

A cost-benefit analysis of implementing a solar plant in a platinum mining company

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ABSTRACT

It stands to reason that a reliable and secure supply of energy is a prerequisite for adequate output and economic growth. The national power utility of South Africa, Eskom, has recently come under fire as exponential tariff increases place organisations under pressure coupled with inadequate power supply leading to power cuts more commonly known as load shedding.

The before mentioned factors have sparked the interest of organisations which are heavily dependent on a constant, reliant and cost-effective supply of electricity to explore other avenues of obtaining electricity.

This study was specifically aimed at confirming if the theoretical findings with regards to solar photo voltaic plants can be practically simulated to prove that solar photo voltaic technology can be implemented on a large scale.

The empirical study and practical simulation focussed on a large-scale solar photo voltaic plant of 54 MW. The plant can supply a mining company with electricity which is competitive when compared to obtaining electricity from conventional methods. The study also incorporated the benefits acquired by mitigating the imminent costs of the carbon tax act which came into effect on 1 June 2019.

This study established that 2,439,753 MWh is on offer over a 20-year period by implementing a 54 MW solar photo voltaic plant. The carbon tax saving equates to R563,205,994 and a R5,614,426,335 saving in electricity costs if the proposed solar photo voltaic plant is implemented. Thus, the mining organisation will have an 11% saving on carbon taxes and a 10% saving on electricity costs respectively throughout the 20-year period if the proposed 54 MW solar plant is commissioned to supply the mining organisation with electricity.

Key words: Carbon tax act, electricity, Eskom, greenhouse gas emissions, mining industry, renewable energy, solar photo voltaic power

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ABBREVIATIONS AND DEFINITION OF KEY TERMS

The key terminology and concepts used in the study are addressed in the following paragraph:

- **Non-renewable resource:** Resource of economic value that cannot be readily replaced by natural means on a level equal to its consumption (Investopedia, 2018).
- **Renewable resource:** Resource of economic value that can be readily replaced by natural means on a level equal to its consumption (Investopedia, 2018).
- **Solar photo voltaic (PV):** Technology that converts sunlight (solar radiation) into direct current electricity by using semiconductors.
- **Net Present Value (NPV):** The present value of all cash inflows are compared to the present value of all cash outflows (Seal, 2015:397).
- **Internal Rate of Return (IRR):** Estimation of the profitability of potential investments.

Abbreviation	Meaning
CH ₄	Methane
CO ₂	Carbon dioxide
DNI	Direct Normal Irradiance
FDI	Foreign direct investment
G	Giga
GDP	Gross domestic product
h	hour
IRR	Internal rate of return
k	Kilo
M	Mega
N ₂ O	Nitrous oxide
NPV	Net present value
oz.	ounce
Pt	Platinum
PV	Photo voltaic
R	South African Rand
t	Metric ton
USD	United States Dollar
VAT	Value added tax
W	Watt
WACC	Weighted average cost of capital

CHAPTER 1

1. AN INTRODUCTION TO THE STUDY

A synopsis of the study is given in this chapter. Electricity supply by Eskom and its effects on the South African economy and platinum mining industry are discussed. An alternative method of generating electricity via a renewable source in the form of a solar photo voltaic plant is also discussed. The costs, implications and benefits of the study are briefly discussed through the problem statement and the relevant objectives.

1.1. INTRODUCTION

Humankind has been generating electricity to empower lives and organisations from the beginning of the first Industrial Revolution. Electricity has effectively replaced the use of water and steam to power machinery and equipment, but this has come at a cost.

The consumption of non-renewable energy resources does not only deplete the resources, but is also responsible for environmental issues such as global warming. Pachauri (2014:2) argued that climate change is substantially influenced by emissions of greenhouse gases such as carbon dioxide (hereafter referenced as CO₂). These gases primarily come from the burning of fossil fuels to generate electricity.

The mining industry plays an important part in the South African economy. The mining industry should be wary of diminishing non-renewable energy resources. Non-renewable energy resources are harmful to the environment. The mining industry is dependent on the national power utility of South Africa (hereafter referenced as Eskom) to constantly supply energy at competitive rates to keep the industry sustainable. Mining organisations are thus seeking alternative sources of energy such as solar photo voltaic plants.

1.2. BACKGROUND

Decreased profit and increased risk to sustainability are imminent as the price for platinum decreases whilst cost of electricity increases (Moolman (2016:1). The price for commodities is not easily controlled, but the rising cost of electricity could be mitigated. It is, therefore, crucial to explore if the implementation of a solar photo voltaic plant can combat the ever-

increasing cost of electricity to such an extent where the platinum mining organisation can solidify a sustainable future.

Coal-fired power stations in South Africa was designed to have a 50-year useful lifespan. Lack of adequately commissioning new power stations and lack of maintenance has threatened to provide an efficient supply of energy (Fisher (2017:2). The national power utility has not maintained and upgraded outdated power stations and has caused numerous occasions where supply could not meet demand. Load shedding occurred, and the platinum mining industry has suffered because of this. This study will aim to find a feasible solution to mitigate the risks of load shedding.

This study will, therefore, attempt to find a feasible solution to save costs by implementing a solar photo voltaic plant. The implementation of these changes will ultimately lower the organisation's carbon footprint (CO₂ emissions), which will benefit the environment and enhance its public reputation. According to Van der Zee (2014:5), another benefit of a lower carbon footprint is the mitigation of imminent carbon taxes which will come into effect in the foreseeable future. The white paper has been released in South Africa, and economists confirmed that the legislation came into effect in South Africa on 1 June 2019.

The study will also yield a benefit for the platinum mining industry in becoming independent from Eskom for some of their energy needs. The platinum mining organisation will become self-sustaining in the long term if a feasible solution in a solar photo voltaic plant is found. Eskom is under financial strain (Reuters (2018). Botha (2015:1) further states that a reliable and secure supply of energy is a prerequisite for adequate output and employment growth within an industry. The sustainability of the platinum mining industry is thus under threat if Eskom cannot deliver constant energy reliably.

It can be argued that this study will attempt to find an executable solution to a pertinent problem facing platinum mines in South Africa. If a solution is found it will contribute to the knowledge of already known theories to combat increasing financial costs to company and increase the overall sustainability of the organisation and aid to retain jobs.

1.3. PROBLEM STATEMENT AND CORE RESEARCH QUESTION

Conventional generation of electricity includes the consumption of non-renewable energy resources. In this regard, Coetzer (2014:2) warned that non-renewable energy resources could be depleted within the next 107 years. Eskom currently consumes coal as its primary resource to generate electricity. Coal comprises of 85% of Eskom's resources to generate electricity (Fisher (2017:1). Coal is limited in nature and becoming costlier to produce. Coal also contributes to global warming as greenhouse gases are emitted into the atmosphere by burning coal to generate electricity.

Eskom's power stations are becoming more unreliable as their remaining life draws closer to an end and new stations have reported issues of being substandard (Maré, 2015:2). A study by Van der Zee (2014:1), furthermore, revealed that Eskom supplies 95% of electricity to South Africa and that electricity tariffs have increased exponentially since the electricity crisis of 2008.

Electricity prices have seen dramatic increases since the energy crisis of 2008 and have led to the platinum mining industry to investigate alternative sources of energy that is renewable in nature. The mining industry is a substantial contributor to the South African economy as it accounts for 8% of South African gross domestic product (hereafter referenced as GDP), 11% of gross-fixed capital, 16% of foreign direct investment (hereafter referenced as FDI) and 6% of tax revenues according to FSE (2018). The platinum mining industry has felt the effects of decreasing commodity prices coupled with increased electricity costs.

From the foregoing background, it is evident that the platinum mining industry relies primarily on Eskom for the supply of electricity. Electricity costs are experiencing exponential increases, which can subsequently result in unsustainability within the platinum mining industry.

The problem being investigated in this study is thus the effect which increasing electricity cost have on the sustainability of a platinum organisation in South Africa and the risks in terms of dependence on the national utility for a constant electricity supply.

A problem exists within the platinum organisation where a decrease in electricity usage has a direct correlation with decreased production. Increased demand for electricity is also forecasted by the platinum mining organisation for the coming years as operations expand. The increase in electricity costs and the possibility of load shedding due to the unreliable supply of electricity have a negative effect on the profit margins and places the platinum organisation with its employees at risk of becoming unsustainable.

The core research question derived from the above-mentioned problem statement is as follows:

What is the cost of implementing a solar plant versus the benefit on cost saving and independence from the national utility within a platinum mining organisation?

Following the guidelines of Bryman (2014:89), it can be argued that the above-mentioned research question is an organisational problem that could be solved through research.

The research question is neither too broad nor too narrow. Resources and key individuals are available to enable the researcher to answer the research question. The study would not require a grant. The research will make a reasonably significant contribution to the area of study.

The above-mentioned research question is an instrumentalist question, this implies that there is observable data that can be measured and compared. An instrumentalist question is also a norm for quantitative studies (Ary, 2018:381).

1.4. RESEARCH OBJECTIVES

1.4.1. Primary research objective

The primary research objective of this study is to do a cost-benefit analysis of implementing a solar photo voltaic plant within a platinum mining company.

1.4.2. Secondary research objectives

The secondary research objectives are divided into two main categories, i.e. literature objectives and empirical objectives.

1.4.2.1. Literature objectives

- **Electricity provision in South Africa**

The objective is to investigate how electricity is provided within a South African context.

- **Alternative sources of electricity in South Africa**

The objective is to investigate alternative sources of electricity within a South African context.

- **Provision of electricity in the mining industry**

The objective is to investigate how electricity is specifically provided to the mining industry.

- **Previous research on costs of conventional electricity versus costs of solar electricity**

The objective is to investigate the costs of generating electricity by the conventional method and alternative sources of electricity.

1.4.2.2. Empirical objectives

The empirical objectives are to:

- **Identify the research method**
The objective is to identify the research method that will best suit this study.
- **Identify the research population**
The objective is to identify the organisation which will form part of the study.
- **Identify the research sample**
The objective is to identify the scenarios which will form part of the study.
- **Obtain information regarding costs and benefits on the identified sample**
The objective is to obtain relevant information from reliable sources regarding costs and benefits on the identified scenarios.
- **Analysis of the information and provide results and conclusions**
The objective is to use the information obtained to conduct proper analyses and to provide results and conclusions.

1.5. RESEARCH METHODOLOGY

1.5.1. Literature study

The following features were researched for the literature review:

- News articles pertaining to Eskom, the South African economy and the relevant organisation being investigated in this particular study.
- Articles that were written by economists specialising in Eskom and the South African economy.
- Credible journals that were written by researchers relevant to this particular study.
- Annual Financial Statements of Eskom and the relevant organisation being investigated in this particular study.
- Integrated reports of Eskom and the relevant organisation being investigated in this particular study.
- Reliable Web searches about renewable energy specific to solar photo voltaic plants.

1.5.2. Empirical study

1.5.2.1. Research method / Design

This study followed a quantitative case study approach.

Bryman (2014:110) states that case study design involves the detailed and intensive analysis of one case which the researcher aims to study in-depth. Bryman (2014:31) further argues that quantitative research is the process of collecting numerical data. Numerical data can be gathered via various techniques and can be quantified to give meaning and find solutions with regard to research problems.

1.5.2.2. Population

The population for research specifies who and/or what should make the data available. The researcher must stipulate if the study will collect data about individuals, organisations, documents and/or other relevant stakeholders (Zikmund, 2013).

This research incorporated the case study of one primary organisation. The organisation is a prominent platinum mining company registered in South Africa and operates primarily in the platinum belt of Rustenburg in the North West province. The main focus of the case study was the comparison of cost and benefits on the conventional method of generating electricity versus solar photo voltaic electricity generation within the platinum operation located in Rustenburg, North West province, South Africa as per figure 1.1.

Figure 1.1: Rustenburg operations locality plan



1.5.2.3. Discussion of the case study

The strategy followed for the case study was based on non-probability testing via convenience sampling.

Bryman (2014:178) argues that a convenience sample is one that is available to the researcher by virtue of its accessibility. It is relatively common for business researchers to make use of the opportunities they have to draw a case study from their own organisation.

The case study compared two scenarios within the platinum mining organisation located in Rustenburg, North West province, South Africa. The two selected scenarios of the same capacity/size were compared over the same period.

One scenario was based on the organisation deciding to disregard the implementation of the proposed solar voltaic plant. The second scenario included the implementation of the proposed solar voltaic plant. The differences were compared to confirm if the benefits of implementing a solar voltaic plant outweigh the costs or not.

1.5.2.4. Collection of data

The nature of the data that was collected was in the form of various internal and external documents, charts and financial reports which are quantifiable by utilising various calculations.

Bryman (2014:276) is of the opinion that documents as sources of data provide researchers with valuable information about the organisation and can be used to build up a description of the organisation and therefore used in the investigation of organisational problems which can be solved by business research.

A substantial number of organisational documents are available in most organisations. This is a heterogeneous group of sources which are vital for research.

The organisational documents collected from the mining organisation included the following:

- Energy consumption bills: The bills indicate the number of kilowatt/hours the operation consumes as well as the tariff cost in Rand value. The consumption bills also indicated the tariff structure.
- Reports on actual energy expenditure for 2018: This was a collection of transactions in kilowatt/hours and in Rand value for each month from January 2018 until December 2018.
- Reports on forecasted energy expenditure from 2019: This was a list of transactions in kilowatt/hours and in Rand value projected for each month from 2019 to 2038.
- Costing reports applicable to energy expenditure and initiatives.
- Costing and benefit reports, quotations and invoices relevant to solar photo voltaic plants. These costs entail capital expenditure cost and operational expenditure cost with their associated benefits, as stated by Ramirez (2017:117).

The above-mentioned documents in the sample are crucial to determine a baseline for energy consumption, the actual and projected costs and benefits of electricity generation through the conventional and renewable method.

These documents are only available in the private domain and key individuals were consulted to acquire the information within the sample.

The following public documents were collected:

- The mining organisation's Annual Financial Statements (AFS) from 2012 until 2018: The AFS enables the researcher to establish a trend of how energy expenditure has risen over time in conjunction with production figures and revenues.
- The mining organisation's Annual Integrated Reports (AIR) from 2012 until 2018: The AIR enables the researcher to establish a trend of identified constraints and what has been set in place to mitigate any risks relating to energy expenditure.
- Eskom tariff structures and rates applicable to the mining industry: Different tariff structures exist within different industries in South Africa. This document provides the rates that are charged in Rand value for each kilowatt/hour consumed by a customer.
- Eskom peak and off-peak schedules which are applicable to the mining industry. This document provides the different rates which are charged in Rand value at different times of the day as well as different seasons within the year.
- Eskom's Annual Financial Statements (AFS) from 2012 until 2018: The AFS enables the researcher to establish a trend of how energy expenditure has risen over time and where the mining industry fits within Eskom's portfolio.
- Eskom's Annual Integrated Reports (AIR) from 2012 until 2018: The AIR enables the researcher to establish a trend of identified constraints of Eskom and what has been set in place to mitigate any risks.
- Mass media articles pertaining to Eskom from 2008 until 2018: Articles elaborating on the management and operation of Eskom provides valuable information in establishing a trend on the position of Eskom according to Botha (2015:1)

The Annual Financial Statements and Annual Integrated Reports are available in the public domain and thus accessible through utilising the internet to obtain the information within the population.

This ensures data which is:

- **Quantifiable:** The historical data and financial reports are utilised in generating numerical data which can be altered into meaningful ratios and analysis (DeFranzo, 2011);

- **Authentic:** The historical data and financial reports are utilised in obtaining secondary data which can be considered as genuine. The reports are audited on an annual basis;
- **Reliable:** The historical data and financial reports are utilised in obtaining consistent data which are repeatable. IFRS ensures that accounting frameworks are consistent (Statistics, 2016); and
- **Homogenous:** The historical data and financial reports are utilised in obtaining data from the same financial sources which results in less variation (Bryman, 2014:275).

1.5.2.5. Analysis of data

- **Data analysis of scenario 1**

Data analysis of the identified scenario 1 was in the form of a simulation where the operation continues with the conventional method of obtaining electricity with its associated costs and benefits.

The Net Present Value (NPV) method was used to analyse the data.

Under the Net Present Value method, the present value of all cash inflows (Scenario 1 will have no cost saving cash inflows) is compared to the present value of all cash outflows (Scenario 1 will have the cost of the conventional method of obtaining electricity) that are associated with normal operations. The variance between the present value of these cash flows, called the net present value, determines whether or not the project is an acceptable investment (Seal, 2015).

- **Data analysis of scenario 2**

Data analysis of the identified scenario 2 was in the form of a simulation of a scalable solar photo voltaic plant with a nameplate capacity of 54 MW.

The study thus consists of a total simulation of a 54 MW solar photo voltaic plant. Costs included to install and maintain a solar photo voltaic plant and the corresponding benefits was studied. Capital cost of the organisation was taken into account, and no other means of acquiring the solar photo voltaic plant was taken into account (i.e. this study was based on the organisation's internal weighted average cost of capital

(WACC) and not based on other capital instruments such as a power purchase agreement (PPA)). The Net Present Value (NPV) method was used to analyse the data.

Under the net present value method, the present value of all cash inflows (Scenario 2 will have cost saving cash inflows) is compared to the present value of all cash outflows (Scenario 2 will have the cost of implementing and maintaining a solar plant) that are associated with an investment project. The variance between the present value of these cash flows, called the net present value, determines whether or not the project is an acceptable investment (Seal, 2015).

- **Programs that will be utilised in this study**

Statistical and data analysis was conducted utilising the following software programs:

- Meteonorm V7
- Microsoft Office Excel 2016
- PVSyst V6.42
- SPSS

1.6. LIMITATIONS OF STUDY

The study was based on a single platinum mining company based in Rustenburg, North-West Province, South Africa. The study was based on two scenarios with the same capacity/size and was compared over the same period.

The study included research done on a solar photo voltaic plant as a renewable energy source. The study excluded the study of other renewable energy sources such as biomass, concentrated solar power (CSP), hydro, landfill gas and onshore wind.

1.7. RESEARCH ETHICS

Research ethics provides guidelines for the responsible conduct of research according to Libguides (2018). Research ethics ensures that a high ethical standard is maintained when conducting research.

The following is a summary of ethical principles which applies to this particular study:

- **Honesty:** Data, results, methods and procedures, and publication status were handled with transparency and honesty. Data was not amended, fabricated or misrepresented.
- **Objectivity:** Bias throughout the different stages of data collection, analysis and interpretation was prevented
- **Integrity:** Promises were kept. Sincerity, consistency and transparency will be displayed through words and deeds.
- **Carefulness:** Records were kept of all research activities and will be destroyed as per the university policy. Errors were avoided by examining the work prudently.
- The **analysis and reporting** of data were done on an ethical level – research methods and techniques were revealed and sources consulted were acknowledged.
- **No questionnaires, surveys or interviews** were distributed/held as this was a case study where quantifiable historical data is necessary as opposed to participant perceptions.

1.8. CHAPTER CONCLUSION

The continuous increase in the electricity tariff reduces the margin for profit as expenses increase. Sustainability is put under risk seeing that electricity is a substantial part of a platinum mine's operating expenses. Lower revenues also lead to a lower dividend distribution to shareholders, and in turn, diminishes the investment environment. These factors cause a snowball effect and ultimately pose a risk to the sustainability and feasibility for a platinum mining organisation to operate within the mining sphere. The platinum mining organisation has to look for an alternative method of generating electricity to alleviate the

financial burden of increased electricity costs. This study researched the costs of increasing electricity and the feasibility of implementing a solar photo voltaic plant to mitigate this increasing cost.

CHAPTER 2

2. LITERATURE REVIEW

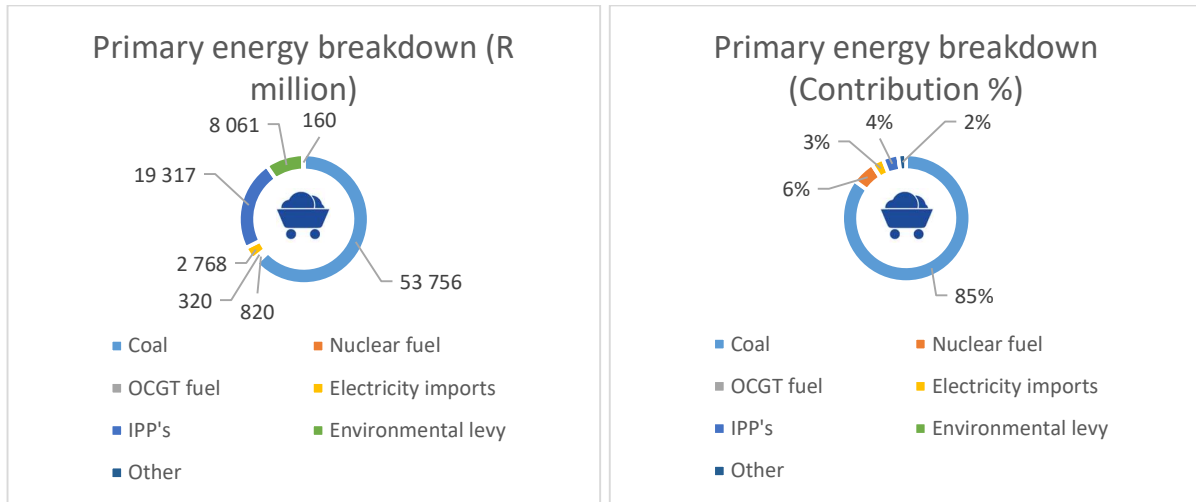
Electricity as a prerequisite for growth is discussed. This chapter includes an elaboration on the supply of electricity within a South African mining context. The economic crisis coupled with non-renewable energy sources is explained. The effects of a renewable electricity resource in the form of solar photo voltaic technology are identified and reviewed. The factors influencing the costs and benefits of this study are identified and discussed in detail.

2.1. ELECTRICITY PROVISION IN SOUTH AFRICA

Eskom is South Africa's national power utility. The entity is owned by the South African government and was established in 1923. Eskom is Africa's largest electricity producer and accounts for 95% of the power supplied to South Africa as stated by Van Wyk (2014:18).

It is imperative to note that Eskom's current electricity capacity is mainly generated by coal fired power stations. Coal contributed 85% of Eskom's capacity in 2017/18 as illustrated by figure 2.1. This percentage is growing annually as coal contributed 84% of Eskom's capacity in 2016/17. Eskom spent R53,756 million in 2017/18 on coal resources as illustrated by figure 2.1, up by R2,781 million compared to R50,975 million spent in 2016/17 as illustrated. A summary of the amounts is illustrated in table 2.1.

Figure 2.1: Primary energy breakdown, R million and contribution % for 2017/18



Source: ESKOM Integrated report 31 March 2018 (2018:80)

Table 2.1: Comparison of the primary energy breakdown, R million & contribution % for 2017/18 and 2016/17

Primary energy breakdown	R million 2017/18	R million 2016/17	R million change	% 2017/18	% 2016/17	% change
Coal	53 756	50 975	2 781	85%	84%	1%
Nuclear fuel	820	727	93	6%	6%	0%
OCGT fuel	320	340	-20	0%	0%	0%
Electricity imports	2 768	2 681	87	3%	3%	0%
IPP's	19 317	19 757	-440	4%	5%	-1%
Environmental levy	8 061	8 086	-25	N/A	N/A	N/A
Other	160	194	-34	2%	2%	0%
Total	85 202	82 760	2 442	100%	100%	0%

Source: Eskom Integrated report 31 March 2018 (Eskom, 2018:80)

Eskom's cost to produce electricity using coal has also increased from R293 per Megawatt hour in 2016/17 to R309 per Megawatt hour in 2017/18. This implies an annual increase in the cost of 5.46% as illustrated in table 2.2 (Eskom, 2018a:80).

Table 2.2: A Comparison of the energy unit cost per Megawatt hour for 2017/18 & 2016/17

Unit cost (R/MWh)	2017/18	2016/17	% change
Coal	309	293	5.46%
Nuclear	94	85	10.59%
OCGT's	2 313	2 072	11.63%
IPP's	2 015	1 714	17.56%
International purchases	358	361	-0.83%

Source: Eskom Integrated report 31 March 2018 (Eskom, 2018:80)

The national power provider requested local banks to reopen lending facilities that had been suspended as the state utility seeks to drag itself out of a crisis that poses a risk to the mining industry's financial stability (Reuters (2018)). There are primarily three options available for Eskom to alleviate the financial burden of the increased cost of production. The first is to borrow more money, which poses a problem with the current banking environment where revolving credit facilities have been suspended based on the report from Reuters (2018). The second is to apply for a government bailout and the third, and most probable option is to increase the price to consumers such as the platinum mining organisations.

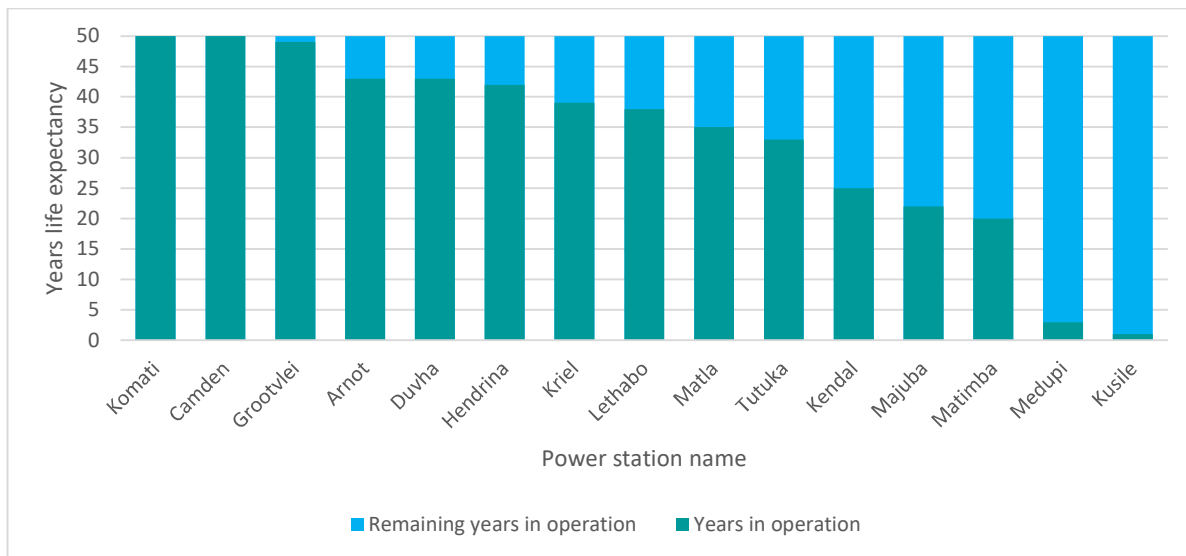
On a macro level, South Africa's inability to supply enough electric power to the economy has led to successive downward revisions of the country's Gross Domestic Product (GDP) growth forecasts, including that of the International Monetary Fund. In a modern, globalising world economy, it stands to reason that a reliable and secure supply of energy is a prerequisite for adequate output and employment growth as stated by Botha (2015:1). The ominous electricity situation has been caused by the incapability of Eskom to meet the demand for electricity.

In analysing the reasons for the regular shortfall of electricity supply, a number of key points emerge that paint a dismal picture of mismanagement and instability. Two decades ago, the Ministry of Energy was in the process of preparing a White Paper on future energy policy. In its submissions to government, Eskom warned that, unless new power stations were commissioned post haste, South Africa would run out of surplus electric power by 2007. This prediction held true (Coetzer, 2014:12), with the first bouts of load-shedding occurring early in 2008 and now reoccurring from 2018 onwards.

The South African platinum mining industry is expanding and subsequently placing Eskom under pressure to supply electricity to match the demand of the expanding industry. Maré (2015:15) is of the opinion that reliable, efficient and cost-effective electricity supply is crucial for further economic and social development.

The delayed expansion and lack of sufficient upkeep of power stations are primarily due to the inexplicable decision by Eskom more than a decade ago to start cutting its maintenance budget according to Botha (2015:1). The coal-fired power stations, as illustrated in figure 2.2 and Appendix 1, have been built with a useful life expectancy of 50 years. The commissioning date of these plants is an indicator of how long these plants have been in operation. The majority of the power stations have been in operation for more than 30 years, and maintenance has been left in the dark. It also takes 8 – 10 years to build a coal-fired power plant. These factors contribute to a significant decrease in reliability on Eskom to produce efficient and cost-effective electricity.

Figure 2.2: Remaining operational years of South African coal-fired power stations



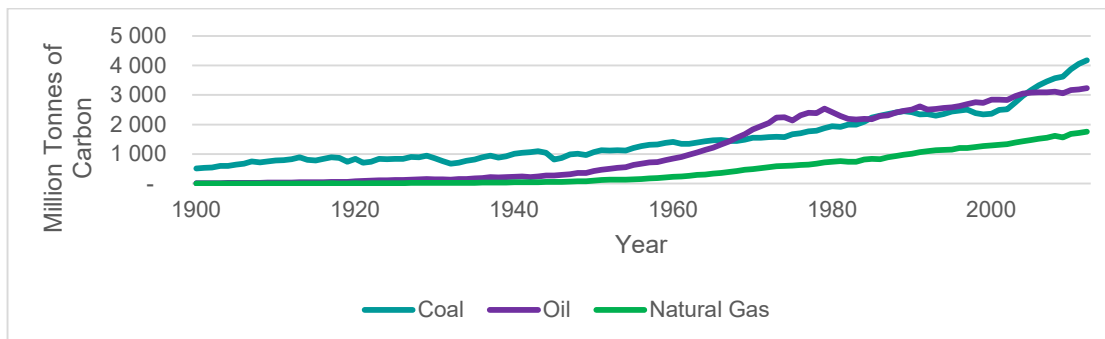
Source: South Africa role coal energy security report (Fisher, 2017:2)

The platinum mining organisation can mitigate their dependence on unreliable coal-fired power stations by implementing an alternative source of energy such as a solar PV plant. The benefit may be two-fold as the organisation will also benefit from a cheaper method of generating electricity coupled with independence from Eskom to generate electricity.

2.2. ALTERNATIVE SOURCES OF ELECTRICITY IN SOUTH AFRICA

Greenhouse gas (GHG) emissions have been increasing since the pre-industrial era. The last 40 years have seen the most GHG deposits into the atmosphere in history. Concentrations of CO₂, CH₄ and N₂O have been released into the atmosphere mainly by burning of non-renewable energy resources to generate electricity. Emissions of CO₂ from fossil fuel combustion contributed about 78% of the total GHG emissions increase from 1970 to 2010 as stated by Pachauri (2014:5). Increased use of coal has reversed the long-standing trend of gradual decarbonisation of the world's energy supply as illustrated by figure 2.3 and Appendix 2.

Figure 2.3: Global carbon dioxide emissions from fossil fuel burning by fuel type, 1900-2012



Source: Climate Change 2014: Synthesis Report (Pachauri, 2014:5)

South Africa is primarily powered by coal, as previously mentioned. Climate change and environmental responsibility have become a foremost influence on how a platinum mining organisation should be operated to reduce its carbon footprint, i.e. CO₂ emissions. The Carbon Tax White Paper has proposed a carbon tax of R120 per tonne carbon dioxide (CO₂) equivalent. This could result in an estimated additional price increase of 6%. It has been proven that large consumers such as the mining industry will change their consumption behaviour if the electricity price increases (Van der Zee, 2014:5).

The Carbon Tax Act (no. 15 of 2019) came into effect from 1 June 2019 in the Republic of South Africa (South Africa, 2019:20) and mining organisations have to report on their emissions. These emissions will be taxed and therefore creates additional financial pressure on the mining industry to reduce their carbon emissions.

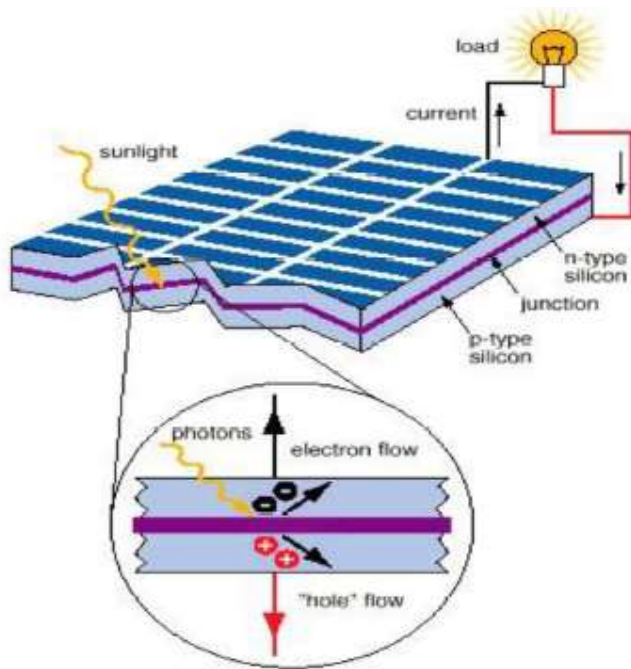
Mining organisations have the obligation to report their tier 2 emissions relating to the activity of consuming electricity generated from the burning of fossil fuels according to the Department of Environmental Affairs (2017:14). This is currently a threat for the mining industry but can be converted into an opportunity by implementing renewable energy as part of their portfolio. The risk of carbon taxes can be mitigated by utilising the renewable energy offset allowance provision within the act. The increased cost for electricity, impending carbon taxes and an increase in demand for electricity are the main reasons for the platinum mining organisation to seek an alternative method of generating electricity with a renewable energy source.

2.2.1. Sun as an alternative source of electricity

The sun consists of gases that are in constant fusion reactions which produce massive amounts of energy, and this energy radiates towards earth in the form of electromagnetic radiation. Once this energy reaches the earth's atmosphere, some of it is reflected back to space, some of it is scattered by clouds and particles present in the atmosphere while the rest reaches the earth's surface (Woodford, 2018:1).

Photo voltaic (PV) systems harness this energy (solar irradiation) to generate electricity through the photoelectric effect. During the photoelectric effect, photons are absorbed by semi-conductive materials and electrons are released in the process. A solar PV cell consists of a semi-conducting material that is specially treated to form an electric field, negative on one side and positive the other. When light strikes the cell, electrons are released from atoms, and if electrical conductors are attached to the negative and positive sides an electric circuit is formed as shown in figure 2.4.

Figure 2.4: Electricity generation using the photoelectric effect in solar cells



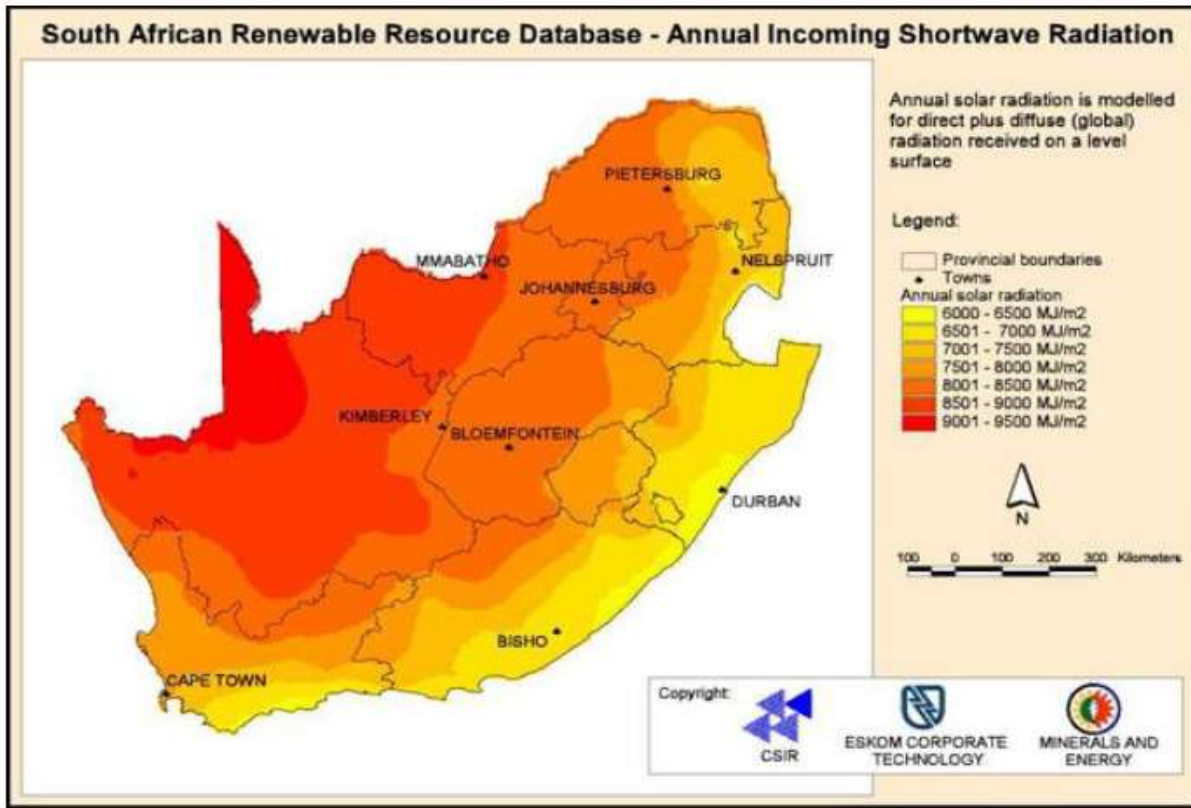
Source: Solar cells (Woodford, 2018:1)

South Africa benefits from more than 2 500 hours of sunshine annually. It is also paramount to note that South Africa receive between 4.5 and 6.5kWh/m² of shortwave radiation. This range is more than double of what Germany receives on an annual basis. Germany already generates 15% of its total electricity demand from solar PV technology (Van Wyk (2014:50).

Van Wyk (2014:50) further explains that South Africa benefits from sunshine all year round. South Africa's renewable energy resource of solar PV potential is among the highest in the world, where the average annual 24-hour solar irradiation of 220 W/m² is on offer.

Figure 2.5 illustrates the annual incoming shortwave radiation of South Africa which shows the potential South Africa has for solar PV technology, especially for the platinum mining industry situated in Rustenburg, North West province which receives between 8,001 – 8,500 MJ/m².

Figure 2.5: Annual incoming shortwave radiation for South Africa



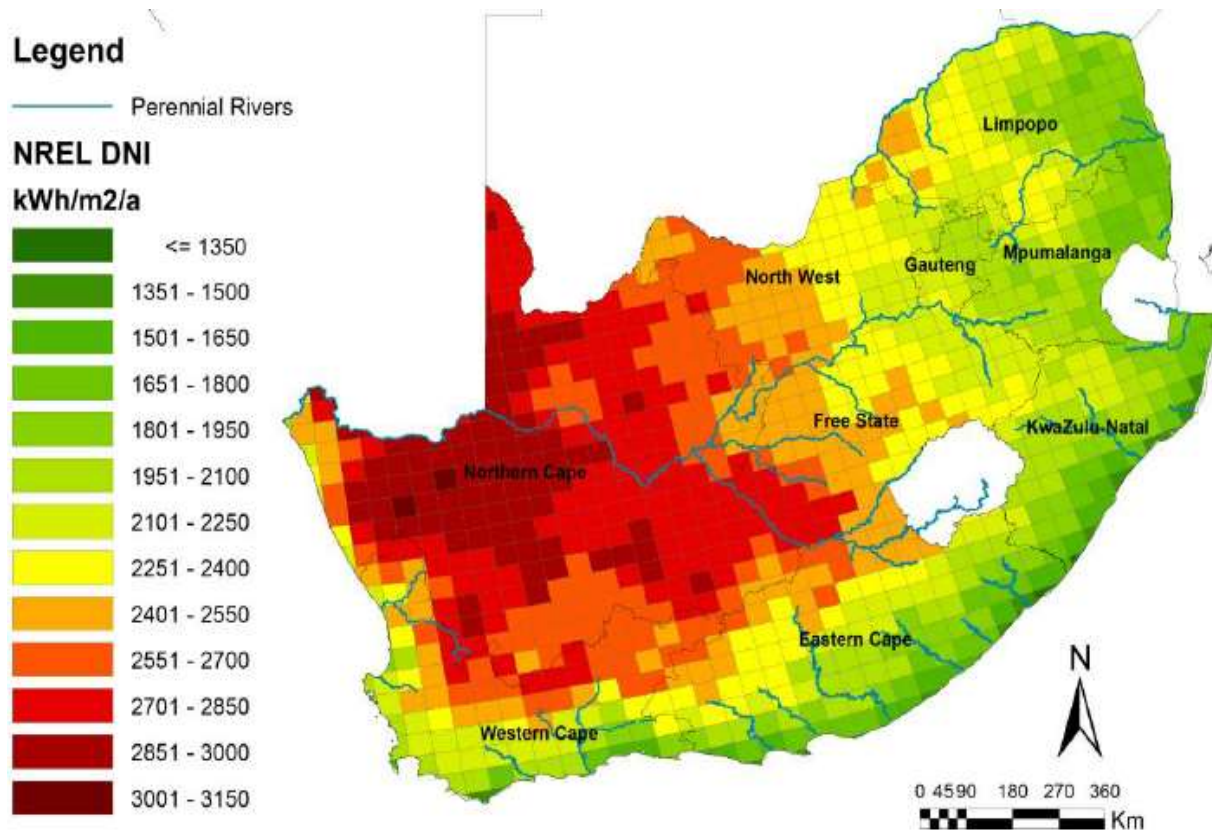
Source: Van Wyk (2014:51)

In addition to the 8,001 – 8,500 MJ/m² illustrated by figure 2.5, one can also calculate the kWh/m² that can be generated by utilising solar PV technology. Direct Normal Irradiance (DNI) is the amount of solar radiation received per unit area by a surface that is always held perpendicular (or normal) to the rays that come in a straight line from the direction of the sun at its current position in the sky.

Typically, you can maximise the amount of irradiance annually received by a surface by keeping it normal to incoming radiation. Direct Normal Irradiance (DNI) maps are utilised to calculate the kWh/m² at a specific point on the map.

The DNI map is a useful tool to test the feasibility of solar PV plants to produce the necessary renewable power to offset costs. The mining organisation in this particular study is situated in a position to receive between 1,951 – 2,400 kWh/m² as illustrated by figure 2.6.

Figure 2.6: Annual DNI-map of South Africa, including main perennial rivers.



Source: Van Niekerk (2017)

2.2.2. Wind as an alternative source of electricity

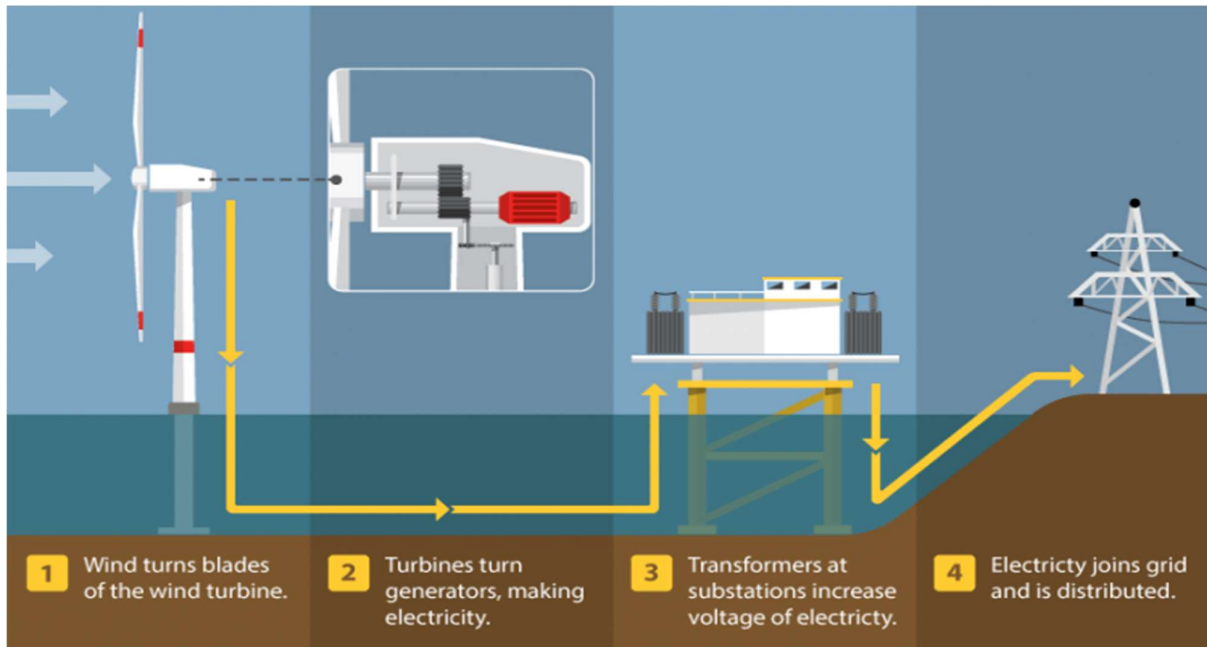
Wind as a source of renewable energy has also sparked interest in the last decade. Geographical positions where a vast amount of onshore wind is on offer is benefitting from this method of generating electricity.

83 countries around the world are utilising wind generation to supply power. Denmark, for example, generates more than 25% of its electricity from wind. Globally there are over two hundred thousand wind turbines operating, with a total nameplate capacity of 282 GW as of the end of 2012. In 2010, wind energy production was over 2.5% of the total worldwide electricity usage and growing rapidly at more than 25% per annum (Van Wyk, 2014:52).

Figure 2.7 illustrates the workings of a typical wind turbine. The wind turns the rotor in rotation. The “rotational energy” is then converted into electricity with the help of a generator,

similar to a bicycle dynamo. From there, the electrical energy goes into the power grid. The height of the system is very important. The larger the plant, the more uniform the wind blows and the more electricity can be generated.

Figure 2.7: Electricity generation using the power of wind

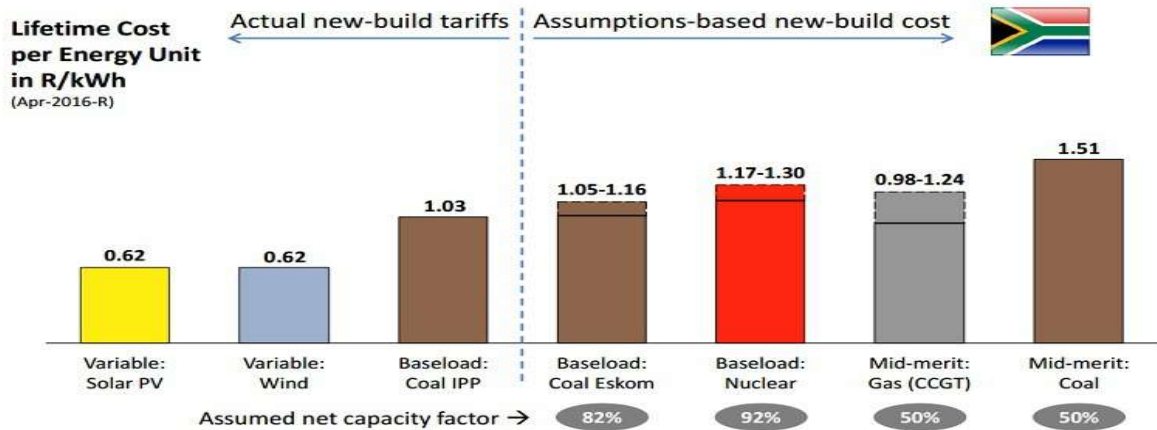


Source: Freeelectricity (2019)

2.2.3. Reasoning behind the choice of solar power as opposed to wind power in the study

Figure 2.8 illustrates that solar and wind technology has become vastly cheaper than conventional coal powered power plants (R1.03 per kWh). The primary reason to utilise solar PV technology rather than wind technology is the geographical position of the mining organisation. The company is based in the North West province, South Africa where wind resources are of limited availability as opposed to coastal provinces where onshore winds are vastly available. The position of the company is prime for utilising solar PV technology, and thus this method is deemed to be the most feasible option to explore in this study.

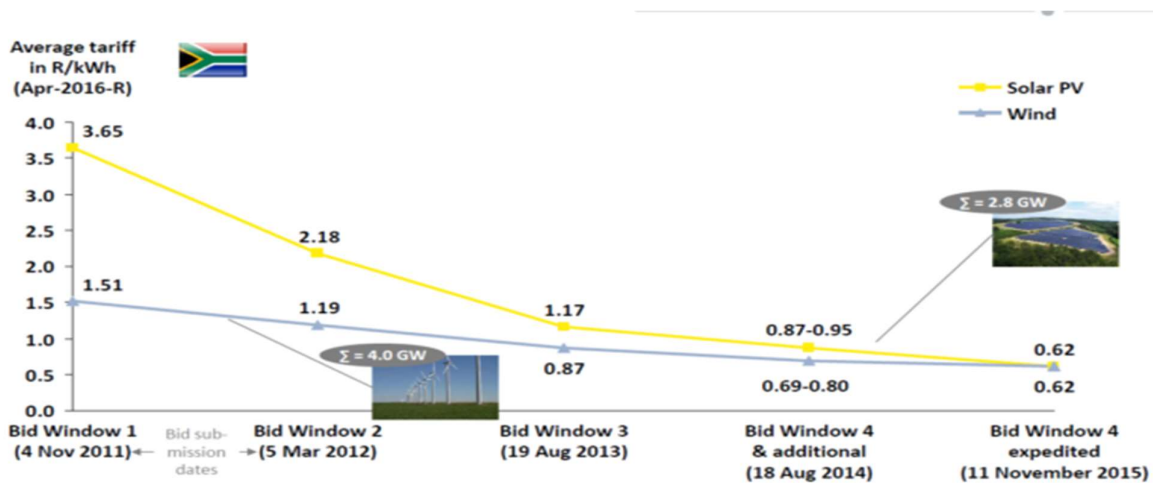
Figure 2.8: CSIR Energy Centre cost comparison for new electricity generation in South Africa in 2016



Source: RenewablesNow (2018)

Figure 2.9 illustrates that solar PV technology and wind technology has the same rate of generating renewable energy from April 2015 onwards (R0.62 per kWh).

Figure 2.9: Average tariff in R/kWh comparison between solar and wind electricity generation from 2011 to 2015



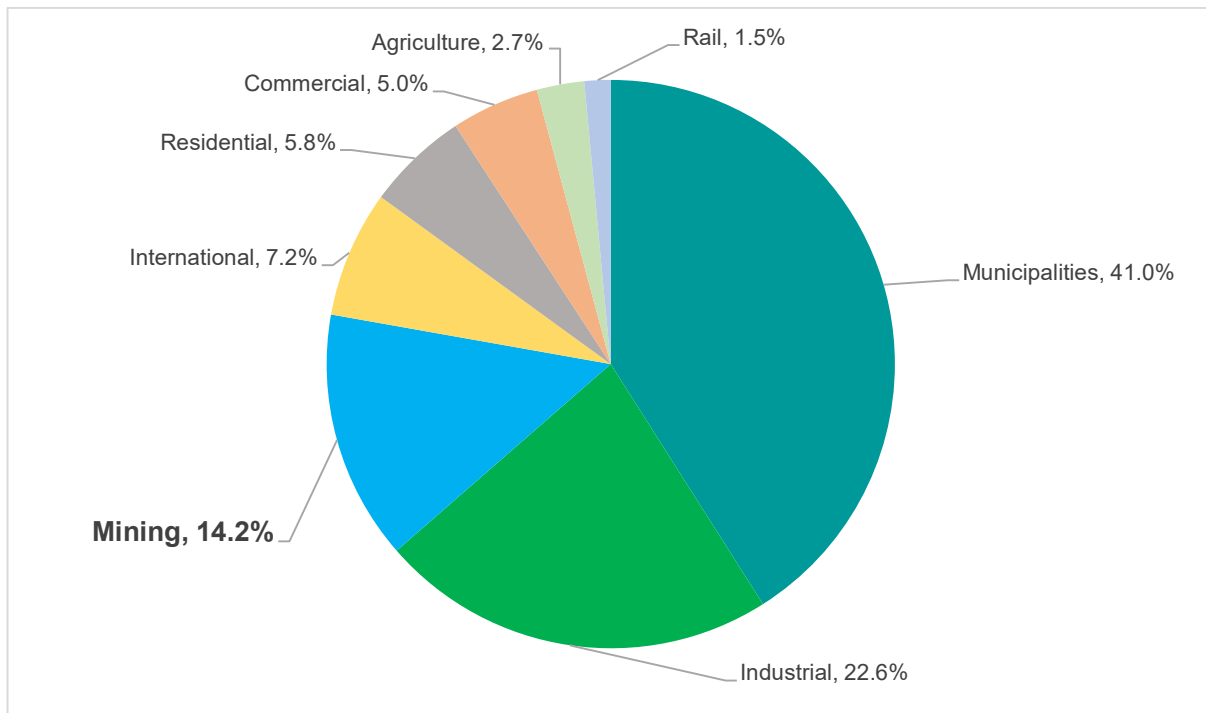
Source: Yelland (2016)

2.3. PROVISION OF ELECTRICITY IN THE MINING INDUSTRY

The electricity crisis of 2008 has changed the way platinum mining operations think about electricity and its implication on operations. The ever-increasing cost to power the platinum mining industry should be mitigated to keep the industry sustainable. Change is thus necessary for the platinum mining industry to survive and subsequently to thrive. A managerial dilemma has been established to seek alternative and independent methods of generating electricity within the platinum mining industry.

The South African economy is primarily based on mineral extraction and processing. Maré (2015:17) argued that mining processes consume some of the highest portions of energy in the country compared to other sectors. Hamer (2014:14) also stated that the mining industry consumes an estimated 15% of the total electricity supply in South Africa. The previous statement from Hamer still holds true as the mining industry is the 3rd largest consumer of electricity in South Africa according to Eskom (2018a:13), consuming an estimated 14.2% in 2018 as illustrated by figure 2.10.

Figure 2.10: Breakdown of Eskom's annual electricity sales per industry as at 31 March 2018



Source: ESKOM Integrated Report 31 March 2018 (2018a:13)

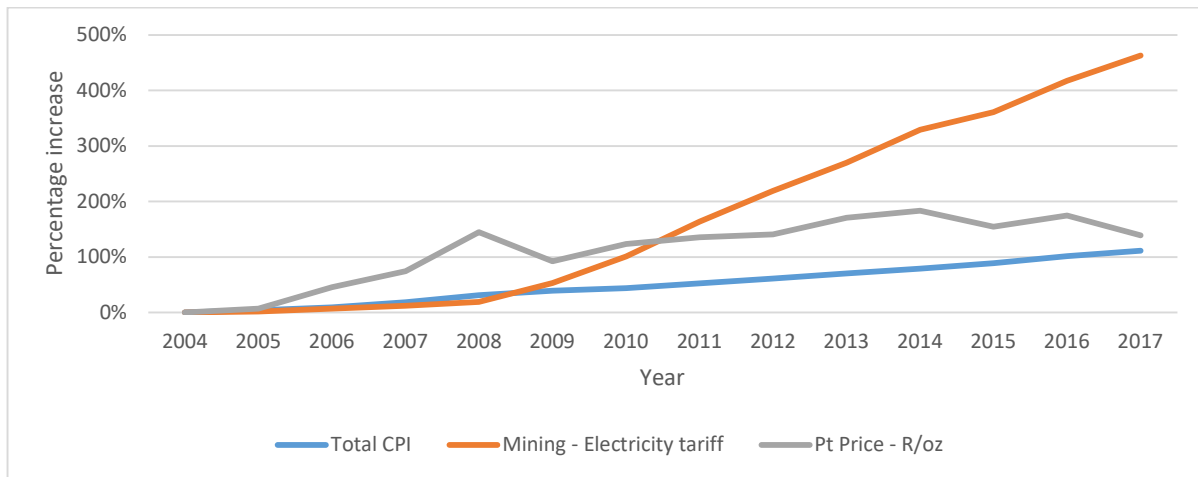
The continuous increase in the electricity tariff reduces the margin for profit as expenses increase. Sustainability is put under risk seeing that electricity is a substantial part of a platinum mine's operating expenses. Lower revenues also lead to a lower dividend distribution to shareholders and in turn diminishes the investment environment. These factors cause a snowball effect and ultimately pose a risk to the sustainability and feasibility for a platinum mining organisation to operate within the mining sphere. Platinum mining organisations have reverted to substantial cost cuts throughout their operations to alleviate the financial burden of increased electricity costs, but these cost cuts are not sustainable and place job security at risk. The platinum mining organisation has to look for an alternative method of generating electricity to alleviate the financial burden of increased electricity costs (Maré, 2015:5).

The higher price of electricity is evident by investigating the tariff increases versus inflation increases per annum. The electricity tariff increase was below inflation between 2004 and 2007. The electricity tariff has seen an exponential rise from the 2008 electricity crisis onwards according to Moolman (2016). Eskom has already applied for a 20% tariff increase for 2018 (as per Slabbert (2017) and more recently, a 30% tariff increase (Gous, 2018). The National energy regulator of South Africa (Nersa) has approved a 13.87% average price increase which has been implemented on 1 April 2019, but Eskom has appealed to have a higher percentage increase (Eskom, 2019).

This rise is well above inflation, and further increases are imminent as the national power provider is under significant financial pressure. South Africa's Eskom will ask local banks to reopen lending facilities that were suspended last year as the state utility seeks to drag itself out of a crisis that poses a risk to the country's financial stability (Reuters, 2018).

Furthermore, the price of platinum is on a downward trend. This implies that platinum is sold for less. Figure 2.11 and Appendix 3 both illustrate the comparison between the percentage increase in the Consumer Price Index (CPI), electricity tariff increases applicable to the mining industry and the price of platinum from 2004 to 2017. It paints a daunting picture of how CPI and the platinum price held parity, whereas the electricity increase has seen an exponential rise. The economic crisis of 2008 was a turning point in the South African economy.

Figure 2.11: Comparison of Electricity tariff, platinum price and CPI increase from 2004 to 2017

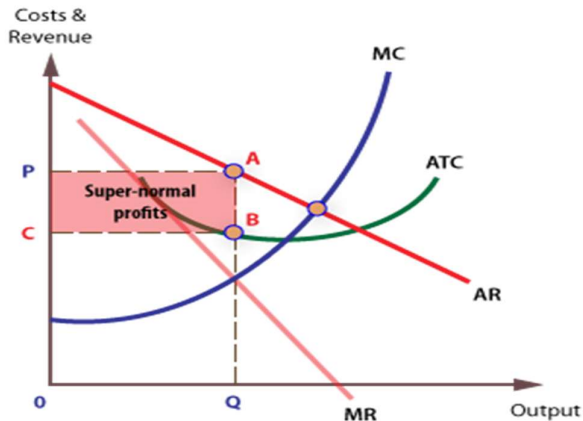


Source: Eskom tariff increases (Moolman, 2016)

The impending electricity crisis has been caused by the incapability of the national power provider to meet the demand for electricity. The damage of a power outage within the mining industry can be severe as evident by the recent power outage at a mining company in South Africa. According to Potgieter (2018:1), approximately 900 miners were trapped underground at the Beatrix gold mine in South Africa's Free State province as rescue operations commenced. These power outages cause economic, emotional and reputational damage to companies within the mining industry.

Furthermore, the national power provider provides a textbook case of a natural monopoly, which should not be allowed to maximise profit, as this leads to lower supply by cutting the maintenance budget and introducing higher prices as there are no alternatives to the power supply on a government level for companies to choose from. Monopolies can maintain super-normal profits in the long term as illustrated in figure 2.12. As with all firms, profits are maximised when $MC = MR$ where MC is marginal cost and MR is marginal revenue. In general, the level of profit depends upon the degree of competition in the market, which for a pure monopoly is zero. Eskom is regulated by NERSA, but can still ultimately bid for price increases where pure competition markets cannot. At profit maximisation, $MC = MR$, and output is Q and price P . Given that price / average revenue (AR) is above average total cost (ATC) at Q , supernormal profits are possible (area $PABC$) (Economicsonline, 2018).

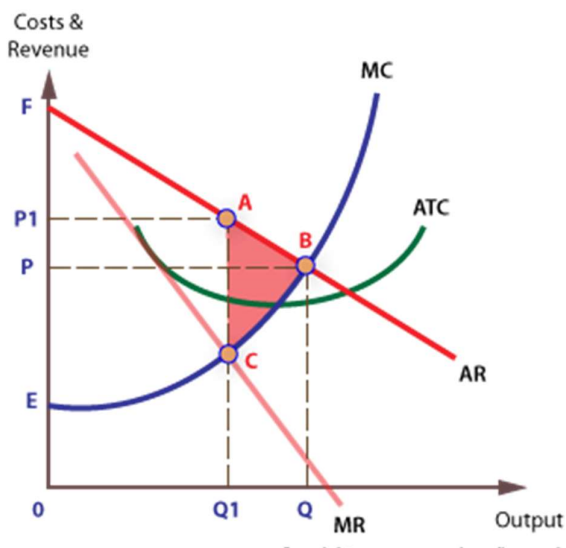
Figure 2.12: Super-normal profit of a monopoly in the long term



Source: Monopoly (Economicsonline, 2018)

Monopolies such as Eskom can charge higher rates to the mining industry due to a lack of competition. Figure 2.13 illustrates this lack of competition where a monopolist may charge a higher price (P_1) rather than a price which is set by supply and demand in a competitive market (P). The area of economic welfare under perfect competition is E, F, B. The loss of consumer surplus if the market is controlled by a monopoly is P, P_1 , A, B. The new area of producer surplus, at the higher price P_1 , is E, P_1 , A, C. Thus, the overall (net) loss of economic welfare is area A, B, C (Economicsonline, 2018).

Figure 2.13: Comparison of a monopoly versus a competitive market

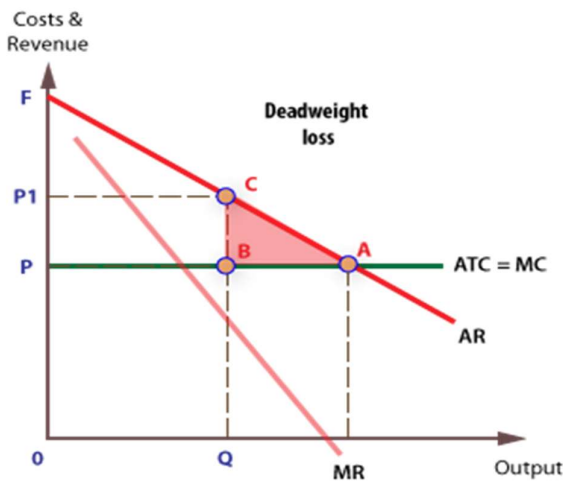


Source: Monopoly (Economicsonline, 2018)

The area of deadweight loss, as illustrated by figure 2.14, shows the inefficiency of a monopoly versus a competitive market.

The following diagram assumes that the average cost is constant and equal to marginal cost ($ATC = MC$). Under perfect competition, equilibrium price and output are at P and Q . If the market is controlled by a single firm such as Eskom controlling electricity in South Africa, equilibrium for Eskom is where $MC = MR$, at P_1 and Q_1 . Under perfect competition, the area representing economic welfare is P , F and A , but under monopoly the area of welfare is P , F , C , B . Therefore, the deadweight loss is the area B , C , A .

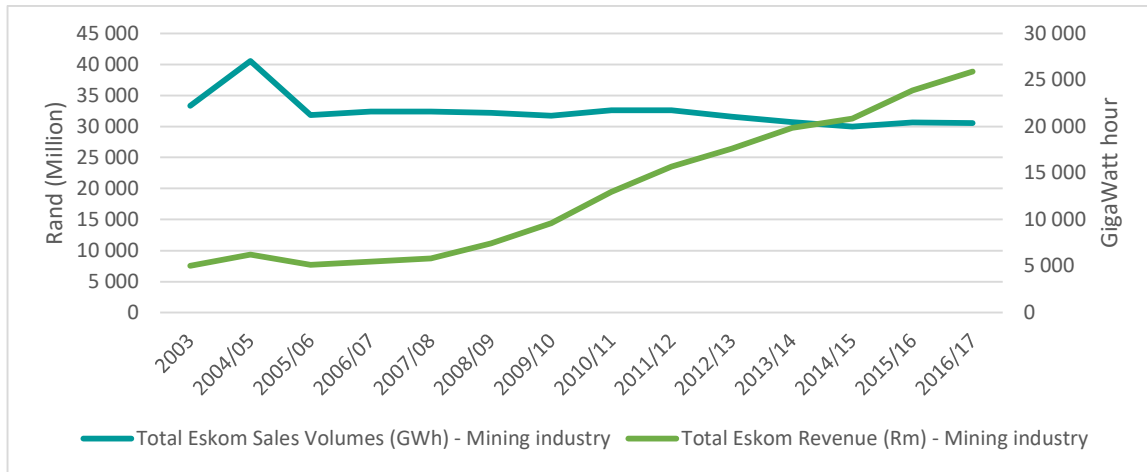
Figure 2.14: Deadweight loss of a monopoly due to a higher price



Source: Monopoly (Economicsonline, 2018)

The inefficiency of Eskom being run as a monopoly can practically be illustrated when comparing the total supply versus the revenue being generated from 2003 to 2017. Figure 2.15 exemplifies the fact that extra revenues are made by increasing prices, but the total supply has had a steady decline in the mining industry. One would expect supply to go up with demand, but lack of competition prohibits the need for Eskom to conform to economic forces bound to a competitive market.

Figure 2.15: Total Eskom revenue (Rm) vs Total Eskom supply (GWh) - Mining industry from 2003 to 2017



Source: Eskom tariff history (Eskom: 2018)

2.4. PREVIOUS RESEARCH ON COSTS OF CONVENTIONAL ELECTRICITY VERSUS COSTS OF SOLAR ELECTRICITY

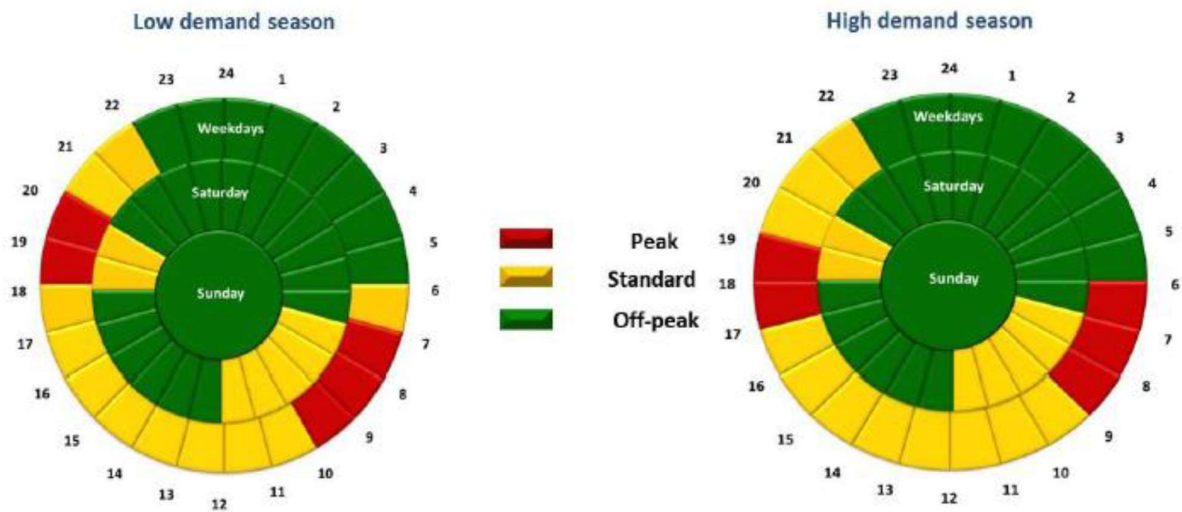
The primary driver for the development of the PV facility is to offset the electrical consumption from the Eskom network, especially during the winter months where the highest tariffs are applied. Table 2.3 and figure 2.16 below illustrates the Eskom Megaflex non-local authority tariffs and the associated tariff structure respectively, which applies to the platinum mining organisation. The time-of-use tariffs are divided into peak, standard and off-peak rates as well as summer (low demand) and winter (high demand) rates, which vary across weekday and weekend energy consumption. The effective increase in tariffs was 17.65% from 2016 to 2019 which raises a red flag towards sustainability.

Table 2.3: Eskom Megaflex time-of-use tariffs for 2019

Type	Tariff (cents/kWh)		Seasonal difference in tariffs
	Summer	Winter	
Peak	94.03	288.29	207%
Standard	64.73	87.34	35%
Off-peak	41.06	47.43	16%

Source: (Eskom, 2018b)

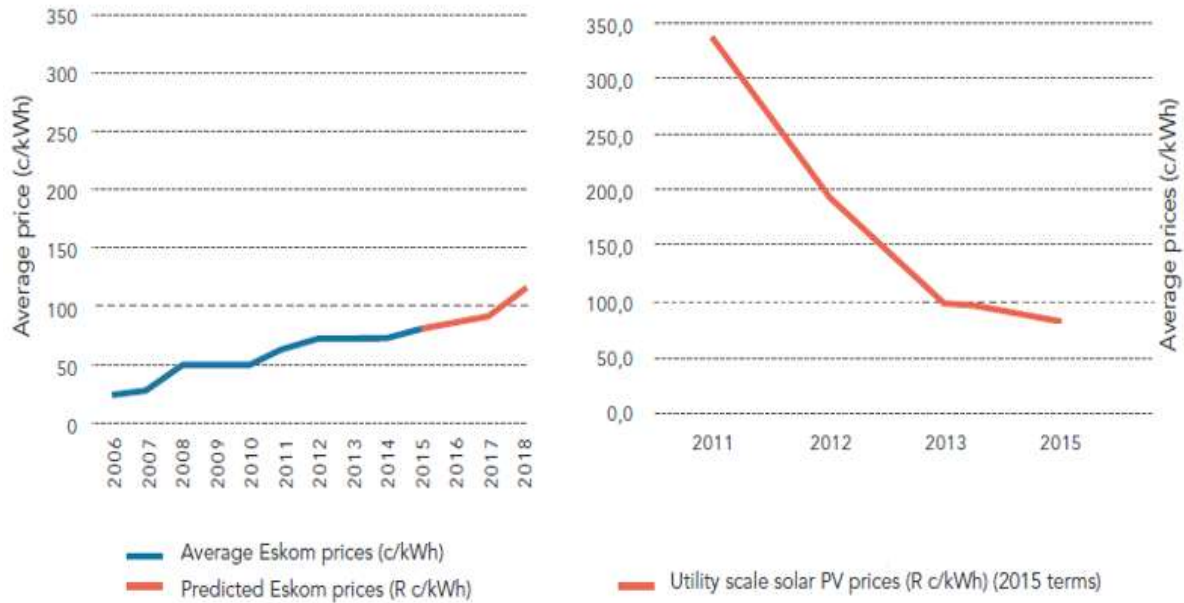
Figure 2.16: Eskom Megaflex time-of-use tariffs



Source: (Eskom, 2018b)

The following graph, figure 2.17 illustrates the increasing cost of conventional electricity generation versus the decreasing cost of solar PV technology electricity generation. The tipping point came in 2015 where it has been found that generating electricity by utilising solar electricity has become more feasible and reliable than generating electricity on the conventional method by burning fossil fuels.

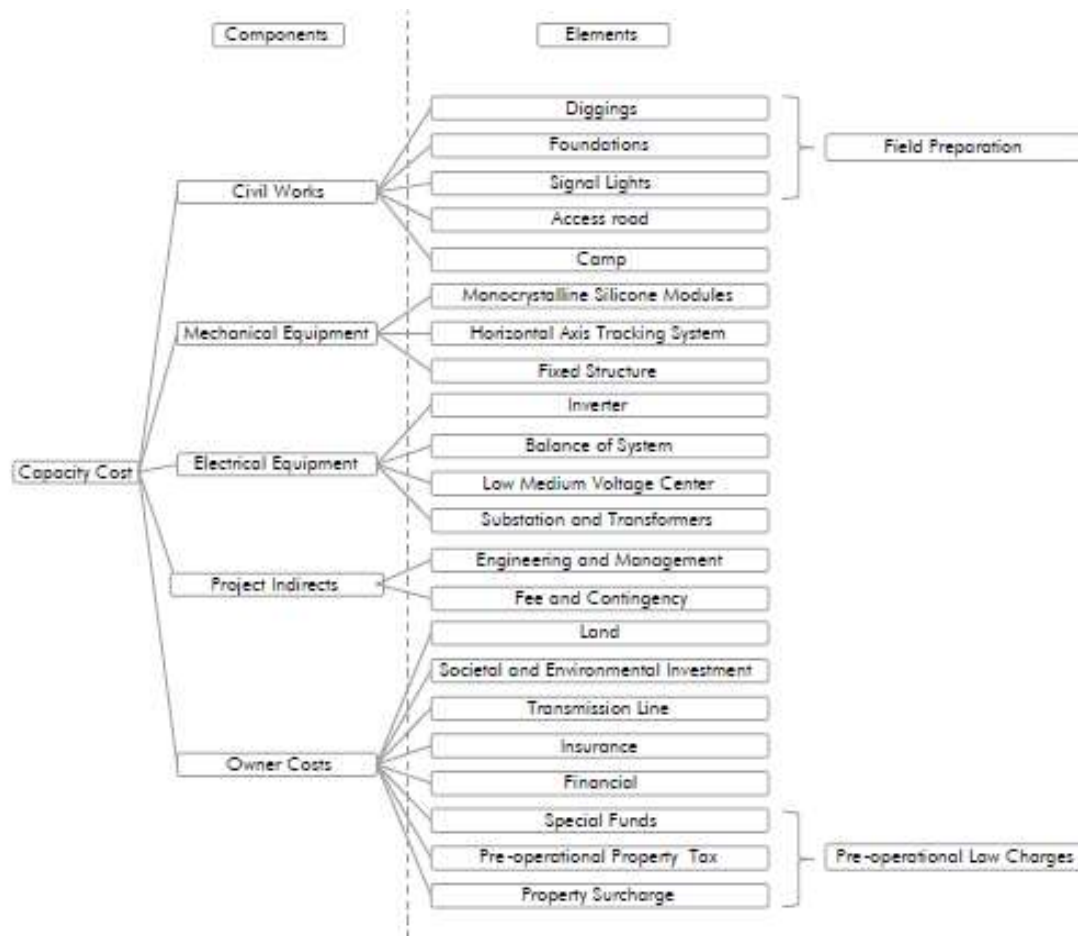
Figure 2.17: Costs of conventional electricity versus the costs of solar electricity



Source: (GreenCape, 2016)

Figure 2.18 shows the typical capital expenditure required to install and implement a PV plant. These amounts vary throughout various regions and have to be investigated within the scope of this study to calculate the estimated costs of capital and operational expenditures inherent to a PV plant.

Figure 2.18: Flow diagram to illustrate costs pertaining to the implementation of a PV plant



Source: (Ramirez, 2017)

2.5. SUMMARY

From the abovementioned literature study one can conclude that South Africa and the underlining mining industry are still extremely dependent on Eskom to provide electricity. The exponential increase in electricity tariffs coupled with the diminishing lifespan of coal fired power plants place the sustainability of mining companies in jeopardy. Alternative sources of energy such as solar photo voltaic power plants are becoming viable options to alleviate the burden of a disrupting power supply coupled with exponential tariff increases in South Africa.

The next chapter includes the empirical study illustrating the clean electricity generation potential of the solar plant coupled with the relevant cost for the implementation of the solar plant.

CHAPTER 3

3. EMPIRICAL STUDY

This chapter includes the quantitative data collection methods and observations made in terms of the relevant sample for this study. The collection of data was included in this chapter where the findings of the relevant data were made available to find a solution for the problem. The methodology of identifying constraints in terms of costs and finding solutions in terms of benefits was explored in detail.

3.1. ELECTRICITY GENERATION THROUGH A SOLAR PV PLANT

Figure 3.1 below shows examples of an existing horizontal single-axis tracking system (0° tilt) and a tilted single-axis tracking system (30° tilt) respectively, which were investigated in this study.

Figure 3.1: Example of a horizontal single-axis tracking

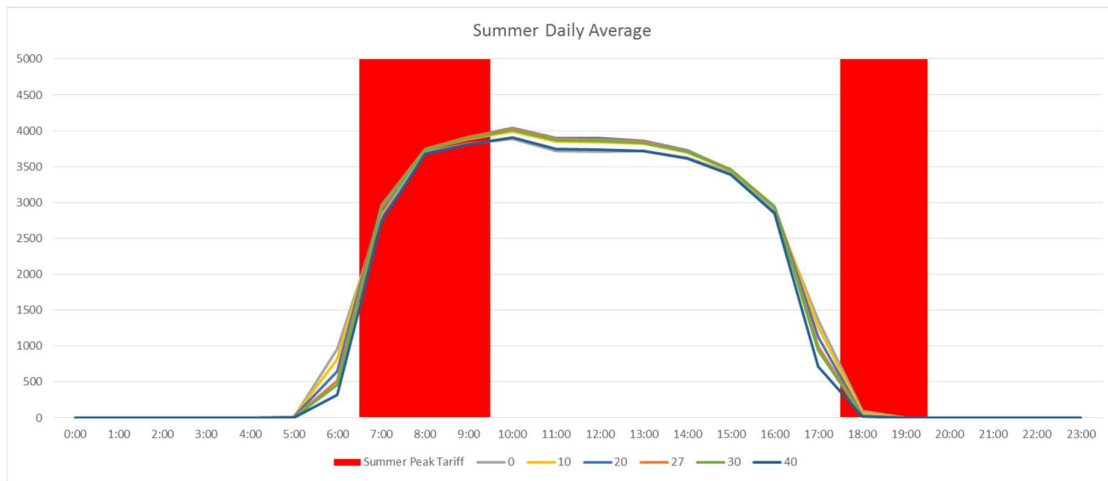


Source: (solarprofessional, 2018)

Figure 3.2 shows the average daily summer yield simulated over a year for the tracking system with varying tilt angles. These yield results cover a period of 9 months from September 2017 to May 2018. The graph also indicates the summer peak tariff periods over a week day shown in red from 7 am to 9 am and then from 6 pm to 8 pm.

The results show that lower tilt angles for tracking systems provide a higher daily yield during summer days than the larger tilt angles ($>30^\circ$). Furthermore, the yield profiles for all tilt angles caters for energy production over the summer morning peak tariff profile as well as a small portion of the summer evening peak tariff.

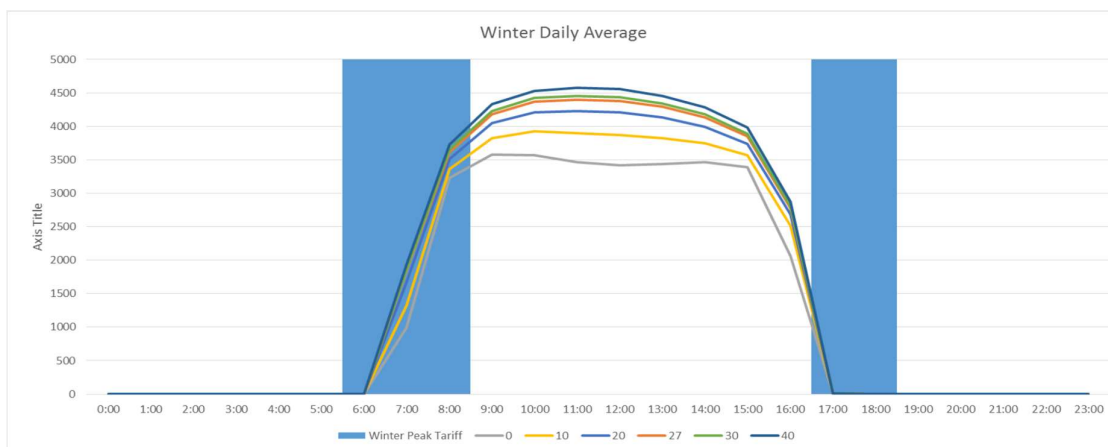
Figure 3.2: Summer daily average solar PV electricity generation



Source: (solarprofessional, 2018)

Figure 3.3 shows the average daily winter yield simulated over a year for the tracking system with varying tilt angles. These yield results cover a period of three months, from June to August. The graph also indicates the significantly higher winter peak tariff periods, shown in blue from 6 am to 8 am and then from 5 pm to 7 pm during the week. The results clearly show that a single-axis tracking system with larger tilt angles yields a substantially higher daily energy production in winter compared to the base case tilt angle. This finding is aligned with the aim of this study, where the focus is to increase winter energy production from the PV facility to offset the high winter tariffs.

Figure 3.3: Summer daily average solar PV electricity generation



Source: (solarprofessional, 2018)

The winter yield results indicate that for the simulated tracking systems, where the tilt angle is north facing, a large portion of the morning winter peak tariff period and only a minor portion of the afternoon winter peak tariff period is catered for.

The PV facility in this study will be constructed in a nominal 54 MW system. Table 3.1 below describes the overall system design characteristics of a total 54 MW PV facility.

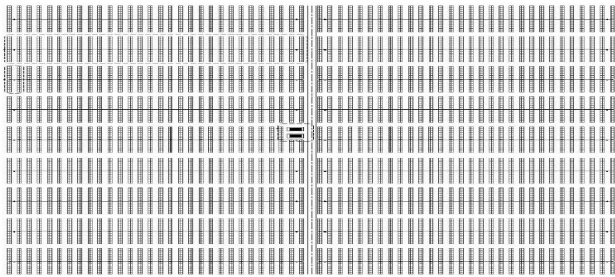
Table 3.1: System design Characteristics of a 54 MW PV Facility

System Design Characteristics	54 MW PV Facility
Nominal DC Capacity (MW)	58
Inverter Capacity (MW)	54
Number of PV Modules	181 104
Number of Inverters	24
Modules per String	28
Row Pitch (m)	5

Source: GreenCape (2016)

To simplify the design and construction of the PV plant, the facility has been divided into modular 4.829MWp inverter blocks, consisting of 18 single-axis tracker array blocks and two inverter-transformer stations. These stations are shown by the two black rectangles at the centre of the block in figure 3.4 below. Each inverter block is made up of 539 strings, which is based on 30 strings per tracker array; however, one array has one less string due to space for the inverter stations. The inverter blocks have also accounted for adequate internal roads to enable maintenance and cleaning of the tracker substructures, tracker actuators and PV modules. The total dimensions of each inverter block, including the servitude for internal roads, are 301m by 294m.

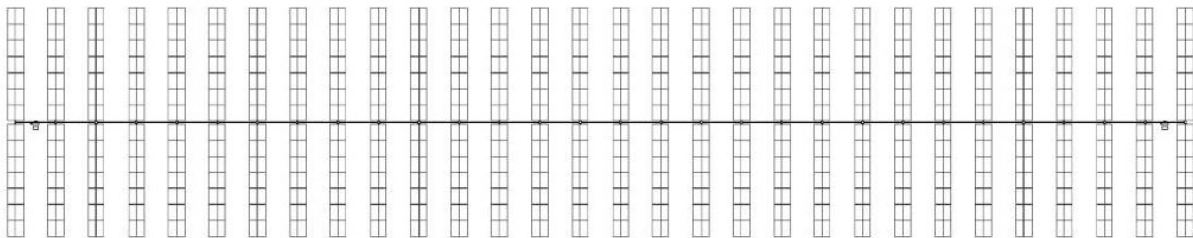
Figure 3.4: Typical 4.829 MW inverter block



Source: Wegenève (2019)

Each tracker array makes up the building blocks of the inverter block shown above, by grouping together a number of horizontal (0° tilt angle) single-axis tracking tables into one unit. A single tracker array consists of 30 strings driven by two actuators. The pitch between each tracker table is designed to be 5.0m. Each string contains 28 modules, where 14 modules are on either side of the drive axis, resulting in 840 modules per tracker array. A typical 268.8kWp tracker array is shown in figure 3.5 below, with a length of 147m and a width of 28.1m.

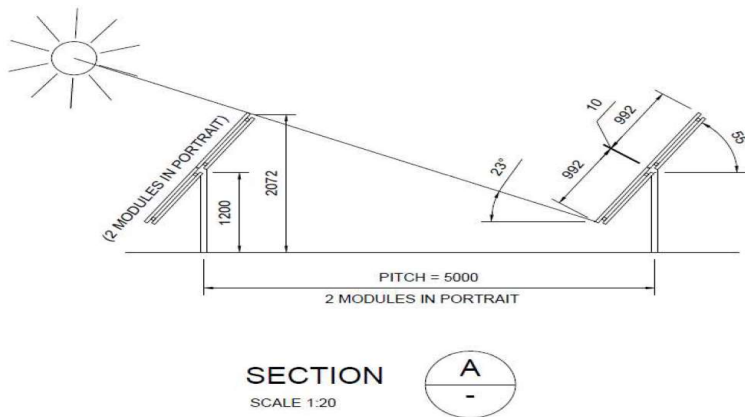
Figure 3.5: Typical 268.8kWp tracker array design



Source: Wegenève (2019)

Figure 3.6 below shows the profile of consecutive tracker tables, where each table has two modules in landscape orientation. The designed spacing between the modules (pitch of 5.0m) is based on a 23° shading limit angle design and discussions with local tracker substructure suppliers. The support of each tracker table is at a height of 1.2m, which raises the highest point of the module to 2.07m above ground when the table is at its maximum tilt of 55° . The available space for operations and maintenance between the tracker tables is 3.0m. This allows for a maintenance vehicle to move between the tracker tables.

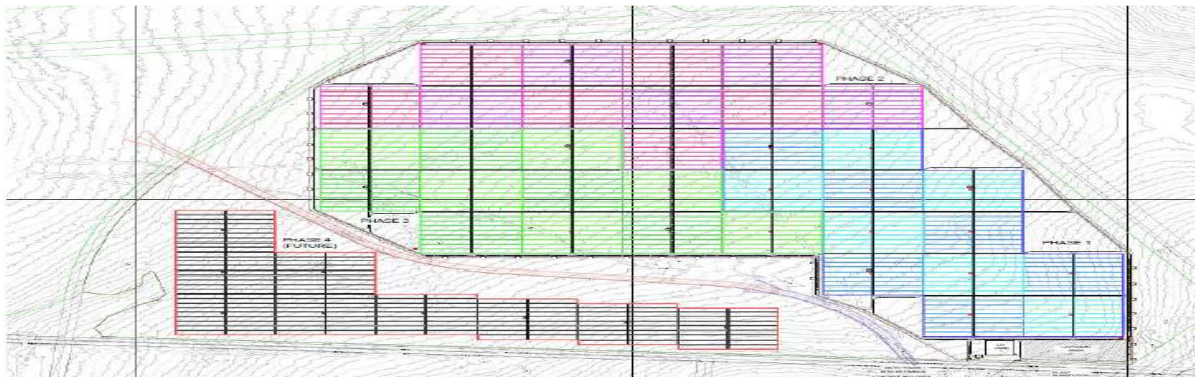
Figure 3.6: Profile of tracker tables (dimensions in mm)



Source: Wegenève (2019)

Figure 3.7 below shows the PV facility site layout design within the available land area at the site, which is bound by its dedicated perimeter fence. The design shows the proposed phasing of the facility as well as the layout of the site electrical infrastructure for the planned electrical interconnection. This study is only focused on the first phase of installing and implementing a 54MW PV plant shown in blue below.

Figure 3.7: PV facility site layout



Source: Wegenève (2019)

3.2. PV YIELD BENEFITS AND METEOROLOGICAL ASSESSMENT

Meteonorm V7 was used to calculate the solar resource for the ground mounted PV facility and compared to the solar resource values from NASA-SSE, PVGIS-Helioclim and PVGIS-SAF databases. Meteonorm data is gathered by interpolating results from records of the

nearest weather stations, and using satellite data where weather station records are not available. NASA-SSE, PVGIS-Helioclim and PVGIS-SAF data are sourced from satellite records (Meteotest, 2019).

The periods over which solar weather data has been gathered for each source is as follows:

- Meteonorm: 1986 - 2005
- NASA-SSE: 1983 - 2005
- PVGIS-Helioclim: 1985 - 2004
- PVGIS-SAF: 1998 - 2005 and 2006 - 2010

Annual Global Horizontal Irradiation (GHI) data has been gathered for the project location from the Meteonorm V7 data source, which has been validated by comparing the data with NASA-SSE, PVGIS-Helioclim and PVGIS-SAF weather data sources. The comparison between the four data sources is shown in table 3.2.

Table 3.2: Comparison of Meteonorm, PVGIS-SAF, NASA-SSE and PVGIS Helioclim annual global horizontal irradiation data

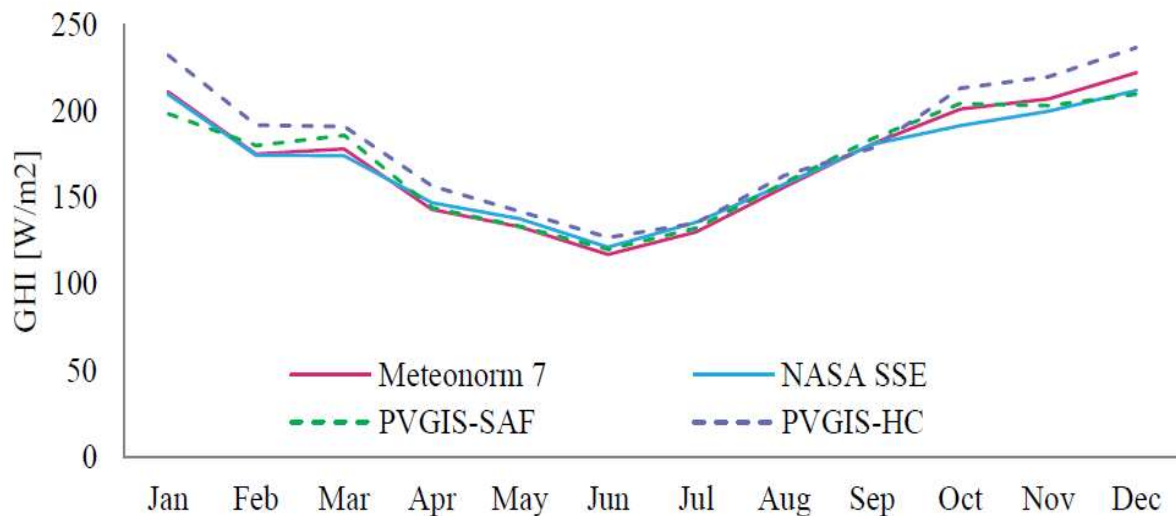
Global Horizontal Irradiation (kWh/m2/period)							
Date	Meteonorm 7	PVGIS- SAF	Diff (%)	NASA SSE	Diff (%)	PVGIS- HC	Diff (%)
Jan	211	198	6.16%	210	0.47%	232	-9.95%
Feb	175	180	-2.86%	174	0.57%	192	-9.71%
Mar	178	186	-4.49%	174	2.25%	191	-7.30%
Apr	143	144	-0.70%	147	-2.80%	157	-9.79%
May	133	133	0.00%	138	-3.76%	142	-6.77%
Jun	117	120	-2.56%	121	-3.42%	127	-8.55%
Jul	130	132	-1.54%	136	-4.62%	135	-3.85%
Aug	156	158	-1.28%	158	-1.28%	163	-4.49%
Sep	181	184	-1.66%	181	0.00%	179	1.10%
Oct	201	204	-1.49%	192	4.48%	213	-5.97%
Nov	207	203	1.93%	200	3.38%	220	-6.28%
Dec	222	210	5.41%	212	4.50%	237	-6.76%
Total	2054	2052	0.10%	2043	0.54%	2188	-6.52%

Source: Meteotest (2019)

It can be seen that the value for the annual global horizontal irradiation provided by Meteonorm is within 0.10% of PVGIS-SAF, 0.54% of NASA-SSE, and 6.52% of PVGIS-Helioclim data. These differences are within a reasonable range and the Meteonorm data is thus considered appropriate to be used for the long-term yield simulation (Meteotest (2019)).

This is confirmed in figure 3.8, shown below, which shows that the Meteonorm data closely tracks the PVGIS-SAF and NASA-SSE sources, except towards the end of the year, where the Meteonorm data is not as conservative as the other two sources. The PVGIS-Helioclim data tracks the other data sources for a short period during July and October; however, it is less conservative for the rest of the year, owing to its higher resource assessment.

Figure 3.8: Comparison of monthly irradiance data



Source: (Meteotest, 2019).

The data parameters from the previous sections were used to generate an annual yield forecast in MWh utilising the PVSyst software resource available within the mining organisation. The 20-year generation forecast, table 3.3, has been generated using Meteonorm weather data with PVSyst v6.42 software. The performance of the solar modules has been adjusted for every year, and the results have been used to generate the probability of yield for the scenario. The annual yield forecast generated by PVSyst accounts for a total plant and grid availability of 98%, which includes the initial PV module degradation effects.

Table 3.3: Twenty-year yield forecast for the 54 MW PV facility

Year of Operation (End of Year)	Annual Yield (MWh/Year)
Year 1	126 826
Year 2	126 317
Year 3	125 808
Year 4	125 298
Year 5	124 789
Year 6	124 280
Year 7	123 770
Year 8	123 261
Year 9	122 752
Year 10	122 242
Year 11	121 733
Year 12	121 224
Year 13	120 714
Year 14	120 205
Year 15	119 696
Year 16	119 186
Year 17	118 677
Year 18	118 168
Year 20	117 149

Source: Meteotest (2019)

Table 3.3 effectively illustrates that a total of 2,439,753 MWh is on offer over a twenty-year period for a 54 MW solar PV plant. The solar PV plant can function for more than the nameplate twenty-years and will still yield positive energy generation if properly operated and maintained. This study, however, caps the plant at 20 years for comparison reasons.

The benefit of saving the 2,439,753 MWh mentioned above is three-fold. Firstly, the exponential increase of Eskom's R/kWh is mitigated due to a decrease in actual kWh used throughout the twenty-year period. Secondly, the imminent carbon taxes on using electricity generated by the burning of fossil fuels is mitigated as electricity is generated by utilizing renewable energy methods. Thirdly, the unreliability of Eskom to supply the necessary electricity is mitigated. The mining organisation will for the first time be in control of some of their electricity needs and could ensure a stable electricity flow to their operations. This is the first step to independence and sustainability.

3.3. COST OF ELECTRICITY UTILISING CONVENTIONAL METHODS

Table 3.4 below shows the total kWh used and corresponding costs in Rand for the mining organisation in 2018. One can clearly see the effective rate tariff increase for the winter months of June, July and August. The total average rate was R0.91/kWh. This rate is still above the current R0.62/kWh of implementing a solar PV plant. The conventional rate is also not cast in stone as the ominous annual electricity increase is experiencing exponential growth. The current outlook is that electricity tariffs will increase by 9% per annum on a real basis. The Eskom electricity bill issued in June 2018 can be viewed in Appendix 4.

The total active energy usage is split between standard, peak and off-peak times. Each of these categories attracts a certain R/kWh rate set by Eskom. The mining organisation is set at the megaflex rates. Megaflex tariff energy rates are differentiated seasonally, per time-of-use (TOU) period, by transmission zone, and by voltage group according to Mahony (2018).

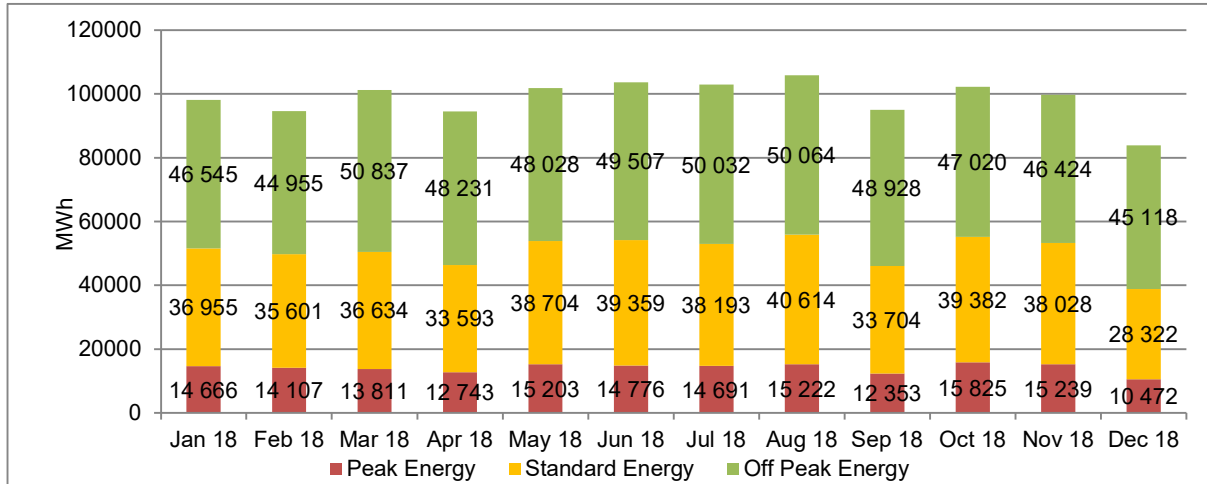
Table 3.4: Electricity usage and costs for the mining organisation for 2018

Date	Standard Energy (kWh)	Peak Energy (kWh)	Off Peak Energy (kWh)	Total Active Energy (kWh)	Total Spend (Rands)	Effective rate Tariff (R/kWh)	Variable rate Tariff (R/kWh)	Variable cost (Rands)	Fixed cost (Rands)
Jan-18	36 955 432	14 665 585	46 544 586	98 165 603	76 103 646	0.78	0.67	65 900 398	10 203 248
Feb-18	35 600 784	14 107 423	44 954 862	94 663 069	74 049 498	0.78	0.68	64 205 431	9 844 066
Mar-18	36 634 028	13 811 086	50 836 767	101 281 881	77 202 672	0.76	0.66	66 689 354	10 513 318
Apr-18	33 592 966	12 742 899	48 230 691	94 566 556	76 513 673	0.81	0.70	65 900 516	10 613 157
May-18	38 703 662	15 202 793	48 027 869	101 934 324	82 934 871	0.81	0.70	71 525 196	11 409 675
Jun-18	39 358 524	14 775 958	49 507 030	103 641 513	124 783 281	1.20	1.09	113 193 658	11 589 623
Jul-18	38 193 397	14 691 249	50 032 470	102 917 116	129 536 064	1.26	1.15	118 020 641	11 515 423
Aug-18	40 613 980	15 222 192	50 064 389	105 900 560	127 876 575	1.21	1.10	116 040 132	11 836 443
Sep-18	33 703 798	12 353 085	48 927 682	94 984 565	76 554 237	0.81	0.69	65 896 103	10 658 135
Oct-18	39 382 208	15 825 389	47 019 658	102 227 255	83 643 692	0.82	0.71	72 202 497	11 441 194
Nov-18	38 027 617	15 238 505	46 424 001	99 690 123	81 677 814	0.82	0.71	70 513 361	11 164 453
Dec-18	28 321 846	10 472 192	45 118 039	83 912 076	68 114 874	0.81	0.70	58 644 393	9 470 481
Total				1 183 884 641	1 078 990 895	0.91	0.80	948 731 679	130 259 216

Source: Internal documents from mining organisation (Name of the mining organisation withheld on request)

Figure 3.9 below illustrates the MWh utilised by the mining organisation for 2018. The MWh is split between standard, peak and off-peak times per month.

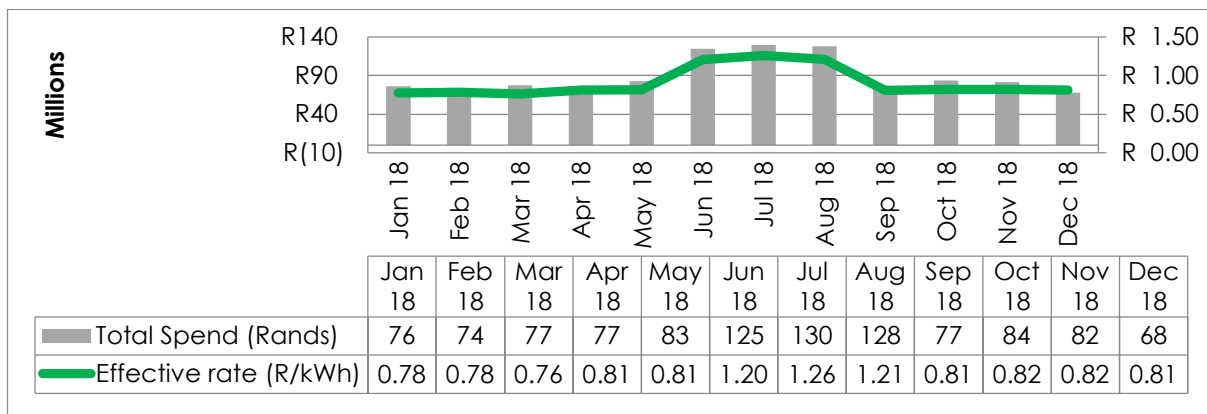
Figure 3.9: Total active electricity usage for the mining organisation for 2018



Source: Internal documents from mining organisation (Name of the mining organisation withheld on request)

Figure 3.10 further illustrates the costs incurred for electricity and the corresponding effective R/kWh. The mining organisation used 1,183,884 MWh which costed them R 1,078,990,895 in 2018. It is thus evident that electricity is one of the most substantial expenses for the mining organisation.

Figure 3.10: Electricity spend and effective rate for the mining organisation for 2018



Source: Internal documents from mining organisation (Name of the mining organisation withheld on request)

Figure 3.11: Electricity cost composition for the mining organisation for 2018

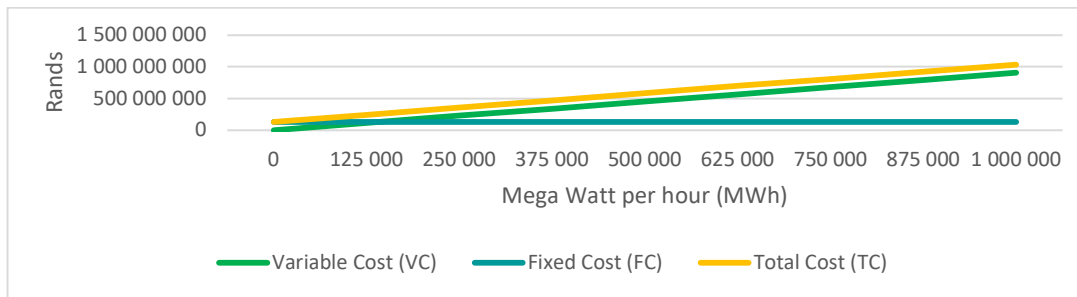


Figure 3.11 illustrates the cost composition of electricity for the mining organisation in 2018. It is necessary to break down the cost in its variable and fixed portions to understand where saving initiatives can occur. The solar PV technology will have an impact on both the variable and fixed portions of the electricity costs within this study.

3.4. COST OF ELECTRICITY UTILISING SOLAR ELECTRICITY

3.4.1. Capital expenditure

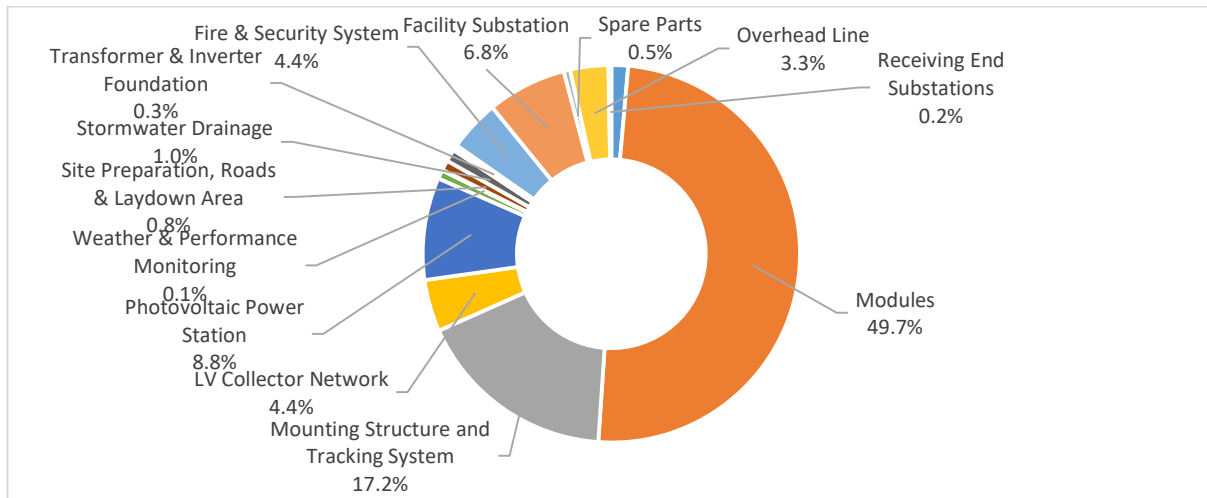
Table 3.5: Estimated capital cost to install and implement a 54 MW PV facility

Description	Reference	Amount (ZAR)
Preliminaries and General	Appendix 5	R 13 110 000
Modules	Appendix 6	R 452 487 620
Mounting Structure and Tracking System	Appendix 7	R 156 746 352
LV Collector Network	Appendix 8	R 40 491 989
Photovoltaic Power Station	Appendix 9	R 79 883 678
MV Collector Network	Appendix 10	R 6 724 576
Weather & Performance Monitoring	Appendix 11	R 755 000
Site Preparation, Roads & Laydown Area	Appendix 12	R 7 676 766
Storm water Drainage	Appendix 13	R 9 561 186
Trenches	Appendix 14	R 655 053
Transformer & Inverter Foundation	Appendix 15	R 2 461 050
Control Building	Appendix 16	R 1 256 002
Fire & Security System	Appendix 17	R 40 005 490
Facility Substation	Appendix 18	R 62 000 000
Spare Parts	Appendix 19	R 5 000 000
Overhead Line	Appendix 20	R 29 886 504
Receiving End Substations	Appendix 21	R 2 156 654
Total (Exclusive of VAT)		R 910 857 920

Source: Quote from supplier (Name of the supplier withheld on request)

The capital outlay of implementing a solar PV plant is quite extensive and expensive as illustrated by table 3.5. A capital investment of R910,857,920 is required to successfully install and commission a 54 MW solar PV plant. A detailed schedule of capital costs can be viewed from Appendix 5 to Appendix 21. Figure 3.12 illustrates the cost breakdown for the necessary components in percentages.

Figure 3.12: Detailed cost breakdown of a 54 MW PV facility



The bulk of the cost is allocated for the modules (49.7%). The second largest cost is allocated to the mounting structures and the tracking system (17.2%). It is imperative not to isolate the capital cost without having operational and maintenance cost in mind. The plant will only perform at the designed specifications if it is well maintained. Thus, there are also provisions made for operational and maintenance expenditure as per GreenCape (2016).

3.4.2. Operational and maintenance expenditure

Weekly Maintenance

The anticipated weekly maintenance activities which should be performed at the PV plant are detailed in table 3.6 below. The maintenance activities will be done by the operational and maintenance personnel.

Table 3.6: Weekly maintenance activities

PV Plant Component	Maintenance Activity
Reference Cells and Pyranometers	Clean and make sure they are in place at the correct angle/orientation
	Visual inspection of temperature sensors

Source: Wegenève (2019)

Monthly Maintenance - The monthly maintenance activities which should be performed at the PV plant are detailed in table 3.7 below.

Table 3.7: Monthly maintenance activities

PV Plant Component	Maintenance Activity
Modules	Check for broken glass or major occurrences of discoloration, bubbling of encapsulate, warpage, etc.
	DC wiring and junction box connections secured and contained as intended; no loose cables, no connectors dipped in water puddles
	Torque testing of mounting hardware
	Cable fastening inspection
	Visual inspection of module junction boxes for discolouration or evidence of thermal effects
	Voltage and current testing of strings
	IV curve tracing for strings
AC and DC Electrical Equipment	Check the condition of Conductors, Connectors, Enclosures, Switchgear and fuses
Inverter Components	Check for Integrity of wiring and terminals, No unusual noises, Controls and LCD screen operation, Cooling fans and Intake air ducts
	Torque testing of wiring components
Communications / Monitoring Equipment	Data storage testing to ensure proper recording
	Meter calibration
	Electrical connections testing
Inverter	Clean or replace intake and exhaust air ducts and filters
	Cleaning fans
	Clean electrical components
	Clean power components heat sinks
	Clean inverter cabinet and check for moisture
	Measure efficiency of DC/AC conversion
	Check settings and MPPT functionality
	Controls and LCD functionality

Table 3.7 (Continued)

PV Plant Component	Maintenance Activity
Mounting Structures	Check for any deformation
	All fasteners secure and in place
	Secure fixing of modules- check for misaligned modules as evidence of slip
	Maintenance of actuator
Site	Check and remove any high vegetation that may cause shading for the modules

Source: Wegenève (2019)

The operational and maintenance expenditure is estimated to be R 1,500,000 per annum and the amount will increase annually in line with CPI set at 6% for this study.

3.5. COST OF CARBON TAX

Carbon taxes are based on the tons of CO₂ that are emitted by generating electricity via means of burning fossil fuels. The tonnes of CO₂ in table 3.8 are calculated based on total electricity sales by Eskom, which is based on the total available for distribution (including purchases), after excluding losses through transmission and distribution (technical losses) and losses through theft (non-technical losses). Thus, to calculate CO₂ emissions, divide the quantity of CO₂ emitted by the electricity sales: 205.5Mt of CO₂ ÷ 212,190 GWh sales = 0.97 tons per MWh.

Table 3.8: Estimated carbon tax payable by the mining organisation in 2018

Date	Total Active Energy (kWh)	Total Active Energy (MWh)	tCO ₂ /MWh	tCO ₂ e	Carbon tax rate Rand per tCO ₂ e	Carbon tax payable in Rand
	A	A / 1000 = B	C	B X C = D	E	D X E = F
Jan 18	98 165 603	98 166	0.97	95 221	120	11 426 476
Feb 18	94 663 069	94 663	0.97	91 823	120	11 018 781
Mar 18	101 281 881	101 282	0.97	98 243	120	11 789 211
Apr 18	94 566 556	94 567	0.97	91 730	120	11 007 547
May 18	101 934 324	101 934	0.97	98 876	120	11 865 155
Jun 18	103 641 513	103 642	0.97	100 532	120	12 063 872
Jul 18	102 917 116	102 917	0.97	99 830	120	11 979 552
Aug 18	105 900 560	105 901	0.97	102 724	120	12 326 825
Sep 18	94 984 565	94 985	0.97	92 135	120	11 056 203
Oct 18	102 227 255	102 227	0.97	99 160	120	11 899 253
Nov 18	99 690 123	99 690	0.97	96 699	120	11 603 930
Dec 18	83 912 076	83 912	0.97	81 395	120	9 767 366
Total	1 183 884 641	1 183 885	0.97	1 148 368	120	137 804 172

Source: Internal documents from mining organisation (Name of the mining organisation withheld on request)

3.6. SUMMARY

One can conclude from the before mentioned empirical study that the mining company may generate 2,439,753 MWh of clean energy over the twenty-year period with an investment of R910,857,920. The mining company currently spends R1,078,990,895 on electricity per annum. This amount will experience above inflation increases in the following twenty years. The company also faces pending carbon taxes of R137,804,172 per annum which is also going to be affected by inflation increases for the next twenty years. It is evident that the company must endeavour to implement alternative sources of energy to offset these imminent costs.

The next chapter illustrates the practical simulation that was conducted. The simulation effectively implements the cost that can be incurred coupled with the relevant benefits that can be obtained on a practical method.

CHAPTER 4

4. PRACTICAL SIMULATION

The costs and benefits identified in chapter 3 were tried and tested on a platinum mining organisation. Two scenarios were tested where in scenario 1 no amendments were implemented as opposed to scenario 2 where the 54 MW solar PV plant was simulated.

4.1. SIMULATION OF SCENARIO 1

4.1.1. Carbon tax costs

The carbon tax rate for tier 2 emissions was R120/tCO₂ as at 2018. This rate is subject to inflation plus 2% (CPI+2%) until the end of phase 1 (December 2022), and will then be increased in line with inflation according to Writer (2019). CPI has been assumed to be 6% for this study. It is also assumed that the MWh will remain constant throughout the project lifetime to have comparable data.

Table 4.1 consist of a calculation of carbon taxes payable by the mining organisation throughout the twenty-year period of the project. These costs do not include the saving benefits of the proposed solar PV plant. One can clearly observe the exponential growth of the R/tCO₂ throughout the period. It is thus imperative for the mining organisation to investigate if implementing a solar PV plant will alleviate these imminent carbon taxes payable by the mining organisation. If these costs cannot be mitigated the mining organisation face carbon taxes payable to the amount of R5,344,941,965 throughout the twenty-year period of the project.

Table 4.1: Estimated carbon tax payable by the mining organisation for the twenty-year period

Period	1	2	3	4	5	6	7	8	9	10
	CF1	CF2	CF3	CF4	CF5	CF6	CF7	CF8	CF9	CF10
Year	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028
MWh ('000)	1 184	1 184	1 184	1 184	1 184	1 184	1 184	1 184	1 184	1 184
tCO ₂ /MWh	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97
tCO ₂ e ('000)	1 148	1 148	1 148	1 148	1 148	1 148	1 148	1 148	1 148	1 148
R/tCO ₂	120	130	140	151	160	170	180	191	202	214
Carbon tax (Rm)	138	149	161	174	184	195	207	219	232	246
Period	11	12	13	14	15	16	17	18	19	20
	CF11	CF12	CF13	CF14	CF15	CF16	CF17	CF18	CF19	CF20
Year	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038
MWh ('000)	1 184	1 184	1 184	1 184	1 184	1 184	1 184	1 184	1 184	1 184
tCO ₂ /MWh	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97
tCO ₂ e ('000)	1 148	1 148	1 148	1 148	1 148	1 148	1 148	1 148	1 148	1 148
R/tCO ₂	227	241	255	271	287	304	322	342	362	384
Carbon tax (Rm)	261	277	293	311	330	349	370	392	416	441

The South African government has made numerous international and national commitments to decrease greenhouse gas (GHG) emissions. One of these commitments is the successful implementation of the carbon tax bill.

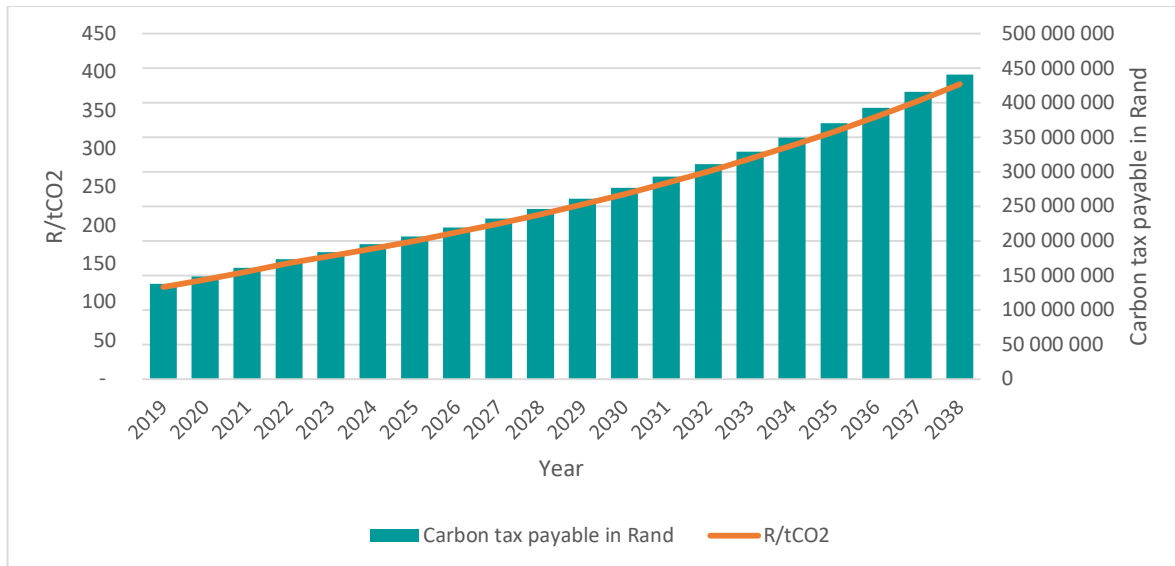
The carbon tax bill, which came into effect in June 2019, aims to remedy South Africa's carbon emissions which is currently disproportionately high. The mining organisation's current consumption of electricity, which is generated by the burning of fossil fuels, has a substantial contribution towards these emissions.

Figure 4.1 below illustrates the carbon tax payable by the mining organisation throughout the twenty-year project period. These taxes may be mitigated if the mining organisation obtains its electricity from another method rather than utilising Eskom's conventional method of burning fossil fuels to generate electricity.

The mining organisation may be inclined to implement the solar PV plant as this will give them the option to mitigate the additional costs of the imminent carbon tax. The carbon taxes

can be offset against the credits of acquiring electricity generated by a renewable source of energy such as the proposed solar PV plant.

Figure 4.1: Estimated carbon tax payable by the mining organisation for the twenty-year period



4.1.2. Electricity costs

The effective electricity rate for the mining organisation was R0.91/kWh as at 2018. This rate is subject to inflation plus the increase established by Eskom and approved by NERSA. CPI has been assumed to be 6% and the approved increase of 3% from Eskom and NERSA, thus a total rate increase of 9% per annum is set for this study. It is also assumed that the MWh will remain constant throughout the project lifetime to have comparable data.

Table 4.2 consists of a calculation of electricity payable by the mining organisation throughout the twenty-year period of the project. These costs do not include the saving benefits of the proposed solar PV plant. One can clearly observe the exponential growth of the R/kWh throughout the period. It is thus imperative for the mining organisation to investigate if implementing a solar PV plant will alleviate these imminent electricity costs payable by the mining organisation.

If these costs cannot be mitigated the mining organisation face electricity payable to the amount of R55,116,588,687 throughout the twenty-year period of the project.

Table 4.2: Estimated electricity payable by the mining organisation for the twenty-year period

Period	0	1	2	3	4	5	6	7	8	9		
	CF0	2019	2020	2021	2022	2023	2024	2025	2026	2027		
Year	CF0	CF1	CF2	CF3	CF4	CF5	CF6	CF7	CF8	CF9		
GWh		1 184	1 184	1 184	1 184	1 184	1 184	1 184	1 184	1 184		
R/kWh		0.91	0.99	1.08	1.18	1.28	1.40	1.53	1.66	1.81		
Electricity payable (Rm)												
		1 077	1 174	1 280	1 395	1 521	1 658	1 807	1 969	2 147		
Period	10	11	12	13	14	15	16	17	18	19		20
	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037		2038
Year	CF10	CF11	CF12	CF13	CF14	CF15	CF16	CF17	CF18	CF19		CF20
GWh	1 184	1 184	1 184	1 184	1 184	1 184	1 184	1 184	1 184	1 184	1 184	
R/kWh	1.98	2.15	2.35	2.56	2.79	3.04	3.31	3.61	3.94	4.29	4.68	
Electricity payable (Rm)												
	2 340	2 550	2 780	3 030	3 303	3 600	3 924	4 277	4 662	5 082	5 539	

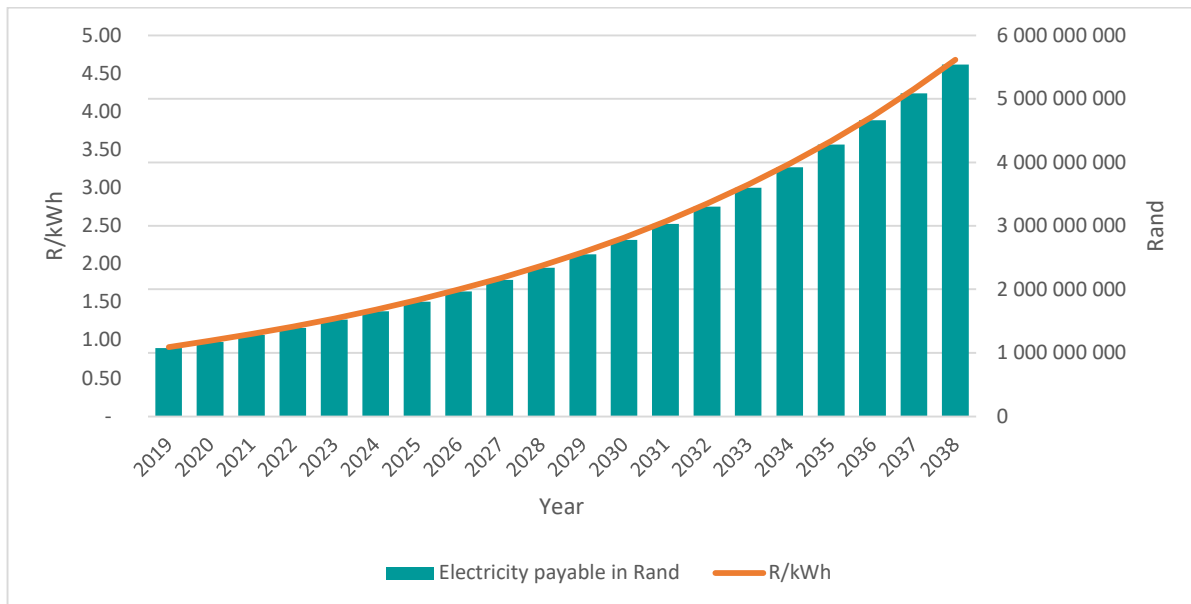
It has already been established in this study that electricity is one of the most substantial costs incurred by the mining organisation. It is thus imperative for the mining organisation to control these costs to keep their operations sustainable.

Unfortunately, the recent above inflation increases in the electricity tariff and unreliability of Eskom to supply constant power to the mining industry has impeded the sustainability of the mining organisation. This has forced them to seek alternative methods of obtaining reliable electricity at affordable rates.

Figure 4.2 below illustrates the electricity costs payable by the mining organisation throughout the twenty-year project period. These costs may be mitigated if the mining organisation obtains its electricity from another method rather than utilising Eskom's conventional method of burning fossil fuels to generate electricity.

The mining organisation may be inclined to implement the solar PV plant as this will give them the benefit to mitigate the additional costs of the increasing electricity tariff imposed by Eskom. They will also receive the additional benefit of having a reliable source of electricity as the solar PV plant is based on renewable energy sources rather than the burning of fossil fuels.

Figure 4.2: Estimated electricity payable by the mining organisation for the twenty-year period



4.2. SIMULATION OF SCENARIO 2

4.2.1. Carbon tax costs saving benefit

The annual MWh saving established in table 3.3 from Chapter 3 has been utilised to calculate the carbon tax amount that can be mitigated by implementing the proposed solar PV plant. Table 4.3 below consists of a calculation of the carbon tax that can be saved throughout the twenty-year project period.

Table 4.3: Estimated carbon tax saving by the mining organisation for the twenty-year period

Period	1	2	3	4	5	6	7	8	9	10
	CF1	CF2	CF3	CF4	CF5	CF6	CF7	CF8	CF9	CF10
Year	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028
MWh ('000) saving	127	126	126	125	125	124	124	123	123	122
tCO2/MWh	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97
tCO2e ('000)	123	123	122	122	121	121	120	120	119	119
R/tCO2	120	130	140	151	160	170	180	191	202	214
Carbon tax saving (Rm)	15	16	17	18	19	20	22	23	24	25

Period	11	12	13	14	15	16	17	18	19	20
	CF11	CF12	CF13	CF14	CF15	CF16	CF17	CF18	CF19	CF20
Year	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038
MWh ('000) saving	122	121	121	120	120	119	119	118	118	117
tCO2/MWh	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97
tCO2e ('000)	118	118	117	117	116	116	115	115	114	114
R/tCO2	227	241	255	271	287	304	322	342	362	384
Carbon tax saving (Rm)	27	28	30	32	33	35	37	39	41	44

The mining organisation faced a total carbon tax payable of R5,344,941,965 throughout the twenty-year period of the project before the implementation of the solar PV plant.

The carbon tax saving equates to R563,205,994 if the proposed solar PV plant is implemented. Thus, the mining organisation will have an 11% saving throughout the twenty-year period if the proposed 54 MW solar plant is commissioned to supply the mining organisation with electricity.

It is evident that the solar PV plant will yield a carbon tax saving benefit if it is implemented to supply the mining organisation with a renewable source of electricity.

Figure 4.3 below illustrates the carbon tax saving that is achievable throughout the twenty-year project period by implementing the proposed 54MW solar PV plant. This saving is also beneficial to the mining organisation as it bolsters their corporate social responsibility. The mining organisation can claim that they endeavour to obtain some of its electricity

requirements from renewable sources and create job opportunities through the employment of staff to install and maintain the plant.

Figure 4.3: Estimated carbon tax saving by the mining organisation for the twenty-year period

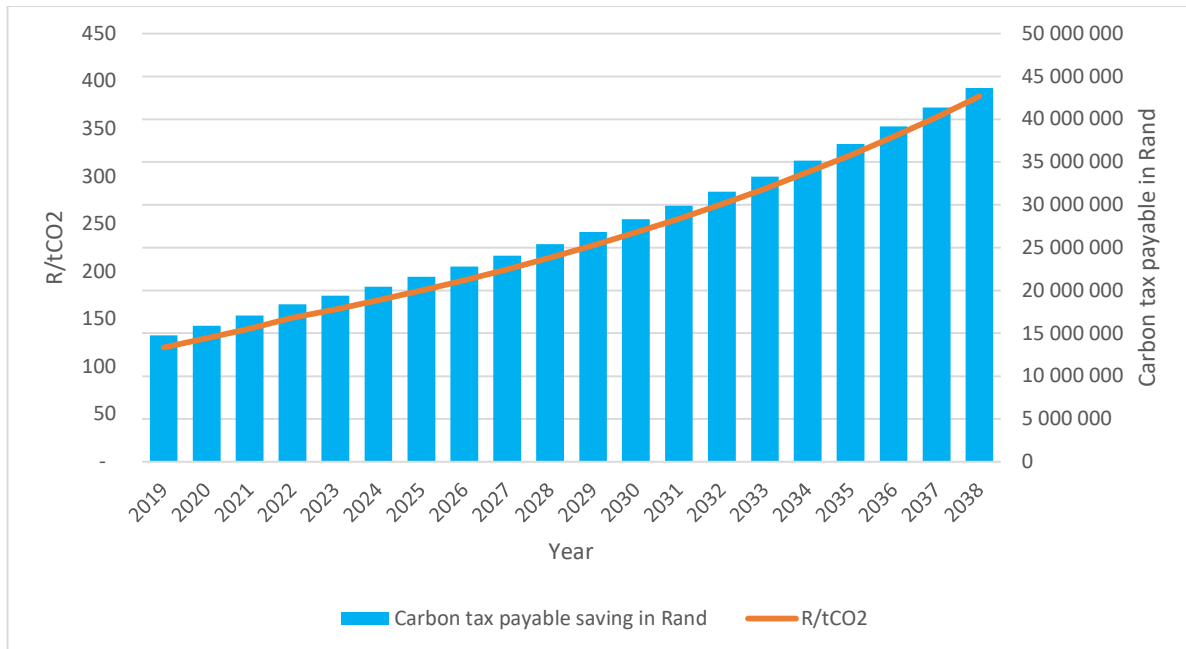
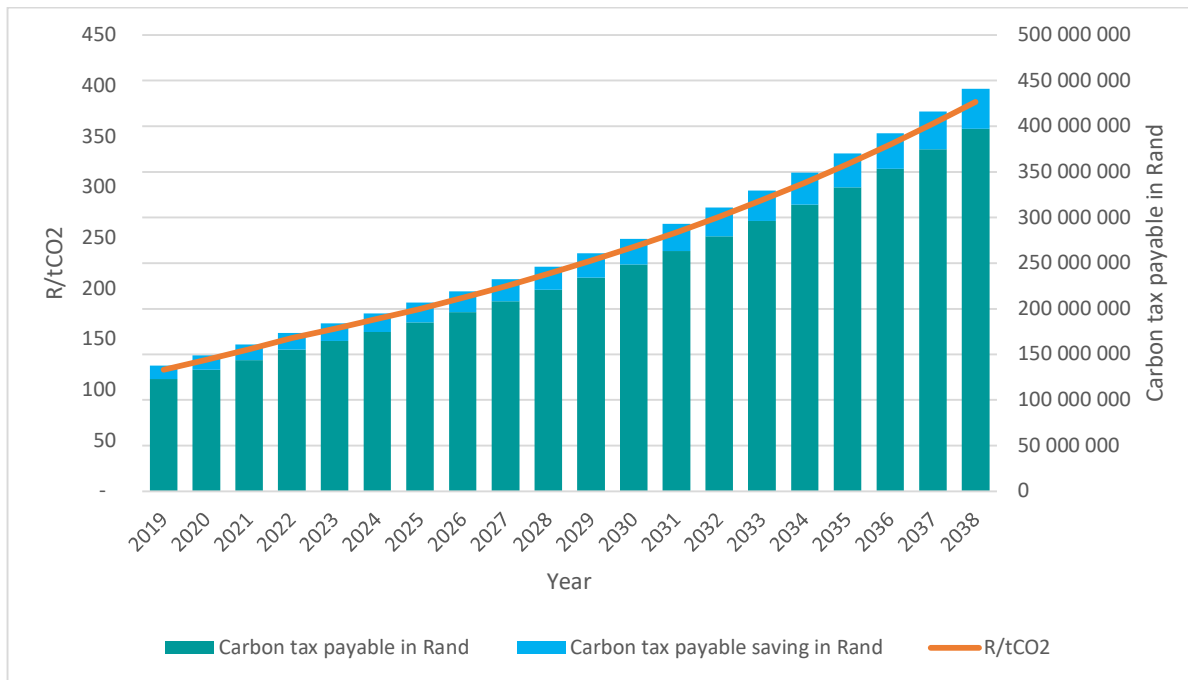


Figure 4.4 below illustrates the holistic carbon tax view showing the total carbon tax payable with the saving of implementing the proposed solar PV plant.

Figure 4.4: Combined estimated carbon tax payable and saving by the mining organisation for the twenty-year period



4.2.2. Electricity costs saving benefit

The annual MWh saving established in table 3.3 from Chapter 3 has been utilised to calculate the electricity amount that can be mitigated by implementing the proposed solar PV plant. Table 4.4 below consists of a calculation of the electricity saving in Rands that can be saved throughout the twenty-year project period.

Table 4.4: Estimated electricity saving by the mining organisation for the twenty-year period

Period	1	2	3	4	5	6	7	8	9	10
Year	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028
Year	CF1	CF2	CF3	CF4	CF5	CF6	CF7	CF8	CF9	CF10
MWh saving ('000)	127	126	126	125	125	124	124	123	123	122
R/kWh	0.91	0.99	1.08	1.18	1.28	1.40	1.53	1.66	1.81	1.98
Electricity saving (Rm)	115	125	136	148	160	174	189	205	223	242
Period	11	12	13	14	15	16	17	18	19	20
Year	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038
Year	CF11	CF12	CF13	CF14	CF15	CF16	CF17	CF18	CF19	CF20
MWh saving ('000)	122	121	121	120	120	119	119	118	118	117
R/kWh	2.15	2.35	2.56	2.79	3.04	3.31	3.61	3.94	4.29	4.68
Electricity saving (Rm)	262	285	309	335	364	395	429	465	505	548

The mining organisation faced a total electricity cost payable of R 55,116,588,687.04 throughout the twenty-year period of the project before the implementation of the solar PV plant.

The electricity saving equates to R 5,614,426,334.91 if the proposed solar PV plant is implemented. Thus, the mining organisation will have a 10% saving throughout the twenty-year period if the proposed 54 MW solar plant is commissioned to supply the mining organisation with electricity. It is evident that the solar PV plant will yield a carbon tax saving benefit if it is implemented to supply the mining organisation with a renewable source of electricity.

Figure 4.5 below illustrates the electricity saving that is achievable throughout the twenty-year project period by implementing the proposed 54 MW solar PV plant. The mining organisation faces an exponential increase in electricity tariffs and the implementation of the proposed solar PV plant will curb this increase in cost. The saving that can be realised may be redirected towards other projects of the same basis to alleviate increases in costs whilst assisting in achieving the organisation's corporate social responsibility targets.

Figure 4.5: Estimated electricity saving by the mining organisation for the twenty-year period

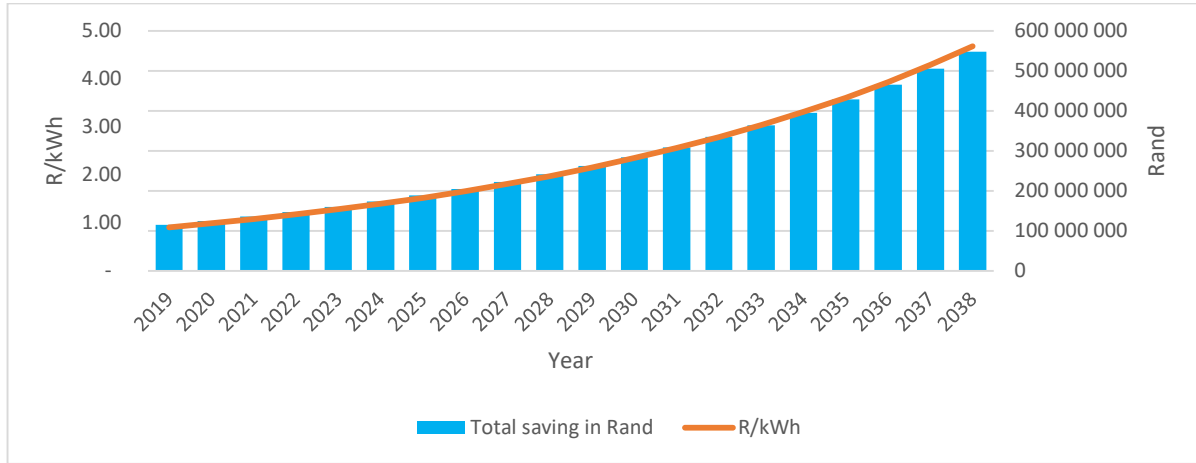
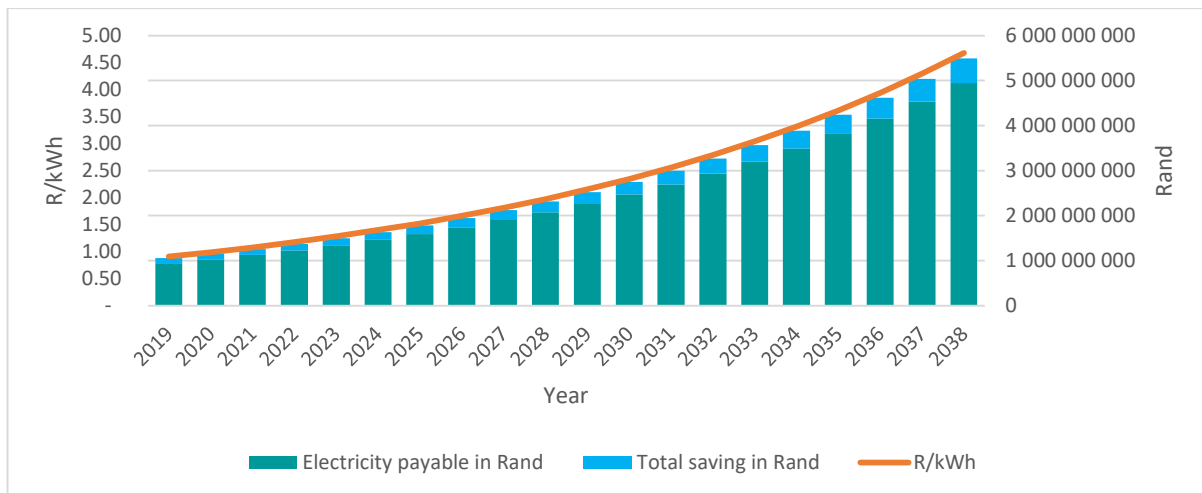


Figure 4.6 below illustrates the holistic electricity consumption view showing the electricity payable with the saving of implementing the proposed solar PV plant.

Figure 4.6: Combined estimated electricity payable and saving by the mining organisation for the twenty-year period



4.2.3. Net Present Value simulation

The net present value model was utilised to determine if the benefits outweigh the costs in this analysis. Table 4.5 below illustrates the net present value model. A 10% discount rate was applied. The model concluded that there is a positive net present value of R1.025 billion. The model further calculated an internal rate of return of 21% that can be realised coupled with a payback period of 5.76 years. The organisation has a prerequisite policy which depicts that a capital project should yield a positive net present value with a payback period of less than 10 years when using the 10% discount rate. The implementation of a 54 MW solar photo voltaic plant is thus a feasible project that may be pursued by the mining organisation as it meets and exceeds all the prerequisite criteria.

Table 4.5: Net present value simulation over the twenty-year period

Period	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038
	CF0	CF1	CF2	CF3	CF4	CF5	CF6	CF7	CF8	CF9	CF10	CF11	CF12	CF13	CF14	CF15	CF16	CF17	CF18	CF19	CF20
GWh		1 184	1 184	1 184	1 184	1 184	1 184	1 184	1 184	1 184	1 184	1 184	1 184	1 184	1 184	1 184	1 184	1 184	1 184	1 184	1 184
R/kWh		0.91	0.99	1.08	1.18	1.28	1.40	1.53	1.66	1.81	1.98	2.15	2.35	2.56	2.79	3.04	3.31	3.61	3.94	4.29	4.68
Electricity payable (Rm)		1 077	1 174	1 280	1 395	1 521	1 658	1 807	1 969	2 147	2 340	2 550	2 780	3 030	3 303	3 600	3 924	4 277	4 662	5 082	5 539
Electricity saving (GWh)		127	126	126	125	125	124	124	123	123	122	122	121	121	120	120	119	119	118	118	117
Electricity saving (Rm)		115	125	136	148	160	174	189	205	223	242	262	285	309	335	364	395	429	465	505	548
Carbon tax saving (Rm)		15	16	18	19	20	21	22	24	25	26	28	29	31	33	34	36	38	40	43	45
Total saving (Rm)		131	142	154	167	180	195	211	229	247	268	290	314	340	368	398	431	467	506	548	593
Investment (Rm)	-911																				
O & M (Rm)		-1.50	-1.59	-1.69	-1.79	-1.89	-2.01	-2.13	-2.26	-2.39	-2.53	-2.69	-2.85	-3.02	-3.20	-3.39	-3.59	-3.81	-4.04	-4.28	-4.54
Cashflow (Rm)	-911	129	140	152	165	178	193	209	226	245	265	287	311	337	365	395	428	463	502	543	589
Cumulative cashflow (Rm)	-911	-782	-642	-490	-325	-146	47	256	482	727	992	1 280	1 591	1 927	2 292	2 687	3 115	3 578	4 080	4 623	5 212
Payback period (Years)		1.00	1.00	1.00	1.00	1.00	0.76	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Discount rate	10%																				
NPV (Rm)	1 025																				
IRR	21%																				
Payback period (Years)	5.76																				

Figure 4.7 below illustrates the cashflow movement for the twenty-year project period. CF0 (Cash Flow period 0) shows the R911 million investment for implementation of the 54 MW solar photo voltaic plant. One can see that the cashflow benefits start to accumulate once the plant is commissioned from 2019 onwards. This benefit is net of the operation and maintenance cost incurred to run and repair the plant.

Figure 4.7: Cashflow projection over the twenty-year period

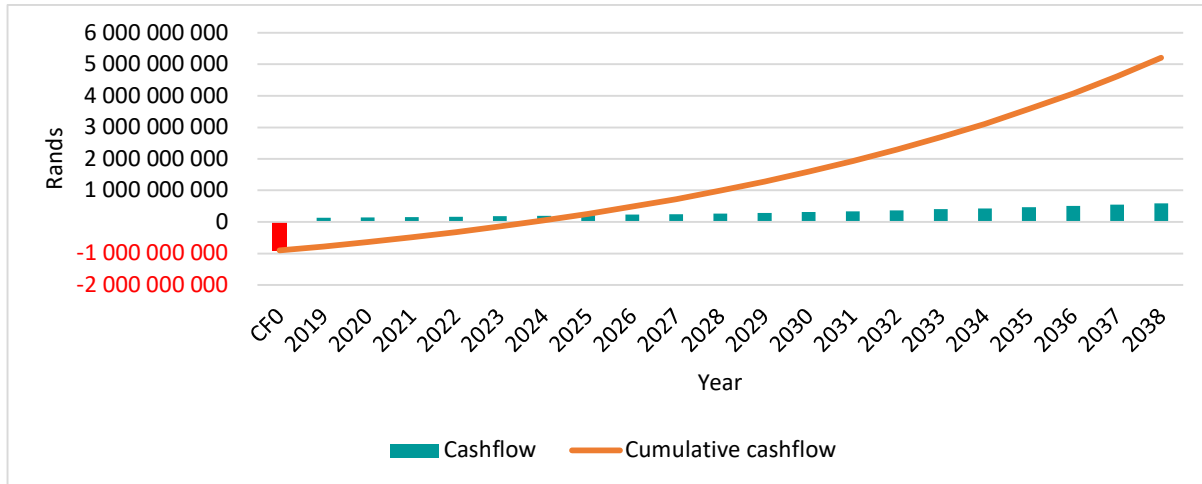
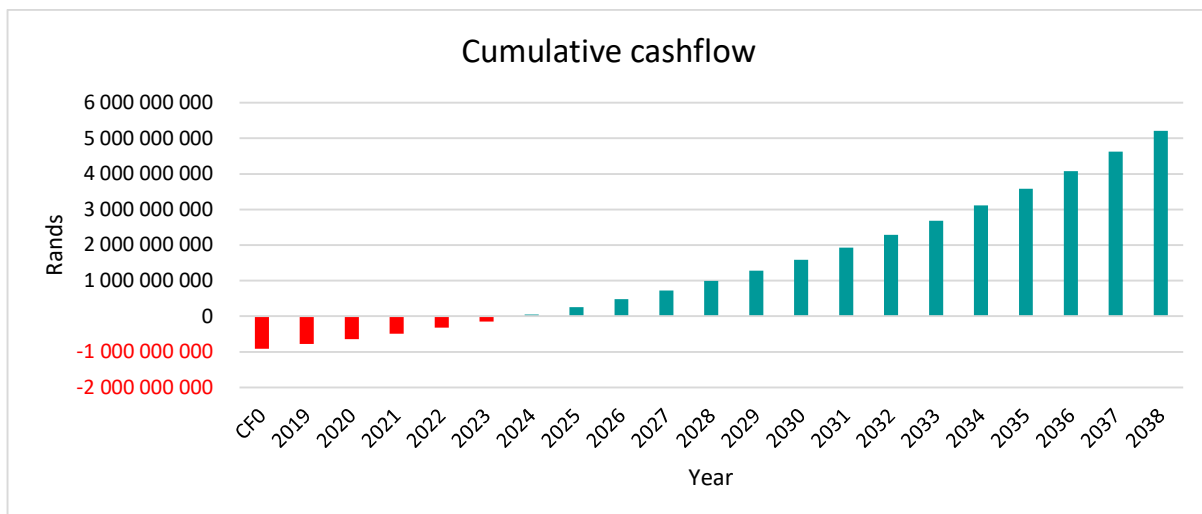


Figure 4.8 below further illustrates the effective cumulative cashflow with the relevant payback period. The cost of the investment in CF0 is recouped by the benefits from 2019 onwards. The solar photo voltaic plant is effectively paid off in 2024 and results in a payback period of 5.76 years which is relatively quick compared to other projects of this magnitude.

Figure 4.8: Cumulative cashflow projection over the twenty-year period



4.2.4. Implementation plan

Table 4.6 below illustrates the typical timeframe to install and implement a 54 MW solar PV plant. It can be noted that it takes about 12 months to complete the installation. This project simulation is based on the decision if the mining organisation decides to install the solar PV plant in January 2020. The electricity and carbon tax savings will thus only realise in 2021 onwards after the commissioning of the solar PV plant.

Table 4.6: Implementation plan to install and commission a 54 MW solar PV project presented in a Gantt chart

ACTIVITY	Start Date	End Date	Duration	CF0											
				2020											
				Q1			Q2			Q3			Q4		
				Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
				1	2	3	4	5	6	7	8	9	10	11	12
Phase 1 - Civil works	2020-01-01	2020-04-30	120												
Diggings	2020-01-01	2020-02-01	31												
Foundations	2020-02-02	2020-03-04	31												
Signal Lights	2020-03-04	2020-03-19	15												
Access road	2020-03-04	2020-03-19	15												
Camp & Security	2020-04-01	2020-04-30	29												
Phase 2 - Mechanical Equipment	2020-05-01	2020-08-31	122												
Silicone Modules	2020-05-01	2020-08-31	122												
Axis Tracking System	2020-05-01	2020-08-31	122												
Fixed Structure	2020-05-01	2020-08-31	122												
Phase 3 - Electrical Equipment	2020-09-01	2020-12-31	121												
Inverter	2020-09-01	2020-10-31	60												
Balance of System	2020-11-01	2020-12-01	30												
Low Medium Voltage Centre	2020-11-01	2020-12-31	60												
Substation & Transformers	2020-11-01	2020-12-31	60												
Phase Duration				Sub section Duration											

4.3. SUMMARY

In Chapter 4 the practical simulation was conducted. The 2 identified scenarios were tested. Scenario 1 had no amendments to their operation and the effect of increased electricity tariffs coupled with carbon tax payable shown an exponential escalation in costs. Scenario 2 had the 54 MW solar PV plant implemented and have shown a 10% saving in electricity costs coupled with an 11% saving in carbon tax payable over the 20-year time span. The simulation yielded positive results for the study. The investment shown a positive Net Present Value and a payback period less than 6 years.

The next chapter is the final chapter of the study. In this chapter the summary of key findings is listed coupled with the relevant recommendations. This chapter also confirms if the study has achieved the study objectives and advises on future studies on the selected topic.

CHAPTER 5

5. CONCLUSIONS AND RECOMMENDATIONS

This chapter contains a summary of all key findings, any limits identified and recommendations based on the knowledge gathered throughout the previous chapters of the study. An additional list of recommendations is provided for future studies relevant to the specific topic identified within this study.

5.1. SUMMARY OF KEY FINDINGS

South Africa has become more dependent on generating electricity via burning fossil fuels such as coal. There is a year on year increase of 1% in Eskom's reliance on coal for the generation of electricity. This is coupled with a 5.46% annual increase in cost to Eskom to generate the electricity by means of burning coal. This cost increase is passed on to the consumer, hence the above inflation tariff increases which put the sustainability of the mining organisation at stake.

Eskom provides a textbook case of a natural monopoly, which should not be allowed to maximise profit, as this leads to lower supply by cutting the maintenance budget and introducing higher prices as there are no alternatives to the power supply on a government level for companies to choose from. Eskom has thus neglected the maintenance of its power plants and has delayed the commissioning of new power plants to adequately supply the mining industry with a sufficient and constant flow of electricity. This has led to power cuts which were dubbed as load shedding in 2008. These power cuts have continued throughout the years and have caused substantial damage to the South African economy, especially within the mining industry which represents 14.2% of electricity consumers within South Africa.

The above-mentioned factors have sparked interest within the mining industry to investigate alternative methods of obtaining a sufficient and constant supply of electricity. There is a persistent drive to save costs within the mining industry as it becomes more expensive to mine with imminent tariff increases. Electricity is a substantial cost in any mining organisation and sustainability usually depends on the effectiveness of the mining organisation to utilise its resources to mitigate substantial costs such as electricity.

South Africa has one of the world's richest resources of solar electricity on offer and is currently highly under-utilised for large-scale power generation. The cost for this technology was one impeding factor for organisations to invest because it was cheaper to obtain electricity from Eskom than any other method, but improvements and relevant cost reductions have made solar technology a viable source of obtaining renewable electricity. The added constraint of the carbon tax bill has fuelled the drive to save electricity costs even further.

The study determined that acquiring electricity via solar photo voltaic technology has become more viable than obtaining electricity by means of burning coal in South Africa. It costs around R0.62/kWh to generate electricity by means of utilising solar photo voltaic technology versus coal fired power plants generating electricity at around R1.05/kWh.

The mining organisation faces carbon taxes payable to the amount of R5,344,941,965 throughout the twenty-year period of the project. This is coupled with an electricity cost payable to the amount of R55,116,588,687 throughout the twenty-year period of the project.

This study determined that 2,439,753 MWh is on offer over a twenty-year period for a 54 MW solar photo voltaic plant. The benefit of saving the 2,439,753 MWh is three-fold. Firstly, the exponential increase of Eskom's R/kWh is mitigated due to a decrease in actual kWh used throughout the twenty-year period. Secondly, the imminent carbon taxes on using electricity generated by the burning of fossil fuels is mitigated as electricity is generated by utilizing renewable energy methods. Thirdly, the unreliability of Eskom to supply the necessary electricity is mitigated.

The carbon tax saving equates to R 563,205,994 and a R 5,614,426,335 saving in electricity costs if the proposed solar photo voltaic plant is implemented. Thus, the mining organisation will have an 11% saving on carbon taxes and a 10% saving on electricity costs respectively throughout the twenty-year period if the proposed 54 MW solar plant is commissioned to supply the mining organisation with electricity.

The mining organisation will for the first time be in control of some of their electricity needs at a reasonable cost and could ensure a stable electricity flow to their operations. This is the first step to independence and sustainability.

5.2. RECOMMENDATIONS

South Africa has a rich resource of solar energy which can be harnessed through technology that has become more feasible than conventional methods such as burning fossil fuels. This study set out to investigate if the benefits of implementing a solar photovoltaic plant outweigh the costs and it has been found that the solar photo voltaic technology is indeed viable and competitive compared to Eskom's coal fire power plants. The study has proven that a large-scale solar photo voltaic plant of 54 MW capacity is viable to be pursued by a mining organisation. It is thus recommended for the mining organisation identified in this study, and other similar companies, to conduct due diligence studies and pursue this as a feasible project.

It is recommended to implement the solar photo voltaic plant as the benefits identified in the study are three-fold and outweigh the costs.

Firstly, the Eskom tariff increases have been above inflation from 2008 onwards. The main factors were identified to be mismanagement and misalignment with maintenance and commissioning of new power plants. Eskom is a natural monopoly and does not conform to economic dynamics of competition to improve efficiencies leading to irregularities in supply and demand. These exponential increases are unsustainable and it is recommended to pursue alternative methods of obtaining electricity, such as the solution identified in this study.

Secondly, the imminent pressure of the carbon tax bill will place organisations in a difficult position financially. These additional costs may be mitigated by obtaining electricity from renewable sources, such as the solution to offer identified in this study. This solution also contributes to the Corporate Social Responsibility of the organisation as it assists to reduce carbon emissions and lowers the unemployment rate as personnel are employed to install and maintain the plant.

Thirdly, Eskom has been known to cut power due to inefficiencies identified in this study. Eskom is also in a financial crisis and requires financial assistance from other parties. Organisations experience unstable and inconsistent electricity flow and this solution can be implemented to ensure a constant and reliable source of clean energy.

5.3. ACHIEVEMENT OF THE STUDY OBJECTIVE

The primary research objective of this study was to do a cost-benefit analysis of implementing a solar photo voltaic plant within a platinum mining organisation.

The findings of this study have delivered successful results to conclude that the benefits outweigh the costs of implementing a 54 MW solar photo voltaic plant within the specific mining organisation.

The net present value model has taken the cost to implement a 54 MW solar photo voltaic plant coupled with the cost to maintain the plant and weighed it up against the saving benefit derived from GWh saved coupled with the relevant carbon tax saved. The net present value model has taken the before mentioned costs and benefits into account and rendered a positive result indicating that the benefits indeed outweigh the costs. There was a positive net present value of R1.025 billion whilst utilising a 10% discount rate. This resulted in an internal rate of return of 21% with a payback period of 5.76 years.

The mining organisation's policy state that projects of this magnitude can be accepted if the discount rate of 10% is utilised and a positive net present value coupled with a payback period of 10 years or less can be achieved. The prerequisites have been achieved and this study is thus a feasible project to be pursued by the mining organisation.

This analysis has also rendered results towards sustainability and responsibility. Corporate Social Responsibility (CSR) takes profit, people and planet into account. The mining organisation can decrease its costs by implementing the 54 MW solar photo voltaic plant and therefore increase its profits, but there are two other benefits inherent to this study as well. The mining organisation will employ personnel who will implement, operate and maintain the plant for the next twenty years. This curbs unemployment and increases the livelihood of the organisation's people. The third benefit is towards the planet. By obtaining electricity by means of the solar photo voltaic plant, the mining organisation is effectively reducing its carbon emissions and helps to save the environment from imminent global warming. This also contributes to the benefit of saving credits for the carbon tax bill.

5.4. RECOMMENDATIONS FOR FUTURE STUDIES

The study has determined that solar photo voltaic technology can alleviate the burden of increasing electricity tariffs, but the implementation of a 54 MW solar photo voltaic plant will not be sufficient enough to supply all the electricity needs for the mining organisation. It is therefore recommended to investigate additional methods of obtaining renewable sources of electricity to further alleviate the electricity constraints currently being experienced within the mining industry.

It is recommended that other methods of reducing electricity consumption within the mining industry be investigated. Future studies may focus on the cost-benefit analysis of implementing a variable speed drive (VSD) within the mining industry to reduce the peak tariffs charged by Eskom.

This study constituted the implementation of a solar photo voltaic plant by means of utilising the organisation's own capital. There are alternative methods of obtaining renewable electricity by means of other financial instruments such as a power purchase agreement (PPA). It is therefore recommended that the incorporation of obtaining electricity by means of a power purchase agreement be utilised for future studies relevant to this topic.

This study focussed on solar photo voltaic technology as a means to generate electricity utilising the sun as a renewable source of power based on the mining organisation's location. There is however the possibility to harness other methods of renewable energy regardless of location. It is therefore recommended to investigate the generation of renewable electricity at one location, for example, wind power at a coastal location, and offsetting the power saving by feeding the electricity generated back into the Eskom grid.

This study was based on a single mining organisation situated in the North-West province, South Africa. It is imperative to conduct the same type of study at other organisations at other locations within the mining industry and additional industries such as the construction, manufacturing and agricultural sectors which also constitutes a large percentage of the total consumers of Eskom electricity. Future studies may utilise the findings of this report as a basis to conduct the same study in other industries to form a collective and practical body of knowledge towards a sustainable South African economy.

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**APPENDIX 1: THE REMAINING OPERATIONAL YEARS OF SOUTH AFRICAN
COAL-FIRED POWER STATIONS**

The remaining operational years of South African coal-fired power stations

Type	Power station name	Years life expectancy	Date of commissioning (Age)	Years in operation	Remaining years in operation
Coal-fired	Komati	50	1966	50	0
	Camden	50	1967	50	0
	Grootvlei	50	1969	49	1
	Arnot	50	1975	43	7
	Duvha	50	1975	43	7
	Hendrina	50	1976	42	8
	Kriel	50	1979	39	11
	Lethabo	50	1980	38	12
	Matla	50	1983	35	15
	Tutuka	50	1985	33	17
	Kendal	50	1993	25	25
	Majuba	50	1996	22	28
	Matimba	50	1998	20	30
	Medupi	50	2015	3	47
	Kusile	50	2017	1	49

Source: South Africa role coal energy security report (Fisher, 2017:2)

**APPENDIX 2: THE GLOBAL CARBON DIOXIDE EMISSIONS FROM FOSSIL FUEL
BURNING BY FUEL TYPE, 1900 – 2012**

Global Carbon Dioxide Emissions from Fossil Fuel Burning by Fuel Type, 1900-2012

Year	Coal	Oil	Natural Gas	Total
Million Tonnes of Carbon				
1900	515	16	3	534
1901	531	18	4	552
1902	543	19	4	566
1903	593	20	4	617
1904	597	23	4	624
1905	636	23	5	663
1906	680	23	5	707
1907	750	28	5	784
1908	714	30	5	750
1909	747	32	6	785
1910	778	34	7	819
1911	792	36	7	836
1912	834	37	8	879
1913	895	41	8	943
1914	800	42	8	850
1915	784	45	9	838
1916	842	48	10	901
1917	891	54	11	955
1918	873	53	10	936
1919	735	61	10	806
1920	843	78	11	932
1921	709	84	10	803
1922	740	94	11	845
1923	845	111	14	970
1924	836	110	16	963
1925	842	116	17	975
1926	846	119	19	983
1927	905	136	21	1062
1928	890	143	23	1065
1929	947	160	28	1145
1930	862	152	28	1053
1931	759	147	25	940
1932	675	141	24	847
1933	708	154	25	893
1934	775	162	28	973
1935	811	176	30	1027
1936	893	192	34	1130
1937	941	219	38	1209
1938	880	214	37	1142
1939	918	222	38	1192

1940	1017	229	42	1299
1941	1043	236	42	1334
1942	1063	222	45	1342
1943	1092	239	50	1391
1944	1047	275	54	1383
1945	820	275	59	1160
1946	875	292	61	1238
1947	992	322	67	1392
1948	1015	364	76	1469
1949	960	362	81	1419
1950	1070	423	97	1630
1951	1129	479	115	1767
1952	1119	504	124	1795
1953	1125	533	131	1841
1954	1116	557	138	1865
1955	1208	625	150	2042
1956	1273	679	161	2177
1957	1309	714	178	2270
1958	1336	731	192	2330
1959	1382	789	206	2454
1960	1410	849	227	2569
1961	1349	904	240	2580
1962	1351	980	263	2686
1963	1396	1052	286	2833
1964	1435	1137	316	2995
1965	1460	1219	337	3130
1966	1478	1323	364	3288
1967	1448	1423	392	3393
1968	1448	1551	424	3566
1969	1486	1673	467	3780
1970	1556	1839	493	4053
1971	1559	1947	530	4208
1972	1576	2057	560	4376
1973	1581	2241	588	4614
1974	1579	2245	597	4623
1975	1673	2132	604	4596
1976	1710	2314	630	4864
1977	1765	2398	650	5026
1978	1793	2392	680	5087
1979	1887	2544	721	5369
1980	1947	2422	740	5316
1981	1921	2289	756	5152
1982	1992	2196	740	5113
1983	1995	2176	741	5094
1984	2094	2199	808	5280

1985	2237	2186	837	5439
1986	2300	2293	831	5607
1987	2364	2306	894	5752
1988	2414	2412	937	5965
1989	2457	2459	984	6097
1990	2419	2506	1019	6141
1991	2348	2616	1063	6233
1992	2360	2508	1095	6165
1993	2301	2538	1129	6180
1994	2361	2562	1139	6286
1995	2446	2584	1157	6420
1996	2473	2622	1209	6544
1997	2500	2698	1208	6653
1998	2394	2763	1243	6644
1999	2356	2734	1270	6611
2000	2371	2836	1288	6766
2001	2496	2838	1312	6929
2002	2525	2829	1344	6998
2003	2747	2959	1391	7421
2004	2971	3053	1437	7812
2005	3163	3087	1476	8106
2006	3335	3097	1524	8372
2007	3467	3095	1559	8572
2008	3576	3113	1620	8769
2009	3625	3065	1568	8738
2010	3877	3165	1692	9246
2011	4062	3202	1722	9538
2012	4175	3235	1765	9740

Note: Annual totals also include emissions from gas flaring and cement production.

Source: Climate Change 2014: Synthesis Report (Pachauri, 2014:5)

**APPENDIX 3: THE GLOBAL COMPARISON OF ELECTRICITY TARIFF, PLATINUM
PRICE AND CPI INCREASE FROM 2004 TO 2017**

Comparison of electricity tariff, platinum price and CPI increase from 2004 to 2017

Comparison of Electricity tariff, platinum price and CPI Rand increase from 2004 to 2017														
	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Total CPI	131.40	136.70	143.50	155.80	171.90	182.78	189.14	200.69	212.37	223.84	235.73	248.05	264.83	277.57
Mining - Electricity tariff	15.07	15.36	16.19	16.90	17.99	23.12	30.25	39.78	48.10	55.74	64.66	69.52	78.01	84.80
Platinum Price - R/oz.	5 284	5 679	7 692	9 203	12 943	10 153	11 788	12 454	12 701	14 325	14 982	13 464	14 519	12 612

Comparison of Electricity tariff, platinum price and CPI Base year increase from 2004 to 2017														
Proportional Increase	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Total CPI	100.00	104.03	109.21	118.57	130.82	139.10	143.94	152.73	161.62	170.35	179.40	188.78	201.54	211.24
Mining - Electricity tariff	100.00	101.95	107.40	112.14	119.40	153.42	200.73	263.95	319.19	369.89	429.07	461.34	517.70	562.75
Pt Price - R/oz.	100.00	107.47	145.55	174.15	244.92	192.12	223.07	235.68	240.34	271.08	283.52	254.79	274.75	238.67

Comparison of Electricity tariff, platinum price and CPI Base year increase as a percentage from 2004 to 2017														
Percentage Increase	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Total CPI	0%	4%	9%	19%	31%	39%	44%	53%	62%	70%	79%	89%	102%	111%
Mining - Electricity tariff	0%	2%	7%	12%	19%	53%	101%	164%	219%	270%	329%	361%	418%	463%
Pt Price - R/oz.	0%	7%	46%	74%	145%	92%	123%	136%	140%	171%	184%	155%	175%	139%

**APPENDIX 4: ESKOM TAX INVOICE FOR JUNE 2018 ISSUED TO THE MINING
COMPANY**

Eskom tax invoice for June 2018 issued to the mining company



ESKOM HOLDINGS SOC LTD REG NO 2002/015527/30
VAT REG NO 4740101508

NORTHERN REGION
PO BOX 8510 JHB 2000

CONTACT CENTRE: (0860) 037566
FAX NO: 0862 437 566
E-MAIL: customerservice@eskom.co.za
WEB: WWW.ESKOM.CO.ZA



TEL: 0860 37566
SMS: 35328

CUSTOMER SELF SERVICE WEBSITE:
<http://tsonline.eskom.co.za>

NORTHERN REGION
PO BOX 8510 JHB 2000

DIRECT DEPOSIT DETAIL
BANK: First National Bank
BRANCH CODE: 255005
BANK ACC NO: 53340098643

YOUR ACCOUNT NO	8096005345
SECURITY HELD	191763998.00
BILLING DATE	2018-07-03
TAX INVOICE NO	809601543511
ACCOUNT MONTH	JUNE 2018
CURRENT DUE DATE	2018-07-10

TAX INVOICE

E-MAIL: Sodidiv@eskom.co.za

ACCOUNT TRANSACTION SUMMARY

PREMIUM CUSTOMER PREMIUM CONNE		R	281,530.94
RCC / SCC CONNECTION CHARGE		R	43,885.52
ADMINISTRATION CHARGE		R	39,481.20
TRANSMISSION NETWORK CAPACITY		R	2,035,241.24
DIST. NETWORK CAPACITY CHARGE		R	4,057,197.82
NETWORK DEMAND CHARGE		R	8,083,938.45
ANCILLARY SERVICE (ALL)		R	393,837.75
ENERGY CHARGE (OFF)	49,507,030.00	R	23,481,184.33
ENERGY CHARGE (PEAK)	14,775,980.00	R	42,597,815.07
ENERGY CHARGE (STD)	39,358,525.00	R	34,375,735.73
AFFORDABILITY SUBSIDY (ALL)		R	3,430,534.10
ELECTRIFICATION AND RURAL SUBS (ALL)		R	7,721,292.81
REACTIVE ENERGY	1,109,377.00	R	149,433.09
SERVICE CHARGE		R	112,379.10

TOTAL CHARGES FOR BILLING PERIOD R **124,783,288.95**

ACCOUNT SUMMARY FOR JUNE 2018

BALANCE BROUGHT FORWARD	(Due Date 2018-06-11)	R	95,375,103.81
PAYMENT(S) RECEIVED	Direct Deposit - 2018-06-11	R	-95,375,103.81
TOTAL CHARGES FOR BILLING PERIOD		R	124,783,288.95
VAT RAISED ON ITEMS AT 14%		R	0.00
VAT RAISED ON ITEMS AT 15%		R	18,717,493.03

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ARREARS					CURRENT	TOTAL DUE R	143,500,779.98
>90 DAYS	61-90 DAYS	31-60 DAYS	16-30 DAYS	0-15 DAYS			
0.00	0.00	0.00	0.00	0.00	143,500,779.98	143,500,779.98	

TOTAL AMOUNT DUE

143,500,779.95

Note: The name of the company and relevant details have been censored to ensure confidentiality as per guidance from the ethical committee.

APPENDIX 5: BILL OF QUANTITY NO.1 - PRELIMINARY & GENERAL

Item Ref	Description	Unit	No. Units	Cost/Unit (ZAR)	Total Cost (ZAR)
	<u>Bill No. 1: PRELIMINARY & GENERAL</u>				
	<u>Allow for Fixed-Charge and Value-related items:</u>				
	- <u>Contractual requirements:</u>				
1	Provide for all insurances as required under the contract including where appropriate professional indemnity insurance for contract designed permanent works.	Sum	1	R 1 200 000.00	R 1 200 000.00
2	- Provide for performance bond as required under the contract	Sum	1	R 1 200 000.00	R 1 200 000.00
3	Contractor's Installation Drawings, Equipment submissions and provision of Samples as required by the contract	Sum	1	R 1 050 000.00	R 1 050 000.00
4	Training of operation and maintenance personnel on commencement of the maintenance period at hand-over:	Sum	1	R 750 000.00	R 750 000.00
5	Provision of all record documentation including "As-Built" drawings and operations & maintenance (O & M) manuals.	Sum	1	R 300 000.00	R 300 000.00
6	Any other contractually required works not listed	Sum Months	1	R 500 000.00	R 500 000.00
	<u>Establishment of Facilities on Site:</u>				
	<u>Facilities for Owner:</u>				
7	- Furnished offices (1 No.)	Sum	1	R 70 000.00	R 70 000.00
8	Wi-Fi network including internet connection	Sum	1	R 10 000.00	R 10 000.00
9	Name Boards (2 No.)	Sum	1	R 15 000.00	R 15 000.00
	<u>Facilities for Contractor:</u>				
10	- Maintenance of roads & dust/stormwater control during construction	Months	12	R 10 000.00	R 120 000.00
11	- Offices and storage sheds	Sum	1	R 250 000.00	R 250 000.00

12	Workshops	Sum	1	R 80 000.00	R 80 000.00
13	Ablution and latrine facilities	Sum	1	R 90 000.00	R 90 000.00
14	Tools and equipment	Months	12	R 10 000.00	R 120 000.00
15	Water supplies, electric power, Wi-Fi network including internet connection and other communications. Communications to comply with requirements of SKA.	Months	12	R 25 000.00	R 300 000.00
16	Dealing with water	Months	12	R 12 500.00	R 150 000.00
17	Access and access control (including security requirements during construction). Laydown Area fence is included in Bill 13.	Months	12	R 65 000.00	R 780 000.00
18	Plant	Months	12	R 55 000.00	R 660 000.00
19	Removal of site establishment	Sum	1	R 125 000.00	R 125 000.00
20	Waste management and general site housekeeping	Months	12	R 20 000.00	R 240 000.00
21	Dealing with or accommodation of traffic	Months	12	R 7 500.00	R 90 000.00
22	Demolition / Removal / Relocation of Existing Infrastructure	Sum	1	R 50 000.00	R 50 000.00
23	Project management and Supervision for Duration of Construction	Months	12	R 250 000.00	R 3 000 000.00
24	Occupational Health and Safety	Months	12	R 40 000.00	R 480 000.00
25	Company and Head Office Overhead Costs for the Duration of the Contract	Months	12	R 65 000.00	R 780 000.00
26	Other Fixed-Charge Obligation:	Sum	1	R 100 000.00	R 100 000.00
27	Other Time-related Obligations	Months	12	R 50 000.00	R 600 000.00
TOTAL CARRIED FORWARD TO SUMMARY					R 13 110 000.00

APPENDIX 6: BILL OF QUANTITY NO.2 – MODULES

Item Ref	Description	Unit	No. Units	Cost/Unit (ZAR)	Total Cost (ZAR)
	<u>Bill No. 2: Modules</u>				
1	<u>Supply and transportation</u> Supply and installation of Jinko JKM320PP-72-DV 320 Eagle PV Modules	No.	181 104	R 2 498.50	R 452 487 619.58
2	- The modules will have output cables of 6 mm ² and have leads of 2m in length for both anode and cathode Sample testing of at least 0.1% of supplied PV modules to be certified by an independent laboratory	No.	181		
TOTAL CARRIED FORWARD TO SUMMARY					R 452 487 619.58

**APPENDIX 7: BILL OF QUANTITY NO.3 – MOUNTING STRUCTURE AND
TRACKING SYSTEM**

Item Ref	Description	Unit	No. Units	Cost/Unit (ZAR)	Total Cost (ZAR)
1	<u>Bill No. 3: Mounting Structure and Tracking System Supply, Installation & Transportation</u> Supply of mounting structure and tracking system as follows: Model: CONTOUR+ Tracker Ingress Protection: IP67 or higher Tracker blocks sized as follows: 30 rows x 28 modules per row 29 rows x 28 modules per row	No.	204	R 156 746 352.32	R 156 746 352.32
2	Detailed design to comply with site specific requirements. All sensitive electrical equipment and terminations to be placed at least 300mm a.g.l..	No.	12		
			1		
3	Transportation of all equipment and associated construction material.	Sum	1		
4	Installation (including all works required for foundations, mounting structure, actuators, and control system) and commissioning of system.	Sum	1		
	Note that actuator power and RS485 communication cables have been allowed for in Bill No.5				
TOTAL CARRIED FORWARD TO SUMMARY					R 156 746 352.32

APPENDIX 8: BILL OF QUANTITY NO.4 – LV COLLECTOR NETWORK

Item Ref	Description	Unit	No. Units	Cost/Unit (ZAR)	Total Cost (ZAR)
	<u>Bill No. 4: LV (DC) Collector Network Supply, Transportation & Installation</u>				
	<u>Conductors & Cable Trays:</u>				
	<u>DC String Cables</u>				
1	900/1500 V Solardac Aberdare or equivalent - 6mm ² Tin-plated Cu PVC insulated single core UV protected Solar Cables	m	580 316	R 10.00	R 5 803 159.03
2	1500 V DC Solar Connectors (Male & Female Pair) (allowance NOT made for DC connectors to connect to string monitor boxes. String cabling will connect through cable glands via screw-type connectors directly to string monitor boxes)	No.	11 923	R 17.60	R 209 842.96
	<u>DC Power Cables</u>				
3	185mm ² Vultex Type B - single core - Aluminium - XLPE, Cu taped screened, PVC sheathed - 1500V or equivalent, including terminations	m	76 596.06	R 117.00	R 8 961 738.79
4	10mm diameter galvanised steel wire used as earthing conductor for PV mounting structures, installed in the roads leading to MV power stations and bonded to the cable tray as well as MV Power Station earth mat. Includes associated clamps for connection to covered galvanised cable tray and bonding to the MV Power station earth mat.	m	4 565	R 40.00	R 182 592.00
5	400 x 120mm galvanised cable tray, including cover, nuts, bolts and other clamps, brackets and mounting accessories. Cable tray to be mounted on top of moulded concrete blocks at an interval of 2.5m, and fixed to concrete block.	m	31 752	R 250.00	R 7 938 000.00
6	200 x 200 x 150mm moulded concrete block for covered cable tray, mounted at intervals of 2.5m	No.	12 701	R 6.00	R 76 204.80
	<u>String Monitor Boxes:</u>				

7	String Combiner Enclosure: 32-Input, 1500V - IP 54 or higher with lockable doors and applicable warning signs - Enclosure to be buried directly in ground, cable entry from bottom via cable glands - 32 x Fuses 20 Amps (1 fuse per String, connected on positive conductor) - DC string connections via screw-type connectors (not solar connectors) - 1 x DC on-load isolator, 300A - 1 x SPD Type 1/2 combination with status contact - 1 x SPD for Data monitor - 1 x DC Power supply (12V - 48V, depending on data logger) - Monitoring System (RS485 output) String Current measurement DC Bus Voltage Measurement Surge Protection Status One additional analogue input for RS485 conversion - Cable terminations and equipment to be located at least 300mm a.g.l.	No.	216	R 80 000.00	R 17 280 000.00
TOTAL CARRIED FORWARD TO SUMMARY					R 40 491 989.12

APPENDIX 9: BILL OF QUANTITY NO.5 – POWER STATION

Item Ref	Description	Unit	No. Units	Cost/Unit (ZAR)	Total Cost (ZAR)
1	<u>Bill No. 5: Photovoltaic Power Station Supply, Transportation and Installation</u> <u>Outdoor PV Power Station</u> Supply of 1 x SMA 2500C-EV MV Photovoltaic Power Station prefabricated cabin, including: - Integrated SMA inverter 1500V (DC) - DC Protection: Fuses, 9 DC inputs - Appropriate SPD for DC input, AC output and RS485 monitoring equipment - DC Input and AC output Isolators - 2500 kVA MV Transformer 33000/400 Vac Dyn11 in integrated container - 33kV MV Switchgear (3-way RMU) in integrated container - Auxiliary LV Board for lighting, ventilation, monitoring, tracker motor supply, control system and security where necessary - ACB as per manufacturer - Auxiliary Services Transformer - Internal Wiring, including inverter/transformer interconnects - Monitoring System - Auxiliary transformer to have capacity for tracker motor supply - Power plant control system according to Grid Code requirements (including localised PLC controllers in each inverter cabin) <u>Auxiliary Systems</u>	No.	24	R 3 100 500.91	R 74 412 021.79
2	3-phase Distribution board 400V/240V / 60A TP for Control Building. Including surge protection and UPS (8-hour standby for 4kVA). To supply lighting, sockets outlets, security (camera system, access gate/boom, electric fence section), SCADA monitoring and other AC auxiliaries (such as gate motors)	No.	1	R 20 000.00	R 20 000.00
3	UPS units for power stations to power tracker motors that includes weather monitoring installations. Two-day standby for a load of 96 kWh.	No.	5	R 150 000.00	R 750 000.00

	Supply and Installation of Data Communication and monitoring system (SCADA), to include amongst others: -Based on Wonderware System Platform 2014 R2 with Device Integration -Intouch for System Platform with Historian Client 2014 R2 - 76 596 m of RS485 cable (7/8-core 0.5mm ² THWN-2 or equivalent as per system manufacturer requirements) shielded, twisted-pair, stranded copper, buried direct in ground or run in cable trays.				
4	- 6 120 m of Multi-mode 8G 50/125 Fibre-Optic cable or equivalent as per system manufacturer requirements, buried direct in ground. - Please refer to communications drawing and take into account what is already supplied by the inverter manufacturer. - Also included in this system is all server hardware (fibre optic switches, storage systems), ethernet/network controllers, HMI/desktop computer interface, SCADA software and all associated licenses.	Sum	1	R 3 486 240.00	R 3 486 240.00
5	Supply, delivery and installation of 3-core single phase 2.5mm ² PVC LV cable for Actuator Power	m	70 992	R 13.40	R 951 292.80
6	10mm galvanised steel earth conductor or flat bar for: Power Station earth mat, including: 2 x galvanised steel earthing rods encircling each pair of MV power station. These will be bonded to the DC an MV earth system.	m	4 608	R 40.00	R 184 320.00
TOTAL CARRIED FORWARD TO SUMMARY					R 79 883 678.46

APPENDIX 10: BILL OF QUANTITY NO.6 – MV COLLECTOR NETWORK

Item Ref	Description	Unit	No. Units	Cost/Unit (ZAR)	Total Cost (ZAR)
	<u>Bill No. 6: MV Collector Network Supply, Transportation & Installation</u> <u>MV collector network</u>				
1	MV Interconnecting cable: Power Station to Power Stations , selected stations: - Vultex Type B - 3 core - Aluminium - 95 mm² - XLPE insulated , Cu tape screened and PVC sheathed or eq. - Aluminium conductor - 33kV rated - Including all cable fasteners/cable ties where/if required	m	2 712	R 343.68	R 932 060.16
2	MV Interconnecting cable: Power Station to Power Stations , selected stations: - Vultex Type B - 3 core - Aluminium - 240 mm² - XLPE insulated , Cu tape screened and PVC sheathed or eq. - Aluminium conductor - 33kV rated - Including all cable fasteners/cable ties where/if required - Suitable for burial (SWA not mandatory)	m	5 192	R 515.93	R 2 678 914.93
3	Cable warning tape to be installed in cable trench as shown on drawings (150mm wide tape required)	m	16 707	R 1.00	R 16 707.00
4	33kV XLPE AL Screened Connectors by IsoTech, Euromold or equivalent	No.	306	R 7 000.00	R 2 142 000.00
5	33kV Screened compact surge arresters to be mounted on Screened Connectors in cable boxes of 22kV switchgear: IsoTech, Euromold or equivalent	No.	153	R 4 000.00	R 612 000.00
	<u>Trench Earthing System for MV cable (trenching measured in Civil Works BoQ)</u>				
6	Lightning risk assessment and Lightning strike mitigation/SANS 62305 compliance report	Sum	1	R 20 000.00	R 20 000.00
7	10mm galvanised steel earth conductor: MV cable trench earth	m	7 904	R 40.00	R 316 176.00
TOTAL CARRIED FORWARD TO SUMMARY					R 6 724 575.95

**APPENDIX 11: BILL OF QUANTITY NO.7 – WEATHER & PERFORMANCE
MONITORING**

Item Ref	Description	Unit	No. Units	Cost/Unit (ZAR)	Total Cost (ZAR)
	<u>Bill No. 7: Weather & Performance Monitoring</u>				
	-				
1	<u>Plant-wide Anemometer devices</u>	No.	1	R 10 000.00	R 10 000.00
1.1	Pole-mounted anemometer installed at positions as indicated on the project drawings, including datalogger/RS485 interface, cable glands and mounting pole/structure. Anemometer to be installed at 1.5m a.g.l.				
1.2	The data logger/RS485 interface connection will be made to the nearest string box. Installation (including mounting plates, platforms, nuts, bolts) and commissioning of Weather station works				
2	<u>Meteorological stations (In PV field)</u>	No.	3	R 180 000.00	R 540 000.00
2.1	These units will be mounted on the tracking structure at the positions indicated on the project drawings. These stations shall include the following equipment:				
2.2	2 x Calibrated reference PV cells				
2.3	1 x Plane-of-Array (POA) Pyranometer (ISO 9060 Secondary Standard)				
2.4	1 x Horizontal pyranometer (ISO 9060 Secondary Standard)				
2.5	1 x PV module temperature sensor with accuracy of +/- 1 degree or better mounted on the back of the closest PV module				
2.6	1 x Anemometer including datalogger/RS485 interface, cable glands and mounting pole/structure mounted in ground. Anemometer mounted 1.5m a.g.l.				
2.7	Weather Station data logger (log 15 days' data at 1-minute intervals, 5-minute averages of 1-minute samples to be recorded every 5 minutes) and SCADA/RS485 or Fibre interface				
2.8	Installation (including mounting plates, platforms, nuts, bolts) and commissioning of Weather station works				
3	<u>Meteorological Station (At Control Building)</u>	No.	1	R 200 000.00	R 200 000.00
3.1	These units will be mounted on or near the Control Building. This station shall include the following equipment:				
3.2	1 x Horizontal pyranometer (ISO 9060 Secondary Standard)				

3.3	1 x Ambient air temperature sensor with accuracy of +/- 1 degree or better				
3.4	1 x Anemometer including datalogger/RS485 interface, cable glands and mounting pole/structure mounted in ground. Anemometer mounted 1.5m a.g.l. or at roof level.				
3.5	1 x Rain gauge				
3.6	1 x Hygrometer				
3.7	Weather Station data logger (log 15 days' data at 1-minute intervals, 5-minute averages of 1-minute samples to be recorded every 5 minutes) and SCADA/RS485 or Fibre interface				
3.8	Installation (including mounting plates, platforms, nuts, bolts) and commissioning of Weather station works				
	<u>Transportation</u>				
4	Transport and delivery to site of Weather monitoring equipment	Sum	1	R 5 000.00	R 5 000.00
TOTAL CARRIED FORWARD TO SUMMARY					R 755 000.00

**APPENDIX 12: BILL OF QUANTITY NO.8 – SITE PREPARATION, ROADS &
LAYDOWN AREA**

Item Ref	Item Type	Description	Unit	No. Units	Cost/Unit (ZAR)	Total Cost (ZAR)
1	SANS 1200 C 8.2.1	<u>Bill No. 8: Site Preparation, Roads & Laydown Area</u> <u>Site Clearance</u> Clear and grub area of all trees and large bushes for whole site area to allow installation of equipment. Phase 1	Ha	134	R 15 000.00	R 2 003 466.00
2	SANS 1200 DM 8.3.4	<u>Laydown Area Preparation</u> <u>Earthworks</u> Cut to fill 150mm layer Compact to 90% mod AASTHO maximum dry density	m³	2 250	R 85.00	R 191 250.00
	(a)	Rockfill, process and compact	m³	225	R 105.00	R 23 625.00
	(b)	Note area based on provisional allocation included in drawing. Contractor to confirm space requirements.				
3		Allow for internal road within laydown area to deliver all material including modules. Turning circle to allow for delivery trucks to enter and exit site along road 8. Contractor to specify requirements.	Sum	1	R 100 000.00	R 100 000.00
4	SANS 1200 D 8.3.4	<u>Importing of materials</u> Opening up and closing down of designated borrow pit	Sum	1	R 150 000.00	R 150 000.00
	(b)					
5	SANS 1200 DM 8.3.2	<u>4m Wide Secondary Gravel Road</u> <u>Preparation of site</u> Preparation and stripping of Site/ removal of topsoil to 50-75mm,	m³	1 654	R 45.00	R 74 418.75
	(a)					

6	8.3.3 (a)	Treatment of road-bed Road-bed preparation and compaction of material to 2) minimum of 93% of mod. AASHTO maximum density (150mm layer)	m³	3 969	R 105.00	R 416 745.00
7	8.3.5	Selected layer compacted to 93% of mod. AASHTO maximum density	m³	198	R 145.00	R 28 775.25
8	8.3.6	Extra-over items 8.3.4 and 8.3.5 for excavating and breaking down material in Hard rock	m³	116	R 450.00	R 52 093.13
9	8.3.7 (b) (c)	Cut to spoil or stockpile hard rock common material	m³ m³	116 2 199	R 115.00 R 85.00	R 13 312.69 R 186 956.44
10	8.3.10	Materials bladed to windrow	m³	110	R 65.00	R 7 148.33
11	8.3.11	Extra-over items 8.3.2, 8.3.4, 8.3.5 for temporary stockpiling of material	m³	220	R 45.00	R 9 897.69
12	8.3.16	Gravel wearing course 150mm gravel surface layer compacted to 95% of mod. AASHTO max. density. (G5 Quality Material)	m³	992	R 350.00	R 347 287.50
13	SANS 1200 DM 8.3.2 (a)	<u>6m Wide Primary Gravel Road</u> Preparation of site Preparation and stripping of Site/ removal of topsoil to 50-75mm, stockpiling, and maintaining.	m³	2 402	R 45.00	R 108 084.38
14	8.3.3	Treatment of road-bed				

	(a)	Road-bed preparation and compaction of material to 2) minimum of 93% of mod. AASHTO maximum density (150mm layer)	m³	5 765	R 105.00	R 605 272.50
15	8.3.5	Selected layer compacted to 93% of mod. AASHTO maximum density	m³	288	R 145.00	R 41 792.63
16	8.3.6	Extra-over items 8.3.4 and 8.3.5 for excavating and breaking down material in Hard rock	m³	264	R 450.00	R 118 892.81
17	8.3.7	Cut to spoil or stockpile				
	(b)	hard rock	m³	264	R 115.00	R 30 383.72
	(c)	common material	m³	5 020	R 85.00	R 426 693.09
18	8.3.10	Materials bladed to windrow	m³	251	R 65.00	R 16 314.74
19	8.3.11	Extra-over items 8.3.2, 8.3.4, 8.3.5 for temporary stockpiling of material	m³	502	R 45.00	R 22 589.63
20	8.3.16	Gravel wearing course 200mm gravel surface layer compacted to 95% of mod. AASHTO max. density. (G5 Quality Material)	m³	7 686	R 350.00	R 2 690 100.00
21		Signage Allow budgetary allowance for road signage	Sum	1	R 11 666.67	R 11 666.67
TOTAL CARRIED FORWARD TO SUMMARY						R 7 676 765.94

APPENDIX 13: BILL OF QUANTITY NO.9 – STORMWATER DRAINAGE

Item Ref	Item Type	Description	Unit	No. Units	Cost/Unit (ZAR)	Total Cost (ZAR)
1	SANS 1200 DA 8.3.1	<u>Bill No. 9: Stormwater Drainage</u>				
		<u>Gravel Road Stormwater Crossing - Drifts</u>				
		Excavation Removal of wearing course and subbase to 200 mm depth, stockpile and maintain. To include superficial recompacting of exposed subbase layer. 1) 4m wide road 2) 6m wide road	m ³ m ³	0.0 195.8	R 165.00 R 165.00	R 0.00 R 32 313.60
2	SANS 1200 G 8.4.3	Concrete Works Concrete: Supply and place Drift concrete. 28-day concrete strength to be 30MPa. 19mm nominal aggregate size 1) 4m wide road 2) 6m wide road	m ³ m ³	0.0 124.0	R 2 150.00 R 2 150.00	R 0.00 R 266 565.60
3	8.4.4	Unformed surface finishes a) wood-floated finish	m ²	826.6	R 25.00	R 20 664.00
4	8.3.2	High-tensile welded mesh Ref. no. 617	m ²	826.6	R 95.00	R 78 523.20
5	SANS 1200 D 8.3.1.2	<u>Stormwater Channel Excavation and Riprap</u>				
		Remove topsoil to a depth of 50-75mm, stockpile and maintain	m ²	27 680	R 35.00	R 968 800.00
6	8.3.2	Excavate material other than topsoil or hard rock Material which is machine excavatable by normal methods using a backacter or similar excavation plant Extra-over for hard rock	m ³ m ³	28 545 1 730	R 100.00 R 250.00	R 2 854 500.00 R 432 500.00

7	SANS 1200 DM 8.3.3 (a)	Treatment of excavation bed Excavation-bed preparation: Rip and compaction of material. Compact 150mm layer to 90% MOD AASHTO max. density	m ³	4 325	R 85.00	R 367 625.00
	SANS 1200DK 8.2.5	Riprap Layer Construct riprap layer: 400mm thick on base and 600mm thick on sides of channel. Graded rock D ₅₀ = 0.45m	m ³	1 730	R 450.00	R 778 500.00
		<u>Typical Cascade Section and Plunge Pool</u>				
8	SANS 1200 D 8.3.1.2	Remove topsoil to a depth of 50-75mm, stockpile and maintain	m ²	4 320	R 35.00	R 151 200.00
9	8.3.2	Excavate material other than topsoil or hard rock Material which is machine excavatable by normal methods using a backacter or similar excavation plant	m ³	4 950	R 100.00	R 495 000.00
	(b)	Extra-over for hard rock	m ³	252	R 250.00	R 63 000.00
10	SANS 1200 DM 8.3.3 (a)	Treatment of excavation bed Excavation-bed preparation: Rip and compaction of material. Compact 150mm layer to 90% MOD AASHTO max. density	m ³	675	R 85.00	R 57 375.00
11	SANS 1200DK 8.2.5	Stream and Plunge Pool Riprap Layer Construct riprap layer: 400mm thick on base and 600mm thick on sides of channel. Graded rock D ₅₀ = 0.45m	m ³	900	R 450.00	R 405 000.00
	8.2.5	Cascade and Plunge Pool Step Riprap Layer				

12	SANS 1200 DM 8.3.3 (a)	Construct riprap layer: 1000mm thick on base and on sides of channel. Graded rock D ₅₀ = 0.90m	m ³	1 890	R 550.00	R 1 039 500.00
		<u>SW Channel</u>				
		Treatment of excavation bed Excavation-bed preparation: Rip and compaction of material. Compact 150mm layer to 90% MOD AASHTO max. density	m ³	10 400	R 85.00	R 884 000.00
		Re-vegetate Channel	m ²	19 032	R 35.00	R 666 120.00
TOTAL CARRIED FORWARD TO SUMMARY						R 9 561 186.40

APPENDIX 14: BILL OF QUANTITY NO.10 – TRENCHES

Item Ref	Description	Unit	No. Units	Cost/Unit (ZAR)	Total Cost (ZAR)
	<u>Bill No. 10: Trenches</u>				
	<u>MV Trenches</u>				
	Single Width				
1	600mm (x 1200mm deep) Trenches: Excavate all material other than hard rock for cable trenches, 600mm wide, and 1.2m deep, including bedding, laying cables, blanket layer, backfill and placement of warning tape	m	3 394	R 72.00	R 244 368.00
2	Excavate hard rock for cable trenches - 20% of total volume estimated to be hard rock	m ³	489	R 250.00	R 122 184.00
	Double width				
3	781mm (x 1200mm deep) Trenches: Excavate all material other than hard rock for cable trenches, 600mm wide, and 1.2m deep, including bedding, laying cables, blanket layer, backfill and placement of warning tape	m	908	R 72.00	R 65 376.00
4	Excavate hard rock for cable trenches - 20% of total volume estimated to be hard rock	m ³	170	R 250.00	R 42 548.88
	Triple width				
5	1200mm (x 1200mm deep) Trenches: - Excavate all material other than hard rock for cable trenches, 1.2m wide, and 1.2m deep, including bedding, laying cables, blanket layer, backfill and placement of warning tape	m	0	R 72.00	R 0.00
6	Excavate hard rock for cable trenches - 20% of total volume estimated to be hard rock	m ³	0	R 250.00	R 0.00
	<u>Control Building LV Supply Trench</u>				
7	600mm (x 800mm deep) Trench containing LV cable: - Excavate all material other than hard rock for cable trenches, 600mm wide, and 800mm deep, including bedding, laying cables, blanket layer, backfill and placement of warning tape	m	0	R 72.00	R 0.00
8	Excavate hard rock for cable trenches - 20% of total volume estimated to be hard rock	m ³	0	R 250.00	R 0.00
	<u>DC Trenches</u>				

9	600mm DC trenches: - Excavate all material other than hard rock for cable trenches, 600mm wide, and 800mm deep, including bedding, laying cables, blanket layer, backfill and placement of warning tape	m	1 815	R 72.00	R 130 680.00
10	Excavate hard rock for cable trenches - 20% of total volume estimated to be hard rock	m ³	174	R 250.00	R 43 560.00
<u>Anemometer Trenches</u>					
11	600mm Power Station trenches containing connecting cables from Inverter to Transformer - Excavate all material other than hard rock for cable trenches, 600mm wide, and 800mm deep, including bedding, laying cables, blanket layer, backfill and placement of warning tape	m	66	R 72.00	R 4 752.00
12	Excavate hard rock for cable trenches - 20% of total volume estimated to be hard rock	m ³	6	R 250.00	R 1 584.00
TOTAL CARRIED FORWARD TO SUMMARY					R 655 052.88

**APPENDIX 15: BILL OF QUANTITY NO.11 – TRANSFORMER & INVERTER
FOUNDATION**

Item Ref	Item Type	Description	Unit	No. Units	Cost/Unit (ZAR)	Total Cost (ZAR)
		<u>Bill No. 11: Transformer & Inverter Foundation</u>				
		<u>Transformer & Inverter Container Foundation</u>				
	SANS 1200 D					
1	8.3.1.2	Remove topsoil to a depth of 50-75mm, stockpile and maintain	m ²	2 379	R 35.00	R 83 281.80
2	8.3.2	Excavate material other than topsoil or hard rock				
	(a)	Material which is machine excavatable by normal methods using a backacter or similar excavation plant	m ³	8 804	R 100.00	R 880 407.60
	(b)	Extra-over for hard rock	m ³	440	R 250.00	R 110 050.95
	SANS 1200 DM					
3	8.3.3	Treatment of excavation bed				
	(a)	Excavation-bed preparation: Rip and compaction of material. Compact 150mm layer to 90% MOD AASHTO max. density	m ³	134	R 85.00	R 11 374.02
4	8.3.5	Selected Fill Fill over excavation with selected fill (G7) in 150mm layers to 95% MOD AASHTO	m ³	2 649	R 200.00	R 529 804.80
5	8.3.16	Gravel Surface Layer 250mm gravel surface layer compacted to 95% MOD AASHTO in 250mm layers (G7/G8 Quality Material)	m ³	595	R 200.00	R 118 974.00
6	SANS 1200 G 8.2.2	Formwork to sides of Foundations (including shutter, bracing, ties, support and all temporary works and consumables)	m ²	379	R 350.00	R 132 526.80
7	8.3.2	Steel Reinforcement: Supply and fix High-Tensile steel reinforcing	t	8.85	R 15 000.00	R 132 678.00

8	8.4.2	(including all supports and temporary works) Blinding Concrete: Supply and place 50mm Blinding Concrete. 28-day concrete strength to be 10MPa. 19mm nominal aggregate size	m ²	161	R 1 250.00	R 201 600.00
9	8.4.3	Concrete: Supply and place Foundation concrete. 28-day concrete strength to be 30MPa. 19mm nominal aggregate size	m ³	98	R 1 400.00	R 137 592.00
10	8.8	HD Bolts to Transformer Foundations: Supply and install M10 Threaded Rod Hot Dipped Galvanized Holding Down Bolts (4 per plate)	No.	576	R 200.00	R 115 200.00
11	8.7	Grout: Supply and place cementitious non-shrink grout nominally 25mm thick	m ³	3	R 3 000.00	R 7 560.00
TOTAL CARRIED FORWARD TO SUMMARY						R 2 461 049.97

APPENDIX 16: BILL OF QUANTITY NO.12 – CONTROL BUILDING

Item Ref	Item Type	Description	Unit	No. Units	Cost/Unit (ZAR)	Total Cost (ZAR)
1		<u>Bill No. 12: Control Building</u>				
		<u>Control Building</u>	No.	1		
		Construct and commission Control Room Building consisting: Single storey Control Room Building, rectangular-shaped on plan, size overall 13,240 x 8,670mm and 3,400mm floor to ceiling, constructed of load bearing cavity brickwork around the perimeter and single skin brickwork internally built off concrete strip foundations, faced externally and generally plastered and painted internally, double pitched timber roof trusses with chromadek roof sheeting over.				
		i.				
		Contractor to provide unit rates for the following areas:				
		<i>Storage Room (17.85m²)</i>	m ²	17.85	R 12 000.00	R 214 200.00
		<i>Control & Security Room (29.2m²)</i>	m ²	29.2	R 12 000.00	R 350 400.00
		<i>Open Office (20.5m²)</i>	m ²	20.5	R 12 000.00	R 246 000.00
2		<i>Change room (12.4m²)</i>	m ²	12.4	R 12 000.00	R 148 800.00
		<i>Kitchen (12.0m²)</i>	m ²	12.0	R 12 000.00	R 144 000.00
		<i>Server Room (7.0m²)</i>	m ²	7.0	R 12 000.00	R 84 000.00
		Supply, delivery and installation of 4-core 16mm ² PVC LV + 10mm ² insulated copper/aluminium/steel earth wire -- Control Building supply cable	m	200	R 30.00	R 6 000.00

3		Allow the following budgetary allowance for all building services, including but not limited to, 4500l rainwater tank, rainwater treatment and recycling, water and sewer reticulation, sewer conservancy tank and soakaway, solar water heating, fire protection, electrical fit-out (installation and commissioning) of the Control Buildings, including earthing, wiring of distribution board(s), lighting, SSOs and data network.	Sum	1		R 0.00
		Vehicle Parking area (Only at Control Room Building)				
4	SANS 1200 DM 8.3.3(a)	Rip formation 150mm deep and re-compact to 93% MOD AASHTO max. density	m ³	19	R 85.00	R 1 632.00
5	SANS 1200 MJ 8.2.2	80mm Interlocking concrete paving bricks on 25mm bedding sand	m ²	128	R 350.00	R 44 625.00
6	SANS 1200 MK 8.2.1(b)	Precast concrete kerbing	m	24	R 270.00	R 6 345.00
7		Signage Allow budgetary allowance for site signage	Sum	1	R 10 000.00	R 10 000.00
TOTAL CARRIED FORWARD TO SUMMARY						R 1 256 002.00

APPENDIX 17: BILL OF QUANTITY NO.13 – FIRE & SECURITY SYSTEM

Item Ref	Description	Unit	No. Units	Cost/Unit (ZAR)	Total Cost (ZAR)
	<u>Bill No. 13: Fire & Security System</u>				
	<u>Perimeter Fencing</u>				
1	A double fencing (3m high) system, surrounding the entire plant, should be erected as a perimeter barrier. The gap between the double fencing should be in excess of 10m, to create a no-man's land.				
	Supply, transportation, installation and commissioning of perimeter fence as follows:				
	- 3m high welded wire mesh fence (inside)	m	11 138	R 710.00	R 7 907 980.00
	- 3m high Clear-vu fence (outside)	m	11 138	R 1 830.00	R 20 382 540.00
	- A secondary electrified fence should be erected within the double fencing system, adding protection and early warning to possible intrusion attempts.	m	11 138	R 340.00	R 3 786 920.00
	Including all foundations, posts, trenching, cables or communications as required				
2	Supply, transportation, installation and commissioning of perimeter gates as follows:				
	- Inner Fence Gate - 6m wide, with a pedestrian gate, built into the main inner gate construction.	No.	2	R 17 050.00	R 34 100.00
	- Outer Fence Gate - 6m wide, with a pedestrian gate, built into the main outer gate construction.	No.	2	R 42 600.00	R 85 200.00
	- Guard House with CCTV Control Room and 3m x 3m Search Cubicle	No.	2	R 67 500.00	R 135 000.00
	<u>CCTV Camera</u>				
3	CCTV Camera to be mounted on post or Control Building to provide view of the facility entrance and external access road.				
	- Minimum of 80m viewing range for 0 Lux	No.	186	25000	R 4 650 000.00
	- Powered by Control Building				
	- To be operated from Control Building				
	- Including all foundations, posts, cables, trenching, as required				
	<u>Laydown Area Security</u>				

4	Supply, transportation, installation and commissioning of perimeter fence as follows: - Dual fence with 1.8 m high diamond mesh fence (outside) and 2.4m high electric fence (inside) - Self-powered using independent PV module and battery system - Able to detect location of intrusion in zones not longer than 100m - Security personnel on site able to determine intrusion zone - Including all foundations, posts, trenching, as required - Include allowance for gate(s) for equipment delivery and to access site as per Contractor requirements.	m	1 045	2750	R 2 873 750.00
5	<u>Fire Protection</u> Fire Extinguishers and other protection equipment as per OHSACT.	Sum	1	150000	R 150 000.00
TOTAL CARRIED FORWARD TO SUMMARY					R 40 005 490.00

APPENDIX 18: BILL OF QUANTITY NO.14 – FACILITY SUBSTATION

1	Earthworks, stormwater management, layer works, compaction, trenches, and other civil works not listed below	Sum	1		
2	Lighting masts (including flood lights) and lightning rods, including earth resistance tests	Sum	4		
3	Building to house MV switchgear, metering, battery backup system, etc. including foundations, brickwork, roof, fit-out, cable trays, cable trenches, ducts, air-conditioning, etc.	Sum	1		
4	Transformer plinth and oil containment bund area: 80MVA transformer	Sum	2		
5	Oil dam	Sum	2		
6	Yard-stone, kerbing, internal concrete road and fence (incl. gates)	Sum	1		
7	Steel work and foundations for mounting of 132kV equipment	Sum	1		
8	Fire barrier steel work and foundation	Sum	0		
9	Earth Mat - 10mm Ø Copper rod, 50mm x 3mm Copper strap, brazed joints and connections, excavations, testing	Sum	1		
10	132kV equipment: - SF6 circuit breakers - Post-insulators - VTs and CTs - Isolators - Surge arresters - 132kV Tubular Busbar	Sum	1		
11	132kV/33kV Power Transformer: - 80MVA - YNd1 vector group as per Eskom Embedded Generation Standard DST 34-1765 / DPL 34-2149 - ONAN (ONAF if required by manufacturer due to ambient conditions) - On-load automatic tap-changer - Oil-filled bushings - Thermometer & Buchholz relay	No.	1		
12	3-core 240mm ² Al XLPE cable 33kV for connection of MV switchgear to MV/HV transformers	m	30		
13	Pad-mounted Neutral Earthing Compensator with Resistor and Transformer (NECRT) use as auxiliary transformer: 100kVA, vector group YNd1d1	No.	1		
14	Overhead conductor: Centipede (to be confirmed)	m	55		

15	33kV Switchgear: - SF6 - IRIG-B signal distribution - Infrared inspection ports, rear and front lockable doors - Condensation heaters - 5 PV plant feeder isolator/CB combination units - 1 Transformer feeder isolator/CB combination unit integrated with transformer protection panel	No.	6		
16	Low Voltage installation including: - DC power, AC power, cables - Protection relays - Control wiring - Mimic panels - Transformer control - Interface with Eskom (iBox, etc.) - Facility (IPP) metering	Sum	1		
17	Substation Automation: Controls, Telecoms, Security, RTU, Fibre Optics Works SCADA system: Equipment including but not limited to: - Equipment racks and containers - Switches, splice boxes, controllers, power supplies, - Computer hardware, software and licenses Facility Monitoring: - String status - Power Station status (inverter, transformer, MV switches) - IPP-substation switch status - Total Active power, reactive power, PF, real power, frequency, irradiation, etc. - Grid Code compliance controls (see SA Renewable Energy Grid Compliance Code)	Sum	1		
18	Provisional amount for reactive power compensation and harmonic filtering equipment, including engineering, foundations, cabling, control panel, fencing, installation and commissioning	Sum	1		
19	Commissioning and Testing	Sum	1		

20	Grid Code Compliance Testing: - Creation of DigSilent model of PV Facility - Simulation of Facility Grid Code Compliance - Reactive Power and Voltage Compliance studies - Power Quality studies: harmonics/flicker - Voltage ride-through - Frequency Response - On-site tests - Data collection & RETEC documentation submission - Dynamic controller Power factory models	Sum	1		
21	Security system and fence for substation area	Sum	1		
22	Power Quality meter measuring power quality as per NRS048 at the Point of Utility Connection	Sum	1		
23	Temporary fencing, barricading etc. during construction	Sum	1		
	<u>Transportation</u>				
24	Transportation and placement of 1x80MVA 132/33kV Power Transformers	Sum	1		
25	Transportation and placement of Electrical Equipment and Steel Structures	Sum	1		
TOTAL CARRIED FORWARD TO SUMMARY					R 62 000 000.00

APPENDIX 19: BILL OF QUANTITY NO.15 – SPARE PARTS

Item Ref	Description	Unit	No. Units	Cost/Unit (ZAR)	Total Cost (ZAR)
	<u>Bill No. 15: Spare Parts</u>				R 5 000 000.00
1	Modules				
1.1	JJinko JKM320PP-72-DV 320 Eagle PV Modules PV Modules	No.	200		R 0.00
2	LV Collector Network				
2.1	1000/600 V 6mm ² Tin-plated Cu PVC insulated single core UV protected Solar Cables	m	300		R 0.00
2.2	1000/600 V DC Solar Connectors (Male & Female Pair)	No.	100		R 0.00
2.3	240mm ² DC Cable Al XLPE/PVC 0.6/1kV type NAYY or equivalent	m	80		R 0.00
2.4	Jointing kits for 240mm ² DC Cable	No.	6		R 0.00
2.5	50mm ² (8mm diameter) galvanised steel wire used as earthing conductor for PV mounting structures	m	10		R 0.00
2.6	400 x 120mm galvanised cable tray, including cover, nuts, bolts and other clamps, brackets and mounting accessories	m	50		R 0.00
2.7	String Combiner Unit as per design	No.	1		R 0.00
2.8	DC Fuses 20 Amps	No.	100		R 0.00
2.9	Type 1/2 Surge Arrestor	No.	5		R 0.00
2.10	Cable ties 200mm (Solar Grade)	No.	200		R 0.00
3	Power Station & Comms				
3.1	Inverter Components:				
3.1.1	DC Fuses	No.	60		R 0.00
3.1.2	IGBT Set	No.	2		R 0.00
3.1.3	DC Breaker	No.	2		R 0.00
3.1.4	AC Breaker	No.	2		R 0.00
3.1.5	Communication Adapter	No.	2		R 0.00
3.1.6	Inverter Surge Protection Units	No.	2		R 0.00
3.2	LV Interconnecting cable	m	1		R 0.00
3.3	Jointing kits for LV Interconnecting cable	No.	6		R 0.00
3.4	2500 kVA MV Transformer 22000/400 Vac Dyn11 in separate container including 33kV MV switchgear and LV Board	No.	1		R 0.00
3.5	Auxiliary Services Transformer	No.	2		R 0.00
3.6	Auxiliary Systems				
3.6.1	RS485 Cable	m	150		R 0.00
3.6.2	Fibre Optic Cable	m	150		R 0.00
3.6.3	Fibre Optic Cable Joint Kit	No.	6		R 0.00
3.7	3-core single phase 2.5mm ² PVC LV cable for Actuator Power	m	210		R 0.00
3.8	Jointing kits for Actuator Power Cable	No.	6		R 0.00
4	MV Collector Network				

4.1	MV Interconnecting cable: Power Station to Power Stations	m	150		R 0.00
4.2	Jointing kits for MV Interconnecting cable	No.	6		R 0.00
4.3	33kV XLPE AL Screened Connectors	No.	3		R 0.00
4.4	33kV Screened compact surge arresters	No.	3		R 0.00
4.5	150mm ² galvanised steel earth conductor	m	50		R 0.00
5	Performance Monitoring				
5.1	Anemometer	No.	2		R 0.00
5.2	Calibrated reference PV cells	No.	2		R 0.00
5.3	Pyranometer (ISO 9060 Secondary Standard)	No.	1		R 0.00
5.4	Module temperature sensor with accuracy of +/- 1 degree or better	No.	2		R 0.00
6	Control Building				
6.1	Set of spare bulbs sufficient to replace all bulbs	Sum	1		R 0.00
6.2	ADSL Router	No.	1		R 0.00
6.3	LAN Router	No.	1		R 0.00
6.4	Fibre Optic Switch	No.	1		R 0.00
6.5	Portable generator for powering one tracker block and associated meteorological equipment during extended outage. H&S Equipment.	No.	1		R 0.00
6.6	To be specified in the Contract. Should allow for all equipment to safely operate the facility including PPE etc.	Sum	1		R 0.00
6.7	Control/Operations Building 4-core LV supply cable	m	10		R 0.00
7	Security System				
7.1	Energizer, including self-powering unit	No.	1		R 0.00
7.2	Wire mesh fence	m	50		R 0.00
7.3	Electric fence	m	50		R 0.00
8	Facility Substation				
8.1	132kV Circuit Breaker	No.	1		R 0.00
8.2	132kV Current Transformer	No.	1		R 0.00
8.3	132kV Voltage Transformer	No.	1		R 0.00
8.4	132kV Isolator (Centre Rotating)	No.	1		R 0.00
8.5	132kV Surge Arrester	No.	3		R 0.00
8.6	33kV Surge Arresters	No.	3		R 0.00
8.7	Protection Relays:				
8.7.1	Protection Relay OC/EF	No.	1		R 0.00
8.7.2	Protection Relay Trfr Diff	No.	1		R 0.00
8.7.3	Protection Relay Trfr AVR	No.	1		R 0.00
8.7.4	Ethernet Communication - Switches	No.	1		R 0.00
8.7.5	Protection Relay Buszone	No.	1		R 0.00
8.7.6	Protection Relay Trfr REF	No.	1		R 0.00
8.8	Tariff Meter	No.	1		R 0.00
8.9	Power Transformer (80MVA 132/22kV):				
8.9.1	Gaskets	Set	1		R 0.00
8.9.2	Bushing (HV, HVN, LV)	Set	1		R 0.00

8.9.3	Pressure relief device/valve	No.	1		R 0.00
8.9.4	Buchholz Relay	No.	1		R 0.00
8.9.5	Winding Temperature Indicator (WTI)	No.	1		R 0.00
8.9.6	Oil Temperature Indicator	No.	1		R 0.00
8.9.7	Magnetic Oil Gauge (MOG)	Set	1		R 0.00
8.9.8	Transformer Protection Kit	No.	1		R 0.00
8.9.9	Thermo Protection Relay	No.	1		R 0.00
8.9.10	Fan	No.	1		R 0.00
8.9.11	Pump	No.	1		R 0.00
8.10	33kV MV Switchgear Panels - Feeder	No.	1		R 0.00
8.11	Cables (XLPE 240mm ² Al)	m	10		R 0.00
8.12	50x3mm Copper Straps	m	20		R 0.00
9	Mounting + Tracker Structure				
9.1	Drive unit	No.	10		R 0.00
9.2	Bearings (to be discussed with supplier)	No.	40		R 0.00
9.3	Complete tracker block components	No.	2		R 0.00
10	Storage				
	Shipping containers to be placed on site to store large spares that cannot be placed in the Control Building warehouse. Quantity and size to be sufficient for material listed.				
10.1	Containers to be placed on concrete sleepers as per inverter container foundation.	Sum	1		R 0.00
TOTAL CARRIED FORWARD TO SUMMARY					R 5 000 000.00

APPENDIX 20: BILL OF QUANTITY NO.16 – OVERHEAD LINE

Item Ref	Description	Unit	No. Units	Cost/Unit (ZAR)	Total Cost (ZAR)
	<u>Bill No. 16: Overhead Line</u>				
1	Preliminary and General				
1.1	Establishment of facilities on site	sum	1	R 345 600.00	R 345 600.00
1.2	Water, electrical and ablution facilities	sum	1	R 113 184.00	R 113 184.00
1.3	Operation and maintenance of facilities	sum	1	R 403 200.00	R 403 200.00
1.4	Removal of site establishment	sum	1	R 129 600.00	R 129 600.00
1.5	Contractors time related items (machinery hire, supervision, site security etc.)	sum	1	R 2 103 840.00	R 2 103 840.00
1.7	Construction regulations	sum	1	R 379 200.00	R 379 200.00
2	Foundations - Supply and Erect				
2.1	Strain foundations - Type 2				
2.1.1	Pole, St 132kV Strain Guyed Monopoles; (0°-90°); 18m	No.	0	R 3 428.25	R 0.00
2.1.2	Pole, St 132kV Strain Guyed Monopoles; (0°-90°); 19m	No.	0	R 3 428.25	R 0.00
2.1.3	Pole, St 132kV Strain Guyed Monopoles; (0°-90°); 20m	No.	6	R 3 428.25	R 20 569.50
2.1.4	Pole, St 132kV Strain Guyed Monopoles; (0°-90°); 21m	No.	4	R 3 428.25	R 13 713.00
2.1.5	Pole, St 132kV Strain Guyed Monopoles; (0°-90°); 22m	No.	5	R 3 428.25	R 17 141.25
2.1.6	Pole, St 132kV Strain Guyed Monopoles; (0°-90°); 23m	No.	1	R 3 428.25	R 3 428.25
2.1.7	Pole, St 132kV Strain Guyed Monopoles; (0°-90°); 24m	No.	0	R 3 428.25	R 0.00
2.2	Strain foundations - Type 3				
2.2.1	Pole, St 132kV Strain Guyed Monopoles; (0°-90°); 18m	No.	1	R 4 726.05	R 4 726.05
2.2.2	Pole, St 132kV Strain Guyed Monopoles; (0°-90°); 19m	No.	2	R 4 726.05	R 9 452.10
2.2.3	Pole, St 132kV Strain Guyed Monopoles; (0°-90°); 20m	No.	7	R 4 726.05	R 33 082.35
2.2.4	Pole, St 132kV Strain Guyed Monopoles; (0°-90°); 21m	No.	6	R 4 726.05	R 28 356.30
2.2.5	Pole, St 132kV Strain Guyed Monopoles; (0°-90°); 22m	No.	5	R 4 726.05	R 23 630.25
2.2.6	Pole, St 132kV Strain Guyed Monopoles; (0°-90°); 23m	No.	1	R 4 726.05	R 4 726.05
2.2.7	Pole, St 132kV Strain Guyed Monopoles; (0°-90°); 24m	No.	1	R 4 726.05	R 4 726.05
2.3	Strain foundations - Rock				
2.3.1	Pole, St 132kV Strain Guyed Monopoles; (0°-90°); 18m	No.	1	R 29 236.20	R 29 236.20
2.3.2	Pole, St 132kV Strain Guyed Monopoles; (0°-90°); 19m	No.	1	R 29 236.20	R 29 236.20

2.3.3	Pole, St 132kV Strain Guyed Monopoles; (0°-90°); 20m	No.	2	R 29 236.20	R 58 472.40
2.3.4	Pole, St 132kV Strain Guyed Monopoles; (0°-90°); 21m	No.	2	R 29 236.20	R 58 472.40
2.3.5	Pole, St 132kV Strain Guyed Monopoles; (0°-90°); 22m	No.	1	R 29 236.20	R 29 236.20
2.3.6	Pole, St 132kV Strain Guyed Monopoles; (0°-90°); 23m	No.	0	R 29 236.20	R 0.00
2.3.7	Pole, St 132kV Strain Guyed Monopoles; (0°-90°); 24m	No.	0	R 29 236.20	R 0.00
CHICADEE					
2.4	Suspension foundations - Type 2				
2.4.1	Pole, St 132kV Intermediate Self-Support Monopoles; 18m	No.	1	R 1 172.85	R 1 172.85
2.4.2	Pole, St 132kV Intermediate Self-Support Monopoles; 19m	No.	3	R 1 172.85	R 3 518.55
2.4.3	Pole, St 132kV Intermediate Self-Support Monopoles; 20m	No.	8	R 1 172.85	R 9 382.80
2.4.4	Pole, St 132kV Intermediate Self-Support Monopoles; 21m	No.	7	R 1 172.85	R 8 209.95
2.4.5	Pole, St 132kV Intermediate Self-Support Monopoles; 22m	No.	9	R 1 172.85	R 10 555.65
2.4.6	Pole, St 132kV Intermediate Self-Support Monopoles; 23m	No.	2	R 1 172.85	R 2 345.70
2.4.7	Pole, St 132kV Intermediate Self-Support Monopoles; 24m	No.	1	R 1 172.85	R 1 172.85
2.5	Suspension foundations - Type 3				
2.5.1	Pole, St 132kV Intermediate Self-Support Monopoles; 18m	No.	2	R 2 202.90	R 4 405.80
2.5.2	Pole, St 132kV Intermediate Self-Support Monopoles; 19m	No.	2	R 2 202.90	R 4 405.80
2.5.3	Pole, St 132kV Intermediate Self-Support Monopoles; 20m	No.	3	R 2 202.90	R 6 608.70
2.5.4	Pole, St 132kV Intermediate Self-Support Monopoles; 21m	No.	3	R 2 202.90	R 6 608.70
2.5.5	Pole, St 132kV Intermediate Self-Support Monopoles; 22m	No.	0	R 2 202.90	R 0.00
2.5.5	Pole, St 132kV Intermediate Self-Support Monopoles; 23m	No.	0	R 2 202.90	R 0.00
2.5.6	Pole, St 132kV Intermediate Self-Support Monopoles; 24m	No.	0	R 2 202.90	R 0.00
2.6	Suspension foundations - Rock				
2.6.1	Pole, St 132kV Intermediate Self-Support Monopoles; 18m	No.	0	R 14 863.80	R 0.00
2.6.2	Pole, St 132kV Intermediate Self-Support Monopoles; 19m	No.	0	R 14 863.80	R 0.00
2.6.3	Pole, St 132kV Intermediate Self-Support Monopoles; 20m	No.	1	R 14 863.80	R 14 863.80
2.6.4	Pole, St 132kV Intermediate Self-Support Monopoles; 21m	No.	1	R 14 863.80	R 14 863.80
2.6.5	Pole, St 132kV Intermediate Self-Support Monopoles; 22m	No.	0	R 14 863.80	R 0.00
2.6.6	Pole, St 132kV Intermediate Self-Support Monopoles; 23m	No.	0	R 14 863.80	R 0.00

2.6.7	Pole, St 132kV Intermediate Self Support Monopoles; 24m	No.	0	R 14 863.80	R 0.00
2.7	TERN Suspension foundations - Type 2				R 0.00
2.7.1	Pole, St 132kV Intermediate Self Support Monopoles; 18m	No.	1	R 1 254.95	R 1 254.95
2.7.2	Pole, St 132kV Intermediate Self Support Monopoles; 19m	No.	3	R 1 229.75	R 3 689.25
2.7.3	Pole, St 132kV Intermediate Self Support Monopoles; 20m	No.	8	R 1 229.75	R 9 838.00
2.7.4	Pole, St 132kV Intermediate Self Support Monopoles; 21m	No.	7	R 1 229.75	R 8 608.25
2.7.5	Pole, St 132kV Intermediate Self Support Monopoles; 22m	No.	9	R 1 229.75	R 11 067.75
2.7.6	Pole, St 132kV Intermediate Self Support Monopoles; 23m	No.	2	R 1 229.75	R 2 459.50
2.7.7	Pole, St 132kV Intermediate Self Support Monopoles; 24m	No.	1	R 1 229.75	R 1 229.75
2.8	Suspension foundations - Type 3				
2.8.1	Pole, St 132kV Intermediate Self Support Monopoles; 18m	No.	2	R 2 357.10	R 4 714.21
2.8.2	Pole, St 132kV Intermediate Self Support Monopoles; 19m	No.	2	R 2 357.10	R 4 714.21
2.8.3	Pole, St 132kV Intermediate Self Support Monopoles; 20m	No.	3	R 2 357.10	R 7 071.31
2.8.4	Pole, St 132kV Intermediate Self Support Monopoles; 21m	No.	3	R 2 357.10	R 7 071.31
2.8.5	Pole, St 132kV Intermediate Self Support Monopoles; 22m	No.	0	R 2 357.10	R 0.00
2.8.6	Pole, St 132kV Intermediate Self Support Monopoles; 23m	No.	0	R 2 357.10	R 0.00
2.8.7	Pole, St 132kV Intermediate Self Support Monopoles; 24m	No.	0	R 2 357.10	R 0.00
2.9	Suspension foundations - Rock				
2.9.1	Pole, St 132kV Intermediate Self Support Monopoles; 18m	No.	0	R 15 458.35	R 0.00
2.9.2	Pole, St 132kV Intermediate Self Support Monopoles; 19m	No.	0	R 15 458.35	R 0.00
2.9.3	Pole, St 132kV Intermediate Self Support Monopoles; 20m	No.	1	R 15 458.35	R 15 458.35
2.9.4	Pole, St 132kV Intermediate Self Support Monopoles; 21m	No.	1	R 15 458.35	R 15 458.35
2.9.5	Pole, St 132kV Intermediate Self Support Monopoles; 22m	No.	0	R 15 458.35	R 0.00
2.9.6	Pole, St 132kV Intermediate Self Support Monopoles; 23m	No.	0	R 15 458.35	R 0.00
2.9.7	Pole, St 132kV Intermediate Self Support Monopoles; 24m	No.	0	R 15 458.35	R 0.00
3	Supply and Erection of Structures				
3.1	Self-Support Monopoles (D-DT-7611)				
3.1.1	Pole, St 132kV Intermediate Self-Support Monopoles; 18m CAH	No.	5	R 34 811.92	R 174 059.60

3.1.2	Pole, St 132kV Intermediate Self-Support Monopoles; 19m CAH	No.	8	R 36 959.92	R 295 679.36
3.1.3	Pole, St 132kV Intermediate Self-Support Monopoles; 20m CAH	No.	18	R 38 503.92	R 693 070.56
3.1.4	Pole, St 132kV Intermediate Self-Support Monopoles; 21m CAH	No.	16	R 40 686.92	R 650 990.72
3.1.5	Pole, St 132kV Intermediate Self-Support Monopoles; 22m CAH	No.	15	R 42 887.92	R 643 318.80
3.1.6	Pole, St 132kV Intermediate Self-Support Monopoles; 23m CAH	No.	1	R 45 709.92	R 45 709.92
3.1.7	Pole, St 132kV Intermediate Self-Support Monopoles; 24m CAH	No.	1	R 48 108.92	R 48 108.92
3.2.	Strain Guyed Monopoles (D-DT-7615)				
3.2.1	Pole, St 132kV Stain Guyed Monopoles; (0°-90°); 18m CAH	No.	3	R 40 636.12	R 121 908.36
3.2.2	Pole, St 132kV Stain Guyed Monopoles; (0°-90°); 19m CAH	No.	4	R 42 785.12	R 171 140.48
3.2.3	Pole, St 132kV Stain Guyed Monopoles; (0°-90°); 20m CAH	No.	15	R 45 261.12	R 678 916.80
3.2.4	Pole, St 132kV Stain Guyed Monopoles; (0°-90°); 21m CAH	No.	12	R 47 444.12	R 569 329.44
3.2.5	Pole, St 132kV Stain Guyed Monopoles; (0°-90°); 22m CAH	No.	11	R 49 645.12	R 546 096.32
3.2.6	Pole, St 132kV Stain Guyed Monopoles; (0°-90°); 23m CAH	No.	2	R 52 467.12	R 104 934.24
3.2.7	Pole, St 132kV Stain Guyed Monopoles; (0°-90°); 24m CAH	No.	1	R 54 866.12	R 79 007.21
3.3	Triple Pole Strain structure				
3.3.1	Pole, St 132kV Triple Stain Guyed Terminal Monopoles; (46°-90°); 14m CAH	No.	17	R 96 297.29	R 1 637 053.85
4	Supply of Conductor and Earth wire				
4.1	Conductor				
4.1.1	ACSR Tern Conductor	km	43	R 62 340.00	R 2 701 815.60
4.1.2	ACSR Chickadee Conductor	km	26	R 46 480.00	R 1 194 536.00
4.2	Earth wire				
4.2.1	OPGW 24 core, rated at 5kA	km	22	R 59 000.00	R 1 298 000.00
5	Supply of Insulators, Hardware and Stays				
5.1	Long Rod insulator, 132kV, 120kN B/S	No.	582	R 1 446.12	R 841 641.84
5.2	132kV Strain assembly 120kN	No.	582	R 1 328.00	R 772 896.00
5.3	132kV Post Insulator 120kN	No.	240	R 2 940.00	R 705 600.00
5.4	132kV Suspension assembly	No.	192	R 669.00	R 128 448.00
5.5	Stay assembly for strain structures (assembly includes shackle, thimble, guy grip, wire, stay plate)	No.	240	R 570.00	R 136 800.00
5.6	Aerial warning devices at major road crossings	No.	165	R 1 095.15	R 180 699.75
5.7	Spiral vibration dampers for OPGW	No.	248	R 130.00	R 32 240.00

5.8	Stockbridge Multi-Frequency Vibration Dampers for Chickadee conductor	No.	142	R 187.92	R 26 684.64
5.9	Stockbridge Multi-Frequency Vibration Dampers for Tern conductor	No.	240	R 198.72	R 47 692.80
6	Stringing				
6.1	DRESSING OF TOWERS WITH OPGW ASSEMBLIES (Including all handling, cartage and installation of line hardware)				
6.1.1	Self-supporting Strain Towers	tower	129	R 1 030.00	R 132 870.00
6.2	STRINGING OPGW (Including all handling, cartage and attaching OPGW to towers)				
6.2.1	OPGW 24 core rated at 5kA (includes 10% allowance for sag and minor changes in tower positions)	m	22 000	R 60.00	R 1 320 000.00
6.3	DRESSING OF TOWERS WITH CONDUCTOR ASSEMBLIES (Including all handling, cartage and installation of line hardware)				
6.3.1	Strain Towers	tower	48	R 6 000.00	R 288 000.00
6.4	STRINGING AND REGULATING OF CONDUCTOR (Including all handling, cartage and attaching conductors to towers)				
6.4.1	ACSR Tern Conductor	m	43 340	R 53.00	R 2 297 020.00
6.4.2	ACSR Chickadee Conductor	m	25 700	R 49.00	R 1 259 300.00
6.5	TESTING (Conductor)				
6.5.1	Mechanical testing of dead-end and mid-span joints for Tern - 3 samples and CSIR testing of components and OPGW equipment	No.	1	R 17 500.00	R 17 500.00
6.5.2	Mechanical testing of dead-end and mid-span joints for Chickadee - 3 samples and CSIR testing of components and OPGW equipment	No.	1	R 17 500.00	R 17 500.00
6.6	TESTING (OPGW)				
6.6.1	Pre-test 24-core OPGW prior to installation	sum	1	R 5 700.00	R 5 700.00
6.6.2	Final OTDR Testing for complete installation	sum	1	R 116 646.00	R 116 646.00
6.6.3	As built Documentations for fibre works	sum	1	R 4 935.00	R 4 935.00
7	Supply & Installation of cabling				
7.1	Cable and O/D yard				
7.1.1	132 kV cable system (all inclusive)	m	263	R 12 750.00	R 3 353 250.00
7.1.2	132kV O/D yard (all inclusive)	sum	1	R 875 000.00	R 875 000.00
8	Labelling				

8.1	LABELS				
8.1.1	Structure identification labels - on each structure	No.	129	R 450.00	R 58 050.00
8.1.2	Line designation labels - supply and install line designation labels on first and last structures	No.	12	R 600.00	R 7 200.00
8.1.3	Line crossing labels - at each line crossing	No.	85	R 600.00	R 51 000.00
8.1.4	Phase disk labels - install at T-offs & terminal	No.	8	R 600.00	R 4 800.00
9	Access and Environmental Works				
9.1	ENVIRONMENTAL AND REHABILITATION REQUIREMENTS				
9.1.1	General rehabilitation of damage caused during construction to structure sites, in accordance with the requirements of the ROD, EMP, TRMSCAAC1	tower	129	R 1 575.00	R 203 175.00
9.2	BUSH CLEARING				
9.2.1	Clearance of small alien species within the servitude as per EMP (by pulling out / lopping below NGL)	km2	0	R 1 000.00	R 0.00
9.2.2	Clearing of sparse bush (max trunk dia. - 200mm, av. spacing 10m)	km2	15	R 1 000.00	R 15 000.00
9.2.3	Clearing of medium dense bush (max trunk dia. - 200mm, av. spacing 5m)	km2	5	R 1 500.00	R 7 500.00
9.2.4	Clearing of dense bush (max trunk dia. - 200mm, av. spacing < 5m)	km2	5	R 1 500.00	R 7 500.00
9.2.5	Clearing of small trees (max trunk dia. 400mm)	tree	25	R 1 000.00	R 25 000.00
9.2.6	Clearing of medium trees (max trunk dia. 800mm)	tree	25	R 1 000.00	R 25 000.00
9.3	Destemming to 100mm below NGL and scraping for vehicle access				
9.3.1	De-stumping of med dense bush (max trunk dia. - 200mm)	km2	5	R 1 000.00	R 5 000.00
9.3.2	De-stumping of small - medium trees (max trunk dia. 800mm)	tree	20	R 2 000.00	R 40 000.00
10	Summary				
10.1	PRELIMINARY AND GENERAL				R 3 474 624.00
10.2	SUPPLY AND INSTALLATION OF FOUNDATIONS				R 548 954.67
10.3	SUPPLY AND ERECTION OF STRUCTURES				R 6 459 324.58
10.4	SUPPLY OF CONDUCTOR AND EARTHWIRE				R 5 194 351.60
10.5	SUPPLY OF INSULATORS, HARDWARE & STAYS				R 2 585 385.84

10.6	STRINGING				R 5 459 471.00
10.7	SUPPLY AND INSTALLATION OF CABLING				R 4 228 250.00
10.8	LABELING				R 184 800.00
10.9	ACCESS AND ENVIRONMENTAL WORKS				R 328 175.00
	CONTINGENCY AND ESCALATION RATE ADDED @ 5%				R 1 423 166.83
TOTAL CARRIED FORWARD TO SUMMARY					R 29 886 503.52

APPENDIX 21: BILL OF QUANTITY NO.17 – RECEIVING END SUBSTATIONS

Item Ref	Description	Unit	No. Units	Cost/Unit (ZAR)	Total Cost (ZAR)
	<u>Bill No. 17: Substation 1 & Substation 2 metering upgrades</u>				
	- <u>Substation 1</u>				R 1 078 327.00
1	132kV equipment: - VTs and CTs	Sum	1		
2	Low Voltage installation including: - Statistical and Tariff metering - Control wiring	Sum	1		
3	- Communication equipment Commissioning and Testing	Sum	1		
	- <u>Substation 2</u>				R 1 078 327.00
4	132kV equipment: - VTs and CTs	Sum	1		
5	Low Voltage installation including: - Statistical and Tariff metering - Control wiring	Sum	1		
6	- Communication equipment Commissioning and Testing	Sum	1		
TOTAL CARRIED FORWARD TO SUMMARY					R 2 156 654.00

APPENDIX 22: LETTER FROM LANGUAGE EDITOR



Dynamic Language &
Translation Specialists

Antoinette Bisschoff
71 Esselen Street,
Potchefstroom
Tel: 018 293 3046
Cell: 082 878 5183
Language@dlts.co.za
CC No: 1995/017794/23

Tuesday, 29 October 2019

To whom it may concern

Re: Confirmation of language edit, typography and technical precision

The MBA dissertation "*A cost-benefit analysis of implementing a solar plant in a platinum mining company*" by SSS Barnard (21658080) was edited for language, typography and technical precision. The referencing and sources were checked as per NWU guidelines.

Final, last minute corrections remain the responsibility of the author.

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Precision ... to the last letter