THE USE OF RENEWABLE ENERGY IN SMALL SCALE MINING

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A research report submitted to the Faculty of Engineering and the Built Environment,
University of the Witwatersrand, Johannesburg, in partial fulfilment of the
requirements for the degree of Masters of Science in Engineering

Johannesburg, 2014

DECLARATION

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

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ABSTRACT

Electricity has been identified as an important input in economic growth and social development. The emergence of electricity sector has in most cases been as a result of increased economic activities; particularly mining and manufacturing. These two industries are known to be large users of electricity; accounting for over 50 per cent. With increased electricity demand, South Africa is facing electricity shortages – this was evident during black-outs in 2008. Coupled with this challenge, is rural electrification and climate change concerns. With grid electrification deemed uneconomical, rural areas are in need of an alternative, cost-effective power supply. This study investigates the potential use of renewable energy (RE) resources in small-scale mining (SSM). By nature, SSM activities are poverty-driven and hence occur mostly in rural areas. Because of their location, their development is hampered by the lack of basic infrastructure in rural areas.

South Africa is well endowed with renewable energy resources. The country's renewable energy base is sufficient enough to power both large-scale and small-scale energy projects. Renewable energy development in the country is still at its infancy stages – with large-scale projects being prioritised. The barriers in the renewable energy sector include: legal and regulatory barriers; lack of R&D; lack of funding mechanisms; technical capacity and knowledge; and cost of renewable energy technologies. High costs associated with renewable energy technologies have been at the forefront. However, improvements in technology and innovation, has decreased the costs considerably making renewable energy technologies comparable with traditional energy resources.

This study has shown that small-scale mining activities can be powered through small-scale renewable energy projects. These are projects with capacities ranging from 1MW to 5 MW. However, the capital costs remain a concern. Access to funding is still a major concern in the sector with the majority still experiencing difficulties obtaining funding. More so, the nature of small-scale mining activities does not allow the uptake of medium to large-term investment decisions. This suggests that the long-term benefits of renewable energy technologies will not be fully realised, if these decisions remain captive to the SSM sector.

It is recommended that, firstly, small-scale mining operations be integrated into rural renewable electrification programmes to ensure sustainability and harmonization. Although it was proven that SSM operations can be powered through RE projects, affordability remains a critical concern. However, since government is rolling out RE projects in rural areas, SSMs can be integrated in those projects. This will ensure that the long-term benefits of renewable energy projects are realised. Secondly, since renewable energy can be used to power a variety of equipment directly, an investigation into potential renewable energy resources to power SSM machines directly should be conducted.

DEDICATION

This research report is dedicated to my family, partner and friends for their continuous support and encouragement.

ACKNOWLEDGEMENTS

I would like to express my gratitude to the following persons and organisations:

1. Dr Hudson Mtegha, my research supervisor for his guidance and support;
2. MINTEK and Small Scale Mining and Beneficiation Division (SSMB), for sponsoring my research and allowing me to use their resources;
3. Maluti Sandstone and Department of Mineral Resources (DMR), for providing me with relevant data needed for the study.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATIONS/SYMBOLS

CGS : Council for Geosciences

CO_2 : Carbon dioxide

CPPP : Community Public Private Partnership

CSP : Concentrated Solar Power

DME : Department of Minerals and Energy

DMR : Department of Mineral Resources

DoE : Department of Energy

DPLG : Department of Provincial and Local Government

ECA : Economic Commission for Africa

EMP : Environmental Management Act

GHG : Greenhouse gases

GJ/ha : Giga-joule per hectare

GW : Gigawatt

GWh : Gigawatt-hour

HDSA : Historically Disadvantaged South Africans

HOMER : Hybrid Optimization Model for Electric Renewable

IDC : Industrial Development Corporation

ILO : International Labour Organisation

IPPP : Independent Power Purchase Procurement

ISCW : Institute for Soil, Climate and Water

kg : kilogram

kW : Kilowatt

kWh :kilowatt-hour

LCOE	: Levelized Cost of Electricity
m/s	: Metres per second
m^2	: square metres
MEPC	: Minerals and Energy Policy Centre
MHSA	: Mine Health and Safety Act
MJ/kg	: Mega-joules per kilogram
mm	: Millimetre
MPRDA	: Minerals Petroleum Resource Development Act
MQA	: Mining Qualification Authority
MW	: Mega-watt
NEMA	: National Environmental Management Act
NERSA	: National Energy Regulator of South Africa
NPC	: Net present cost
NQF	: National Qualification Framework
NREL	: National Renewable Energy Laboratory
NSC	: National Steering Committee
PV	: Photovoltaic
R&D	: Research and Development
RDP	: Reconstruction Development Programme
RE	: Renewable Energy
REFIT	: Renewable Energy Feed-In-Tariff
RES	: Renewable Energy System
SADB	: South African Diamond Board
SSM	: Small-scale mining/miners
TWh	: Terawatt-hour
USD	: United State Dollars

W/m^2 : Watt per square metre

CHAPTER 1: BACKGROUND AND MOTIVATION

1.1. Introduction

Significant small scale mining (SSM) activities exist in South Africa. One challenge facing SSM in the country is the lack of current data on size, activities and geographical distribution of the sector. Most studies were conducted about 10 years ago. There is currently no conclusive estimate; but the number of people participating in the sector is estimated between 10,000 and 30,000 (Drescher, 2001; Limpitlaw and Hoadley, 2004; Buxton, 2013). A significant number of these are women working as employees. Small-scale mining activities in the country are expected to increase since government has recognised the sector. The Department of Minerals (DMR) has reported an increase in the mining permits from 103 in 2005 to 141 in 2006 (DMR, 2011). Small scale miners exploit almost all types of mineral commodities, but are most attracted to gold, diamonds, semi-precious minerals and industrial minerals (Dreschler, 2001). The latter class has been identified by the DMR as being suitable for SSM activities in the country. This is because this class is easy to extract and beneficiate. Further, there exists a significant local market. According to Motsie (2009), industrial minerals contributed 4.6 per cent of the total production sales revenue in 2009 – with local sales contributing over 90 per cent to the total sales.

SSM activities have been marked as a tool to reduce poverty and create employment in the country. Because of its origin, it provides a good platform for the Historically Disadvantaged South Africans (HDSAs) to participate and benefit from the country’s mineral endowment since most are based in rural communities where economic opportunities are limited. The sector has not fully delivered on its envisaged potential because of the ills in the sector. One of the challenges is the lack of resources to properly conduct their operations. This study focuses on electricity as an important input in small-scale mining activities. With the majority of SSM activities located in rural areas, access to basic services and infrastructure remains a challenge (Buxton, 2013). The lack of infrastructure impacts on the running and operation of SSM activities. It is therefore difficult for most operations to grow and expand without reliable and cost-effective power supply.

According to White and Koopman (2011), about 30 per cent of the country still needs to be electrified – with 51 per cent of these lying in rural areas of the country. Grid electrification in certain rural areas has been deemed uneconomical because of the high costs associated with extending grid-lines to isolated areas. This is further aggravated by Eskom’s capacity constraints. This suggests that most rural areas may be without electricity until cheap alternatives are developed.

This research study looks at renewable energy (RE) sources as potential alternatives for small scale mining activities in rural areas. Given the nature of SSM activities, it is established that energy requirements are low compared to medium and large operations. This is largely because small-scale activities remain labour intensive, with electricity only required during processing and beneficiation stages. The study aims to assess the suitability of RE use in small-scale mining.

Possible benefits from the use of RE in small-scale mining are:

- Delivering on the Constitutional right – The Constitution (Act No. 108 of 1996) requires government to establish national energy policy to ensure that energy resources are tapped into and delivered to cater the needs of the nation (DME, 2003). The government is required to provide electricity to all. Studies have shown a positive relationship between electricity access and poverty alleviation.

- Improved growth rates in the small scale mining sector as many operations with be able to grow and expand. This will in turn create employment thereby contributing to rural development and community upliftment. It must be noted that electricity availability is one of the many challenges facing the sector. However, it is an important input in mining, whether large or small.
- Reduce greenhouse gas (GHG) emissions from power generation. South Africa is amongst the largest contributors to GHG emissions in Africa. In 2005, the country contributed 1.1 per cent of global emissions which accounted approximately 40 per cent of emissions in Sub-Saharan Africa (Pegels, 2009).
- Diversification and security of supply – There is a need to diversify the country's energy mix because of: (1) Tightening climate change legislations. The world is moving towards a low carbon business environment and (2) To be able to meet the future demands as population continues to grow. Security of supply remains at risk with the growing demand. This was evident in the 2008 power shortages.

1.2. Problem definition

The lack of access to energy remains a major challenge in developing countries. About 1.5 billion people across the world still live without electricity. The number of people living without electricity is estimated at 587 million in Sub-Saharan Africa (World Bank, 2010). In South Africa, 30 per cent of the country remains without electricity – with 51 per cent located in rural areas of the country (White and Koopman, 2011). According to World Bank (2010), enhanced energy access is essential to poverty alleviation. Without access to electricity, businesses cannot function properly and this impacts negatively on rural development. Electricity is therefore an important input in economic growth and social development.

Studies (Dreschler, 2001; Mutemeri and Petersen, 2004; Buxton, 2013) have shown that SSM activities are dominant in rural areas where economic activities, and in most areas infrastructure to support businesses is limited. As a result, most operations cannot operate effectively. Electricity in small-scale operations is mostly used during processing and beneficiation stages in the value chain. Value addition is crucial given the types of minerals that are exploited – these are normally low value minerals. It therefore results in increased revenue from sales, and also creates added employment. The use of generators is very common in small-scale operations. This is because generators offered the cheapest option. However, with rising fuel costs, generators are becoming expensive and this is impacting on the profitability of most operations. There is therefore a need for a cost-effective energy supply in the small-scale sector to ensure grow and sustainability.

1.3. Aims of study

The objective of the study was to assess the potential of using RE resources in small scale mining activities in South Africa. This was to be achieved through:

- Understanding the small-scale mining sector in South Africa, with particular focus on the energy requirements of the sector.
- Understanding the electricity sector in South Africa. Great attention was directed to the renewable energy sector. The different types of renewable energy resources were reviewed and the country’s potential assessed.

- A case study was conducted with the objective of assessing the suitability of renewable energy use in small scale mining. This included both the technical and economic feasibility assessments. Renewable energy resources were further compared to the traditional energy sources.

Small scale mining represents the poor and marginalised communities in South Africa, many of which continue to live below the poverty line because of limited economic opportunities. The study assumes that there is a positive link between small scale mining and rural development, and hence the need to address challenges faced by the sector.

1.4. Methodology

The research methodology adopted consisted largely of secondary data, with a small percentage of primary data. Secondary data was collected through desktop research and literature reviews. The author studied journal articles, books and internet sources to compile the secondary data. Primary data was obtained through a site visit which was undertaken as part of the case study. The author also conducted informal interviews with relevant stakeholders.

1.5. Report structure

The report is organised as follows:

Chapter 1 introduces the study and outlines the motivation and background of the study. It also defines the problem statement and objectives of the study.

Chapter 2 is an overview of the small scale mining activities in South Africa. It focuses on the definition, size of the sector, challenges and developments in the sector.

Chapter 3 examines the electricity sector in South Africa. It focuses on structure of electricity sector, electricity challenges, rural electrification and current developments in the sector.

Chapter 4 defines the different types of renewable energy resources. It also underlines developments in the sector looking at capacities and growth rates, policy and promotion and investment opportunities. South Africa’s renewable energy endowment is also reviewed in this chapter.

Chapter 5 presents the case study that was conducted at Maluti Sandstone in the Free State Province. The technical and economic feasibility assessment is included in the chapter. HOMER computer system was used to conduct the feasibility assessment.

Chapter 6 provides a discussion on the suitability of renewable energy technologies in small-scale mining operations. This is looked at in terms of: potential of the sector; electricity crisis and rural electrification; renewable energy potential; renewable energy developments and barriers; and capability and capacity of small scale sector.

Chapter 7 provides conclusions and recommendations.

CHAPTER 2: OVERVIEW OF SMALL SCALE MINING IN SOUTH AFRICA

2.1. Definition

South Africa uses the National Small Business Development Amendment Act No. 26 of 2003 to define small scale mining activities. SSM is classified into three areas by the Act, which is; micro, very small, and small. Table 1 summarises the three classes of SSM as defined by the Act.

Table 1: Classification of mining and quarrying operation (National Small Business Amendment Act)

Size of class	**Total full time equivalent of paid employees**	**Total turnover**	**Total gross asset value (fixed property excluded)**	**Level of technology**	**Output (tons/annum)**
Micro	< 5	< R 200 000	< R 100 000	Rudimentary, non-mechanised	< 2 000
Very small	< 20	< R 4 million	< R 2 million	Simple technology	< 10 000
Small	< 50	< R 10 million	< R 6 million	Low to medium technology	< 60 000

South Africa uses the number of employees, total annual turnover and total assets to define small scale mining activities. According to the Act, small scale mining activity is a “mining activity that employs less than 50 people, and has an annual turnover of less than R 10 million with moveable assets of less than R 6 million”.

The last two columns of Table 1 were taken from studies conducted by Mutemeri and Petersen (2002) and Scott et al (1998). These two studies went a step further and looked at the level of technology deployed in the sector and annual output. This was done to broaden the SSM definition. Although not part of the official definition, these two factors are important in distinguishing small scale mining from large scale mining. In terms of the level of technology, there are two extremes. The SSM sector ranges from small and informal operations that provide subsistence to medium operations that make profits. The micro and very small mining activities involve little or no mechanization and most are associated with the use of rudimentary tools (such as pick, shovel and wheelbarrow). The small and medium enterprises are profit-orientated; their operations involve the use of mechanisation, however, on a limited scale. The production rates increases as the level of technology increases. It should be noted that the revenue made (annual turnover) will differ between mineral commodities.

2.2. Size of the sector

The SSM sector in South Africa is very small compared to other countries, particularly in Africa. It is well below the suggested mineral endowment of the country. The SSM sector in the country employed between 10,000 and 30,000 people compared to 550,000 and 350,000 – 500 000 in Tanzania and Zimbabwe respectively in 2001 (ECA, 2002; Limpitlaw and Hoadley, 2004; Buxton, 2013). Nonetheless, significant increase in the number of people participating in the sector was observed after 1994. SSM activities received attention from government which recognised it as a platform to foster economic growth through participation of the HDSAs in the mining industry. Since then, the number of small scale miners in the country has been on the increase. The DMR has reported an increase in number of mining permits applications from 103 in 2005 to 141 in 2006 (DMR, 2011).

Figure 1 below gives the estimated number of small scale mines in South Africa by province. The data was obtained from the DMR's Small Scale Mining Directorate (DMR, 2012). Please note that the data was last updated in 2010 before the new online system (SAMRAD system) was introduced.

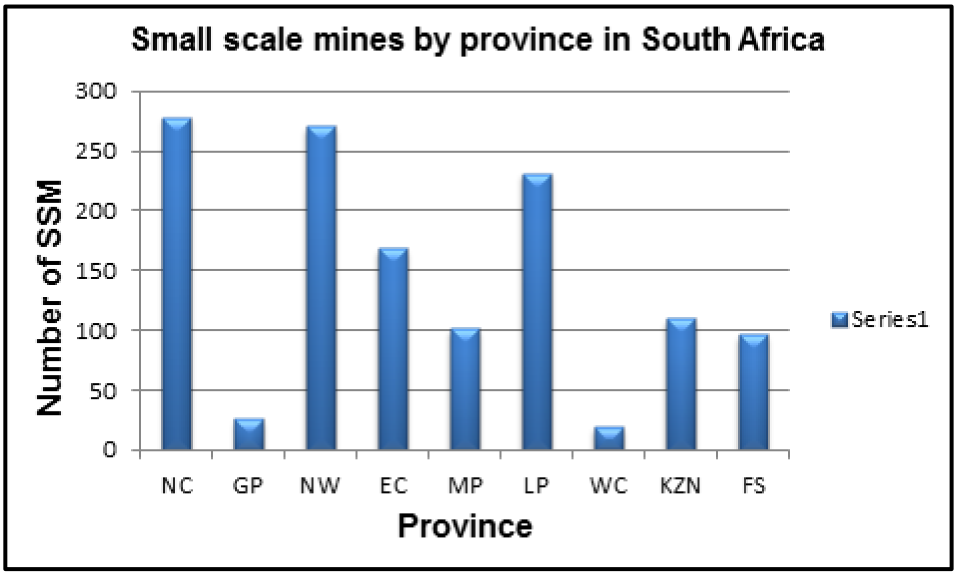


Figure 1: Small-scale mining activities in South Africa, by province (Source: DMR, 2012)

The provinces with the highest number of SSM activities are: Northern Cape, North West, Eastern Cape and Limpopo. Gauteng and Western Cape Provinces have the lowest level of small scale mining activities. The provinces with the highest number of small scale mining activities are amongst impoverished provinces in the country. More so, the mineral endowment of the provinces plays a major role in attracting small scale miners.

Please note that the figures presented here only cover operations with valid mining licences. This was just to give an indication of size and areas where SSM activities are dominant in the country. It is known that many SSMs operate without mining licences. To date, the DMR does not have conclusive records of illegal operations, although in some areas they are aware of these operations. Because there are no economic alternatives, it has become difficult to stop these illegal operations as they are their only source of income. This is happening in the Northern Cape where semi-precious minerals continue to be mined illegally. The government has on several occasions stopped these illegal operations. With unemployment rate in the province at 29.9 per cent (Statistics SA, 2011), mining plays a vital role in providing livelihoods.

2.3. Mineral commodities of interest

Small scale miners in South Africa exploit a variety of mineral commodities. In the past they were most attracted to the easily marketable minerals such as gold, diamonds and semi-precious minerals that can be sold on the black market. The popularity of industrial minerals is increasing amongst small scale miners. Industrial minerals are defined as “any rock, mineral or naturally occurring substance with economic value excluding metal ores, mineral fuels and gemstones” (Jeffrey, 2006). Their economic potential relates to a generally high volume of ore and a low value mineral commodity. Most of these minerals outcrop on surface or are close to the surface making extraction simple. It allows the use of rudimentary tools such as picks, shovels and chisels. Table 2 summarises the popular minerals mined in the different provinces in South Africa

Table 2: Types of minerals mined by SSMs in South Africa (Source: DMR, 2012)

Province	**Mineral commodity**
Northern Cape	Diamonds, tiger's eye
North West Province	Stone aggregate, diamonds (alluvial), dimension stone
Eastern Cape	Stone aggregate, clay, sand
Mpumalanga	Gold, river sand, coal
Limpopo Province	Sand, dimension stone, brick clay
Free State	Sand, sandstone, salt, stone aggregate
Western Cape	Sand
Gauteng	Clay, sand
Kwazulu-Natal	Sand, clay, coal

Table 2 was erected from the SSM national database. This is a database of SSMs who have been granted mining permits. Even though it is known that there are SSMs exploiting gold, particularly in the Gauteng region, no mining permit has been granted for gold. According to the DMR, the majority of SSM activities exploit industrial minerals, merely because most deposits appear near to the surface making the use of rudimentary tools allowable (DMR, 2011). The popular minerals include: stone aggregate, sand, clay and dimension stone. According to the DMR, stone aggregate account over 50 per cent of the industrial minerals production. There are over 340 producers of stone aggregates in the country. It is followed by clay, dimension stone and silica with 153, 79 and 20 producers respectively (Motsie, 2009). These figures include small, medium and large-scale operations. Diamonds are predominantly found and mined in the Northern Cape and North West Provinces. The Northern Cape houses one of the largest and most economical tiger's eye deposits in the world.

2.4. Legislation governing SSM in South Africa

The SSM sector is subjected to the same legislation as large scale mining activities. The different pieces of legislation cover; mineral licenses, environmental protection and conservation, labour practices and skills development and transfer. Attention will be directed to the Mineral and Petroleum Resources Development Act (MPRDA) No. 28 of 2002 as it governs all mining activities in South Africa and hence recognises small scale mining activities. The different legislations are discussed below.

2.4.1. Mineral Petroleum Resource Development Act

The MPRDA is the main legal framework regulating the mining industry in South Africa, including small scale mining activities. Under the Act, the State is recognised as the custodian of the nation's mineral resources. This means that all natural resources above and below the ground belong to all citizens of South Africa. The State, acting through the Minister of DMR, is responsible for the administration and management of minerals resources. The Minerals and Mining Policy of South Africa was developed in 1998 after the major political change. The policy was developed to remedy the historical injustices and also get rid of Apartheid exclusionary practices. Objective 2(c) of the Act seeks to provide equitable access to nation's mineral and petroleum resources to all people of South Africa. The MPRDA provides a platform for HDSAs to participate and benefit from the minerals and mining industry. Under the Act, anyone can apply for a mining licence allowing him or her to mine.

There are different types of mining licenses that the public can apply for. These include: reconnaissance permits, prospecting rights, mining rights, mining permits, retention permits and permission to remove. Mining permits were designed specifically for small scale mining activities in South Africa. Mining permits are issued if: mineral resource in question can be exploited optimally within a period of two years, and the potential mining area does not exceed 1.5 hectares in extent. Further, no other person must hold a prospecting right, mining right, mining permit or retention permit of the same mineral and land. Mining permits are valid for the period stipulated in the permit, which may not exceed two years. However, it may be renewed for three periods with each not exceeding one year. It is valid for a total of five years (Government Gazette, 2002).

2.4.2. Mine Health and Safety Act

The Mine Health and Safety Act (MHSA) No. 29 of 1996 protects the health and safety of employees and all other persons working in the mining industry (President's Office, 1996). Safety remains a challenge in small scale mining sector. Most operations do not adhere to the required practices and standards. This is brought by inadequate information on health and safety, lack of skills in the sector and lack of proper technology. Small scale mining continues to use trial and error methods impacting health and safety of employees. More so, the health and safety of SSM operations is not fully regulated. Many of the incidents that occur in the sector remain unreported. This is worse in illegal operations where the bottom line is taking out the valuable mineral and selling for money.

2.4.3. Environmental legislation

Section 24 of the Constitution recognises the right of everyone in South Africa to; "(a) to an environment that is not harmful to their health or well-being; and (b) to have the environment protected, for the benefit of present and future generations, through reasonable legislative and other measures that: (i) prevent pollution and ecological degradation; (ii) promote conservation; and (iii) secure ecologically sustainable development and use of natural resources while promoting justifiable economic and social development*".*

Mining activities are very detrimental to the environment. South Africa is currently dealing with bad legacies that were left behind by historical mining activities before the new legislation was introduced. Back then, legislation focused primarily on economic gains from mining. The legislation covered very little aspects of environmental protection and conservation. As a result, mining companies used careless mining methods, and did not reserve funds to remedy the environment once mining ceased (Swart, 2003).

The government has inherited the environmental damage as most owners are nowhere to be found. Examples of bad legacies are (but not limited to): acid mine drainage, water pollution in Witbank-Middleburg area as a result of coal mining, derelict and ownerless mines threatening the health and safety of surrounding communities (e.g. Asbestos mines in the Northern Cape) and issues of climate change. Post-1994 environmental legislations were introduced to remedy the environment damages and to avoid bad legacies in the future.

The Minerals Act 1991 was succeeded by the MPRDA in 2004. In addition, several environmental legislations were introduced. These are (amongst others): National Environmental Management Act (NEMA) 107 of 1998, National Water Act 107 of 1998, National Heritage Resources Act 25 of 1999, National Environmental Management (NEM) for Air Quality, Protected Areas, and Waste Acts. The legislations deal with: water conservation (quality and quantity), waste disposal and management, air quality, biodiversity conservation, and so forth.

The primary objective of these legislations is to protect the environment and to ensure sustainable development of mineral resources. Small scale mining operations are required to abide by the environmental requirements. Under the MPRDA, SSMs are required to submit Environmental Management Plans (EMP) as part of the mining permit applications. Section 41 of the MPRDA, further requires mines to make financial provision to cover their rehabilitation liability. The rehabilitation cost is determined by the DMR and it depends on the degree of environmental impacts the mine activities will result into. According to Mahala (2012), the cost of application can amount to +/- R100 000 for small scale mining operations.

2.4.4. Labour Relations

The Labour Relations Act No.55 of 1995 gives effect to Section 27 of the Constitution. Other objectives of the Act are (but not limited to): (1) to regulate the organisational rights of trade unions; (2) to promote and facilitate collective bargaining at the workplace and at sectoral level; (3) to regulate the right to strike and recourse to lock-out in conformity with the Constitution (President's office, 1995). The Labour Act also protects the rights of workers as outlined in the Constitution. Other pieces of legislations protecting the rights of employees include; Basic Conditions of Employment Act of 1997, Employment Equity Act 1997 and Skills Development Act of 1998 (Mutemeri and Petersen, 2002).

2.4.5. Skills Development Act

The Skills Development Act No. 97 of 1998 provides an institutional framework that develops and implements national, sector and workplace strategies. The primary objective of the framework is to improve the skills of the South African workforce. The Act was introduced to improve productivity of the workforce, promote selfemployment and encourage employers to use the workplace as a continuous learning environment thereby transferring skills (Government gazette, 1998). The Mining Qualification Authority (MQA) is mandated to address the skills shortages in the South Africa's Mining and Minerals Industry. The MQA was established by the MHSA No. 29 of 1996 and is a registered Sector Education and Training Authority for the Mining and Minerals Sector in terms of the Skills Development Act No. 97 of 1998 (MQA website). MQA facilitates skills development in the mining industry, with small scale mining also included. Qualifications offered by MQA are registered at national level and form part of the National Qualification Framework (NQF). MQA offers qualifications on NQF level 1 to 4 for small scale mining operations (Michael et al, 2012).

2.5. Challenges in the sector

The SSM sector has received a lot of attention from governments in many part of the world, especially in developing countries. The sector was recognised as a potential driver for rural development, and hence many governments have made attempts to develop and grow the sector. Countries, such as Ghana and Tanzania have made considerable progress on SSM. Ghana's SSM sector continues to grow after it was legalised in 1989 (Amankwah and Anim-Sackey, 2003). SSM sector in Tanzania contributes over 70 per cent of the country's mineral export earnings (Economic Commission for Africa, 2002). South Africa is lagging behind most of these countries with similar mineral endowment. The size of the sector is small and progress has been relatively slow. The SSM sector in the country remains faced with numerous challenges prohibiting its development and growth. The comparison between the three countries was based on the fact that all three are resource-rich countries. More so, all have recognised SSM as an important driver for poverty alleviation. Parallels can also been drawn in terms of the challenges faced by the SSM subsector. The challenges are discussed below.

2.5.1. Limited access to finance

Lack of access to finance remains a challenge in the sector. Most operations are unable to kick-start because of lack of capital to procure equipment and to fund operating costs. The nature of operations and its legacy (known to be destructive, dangerous and illegal) has marked the sector high risk. As a result, funding institutions are reluctant to offer financial assistance to SSMs (Mutemeri and Petersen, 2002). This is further aggravated by the lack of knowledge on potential funders, particularly government-supported funding institutions (Scott et al, 1998). A study conducted by the Scott et al (1998) made the following conclusions after interviewing a number of miners regarding access to funding: (1) Access to finance was identified as a constraint by all SSMs, (2) Few SSMs have heard of state-assisted funding bodies, with Khula Enterprise Finance being the better known. However, no SSM have been successful in obtaining funding from Khula and (3) Several SSM had approached funding institutions in the past, but were unsuccessful because collateral was a requirement.

2.5.2. Limited access to markets

Market availability has improved considerably for SSM in South Africa. This is because most are exploiting industrial minerals as opposed to precious minerals. Industrial minerals have a significant market locally. The challenge is the distance to markets for most SSMs and the quality of products. Most operations are located far from markets. This increases their transporting costs thereby impacting on the profitability of the operations. This is further worsened by increases in fuel prices. The lack of skills and appropriate equipment has adverse impacts on the type products sold to the markets – these are often low quality and uncompetitive.

2.5.3. Poor infrastructure

SSM operations are located in rural areas with poor infrastructure. These include roads, electricity and communication infrastructure. The poor infrastructural conditions make it difficult for SSM to run their operations profitably. Moreover, SSM are unable to expand their operations due to limited infrastructural capacity. Infrastructure conditions have significant effect on the ability of businesses to produce quality and competitive products. Roads in rural areas are unpaved and poorly maintained, communication networks very poor and electricity is unreliable. Most operations would invest in expensive on-site power generators to keep business going. In most cases, small-scale operators do not have the financial means to procure expensive generators.

2.5.4. Human resource development

Miners lack the necessary skills to conduct their operations appropriately, adhering to the health and safety and environmental standards, and also to produce quality and competitive products. Miners have very little knowledge, if any, on mining and processing techniques. The mining and processing activities are carried out through trial and error methods resulting in negative impacts to the environment and health and safety hazards. The basic skills and training that the miners require include: basic geology (minerals identification), mining and processing and/or beneficiation techniques, health and safety training, environmental protection and rehabilitation, and different legislation applicable to SSM.

2.5.5. Limited Research and Development towards SSM

The level of funding and local infrastructure to support research and development in SSM is minimal (United Nations Economic and Social Council, 2003). Although, numerous attempts have been made to address Research and Development (R&D) gaps in the sector, the results are unsatisfactory when compared with the large-scale mining sector. There are not many institutions and/or companies that specialise entirely in small scale mining. MINTEK and Council for Geosciences (CGS) have offices dedicated to small scale mining research. The two organisations are partly funded by government. The main challenge facing the two organisations is the inadequate financial resources to fully assist SSMs.

2.6. Developments in the sector

Growth of SSM activities in South Africa has accelerated since its recognition in 1994. The democratic government did away with apartheid legislations that excluded the majority of the population from participating in the mining and minerals industry. The new legislation provided platform for HDSAs to take part in mining. Women and youth also developed interest in mining with many working as miners.

In creating a favourable environment, government established the National Small-Scale Mining Development Framework in 1998. The framework was established with the aim of providing SSMs with technical and financial assistance (Dreschler, 2001). This was a piloting programme which after a year was revised. The National Steering Committee (NSC) succeeded the National Small-Scale Mining Framework in 2000. The NSC comprised of multi-stakeholders with expertise in minerals, mining and financial services. These included; MINTEK, CGS, CSIR-Miningtek, Industrial Development Corporation (IDC), Minerals and Energy Policy Centre (MEPC), Khula

Enterprise Finance, Ntsika Enterprise Promotions, South African Diamond Board (SADB) and Community Public Private Partnership (CPPP). The NSC was tasked to develop financially viable and sustainable small scale mining projects. The government established the Small Scale Mining Directorate in 2004 to work in conjunction with NSC. The NSC was replaced in 2005 with the Small Scale Mining Board (SSMB). In 2008, the SSMB also failed to fulfil its mandate, and the new Small Scale Mining Directorate was formed (DMR, 2011).

The current office responsible for SSM sector is the Small Scale Mining Directorate (DMR, 2011). The primary objectives of SSM office are (1) providing guidance to meet regulatory requirements to start mining operations, (2) linking potentially sustainable projects with finance institutions and/or investors, and (3) providing support to DMR’s funded projects on making their operations sustainable and profitable (Masetlana, 2013). Current developments in the sector include:

- Small scale mining strategy – The Department in collaboration with relevant stakeholders are in a process of drafting new strategy for the SSM sector. The stakeholders that participated in the strategy included: MINTEK, CGS, MQA and DMR’s Small Scale Mining Regional Offices in all provinces. The strategy is currently under review in the department. According to Masetlana (2013), the emphasis of the new strategy is on community-based projects where interventions are mostly needed as opposed to allocating scarce resources to benefit the few; and

- MPRDA revision – The growth and sustainability of small scale mining activities is limited by the conditions of mining permit. The permit is valid for two years, and can be renewed for a period not exceeding one year for three times. This gives a small-scale operation a total of five years life of mine. There is also a limitation of size of the potential mining area. The potential mining area should be within 1.5 hectares in extent. It is reported that the DMR is looking into increasing the validity of the permit and area extent (Mahala, 2012).

2.7. Conclusion

SSM presents an opportunity for HDSAs to participate and hence benefit from the mining and minerals industry. Its size, however, is still small compared to countries with similar mineral endowment, particularly in Africa. Nonetheless, there has been significant increase in the HDSA's participation after its recognition by government in 1994. The government recognised SSM as an opportunity to address some of the developmental challenges (i.e. poverty, unemployment and inequality), particularly in rural and marginal communities where economic activities are limited. This is where the majority of HDSAs reside.

Progress in SSM has been relatively slow despite government's initiatives to develop the sector. More so, government's initiatives have not been able to achieve the desired results. As a result, the sector is still faced with numerous challenges that are hampering progress and growth. Poor infrastructure in rural areas is one of the challenges. This covers poor roads, water systems, communication infrastructure and electricity. The latter plays an important role in SSM. Electricity is required to ensure that operations are run efficiently and effectively. In most operations, electricity is mostly required during beneficiation stage in the value chain. Value addition is important in SSM because of the nature of minerals commodities being exploited.

CHAPTER 3: ELECTRICITY SECTOR IN SOUTH AFRICA

3.1. Historical background

South Africa has a long history of mining. Mining activities in South Africa started as early as the 1867 when diamonds were discovered on the banks of the Orange River (Edward et al, 2002). This was later followed by the discovery of gold on Langlaagte Farm near Johannesburg in 1886 (SAHO website, n.d) Gold mining grew substantially. In 1970, gold mining industry in South Africa contributed 68 per cent to the global production (Mining IQ, n.d). The discovery of gold led to rapid development and industrialisation of South Africa. This in turn led to the emergence of the electricity sector.

The first commercial central power station was built in 1897 by the Rand Central Electric Works (Eberhard, 2007). The power station supplied mainly the gold mining industry in and around Johannesburg. Over the next decades many mines built power stations to power their operations and also surrounding towns (mine towns). During 1920s, government started debating the concept of connecting individual power stations into a single network. The Electricity Act No.42 of 1922 created the Electricity Supply Commission (ESCOM). ESCOM was given the task to establish generation and distribution undertakings to supply electricity at the lowest possible cost (Eberhard, 2007). Through this task, ESCOM was involved in power supply in Durban, Cape Town and other major towns and cities in the country. In 1948, ESCOM purchased largest private producer of electricity, Victoria Falls Power, and controlled most power stations in the country. The Electricity Act was amended and the new ESKOM and Electricity Act in 1987 were introduced. ESCOM was renamed

ESKOM (Eberhard, 2007). ESKOM is currently the main supplier of electricity in South Africa.

3.2. Electricity supply and major players

Figure 2 shows the structure of electricity industry in South Africa. ESKOM is the major supply of electricity accounting over 90 per cent of power supply. Other suppliers are private companies and municipalities. ESKOM controls the entire (100 per cent) of the system's transmission assets. More so, it supplies about 60.9 per cent of electricity to final consumers with the remaining 39.1 per cent supplied by municipalities. Current end-use demand is 90 per cent of the total supply with the remaining 10 per cent being the reserve margin.

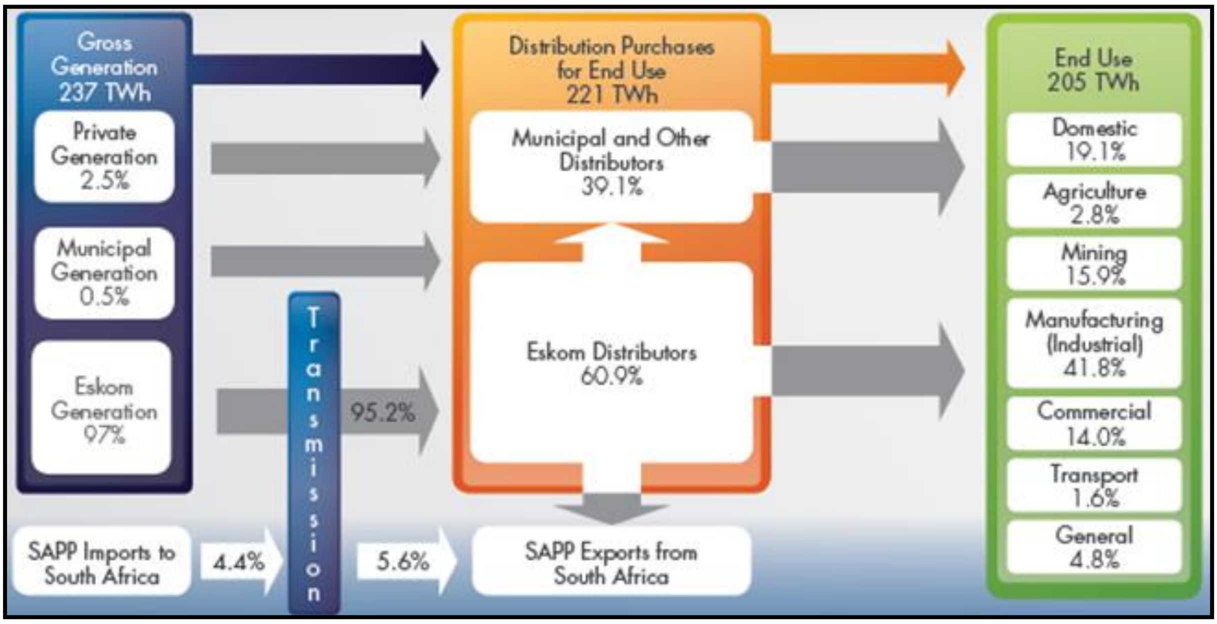


Figure 2: Structure of electricity industry (Source: NERSA, 2006)

Coal is a significant source of the country's power generation. South Africa's power generating technology is based largely on coal as a fuel source. Figure 3 below shows the different sources of electricity generation in the country. South Africa houses considerable coal deposits in the world. Its reserves are currently estimated at 30 408 million tonnes. In 2009, the country produced about 250.6 million tonnes of coal ranking it the seventh largest producer in the world (Ikaneng, 2009).

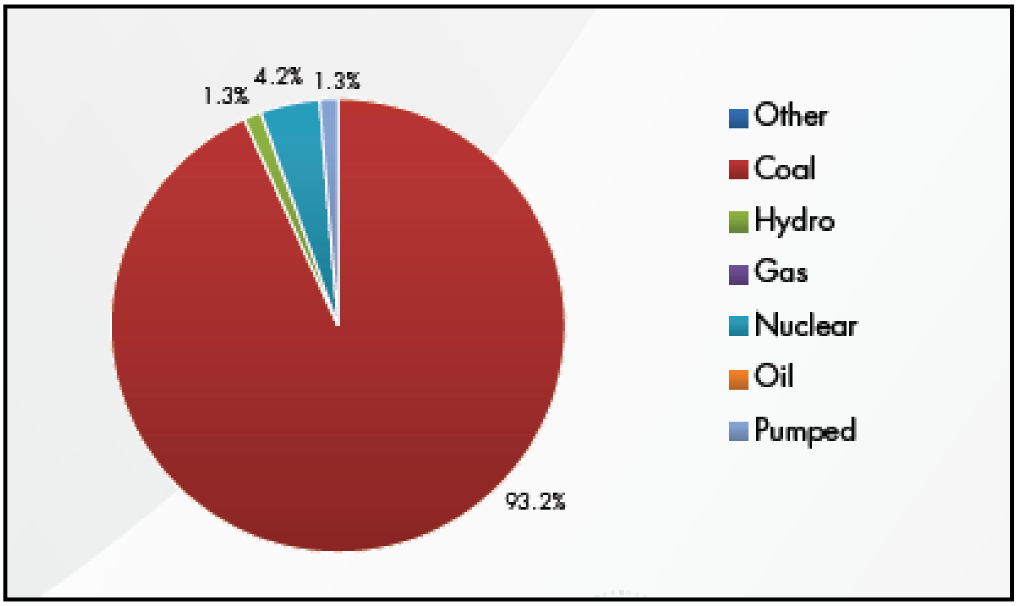


Figure 3: Energy sources used in electricity generation in South Africa (Source: NERSA, 2006)

Coal accounted 93.2 per cent of power generation in South Africa in 2006. It was followed by nuclear energy with 4.2 per cent. Hydro and storage energy accounted about 2 per cent to the total electricity output. Figure 4 illustrates the power stations in South Africa. There were forty-three (43) power stations in 2006. Total energy generated amounted to 237 TWh, of which 93 per cent was generated from seventeen (17) coal fired power stations. ESKOM generates electricity all across power stations, excluding bagasse which is generated entirely by private companies. Municipalities are only involved in pumped storage and gas turbines power generation.

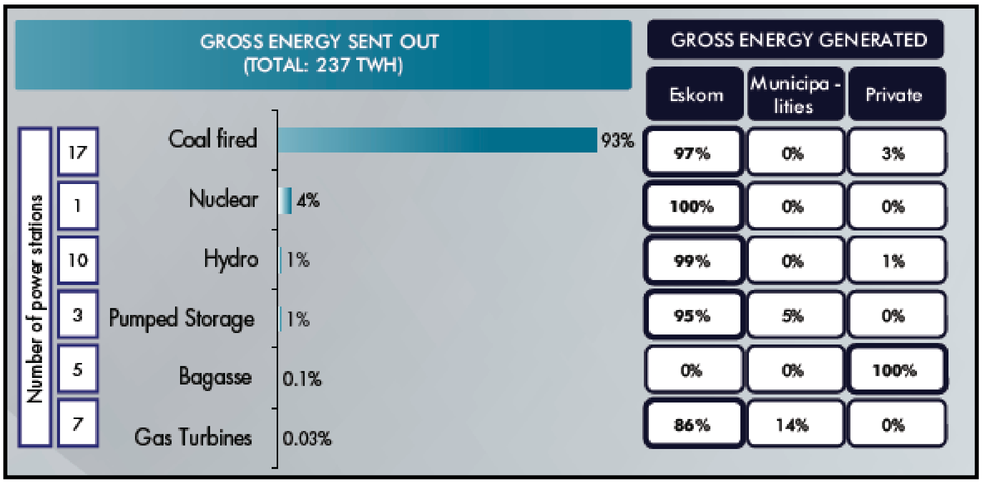
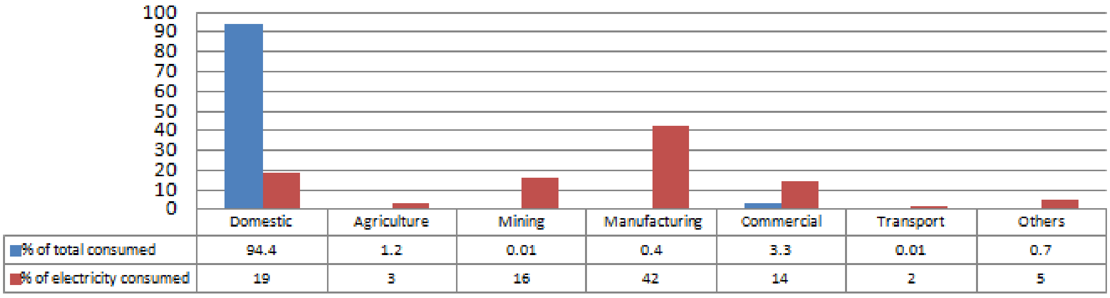


Figure 4: Power stations in South Africa (Source: NERSA, 2006)

Koeberg Nuclear Station is the only nuclear energy station in South Africa. It is located in Melkbosstrand in the Western Cape Province. The power station started operating in 1984 (ESKOM COP17 Fact Sheet, 2011b). According to Kessides et al (2007) Keoberg has a capacity of 1840 MW. There are 10 hydro power stations in South Africa. Total installed capacity in South Africa taking into account all sources equals to 43 842 (NERSA, 2006).

3.3. Electricity consumption in South Africa

Figure 5 shows major consumers of electricity in South Africa. The bulk of electricity is consumed by the industrial sector. This includes: mining, manufacturing and commercial businesses. However, over 94 per cent of end-users are domestic customers consuming 19 per cent of electricity. Agriculture and transport sectors consume the lowest electricity and have lowest number of end-users. The demand of electricity increased to 35 000 MW in 2006 (NERSA, 2006). This forced ESKOM to operate at nearly full capacity, thereby reducing its reserve capacity to 10 per cent. The demand is expected to increase by 4 per cent annually doubling the demand by 2025 (Pegels, 2009).



	Domestic	Agriculture	Mining	Manufacturing	Commercial	Transport	Others
🟦 % of total consumed	94.4	1.2	0.01	0.4	3.3	0.01	0.7
🟥 % of electricity consumed	19	3	16	42	14	2	5

Figure 5: Electricity customer consumption profile (Source: NERSA, 2006)

3.4. Selling prices

Figure 6 shows the comparison between South Africa's electricity tariffs and the world. Average electricity tariffs in South Africa remained the lowest in the world in 2011. The reasons for low electricity prices were: (1) South Africa has vast coal mining resources and hence 95 per cent is generated from coal. More so, the plants are located close to the mines; (2) ESKOM does not pay tax and/or dividends to government; (3) The cost does not include the cost of environmental and social impacts as a result of power generation (Spalding-Fecher and Motibe, 2003).

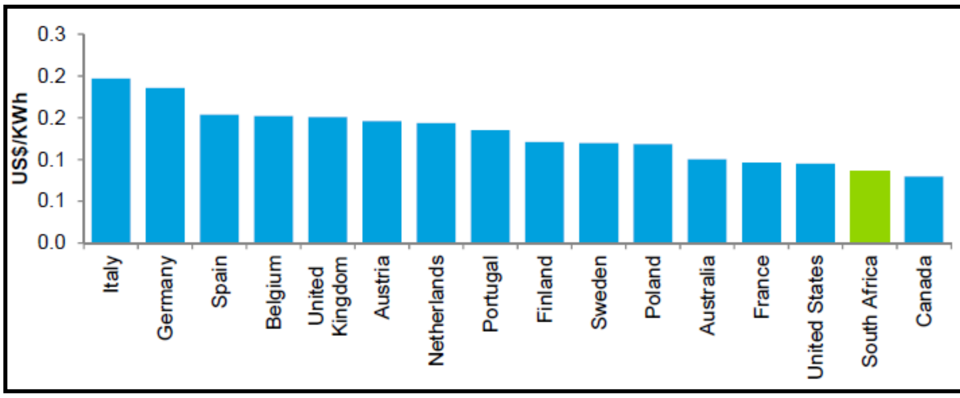


Figure 6: Average electricity price comparison (US$/kWh), 2011 (Source: Deloitte, 2011)

Despite low prices in comparison to the world, South Africa’s prices have been on the increase since 2008 power shortages. About 78 per cent increase was recorded between 2008 and 2011. This led to the country dropping to second place after Canada (Deloitte, 2011). During 2012/13, ESKOM proposed a 16 per cent increase annually over the next five years. This was rejected by NERSA which only approved 8 per cent increase (Mail and Guardian, 2013).

3.5. Electricity concerns in South Africa

There are a number of challenges that the electricity sector in South Africa is faced with. The two most important are (1) demand/supply imbalance and (2) environmental damage and climate change. The two challenges are discussed below.

3.5.1. Demand/supply imbalance

In response to the energy crisis in 2008, ESKOM made a presentation to the Parliamentary Committee in February 2009. The objective of the presentation was to outline the current state and future of electricity sector in South Africa. The company identified imbalance between electricity supply and demand as the major cause of energy crisis in 2008 (Inglesi and Pouris, 2010). Reserve margin of energy supply has declined considerably over the years. Reserve margin is the spare plant available when the highest demand of the year is recorded. ESKOM identified the following as main factors causing reserve margin to decline: (1) The sector saw a 50 per cent increase in demand between 1994 and 2007 (2) Major economic development in South Africa, and (3) Delayed decision-making by government with regards to expanding and/or building additional power supply (Inglesi and Pouris, 2010).

ESKOM is currently operating at nearly full capacity. The current reserve margin ranges between 8 to 10 per cent, compared to the target of 15 per cent minimum (DME, 2008). Two power stations namely; Medupi and Kusile (both coal-fired) are under construction. According to ESKOM, construction of coal-fired power stations can take about 10 years to complete. However, because of the urgent need to boost our supply, the projects have been fast-tracked and ESKOM hopes to reach full capacity in 8 years.

Kusile power station is located in Emalahleni, Mpumalanga Province. The station will consists of six units with each supplying approximately 800 MW, thus giving a total output of 4800 MW. Completion of the power station is planned for 2018. The other power station, Medupi power station is located in Lephalale in Limpopo Province. Medupi power station also has six units with each yielding 794 MW. Full commissioning is planned for 2015 (ESKOM COP17 Fact Sheet, 2011a). Medupi is expected to add 800 MW to the grid in December 2013.

3.5.2. Environmental damage and climate change

Extensive use of coal for power generation has placed South Africa in the fore-front of climate change. South Africa is amongst the major contributors to climate change in the world, particularly in Africa. South Africa contributed about 1.1 per cent to the global emissions which equated to approximately 40 per cent of emissions in sub-Saharan Africa in 2005. In 2000, the country’s per capita emission rate was 8.8 tonnes CO_2 well above global average of 6.7 tonnes and double the sub-Saharan average of 4.5 tonnes (Pegels, 2009). Climate change will have adverse impacts on South Africa. Examples of some of the effects of climate change include:

- Extreme changes in temperature – temperatures in coastal and interior parts of the country are anticipated to increase by 1 to 2 ºC and 3 to 4ºC respectively by 2050 if nothing is done (COP 17, 2011);

- Change in rainfall patterns coupled with increasing evaporation rates – South Africa is a water-stressed country. The country receives about 460 mm of rainfall annually well below the world average of 860 mm. The country is facing water quality and quantity crisis (Claassen, 2010). Major water catchments have been polluted by mining activities. The water quality is expected to deteriorate as historical environmental legacies become apparent (i.e. decanting of acid mine drainage). In 2005, more than 95 per cent of the fresh water resources in the country had been allocated (Oberholster, 2010). Water crisis in South Africa is apparent;

- Biodiversity will be adversely affected - Biodiversity is the "variety among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems and ecological complexes of which they are part" (Watson 2012). Biodiversity covers a range of ecosystem services on which living organisms (i.e. humans) depend on for survival (i.e. food security). High level of extinction is predicted in grasslands, fynbos and succulent Karoo of South Africa (COP 17, 2011); and

- Other impacts are: (1) climate change will increase diseases thereby threatening the health of people, and (2) it will also pose a threat to businesses. Possible business risks can be categorised into four classes, namely: physical risk, regulatory and legal risk, market risk and reputational risk. Physical risks are disruptions that result from extreme weather changes, such as flooding or increased costs of raw material. Regulatory risks come as legislation requirements change, for example government can introduce instruments to try and combat and/or reduce greenhouse emissions. These may include taxes or, in some cases, incentives. Market risks result from changes in market conditions. The world at large is aware of climate change and its impacts, in support of reducing causes of climate change they may shift to products that do not contribute to climate change. Examples are electric cars and other green technologies. In essence consumer preferences change. Companies whose businesses result in adverse impacts on the environment may damage their image and reputation (Watson, 2012). It is important for companies to strive towards carbon efficient processes.

3.6. Rural electrification

Under the apartheid government, the majority of the population in South Africa were not included in the energy policies. Back then, the energy policies were planned around the white population which accounted for only 12 per cent of the total population. Energy supply to industries such as mining, chemical and agriculture were of paramount importance to the government. In return, the black population lived without electricity, particularly in the rural areas. According to Davidson and Mwakasonda (2003), only about 36 per cent of the black-households had access to electricity. The new government in 1994 introduced drastic changes to reduce poverty and reduce the gap between the minority and majority populations in South Africa. A number of development policies were introduced. The Reconstruction Development Programme (RDP) was one of the important development policies. The RDP programme is a policy framework for integrated and coherent socio-economic progress. Its primary objective was to eradicate all apartheid exclusionary practices. The RDP encompassed six principles, namely; integration and sustainability, people-driven, peace and security, nation building, meeting basic needs and building the infrastructure. The two latter principles aimed to provide access to services crucial to development such as electricity, water, telecommunications, transport, health, education and training for HDSAs (Government gazette, 1994).

“Electricity access to all” was one of the pillars of development policies. The RDP set a target of increasing electricity access from 36 to 66 per cent in 2001. The 2001 target was exceeded and the majority of the population were electrified. Grid electrification in South Africa has been very successful with about 70 per cent households now having electricity. However, the challenge that remains is delivering electricity to the minority in the remote rural areas. More urban areas have been electrified compared to rural areas. Of the 30 per cent that still needs electrification, 51 per cent of them live in remote rural areas of South Africa (White and Koopman, 2011).

ESKOM has indicated that grid electrification in rural areas is very expensive, and hence not economically viable. This is made by the fact that: (1) the areas are located far from electric grid, (2) in most areas, transmission lines do not exist, (3) Low population density and (4) the residents are located far from each other. Further, the significant rise in the installing costs is making grid electrification in rural areas very uneconomical. Figure 7 shows the average cost per installation from 1991 to 2009.

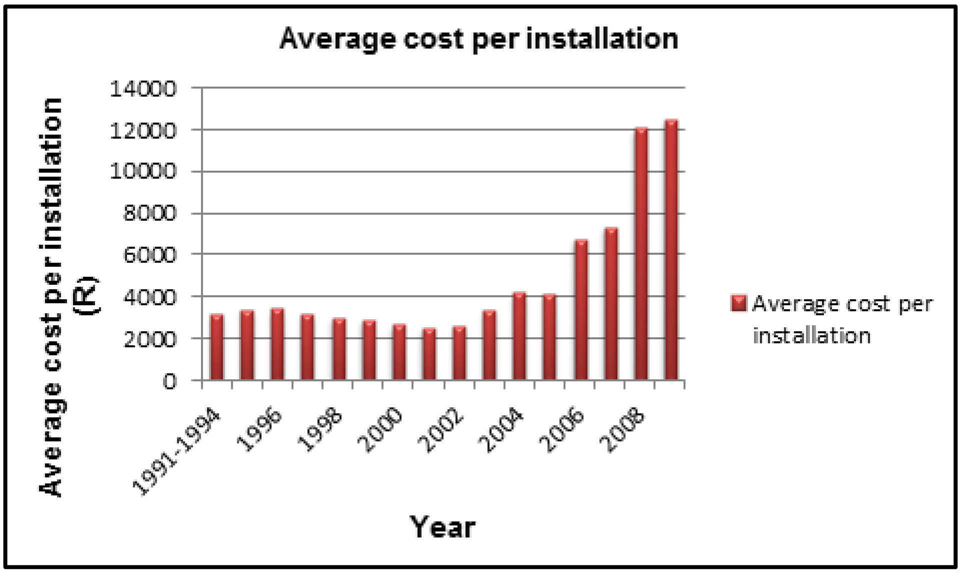


Figure 7: Average cost per installation (Source: White and Koopman, 2011)

The average cost per installation has been relatively constant between 1991 and 2005. A significant increase in the cost was observed in 2006. This increment more than doubled in 2008. The cost per installation currently stands at R 12,435. The main reason behind the significant costs is the cost of reticulation – these are high for rural areas because of the lack of distribution infrastructure (e.g. distribution lines). This is one major factor inhibiting grid electrification in rural areas. To date South Africa has not been able to meet its objective of electricity access to all. A percentage of the population still lives without electricity and this disadvantages them both socially and economically.

3.7. South Africa's development objectives

South Africa remains committed to providing electricity to all. Grid electrification has so far been able to provide most of the parts of the country with electricity except the remote rural areas. It has been established that grid electrification cannot deliver electricity to remote rural areas (White and Koopmann, 2011). The potential alternative is off-grid electrification options such as renewable energy sources. Progress has been relatively slow with renewable energy contributing less than 1 per cent of the total power output in South Africa. The main barriers are:

- Renewable energy technologies remain expensive compared to conventional energy suppliers;
- Significant investment capital is required during implementations coupled with long lead periods;
- There is lack of consumer awareness on benefits and opportunities of renewable energy;
- Financial, legal, regulatory and organisation barriers; and
- Market power of utilities (e.g. Generation and distribution is dominated by ESKOM) (Department of Minerals and Energy, 2003).

With the world now moving towards clean technologies and sustainable development, renewable energy sources are becoming more attractive. South Africa has participated in a number of forums where climate change and mitigation plans were discussed. In 2002, South Africa hosted the World Summit on Sustainable Development and global climate change was on the agenda. South Africa together with other countries committed themselves to promote renewable energy. Consequently, in November 2003, the White Paper on Renewable Energy was introduced. The policy aims to develop an environment in which renewable energy industry can operate, grow and contribute to mainstream economy and to the global environment. The policy encompasses government’s vision on the role of renewable energy in the energy sector which states as follows; *"An energy economy in which modern renewable energy increases its share of energy consumed and provides affordable access to energy throughout South Africa, thus contributing to sustainable development and environmental conservation"* (DME, 2003). More so, South Africa hosted the United Nations Climate Change Conference in 2011. Despite long negotiations, 193 countries that took part in the conference reached an agreement to reduce carbon emissions. South Africa set a target of 10 000 GWh of renewable energy contribution by 2013. Primary focus is currently on biomass, wind, solar and small-scale hydro. Renewable energy projects and/or investments made towards projects are:

- Standard Bank has signed an agreement with Industrial & Commercial Bank of China to jointly offer R 20 billion in funding support for renewable energy projects in South Africa. The funding is expected to fund renewable energy projects until 2025 (Standard Bank, 2013);
- ESKOM is constructing the Sere Wind Farm in the Western Cape Province. The project is funded by World Bank, French Development Agency, Agence Française de Développement and Clean Technology Fund. The project is expected to finish in October 2013 (ESKOM COP 17 fact sheet, 2011c);
- Other ESKOM renewable energy project is the solar energy project in Upington, Northern Cape Province. The project was funded by World Bank. The plant will be operational in 2016 (Van Niekerk, 2012); and
- The IPP Procurement Programme was launched in 2011 by the Department of Energy. The programme was designed to contribute towards the target of 3

725 megawatts and towards socio-economic and environmentally sustainable growth. Most IPP projects are solar projects and are based in the Northern Cape Province (Van Niekerk, 2012).

3.8. Conclusion

Despite success of the RDP, rural electrification remains a problem in South Africa. Grid electrification has not been able to reach rural areas of the country. This is where the majority of SSM activities take place. The costs of installation using grid power in rural areas are very high thus making it uneconomical. Off-grid electrification, such as renewable energy sources seem to be the viable option to ensure “electricity access to all”.

Renewable energy sources are becoming more attractive and their utilisation is becoming more competitive. There is also increased awareness with majority of people now aware of impacts of coal-power generation on the environment. The government is also moving towards RE and is creating a favourable environment to foster development and implementation of RE projects. The private sector is also playing an important role in support of RE projects.

CHAPTER 4: RENEWABLE ENERGY RESOURCES

4.1. Definition

Renewable energy is energy generated from sources that do not disturb the natural energy balance of the earth (as opposed to non-renewable sources). Types of renewable energy sources include: solar, waste, wind, hydro, geothermal, and biomass. The use of renewable energy dates back to ancient times. Traditional biomass, mostly wood, was used for cooking and heating. Solar has also been used for heating. Many developing countries, particularly in Africa and Asia still use renewable energy sources for cooking and heating (Demirbas et al. 2009).

4.2. Renewable energy sources

The different sources of renewable energy are discussed below.

4.2.1. Biomass energy

Biomass refers to all organic material from plants and animals such as trees, crops, animal waste, industrial waste, municipal waste and algae. Biomass energy is the conversion of biomass into useful forms of energy such as heat, electricity and liquid fuels (Herzog et al, n.d). Biomass energy originates from solar energy; this is the energy from the sun which gets collected and stored in plants during a process of photosynthesis. The majority of the biomass energy is produced from wood and wood waste (about 64 per cent). It is followed by municipal waste with 24 per cent and agricultural waste and landfill gases with both contributing 5 per cent (Demirbas et al., 2009).

According to Hall et al (1993), biomass energy accounted about 15 per cent of world total energy. Further, about 38 per cent of population in developing countries use biomass as source of energy. The net energy available from biomass when combusted equates to about: 8 MJ/kg for green wood, 20 MJ/kg for dry plant matter and 55MJ/kg for methane. According to Dale et al (2004), this compares to about 23 MJ/kg to 30 MJ/kg for coal.

Biomass can be converted into useful forms of energy using a variety of technologies. The two major conversion categories are direct combustion and thermochemical conversion processes. Direct combustion uses the same principle as electricity generation from coal. The biomass is burnt at a constant rate in a boiler plants (or furnace) to produce heat, steam and/or electricity. Direct combustion is the main process used to convert biomass. Like coal power generation, this process produces greenhouse gases (i.e. carbon dioxide, nitrogen oxides). However, the quantities produced are small compared to coal sources. Thermochemical process can be divided into three sub-processes, namely: gasification, pyrolysis and direct liquefaction. With the different thermochemical sub-processes, biomass is used indirectly; it is converted into liquid products such as bio-oil or bio-crude, charcoal and non-condensable gases and methanol (Cyulinyana, 2011 and Demirbas et al, 2009).

Biomass energy provides an opportunity to diversify the energy supply with environmental, economy and energy security benefits. It also presents an opportunity for rural development and added employment. However, there are several environmental concerns attached to its use. These are: (1) carbon dioxide emissions released during power generation, (2) deforestation, and (3) water availability. It has been argued by Hall et al (1998) that if biomass is grown sustainably, CO_2 will not build-up in the atmosphere (as it is the case with coal sources). It is also believed that CO_2 released during combustion will be offset by the CO_2 extracted during photosynthesis (Hall et al, 1993).

Another concern is deforestation. However, this can be resolved by using residues from on-going agricultural and forestry industries, harvesting industries or dedicating plantations to grow biomass. Availability of land can be a challenge for the latter. Another concern around biomass energy is food security as the population continues to grow; this means that more land will be required for agriculture.

4.2.2. Solar energy

Solar energy is simply energy from the sun. It involves capturing and harnessing the sun's energy and converting it into useful forms of energy. This can be done in three ways, namely: (1) passive solar designs where a building is designed in such a way that it is able to capture maximum sunlight thereby reducing the need for artificial lighting and heating, (2) active solar water heating where radiation is converted to heating, and (3) solar photovoltaic (PV) to convert sunlight into electricity (Fräss-Ehrfeld, 2009). Significant progress has been made over the years in developing solar energy technology. PV technology is now well established and awareness around its use continues to grow.

The efficiency of solar energy depends on direct sunlight. According to De Laquil et al (1993) good solar power plant must receive at least 2,500 kWh per m^2 on average annually. This corresponds to an average daily sunlight of 6.8 kWh per m^2. Solar energy is the most abundant source of electricity. According to Hamilton (2011), if captured correctly, it could exceed current and future electricity demands. Solar power would lower emissions and hence decrease long-term energy costs. It presents an opportunity for job creation, particularly in the manufacturing industry. It is estimated that about 248 jobs per TWh will be created compared to 116 in coal fired plants (DME, 2003). Solar PV grid power is the fastest growing RE in the world. Its world use increased by 60 per cent between 2007 and 2012 (McGinn, 2013). Solar PV has dominated the RE deployment in rural areas. Because of the decline in prices, solar PV has rendered small installations affordable (McGinn, 2013).

One major barrier to solar energy has always been the costs associated with its use. This encompasses the cost of manufacturing and cost of installation. However, improvement in technology and efficiency has decreased the associated costs considerably. According to White and Koopman (2011), capital costs of solar installation currently compares favourably with grid electrification. The capital cost per household for solar in 2006 was R 4,000 compared to R 6,000 and R 7,000 for grid electrification. Since then, grid electrification costs rose to an alarming R 12,000 per connection in 2009/10 (White and Koopman, 2011).

4.2.3. Wind energy

Wind energy is harnessed from power contained in moving air. Wind turbines are used to convert moving air to electric power. Like solar energy, wind energy is available in all geographical locations in the world. The efficiency of wind energy, however, depends on the quality of wind resource. Major uncertainty lies with intensity and quality of wind. Average wind speeds of 4.0 to 4.5 m/s are required for a small turbine to generate power of approximately 100 kW (Brunswick Canada, n.d). Wind speeds are generally high at top of mountains, shoreline and places clear of trees and structures.

The use of wind energy has increased over the years. Benefits of wind energy include: clean energy source, security of supply, and low cost. Its world-use increased by 25 per cent between 2007 and 2012 (McGinn, 2013). About 260 TWh was produced from wind sources in 2008; this contributed about 1.5 per cent of the global electricity consumption. More so, about 440,000 jobs were created from wind technology (Fräss-Ehrfeld, 2009).

4.2.4. Hydropower

Hydropower is generated from the power of water. Power can be obtained from surface water and oceans. Hydropower covers: hydroelectric, tidal, ocean current and wave power. Its efficiency is dependent on the volume and the kinetic energy of the falling or running water. According to Michaelides (2012), hydropower has the potential to meet 25 per cent of the energy demand in the world. Hydropower technologies are classified into three, namely: micro-hydro (1 to 100 kW), mini (or small) hydro (101 kW to 10 MW) and large-hydro (greater than 10 MW) (Industry Study Department, n.d).

Hydropower is widely used in developed countries, particularly in Europe and North America. Hydropower generated about 2600 TWh per year worldwide which accounts to 19 per cent of the world’s electricity production. Half of this capacity was produced in Europe and North America (Herzog et al, n.d). Hydropower has also played an important role in rural electrification. According to Herzog et al (n.d), about 300 million of the population in China depend on small hydro. Average growth in hydropower has been relatively small reported at a mere 3.3. per cent between 2007 and 2012 (McGinn, 2013). This is because its use in developed countries has stabilised. Over 65 per cent of developed countries already have hydropower plants running. Developing countries are lagging behind. However, hydropower use is expected to grow in developing countries because it is not fully tapped into (Herzog et al, n.d).

4.2.5. Geothermal energy

Geothermal energy is derived from thermal energy from the earth’s crust. The presence of thermal energy is usually indicated by: volcanoes, hot springs and steam vents. Exploration and drilling programmes are required to locate potential areas with thermal energy. Once located, steam is pumped to the surface and used as heat directly or converted to electricity (Herzog et al, n.d).

It is estimated that one per cent of heat (or steam) contained within 10 kilometres of the earth crust can generate about 500 times as much as energy contained in all oil and gas resources. Potential is estimated at 12,000 TWh per year. However, it is unevenly distributed, and is usually at great depths making accessibility difficult. Geothermal energy generated 44 TWh in 1997 which accounted for only 0.3 per cent of the world total energy production. Geothermal use grew by a mere 4 per cent between 2007 and 2012 (McGinn, 2013). Africa is lagging behind with geothermal energy advancements. It produced about 390 GWh in 1997 which contributed only 1 per cent to the total geo-energy supply (Herzog et al, n.d).

There are environmental impacts associated with the use of geothermal energy. Geothermal fluids (steam) contain gases such as nitrogen and carbon dioxide. However, according to Herzog et al (n.d), existing technology is able to control the gases and to ensure that only small amounts are released into the environment.

4.3. Developments in RE sector

This section looks at developments and overall progress made thus far in the RE sector around the world.

4.3.1. Power capacities and growth rates

Capacity of RE increased by 8.5 per cent from 1 250 GW in 2010 to 1 470 GW in 2012. This compares to a mere 240 GW five years ago. With energy access and security being prioritised, the deployment of RE technologies has increased significantly in both developed and developing countries (McGinn, 2013). Figure 8 shows the average growth rates of the different RE technologies in the world.

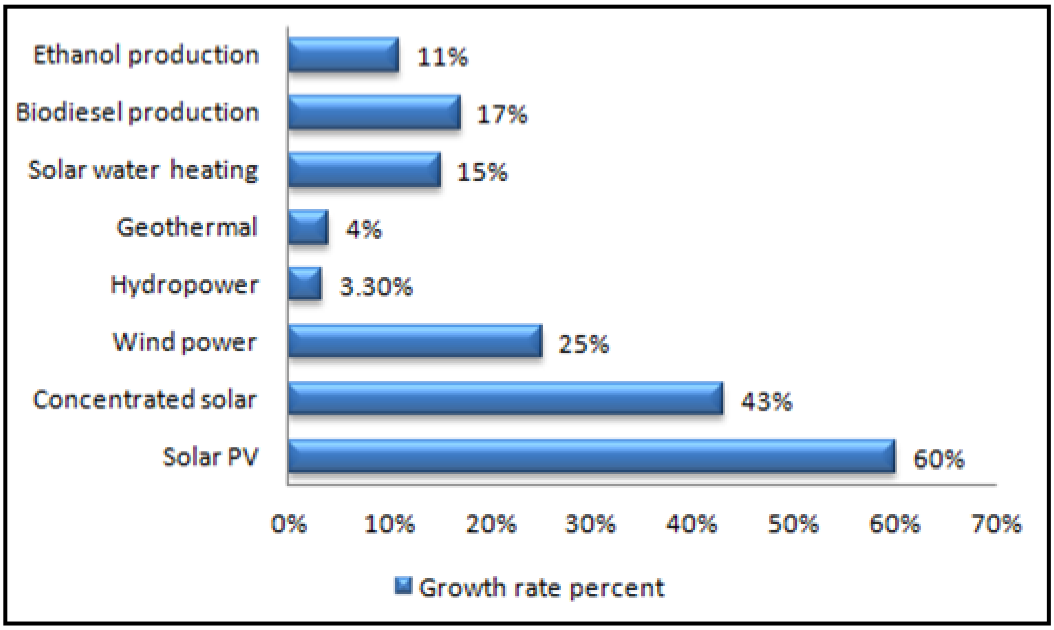


Figure 8: Average annual growth rate of RE capacity, 2007 – 2012 (Source: McGinn, 2013)

Wind power remains the largest component of RE accounting 39 per cent of the installed capacity. Wind power grew by 25 per cent between 2007 and 2012 to 283 GW. The United States and China lead with a combined capacity of 60 per cent.

Solar power is the fastest growing RE technology; this includes both PV and CSP. PV and CSP grew by 60 per cent and 43 per cent respectively. Because of increased competition, the industry has experienced declining prices. This has worked in the favour of consumers; there is more deployment of solar technologies around the world. Hydropower grew by a mere 3.3 per cent from 2007 to 2012. With markets in developed countries stabilising, new markets are opening up in developing countries. An estimated 30 GW came into production in 2012. The use of biomass in power and transport sectors has been on the increase. The production of ethanol and biodiesel grew by 11 per cent and 17 per cent respectively. The exploitation of geothermal energy is growing despite the environmental concerns surrounding it. A growth rate of 4 per cent was reported between 2007 and 2012. It has been reported that over seventy-eight (78) countries are tapping into their geothermal sources. Leading countries are the United States, China and Sweden. .

4.3.2. Policy and promotion

Countries around the world have recognised the importance of reducing carbon emissions and creating favourable environment that promotes the use of clean energy sources. In 2007, only about 66 countries had set targets to increase the use of RE sources (Renewables Global Status Report, 2007); this has increased tremendously to 109 countries in 2010 and 138 countries in 2012 (McGinn, 2013). Although most are developed countries, developing countries are also stepping to the challenge. South Africa is amongst the leading countries in Africa that has prioritised energy access and sustainability by the deploying of RE technologies Table 3 shows RE promotion policies available in some developing countries.

Most countries have adopted feed-in tariffs, subsidies and tax credits policy options as instruments to promote RE use. China and India are at the fore-front in developing countries. The shaded entries mean that some provinces (or states) within the countries have only provincial policies (i.e. national policies have not yet being implemented). In the case of South Africa, the shaded entries mean that the policy instruments have recently been introduced. The DME introduced the IPP programme in 2011 to promote RE use in the country. It uses the bidding process to give out tenders. More so, there have been investments directed towards RE projects.

Table 3: Renewable energy promotion policies (Renewables Global Status Report, 2007)

Country	Feed-in tariff	Renewable portfolio standard	Subsidies, grants or rebates	Investments or tax credits	Sales tax energy tax, VAT reduction	Tradable RE certificate	Energy production payments, Tax credit	Net metering	Public investment. Loans, financing	Public competitive bidding
Algeria	X			X	X	X				
Argentina	X		X		X					
Brazil	X								X	X
Chile			X							
China	X		X	X	X				X	X
India			X	X	X		X		X	X
Indonesia	X									
Mexico				X				X		
Morocco				X						
Philippines			X	X	X				X	
South Africa			X						X	X
Tunisia			X	X						
Uganda	X								X	

4.3.3. Investments towards RE

An estimated US$ 244 billion was invested towards RE capacity worldwide in 2012. This increased from US$ 227 billion in 2010 (Renewables Global Status Report, 2012). Solar power received the highest shares accounting over 57 per cent of the total investment. This equated to about US$ 140.4 billion. Wind and hydro (projects exceeding 50MW) followed accounting an estimated US$ 80.3 billion and US$ 33 billion. China remained at the top with a total investment of USD 64.7 billion. It was followed by the Unites States (US$ 34.2 billion), Germany (US$ 19.8 billion) and Japan (US$ 16 billion). South Africa raised a total investment of US$ 5.7 billion; this compared to Brazil (US$ 5.3 billion) and France (US$ 4.6 billion).

The World Bank is one of the largest lending institutions. It provided a total of US$ 12.5 billion for RE projects and programs around the world over a period of six years since 2007 (World Bank Data). Figure 9 and Figure 10 shows the distribution of loan according to different RE projects and funding issued by World Bank for the past six years.

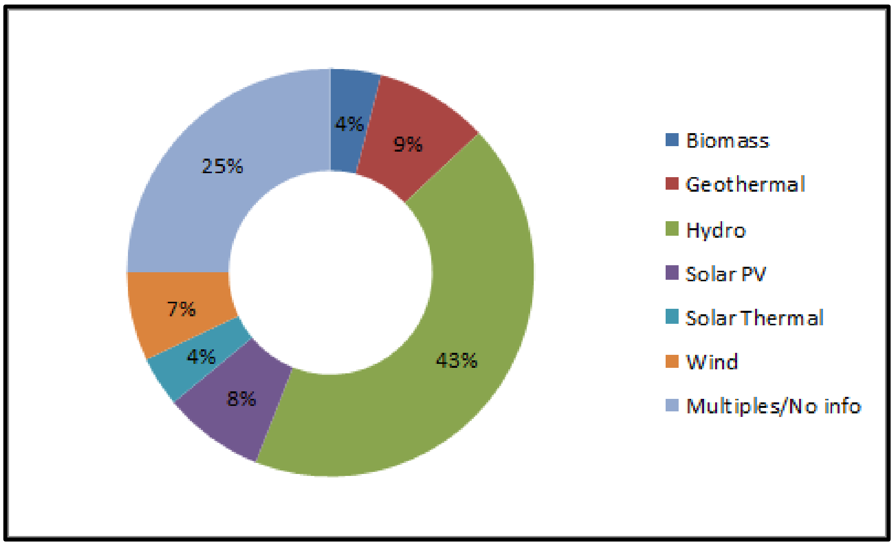


Figure 9: Distribution of funding according to RE projects (World Bank data, 2012)

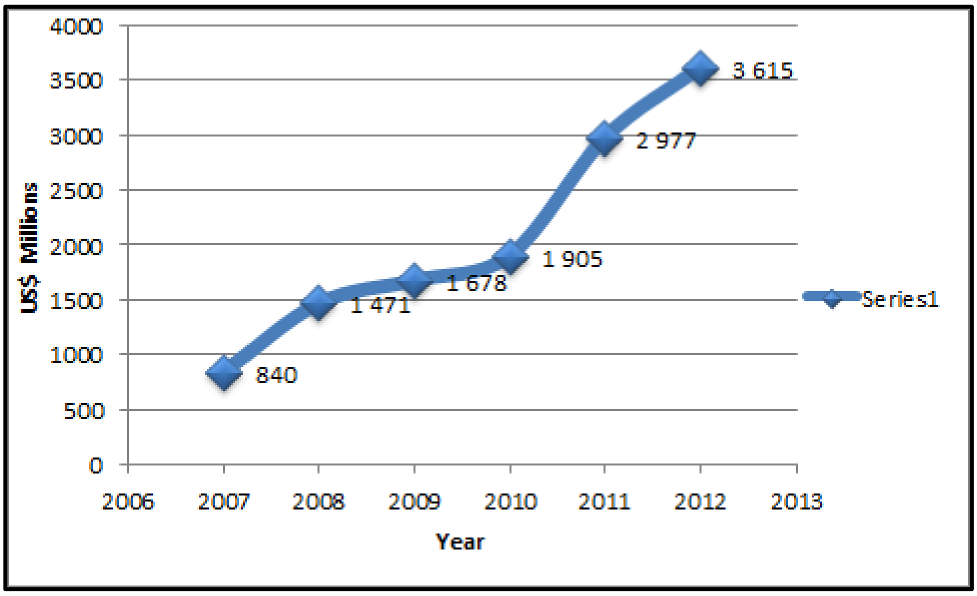


Figure 10: RE funding issued by the World Bank between 2007 and 2012 (Source: World Bank data, 2012)

According to the two figures, funding from World Bank has been on the increase since 2007. Of the US$ 12.5 billion that was issued, hydro technology received the largest share (about 43 per cent). It was followed by geothermal, solar PV and wind. Biomass received the lowest share of the funding.

4.3.4. RE cost comparison

Costs have long been the main barrier for the use of RE sources in power generation. However, the improvements of RE technologies have decreased the costs significantly. More so, market barriers of some RE technologies have been removed as certainty around RE continues to increase. Although still higher than traditional sources, RE technologies are expected to be competitive with traditional sources in the long-term. Table 4 compares the different RE sources with conventional sources for power generation.

Conventional sources still remain the cheapest source of electricity compared to RE technologies. However, the cost of RE technologies such as solar PV continues to fall. The price of solar PV declined considerably between 2005 and 2013. The drop in price is merely due to the increase in competition leading to excess manufacturing capacities. However, looking at GHG emissions, conventional sources continue to emit the largest portion of GHG. Based on projected costs for 2030 (which take into account the CO_2 emissions), RE sources and traditional sources become competitive. The gap between RE and traditional sources is anticipated to narrow when environmental impacts (i.e. CO_2 emissions) are factored in. Hydro technology is currently the cheapest amongst RE sources. This explains the highest investment directed to it. Biomass is also amongst the cheapest; however it has low efficiency rates. And because of good onshore winds, the cost of wind technology has improved. Traditional sources lag behind in terms of operational efficiencies. Although RE sources offer renewable and sustainable resource base, estimated reserve capacity for coal is 155 years. It will therefore take time for RE to fully replace coal power generation. But the promotion of RE is a step in the right direction.

Table 4: Advantages and disadvantages of different sources of electrical energy (Source: Fräss-Ehrfeld, 2009; Kost et al, 2013).

Energy source	**Technology considered**	**2005 cost (EUR/MWh)**	**2013 cost (EUR/MWh)**	**Projected cost for 2030 (incl. 20-30 EUR/t CO_2)**	**GHG Emissions (kg CO_2 eq/MWh)**	**Efficiency (%)**	**Proven reserves or annual production**
Natural gas	Open cycle gas turbine CCGT	45-70 35-45	75 - 98	55-85 40-55	440 400	40 50	64 years
Coal	CFBC IGCC	35-45 40-50	38 – 53 (Brown) 63 – 80 (Hard)	50-65 55-70	800 750	40-45 48	155 years
Oil	Diesel engine PF	70-80 30-40		80-95 45-60	550 800	30 40-45	42 years
Biomass	Biomass generation plant	25-85		25-75	30	30-60	Land constraints (Renewable)
Wind	On-shore Off-shore	35-175 50-170	45 – 107 119 - 194	28-170 50-150	30 10	95-98 95-98	Renewable
Hydro	Large Small (< 10MW)	25-95 45-90		25-90 40-80	20 5	95-98 95-98	Renewable
Solar	PV	140-430	98 – 142 (small) 78 – 118 (Utility)	55-260	100		Renewable

4.4. South Africa's potential

4.4.1. Biomass energy

South Africa is a dry country; with most of its parts deserts and semi-deserts. Of the total land surface area, only about 1.2 per cent consists of forests (Winkler et al, 2006). Figure 11 shows biomass resource base of the country. The biomass resource potential was modelled from wood, agriculture residues and grasses.

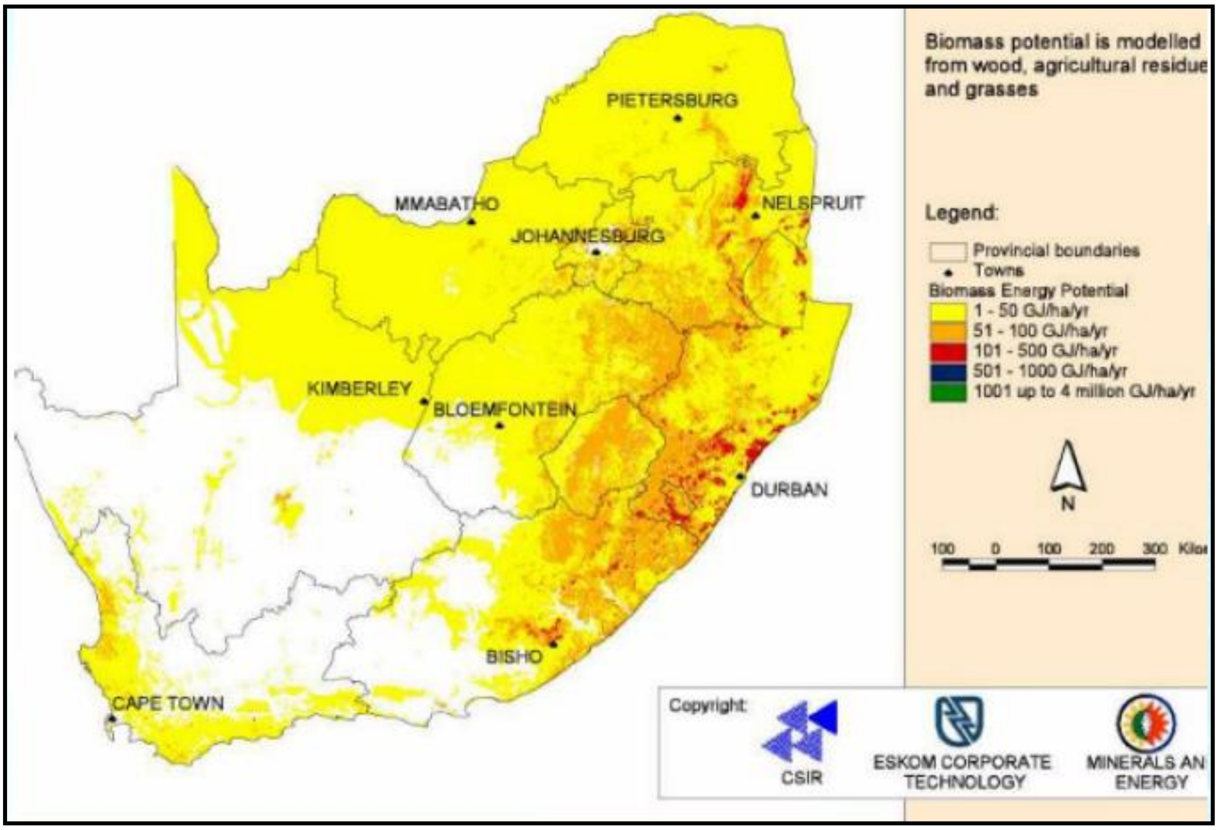


Figure 11: Biomass potential for South Africa (Source: www.sabregen.co.za)

Most parts of the country have biomass energy potential ranging between 1 to 50 GJ/ha per year. Energy potential increases as we move to the eastern part of the country. Parts of Mpumalanga and KwaZulu-Natal Provinces have potential of 51 to

500 GJ/ha per year. This is where the major sugar cane industries are located. The country’s sugar cane production amounts to about 20 million tons a year. About 7 million of bagasse (residues) is produced. This is estimated to produce energy of about 6.7 MJ/kg (Winkler et al, 2006). At present, sugar cane industries use the bagasse to generate energy for their own use.

Fuel wood was also identified as potential source for biomass energy. The following resources were identified under fuel wood: commercial plantations, alien vegetation, sawmills (woodchips, saw-dust and bark) and pulp mills. According DME (2003), the viability of wood as potential source lies with the wood, pulp and paper industries. The industries consist of two operations, that is: production of timber and production of wood pulp for paper manufacturing. The latter operation requires energy and hence the residues from first operation are used to steam the second operation and provide electricity.

Kwazulu-Natal, Mpumalanga and Eastern Cape Provinces were identified as having potential for biomass energy from grass. Potential energy from grass was estimated at 84GJ/ha per year along the low-lying areas of the provinces (DME, 2003).

South Africa faces the same challenge that hampers biomass power generation; that is land availability. With the growing population, land is required for residential purposes and agriculture. The latter is important to the country because it is a significant provider of employment for rural populations. Another discouraging factor is that available biomass (with potential) is already in use. Biofuels may have potential compared to traditional biomass sources. There has been growing research interest in bio-fuels. Stellenbosch University, University of Western Cape, North

West University, University of Cape Town and Biosciences CSIR are amongst institutions that are conducting research studies on the use of biofuels (Van Niekerk, 2012).

4.4.2. Solar energy

South Africa is amongst the countries in Africa that receives the highest annual radiation. Annual daily solar radiation average for the country is 220W/m^2. It is amongst the highest in the world, compared to 150W/m^2 for parts of the United States of America and about 100 W/m^2 for Europe (Winkler et al, 2006). Figure 12 shows the annual solar radiation received by the country.

There exists considerable potential for solar power generation in the country. Almost all parts of the interior have insolation in excess of 6000 MJ/m^2 The Northern Cape Province receives the highest sunshine in the country. Other areas that have potential are: North West, Free State, Limpopo and Gauteng Provinces.

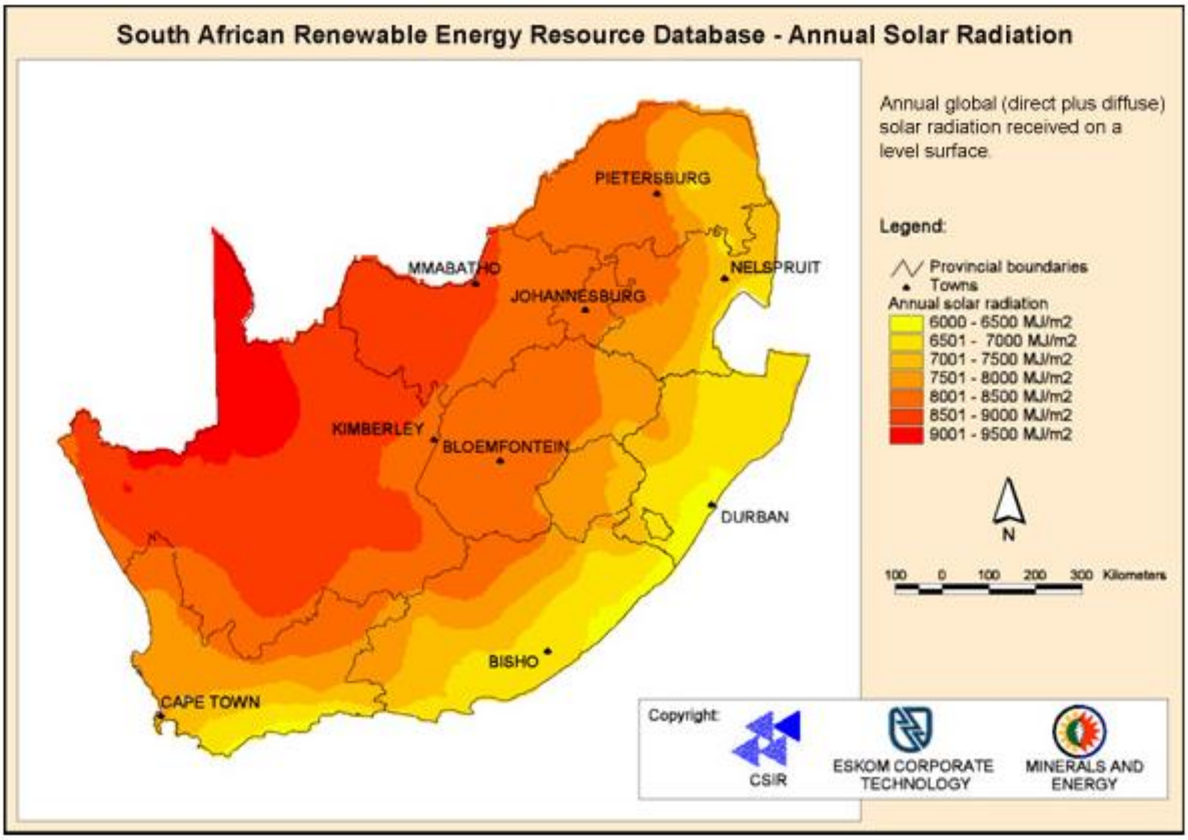


Figure 12: Annual solar radiation (Source: www.sabregen.co.za)

4.4.3. Wind

Figure 13 shows the distribution of wind resources in South Africa. The country's wind resources are found mostly along the coastal areas. Such areas have wind speeds exceeding 4 m/s. The interior parts of the country have low wind potential. Conclusions to the study conducted by Diab (1995) on wind power potential in the country were:

- Wind power potential is good along the entire coast with localised areas such as the coastal promontories also having good potential. Mean annual speeds in those areas are above 6 m/s;

- Moderate wind power potential areas include the Eastern Highveld Plateau, Bushmanland, Drakensburg foothills in the Eastern Cape and Kwazulu-Natal; and
- Areas with low wind power include the folded mountain belt, Western and Southern Highveld Plateau, the Bushveld basin, Lowveld, Northern Plateau, Limpopo Basin, Cape Middleveld and Kwazulu-Natal interior.

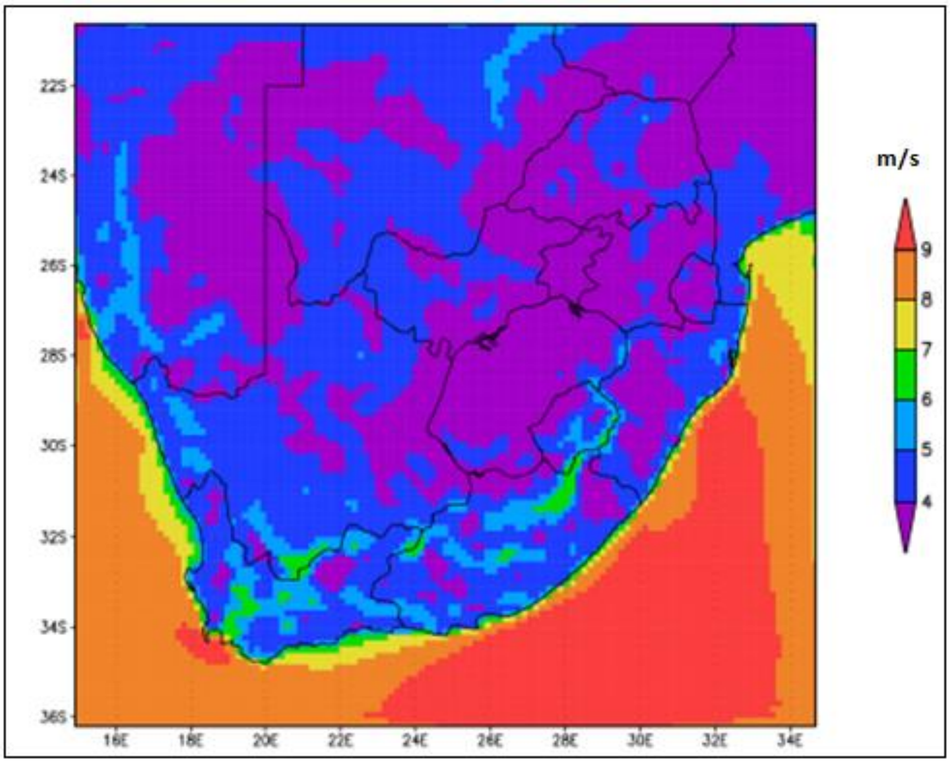


Figure 13: Wind resource potential of South Africa (Hagemann, 2008)

4.4.4. Hydropower

Figure 14 shows hydropower potential in South Africa. Most of the country's hydropower potential lies along the eastern escarpment. Areas with significant potential include: Eastern Cape and KwaZulu-Natal Provinces. According to Wrinkler et al (2006), about 3 500 to 5 000 potential sites have been identified for mini-hydropower generation. At present, hydropower accounts about 2.3 per cent of the total energy supply.

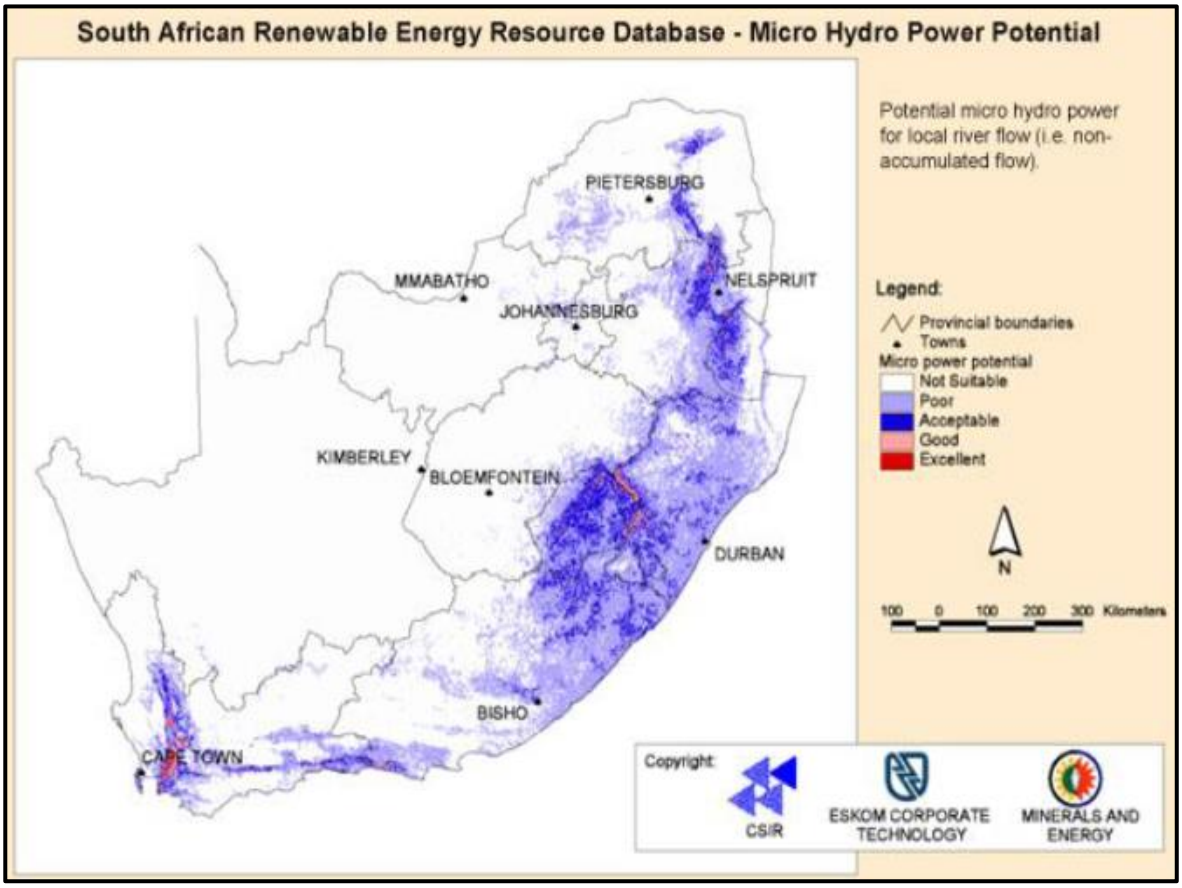


Figure 14: South Africa's micro hydropower potential (Source: www.sabregen.co.za)

4.4.5. Geothermal energy

Research in geothermal energy potential of South Africa has been minimal until recently. The rise in energy costs and prevailing energy shortages have created interest in geothermal energy. At present, there is no production of geothermal energy in the country. According to Swiss Business Hub (2011), there are three different sources of geothermal energy, namely: magmatic, frictional and radioactive heat sources. South Africa has radioactive heat source that can be exploited for power generation. It is estimated that the source is located about 4 000 m to 6 000 m in the earth's surface. The challenges that currently prevail are: (1) cost of exploration (i.e. drilling costs), (2) lack of geothermal skills and knowledge in the country, (3) financial support, and (4) favourable regulatory environment. Nonetheless, geothermal research and support is expected to grow as government is looking for alternatives to coal-power generation.

4.5. Conclusion

There have been significant improvements in RE developments and application across the world. Most countries are moving towards RE and are playing a major role in creating a favourable environment that promotes the application of RE for power generation. Developed countries are leading in this regard. Although trailing behind, developing countries such as China, India, Algeria and South Africa have also stepped to the challenge. They too have put in place mechanisms that encourage RE industry development.

South Africa is endowed with significant RE resources. Amongst the RE resources that were reviewed; solar, wind and hydro hold the greatest potential to fulfil the needs of those who remain without electricity. The country's solar resources are more concentrated in the interior. Almost all parts of the interior have insolation higher than 6000 MJ/m^2. The Northern Cape Province has the greatest potential as it receives the highest sunshine. Other provinces that have potential are: North West, Free State and Limpopo Province. Wind resources are concentrated along the coastal areas of the country. Areas with potential include: Eastern Cape and KwaZulu-Natal Provinces. Parts of Mpumalanga, Eastern Cape and Kwazulu-Natal have potential for micro-hydro power projects.

CHAPTER 5: FEASIBILITY STUDY

5.1. Introduction

SSM operations in South Africa exploit a variety of minerals. However, a number of mining permits are lodged for: stone and aggregate, alluvial diamond, clay, sand and dimension stone (DMR, 2012). The latter mineral consumes more electricity since it requires further processing and value addition. For that reason, it is selected as focus mineral for this study. Dimension stone encompasses all naturally occurring rock material that can be cut and shaped for use as blocks, slabs, sheets or other construction units (Jeffrey, 2006). These include: granite, sandstone, marble and slate.

A sandstone operation in the Free State was selected as a case study for this research. The case study aims to assess the potential of RE resources to satisfy the energy requirements of a small scale mining operation. The following methodology was used:

- A small-scale mining operation (sandstone operation) was identified and selected. The operation is located in the Phuthadithjaba region of the Free State Province;
- A site visit to the operation was undertaken. The objective of the visit was to conduct a site preliminary survey in order to understand the operation's mine value chain and to determine the energy requirements of the operation;

- Renewable energy resources in the area were located and yearly data obtained. Only solar and wind resources were located in the area. For this reason; other renewable energy sources are not considered in the study.

- An assessment was done to evaluate the technical and economic feasibility of using the available renewable energy resources.

5.2. Site description

Maluti Sandstone is located in Phuthadithjaba area in the Free State Province. The operation is owned by Mr John Kharafu. Maluti Sandstone is involved in the entire mine value chain of sandstone (i.e. from quarrying to sales). Figure 15 shows the location of Phuthadithjaba area.

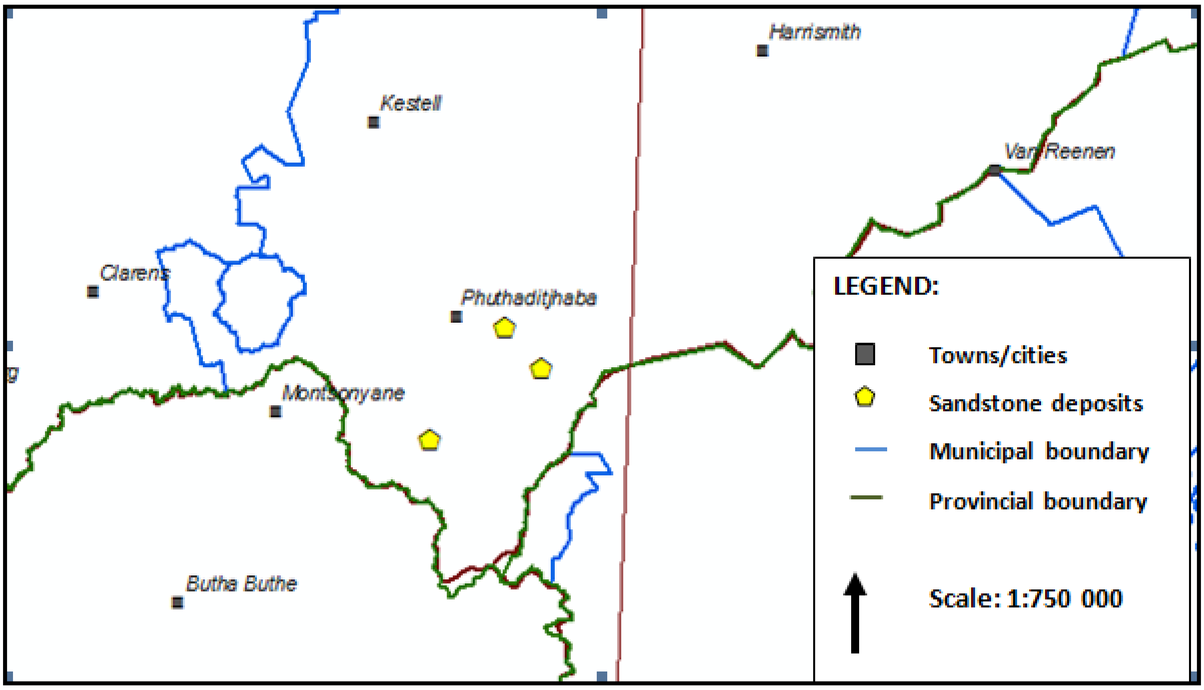


Figure 15: Location of Phuthadithjaba

Phuthadithjaba is one of the three towns under the administration and management of Maluti-A-Phofung Local Municipality. The municipality houses a population of 360,787 with over 80 per cent residing in Phuthadithjaba area. The area is rated poor because over 80 per cent of its population lives below household subsistence level (DPLG, 2007). Access to basic services is still a challenge in the area. Parts of the municipality are connected to the main electricity grid. However, about 43 per cent of households in the municipality have no access to electricity (DPLG, 2007).

5.3. Energy requirements for SSM

An energy audit was conducted on site during the site visit. Maluti sandstone is involved in the quarrying and processing of sandstone. The quarrying process involves the use of rudimentary tools to extract the stone from the ground. Hence no electricity is used during this process. Electricity is used during processing where sandstone is cut into different sizes and shapes according to customers' orders. Figure 16 illustrates the sandstone processing flow diagram.

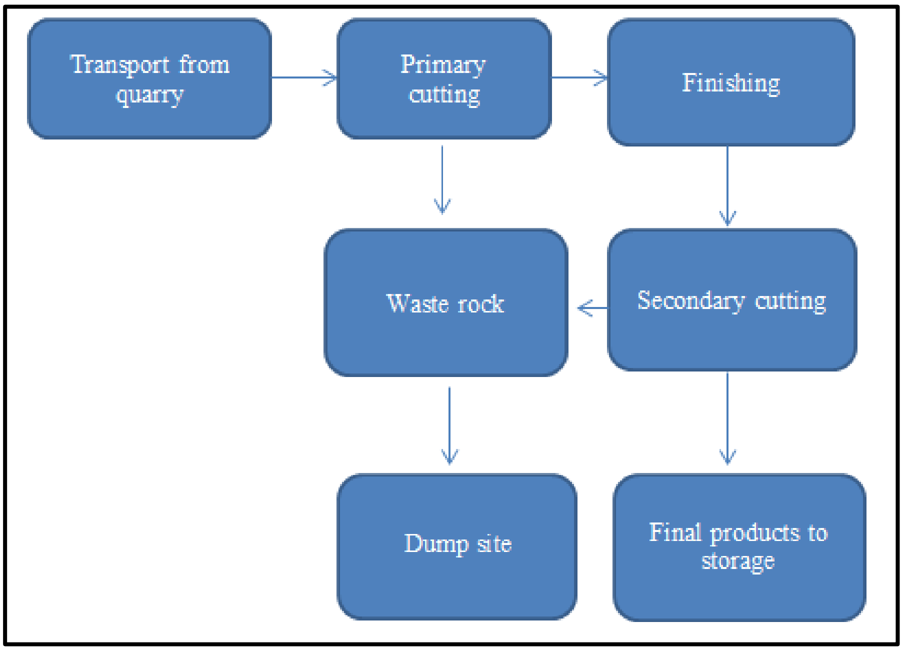


Figure 16: Sandstone processing flow-diagram (Source: Maluti Sandstone)

The sandstone blocks from the quarry undergo a number of cutting stages depending on the customers' specifications. The operation owns five (5) cutting machines with blade sizes: 300 mm, 600mm, 800 mm and 1200 mm. The utilization of the machines depends on the available orders. In addition to the cutting machines; a water pump was identified as one of the equipment that requires electricity to operate. There is a borehole on-site that provides water.

To estimate the energy requirements for the operation, the following factors were taken into account:

- The operation work one ten-hour shift per day;
- The operation operate 6 days a week; and
- Energy required for lights and other small appliances are ignored.

Please note that machine utilization is dependent on the number of orders that are available. The number of orders usually differs every month because access to markets remains a challenge. Hence the operation works on an order-to-order basis. The 10-hour shift is based on the total production of 1,250 m^2 per month (e.g. sandstone products are sold per square metre).

Table 5 gives information on the number and the types of cutting machines found on site.

Table 5: List of equipment on site

Equipment	Quantity	Rated power (kW)
300 mm circular saw	1	7.5
600 mm circular saw	2	15
800 mm circular saw	1	18.5
1200 mm circular saw	1	27
Water pump	1	0.7

With the above factors and collected information, the energy requirements for the operation were estimated. The results are summarised in Table 6 below.

Table 6: Estimated energy load for operation

Equipment	Quantity	Rated power (kW)	No. of hours per day	Consumption (kWh/day)
300 mm circular saw	1	7.5	3	22.5
600 mm circular saw	2	15	4	120
800 mm circular saw	1	18.5	6	111
1200 mm circular saw	1	27	3	81
Water pump	1	0.7	10	7
			TOTAL	**341.5**

The energy requirement for Maluti Sandstone operation is 341kWh/day. Figure 17 shows the load distribution profile of the operation. The 600 mm and 800 mm blade size machines combined constitute over 60 per cent of the load profile. It must be noted that the load profile will differ according to the size available orders. This is based on the assumptions that were made.

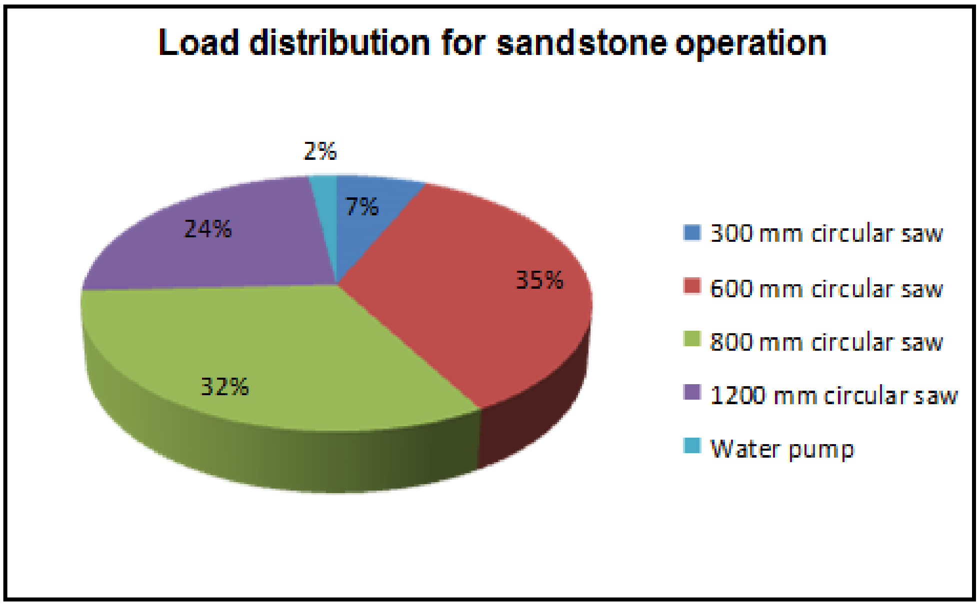


Figure 17: Load distribution profile

5.4. Resource Data

Resource data was obtained from the Agricultural Research Council's Institute for Soil, Climate and Water (ISCW). There is no weather station at Phuthadithjaba. The nearest station was identified to be as used as a proxy. It was assumed that weather conditions in the two areas were the same. Table 7 gives details of the station used.

Table 7: Details of weather station 30647

Station name	Golden gate: Clarens
Station number	# 30647
Latitude	-28.50381
Longitude	28.5838
Altitude	1849

Table 8 gives the wind and solar data of the study area.

Table 8: Wind and solar data (ISCW, 2012)

	Wind data	**Solar data**	
Month	**m/s**	**MJ/m²**	**kWh/m²**
Jan	2.18	28.04	7.79
Feb	1.64	23.7	6.58
Mar	1.67	20.25	5.63
Apr	1.61	18.29	5.08
May	1.43	13.99	3.89
Jun	1.77	12.92	3.59
Jul	1.94	14.01	3.89
Aug	2.01	16.08	4.47
Sep	2.6	19.16	5.32
Oct	2.34	22.67	6.30
Nov	2.41	23.93	6.65
Dec	1.93	22.67	6.30
AVERAGE	**1.96**	**19.64**	**5.46**

It can be seen that the area is poor in wind resources with an average of 1.96 m/s. Generally, the installation of wind turbines is considered for wind speeds above 5 m/s with few months below 4 m/s (Kassam, nd). These are considered adequate for wind turbines. Figure 18 is a power curve for Cal-ePower 10kW wind turbine. The turbine’s rated power is 10kW at 11 m/s. Its cut-in wind speed is rated 3.0 m/s. This makes the area wind speeds too low for wind turbines. For this reasons, wind energy is disqualified as a potential renewable energy source for the study.

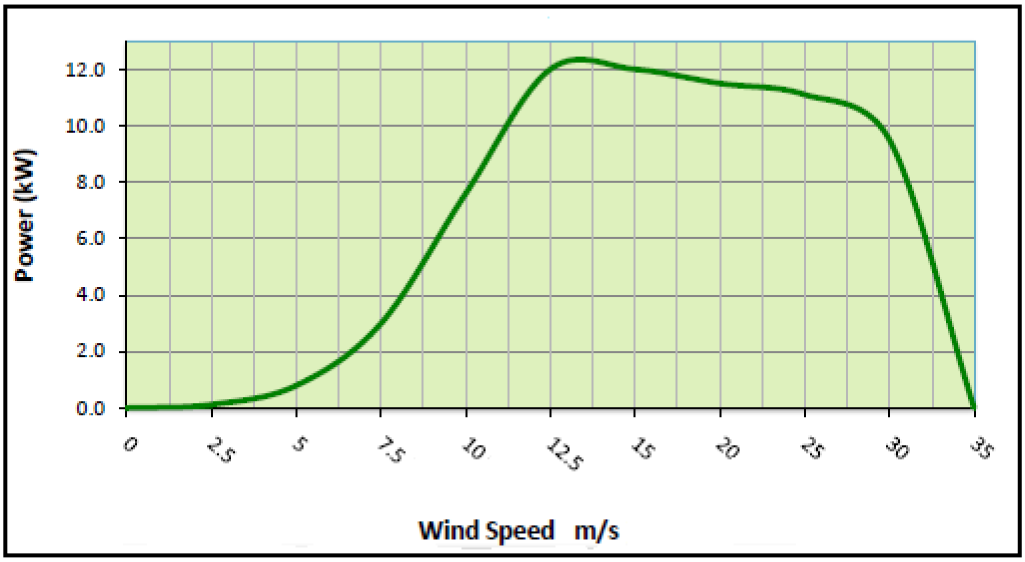


Figure 18: Power curve for 10kW wind turbine (Source: www.cal-epower.com)

The area receives good sunshine during the summer months. During these months, solar radiation is fairly constant. The average solar radiation is 5.46kWh/m^2. Generally, annual radiation of 4kWh/m^2 and above is considered adequate. This qualifies solar energy as a potential source of power generation.

5.5. Feasibility assessment

5.5.1 Background

Hybrid Optimization Model for Electric Renewable (HOMER) computer software was used to conduct the feasibility assessment. HOMER is a modelling tool used to evaluate design options for off-grid and grid-connected power systems (NREL, 2011). Its use extends to remote, stand-alone and/or distributed power systems. HOMER was developed in 1993 by the Department of Energy (in the United States) for internal use. It is currently administered by the National Renewable Energy Laboratory (NREL). Its primary function is to evaluate technical and economic feasibility of power systems. This is done through simulations, optimization and sensitivity analyses. It aims to assists in planning and decision-making in power generation projects.

For this study, HOMER was used to assess:

- Adequacy – Given the resource available, HOMER was used to assess if the Renewable Energy System (RES) can adequately and reliably serve the power demands; and
- Costs of RES – Determine the costs implications of different options. HOMER uses the Net Present Cost (NPC) to determine optimum RES configuration. The NPC encompasses the total cost of installation and operating the system over its life span.

A set of data is required to run HOMER. The data required include: site load data (i.e. load which the system must serve), renewable resource data and details of system components.

5.5.2. Proposed system designs

Stand-alone RES are often found cost-effective when compared to traditional energy systems (i.e. diesel generators). This is because their operational and maintenance costs are very low. According to Givler and Lilienthal (2005), this is true for certain load requirements. There is a threshold load above which traditional and/or hybrid systems (i.e. PV/generator system) become cost-effective. The study proposes three scenarios for assessment. These are:

- Scenario 1 is the stand-alone PV system. This is the conventional process of producing electricity from solar energy. PV modules generate DC power which is converted to AC power using an inverter. Batteries are added to the system for storage purposes.

- Scenario 2 is the hybrid system. A diesel generator is added to PV system as backup. The generator will provide power when weather conditions limit solar resource.

- Scenario 3 is diesel generator stand-alone system. The use of diesel generators in rural areas is very common. This is because generators were found to be affordable options to grid electrification for rural areas. Generators are also cost-effective on initial capital costs when compared to renewable energy sources. However, due to rising cost of fuel, they are becoming comparable to RE sources.

Figures 19, 20 and 21 show the proposed system configurations in HOMER.

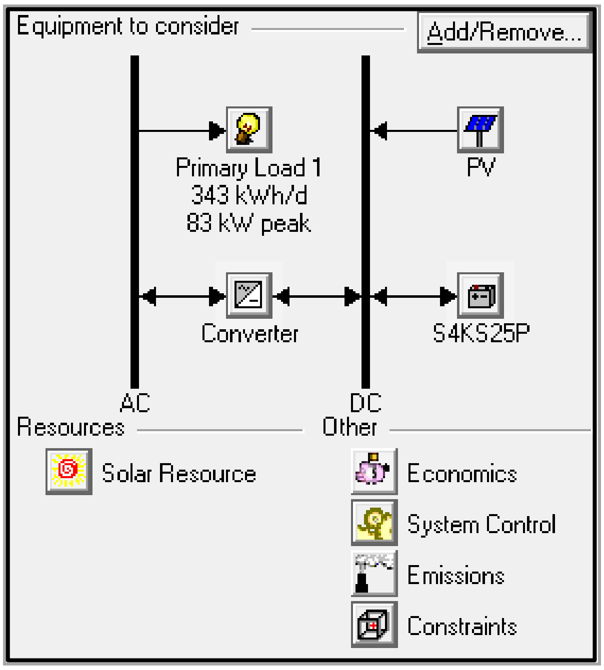


Figure 19: Schematic diagram of scenario 1

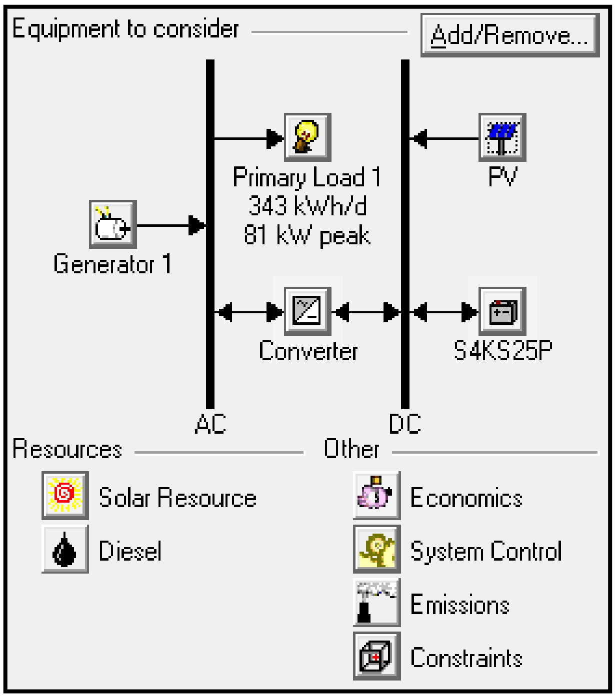


Figure 20: Schematic diagram of scenario 2

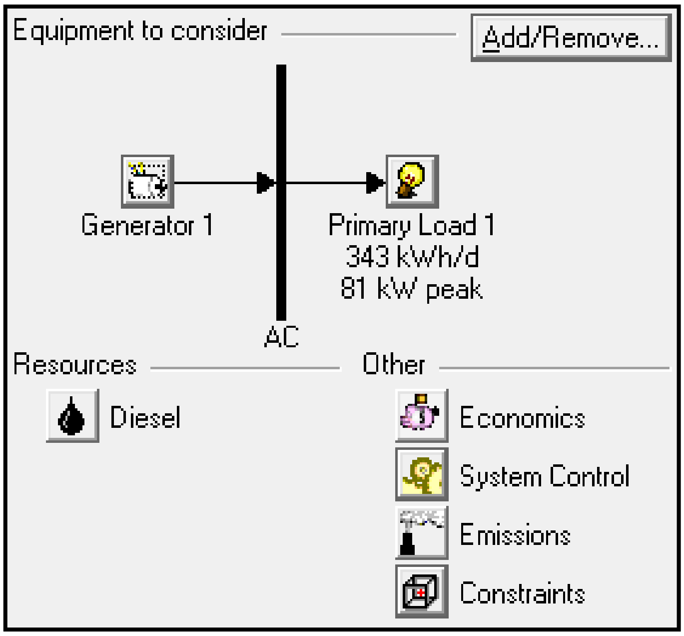


Figure 21: Schematic diagram of scenario 3

In all system designs, HOMER considers the load, system components (equipment), and resources needed to run the components. Primary load is the load needed to be served. HOMER requires hourly-load data for modelling. Hourly-load profile for the operation was formulated from the estimated 1-day load data (see table 6). It was assumed that the operation works 10-hour shift daily. The shift starts at 06:00 and ends at 17:00. Please note that the number of working hours depend on the size of orders, types of orders and hence the utilization of machines. HOMER factors in random factors to take into account variability. The energy consumed by operation equates to 343kWh/day at 83kW peak.

Resources required to run the proposed systems are solar resource and diesel. Technical and cost data of the components is summarised in table 9 below. The data was compiled from suppliers, manufacturers and literature studies.

Other input data required by HOMER is included in the appendices. It must be noted that HOMER uses US dollars as a standard currency. Hence, all the information is provided in US dollars.

Table 9: Technical and cost data for system components

	PV module	**Converter**	**Battery**	**Diesel generator**
Size (kW)	1	1	1156 Ah	7
Capital cost (US$)	6000	700	850	2000
Replacement cost (US$)	5000	600	600	1600
O & M cost ($/yr)	15	10	15	0.5/hr
Life span (yr)	20	15	3-5	
De-rating factor/efficiency	90	85		

5.5.3. Results

HOMER uses the Net Present Cost (NPC) as a primary measure to determine feasible configurations. NPC includes all the costs that are incurred over the lifetime of the system. Feasible configurations are those that meet the specified load, available resources and/or specified constraints. Three separate simulations were run in HOMER as per the given scenarios. In addition to NPC, the following measures were used to evaluate the results.

- *Levelized cost of electricity* is the average cost per kWh of useful energy produced by the system.
- *Maximum annual capacity shortage* is the percentage of the yearly load that is allowed to go unserved by the system.

- *Excess electricity* is the surplus electricity not used by the system and goes to waste. This occurs when there is a surplus of power being produced.
- *Unmet electric load* is the load that power system is unable to serve. This occurs when electric demand is more than the supply.

Scenario 1

Scenario 1 was modelled under 0%, 5%, 10%, 15%, 20%, 30%, 40% and 50% maximum annual capacity shortage. At 0%, the system is expected to meet all the load demands (i.e. this is the ideal system). Moving from 0 % makes provision for unserved load (or unmet load). Different sizes (in terms of kW) of PV and converters were considered during the study. The largest size of PV considered was 1000 kW. A de-rating factor of 90 per cent was used for all the PV sizes. A de-rating factor takes into account all factors that would vary the performance of PV from the ideal such as temperature, wind, lighting etc. (Li et al., 2013). Table 10 gives the optimum configurations according to the capacity shortage.

Table 10: Simulation results for scenario 1

Maximum annual capacity shortage (%)	PV size (kW)	Converter size (kW)	No. of battery	NPC ($)	Unmet load (%)
0	-	-	-	-	-
5	200	100	14	1 497 605	2.7
10	200	50	10	1 440 585	5.0
20	100	50	14	758 322	10.9
30	100	40	4	734 407	18.2
40	100	30	4	724 091	27.0
50	100	30	-	621 000	29.1

No feasible solution was found at 0 % capacity shortage. This means that the largest PV used in the model cannot supply the entire load. The solution would be to increase the size of PV or to make provision for unmet load. Provision for unmet load improves the NPC of the system. Allowing some load to go un-served means that the system does not need to be designed for extreme and worst conditions (Givler and Lilienthal 2005). This is often the case for RE systems because they are dependent on weather conditions. It is expected of them not to perform during some periods in the year because of changing weather conditions. Allowing unmet load also lowers initial capital costs.

For this study, a 10 % constraint was placed on the system. The cost-effective configuration at 10 % was found to be a combination of 200 kW PV, 50 kW converter and 10-battery bank. This configuration has an NPC of US$ 1 440 585 at US$.0948 cost of energy. The PV array system can produce 395 404 kWh per year resulting in unmet load of 5 per cent and excess electricity of 64 per cent.

Figure 22 is a cash flow summary of a PV stand-alone system. The capital costs constitute the largest percentage of the costs. The system’s operating costs account only 1 per cent of the total costs.

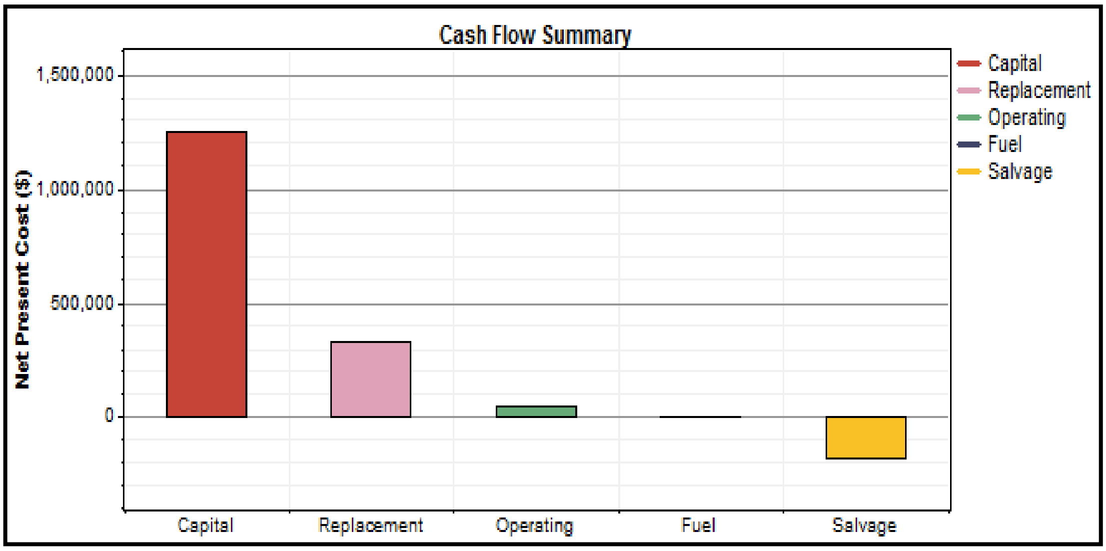


Figure 22: Cash flow summary for PV stand-alone system

Scenario 2

A diesel generator was added to the system to provide backup. The system was run at different renewable energy fractions. RE fraction is the fraction of power provided to the load that originated from renewable power sources. Table 11 gives the simulation results. The technical and cost data of diesel generator is given in Table 9 above. The diesel price was taken at US$ 1.02 per litre.

Table 11: Simulation results for hybrid system

Constraint (%)	PV (kW)	Generator (kW)	Battery (Quantity)	Converter (kW)	Operating cost ($)	Total NPC ($)	COE ($/kWh)	RE fraction (%)
90	200	30	20	50	20 349.00	1 520 695.00	0.95	0.96
80	100	40	20	50	20 615.00	926 952.00	0.579	0.89
70	100	40	20	50	20 615.00	926 952.00	0.579	0.89
60	50	40	12	40	27 001.00	694 790.00	0.434	0.62
50	50	40	12	40	27 001.00	694 790.00	0.434	0.62
40	50	40	12	40	27 001.00	694 790.00	0.434	0.62
30	50	40	12	40	27 001.00	694 790.00	0.434	0.62
20	50	40	12	40	27 001.00	694 790.00	0.434	0.62
10	50	40	12	40	27 001.00	694 790.00	0.434	0.62

The table shows the optimum configurations according to the different constraints percentages. The actual fraction modelled by the system is depicted as RE fraction percentage. The feasible distribution point of the system is 62 per cent as determined by the total NPC. This means PV array will supply 62 per cent of the load. Figure 23 shows the monthly average power production. The distribution of power is relatively the same in all the months. The system architecture is made up of 50kW PV, 40kW generator, 40kW converter and 12-battery bank. The months with highest production are: August, January, March and September.

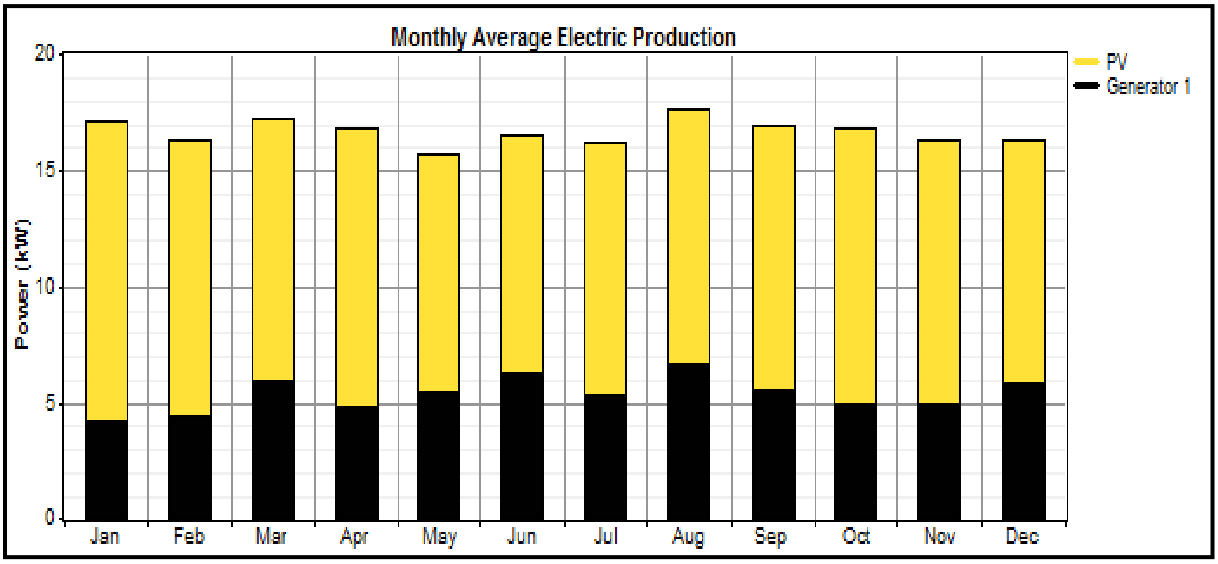


Figure 23: Monthly average electric production

The total NPC is estimated at US$ 694 790 with cost of electricity of US$ 0.434. The addition of generator has improved the NPC by over 50 per cent. Figure 24 shows the distribution of costs by system components.

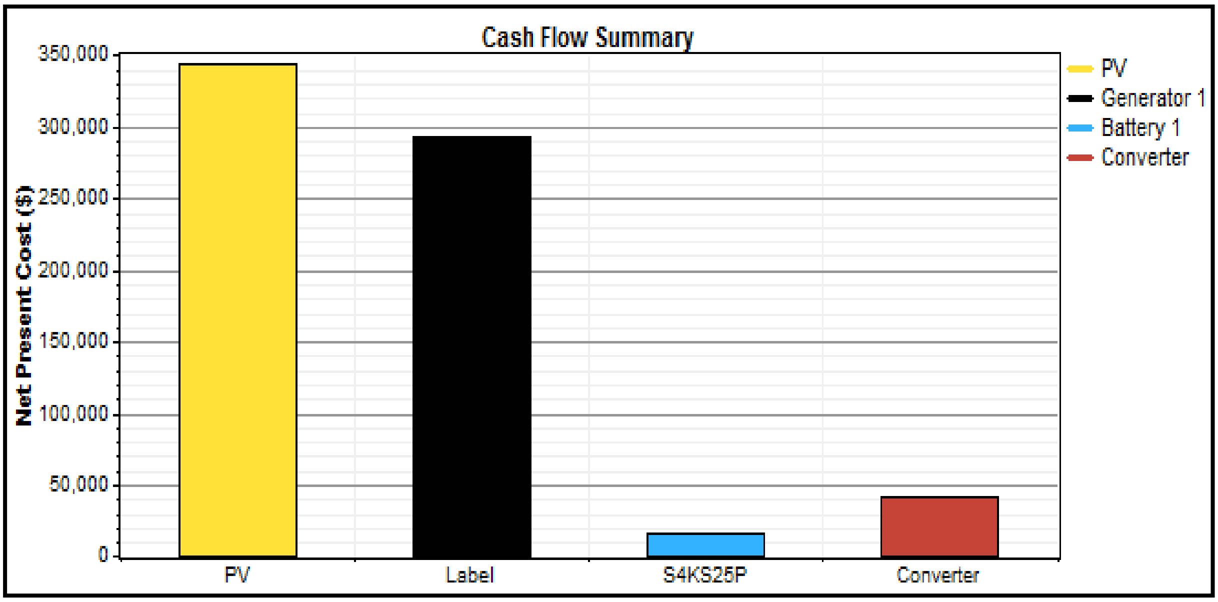


Figure 24: Cash flow summary for hybrid system

PV accounts 49 per cent of the total NPC. This compares to 42 per cent of generator. The biggest cost component for generator is the cost of fuel. Figure 25 gives the cash flow summary by cost component. Compared to scenario 1, the operating costs have increased by 42 per cent to US$ 27 001 per year. There is also a reduction in the cost of electricity from US$ 0.948/kWh to US$ 0.434/kWh. This equates to a cost saving of 54 per cent.

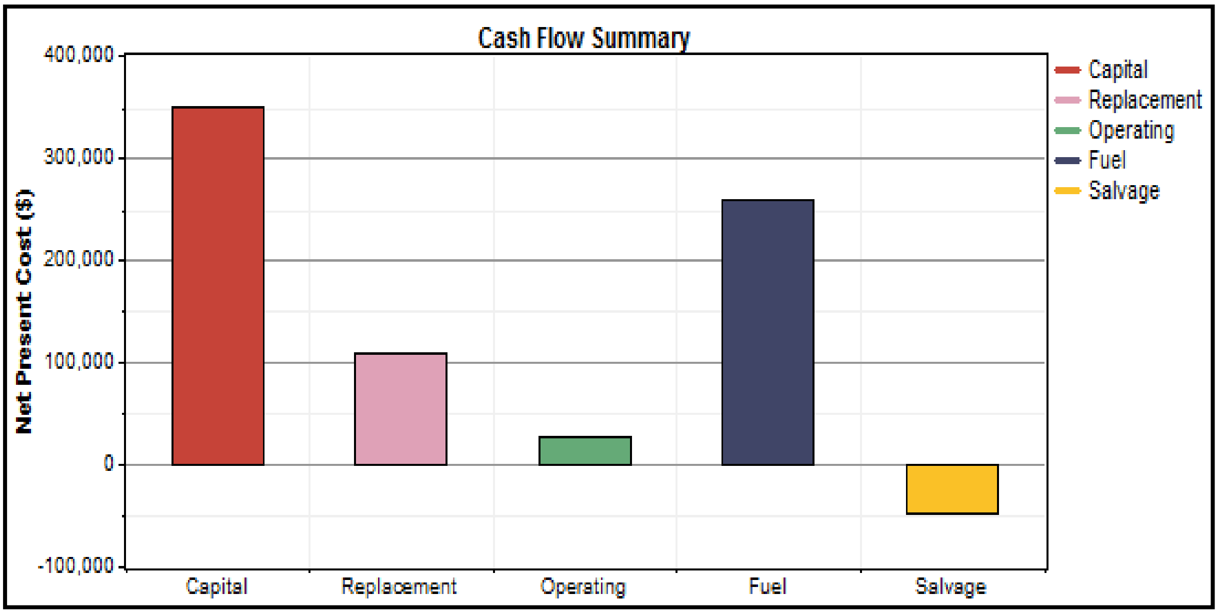


Figure 25: Cash flow summary by cost components

The hybrid system is able to supply the entire load with no unmet load and about 3.5 per cent of excess electricity. Because of the use of diesel, the generator introduces GHG emissions. The system is estimated to require 19 791 litres of diesel per year. Table 12 gives the amounts of GHG produced by the system. The system will produce an estimated 52 117 kg of CO_2 per year. Other harmful gases that will be produced include carbon monoxide, sulphur dioxide and nitrogen oxides.

Table 12: GHG emission for hybrid system

GHG emission	Emission (kg/year)
Carbon dioxide	52 117
Carbon monoxide	129
Sulphur dioxide	105
Nitrogen oxides	1 148
Unburned hydrocarbons	14.2

Scenario 3

Scenario 3 presents a stand-alone diesel generator system. The system was modelled using the same technical and cost data presented in Table 9. A diesel price of US$ 1.02 per litre was also used in this model. Different generator sizes were modelled. The optimum generator-size as determined by HOMER is 100kW. The 100kW generator is able to serve the entire load resulting in no unmet load and no excess electricity.

Figure 26 shows cash flow summary of the system by cost components. The total NPC of the system is US$ 1 592 263 with US$ 0.995/kWh cost of electricity. Fuel costs constitute the largest share of the total costs. The system will require 101 379 litres of diesel resulting in 266 963 kg CO_2 emissions per year. This is an 80 per cent increase from scenario 2. Operating costs have increased significantly compared to the two scenarios above. System’s operating costs are estimated at US$ 122 322 compared to US$ 15 417 and US$ 27 001 for scenario 1 and 2 respectively. The cost of electricity is however comparable to scenario 1 with only a 5 per cent difference. Scenario 2 remains the cheapest in terms of the cost of electricity.

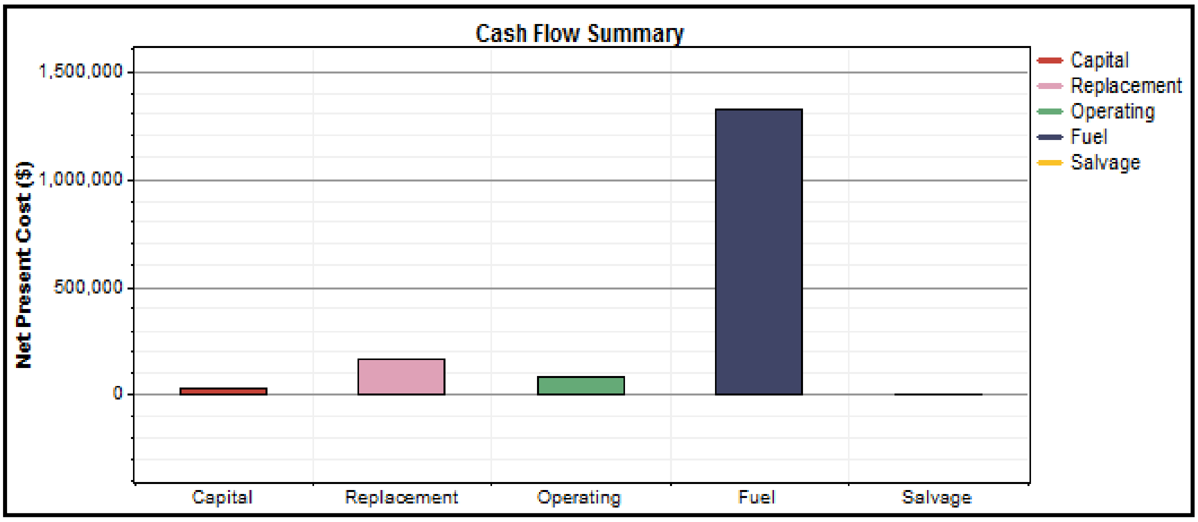


Figure 26: Cash flow summary for scenario 3 by cost component

5.5.4. Discussions

Table 13 summarises the technical and economic performance of the three scenarios. Unmet load and excess electricity are used to evaluate the technical feasibility of the system. Technical evaluation assesses the ability of the system to meet the load demands. Economic feasibility takes into account the cost components and determines the cost effective system. It is evaluated by the following cost factors: NPC, LCOE, operating cost and initial capital cost of the system.

Table 13: Technical and economic evaluation results

	Unmet load (%)	Excess electricity (%)	Total NPC ($)	LCOE ($/kWh)	Operating cost ($/yr)	Initial capital cost ($)
Scenario 1	5	64.2	1 440 585	0.948	15 417	1 243 500
Scenario 2	-	3.5	694 790	0.434	27 001	349 629
Scenario 3	-	-	1 592 263	0.995	122 322	28 571

Scenario 1 is a stand-alone PV system. Under the specified conditions, scenario 1 was unable to supply the entire load. A 5 per cent unserved load and excess electricity of 64 per cent was recorded. A possible solution to the latter would be to increase the battery bank or use the electricity to power other loads, or transfer it to the grid distribution network. The assessment of these options is beyond the scope of this research.

The required initial capital costs for scenario 1 are estimated at US$ 1 243 500 for a 200 kW module (this includes converters and battery bank). It is observed that the cost of PV reduces considerably with the size of PV. This is evident in scenario 2. The PV cost of reduces to US$ 300 000 for a 50kW PV array. The cost of electricity for scenario 2 is low compared to the two other scenarios. Operating costs are estimated at US$ 27 001 as compared to US$ 15 417 for scenario 1. However, this is well below scenario 3 with estimated operating costs at US$ 122 322. Generators require low initial investment but high operational costs. The high operational costs are as a result of rising fuel prices. This makes scenario 3 comparable to scenario 1 in terms of total NPC and cost of electricity.

HOMER uses NPC as a primary measure to determine the cost-effective system. On the basis of NPC, scenario 2 is the feasible solution. This is further supported by the cost of electricity. Scenario 2 is taken as the feasible solution. The system architecture is made up of 50kW PV, 40kW generator, 12-battery bank and 40kW inverter.

5.6. Conclusion

PV stand-alone systems are still expensive options in terms of the initial investment cost compared to traditional diesel generators. However, the rising cost of fuel is changing the cost profiles. PV systems are becoming comparable with generators in terms of NPC and cost of electricity because of rising fuel prices. The addition of generator to PV system has however yielded improved results. Khatib et al (2011), Ismail et al (2011) and Hrayshat (2009) studies concluded that PV/generator systems are feasible as compared to diesel generator system or PV stand-alone systems. This is also evident in the case study conducted. Hybrid systems are attractive options because of their lowered capital costs and GHG emissions. More so, the utilization of PV system is maximised resulting in increased reliability.

However, it must be noted that the feasibility of RE resources for power generation depends on a number of factors. The use of RE sources is area-specific. Not all the areas have adequate RE resources for power generation. It is important to locate the suitable RE sources in a given area. Another important factor is the load profile of an area (or operation). Different operations will have different supply requirements. Hence, the economic and technical feasibility will vary according to different operations and specifications. Small-scale operations exploit a wide range of minerals. And hence, the energy requirements will differ according to the type of commodity and size of operation. Other factors such as available surface area (i.e. for mounting PV arrays), the mine affordability, CO_2 taxes (if any), feed-in-tariffs or any other subsidies were not considered. Some of these factors are however covered in the subsequent chapter.

CHAPTER 6: SUMMARY OF DISCUSSIONS

6.1. Introduction

This chapter looks at research findings and link them to the research objectives and problem statement. The chapter aims to answer the author's research question: will it work? The chapter establishes facts about SSMs potential for rural and economic development; electricity as a key driver to economic development; and electricity crisis with particular focus on rural electrification. It also assesses the following factors: renewable energy endowment; RE development and barriers; and SSM capability and capacity. The capability and capacity of SSM is assessed in terms of affordability and access to funding. These are taken as the major determinants for establishing whether RE use in SSM will work or not.

6.2. Potential of SSM

The potential of small scale mining in the world cannot be overlooked. The SSM sector provides livelihoods to poor communities in many parts of the world, particularly in developing countries. SSM is playing an important role in economic development (Amankwah and Anim-Sackey, 2003; Hilson, 2009; Buxton, 2013). It is estimated that the sector employs between 20 and 30 million people worldwide (Buxton, 2013). This is compared to an estimated 13 million people in 1999. There has been a significant increase in the number of people participating in the sector. This increase has largely been driven by dropping commodity prices affecting the performance on large-scale operations. People participating in SSM in Africa are estimated at 8 million (Benkenstein, 2012); this compares to between 3 to 3.7 million in 1999 (ILO, 1999). According to Buxton (2013), the SSM subsector employs 10-

times more people than the large-scale mining sector. More so, it has been successful in stimulating local economic development. However, contribution to economic development differs from country to country. The level of contribution depends mainly on the level of recognition and hence the mechanisms in place to foster and support the sector by government. In many countries, the SSM sector has been recognised as an important driver for rural development through job creation. Positive economic contributions are evident in countries such as Ghana, Tanzania and Zambia. Small scale mining in Ghana has contributed significantly to socio-economic development in the country. It has provided employment to rural communities which in turn has reduced rural migrations, promoted local economic development and contributed towards poverty alleviation (Amankwah and Anim-Scakey, 2003). Zambia’s SSM activities account for 80 per cent of the emeralds production which represents approximately 20 per cent of the total world output (ECA, 2002).

South Africa’s SSM sector is still small compared to other countries. However, an increase in the number of SSM activities has been observed. South Africa has a long history of mining. With mining being the backbone of the country’s economy, it contributed 18.7 per cent to the nation GDP in 2010. More so, a total of 1.3 million jobs were provided by the industry (i.e. this included both direct and indirect jobs) (Baxter, 2013). The country is known for its vast mineral resources – most of which are exploited by large-scale mining operations. However, it has been established that there exists considerable number of smaller deposits which are deemed uneconomical by large mining companies. These have been identified as being suitable for small scale mining.

Although not fully developed, the SSM sector has an important role to play in the mining industry and in South Africa as a whole. Because of its origin, it has the potential to directly address some of the challenges faced by rural communities. Small scale mining has the potential to provide a platform for rural communities to participate and share in the benefits of the mining industry. This potential cannot be overlooked, but in the same light the challenges faced by the sector cannot be ignored. It has been established that for the sector to realise its potential, a number of issues should be addressed. Access to electricity is one of the many challenges that small operations face because of their location.

6.3. Electricity crisis and rural electrification

It is widely acknowledged that electricity plays a vital role in socio-economic development, particularly in rural areas. Leung (2005) study on the effect of electricity consumption on social and economic development found a strong correlation between electricity consumption and socio-economic development. According to Leung, electricity consumption can directly stimulate economic growth which will in turn enhance social development. Dornan (2014) concluded that electricity facilitates economic activity and the provision of basic services. World Bank (2010) also identified electricity access as being essential to poverty alleviation.

In most regions, the emergence of the electricity sector is as a result of increased industrial activities, particularly mining and manufacturing activities. These activities are known to be large users of electricity. Electricity is an important input in all mining activities, whether large or small. The country experienced electricity shortages during 2008 which resulted in load-shedding. The mining industry was adversely affected as operations largely depend on electricity. Since then, the drive by mining companies (and government) has been towards decreasing and managing energy utilization. However, recent concerns about climate change have shifted the focus to sustainable energy sources. Coupled with these concerns, is the ongoing challenge of rural electrification. According to White and Koopman (2011), about 30 per cent of the country is without access to electricity. This translates to more than 10 million people with the majority residing in rural parts of the country. Grid electrification has been ruled out as a possible option because of the high costs associated with extending grid lines to isolated rural areas. Access to electricity in South Africa is a constitutional right. It is therefore acknowledged that rural electrification is a concern that needs to be addressed. Renewable energy options have been identified as possible solutions for rural electrification (Borhanazad, 2013; Shaaban and Petinrin, 2014). Renewable energy use, particularly in rural areas, continues to grow in many parts of the world. This is because RE technologies are becoming attractive and comparable to traditional energy sources. More so, there is an increase in investments opportunities from both private and public sectors.

6.4. RE potential and capacity

South Africa’s renewable energy resources have a significant role to play in the energy sector, society and the economy. According to (Deichmann et al, 2010), the country’s renewable energy base is sufficient enough to be exploited using available technologies. The potential is estimated at 1.3 times the current consumption (Deichmann et al, 2010). Most of these resources remain untapped and this provides an opportunity to address electricity shortages and most importantly rural electrification. Examples of potential renewable energy resources include: solar, wind, hydro and biomass.

Biomass remains the source of fuel in most rural areas. Rural communities still collect wood to use for cooking and heating. Biomass currently contributes between 9 and 14 per cent of the primary energy supply (Holm et al, 2008). The biomass potential in the country is relatively small. This is because most parts of the country are classified as deserts and semi-deserts with only 1.2 per cent consisting of forests. The largest potential lies in the sugar and pulp industries. According to Banks and Schäffler (2006), there exists an estimated total potential of 12.7 TWh per year from sugar cane, forestry, sawmill, pulp and paper industries. However, this potential biomass is currently being used by these industries to power their own operations. A lot of research has been directed to the production of biofuels from biomass. However, the same concerns still remain: land availability and food security. The challenge with biomass is that it is only regarded renewable if production is sustainable.

Solar has the highest potential compared to other sources. South Africa is ranked amongst the countries that receive the excellent radiation with average daily solar radiation varying between 4.5 and 7kWh/m^2 during summer months. Some areas receive as high as 6.5kWh/m^2 during winter months. There exists considerable potential for solar in the country for both power generation and solar heating.

Wind resources are rated fair to reasonable in the country. The country's wind resources are mostly concentrated along the coastal areas and the escarpment with wind speeds exceeding 4 m/s. The use of wind power has been to power water pumps. The focus has now shifted to wind power as a possible source for power generation. A study conducted by CSIR et al (1998) identified ten (10) areas with high wind potential (see Table 14). These areas were found viable for installation of small-scale wind turbines (i.e. 1kW and 5 kW).

Table 14: Areas with high wind speeds in South Africa (Source: CSIR et al, 1998)

Site	**Annual mean wind speed (m/s)**
Gains Castle	13.94
Springbok	8.27
De Aar	6.88
Langebaan	6.88
Simonstown	6.65
Cape Town	6.63
Koningnaas	6.20
Ixopo	5.82
Geelbek	5.62
Noupoort	5.60

South Africa’s *hydropower potential* is relatively low. At present, hydropower constitutes about 1 per cent of the energy production. Most plants are small hydro plants producing less than 10 MW. According to Banks and Schäffler (2006), potential in hydropower lies in importing from other neighbouring countries. At present, there is no production of *geothermal energy.* Ongoing research has identified the Southern Cape Folded Mountains for holding significant superheated water which could potentially contribute to the energy mix (Holm et al, 2008). Other potential options include: solar thermal electric, solar thermal heating, wave energy, and landfill gas. These were not considered for this study.

6.5. RE development and barriers

South Africa's renewable energy contribution is currently small. Table 15 indicates the renewable energy contribution in comparison with the total grid electricity. Although the figures are outdated, not much has changed since the introduction of the White Paper on Renewable Energy in 2003. Renewable energy still accounted less than 1 per cent to the energy mix in 2012 (SAinfo reporter, 2014)

Table 15: Renewable energy contribution to energy mix (Source: Banks and Schäffler, 2006)

	Existing mixed-grid production	Hydropower	SWH (2005)	PV (2002)	Wind	Biomass
Capacity (MW)	39 493	661	652	12.1	29	200
Annual production (GWh)	207 000	1 057	1 377	21	29 (including 23MW at boreholes)	700

A RE target of 10 000 GWh was set by government to be achieved in 2013. Government gave itself ten (10) years to increase its renewable energy capacity. In 2009, progress was reviewed at the Renewable Energy summit held in Pretoria. The main concern raised at the summit was the pace of implementation. It was reported that progress has been relatively slow – with only 10 per cent of the target achieved. The poor results were attributed to the lack of implementation (DME, 2009; Trollip and Marquard, 2014). However, thereafter progress improved significantly through the introduction of the Renewable Energy Programme called the Renewable Energy Independent Power Purchase Procurement Programme (REIPPPP). To date, the Department of Energy (DoE) has approved a total of sixty-four (64) RE projects across the country. The projects are expected to add an additional 3 900 MW to the energy mix upon completion (SAinfo reporter, 2014).

The country's reliance on coal as a primary source of electricity is still dominant – mainly because coal remains the cheapest option and South Africa is well endowed with coal resources. Moving away from coal is set to take time, particularly because South Africa is a developing country. A number of constraints were identified during the summit as hampering development of RE in the country. These are discussed below.

6.5.1. Legal and regulatory barriers

Legislative framework is essential to support and facilitate the development and use of renewable energy in the country. It is the responsibility of government to create a favourable environment to enable the development of RE sector. The environment is made favourable by policy which acknowledges and recognises the role of RE in the country, economy and society. South Africa has recognised the potential contribution of RE to the energy mix, and hence to the development of the country. The Renewable Energy White Paper (2003) clearly pledges the country's support to the development of RE sector. Its support and motivation was re-affirmed during the review summit in 2009. Inadequate legal and regulatory framework was identified as a constraint during the 2009 Renewable Energy Summit. This prompted the government to introduce a number of policy instruments to provide direction for RE development in the country (Thabethe, 2010). Policies that were introduced included:

- National Integrated Energy Plan (IEP)
- Renewable Energy Market Transformation (REMT)

- Renewable Energy Feed-In-Tariff (REFIT)
- Renewable Energy Independent Power Producer (RE IPP) programme
- Renewable Energy Finance Subsidy Office (REFSO)
- Biofuel Industrial Strategy
- Demand Side Management Subsidy Solar Heater Programme
- Traffic lights and public lighting.

Most of the above policies were recently introduced and hence most are still in their infancy stages. Further, these instruments are initiatives of the Department of Energy in collaboration with ESKOM and other government departments. However, the introduction of the Renewable Energy Independent Power Producer Programme has introduced the participation of the private sector. According to DME, this has reduced the funding burden on government and ESKOM. Private sector participation provides an opportunity for diversification, particularly in terms of supply.

6.5.2. Limited funding instruments

The provision of fiscal and financial instruments has also been identified as an important driver to RE development. Financial instruments are particularly important because they make RE technologies cost-competitive. They also play a role in reducing the risks associated with RE technologies. This in turn increases investors' confidence – thus making way for investment opportunities. According to the DME (2003), government funding (for RE) is crucial because it lays a foundation for confidence and this in turn attracts funding from donors and private/public sectors. There are a number of fiscal instruments which governments adopt to promote RE development. These include: budget allocations, subsidies, levies, tax rebates and other incentives. Investment incentives, production incentives and subsidies have proved successful in promoting RE developments (DME, 2003).

In 2009, the National Energy Regulator of South Africa (NERSA) approved Renewable Energy Feed-In-Tariffs (REFITs). REFITs (in South African context) were defined as mechanisms that aim to promote and oblige specific entities to purchase power output from renewable energy generators at pre-determined prices. The approved RE projects included: landfill gas; biomass; biogas; concentrated solar power (CSP) (with and without storage); wind; small hydro; and ground-mounted photovoltaic. REFITs were specifically designed for RE projects with a minimum capacity of 1MW. Table 16 gives the summary of REFITs.

Table 16: REFITs for renewable energy projects (Source: NERSA, 2011)

RE technology	**REFIT (R/kWh)**		
	2009	**2011**	**% Change**
Wind	1.25	0.938	-24.9
Landfill gas	0.90	0.539	-40.1
Small hydro	0.94	0.671	-28.6
CSP trough with 6 storage	2.10	1.836	-12.6
CSP trough without storage	3.14	1.938	-38.3
CSP central receiver tower	2.31	1.399	-39.4
Photovoltaic (ground-mounted)	3.94	2.311	-41.3
Biomass solid	1.18	1.060	-10.1
Biogas	0.96	0.837	-12.9

In 2011, NERSA revised the 2009 approved REFITs. The revised tariffs came out lower than the original. According to NERSA (2011), this was as a result of the changes in the exchange rate and cost of debt. Solar PV, landfill gas and CSP experienced the largest percentage decreases. Following a number of concerns, the REFITs were abandoned making way for the Independent Power Purchase

Procurement Programme (IPPP). The programme uses the tender bidding process to select cost-competitive renewable energy projects. Figure 27 summarises the bidding process as followed in the IPPP programme.

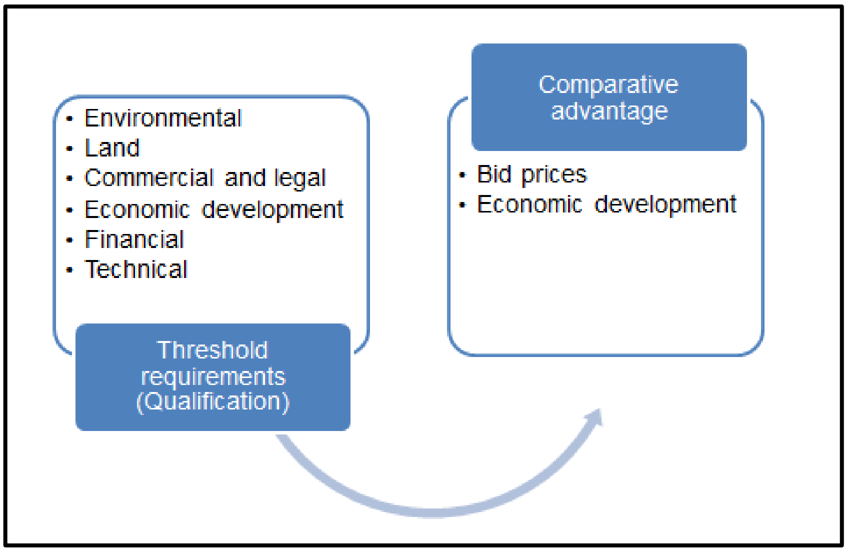


Figure 27: IPPP bidding process (Source: DoE, 2013)

The bidding process is divided into two primary evaluation stages. The bidders are assessed according to the six (6) threshold requirements during the first stage. The second stage is based on comparative advantage. This looks at the bid price and economic development gains in terms of: job creation, local content, enterprise development and other socio-economic gains. Bid price and economic development gains account for 70 % and 30 % respectively of the decision-making. There have been three biddings to date.

Table 17 gives the summary of the capacity allocations from the bidding processes. It shows the approved capacities according to RE projects during three bidding windows.

Table 17: Renewable energy capacity allocation through IPPP programme (Source: DoE, 2013)

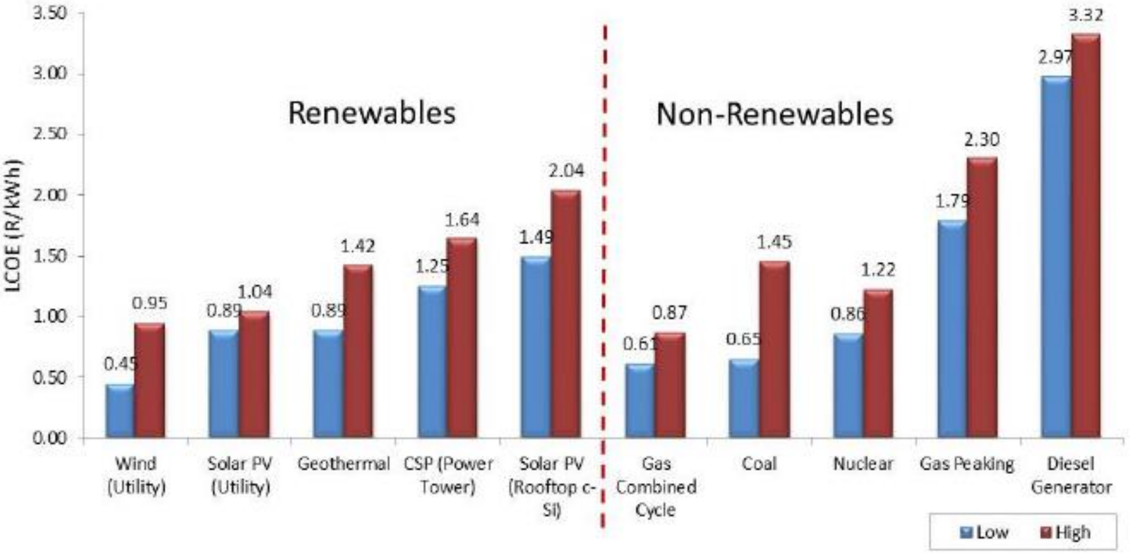
Technology	**MW capacity allocated**		
	(1) Window	**(2) Window**	**(3) window**
Solar photovoltaic	632	417	435
Wind	634	563	787
Concentrated solar	150	50	200
Landfill gas	0	0	18
Small hydro (≤40MW)	0	14	0
Biomass	0	0	16
Biogas	0	0	0
Total	**1 416**	**1 044**	**1 456**

A total of 47 projects were approved during the first and second bidding windows. Government realised a total investment of US$ 6 billion during the first bid (Eberhard, 2013). The IPPP has thus far yielded positive results. It has not only boosted renewable energy base, but also contributed to socio-economic development through job creation. A total of 20 000 temporary construction jobs and 35 000 operational jobs were created during the three bidding windows (Eberhard et al, 2014). Private sector participation has also lessened the burden on government.

The IPPP programme is largely focused on large-scale renewable energy projects. The projects that have been approved (through the IPPP programme) are large-scale projects with capacities exceeding 50 MW. This is particularly the case for solar PV, CSP and wind projects. Biomass and landfill projects have capacities less than 20 MW. There has been relatively less focus directed to small scale renewable projects. The Department of Energy (DoE) defines small-scale renewable energy projects (SSRE) as projects with capacities in the range of 1 MW to 5 MW. Small scale renewable projects have been identified as ideal for areas with low rates of electricity. The DoE has recently announced its support for small scale renewable energy projects. Through the IPPP programme, the department has allocated 200 MW for small projects. A Request for Information (RFI) document has been released to the public to assess the market readiness for small scale projects (DoE, 2010). It is expected that the same processes will be followed as the original IPPP programme, and hence the same positive results are expected.

6.5.3. High costs associated with RE

Cost has long been a barrier to renewable energy use. When compared to traditional sources (i.e. fossil fuels), RE technologies come out expensive. This is however taking a turn; RE technologies are becoming comparable with conventional sources. This is more evident in off-grid and isolated areas where grid electrification is uneconomical. Figure 28 shows the costs of RE technologies in comparison with non-renewable technologies.



(Lazard, 2013)

Figure 28: Benchmarked Levelized Cost of Energy (2013) (Source: Lazard, 2013)

The costs are based on the department’s price caps as proposed for the Small Projects Independent Power Producer Procurement Programme. The cost of diesel generators has increased significantly making it by far the expensive option. This is concerning because generators are supposed to be cheapest source as they are widely used in rural areas. Renewable technologies compare favourably with coal and nuclear. The costs of RE technologies are expected to decline with improvements in technology and innovation, increased market growth, global economies of scale, local economies of scale and increased government support through subsidies, funding and investment opportunities. In addition, the rising oil prices and high capital expenditures required for fossil power stations are expected to work in their favour.

6.5.4. Other challenges

Other challenges include the lack of: research and development (R&D); awareness and education; technical capacity and knowledge; and technology development. Investing in R&D is particularly important for continuous technology development and innovation. Technology improvements have played a big role in making RE technologies cost-competitive and attractive. Awareness and education is directly linked to acceptance of RE projects (Liu et al, 2013). Acceptance by private sectors, financial institutions, government departments, entrepreneurs, and public is equally important in driving RE development. The level of acceptance and support is influenced by the level of knowledge and information. The majority of people are aware of the downsides of fossil energy sources, but very few understand the benefits and opportunities of renewable energy sources. Rural communities are particularly disadvantaged in this regard.

6.6. Small scale miners – capacity and capability?

The capacity and capability of small scale miners is assessed in terms the following three (3) factors:

- Energy requirements for small scale operations;
- Affordability; and
- Access to funding and government support.

6.6.1. Energy requirements for small scale operations

Energy requirements for small scale mining operations are low compared to medium and large operations. This is because small-scale activities are labour intensive and largely rely on rudimentary tools. The use of rudimentary tools is still dominant in the sector. Miners continue to use rudimentary tools because most deposits outcrop on surface with some in close proximity to the surface. In most operations, electricity is required during processing. However, this depends on the type of minerals being produced. Further processing and beneficiation is normally required for minerals that are sold for their physical appearance and not for their metal content. Examples are: sandstone, granite, slate, marble, semi-precious stones etc. The amount of energy required will depend on: mineral being exploited; mining and processing activities; scale of operations; and size of orders which influences production rates and operating hours. The energy requirement for the case study was estimated at 341kWh/day. This was based on certain production rates and operating hours. However, it can be deduced that energy requirement for a typical small scale operation is less than 5 MW – considering the nature of most operations. This makes SSM operations suitable for small-scale renewable energy programme.

6.6.2. Affordability

Access to electricity is defined as a function of availability and affordability. The latter refers to the ability of a household to pay the upfront connection costs and energy usage costs (UNCTAD, 2010). This definition does not only apply to individuals (or households), but also businesses or operations. A study conducted by Baartjies (2006) on income distribution in Maluti-A-Phofing Local Municipality (Free State Province) found out that over 90 per cent of the households earn less than R 2 500 per month, with a staggering 70 per cent having no formal income (Baartjies, 2006). Affordability therefore remains an area of great concern in rural areas.

The DMR defines SSM activity as an activity that employs less than 50 employees, with an annual turnover of less than R 10 million, with fixed and moveable assets of less than R 15 million. This is hardly the case for most small scale mining operations. In many areas, small-scale mining activities remain a source of livelihood and subsistence income. Very little profit is made from small scale activities. This is attributed to a number of factors, namely:

- Most operations are conducted on hand-to-mouth basis. The little profits generated are normally used to support the family and for survival. In most cases, there is usually not enough to save or invest back into the business. However, the lack of business skills or knowledge plays a vital role in this case. SSM activities are not seen as a business ventures (with potential to grow), but a short-term means of survival.
- The lack of market also contributes to low profits generated by SSM operations. Most small scale operations are located in remote areas – far from major markets. Most operations depend on local markets for support – which

in most cases are poor communities. As a result, operations will work on an order-to-order basis making the realisation of profits difficult. Exploitation by end-users also contributes to miners realising little profits. Because of very little knowledge about the market and value of minerals – prices are often dictated by buyers. This is evident in the Northern Cape semi-precious mining sector. With lack of marketing skills, miners are usually limited to areas in which they operate. Most largely depend on word-of-mouth advertising as a means of marketing.

- The value of the mineral being exploited directly influences the amount of income generated. Most SSM operations exploit low value and high bulk minerals. With these types of minerals, profits are realised if the mineral is sold in bulk. This is often difficult because of the lack of markets. More so, the profits are usually outweighed by the transportation costs and fuel costs.

In general, the majority of SSM operations make very little profits. There is usually not enough to invest back into the business. However, there are some operations that are realising better profits. Moeletsi and Legoale (2014) refer to these types of SSMs as established small-scale miners. Established miners usually operate as business entities with clear business goals and aspirations. They apply business practices and hence see value in investing back into the business. Maluti Sandstone (case study) is an example of an established operation. The operation is operated as a business venture with clear business goals. The operation has over the years invested in improved technology and continuous market research. This has yielded better returns and hence improved their production performance which allows them to deliver on big orders. Further, they have expanded their market to other areas.

Figure 29 shows cash-flow for Maluti Sandstone for a period of one year. The operation made a profit of R103 283. Detailed cash-flow statement for the operation is included in the appendices.

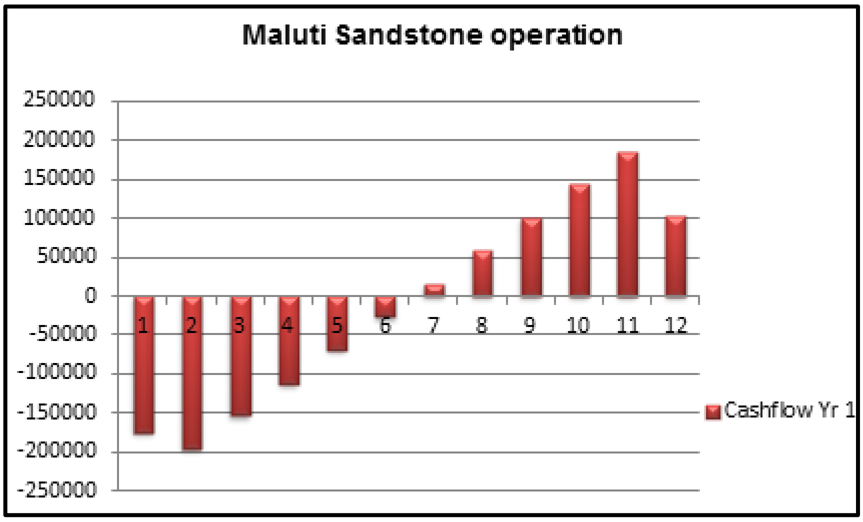


Figure 29: Cash flow for Maluti Sandstone operation

Table 18 gives the summary of estimated costs for small scale renewable energy technologies.

Table 18: Cost associated with renewable energy technologies (Source: Frost and Sullivan et al, 2013)

Technology	Capital cost (R/kW)	LCOE (R/kW)
Off-grid solar (PV)	40,000 – 50,000	1.40
Wind (1kW)	45,000	1.00
Wind (5 kW)	200,000	
Biogas	15,000-20,000	0.90
Landfill gas	11,000 – 12,000	0.94
Biomass		1.4
Diesel generator (5kW)	11,000	3.32

Using this table as reference, it is clear that the majority of SSMs will not be able to fund small scale renewable energy projects from their own cash-flows. Even established miners will need some financial assistance. Funding options for SSMs are discussed in the subsequent section.

Another factor that influences the investment decision is the life of mine for small-scale operations. Small scale operations are restricted by the validity (or duration) of mining permits. Mining permits are valid for two (2) years with maximum renewal of five (5) years. Because of this restriction, SSMs do not invest in medium to long-term business ventures.

6.6.3. Access to funding

Access to funding has been identified as a major constraint to the development of SSM sector. The majority of SSM operations find it difficult to access funding. This is because SSM operations are regarded as high risk activities (Scott et al 1998; Mutemeri and Petersen, 2002; Hentschel et al, 2003; DMR, 2011). According to Dreschler (2001) funding institutions are reluctant to offer financial assistance to SSM operations because of the lack of trust and accountability as most operations are run informally and illegally. The lack of trust is also influenced by many uncertainties surrounding SSM operations. These are in relation to: mineral resource potential; lifespan of the deposit; value of the deposit; market availability; cash-flows ; and skills and capacity in the sector. Perceptions around the sector still play an important role despite the fact that SSM activities are recognised as important drivers for economic growth by government.

Extensive research has been conducted around the issue of funding in the Small Micro Medium Enterprise (SMME) sector looking at both the demand-side and supply-side (Falkena et al, 2001; Mahembe, 2011; Mazanai and Fatoki, 2012). The issue of funding is actually two-phased. SMMEs are complaining about the scarcity of funding, while funders are reporting large amounts that remain unspent. Mahembe (2011) suggests that there are numerous sources of credit available for small businesses. Falkena et al (2011) reported that many applications are declined and hence only a few succeed in obtaining funding. Mass and Herrington (2006) agree with Mahembe (2011) that there seems to be sufficient funds for SMMEs, but securing funds proves difficult for most SMMEs. Foxcroft et al (2002) study on SMMEs application for finance found out that of the 80 per cent that applied for funding; only 27 per cent was approved by banks. The remaining 20 per cent never applied for finance because of the lack of knowledge on potential funding. There seems to be a disconnection between funders and SMMEs. This is referred to as financial gap (Mazanai and Fatoki, 2011; Mahembe, 2011). It is suggested that the financing gap is as a result of the lack of communication and information sharing (in terms of procedures, requirements, terms and conditions etc.) from supply-side. More so, challenges of collateral security, viable business plan and legality of operation still persist from the demand-side. All these are important to commercial banks and investors.

Small-scale mining activities are funded mostly through three areas, namely: (1) government initiatives/support; (2) donors; and (3) middlemen/buyers (Dreschler, 2001). Small-scale miners usually get into contracts with buyers in agreement that buyers will sponsor their operations (in the form of capital or equipment) in exchange of selling products at pre-determined prices (which are usually low prices). This has not proven feasible and has resulted in exploitation because of inequalities in bargaining powers. There are international programmes that fund SSM activities. These are usually in the form of soft loans and grants (Drescher, 2001). Proof of business viability and impact to socio-economic serves as the main criteria for these grants. However, most funding opportunities are offered through government initiatives. Government support includes both financial and non-financial support. Although most of these initiatives are designed for small-scale mining; business requirements still apply. Small-scale operations are required to be legal. More so, the operations should prove to be viable businesses with the ability to repay the loan. Examples of potential funders in South Africa are:

- Small Enterprise Finance Agency (SEFA);
- Department of Trade and Industry;
- Business Partners Limited;
- Commercial banks (with dedicated SMME divisions);
- National Empowerment Fund;
- National Development Agency;
- Small Enterprise Development Agency (SEDA);
- Department of Economic Development (at Municipal level);
- Large mining companies (e.g. Anglo American’s Community Fund and Small Business Hub Programme).

6.7. Conclusion

The energy requirements for small scale mining operations are low, making them suitable to be powered through Small-Scale Renewable Energy (SSRE) projects. The country’s renewable energy endowment is sufficient to power both large-scale and small-scale energy projects. With the current IPP programme, focus is on large-scale renewable projects. The implementation of small-scale projects is still under discussion. Nonetheless, the cost of setting up such projects remains a concern. Unlike large operations; small scale operations cannot afford to fund or invest in RE projects from equity capital or cash-flows (which in most cases does not exist). The profits made by SSM operations are only enough to keep the business running on a day-to-day basis. SSMs will therefore require financial assistance to venture into such investments. Access to funding has proven difficult for most SSM operations given the nature of business. However, it has been established that there exist several institutions that offer funding to SMMEs. Funding is usually in the form of loans (as opposed to grants), and hence small businesses are required to meet certain business requirements largely around the ability to repay the loan.

The establishment of renewable energy projects (or any long-term investment project) is also limited by the legalities attached to small scale mining activities. The reason why most SSM operations do not invest back into the business or make medium to long-term investment decisions is because of the lifespan of their operations. By law, mining licenses for SSMs are valid for two (2) years with a maximum renewal of five (5) years. Renewable energy projects are long-term investments with long-term benefits. Lifespans of RE technologies range from 10 to 30 years. With the current legislation, it makes sense for SSMs to opt for generators because they match their lifespan requirements. More so, generators are less costly and are affordable to most SSMs. This restriction impacts on sustainability and growth of the sector.

CHAPTER 7: CONCLUSION AND RECOMMENDATIONS

7.1. Conclusion

The study was set out to assess the feasibility of using renewable energy in the small scale mining sector. This included both the technical and economic feasibility. By nature, small-scale mining activities are poverty-driven and are most dominant in rural areas. Because of their location, their development is normally hampered by the lack of basic services and infrastructure as it is the case in most rural areas. This study looked at electricity as an important input in small-scale mining. Rural areas in South Africa still remain without access to electricity. A study conducted by White and Koopman (2011) estimated that a total of 51 per cent rural residents live without electricity. In most of these areas, grid electrification has been deemed uneconomical because of their geographical locations from the national grid. Renewable energy resources have been identified as potential solution for off-grid electrification. This is partly because most rural areas have significant renewable energy resources with vast potential.

South Africa's electricity sector is dominated by coal as the main primary source of electricity. Power generation from coal accounts over 93 per cent. It is followed by nuclear power with a mere 4 per cent. Renewable energy sources contribute very little to the energy mix. It is believed that South Africa is well endowed with renewable energy resources that could potentially address electricity concerns in the country. Development of renewable energy in the country is still at its infancy stages. The main constraints as identified by government were: legal and regulatory barriers; lack of funding mechanisms; cost of renewable energy technologies; lack of R&D;

and technical capacity and knowledge. There have been noticeable attempts by government and other stakeholders to address these constraints and there has been promising progress. The existing IPPP has yielded positive results in terms of increasing renewable energy contribution. It can be concluded that, although the sector is still small, progress is noticeable. It is clear that government commitment and support is important in that the level of commitment determines the level of progression.

Small scale mining activities are widespread in South Africa. There is no conclusive estimate, but the total number of people participating in the sector is estimated between 10,000 and 30,000. The number of small scale miners is continuously on the increase since it was recognised by government. Small-scale mining activities are more concentrated in poverty-stricken areas, such as: Northern Cape, Limpopo, North West and Eastern Cape Provinces. However, mineral availability is also a determining factor. Small-scale mining activities in the country have been identified as having potential to create jobs, particularly in rural areas where economic activities are limited. According to the DMR, small scale mining provides a good platform to ensure the involvement of disadvantaged groups in the mineral sector. However, like most SMMEs, the SSM sector is faced with a number of challenges hampering its envisaged potential. As it stands, most SSM operations remain a source of livelihoods and subsistence income. Because of their location, most SSM operations cannot operate effectively due to lack of access to electricity. Most operations invest in generators for power supply. The use of generators is becoming expensive due to the rising costs of fuel and this is impacting on the profitability of most operations. There is therefore a need for a cost-effective energy supply system in the small scale sector.

This study is based on a sandstone operation in Phuthadithjaba, Free State Province. Like most SSM operations, energy requirement for Maluti Sandstone was low. This is because the operation is largely labour intensive, with electricity only used during processing stages. The operation is located in an area that receives good sunshine, and hence solar was used for the assessment. Although South Africa is rated amongst the countries with diverse rich renewable energy resources, the use of renewable energy is area-specific. It is therefore important to locate potential RE resource (s) in a given area. Based on the findings, it was concluded that the integration of energy systems (i.e. solar and generator) seems feasible as compared to stand-alone systems. Generators remain cheap in terms of start-up capital; however their long-term costs are high. Hybrid systems not only offer an affordable option, but also eliminate disadvantages of different systems thereby ensuring reliability and security of supply. It is clear that renewable technologies are becoming favourable and attractive solutions because of their long-term benefits as compared to traditional sources.

Given the energy requirements for SSM operations, they can be powered through SSRE projects. These are projects with capacities ranging from 1 MW to 5 MW. It has been established that the country's RE endowment is suitable for both large-scale and small-scale projects. While it is acknowledged that SSM operations can be powered through SSRE projects, affordability and investment opportunities of such projects remain a critical concern. With current focus on the deployment of renewable energy projects for large-scale purposes, the environment is not yet favourable for small-scale projects. Hence, the establishment of such project will require significant capital investment without any subsidies from government. Unlike large operations; small scale operations cannot afford to meet these capital requirements because of the nature of their business. This means that SSMs will require financial assistance to invest in medium-to-long investment ventures. Access to funding has long been a barrier in the SSM sector merely because of the risk associated with the operations. However, studies suggest that there are sufficient sources of credit available for SMMEs, but proof of credibility and collateral security remains the biggest challenge for SMMEs.

The use of renewable energy in small-scale mining is again questioned because of the current legislation in the sector. As stated above, the reason why most SSMs do not invest in medium to long-term investments is because of legislation restrictions. Small-scale mining operations are limited to maximum five (5) year life of operation. Because of this, it does not make economic sense to enter into medium to long term investments. Renewable energy projects are regarded as long-term investments with lifespans ranging from 10 to 30 years. This means that long-term benefits of RE technologies will not be realised if adopted in the small-scale sector. More so, given the profitability of SSM operations and capital investments for RE technologies, payback periods are estimated to be longer than 5 years.

7.2. Recommendations

The challenges facing the small scale mining sector are interrelated. It is therefore important that a holistic problem-solving approach is adopted. Literature suggests that legislation underpins most of the constraints in the sector. There is a need for proper legislative framework that will provide the necessary policy direction and action plan to ensure sustainability and growth in the sector. It is important for policy to speak to all issues affecting the sector – taking into account sustainability as a key objective.

Access to electricity is a function of availability and affordability. Literature proves that South Africa is well endowed with renewable energy resources, technically feasible to be exploited using existing technologies for both large-scale and small-scale use. The critical barrier is affordability – which for SSMs is linked to access to funding. It has been established that the issue of funding is two-phased. The issues around the demand-side revolve around credibility of operations. Small businesses are expected to meet basic business requirements. It is important for operations to prove that they are viable businesses with sound business plans. This necessitates them to start applying business practices in their operations. The lack of skills, particularly business skills is a gap in the sector. SSMs will therefore need business skills training. The formation of groups within the sector should also be encouraged as part of information and skills sharing. This will add value particularly to emerging miners. Part of the institutional support should be linking SSMs with large-scale operators. In this relationship, large operations will assist with mentoring and providing practical business advice to SSMs. The issues around supply-side revolve around complex application processes and unclear procedures and requirements. More so, businesses are not aware of available funding mechanisms. Funding institutions should increase awareness on available funding opportunities, particularly in rural areas. Working with local municipalities and using local platforms could prove useful in educating and making SMMEs aware about different funding mechanisms.

Although the IPPP for large-scale renewable energy projects has yielded positive results, the development of small-scale renewable energy programme must be designed in such a way that it is favourable to small businesses to allow them to take part in the programme. Government should consider special provisions as means of making uptake attractive to small and medium businesses. SSRE projects provide good business opportunities for small businesses.

The benefits of the use of renewable energy in small-scale mining are questioned. Although long-term benefits of renewable energy technologies are noted, its use in small-scale mining and the benefits thereof at that level are still unclear. As it stands, it does not make sense to invest in medium to long-term ventures in small-scale mining sector. Perhaps the use of renewable energy should not be looked at in terms of electricity generation, but as a means of powering various pieces of equipment and machinery (i.e. mechanical energy). It is recommended that an investigation be undertaken to assess if available renewable energy resources can be used to directly convert energy to power machines such as centrifugal separators, jack hammers, milling equipment, conveyor belts, pumps, and even moving equipment.

Meanwhile, it is recommended that small-scale mining operations be integrated into rural renewable electrification programmes to ensure sustainability and harmonization. Because of low energy requirements, they do not need stand-alone power systems dedicated solely to their operations. This will ensure that long-term benefits of renewable energy systems are realised by the entire community. In this case, the system will continue to power local residents even after SSM operations have reached their life of mine.

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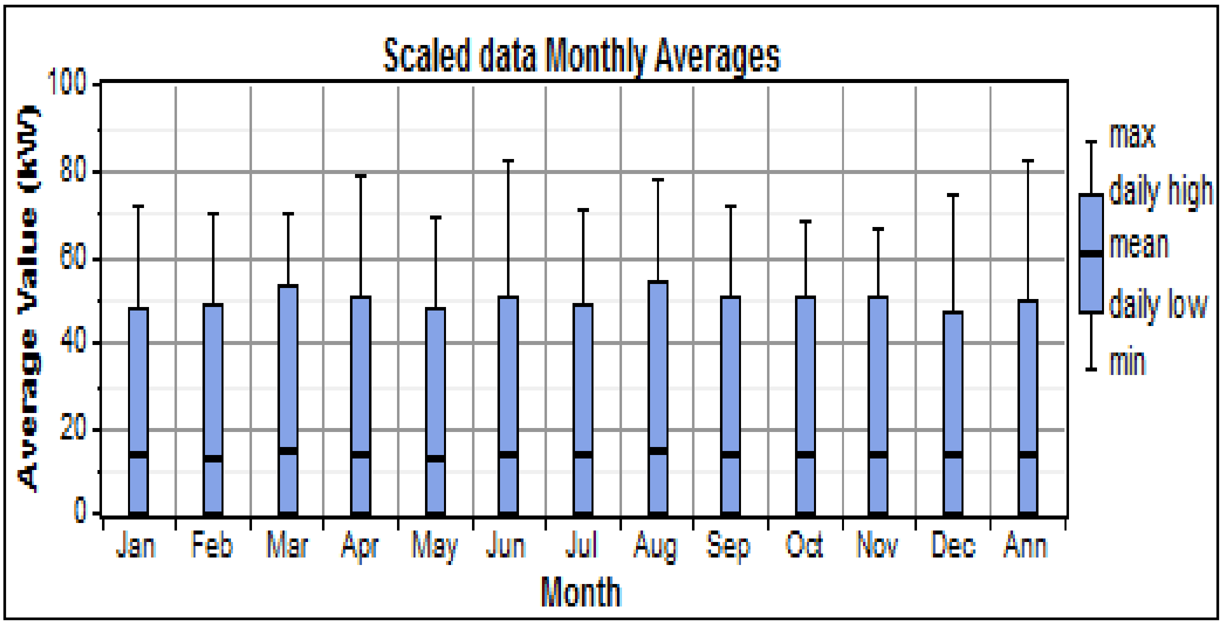
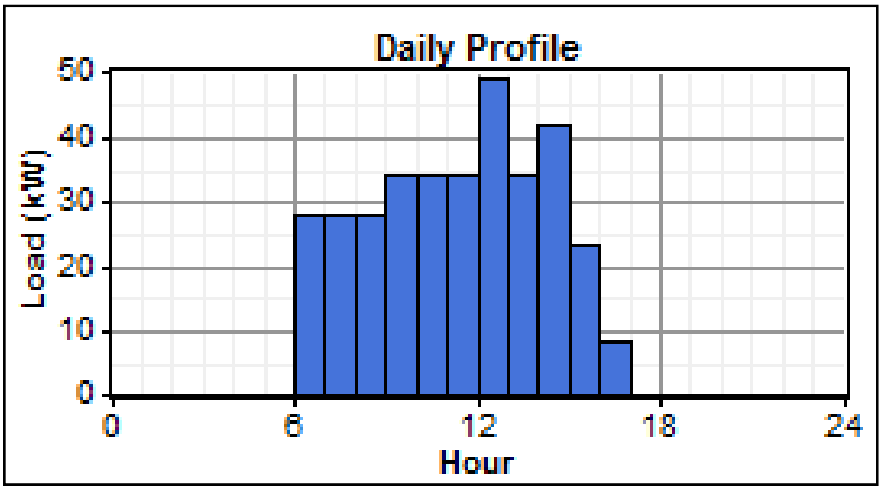
APPENDICES

Appendix A: Site load profiles

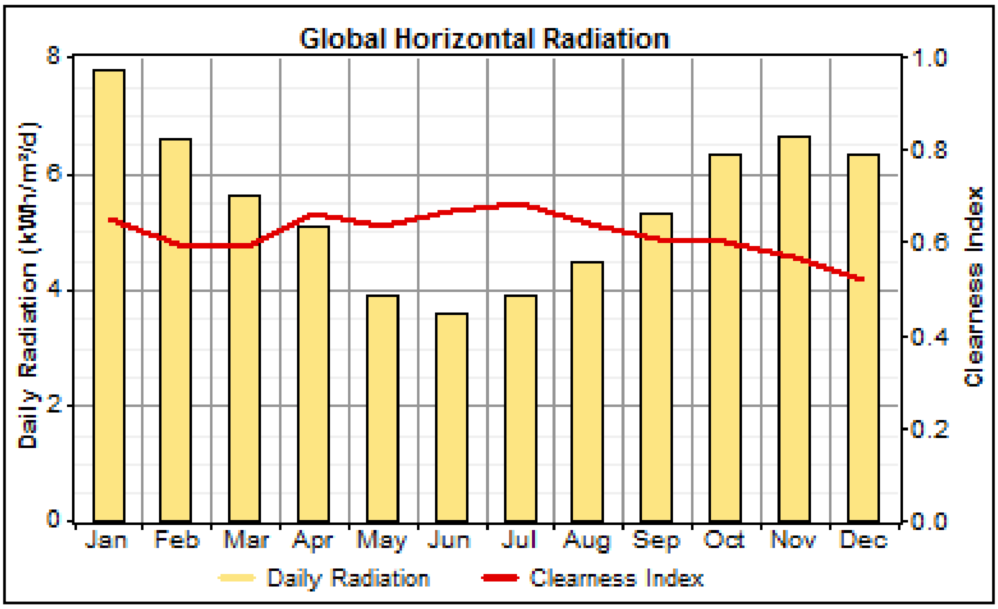
Monthly averages



Daily profile



Appendix B: Solar resource profile



Appendix C: Maluti Sandstone Cash-flow Statements

Monthly Projected Income Statement & Cash Flow

MALUTI SANDSTONE - J KARAFU

YEAR 1

Input Block

Anticipated Percentage of Sales on Cash Basis	35%
Anticipated Percentage of Sales on 30 day credit Basis	65%
Unit Selling Price (per sqm - cut)	R 78.50
Budgeted Amount for Project	529,071

Sqm Metres	800	1,250	1,250	1,250	1,250	1,250	1,250	1,250	1,250	1,250	1,250	1,250		
Cumulative Number of Sqm Produced	800	2,050	3,300	4,550	5,800	7,050	8,300	9,550	10,800	12,050	13,300	14,550		
Dateline	Month 1	Month 2	Month 3	Month 4	Month 5	Month 6	Month 7	Month 8	Month 9	Month 10	Month 11	Month 12		Totals
Income	R 62,800	R 98,125	R 98,125	R 98,125	R 98,125	R 98,125	R 98,125	R 98,125	R 98,125	R 98,125	R 98,125	R 98,125		R 1,142,175
Sale of Sandstone Units (per sqm)	R 62,800	R 98,125	R 98,125	R 98,125	R 98,125	R 98,125	R 98,125	R 98,125	R 98,125	R 98,125	R 98,125	R 98,125		R 1,142,175
Gross Profit	R 62,800	R 98,125	R 98,125	R 98,125	R 98,125	R 98,125	R 98,125	R 98,125	R 98,125	R 98,125	R 98,125	R 98,125		R 1,142,175
Overhead Total	R 61,607	R 61,136	R 61,136	R 62,736	R 61,136	R 61,136	R 61,136	R 61,136	R 61,136	R 61,136	R 61,136	R 65,136		R 674,369
Semi-skilled(commissioned)	R 20,000.00	R 31,250.00	R 31,250.00	R 31,250.00	R 31,250.00	R 31,250.00	R 31,250.00	R 31,250.00	R 31,250.00	R 31,250.00	R 31,250.00	R 31,250.00		R 363,750
Supervisor	R 12,000.00	R 12,000.00	R 12,000.00	R 12,000.00	R 12,000.00	R 12,000.00	R 12,000.00	R 12,000.00	R 12,000.00	R 12,000.00	R 12,000.00	R 12,000.00		R 144,000
Rental Office Space	R 2,000.00	R 2,000.00	R 2,000.00	R 2,000.00	R 2,000.00	R 2,000.00	R 2,000.00	R 2,000.00	R 2,000.00	R 2,000.00	R 2,000.00	R 2,000.00		R 24,000.00
Office Equipment rental	R 1,200.00	R 1,200.00	R 1,200.00	R 1,200.00	R 1,200.00	R 1,200.00	R 1,200.00	R 1,200.00	R 1,200.00	R 1,200.00	R 1,200.00	R 1,200.00		R 14,400.00
Communications	R 500.00	R 500.00	R 500.00	R 500.00	R 500.00	R 500.00	R 500.00	R 500.00	R 500.00	R 500.00	R 500.00	R 500.00		R 6,000.00
Printing & Stationary	R 400.00	R 400.00	R 400.00	R 400.00	R 400.00	R 400.00	R 400.00	R 400.00	R 400.00	R 400.00	R 400.00	R 400.00		R 4,800.00
Travel & Sustenance	R 9,000.00	R 4,500.00	R 4,500.00	R 4,500.00	R 4,500.00	R 4,500.00	R 4,500.00	R 4,500.00	R 4,500.00	R 4,500.00	R 4,500.00	R 4,500.00		R 58,500.00
Marketing	R 8,000.00			R 1,600.00									R -	R 9,600.00
Audit Fees												R 4,000.00		R 4,000.00
Water & Lights	R 3,000.00	R 3,000.00	R 3,000.00	R 3,000.00	R 3,000.00	R 3,000.00	R 3,000.00	R 3,000.00	R 3,000.00	R 3,000.00	R 3,000.00	R 3,000.00		R 36,000.00
Fuel	R 2,500.00	R 2,500.00	R 2,500.00	R 2,500.00	R 2,500.00	R 2,500.00	R 2,500.00	R 2,500.00	R 2,500.00	R 2,500.00	R 2,500.00	R 2,500.00		
U.I.F.	R 353	R 353	R 353	R 353	R 353	R 353	R 353	R 353	R 353	R 353	R 353	R 353		R 4,241.28
S.D.L. (Skills Development Levy)	R 320	R 433	R 433	R 433	R 433	R 433	R 433	R 433	R 433	R 433	R 433	R 433		R 5,077.50
Depreciation	R 2,333	R 3,000	R 3,000	R 3,000	R 3,000	R 3,000	R 3,000	R 3,000	R 3,000	R 3,000	R 3,000	R 3,000		R 35,333.13
Operating Profit (PBIT)	R 1,193	R 36,989	R 36,989	R 35,389	R 36,989	R 36,989	R 36,989	R 36,989	R 36,989	R 36,989	R 36,989	R 32,989		R 402,473.09
Interest	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -		R -
Profit before Tax (PBT)	R 1,193	R 36,989	R 36,989	R 35,389	R 36,989	R 36,989	R 36,989	R 36,989	R 36,989	R 36,989	R 36,989	R 32,989		R 402,473.09
Tax	R 358	R 11,097	R 11,097	R 10,617	R 11,097	R 11,097	R 11,097	R 11,097	R 11,097	R 11,097	R 11,097	R 9,897		R 120,741.93
Net Income (NPAT)	R 835	R 25,892	R 25,892	R 24,772	R 25,892	R 25,892	R 25,892	R 25,892	R 25,892	R 25,892	R 25,892	R 23,092		R 281,731.16
Dividends	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -		R -
Retained Earnings for Month	R 835	R 25,892	R 25,892	R 24,772	R 25,892	R 25,892	R 25,892	R 25,892	R 25,892	R 25,892	R 25,892	R 23,092		R 152,269.39
Retained Income(Loss) beginning of Month	R -	R 835	R 26,728	R 52,620	R 77,392	R 103,285	R 129,177	R 155,069	R 180,962	R 206,854	R 103,285	R 129,177		R -
Retained Income(Loss) End of Month	R 835	R 26,728	R 52,620	R 77,392	R 103,285	R 129,177	R 155,069	R 180,962	R 206,854	R 232,746	R 129,177	R 152,269		R 152,269.39

	Month 1	Month 2	Month 3	Month 4	Month 5	Month 6	Month 7	Month 8	Month 9	Month 10	Month 11	Month 12	Totals
Capital Expenditure	R 140,000	R 40,000	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -	R 180,000.00
Circular Saw	R 40,000.00												R 40,000.00
Circular Saw 1200mm (custom made)		R 40,000.00											R 40,000.00
Compressor -Atlas Copco	R 100,000.00												R 100,000.00
Closing Bank Balance (carried forward)	R -174,793	R -195,266	R -152,777	R -111,888	R -69,398	R -26,909	R 15,580	R 58,069	R 100,558	R 143,047	R 185,536	R 103,283	R 103,283.04

MALUTI SANDSTONE - J KARAFU

YEAR 2

Number of Units	1250	1250	1250	1250	1250	1250	1250	1250	1250	1250	1250	1250	
Accumulative Number of Units	15800	17050	18300	19550	20800	22050	23300	24550	25800	27050	28300	29550	
Dateline	Month 1	Month 2	Month 3	Month 4	Month 5	Month 6	Month 7	Month 8	Month 9	Month 10	Month 11	Month 12	Totals
Income	**R 98,125.00**	**R 98,125.00**	**R 98,125.00**	**R 98,125.00**	**R 98,125.00**	**R 98,125.00**	**R 98,125.00**	**R 98,125.00**	**R 98,125.00**	**R 98,125.00**	**R 98,125.00**	**R 98,125.00**	**R 1,177,500.00**
Sale of Units	R 98,125.00	R 98,125.00	R 98,125.00	R 98,125.00	R 98,125.00	R 98,125.00	R 98,125.00	R 98,125.00	R 98,125.00	R 98,125.00	R 98,125.00	R 98,125.00	R 1,177,500.00
Gross Profit	**R 98,125.00**	**R 98,125.00**	**R 98,125.00**	**R 98,125.00**	**R 98,125.00**	**R 98,125.00**	**R 98,125.00**	**R 98,125.00**	**R 98,125.00**	**R 98,125.00**	**R 98,125.00**	**R 98,125.00**	**R 1,177,500.00**
Overhead Total	**R 73,635.92**	**R 61,135.92**	**R 61,135.92**	**R 62,735.92**	**R 61,135.92**	**R 61,135.92**	**R 61,135.92**	**R 61,135.92**	**R 61,135.92**	**R 61,135.92**	**R 61,135.92**	**R 65,135.92**	**R 685,731.28**
Supervisor	R 31,250.00	R 31,250.00	R 31,250.00	R 31,250.00	R 31,250.00	R 31,250.00	R 31,250.00	R 31,250.00	R 31,250.00	R 31,250.00	R 31,250.00	R 31,250.00	R 375,000.00
Casual Labourers (Commission)	R 12,000.00	R 12,000.00	R 12,000.00	R 12,000.00	R 12,000.00	R 12,000.00	R 12,000.00	R 12,000.00	R 12,000.00	R 12,000.00	R 12,000.00	R 12,000.00	R 144,000.00
Rental Office Space	R 2,000.00	R 2,000.00	R 2,000.00	R 2,000.00	R 2,000.00	R 2,000.00	R 2,000.00	R 2,000.00	R 2,000.00	R 2,000.00	R 2,000.00	R 2,000.00	R 24,000.00
Office Equipment rental	R 1,200.00	R 1,200.00	R 1,200.00	R 1,200.00	R 1,200.00	R 1,200.00	R 1,200.00	R 1,200.00	R 1,200.00	R 1,200.00	R 1,200.00	R 1,200.00	R 14,400.00
Communications	R 500.00	R 500.00	R 500.00	R 500.00	R 500.00	R 500.00	R 500.00	R 500.00	R 500.00	R 500.00	R 500.00	R 500.00	R 6,000.00
Printing & Stationary	R 400.00	R 400.00	R 400.00	R 400.00	R 400.00	R 400.00	R 400.00	R 400.00	R 400.00	R 400.00	R 400.00	R 400.00	R 4,800.00
Travel & Sustenance	R 9,000.00	R 4,500.00	R 4,500.00	R 4,500.00	R 4,500.00	R 4,500.00	R 4,500.00	R 4,500.00	R 4,500.00	R 4,500.00	R 4,500.00	R 4,500.00	R 58,500.00
Marketing	R 8,000.00			R 1,600.00									R 9,600.00
Audit Fees	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -	R 4,000.00	R 4,000.00
Water & Lights	R 3,000.00	R 3,000.00	R 3,000.00	R 3,000.00	R 3,000.00	R 3,000.00	R 3,000.00	R 3,000.00	R 3,000.00	R 3,000.00	R 3,000.00	R 3,000.00	R 36,000.00
	R 2,500.00	R 2,500.00	R 2,500.00	R 2,500.00	R 2,500.00	R 2,500.00	R 2,500.00	R 2,500.00	R 2,500.00	R 2,500.00	R 2,500.00	R 2,500.00	
U.I.F.	R 353.44	R 353.44	R 353.44	R 353.44	R 353.44	R 353.44	R 353.44	R 353.44	R 353.44	R 353.44	R 353.44	R 353.44	R 4,241.28
S.D.C. (Skills Development Levy)	R 432.50	R 432.50	R 432.50	R 432.50	R 432.50	R 432.50	R 432.50	R 432.50	R 432.50	R 432.50	R 432.50	R 432.50	R 5,190.00
Depreciation	R 2,999.98	R 2,999.98	R 2,999.98	R 2,999.98	R 2,999.98	R 2,999.98	R 2,999.98	R 2,999.98	R 2,999.98	R 2,999.98	R 2,999.98	R 2,999.98	R 35,999.80
Operating Profit (PBIT)	**R 24,489.08**	**R 36,989.08**	**R 36,989.08**	**R 35,389.08**	**R 36,989.08**	**R 36,989.08**	**R 36,989.08**	**R 36,989.08**	**R 36,989.08**	**R 36,989.08**	**R 36,989.08**	**R 32,989.08**	**R 425,768.92**
Interest	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -
Profit before Tax (PBT)	**R 24,489.08**	**R 36,989.08**	**R 36,989.08**	**R 35,389.08**	**R 36,989.08**	**R 36,989.08**	**R 36,989.08**	**R 36,989.08**	**R 36,989.08**	**R 36,989.08**	**R 36,989.08**	**R 32,989.08**	**R 425,768.92**
Tax	R 7,346.72	R 11,096.72	R 11,096.72	R 10,616.72	R 11,096.72	R 11,096.72	R 11,096.72	R 11,096.72	R 11,096.72	R 11,096.72	R 11,096.72	R 9,896.72	R 127,730.68
Net Income (NPAT)	**R 17,142.35**	**R 25,892.35**	**R 25,892.35**	**R 24,772.35**	**R 25,892.35**	**R 25,892.35**	**R 25,892.35**	**R 25,892.35**	**R 25,892.35**	**R 25,892.35**	**R 25,892.35**	**R 23,092.35**	**R 298,038.24**
Dividends	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -
Retained Earnings for Month	**R 17,142.35**	**R 25,892.35**	**R 25,892.35**	**R 24,772.35**	**R 25,892.35**	**R 25,892.35**	**R 25,892.35**	**R 25,892.35**	**R 25,892.35**	**R 25,892.35**	**R 25,892.35**	**R 23,092.35**	**R 298,038.24**
Retained Income(Loss) beginning of Month	R 152,269.39	R 169,411.75	R 195,304.10	R 221,196.45	R 245,968.81	R 271,861.16	R 297,753.51	R 323,645.87	R 349,538.22	R 375,430.58	R 401,322.93	R 427,215.28	R 152,269.39
Retained Income(Loss) End of Month	**R 169,411.75**	**R 195,304.10**	**R 221,196.45**	**R 245,968.81**	**R 271,861.16**	**R 297,753.51**	**R 323,645.87**	**R 349,538.22**	**R 375,430.58**	**R 401,322.93**	**R 427,215.28**	**R 450,307.64**	**R 450,307.64**
Dateline	Month 1	Month 2	Month 3	Month 4	Month 5	Month 6	Month 7	Month 8	Month 9	Month 10	Month 11	Month 12	
Capital Expenditure	**R -**	**R -**	**R -**	**R -**	**R -**	**R -**	**R -**	**R -**	**R -**	**R -**	**R -**	**R -**	**R -**
													R -
													R -
													R -
Closing Bank Balance c/fwd	**R 133,272.10**	**R 175,761.16**	**R 218,250.22**	**R 259,139.28**	**R 301,628.34**	**R 344,117.40**	**R 386,606.46**	**R 429,095.52**	**R 471,584.58**	**R 514,073.64**	**R 556,562.70**	**R 467,321.09**	**R 467,321.09**