energy on a project that has demand for less than seven to 10 years or an available US$30M for investment. Technological changes could again disrupt the energy investment space, and improve project outcomes for renewable energy investment.

In conclusion, the Global Climate Change Agenda and imperative to reduce GHG emissions creates an enabling environment for renewable energy investment which aims to mitigate the impact of climate change (Elum and Momodu, 2017). This enabling environment is widely supported at an intergovernmental and international level with many governments developing policies to achieve the desired outcomes (Huenteler, Niebuhr, and Schmidt, 2016). Investment in energy projects is not restricted to renewable energy projects, and in some instances non-renewable energy investments continue. This is largely driven by the financial aspects of the energy investment and associated return on investment (Kamara, 2016). The factors that influence the return on investment, as shown in this research, tend to be unique to the investment project and mining industry. They support the outcome of certain financial investment hurdles beings met or achieved, primarily related to risk and reward. Incentivising renewable energy investments would be successful if they influence the return on the investment. The study identified that the changing renewable energy landscape, in the form of adaptive technology related to energy storage, could materially influence the outcome of investment modelling, and drive additional renewable energy investments (Hadjipaschalis *et al.*, 2009). Adaptive technologies should therefore be continually pursued when considering energy investment initiatives.

Limitations to the Study

The research and interviews were based on determining and understanding the most influential determinants related to energy investment decisions in the private sector and mining industry. The nature of the determinants and the most influential determinant in investment decisions reflects this, along with the project and mining specific nature of the investment decisions. Should the scope of the study be broadened to additional industries, additional determinants may be identified and those with the most influence on an investment decision may also be different. Similarly, only four subject matter experts were interviewed, and had more experts been interviewed, a wider base of information may have been available to trend the determinants that were most influential on the investment decision.

Mining case studies for renewable energy investment decisions were considered at the onset of the research. The case studies were not used in the analysis of the determinants due to sensitivities in the financial modelling components of the projects, and regulatory delays in project authorisations, which resulted in restricted publically available information to be used in the research.

Lastly, whilst the determinant of base load requirements is applicable to the mining industry, it is likely to be applicable to other industrial processes too. .

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Appendices

Appendix 1: Interviewee Questionnaire

Determinants that influence renewable energy investments.
Survey Interview Questionnaire

Context

Renewable energy sources are being driven as the solution for energy supply challenges globally. Investment in renewable energy is increasing, however investment in non-renewable energy supply continues. As such, this research will aim to identify key influencers in renewable or non-renewable energy investment decisions when renewable options may be available. The following determinants will be considered when evaluating the influences in the investments decision:

- **Global drive towards GHG emissions reductions:** Global and country response to climate change and high levels of GHGs in the atmosphere.
- **Security of Energy Supply (reliability and pricing):** Reliability, continuity and certainty of electricity supply; and affordability, certainty and predictability in the pricing and associated increases, for electricity.
- **Life of Operation Assumptions:** The remaining, profitable, life of an operation or mine, on which business planning decisions and commitment can be made.
- **Mining Demand Side Requirements:** Activity specific requirements of the operations from an electricity supply perspective e.g. unique base load or start-up requirements.

Participation is the survey is voluntary and will remain anonymous and confidential. Information obtained during the survey will not be communicated in a way that identifies participant or participant's company. Participants may opt out of answering any of the questions and are under no obligation to share any information that may compromise the participant or participant's organisation.

Interview Questionnaire

A: Case Study Participants:

1. Please briefly describe your renewable energy investment project
2. Please describe the status of the investment project e.g. feasibility, execution and construction, operational etc.
3. Please will you share (if you are prepared to do so) the overall investment cost of the energy investment project

B: All Participants:

1. Please may you comment on the following drivers or determinants, in your experience, in influencing energy investment projects you have worked on (renewable or non-renewable):
   - Global drive towards GHG emissions reductions
   - Security of Energy Supply (reliability and pricing)
   - Life of Operation Assumptions
   - Mining Demand Side Requirements
2. Are there other drivers, or determinants, that you feel are material in investment project decisions that have not been considered above?
3. Please may you rate these determinants (question B1 above), including any you have identified, in influencing investment decisions as follows:

   1 = Least Influential: Immaterial determinant – not considered

   2 = Unimportant determinant: does not influence decisions

   3 = Neutral determinant: does not influence decision in either direction, but is considered

   4 = Important determinant: can influence decisions

   5 = Most Influential: Material determinant - can ‘make or break’ decisions
4. Please may you elaborate on any noteworthy points in the rating process or decision making process
5. In order to try and objectively analyse the determinants identified in question B1, please rate the following criteria identified for each determinant as being applicable or not in the investment decision (i.e. yes or no):

5.1 Global drive towards GHG emissions reductions

a. Legal or regulatory requirements to reduce GHG emissions (e.g. Country Paris Agreement commitments)
b. Corporate strategy for climate / GHG emissions reduction
c. Corporate strategy to invest in renewable energy
d. Investor or external ESG influences to reduce GHG emissions or invest in renewable energy
e. Current CDM Investment Project(s) within organisation

5.2 Security of Energy Supply (reliability and pricing)

a. Rising increases in cost of current energy supply Unpredictable increases in cost of current energy supply Instability in pricing
b. Unpredictable increases in cost of current energy supply Instability in pricing
c. Inability to secure a 'development' or 'stability' agreement for energy pricing and control
d. Unreliable, and therefore interrupted, supply of electricity due to generation constraints
e. Unreliable, and therefore interrupted, supply of electricity due to transmission constraints

5.3 Life of Operation Assumptions

a. Life of Mine is shorter than investor payback period
b. Life of Mine is shorter than renewable energy investment payback period
c. Life of Mine is incompatible with incentive (e.g. government) period
d. Life of Mine assumptions did not allow for adaptive management to energy investment (changing landscape)
e. Investment or utilisation of renewable energy investment does not extend beyond life of mine

5.4 Mining Demand Side Requirements

a. Base load considerations fully exclude renewable energy as an option

b. Base load considerations cannot be adequately met by renewable energy requirements
c. Renewable energy generation constraints are incompatible with operational requirements
d. Renewable energy storage solution is inadequate
e. Renewable energy storage solution is cost prohibitive

6. Are there other criteria for these four determinants (B5) that you feel are material in investment project decisions that have not been, and should be, considered?
7. Do you have any recommendations for determinants that governments or regulators, investors or financiers, project proponents, and / or stakeholders should take into consideration in *renewable energy investments* in order to streamline or incentivise further investment?
8. Do you have any recommendations for determinants that governments or regulators, investors or financiers, project proponents, and / or stakeholders should take into consideration in *non-renewable energy investments* in order to improve or dis-incentivise further investment?
9. Do you wish to add any additional considerations for renewable energy investment projects?
10. Do you have any comments you would like to provide on the survey process?

Thank you

DETERMINANTS THAT INFLUENCE RENEWABLE ENERGY INVESTMENTS

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02 November 2018

Declaration

I declare that this research report is my own, unaided work. It is being submitted for the Degree of Masters of Science at the University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination at any other University.



(Signature of candidate)

2nd day of November 2018 in Johannesburg

Abstract

The Kyoto Protocol, Global Climate Change Agenda and imperative to reduce greenhouse gas emissions has gained significant traction recently as decision makers attempt to mitigate the impacts of climate change. Energy that is produced from non-renewable energy sources, such as fossil fuels, is a significant contributor to greenhouse gas emissions, and by displacing non-renewable energy production and consumption with renewable energy production, greenhouse gas emissions can be reduced. This is particularly relevant to the mining industry, which is a significant consumer of energy, particularly energy from non-renewable fossil fuel sources. Consumption of renewable energy for mining related activities presents a cost saving opportunity for the industry and could support mitigating the effects of climate change. This research aimed to identify the main determinants that influence decisions in energy investment projects, and specifically, to determine the most influential determinant in energy investment decisions, particularly in the mining industry. Through interviews of subject matter experts in the mining industry, sustainable development, renewable energy and renewable energy project investment and finance, the results suggest that Life of Operation, i.e. life of mining asset or operation, was the most influential determinant in making energy investment decisions. Security of Energy Supply in which cost, reliability and availability are secured through the energy investment closely follows as the second most influential determinant.

The Global Climate Change Agenda may create an enabling environment for renewable energy investments, however the key drivers in such decisions are the financial aspects of the investment.

Keywords: renewable energy, greenhouse gas emissions, mining, life of operations, security of energy supply, base load energy requirements, Global Climate Change Agenda, financial investment

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Nomenclature

CDM	Clean Development Mechanisms
COP21	Conference of the Parties of 1992 United Nations Framework Convention on Climate Change, COP21 was the 21st conference in Paris
CSP	Concentrated Solar Power
EPC	Engineer, Procure, Construct
ESG	Environment, Social, Governance
GHG	Greenhouse Gas
GWh	Gigawatt Hour
IPCC	Intergovernmental Panel on Climate
IPP	Independent Power Producer
IRR	Internal Rate of Return
MW	Mega Watts
NPV	Net Present Value
PPA	Power Purchase Agreement
PV	Photovoltaic
REIPPP	Renewable Energy Independent Power Producer Projects
REN21	Renewable Energy Policy Network for the 21st Century
UNFCCC	United Nations Framework Convention on Climate Change
US$	United States Dollars
WEF	World Economic Forum
WWF	World Wide Fund for Nature

Chapter 1: Introduction

Renewable energy sources are being driven as the solution for energy supply challenges globally, pushed by considerations such as ‘cleaner’ energy and reduction in greenhouse gas (GHG) emissions as part of the ‘Global Climate Change Agenda’ (Akuru, Onukwube, Okoro, and Obe, 2017; Mohammed, Mustafa, Bashir, and Ibrahem, 2017). Renewable energy sources also present practical solutions for remote areas where grid supply may be challenging, or as a potential cost savings opportunity (Sonnenschein, 2016). On a large commercial and industrial scale, renewable energy may be supported by a non-renewable power supply to ensure operational continuity for power supply security, when renewable energy storage is not viable, or fully available (Kempton and Tomić, 2005; Evans, Strezov, and Evans, 2009).

Investment in renewable energy is increasing, albeit it at a slow pace, and can achieve objectives such as reduction in GHG emissions, cost savings through the use of a non-depletable source of energy and contribute towards economic growth (Soberanis, Alnaggar, and Mérida, 2015; Can Şener, Sharp, and Anctil, 2017). Investment in non-renewable energy supply however also continues (Kahia, Aïssa, and Lanouar, 2017). It is speculated that this may be due to cost, Security of Energy Supply, renewable resources availability (such as sunshine, wind) or limited availability of effective energy storage options. Paradoxically, non-renewable energy supply and continued investment in existing supplies may also be an important requirement to successfully invest in and grow renewable energy supply (The Economist, 2017).

The African mining industry is often cited as a significant consumer of fossil fuels, and therefore significant emitter of GHGs (Holmberg, Kivikytö-Reponen, Härkisaari, Valtonen, and Erdemir, 2017). Mining typically utilises significant amounts of energy to access the ore body of the material being mined, particularly in ventilation, cooling and materials movement in deep underground mining and/or materials movement, utilising heavy earth moving equipment or

facilities (Holmberg *et al.*, 2017; Vyhmeister, Aleixendri, Bermúdez, Pina, Fúnez, Rodríguez, Reyes-Bozo, 2017). Associated infrastructure, services and mineral processing also require energy, all of which has traditionally been provided by non-renewable sources (Limanskiy and Vasilyeva, 2016). As a significant consumer of energy and emitter of GHGs, the mining sector potentially has significant opportunities in the reduction of GHG emissions with renewable energy sources. However, the resource investment, particularly capital investment, is likely to be significant for the conversion to, or utilisation of, renewable energy sources (Vyhmeister *et al*., 2017), particularly in remote areas or countries with already limited energy and/or renewable energy generation and supply opportunities. The intense 'base load' energy demands of the mining sector also present an energy security challenge, particularly when considering renewable energy (Bajpai and Dash, 2012; McLellan, Corder, Giurco, and Ishihara, 2012). Investment in energy generation from non-renewable sources continues, such as the South African national utility (Eskom) investment in the 4,764MW Medupi and 4,800MW Kusile coal-fired stations (Eskom, 2017). However, opportunities for renewable energy use exist and are being implemented, for example the 82.5MW Paleisheuwel Concentrated Solar Power (CSP) Project and 10MW Enel Upington photovoltaic power plant situated in the Northern Cape (Africa News Agency, 2016). Whilst these schemes may not compare in size with the coal fired power stations, they demonstrate that large scale renewable energy production is possible.

So, what is influencing renewable energy investments? Conversely, what is influencing the investment in non-renewable energy when renewable options may be available?

1. 1 Aim and Objectives of the Study

The aim of this study was to identify the most influential determinant in an energy investment project decision, and determine the amount of influence the remaining determinants have on a decision. This, in turn may identify why non-renewable

energy investments continue, despite the apparent global drive for cleaner energy production and the benefits of renewable energy investments.

The objectives of the study were to:

- identify the most applicable drivers or determinants of energy investment decisions;
- ascertain the most influential determinant or driver of investment decisions through interviews with subject matter experts in energy generation, renewable energy investment, financial and commercial considerations in energy investment, sustainability and the mining industry;
- determine the influence the remaining determinants have in an energy investment decision;
- assess the suitability of objective criteria of the determinants that influence investment decisions, once again through the interview of subject matter experts, and
- where appropriate, identify enablers for renewable energy investments.

1.2 Layout of Research Report

The chapters of this report are designed to follow the aims and objectives of the report, and present data in the chronology in which it was obtained. Chapter 1 includes an introduction to the study as well as the aim and objectives of the research. Chapter 2 provides a literature review, giving insights in the energy challenges of the mining industry, the challenges and opportunities associated with renewable energy and an investigation in the determinants identified to influence decision-making with regards to renewable energy. Chapter 3 summarises the methodology used for this research and Chapter 4 presents the results obtained. Chapter 5 closes with a discussion of the findings and the implications of the insights gained for the future of renewable energy in the mining sector. A reference list follows this last chapter, and appendices are found at the end of this research report. Figures and tables and numbered consecutively throughout the report.

Chapter 2: Literature Review

It is widely accepted that anthropogenic climate change and associated greenhouse gas (GHG) emissions are affected by energy consumption, through energy production (Weisser, 2007; Evans *et al.,* 2009; Ou, Xiaoyu, and Zhang, 2011). Converting energy from a non-renewable fossil fuel to a renewable form may therefore have a significant impact on the reduction of the GHG emissions footprint. There is a global climate change drive, most recognisably through the Intergovernmental Panel on Climate (IPCC) and United Nations Framework Convention on Climate Change (UNFCCC). The IPCC represents a body of international scientists whose research and assessments are consolidated and interpreted to provide governments. This includes policy makers, with scientific information on climate change, risks, impacts and possible mitigation and management measures to address these impacts. This information is intended to inform decision making, policy, and importantly, the UN Climate Conferences (Osorio-Arce *et al*., 1988).

The objective of the UNFCCC is to ensure the "stabilisation of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system" (UNFCC, 1992, page 9). This should be ensured in a manner that allows ecosystems to adapt naturally, protects food security and ensures that economic development is not compromised. The Kyoto Protocol, an international treaty negotiated in 1997, enacted in 2005 and extended to 2020, is a binding agreement in which industrialised countries have set reduction targets for their collective GHG emissions (Kyoto Protocol, 1997). The UNFCCC has further initiated the setting of reduction targets and associated mitigation strategies, including strategies in the energy sector for developing nations (Amrutha, Balachandra, Mathirajan, 2017).

The 'Paris Agreement', which was negotiated by the UNFCCC Conference of Parties (COP) in December 2015 and enacted in November 2016, specifically

addresses the mitigation of GHG emissions, adaptation to the effects of climate change as well as the financing mechanisms for these aspects (UNFCCC, 2017a). As a means of achieving the commitments set out in the Paris Agreement, there is an imperative for a significant and fast transformation in the energy generation space (Clemencon, 2016).

Countries that participate in the Paris Agreement are required to mitigate climate change by determining their contribution to climate change (their GHG emissions footprint), provide plans to address these and report on the progress in mitigating climate change in a manner that exceeds previous targets (UNFCCC, 2017b). Ultimately, these interventions are aimed at preventing the predicted temperature increase going beyond 2^{o}C and, where possible, work towards a 1.5^{o}C increase limit to reduce the effects of climate change (Rohit, Devi, and Rangnekar, 2017). Countries are also required to improve their ability to adapt to climate change effects in a sustainable manner (UNFCCC, 2017b). The Paris Agreement - recognises that mitigation and adaptation need to be complemented with an enabling financial environment that contributes to reduced GHG emissions and climate resilience (Reboredo, Quintela, and Otero, 2017). Arguably, an enabling financial environment can unlock mitigation and adaptation initiatives and provide a real driver for managing climate change. This enabling driver presents an opportunity for growing and technologically advancing developed and developing economies. As the demand for energy grows, GHG emissions from energy generation can be mitigated through mechanisms of energy savings, efficient consumption and / or increased use of renewable energy sources (Tezer, Yaman, and Yaman, 2017). This can be optimised or fast tracked through a financially enabling environment.

The World Economic Forum (WEF) maintains that, to ensure equitable and sustainable economic growth particularly in developing countries, a transition to “green growth” economic development is required. This includes investment in renewable energy technology in developing countries to reduce GHG emissions. They have however identified slow and inadequate progress as investment in

fossil fuel energy generation continued to exceed investment in renewable energy generation in 2013 (World Economic Forum, 2013). A World Wide Fund for Nature (WWF) report re-iterates, after reviewing European investor practices, that whilst financial regulators and investors are increasing their commitment and investment decisions to achieve a reduction in GHG emissions in line with the Paris Agreement, the rate of and extent to which this is achieved is not sufficient (Godinot and Vandermosten, 2017). Therefore, the reason or cause for the pace at which this is achieved is in question.

2.1 Non-Renewable and Renewable Energy

Energy exists in many forms on Earth and humankind has utilised this energy in its different forms and sources over time. Some of the forms in which energy exists includes solar energy, thermal energy, and kinetic energy.

The energy sources available have not materially changed over time, but man's ability to harness this energy in an efficient manner or on a large scale and continuous manner has changed over time. These energy sources consist of non-renewable and renewable sources with non-renewable energy supply being the dominant source of energy supply for electricity generation, for distribution and use in the United States of America in 2016 (U.S. Energy Information Administration, 2016), as data for 2006 to 2015 illustrate in Table 1 below.

Table 1: Electricity generation by source (non-renewable and renewable), in thousand megawatt hours, in the United States in 2016. (Source: U.S. Energy Information Administration, 2016. p15)

Period	Renewable Total	Renewable % of Total	Non-Renewable Total	Non-Renewable % of Total	Total Generation at Utility Scale Facilities
2006	392,188	10%	3,672,514	90%	4,064,702
2007	358,083	9%	3,798,663	91%	4,156,745
2008	386,448	9%	3,732,939	91%	4,119,388
2009	425,025	11%	3,525,306	89%	3,950,331
2010	434,730	11%	3,690,329	89%	4,125,060
2011	521,069	13%	3,579,071	87%	4,100,141

Period	Renewable Total	Renewable % of Total	Non-Renewable Total	Non-Renewable % of Total	Total Generation at Utility Scale Facilities
2012	503,410	12%	3,544,356	88%	4,047,765
2013	530,980	13%	3,534,984	87%	4,065,964
2014	545,867	13%	3,547,738	87%	4,093,606
2015	557,671	14%	3,529,709	86%	4,087,381

The information provided above illustrates the large dependence on non-renewable energy sources for power generation and distribution, primarily using natural gas, coal and nuclear fuel sources for electricity. In 2015 3.5million GWh of electricity were generated at utility scale from non-renewable sources whilst 0.6million GWh of electricity were generated at utility scale from renewable sources (Source: U.S. Energy Information Administration, 2016. p15).

Fossil fuel energy supply is the primary fuel source used globally for non-renewable electricity generation and consists of five types of fossil fuels: coal, petroleum coke, petroleum liquids, natural and other gas. These along with nuclear fuels typically make up the fossil fuel source for energy generation and / or are ‘non-renewable’ (International Energy Agency, 2016). Thermal generation utilises these energy sources in generating electricity (International Energy Agency, 2016).

Renewable energy has undeniably undergone a radical transformation over the last decade. The Renewable Energy Policy Network for the 21st Century (REN21) attributes this largely to changes in policy, financing opportunities, improvements in renewable energy supply, security and the Global Climate Change Agenda demanding cleaner energy (REN21, 2016). REN21 (2016) also recognises developing and emerging economies’ demand for energy increase, thus driving the renewable energy market from another demand perspective. Whilst renewable energy is not the majority contributor to power generation and supply, the use of renewable energy on a utility generation scale has increased by more than 40% in the last 10 years, in the United States of America, as shown in Table 1 above. The predominant forms of renewable energy include solar and

solar photovoltaic (PV), concentrated solar power (CSP), hydropower from flowing water, wind power, bioenergy (such as fuel generated from plant matter, for example sugarcane), geothermal power (REN21, 2016) and hydrogen fuel (Renewable Energy World, 2016).

The sun's energy can be used directly and indirectly in many ways to harness its energy, and in some instances generate power or electricity. Solar energy or direct heat from the sun is perhaps the simplest form of harnessing the sun's energy, but is mostly useful for heating. The sun's energy, when it is available during the day, needs to be converted into a useable from of energy supply such as solar thermal power or solar PV before it can be used commercially (Mills, 2004).

Solar PV utilises the energy (photons) from the sun and converts it to direct electricity using specialist semi-conductors (Eskom, 2014). The PV effect utilises photons of light or light energy to excite electrons contained in specialist semi-conductor material which in turn converts them to charge carriers for an electric current, essentially creating a direct current of electricity (Eskom, 2014). This electric current can be used directly as electricity or to charge a battery storage system which will store energy, or electricity, when the sun is not shining. The cost of these batteries, and low efficiencies or short lifespan, make this option very expensive on a commercial scale (Vyhmeister *et al*., 2017). Battery technology, for the purpose of renewable energy storage, is evolving rapidly (Olabi, 2017; Caldera and Breyer 2018).

CSP utilises various methods to capture or concentrate solar energy to a central collection point in which heat energy is used to heat a heat-transfer-fluid or system. This in turn is utilised to generate electricity through a turbine and the Faraday process. Two main types of CSP generation are utilised, one of which allows for a thermal storage solution through the use of thermal storage material, such as molten salt, in order to retain thermal energy captured during the day for extended use when the sun is no longer shining (Hussain, Arif, and Aslam, 2017). This increases the capacity factor of CSP. Capacity factor is the ratio of the actual

energy generated for use from a facility to the potential energy that could be generated from a facility, with the higher the capacity factor the better for efficient energy generation and use (Jha and Puppala, 2017). CSP is a relatively new and expensive technology with limited large-scale applications. The land requirements for such a project are also likely to be significant (Lilliestam, Bielicki, and Patt, 2012).

Hydropower utilises kinetic energy, the energy in moving water, such as a river, to drive a turbine, which in turns generates electricity. The energy supply, or river, needs to have sufficient all year flow in order to ensure full generation potential is met, and the river should preferably not be sensitive to seasonal fluctuations in water flow. Modifications to the existing river hydrology are likely to be required in order to install the power generation system and to protect the aquatic ecology, where possible. Modifications and alterations to the hydrological flow may have long lasting impacts on the aquatic ecology. Given the constant flow of water in a river and through a turbine, the capacity factor of hydropower is generally high (Bartle, 2002).

Hydropower pump and store power generation utilises two dams and a river (or pathway). Water is captured in the first dam, which is situated high enough to generate energy through turbines when water is released from this dam and reports to the lower second dam. Here it is contained, and pumped back up to the first dam at an appropriate time. The appropriate time is normally during non-peak energy use conditions with low electricity costs, where the water is stored before release again (Tran and Smith, 2017). These pump and store schemes are ideally suited to provide peak flow of electricity. This method comes at a high cost in that energy (electricity) is required to pump the water back to the storage scheme and the overall electricity consumption for pumping can exceed the electricity production from the scheme (U.S. Energy Information Administration, 2016). This form of power is therefore only viable to provide peak supply.

Wind power is a long established, yet relatively inefficient (Olabi, 2017), method of generating electricity, or harnessing energy. It uses large wind turbines (blades) which turn in the correct wind conditions and generate electricity, or drive a shaft system to perform work. Modern wind turbines are able to generate electricity when the wind is blowing, which can be modelled and predicted to some extent. Wind is not constant, which means that the capacity factor of this form of power generation is low, and power is not always available or predictable (Munguia, 2016). Wind turbines may also create unintended environmental impacts, particularly related to birds and bats.

Bioenergy essentially utilises biological material in order to generate energy. The most common application of this is biofuels, which utilise plant material to feed combustion, heat generation or other processes. Whilst biofuels may be a renewable energy source, and a cleaner form of energy production, there are many inherent environmental and social risks associated with it. These could be changes to biodiversity in the biofuel growing area, conflict over land use, specifically around land used for food production, risk to small scale farmers who invest fully in a single crop which may fail, and the farming of the biofuels may rely on non-renewable fuel (Fischer, Hizsnyik, Prieler, Shah, and Van Velthuizen, 2009).

Geothermal energy is natural energy that is derived from fluid (water or steam) heated by the earth's core and / or in some instances molten lava reserves in close proximity, which are under pressure and can be easily harnessed to generate power from the heated fluid through a conventional electricity generation process (Energy.gov, 2016).

Hydrogen can be used to generate a fuel, or fuel cell, which in turn can generate power. This occurs when a chemical reaction (not combustion) converts a hydrogen atom into heat and water, thus generating energy for use (Energy.gov, 2016).

Renewable energy technology poses a range of options that could be used to generate cleaner energy and complement or displace existing non-renewable energy generation, although with less availability then many forms on non-renewable energy. Renewable energy technologies are not appropriate in all situations, as some have advantages and disadvantages in different operating circumstances. For example, hydropower is dependent on an appropriate water source that delivers appropriate flow conditions all year round, which is readily available (Bartle, 2002). The source of power (hydrology) may not necessarily be close to the demand and as such, additional transmission infrastructure may be required. CSP is able to generate renewable energy and provide a form of storage that can extend power generation duration during the day. The sun, infrastructure and space requirements may once again pose a limiting factor to where the demand is required as significant generational schemes are likely to be located in desert-like conditions. CSP may also require significant infrastructure capital investment (Lilliestam *et al.*, 2012). Other renewable energy sources such as wind power may only be able to provide a small percentage of renewable energy requirements based on the availability of wind, and as such this may need to be supplemented, in most cases, with other renewable (or non-renewable) sources (Sharifzadeh, Lubiano-Walochik, and Shah, 2017) such as PV or thermal generation. Renewable energy solutions are therefore unique to each energy demand situation and should be configured accordingly. This is particularly applicable for costing and financial investment around the renewable source, as the energy source needs to be sustainable and affordable.

Niesten, Jolink, and Chappin (2017) researched renewable energy wind investment in the active Dutch onshore wind renewable energy sector. Niesten *et al.* (2017) determined that financial considerations were informed by elements such as renewable energy investment experience, industrial and energy generation experience. These all play a significant role in influencing energy investment, despite the established nature of this sector of renewable energy.

2.2 Energy Investment Determinants

Renewable energy generation solutions are available and in many instances exist as proven technology (Dincer, 2000; Elabban, Abu-rub, and Blaabjerg, 2014).

The determinants that can influence the choice of energy generation solution have been identified in a number studies. Zharan and Bongaerts (2017) have identified a series of mining renewable energy investment project case studies that have been implemented through arrangements such as a Power Purchase Agreement (PPA) with a service provider or the use of an Independent Power Producer (IPP). Importantly, a key consideration in the case studies presented by Zharan and Bongaerts (2017) was the mine life effect, i.e. the life of the mining operations are a key consideration in an energy investment.

An analysis into completed or established renewable energy investments in Europe, undertaken by Papież, Śmiech, and Frodyma (2018), modelled four determinants for energy investment. This first determinant is the environment, which considers the impact of energy consumption, specifically GHG emissions, and high levels of carbon dioxide emissions associated with non-renewable energy generation. Essentially, this determinant refers to environmental impact, or conversely, the determinant is to avoid environmental impact (Global Climate Change Agenda aspirations). This determinant is a common feature in literature regarding renewable energy investments and is often proposed as a reason or motivation for renewable energy investment (Christensen and Hain, 2017; Zeng, Liu, Liu, and Nan, 2017; Surroop and Raghoo, 2018).

The second determinant identified by Papież *et al.* (2018) is Security of Energy Supply, where energy self-sufficiency, renewable or non-renewable mix, and ability to fully access and utilise the available energy influence the energy investment approach. This is further supported by volume and cost of importing energy to meet a project or country's demand and this volume and cost consideration is evaluated against the country's renewable energy supply in the energy mix: GDP per capita Papież *et al.'s* (2018) consideration of the third determinant, economic influences related largely to the local economic

development status of the country. It considers the country's GDP, energy consumption both per capita relative to GDP, and the proportion and cost of renewable energy consumption. Another component of economics or costs is subsidies as recognised by Moriarty and Honnery (2007). Moriarty and Honnery (2007) caution against using costs for comparative purposes as the subsidies are not always easily recognisable or transparent and may incorrectly impact on assessment outcomes.
Lastly, Papież *et al.* (2018) identifies political influences in energy investments as the fourth determinant, although this was restricted to consideration of EU Membership of the countries that invest in renewable energy.

Gómez-Navarro and Ribó-Pérez (2018) identified further influences in energy and potential renewable energy investments, which are divided into three main categories: technical, social and economic. The technical elements identified by Gómez-Navarro and Ribó-Pérez (2018) include security of energy supply in the form of lack of grid connectivity and therefore transmission challenges, tariff challenges (pricing) and insufficient understanding of the potential of renewable resources and options. Gómez-Navarro and Ribó-Pérez (2018) identified the social influences related to lack of planning from a regulatory environment perspective, poor public-private organisation and insecurity related to regional civil unrest and potential armed attacks. Finally, Gómez-Navarro and Ribó-Pérez (2018) identified the economic influences as high capital or investment costs in renewable energy, inability to fully internalise environmental costs of non-renewable energy generation, competing subsidies offered to non-renewable energy sources and tariffs that do not differentiate between renewable and non-renewable energy generation.

Energy requirements, from a mining perspective, cannot be considered without ensuring that minimum operating requirements, or base load requirements, are met through the energy investment approach (Moriarty and Honnery, 2007). Where these requirements cannot be secured through a renewable energy

generation source, energy storage will be a critical consideration Hadjipaschalis, Poullikkas, and Efthimiou, 2009)

Lastly additional determinants could include environmental and social pressures and expectations (Phadke, 2018) which include environmental permitting requirements and social acceptance of renewable energy initiations, or social rejection of non-renewable energy generation. Land access is also an important consideration for renewable energy investment, particularly in instances where there is competition for land (Fischer, Hizsnyik, Prieler, Shah, and Van Velthuizen, 2009) and potential unintended environmental impacts such as biodiversity impacts (Moriarty and Honnery, 2007). Selosse, Garabedian, Ricci and Maïzi (2018) identified the need for a favourable regulatory and policy environment for renewable energy investment to occur, as well as secure legislation in the energy sector (Kamara, 2016).

From the determinants identified above, available renewable energy options or potential options, were not considered further. The type of renewable energy solution available does not necessarily influence whether or not a renewable energy solution is possible or desired. Rather it is likely to determine whether more work is required, or what *type* of renewable energy source is utilised and the opportunities and limitations for that solution (Tezer *et al*., 2017). This determinant was therefore considered unlikely to assist in determining why a decision is taken to invest, or not invest, in renewable energy, given the site specific context of options available.

Dependence on non-renewable energy options from a subsidy, tariff, cost of capital or cost of financing perspective was considered to be an unlikely scenario to influence a decision as it could be equally applicable to renewable energy options (Kahia *et al.*, 2017). Given the global response to the climate agenda and evolving financing and regulatory environments, this determinant was seen as likely to be moot.

The determinants of environmental permitting requirements, biodiversity impacts social opportunities or challenges, political influences, security and land access opportunities or challenges may be grouped together from a 'sustainable development' classification or perspective, which is a common grouping in the mining industry (Hilson and Murck, 2000; Azapagic, 2003). This determinant is unique to individual site contexts in terms of what may be applicable and required. It is also common to individual site contexts in that it needs to be considered for any energy investment (World Economic Forum, 2013; Waite, 2017). It is therefore equally unique yet equally applicable at each site, and it is difficult to determine their influence, if any, on the investment decision. They were therefore not considered further.

Government subsidies were not considered further due to the complex opportunities and constraints that may exist for renewable and non-renewable options and that which may have been negotiated, but not publicised, between mining companies, suppliers, service providers and government (Xie, Li, Xia, Liang, and Zhang, 2017). This determinant was therefore not considered any further, It was, however, was indirectly considered as part of pricing or Security of Energy Supply and was therefore noted where applicable. Security of Energy Supply also considers the tariff as a determinant and the security or predictability associated with that.

Financial considerations, government subsidies, costs of energy generation and supply, technical constraints around Security of Energy Supply, evolution of the in-country electricity generation and supply, etc. are determinants that were grouped together. This was included for further research and analysis as they are likely to materially influence decision making from the perspective of Security of Energy Supply, and were therefore considered as part of the consolidated determinant "Security of Energy Supply (reliability and pricing)".

“Life of Operation Assumptions” was identified as an important and relevant determinant as the investment life span is directly influenced by this, and therefore a key determinant in the investment decision.
“Mining Demand Side Requirements” could determine whether a proposed renewable energy investment can be supported in continued mining operations and as such is a key determinant.

Broader environment, social, governance, and sustainability considerations, climate change and GHG emissions response, government policy, enabling regulatory environment, policies or policy interventions, are determinants that were grouped together to be addressed as part of the Global Climate Change Agenda. These are likely to include policy and legislative drivers in investment decisions (Elum and Momodu, 2017). This group is referred to “Global Drive towards GHG emission Reduction” and is considered further.

Therefore, to establish a set of determinants and associated criteria for influencing the renewable energy investment decision, the following determinants, in no order of importance, were used:

- **Global Drive towards GHG emission Reduction:** Global and country response to climate change and high levels of GHGs in the atmosphere;
- **Security of Energy Supply (reliability and pricing):** Reliability, continuity and certainty of electricity supply, and affordability, certainty and predictability in the pricing and associated increases, for electricity;
- **Life of Operation Assumptions:** The remaining, profitable, life of an operation or mine, on which business planning decisions and commitments can be made; and
- **Mining Demand Side Requirements:** Activity specific requirements of the operations from an electricity supply perspective e.g. unique base load or start-up requirements.

2.3 Investment Approaches

Companies with established investment systems and processes typically follow a complex process when considering an investment for the business. Various drivers may be present in determining the need for an investment, such as business continuity, business improvement, strategic investment, reputational management, etc. However, a systematic approach is applied to understand the need for the investment, the options available to the investment, the financial implications of the investment, and how the investment will be executed (Strantzali and Aravossis, 2016).

Systematic approaches could include a life-cycle analysis, cost-benefit analysis or multi-criteria decision aids (Strantzali and Aravossis, 2016). These are usually combined with an investment model for a project, or investment in which alternatives, options, risks, uncertainties can be modelled and compared in financial terms for a project decision to be taken (Focacci, 2017). The investment model considers, where appropriate, the current status quo, baseline conditions or base case and it is against this that alternatives or options can be measured. The base case for an energy investment model could be the current energy supply, inclusions and exclusions. The investment model is then used to develop scenarios much like scenario planning, in which the outcomes of technical, risk, financial and other processes can be modelled (Soberanis *et al*., 2015).

At the start of an investment, a company or project will have a certain set of criteria against which decisions must be made. These criteria could typically include legal compliance, technical reliance (although 'proven technology' may not necessarily be a requirement), environmental, social and governance considerations as part of good corporate governance and / or impact management (King, 2016). Furthermore impact on business, for example losses or gains should the project be implemented, cash flow risk and requirements, capital investment requirements, operating cost requirements, and maintenance costs are important criteria against which a decision is also likely to be made (Kamara, 2016). This enables total cost of energy, return on the investment from net present value (NPV) and internal rate of return (IRR) of the investment (Ye,

Zhang, Jiang, Miao, and Li, 2017) to be determined. NPV is the value of a project, in today's terms, after considering the cash inflows and outflows over its life. The cash inflows may be determined by, for example, cash generated by the sale of a mining product, like platinum, and the outflows influenced by the cost of electricity (Percoco and Borgonova, 2012). IRR is a method, utilising certain assumption, that is used to calculate return on, or profitability of, an investment (Percoco and Borgonova, 2012). These criteria may also become 'hurdles', which the investment case must overcome for it to have a positive outcome. Overcoming hurdles in investment modelling is important as projects and initiatives compete for capital. Capital is not freely available and comes at a cost to a business or project, regardless of whether a company is able to 'self- fund' or attract external investment. Ultimately, the preferred outcome of investment modelling should ensure that the company's internal requirements are met and the investment returns are in line with the company requirements (Christensen and Hain, 2017).

In the case of an energy investment project, alternative supply options should be modelled including existing supply, renewable options, non-renewable options, hybrid options etc. The investment modelling should also consider funding options and the cost of those over the life of the investment (Christensen and Hain, 2017). These costs include the cost of funding and the cost of cash flow and are likely to trade off against each other, for example, higher upfront capital investment against a lower operating costs, or vice versa. Whilst the trade-offs themselves may show suitable outcomes for all options, when compared against the hurdles, the preferred trade-off may become immediately apparent (Vyhmeister *et al*., 2017).

Financiers or lenders often drive a 'greener' agenda and a trend is emerging in which major lenders are shifting to cleaner energy investments or energy investments with a renewable energy component (Schwerhoff and Sy, 2017). Together with this, volatile commodity prices, a changing energy generation and supply landscape, investment modelling hurdles, climate agenda drivers and

requirements, society demands and business operating requirements play a key role in investment decisions which are complex with multiple dependencies and interrelationships (Cunico, Flores, and Vecchietti, 2017).

Ming, Ximei, Yulong, and Lilin (2014) have evaluated China's renewable energy investment, which has undergone rapid growth attributable to China's policies that support such investment. Whilst China has had considerable investment in wind and PV renewable energy initiatives, the financing aspect has significantly influenced the investment approaches, particularly through the investment environment, organisations and bodies that can finance the required renewable energy investments and have the means to do so, source of the investment funds and expectations on returns of those funds (Ming *et al.,* 2014). This evaluation demonstrates the importance of financing mechanisms and arrangements despite a regulatory environment and available renewable energy resources that easily support renewable energy investments.

Chapter 3: Methodology

3.1 Identification of Key Determinants

From the determinants, in no order of importance, identified in the Literature Review in Chapter 2, the following determinants were determined to be relevant factors in influencing energy project decision making:

- **Global Drive towards GHG emission Reduction:** Global and country response to climate change and high levels of GHGs in the atmosphere;
- **Security of Energy Supply (reliability and pricing):** Reliability, continuity and certainty of electricity supply, and affordability, certainty and predictability in the pricing and associated increases, for electricity;
- **Life of Operation Assumptions:** The remaining, profitable, life of an operation or mine, on which business planning decisions and commitment can be made; and
- **Mining Demand Side Requirements:** Activity specific requirements of the operations from an electricity supply perspective e.g. unique base load or start-up requirements.

In order to determine which of these is the most influential in influencing energy investment decisions, and to determine how the remaining determinants influence the decisions, they were evaluated in interviews with subject matter experts. In order to support these interviews and ensure an element of rigor and repeatability, the determinants were further elaborated on using five criteria specific to each. These criteria, which are presented in Table 2, are specifically related to the determinants and were used to assess the determinants and their contribution to energy investment decision making. These criteria were identified from the literature review and used for the development of the key determinants for the study (Chapter 2) and are summarised below.

Table 2: Criteria for Determinants

Global Drive towards GHG emission Reduction	Security of Energy Supply (reliability and pricing)	Life of Operation Assumptions	Mining Demand Side Requirements
Legal or regulatory requirements to reduce GHG emissions (e.g. Country Paris Agreement commitments)	Rising increases in cost of current energy supply	Life of Mine is shorter than investor payback period	Base load considerations fully exclude renewable energy as an option
Corporate strategy for climate / GHG emissions reduction	Unpredictable increases in cost of current energy supply Instability in pricing	Life of Mine is shorter than renewable energy investment payback period	Base load considerations cannot be adequately met by renewable energy requirements
Corporate strategy to invest in renewable energy	Inability to secure a 'development' or 'stability' agreement for energy pricing and control	Life of Mine is incompatible with incentive (e.g. government) period	Renewable energy generation constraints are incompatible with operational requirements
Investor or external ESG influences to reduce GHG emissions or invest in renewable energy	Unreliable, and therefore interrupted, supply of electricity due to generation constraints	Life of Mine assumptions did not allow for adaptive management to energy investment (changing landscape)	Renewable energy storage solution is inadequate
Current CDM Investment Project(s) within organisation	Unreliable, and therefore interrupted, supply of electricity due to transmission constraints	Investment or utilisation of renewable energy investment does not extend beyond life of mine	Renewable energy storage solution is cost prohibitive

3.2 Evaluation Criteria

To ensure that the determinants were considered in the most objective way possible, the determinants for influencing the investment decisions were rated on a scale of 1 to 5, with 1 being the least likely influence on the investment decision, and 5 being the most likely influence on the investment decision. The determinants were assessed during interviews, with highest rating representing the key driver for the investment decision as discussed in more detail.

To support the analysis of the determinants and further enhance the consideration of the determinants and applicability to energy investment

decisions, each of the criteria identified in Table 2 were assessed in a binary manner, i.e. yes or no, with regards to their relevance to the determinant for assessment purposes. This enabled the determinants to be considered in further detail, without compromising the primary objective of comparing the four determinants against each other in order to determine that which is most applicable the energy investment decisions.

3.3 Interviews

Interviews were identified as a means to assess the most influential determinants in the decision process for energy investments. In order for targeted and useful interviews to be concluded, industry subject matter experts as well as representatives from renewable energy projects and investment financing, were identified as potential interviewees for the study.

A questionnaire for the interviews was developed in such a way that both qualitative and quantitative, or easily measurable and comparable information was gathered. Context could be set, structured questions could be answered in a way in which determinants could be ranked, and less structured questions were developed in order to facilitate discussion, and identify any potential gaps in the approach to the determinants or decision making process. The questionnaire is presented in Appendix A. Ethics Clearance was obtained from the University of the Witwatersrand's Human (non-medical) Ethics Committee (clearance number HA1808).

The interviewees were contacted telephonically or via email in order to request an interview, and subject to their approval, a Participant Information Letter, Consent Form and copy of the questionnaire were provided. Interviews were undertaken during normal business hours, in a place of business or public place (such as coffee shop) and in line with the questionnaire.

In total, four people were interviewed:

- Interviewee 1: Current mining industry experience, non-renewable and renewable energy expertise in both technologies and energy, decision making for project experience and sustainability subject matter expert. Works in

private sector mining and renewable energy. Recent energy investment experience (2017 / 2018).

- Interviewee 2: Current mining industry experience, and renewable energy subject matter expert, sub-Saharan African investment, geopolitical and sustainable development expert. Works in private sector mining and renewable energy. Recent energy investment experience (2017 / 2018).
- Interviewee 3: Subject matter expert on non-renewable and renewable energy, subject matter in energy investments (technology, finance and sustainable development) and sustainability expert. Works in private sector mining, in sustainable development in climate, carbon and energy areas. Recent energy investment experience (2017 / 2018).
- Interviewee 4: Subject matter expert on renewable and non-renewable energy, renewable and non-renewable energy investments (technology, finance, commercial, legal, sustainable development and project management), commercial or investment modeller and implementer, mining experience. Works in the private sector for mining and 'energy' clients (such as funders, suppliers, energy producers, energy users etc.).

The data from the interviews were noted, summarised and categorised according to the determinants, criteria and additional considerations. Data from all four interviews were then compared in order to identify common themes, common determinants and ranking of the determinants and criteria. During the interviews, it was apparent that the criteria for the determinants could not necessarily be considered in a binary manner, some criteria were mutually exclusive, and other criteria were mutually inclusive. Similarly, the determinants were not necessarily mutually exclusive but could be complementary in a chronological manner. For example, the key determinant allowing the investment process to begin was identified, and was further complemented by secondary and tertiary determinants or considerations. The determinants could also be ranked in order of influence or importance, thus achieving the objective.

The scores for each determinant by each interviewee was plotted to determine if there was any relationship between the determinants, or any pattern in the how the determinants were related to each other. This could be considered for each determinant or each interviewee's response.

3.4 Research Limitations

The research and interviews were based on understanding the most influential determinants related to energy investment decisions in the private sector, specifically the mining industry. The subject matter experts as such have considerable mining and renewable energy experience. Other private sectors such a manufacturing were not considered as part of the scope. Broader scope may influence the determinants that are considered for investment decisions, or even the outcome of the most influential determinant.

Furthermore, only four subject matter experts were interviewed, and a wider range of experts may have yielded a more diversified outcome.

Chapter 4: Results

This study has focussed on determinants most likely to influence energy investment decisions related to the mining industry, and determine which of these are the most influential in energy investment decisions. Whilst the Global Climate Change Agenda and supporting international and intergovernmental protocols and policies create an enabling environment for renewable energy investment, the determinants considered in this study relate to mining aspects of project decision making processes, in the private sector. These determinants are analysed through the views of mining, sustainability and renewable energy investment experts who are able to assess the most influential determinants based on experience in their field of expertise.

As part of the interviews, interviewees rated those determinants, on a scale of 1-5, where 1 is the least likely to influence investment decisions for an energy investment, and 5 is the most likely to influence an investment decision. The consolidated outcome of the interviews is presented in Table 3. Interviewee 1 and Interviewee 4 rated Life of Operation Assumptions as 5, which is the determinant most likely to influence energy investment decisions. Interviewee 2 and 3 rated Security of Energy Supply as 5, or the determinant most likely to influence energy investment decisions. Global Drive towards GHG emission reduction had the lowest overall score of 8 or 40%, and is therefore the least likely determinant to influence an energy investment decisions. Security of Energy Supply has the second highest score of 16 or 80%, and Life of Operation Assumptions had the highest score of 17 or 85%, which confirms that this is the determinant most likely to influence renewable energy investment decisions.

Table 3: Summary of interview outcomes in assessing the influence of determinants on investment decision

Determinant	Interview 1 Mining & Sustainability Expert	Interview 2 Mining & Renewable Expert	Interview 3 Renewable & Sustainability Expert	Interview 4 Renewable Expert	Score
Global Drive towards GHG emission Reduction	2	3	2	1	8 40%
Security of Energy Supply (reliability and pricing)	3	5	5	3	16 80%
Life of Operation Assumptions	5	4	3	5	17 85%
Mining Demand Side Requirements	4	2	4	4	14 70%

Mining Demand Side Requirements were found to play a part in influencing investment decisions, although it was not the primary or secondary determinant. The combination of the Life of Operation Assumptions, Security of Energy Supply and Mining Demand Side Requirements suggests that each investment decision is determined by bespoke or specific elements. This includes the duration, location and type of operation or project.

4.1 Life of Operation Assumptions

Life of Operation Assumptions were collectively, and in two instances, the most influential determinant in energy investment decisions (Table 3). From the interviews it emerged that these assumptions are the most critical. They determine whether or not there is sufficient time for investment capital and financing costs to be recovered through the reduced energy generation costs or cost savings. The guaranteed life of an operation or facility determines the bankability of the energy investment. Similarly, the longer operational life of a facility, the better the returns of the investment may to be. From a renewable energy perspective, a financed project such a Power Purchase Agreement (PPA), or even an owner Engineer, Procure Construct (EPC) Project, which the interviewees identified as being less common, a capital investment for project will have a certain period of time in which the capital and other financing costs will be

recovered. After the cost recovery period, savings in energy generation from, for example, a solar PV project, which are most common in the interviewees' experience, delivers a financial return on the investment. In a PPA arrangement, the costs of capital, finance and generation will be evenly spread over the life of the renewable energy investment, which will be the same as the guaranteed life of the operation, in the form of a tariff. The interviewees agreed, with the exception of one, that EPC Project energy generation contracts, particularly for renewable energy, are generally not very popular or common.

Interviewee 1 explained that a guaranteed life of operation, in mining terms, is generally accepted as being the resource determination. This refers to the resource that has been declared within a prescribed and industry accepted deterministic limit of certainty. Whilst mining operations may have identified more ore reserves that have not been included in the resource calculation, these reserves, inferred reserves, or in some instance 'blue sky' reserves are known to exist. They have also been tested for their availability to within a prescribed and industry accepted, lower, deterministic limit of certainty. Reserves, inferred reserves and blue sky reserves do not have sufficient certainty regarding their availability, mine-ability or processing ability for the mining operation to guarantee performance or delivery. As such, planners and financiers are not prepared to make significant financial commitments or accept guarantees on reserves, inferred and / or blue sky reserves. This in turn does not allow PPA or EPC Project contracts to be established on potential life of mine. This is a limiting factor in financing energy investments.

Interviewee 1 and 4 elaborated that non-renewable energy investments can be structured in such a way that smaller thermal generators or modular components are deployed for the life of operation. These can be upgraded, added on, or removed to another site should life of mine operations extend. The non-renewable energy investment sector is well established and many options and iterations are available for energy generation along this operating configuration. As such, almost any configuration or arrangement can be accommodated.

Renewable energy investments generally have a minimum generation capacity, which three of the four interviewees agreed was around 20MW (although this could be as low at 10MW). Economy of scale is important, in order to ensure a viable investment proposition. This is not an absolute requirement, and is dependent on other variables but can be used as guideline. In order for a successful renewable energy investment agreement to be established, using a PPA for example, the Life of Operation Assumptions would need to be a minimum of 7 to 10 years. Interviewees were in general agreement around this, and once again, other variables could influence this period and it is therefore not absolute, but rather a useful guideline. Lastly, one interviewee indicated that currently, the size and life of the project would also likely need to trigger an investment value of US$30million or more. This will secure an acceptable return on investment to meet the investment criteria relative to the cost of capital and finance.

The interviewees indicated that the bankability of an energy investment, particularly a renewable energy investment, may seem to be driven by financing. However, they indicated that financing is not the driver, it is rather an enabler, or a risk modifier. As such, financing should not be considered as a determinant to energy investment but rather a tool that can be utilised in different ways to influence an energy investment, particularly a renewable energy investment. This presents an opportunity in the renewable energy investment space, particularly private investment projects. All interviewees agreed that the financing component of the Paris Agreement supports renewable energy investment in the public investment space, but not necessarily the private investment space...

In summary the Life of Operation Assumptions is the primary determinant or influencer in energy investment decisions. Once secured, Life of Operation Assumptions will determine tariff, which means that a longer life of mine will secure a lower tariff for energy generation over the life of the project. The life of operation will influence the tariff but not determine the viability of the project (beyond certain underlying assumptions of bankability or revenue). This view was supported by two different interviewees' perspectives.

If a Life of Operation Assumption is too short to meet, for example, the requirements of a bankable renewable energy investment, the project will not be discarded. Rather, the proponent will still consider the energy investment, particularly if it is a necessity for the operation or business, but simply re-evaluate or select a different technology. As mentioned previously, this could be a non-renewable choice or a variation of a hybrid approach. This illustrates that Life of Operation Assumptions need to provide certainty for the investment, and that this will in turn influence the technology, which may be renewable energy.

Lastly, if Life of Operation Assumptions have established a viable investment, the technology and Security of Energy Supply can be modified as required and delivered. Nevertheless, remote and captive mining operations that may be very sensitive to the cost of energy and have a short, guaranteed, life of operation. They may be challenged to achieve security in the form of affordability, and may also need to rely on thermal generation to secure an investment. No examples or instances were identified or discussed by the interviewees where an energy solution, and therefore investment, could not be secured. Whilst this does not mean that such projects do not exist, it does indicate that their occurrence may be limited, and more importantly other factors may play a key role in the investment decision. Mining projects generally need significant capital investment for infrastructure and requirements upfront, and generally need a suitable life of operation to fund this, which in turn should be able to provide a significant amount of time for an energy investment return.

4.2 Security of Energy Supply

Whilst the interviews focused on reliability and affordability, it became evident from an interviewee that Security of Energy Supply consists of three main components, i.e. reliability, affordability *and* availability. This was not captured as such prior to the interviews, and was an important gap or incomplete consideration of this component. All three components are required to ensure Security of Energy Supply, and is best illustrated in Figure 1 below.

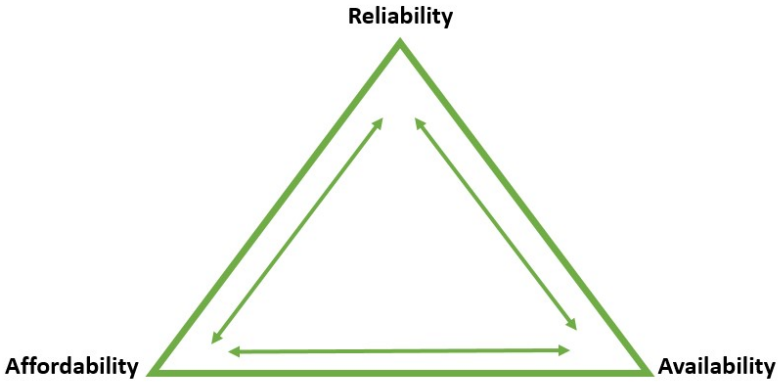


Figure 1: Energy Security Triangle (based on interview results)

The following points have been summarised from the interview in order to fully explain Security of Energy Supply. Reliability involves a consistent, predictable supply of energy. This is illustrated through a utility that may supply a consumer, for example a mining operation, with electricity, and that supply is not interrupted, unpredictable or does not fluctuate. This ensures that the consumer can utilise this energy in a planned predictable manner that meets their requirement on a consistent and reliable basis.

Affordability refers to the pricing or cost of energy for consumption. Affordability includes the actual tariff for generation, and where required transmission cost and predictability in price increases. The affordability or cost of energy is likely to be a key consideration for the viability of a particular energy supply and in some instances may be too expensive, or unaffordable, for the energy to be utilised. This is particularly relevant where other forms of energy are available that may be more cost effective.

Availability considers the energy available to meet a consumer's demand, for example the generation available from a utility is sufficient to be able to supply to the consumer. This refers to the sufficiency or availability of the required energy. It is important to note that renewable energy availability could be effected by available sun or wind (which determines Capacity Factor) or events such as

droughts affecting hydropower availability. From a renewable energy perspective it could also refer to the availability of the natural resource for generation purposes. For example, sufficient solar radiation or sufficient wind energy or hydrological components to meet the requirements. Availability also considers the ability, where required, to transmit the energy to the consumer. Security in availability would therefore typically mean that there is sufficient electricity available for use, and it can be transmitted, if required, for use.

These considerations do not exist in isolation but need to be considered together in order to ensure Security of Energy Supply, as shown in the Energy Security Triangle, in Figure 1 above.

Interviewee 4 supported considerations of the Energy Security Triangle, through a non-renewable example. Thermal coal energy generation, with a reliable or predicable source of coal, is an established and effective manner to secure energy supply. This provides a typical example of where a non-renewable energy source such as this may be selected over a renewable source for energy supply, particularly for large-scale generation. Thermal (coal) generators can ensure available energy when it is required at any time of day and during peak demand, with a predictable cost and reliably. Security of Energy Supply in non-renewable energy investment, using thermal coal power, may therefore determine the outcome of an energy investment. Security of Energy Supply is not restricted to non-renewable energy. A renewable energy source, for example solar PV, can be modelled for reliability, affordability and predictable availability. This could displace a portion of non-renewable energy generation, thereby presenting a hybrid type approach which may reduce energy generation costs and meet the Security of Energy Supply requirements, as discussed by the interviewee.

Security of Energy Supply was an important determinant for all interviewees and whilst not all agreed that this is the most influential determinant, all agreed that it is influential in investment decisions.

The two interviewees that rated Life of Operation Assumptions as being more influential than Security of Energy Supply agreed that once a bankable investment is secured, Security of Energy Supply could be considered, and achieved, through technology choices such as PV and wind. The two interviewees that rated Security of Energy Supply as being more influential than Life of Operations Assumptions provided directly opposing views to each other. Interviewee 2 stated that once the technical requirements of an investment can be secured, the client and investor financial requirements can be secured. Interviewee 3 determined the second most influential consideration to the Mining Demand Side Requirements, which perhaps also 'dilutes' the view that Security of Energy Supply is the most influential determinant. In summary, Security of Energy Supply was scored as the second most important determinant in influencing an energy investment decision. This view was supported by two different interviewee perspectives.

Life of Operations Assumptions and Security of Energy Supply each had two interviewees rating them as the as the most influential determinants in energy investment decisions.

4.3 Mining Demand Side Requirements

Mining Demand Side Requirements are an important influencer in energy investment decisions and with the exception of one interviewee was rated as the second most influential determinant. However, the overall score did not fully support this, and it was determined to be the third most influential determinant. It supports the discussion above that the determinants that are influential in decision-making are related to the unique nature of the mining operations, jurisdictional setting and mining activities. All interviewees consistently and firmly agreed that Mining Demand Side Requirements related to base load cannot be met solely through renewable energy supply without storage.

This energy demand cannot be achieved by renewable energy without storage, such as battery storage of solar PV, or as it was hypothesised, hydropower with

storage, although that in itself may not be secure. As such, there was consensus amongst the interviewees that mining operations need an alternative non-renewable energy supply to meet base load requirements, as solar PV storage is currently not economically viable for mining operations. It is therefore evident that base load power requirements need to be met for an energy investment decision, through whatever means, and that this cannot be provided by renewable energy. Renewable energy rather displaces the potential non-renewable energy supply to other operational requirements, when it is available. This means that a non-renewable or hybrid renewable energy solution can be implemented, with variable configurations.

4.4 Global Drive towards GHG Emissions Reduction

Ironically, the Global Drive towards GHG Emissions Reduction, loosely referred to as the Global Climate Change Agenda, is one of the key triggers of renewable energy growth, and a driver to reduce GHG emissions., However when considering the investment case for energy including renewable energy, this was found to be least influential.

All interviewees confirmed that this is least likely to influence investment decisions. Two interviewees confirmed that a company directive to invest in renewable energy achieves better outcomes than those companies that do not have such directives or strategies. It was suggested that these companies also have a less risk-averse view on renewable energy investment, that which favours investment and has more enabling views, for example on new technologies, funding models, commercial arrangements for power supply etc. Activists, lobbyists, non-governmental organisations were also identified as being a low driver or influencer of investment decisions. Essentially the interviewees recognised that the Global Climate Change Agenda is driven through business, where government policies are driving renewable energy investment in accordance with targets set for and by the Global Climate Change Agenda such as the Paris Agreement or COP 21.

Whilst interviewees agreed that there are significant jurisdictional differences, developed and developing country governments are driving renewable energy across the private and public sectors. Developing countries have a strong focus on renewable energy investments, and in many instances the private sector is able to catalyse much needed growth in the energy sector.

Despite business objectives, government influences and Global Climate Change Agenda opportunities for renewable energy investment, consensus maintained that the decision to invest in renewable energy would only be taken if there were a financial advantage when compared with the status quo. Carbon credits are not an advantage or driver. The market drivers for carbon credits, as indicated by an interviewee, do not exist and therefore this is currently regarded as a potential upside with possible future value, although not bankable.

One interviewee suggested, anecdotally, that there seems to be a lot of 'green agenda' money for investment, although not enough renewable energy opportunities exist. This is partly attributable to investors not wanting to work with the private mining sector due to legacy and reputational issues. Another interviewee suggested that in this line of thinking, private mining companies present catalytic opportunities to develop energy investment opportunities for communities. Although, where private mining companies can be enablers, some country legislation does not necessarily allow for these opportunities to be realised. Rigid investment models may also not recognise potential returns beyond certain operating assumptions, which are limited to the mining aspects such as life of mine. Furthermore, technological improvements may be required to support growth in community related renewable energy investment. An incentive programme or procurement initiative such as South Africa's Renewable Energy Independent Power Producer Project (REIPP), which has the potential to be very successful enabler and other African countries beyond South African, may benefit from such an initiative.

Interviewees were asked to identify any possible gaps in the determinants that were material to the decision-making process for energy investments. The interviewer identified legal or regulatory requirements as possibly being such a gap, which was identified upfront in the first interview, and considered in all subsequent interviews. Whilst all interviewees discussed and considered legal and regulatory requirements, it was consistently reported that this did not influence investment decisions in this context. Some interviewees recognised the importance of legal and regulatory requirements, but they were not determined to be enablers. Reasons for this include legislation that is focused on public investment, legislation that is aspirational in Global Climate Change Agenda targets but immature in development, and utility protectionism in some instances. As such, this has not been identified as a determinant, and not useful for further consideration.

Based on the outcomes of the interviews, and the drivers of the investment decision, a Hierarchy of Determinants Influencing Investment Decisions has been developed and is presented below in Figure 2.

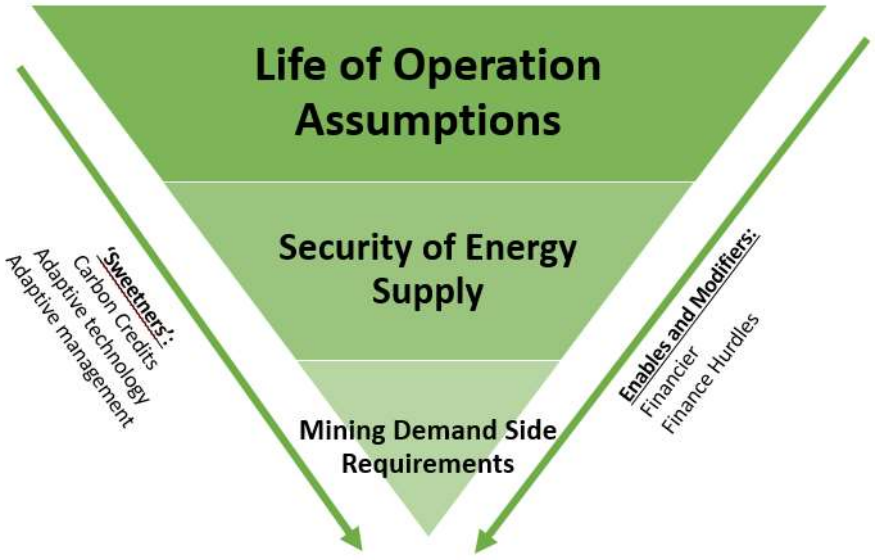


Figure 2. Hierarchy of investment decision influencers (based on the outcome of the interviews)

In support of this hierarchy, and a consistent outcome of each interview, is the variability between project, location and jurisdictions for energy investment projects. This extends to how this variability is a likely to be key factor in the determinants that influence the investment decision. As part of the interviews, it was therefore reiterated that the scope and boundary of the study was limited to private energy investments (not public), mining sector energy investments and a South African and African (continent) context, recognising that these two are materially different. Jurisdiction considerations, specifically in Africa (in general, but excluding South Africa) and South Africa became very evident in all interviews and discussions.

The outcomes of the interviews are presented plotted below in Figure 3 which identifies the pattern of investment decision determinants. This presents the most influential determinants as those that are bespoke to the energy investment projects and its needs. This representation also confirms the important influence that Mining Demand Side requirements have on the investment decision, and whilst this was not the most important influence for investment decisions, it re-iterates the bespoke nature and / or requirements being keep factors in decision-making processes.

For completeness, Regulatory Framework was included in this illustration, although, like Global Climate Change Agenda, it is clear that these determinants do not influence an energy investment decision and plot to the left of the illustration. This is perhaps supported by the apparent pattern of determinants likely to influence decisions being those that are unique and specific to each project, e.g. Life of Operation Assumptions is unique for each project which in turn determines the technology choice (renewable or non-renewable, followed by tariff or cost of that investment). The same project, located in a different jurisdiction, for example, may have a different outcome.

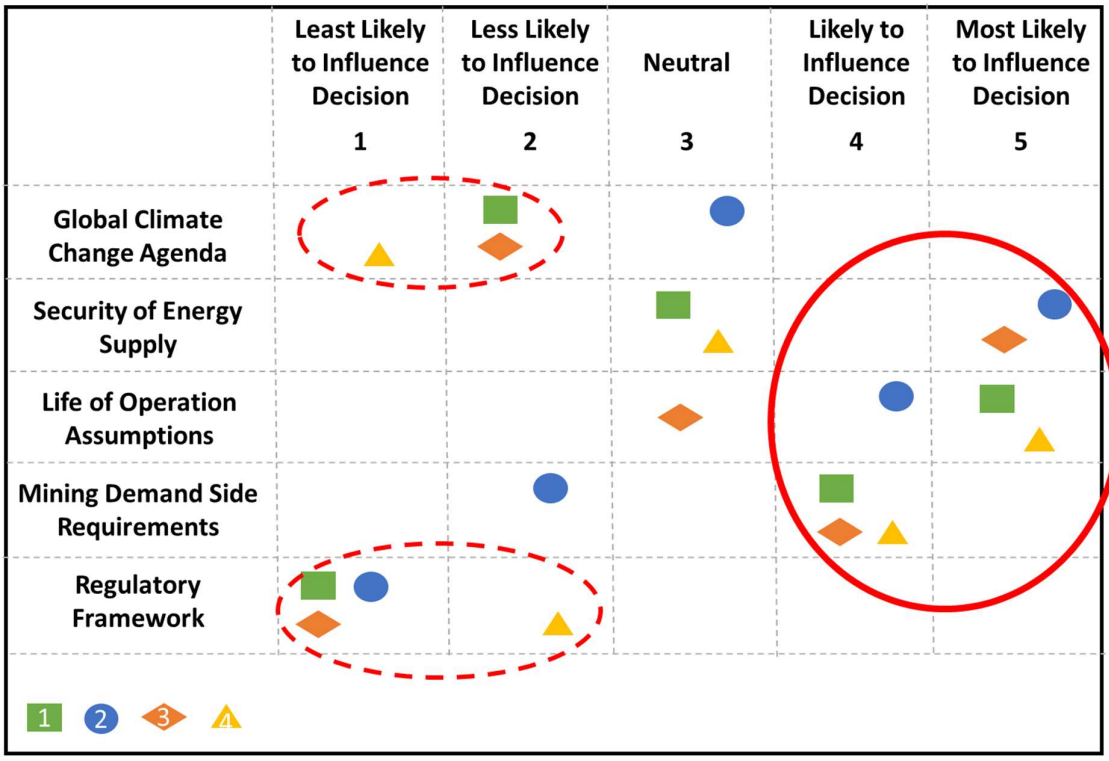


Figure 3: Pattern of influence of key determinants on investment decisions

4.5 Objectively Assessing the Determinants

In order to fully understand the interviewees' perspective on the identified key determinants, and ensure an element of objectivity and repeatability, detailed criteria were assessed with the interviewees. These criteria were assessed in a binary fashion in order to determine how they contributed to the determinant. It was expected that all criteria would not necessarily be relevant to the determinant. Generally speaking, there was a large degree of consistency in the interviewees' considerations of the criteria, although there were some exceptions (see Table 4). Notably, of the five criteria presented for Mining Demand Side Requirements, only one criterion was applicable to the determinant, in the context of this report and the energy investment scope and boundaries. This criterion was related to base load, which is essential for mining operations and energy investments cannot be considered without base load. Interviewees were fully aligned on this.

Although this determinant was deemed to be the least likely to influence an energy investment, the interviewees were mostly in agreement that corporate strategies to reduce emissions, or to invest in renewable energy initiatives were the most relevant and supportive of this determinant. Interviewees were split on the ESG investment pressure and legal or regulatory requirements, with half agreeing that this is relevant to this determinants influence, and half not. Consensus was largely achieved for clean development mechanisms (CDM) or carbon credit opportunities as being irrelevant to the determinant.

Table 4: Criteria for global climate change agenda

Determinant: Global Climate Change Agenda **Criteria**	**Interview 1 Mining & Sustainability Expert**	**Interview 2 Mining & Renewable Expert**	**Interview 3 Renewable & Sustainability Expert**	**Interview 4 Renewable Expert**	**Score**
Legal or regulatory requirements to reduce GHG emissions (e.g. Country Paris Agreement commitments)	Y	Y	N	N	Y = 2 N = 2 N/A = 0
Corporate strategy for climate / GHG emissions reduction	N	Y	Y	Y	Y = 3 N = 1 N/A = 0
Corporate strategy to invest in renewable energy	N	Y	Y	Y	Y = 3 N = 1 N/A = 0
Investor or external ESG influences to reduce GHG emissions or invest in renewable energy	N	Y	Y	N	Y = 2 N = 2 N/A = 0
Current CDM Investment Project(s) within organisation	N	N	Y	N	Y = 1 N = 3 N/A = 0

Interviewees were generally in alignment that the main contributors to Security of Energy Supply were security of affordability, which includes rising costs or unpredictability in costs (Table 5).

In terms of the criteria for Life of Operation Assumptions, interviewees were largely aligned on the applicability of these criteria with the exception of the last criterion (Table 6). Outcomes of the interview focused on guaranteed Life of

Operation Assumptions, i.e. proven resources in order to secure the bankability of the investment. Agreement was unanimous on the requirement of the payback period of an investment or of a renewable energy investment being the applicable criterion for the investment decision. There was mostly agreement on adaptive energy opportunities. Lastly, interviewees were divided on the applicability of criteria related to an investment that could be realised within the life of mine.

Table 5: Criteria to security of energy supply

Determinant: Security of Energy Supply **Criteria**	**Interview 1 Mining & Sustainability Expert**	**Interview 2 Mining & Renewable Expert**	**Interview 3 Renewable & Sustainability Expert**	**Interview 4 Renewable Expert**	**Score**
Rising increases in cost of current energy supply	Y	Y	Y	Y	Y = 4 N = 0 N/A = 0
Unpredictable increases in cost of current energy supply Instability in pricing	N	Y	Y	Y	Y = 3 N = 1 N/A = 0
Inability to secure a 'development' or 'stability' agreement for energy pricing and control	N	Y	N/A	Y	Y = 2 N = 1 N/A = 1
Unreliable, and therefore interrupted, supply of electricity due to generation constraints	Y	Y	Y	Y	Y = 4 N = 0 N/A = 0
Unreliable, and therefore interrupted, supply of electricity due to transmission constraints	N	Y	Y	Y	Y = 3 N = 1 N/A = 0

The interviewees were unanimous in the consideration of the criteria related to Mining Demand Side Requirements, asserting that base load energy must be available for mining operations as presented in the context of this study (Table 7). Should base load requirements not be met, the investment is not viable. In support of this, renewable energy solutions, without storage, will not be able to meet base load requirements, and as such, a non-renewable or hybrid solution is required.

Table 6: Criteria for life of operation assumptions

Determinant: Life of Operation Assumptions Criteria	Interview 1 Mining & Sustainability Expert	Interview 2 Mining & Renewable Expert	Interview 3 Renewable & Sustainability Expert	Interview 4 Renewable Expert	Score
Life of Mine is shorter than investor payback period	Y	Y	Y	Y	Y = 4 N = 0 N/A = 0
Life of Mine is shorter than renewable energy investment payback period	Y	Y	Y	Y	Y = 4 N = 0 N/A = 0
Life of Mine is incompatible with incentive (e.g. government) period	N/A	N	N/A	N	Y = 0 N = 2 N/A = 2
Life of Mine assumptions did not allow for adaptive management to energy investment (changing landscape)	N/A	N	N	N	Y = 0 N = 3 N/A = 1
Investment or utilisation of renewable energy investment does not extend beyond life of mine	Y	N/A	N	Y	Y = 2 N = 1 N/A = 1

Table 7: Criteria to mining demand side requirements

Determinant: Mining Demand Side Requirements Criteria	Interview 1 Mining & Sustainability Expert	Interview 2 Mining & Renewable Expert	Interview 3 Renewable & Sustainability Expert	Interview 4 Renewable Expert	Score
Base load considerations fully exclude renewable energy as an option	Y	Y	Y	Y	Y = 4 N = 0 N/A = 0
Base load considerations cannot be adequately met by renewable energy requirements	N/A	N/A	N/A	N/A	Y = 0 N = 0 N/A = 4
Renewable energy generation constraints are incompatible with operational requirements	N/A	N/A	N/A	N/A	Y = 0 N = 0 N/A = 4
Renewable energy storage solution is inadequate	N/A	N/A	N/A	N/A	Y = 0 N = 0 N/A = 4
Renewable energy storage solution is cost prohibitive	N/A	N/A	N/A	N/A	Y = 0 N = 0 N/A = 4

Chapter 5: Discussion

With recognition of the climate agenda and the importance of reducing greenhouse gas (GHG) emissions, renewable energy investments present an opportunity to replace, displace or supplement non-renewable energy generation (Wüstenhagen and Menichetti, 2012.; Mostert, 2014.). The decision to invest in energy projects, and specifically renewable energy projects, seems to be consistently influenced by the financial aspects of a project, as identified by Wüstenhagen and Menichetti (2012). Wüstenhagen and Menichetti (2012) report that when considering renewable energy investments for which there is a Global Climate Change Agenda imperative to investment, and in many instances an enabling policy environment for investment in renewable energy, it is the economics associated with the financial investment that determine the rate at which renewable energy investments are made. Traditional risk and return metrics that are considered as part of the financial modelling and considerations for investments are the drivers for the investment. Risk and return are usually unique to the energy investment scenario and aim at reducing risk and maximising return (Wüstenhagen and Menichetti, 2012). This can be achieved through determinants such as those identified in this study. This is further supported by a Nordic renewable energy investment study in which Boomsma, Meade, and Fleten (2012) identified financial aspects of an investment decision being influenced by the return on the investment, and the ability to enhance the return through increased Security of Energy Supply. This can be done through utilising improved pricing or a higher, secure tariff for the investment. Boomsma *et al.* (2012) found that improved security of cost supports an earlier initiation of renewable investments. Furthermore, this can be supplemented through additional financial support, such as subsidies, or a larger investment capital. Project investment decisions, in the context of this study, are clearly dependent on the outcome of the financial model and financial metrics that need to be met. Key to this is that a successful investment decision outcome assumes that for a replacement, or renewable energy displacement project, the investment must be more cost effective than the status quo. It is highly unlikely that an investment

that cost more than the status quo will be made. This is generally not materially influenced by the Global Climate Change Agenda or supported by appropriate regulatory requirements.

The most applicable drivers of energy investment decisions, along with criteria that can be used to objectively measure them, were identified in this report through interviews with subject matter experts. With the mining industry as context, the four determinants in energy investment decisions were analysed to determine which is the most influential. Enablers to further renewable energy investments were identified through discussion with interviewees. Interestingly, no interviewees had the exact same ranking of determinants for investment decisions. It is likely that this is a reflection of the bespoke nature of each energy solution or project. More importantly, the most influential determinants were consistently those that influence the financial viability of a project or investment decision. The imperative to reduce GHG emissions and the Global Climate Change Agenda, which are least likely to influence the financial model of an investment, was also the least likely determinant to influence an investment decision.

Life of Operation Assumptions was identified to be the most influential determinant, followed by Security of Energy Supply assumptions. Mining Demand Side Requirements were also influential in the investment decision, but not a primary influencer. The uniqueness of a project, and location seem to drive the influencers in the investment decision, which ultimately related to the financial viability of the investment (Masini and Menichetti, 2012). The results demonstrated that the life of the project is key to determining the viability of the project. Once the viability has been established, the technology choice will be made in a manner that ensures Security of Energy Supply. The results have clarified that Security of Energy Supply consists of three components, i.e. reliability, affordability and availability, and as such all analyses should ensure that all there components are considered.

Risk-averse investment assumptions or companies with a significant focus on core business and / or more conservative or traditional approaches to investment may not readily consider a hybrid model for energy supply. In this instance, if the Global Climate Change Agenda does not enable them to adjust their investment approach, other drivers such as corporate climate change strategies, corporate renewable energy performance indicators and possibly even shareholder pressure could enable a shift to renewable energy investments. This however, is unlikely to drive the investment. Mostert (2014) proposed that, when considering a renewable energy investment, a broader consideration of the financial aspects should be made. This includes environmental, social and human aspects of an investment. Should Mosterts' (2014) approach be successfully applied, one could possibly improve the financial aspects of an investment decision by internalising the Global Climate Change Agenda, reducing GHG emissions and enhancing possible social benefits of renewable energy investments. This would also be consistent with Mosterts' (2014) recommendation of utilising a sustainable development approach towards energy investments.

When evaluating financial models utilised for renewable energy investment projects in Brazil, China, India and South Africa, Kamara (2016) noted the differences in approach, context and jurisdictional context was acute and evident in the investment models used for those countries. Furthermore, where similarities in some countries' financial models or economic context may exist, Kamara (2016) reported that similar financial models would not necessarily work, but rather a unique approach is required for each context. Jurisdictional comparisons are therefore important considerations when evaluating projects and energy investment decisions. The scope and context of the study, which is the mining industry in an African context, is a critical fact that needs to be considered. This includes distinguishing between Africa and South Africa from an African perspective, as the South African context is markedly different to the remaining African context. South Africa is currently experiencing considerable renewable energy investment (Kamara, 2016) which, identified by some interviewees, may be attributable to an innovative renewable energy procurement

programme. Furthermore, country governance and risk are key considerations in financing an investment, and as such the industry, country context and risk profile, infrastructure, credit worthiness, tax incentives etc. related to an energy investment could be hugely variable between different industries and countries. Komendantova, Patt, Barras, and Battaglini, (2012) identify significant renewable energy generation opportunities in North Africa that could benefit both North Africa and Europe. In order to harness this potential, substantial private foreign direct investment would be required, however, geopolitical risk such as regulatory challenges, political instability and terrorism influence the investment risk and financial hurdles for investment (Komendantova *et al.*, 2012).

Adaptive technology could influence the investment models and determinants in that they could materially change the underlying assumptions. Hadjipaschalis *et al.* (2009) recognise the benefits of renewable energy sources such as cleaner energy production and continual improvements in technology. In some instances, however, renewable power generation can only compete with non-renewable power generation sources where the supply is supplemented with storage of the renewable energy in order to increase reliability. This is currently not occurring on a large, commercially viable scale. In the context of this study, renewable energy storage could significantly influence the Life of Operation Assumptions due to the cost of the capital required for storage, or alternatively, a reduction in capital costs for non-renewable infrastructure. Similarly, re-deployable solar PV panels could significantly influence the Life of Operation Assumptions in that the PV panels could be utilised for a short life of operation mine or project and then redeployed to another, resulting in the capital or investment burden return being significantly lower. This may result in a viable or lower tariff for renewable energy on a project that has demand for less than seven to 10 years or an available US$30M for investment. Technological changes could again disrupt the energy investment space, and improve project outcomes for renewable energy investment.

In conclusion, the Global Climate Change Agenda and imperative to reduce GHG emissions creates an enabling environment for renewable energy investment which aims to mitigate the impact of climate change (Elum and Momodu, 2017). This enabling environment is widely supported at an intergovernmental and international level with many governments developing policies to achieve the desired outcomes (Huenteler, Niebuhr, and Schmidt, 2016). Investment in energy projects is not restricted to renewable energy projects, and in some instances non-renewable energy investments continue. This is largely driven by the financial aspects of the energy investment and associated return on investment (Kamara, 2016). The factors that influence the return on investment, as shown in this research, tend to be unique to the investment project and mining industry. They support the outcome of certain financial investment hurdles beings met or achieved, primarily related to risk and reward. Incentivising renewable energy investments would be successful if they influence the return on the investment. The study identified that the changing renewable energy landscape, in the form of adaptive technology related to energy storage, could materially influence the outcome of investment modelling, and drive additional renewable energy investments (Hadjipaschalis *et al.*, 2009). Adaptive technologies should therefore be continually pursued when considering energy investment initiatives.

Limitations to the Study

The research and interviews were based on determining and understanding the most influential determinants related to energy investment decisions in the private sector and mining industry. The nature of the determinants and the most influential determinant in investment decisions reflects this, along with the project and mining specific nature of the investment decisions. Should the scope of the study be broadened to additional industries, additional determinants may be identified and those with the most influence on an investment decision may also be different. Similarly, only four subject matter experts were interviewed, and had more experts been interviewed, a wider base of information may have been available to trend the determinants that were most influential on the investment decision.

Mining case studies for renewable energy investment decisions were considered at the onset of the research. The case studies were not used in the analysis of the determinants due to sensitivities in the financial modelling components of the projects, and regulatory delays in project authorisations, which resulted in restricted publically available information to be used in the research.

Lastly, whilst the determinant of base load requirements is applicable to the mining industry, it is likely to be applicable to other industrial processes too. .

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Appendices

Appendix 1: Interviewee Questionnaire

Determinants that influence renewable energy investments.
Survey Interview Questionnaire

Context

Renewable energy sources are being driven as the solution for energy supply challenges globally. Investment in renewable energy is increasing, however investment in non-renewable energy supply continues. As such, this research will aim to identify key influencers in renewable or non-renewable energy investment decisions when renewable options may be available. The following determinants will be considered when evaluating the influences in the investments decision:

- **Global drive towards GHG emissions reductions:** Global and country response to climate change and high levels of GHGs in the atmosphere.
- **Security of Energy Supply (reliability and pricing):** Reliability, continuity and certainty of electricity supply; and affordability, certainty and predictability in the pricing and associated increases, for electricity.
- **Life of Operation Assumptions:** The remaining, profitable, life of an operation or mine, on which business planning decisions and commitment can be made.
- **Mining Demand Side Requirements:** Activity specific requirements of the operations from an electricity supply perspective e.g. unique base load or start-up requirements.

Participation is the survey is voluntary and will remain anonymous and confidential. Information obtained during the survey will not be communicated in a way that identifies participant or participant's company. Participants may opt out of answering any of the questions and are under no obligation to share any information that may compromise the participant or participant's organisation.

Interview Questionnaire

A: Case Study Participants:

1. Please briefly describe your renewable energy investment project
2. Please describe the status of the investment project e.g. feasibility, execution and construction, operational etc.
3. Please will you share (if you are prepared to do so) the overall investment cost of the energy investment project

B: All Participants:

1. Please may you comment on the following drivers or determinants, in your experience, in influencing energy investment projects you have worked on (renewable or non-renewable):
   - Global drive towards GHG emissions reductions
   - Security of Energy Supply (reliability and pricing)
   - Life of Operation Assumptions
   - Mining Demand Side Requirements
2. Are there other drivers, or determinants, that you feel are material in investment project decisions that have not been considered above?
3. Please may you rate these determinants (question B1 above), including any you have identified, in influencing investment decisions as follows:

   1 = Least Influential: Immaterial determinant – not considered

   2 = Unimportant determinant: does not influence decisions

   3 = Neutral determinant: does not influence decision in either direction, but is considered

   4 = Important determinant: can influence decisions

   5 = Most Influential: Material determinant - can ‘make or break’ decisions
4. Please may you elaborate on any noteworthy points in the rating process or decision making process
5. In order to try and objectively analyse the determinants identified in question B1, please rate the following criteria identified for each determinant as being applicable or not in the investment decision (i.e. yes or no):

5.1 Global drive towards GHG emissions reductions

a. Legal or regulatory requirements to reduce GHG emissions (e.g. Country Paris Agreement commitments)
b. Corporate strategy for climate / GHG emissions reduction
c. Corporate strategy to invest in renewable energy
d. Investor or external ESG influences to reduce GHG emissions or invest in renewable energy
e. Current CDM Investment Project(s) within organisation

5.2 Security of Energy Supply (reliability and pricing)

a. Rising increases in cost of current energy supply Unpredictable increases in cost of current energy supply Instability in pricing
b. Unpredictable increases in cost of current energy supply Instability in pricing
c. Inability to secure a 'development' or 'stability' agreement for energy pricing and control
d. Unreliable, and therefore interrupted, supply of electricity due to generation constraints
e. Unreliable, and therefore interrupted, supply of electricity due to transmission constraints

5.3 Life of Operation Assumptions

a. Life of Mine is shorter than investor payback period
b. Life of Mine is shorter than renewable energy investment payback period
c. Life of Mine is incompatible with incentive (e.g. government) period
d. Life of Mine assumptions did not allow for adaptive management to energy investment (changing landscape)
e. Investment or utilisation of renewable energy investment does not extend beyond life of mine

5.4 Mining Demand Side Requirements

a. Base load considerations fully exclude renewable energy as an option

b. Base load considerations cannot be adequately met by renewable energy requirements
c. Renewable energy generation constraints are incompatible with operational requirements
d. Renewable energy storage solution is inadequate
e. Renewable energy storage solution is cost prohibitive

6. Are there other criteria for these four determinants (B5) that you feel are material in investment project decisions that have not been, and should be, considered?
7. Do you have any recommendations for determinants that governments or regulators, investors or financiers, project proponents, and / or stakeholders should take into consideration in *renewable energy investments* in order to streamline or incentivise further investment?
8. Do you have any recommendations for determinants that governments or regulators, investors or financiers, project proponents, and / or stakeholders should take into consideration in *non-renewable energy investments* in order to improve or dis-incentivise further investment?
9. Do you wish to add any additional considerations for renewable energy investment projects?
10. Do you have any comments you would like to provide on the survey process?

Thank you