OPTIMUM RELIABILITY INTEGRATED WEF RENEWABLE TECHNOLOGY INTO THE ESKOM DISTRIBUTION GRID, IN THE EASTERN CAPE OPERATING UNIT

By

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DECLARATION

I…Siyamthanda Luthando Matondolo……the undersigned, hereby declare that this dissertation submitted for the Master of Engineering in Electrical at the Cape Peninsula University of Technology, is my own original unaided work, except were stated otherwise. It has not previously in its entirety or in part been submitted to any other institution for a degree. I further declare that all sources cited or quoted are indicated or acknowledged by means of a comprehensive list of references.

Signed: Date…07…./…11.… /…2022

ABSTRACT

The country (RSA) has been a massive upsurge in demand for electricity energy most after fall of apartheid era and as result of rapid industrial development, rapid immigration growth around urban areas and massive rural electrification led to severe energy crisis today. Currently the government through Integrated Energy Plan the plan is to have mixed energy source and the country is moving away from fossil such as coal energy source to more environmentally friendly energy source. Since 2013 until today (October 2022) South African government has been approving and giving Independent Power Producers (IPPs) to connect to the Eskom grid network. Having renewable energy on the network grid which have far low carbon emission compared to current coal source, address energy crisis and aim to reduce carbon emission. One of the main renewable energy technologies which is being connect to the network grid is Wind Energy Facilities (WEF) which the research will be looking into the optimum reliability of it in depth. The energy crisis in the country has necessitated to bring mixed energy source that will be sustainable and reliable for our developing country therefore implementing the correct renewable energy is a fundamental necessity and access to the right renewable energy services provides opportunities for development and improving well-being.

This research is an attempt to investigate the optimum reliability for integrated Wind Energy Facility (WEF) renewable technology into the Eskom distribution grid in the Eastern Cape Operating Unit (ECOU). Eskom as main power utility in South Africa, most of Eskom power network has experienced rapid expansion since the mid 1990's in keeping with the government's policy of extending electricity as a basic service to millions of previously disadvantaged citizens. Since the inception of the electrification program (or universal access) in 1991 Eskom has connected 4.05 million new households to the electricity grid (Eskom Integrated Report, 2019).

Currently government is spearheading "just transition" energy source from mainly coal to renewable energy which necessitated the need for this research so that in the main can assist and recommend to the government the right renewable energy that can address energy crisis and give long lasting sustainable energy supply to the RSA citizens. With network performance at unacceptably poor levels compared to international benchmarks, and with a remaining three million households, over

and above the normal growth, to be connected by 2025, Eskom wanted to understand the impact of the additional electrification customers on network performance (PA Consulting/BA Energy Solutions, 2010). Applications are geared in the direction of network grid integration of renewable energy sources such as WEF into Eskom Distribution network grid as results of environmental concerns and the quest for energy security (T.R. Ayodele, A.A. Jomih, J.L. Munda & J.T. Agee, 2012). The increasing share of renewable energies, especially WEF will require coordinated efforts in order to adapt them to the future utility network grid infrastructure (Antonello Gaviano, Karl Weber, Christian Dirmeier, 2020). In 2010 Energy for all 2030 report according to (Samchez, 2010), one fourth of humanity has no access to electricity and nearly half of the world's population cook with solid biomass using inefficient technologies keeping them trapped in poverty with little or no chance to escape from it and that includes deep rural areas of South African especially in the area of Eastern Cape Province.

Another important in this research that assist in assessing and evaluating optimum reliability of WEF will be to do thorough scope on load forecast mainly in the area of our research. This approach of evaluation inclusive doing load forecaster will address mainly research methodology, collected and analysed data because for our research and our chapter five (5) will be part of data analysis which is comparative research study. The effective and economic investment of the electrical power distribution structure is a load forecaster responsibility. To do this, the load forecaster has to look forward to how much power should be distributed also where and when it will be required. The fundamental to supply development is a well-planned and coordinated medium-to-long span load forecast. This gives the future estimate forecast demand electrical in terms of the location, magnitude and temporal (time) features. The load forecaster ought to continuously be looking forward as conceivable in an effort to integrate the planning of generation, transmission, sub-transmission, distribution, embedded/distributed generation and demand side options, to ensure that the development of grid networks and the usage of resources are optimum. "The intention of supply development is to offer a systematic and efficient extension of apparatus and amenities to meet the functionality's future potential electricity requirement with an appropriate echelon of reliability."

DEDICATION

“This dissertation is dedication to my family first my wife Pholosho Mildred Mmanare Matondolo for the love and support she gave me throughout my postgraduate studies…ILOVEYOUBabes.

My mom: Nikiwe Gloria Mengcane always praying for me, my siblings Yandisa Cele, Mkhululi Matondolo and Mzwamadoda Matondolo).”

“To my late colleague, big brother, friend, running partner Mr. Jacob Ntate Mooka (אחי היהודי) “my Jewish brother”, (מי ייתן ונשמתך לנוח בשלום נצחי) “may your soul rest in eternal peace.”

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LIST OF ACRONYMS

AC	Alternative Current
ADMD	After Diversity Maximum Demand
BRICS	Brazil, Russia, India, China and South Africa
BQ	Budget Quotation
CAPEX	Capital Expenditure
OPEX	Operational Expenditure
CO2	Carbon Dioxide
CCIs	Current-Controlled Inverters
CFL	Combine Fluorescent Lamps
CSIR	Council Scientific and Industrial Research (CSIR)
CSP	Concentrated Solar Power
CHP	Combined Heat Power
Cogen	Cogeneration
DEA	Department of Environment Affairs
DSM	Demand Side Management
DoE	Department of Energy
DC	Direct Current
EE	Energy Efficiency
EOI	Expression of Interest
WEF	Wind Energy Facility
RE	Renewable Energy
WPP	Wind Power Plant
ESCOM/Eskom	Electricity Supply Commission
PV	Photovoltaic

LV	Low Voltage (<1kV)
MV	Medium Voltage (1kV to 33kV)
HV	High Voltage (>33kV to132kV)
Km	Kilometres
kVA	Kilovolt Ampere
MVA	Megavolt Ampere
MW	Mega Watts
GW	Giga Watts
RPP	Renewable Power Producer
IPP	Independent Power Producer
REIPPPP	Renewable Energy Independent Power Producer Procurement Program
PPAs	Power Purchase Agreements
ZAR/R	Rand (RSA currency)
$US	Dollar (US currency)
EUR	Euro (EU currency)
NERSA	National Energy Regulator of South Africa
ECOU	Eastern Cape Operating Unit
CT	Current Transformer
VT	Voltage Transformer
SAIDI	Supply Average Interruption Duration Index
SAIFI	Supply Average Interruption Frequency Index
OU	Operating Unit
GDs	Generation Developers
IEA	International Energy Agency
SA	South Africa/n
RSA	Republic of South Africa
US	United States

EU	European Union
CPUT	Cape Peninsula University of Technology
UCT	University of Cape Town
UJ	University of Johannesburg
TUT	Tshwane University of Technology
F'SATI	French South Africa Institute of Technology
ICE	Indicative Cost Estimate
IDRC	International Development Research Centre
GDP	Gross Domestic Product
OSS	Open-Source Software
IN	Internet
SCADA	Supervisory Control and Data Acquisition
NIE	New Industrial Emerging
QoS	Quality of Supply
SUBTRANSMISSION	66kV and 132Kv
NDP	National Development Plan
PEM	Project Evaluation Model
RTU	Remote Terminal Unit
UAP	Universal Access Program
OUTA	Organisation Undoing Tax Abuse
GVA	Gross Value Added
GVA-R	Gross Value Added – Ratio
MTS	Main Transmission Substation
TDP	Transmission Development Plan
TDF	Transmission Demand Forecast
TOSP	Time of System Peak
ISEP	Integrated Strategic Electricity Plan
YoY	Year on Year

PNIF	Provincial Network Integrated Forum
IDZ	Industrial Development Zone
GLF	Geographic Load Forecast
EIA	Environment Impact Assessment
GWEC	Global Wind Energy Council
RFP	Request for Proposal
NDP	National Development Plan
SO2	Sulphur Dioxide
WHO	World Health Organization

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CHAPTER1: OVERVIEW OF THE RESEARCH

1.1 INTRODUCTION AND BACKGROUND OF THE RESEARCH

Since the oil crises in the early 1970s there has been vigorous worldwide research and improvement in the field of renewable energy resource and systems. During this time, energy alteration systems that were based on renewable technologies give the impression to be most advanced attractive and smart because of facts such as the projected high cost of oil and the cost effectiveness estimates and easy implementation of renewable energy source. Additionally, in more present times, it has been realised that renewable energy sources such as Wind Energy Facility (WEF) systems can have a beneficial impact on the following: essential technical, environmental, economic, and political issues of the world (Dincer, 2019).

A wide range of natural resources fall under the different types of renewable technologies generation. These renewable technologies (natural resources) include fossil fuels, hydro, fuel cells such as coal, land fill gas, wind, geothermal, solar and co-generation which according to the South African National Energy Regulator (NERSA). These different technologies operate under different conditions and utilise different machinery. Typical sample (Co-generator is a source of electrical power that is a co-product, by-product, waste product or residual product of an underlying industrial process). Some of the most common types of energy source for rotating and non-rotating machines include fossil fuel i.e., coal, hydropower, landfill gas, biomass, wind power, geothermal and solar photovoltaic (Antonello Gaviano, Karl Weber, Christian Dirmeier, 2020). According to (Hartely, 2009) the renewable energy technologies use the energy inherent in sunlight and its direct and indirect impacts. These resources represent a massive energy potential which dwarfs that of equivalent fossil resources. Problems with electricity energy supply in South Africa (S.A) are correlated to global warming or climate change, environmental concerns as air pollution, acid rain, ozone weakening, forest destruction and emission of radioactive substances (Dincer, 2019).

Coal traditionally dominates the energy supply sector in South Africa. Eskom generates 77 percent of South Africa’s electricity from coal fired stations. South Africa (SA) is gifted with coal with over 200 years of coal reverses. In 2007 South Africa (SA) coal production totalled 244 986 million tonnes and consumed 170 500 million tonnes (Thabethe, 2010). South Africa (SA) produces an average of 224million tones of marketable coal annually making it the fifth large coal producing country out of 65 of the world's greatest producers of coal (Thabethe, 2010). Even though Eskom is the seventh largest electricity utility in the world with overloaded capacity, cheap electricity, rapid growth in the economy during the post-apartheid era and massive rural electrification led to severe constraint in electricity generation that led Eskom load shedding in 2008. Department of Minerals and Energy then came up with a National Response to South Africa's electricity shortage policy document. The plan included demand and supply intervention measures to counter electricity shortages. Supply side measures included meeting current demand by expanding energy mix through development of renewable energy such as WEF.

Renewable energy technologies become important as environmental concerns increases, utility cost climb and labour costs escalate, this results to global economic uncertain. Operating and financial attributes of renewable energy technologies such as WEF which include flexibility and low operating cost are substantial different than those traditional fossil fuel/coal energy base technologies whose attributes include large investments, long implementation lead times and operating cost uncertainties for future fuel costs (Dincer, 2019).

Main solution to the imminent electricity energy supply shortage problem we are facing such as load shedding is to make much more usage of renewable energy sources such as Wind Energy Facility (WEF) technology. Renewable energy technologies such as WEF are often not well appreciated and therefore they are often valued to be not cost effective as traditional technologies such as coal. Renewable energy technologies benefits that are often not considered must be accounted for rather than to be seen as direct replacements for existing technologies so that their benefits and costs are considered such as providing small incremental capacity addition to the existing energy system with short lead time than long lead time units such as nuclear power stations as proposed by former president Jacob Gedleyihlekisa Zuma administration.

The market demand for renewable energy technology such as WEF by the developing nations is growing as they seek a better standard of living. The impact of global use of renewable energy technology systems will certainly reduce the pollution levels and for the past decades tremendous progress has been made on utilising the renewable energy technologies as one of the sources to reducing global warming.

Globally, the renewable energy industry is projected to grow rapidly over the next decade. The International Energy Agency (IEA) estimates a 15-20% of total energy supply contribution from renewable energy (International Energy Agency, 2020). This is due to renewable sources of energy having significant likely for increasing security of supply by expanding the energy supply range and increasingly contributing towards a long-term sustainable energy future to the existing network grid. According to (International Energy Agency, 2020), in terms of environmental impact, renewable energy generation results in the emission of less greenhouse gases than fossil fuels. Furthermore, renewable energy generation technologies save on water consumption in comparison with coal-fired power plants.

Power system electrical energy supply is the transformable currency of technology, without power system electrical energy supply the whole fabric of human civilisation as we know it would disintegrate. The effects of load shedding and power-cuts in electricity supplies to a city shows how totally human civilisation dependent we are on power system energy such as electricity in this case. Hospitals, education systems, transportation systems, buildings etc. which we use everyday dependent on electricity. As population grows especially in urban areas the need for more electricity is getting worse in South Africa. Enhance human civilisation lifestyle and energy demand rise together and the wealthy industrialised economies which contain 25% of the world's population consume 75% of the world's electricity supply energy (Dincer, 2019).

The research is going to look at holistic perspective on optimum reliability for integrated Wind Energy Facility (WEF) renewable technology into the sub-transmission and medium voltage (MV) of Eskom distribution grid in the Eastern Cape Operation Unit (ECOU). On Eskom existing network will mainly concentrate on (WEF) renewable technology. Coal utilisation in South Africa is the main contributor to carbon dioxide emissions, which is the main greenhouse gas that has been linked to climate change and indeed South Africa has one of the highest levels of carbon dioxide emission per capita in the World (Jos G.J. Olivier, 2018). Recently there have been number of requests from renewable energy technologies Generation Developers (GDs) and their consultants (intending to connect generators to Eskom Medium Voltage (MV) distribution which main include 11kV and 22kV rated voltage, and sub-transmission which include 66kV and 132kV rated voltage direct access to Eskom grid in the ECOU.

The accessibility of a renewable energy resource does not mean that resource can readily be used as an energy source. To utilise a resource several factors, need to be considered: the conversion system, quality of the fuel, conversion cost, transport cost as well as the size and location of the demand. In this chapter research will provide a preliminary overview of Eskom's Eastern Cape Operation Unit (ECOU) technical renewable energy resource potential developments of advanced renewable energy technology such as WEF can serve as cost effective and environmental responsibility as alternatives to the existing traditional energy generation technologies to significantly increase the current contribution to South African electricity energy demands.

1.2 STATEMENT OF THE RESEARCH PROBLEM

There has been an enormous increase in demand for electricity energy in South Africa in recent years as a result of rapid industrial development, rapid immigration growth around urban areas and massive rural electrification led to severe energy crisis today. South Africa is gifted with coal and relies heavily on coal to meet its energy needs. Coal as a primary energy source, with coal providing 75 percent of based power generation system that provide low-cost energy supply with a grid that is further extended to deep rural areas, to millions of residential, commercial and institutional consumers (Department of Mineral and Energy RSA, 2019). At the same breadth South Africa is well gifted with renewable energy resources that can be alternative sustainable energy supply and mostly these have remained largely untapped.

In 2008, South African government declared an emergency of electrical shortage in the Republic of South Africa (RSA). A roll out of rural mass electrification, strong economic growth in several industrial sectors, and inadequate maximum load planning ended in demand for power that began to surpass existing electricity energy supply. That resulted in systematic power outages across the country. Many of these systematic power outages which lasted for several hours spread viciously as it quickly became clear that undersupplied coal production systems and coal delivery coordination could not keep up with the demand (Fell, 2018). From all sectors such as restaurants, financial banking centres, large/small factories to tourism sector (guesthouse, hotel, lodge etc.), hospitals and individuals were forced to endure lengthy power outages and electricity rationing (Joel Krupa & Sarah Burch, 2021).

Between 2002 and 2009, South Africa increased its coal production from 124.1 to 141.2 million tonnes of oil equivalent per year and became the sixth largest producer of coal (Joel Krupa & Sarah Burch, 2021). This vast rapid development in heavily polluting fossil fuel energy use is compared with relatively little primary contribution from renewable sources. Renewable energy technology is deeply linked with many aspects of sustainable development but historically policies have not chosen renewable energy technologies and have led to a propagation of private and public sector funding for more lucrative deals, heavily polluting energy generation technologies (Jefferson, 2018).

Business principles have become an instrumental force in the evolution of politics, economics, and culture, both in South Africa and globally, yet this power structure has often resulted in inequality and economic injustices as wealth and power grow demand increases focused contributing to significant environmental dilapidation through, green-house gas emission increases, biodiversity losses, and airborne pollution (Ahumada, 2019). This research study will investigate and determine the diverse challenges that are the results of the integration of renewable energy technology specifically Wind Energy Facility technology into the sub-transmission and MV network grid in the (ECOU) to improve electricity energy supply to the country which will result to economic improvement and increase investment for renewable energy technologies by private and public sectors.

1.3 RESEACH QUESTION (HYPOTHESIS), SUB-QUESTIONS AND OBJECTIVES

Research questions, according to (Paul D. Leedy & Jeane Ellis Ormrod, 2018) provide another means for guiding directing research's thinking and are more common in qualitative studies. The research problem, research question, sub-questions and research objectives are expanded upon in Table 1. below.

Table 1: Research question, sub-questions and objectives presentation
Table 1: Research question, sub-question 1 and objectives presentation

Table 2: Research question, sub-questions and objectives presentation

Research problem	An analysis investigates and determine challenges of optimum reliability for integrated Wind Energy Facility (WEF) renewable technology into the sub-transmission and medium voltage (MV) of Eskom power system distribution grid in the Eskom Eastern Cape Operating Unit (ECOU).
Research questions	What are the current status and challenges on the optimum reliability for integrated Wind Energy Facility (WEF) renewable technology into the sub-transmission and medium voltage (MV) of Eskom power system distribution grid in the Eskom Eastern Cape Operating Unit (ECOU)? Why WEF renewable energy technology? Why and comparative studies on offshore and inland WEF? Underlying factors and look at social (private & public) attitude toward

	WEF renewable technology, and WEF renewable energy and sustainable development for load flow studies, low voltage, harmonics, frequency deviation, faulty level etc. Investigate grid connection code and reliability for existing and new WEF renewable energy technology integration into sub-transmission and MV network grid in the ECOU, how reliable they are? Investigate and do comprehensive research comparative studies for WEF renewable energy technology integration into sub-transmission and MV network in the ECOU, how is the role of National Government and Eastern Cape Government in promoting renewable energy technologies and look at policy makers on renewable energy technologies. Investigate markets and cost, promoting development; motivate the market for more power producers on order to promote employment opportunities by investing into WEF renewable energy as an alternative generation source in our crumpling power system and shortage of generation source?

Table 3: Research question, sub-questions and objectives presentation

Research sub-question	**Research method(s)**	**Objectives**
What are objective and strategic goals: looking at planning, technical challenges, social impact, economic effects, environmental impacts and cost for optimum reliability integrated of Wind Energy Facility (WEF) renewable technology into the sub-transmission and medium voltage (MV) of Eskom power system distribution network in the ECOU grid?	Literature analysis Case study analysis (structured and unstructured), Experiential Analysis, Ethnographic Observation, Protocol Studies	Strategic goals and supporting objectives will be instrumental in facilitating the development increase of an enabling framework in order for private & public sector to invest into integration of Wind Energy Facility (WEF) renewable technology and reduction of pollution caused by fossil fuel/coal become reality so that government commit to promoting renewable energy such as WEF. Research to mitigate through five key strategic areas to be addressed, i.e., technical challenges, load forecast, financial costs, loadshedding, smart and advance renewable energy technologies, and

Research sub-question	Research method(s)	Objectives
		sustainable renewable energy development such as WEF.
What are the essential elements for renewable energy sustainable development, challenges and opportunities of WEF, Dynamic studies of WEF model for the simulation of power fluctuation on PowerFactor (DigSilent), The political ecology of South Africans renewable energy policy?	Literature analysis Case Study (structured and unstructured) descriptive. Experiential Analysis, Ethnographic Observation, Protocol Studies	Determine how renewable energy that is produced from sustainable natural sources will contribute to sustainable development of renewable energy such as WEF. As most of the sources are indigenous and naturally available in S.A which make energy supply is affordable and cheaper compare currently. South Africa is well endowed with abundant renewable energy resources that can be converted to productive energy uses. Review of WEF renewable energy storage technologies applications. Key challenges on the political economy of renewable energy and investment challenges. Optimization methods applied to renewable energy and sustainable energy.
What are the current theories, implementation and challenge of sustainable energy performance of WEF renewable technology optimum reliability integrated WEF technology into the sub-transmission and MV of Eskom distribution grid in the ECOU? What philosophy and requirements to integrate	Literature analysis Case study (descriptive). Experiential Analysis, Ethnographic Observation, Protocol Studies	Need to determine how the South African distribution network code also mandates each distributor to have an interconnection standard specifying the technical criteria for the connection of a renewable energy generator. Determine the information in order to operate a renewable energy generator in parallel with the Eskom distribution grid, the renewable energy generator is required to have a grid connection agreement. This grid

Research sub-question	Research method(s)	Objectives
renewable energy generation into Eskom distribution grid?		connection agreement is a separate agreement from the commercial agreement. The commercial agreements will address energy tariffs for generation exported into the utility network and wheeling agreements for customers selling the generated power to Eskom or another party.
What are the legal and regulatory requirements principles are recommended to connect or integrating of WEF renewable technologies into the Eskom distribution grid system? What are the developing renewable energy supply barriers, targets, policies and actions for sustainable renewable energy technology?	Literature analysis Case study (descriptive). Experiential Analysis, Ethnographic Observation, Protocol Studies	The Electricity Regulation Act 4 of 2006 details the legislative requirements with regard to the generation, transmission, distribution and trading of electricity. In this regard, the operator of a grid-connected generator is required to hold a licence from the Regulator (Section 8). Operators of non-grid connected generators are not required to hold a license provided that the plant is designated only for own-use and is not used commercially (Schedule II). First, what are the barriers and impediments to increasing renewable energy in national regions and states? Some studies show that renewable solutions often face difficult technical, institutional and economic problems and impediments (e.g., poor financing arrangements, high technical risks, unhelpful regulation, and faulty market systems.

1.4 PRELIMINARY LITERATURE REVIEW

1.4.1 Introduction of Preliminary Literature Review

According to (Remenyi et.al., 2019), the research preliminary literature review as consists of three fundamental stages namely: Reviewing the literature, formulising a research question, Establishing the methodology, collecting evidence, Analysing the evidence, developing conclusions, Understanding the limitations of the research, Producing management guidelines or recommendations etc. A preliminary literature review is a summary and explanation of the comprehensive and current state of philosophy knowledge on a constricted topic as found in academic books and journal articles.

There are two kinds of preliminary literature reviews you might write at varsity: one that students are asked to write as a stand-alone assignment in an undergraduate course, often as part of their training in the research processes in their field, and the other that is written as part of an introduction to, or preparation for, a longer work, usually a thesis or research report in their postgraduate studies. The focus and perspective of your preliminary literature review and the kind of hypothesis or thesis argument will be determined by what kind of preliminary literate review we are writing in this research.

1.4.2 Core Preliminary Literature Review

The initial electricity utilities in South Africa were established over 100 years ago by the municipalities in the main towns and by private companies supplying the rapidly developing mines, industries and businesses. Political aspects were evident in the establishment of the Electricity Supply Commission (Escom) as a national public utility in 1923 and the termination of the licence for private electricity supply by the Victoria Falls and Transvaal Power Company in 1949 (Gaunt, 2008). Later during the 1970s and 1980s, electrification was extended to meet socio-economic objectives when, urged by political pressures, Escom which became Eskom in 1987 extended funded supplies to farms and rural service centres, to support agriculture and develop rural areas. Consequently, Eskom was the supplier to most mines and large industries, the railways, the rural areas, municipal re-distributors, and in a few municipal areas. At that stage, only about one third of all households in South Africa had access to electricity (Gaunt, 2008).

The “Universal Access Program” (UAP) or ‘‘Electricity for-All’’ programme began at about the time that South Africa started going through political change from apartheid to a broadly democratic government in early 1990s up to today. South Africa electrical utility company Eskom and others electrical utilities in the world constantly striving to enhance their level of service to their customers while at the same time minimising their impact on the environment. In order to achieve these goals, utilities need to have access to accurate information relating to how and when consumers are using electrical power and their generation impact to the environment. This information is vital for grid capacity and power plant construction planning (Eskom Integrated Report, 2019).

Eskom need to also provide power of high quality which is sustainable and stable in voltage and frequency, but also free from excessive harmonic distortion and emissions of greenhouse gases, such as carbon dioxide which result to climate change problem not only South Africa but globally. Several scientific research has confirmed that climate change has started affecting the atmosphere and the African continent (Edson L. Meyer & Kola O. Odeku, 2017). There are global fears concerning climate change are now devastating as various governments of the world are busy creating policies and measures to reduce the carbon dioxide emissions that cause climate change.

The African continent is likely to be severely affected by climate change if the global warming continues without being halted or abating and measurement controls (Johnson, 2013). The satire is that almost all developing especially African countries are more worried with the issues of access to electrification energy in order to advance and growth industrial production and output, economic growth and improvement as opposed to policies that would reduce carbon dioxide emissions and stop climate change (Davison Ogunlade & Harald Winkler, 2018). Globally there is sufficient agreement that sustainable development includes an integration of environmental protection and economic growth. Economic growth and development can still be achieved through alternative energy sources such as renewable energy as opposed to fossil fuels (Nico Schrijver & Friedel Weiss, 2019).

One of the methods that should be careful consider in order for developing African countries to grow their economies by utilising their natural resources without contributing to climate change is to inspire more environmentally sustainable energy sector expansion such as WEF renewable energy technology. South Africa is currently the first nation in Africa to utilise this method (Edson L. Meyer & Kola O. Odeku, 2017), which is the primary reason South African particular in Eastern Cape province has been chosen as a case study area of this research. The precarious role played by renewable energy in achieving sustainable development has been well recognised in the renewable energy policy literature (Bhattacharyya, 2018).

Although most African developing countries are the most vulnerable to the effects of climate change, they do not identify or consider climate change as an urgency importance or serious matter to be controlled with gravity it deserves (Davison & Winkler et al., 2017). Instead, most African leaders and policy makers have associated the issue of energy and natural resources to poverty improvement and alleviation which they consider poverty as the major challenge facing the continent (NEPAD, 2018). There will if not already now a price to be paid for this inaction and lackadaisical attitude towards association the issue of energy and natural resource to poverty (Martin, Agerup et al., 2018). Any major catastrophe from climate change would affect the natural resources and economies of most developing countries especially African developing countries.

The agreement appears to exist that without inexpensive, affordable, reliable and clean energy services to the population, energy sustainable development cannot be achieved. Yet, the situation in terms of energy access has not changed much even after a decade, and billions of people are without access to such vital services and according to (IEA, 2018), even by 2030 this problem will not diminish unless actions are taken urgently (Batthacharyya, 2017). South Africa (SA) is a middle-income economy with one of the highest levels of inequality in the world—close to 30 percent unemployment and a high incidence of poverty (Cassim, 2019). The challenge is intricated by the fact that the economy continues to experience low growth. There is a critical discussion about how best to create long-run growth and reduce inequality and poverty in South Africa. There has been an enormous increase in demand for electrification energy in South Africa in recent years as a result of rapid industrial development, rapid immigration and population growth around urban areas and massive rural electrification led to severe energy crisis today (Cassim, 2019).

South Africa, as a developing country, is the most industrialised within the African continent. It is well gifted with natural resources such as coal, gold, diamonds, metals, and minerals.

Its overall economy is primarily reliant on energy production and utilisation, with coal accounting for seventy-five percent (75%) of the fossil fuel (coal) demand and ninety-one percent (91%) of electricity generation (Edson L. Meyer & Kola O. Odeku, 2017). The energy sector contributes nearly fifteen percent (15%) of gross domestic product (GDP) and provides around ±250,000 jobs (Edson L. Meyer & Kola O. Odeku, 2017). Equated to other African countries, the South African economy is energy-demanding, and the energy consumption rate is very high. This is mainly due to the heavy mining industries, such as iron and steel, cement, aluminium, etc.

Furthermore, it is the most electrified country in Africa; electricity plays a pivotal role in the economy and improves the quality of life of the previously disadvantaged majority in addition to supporting large-scale industrial development (Davison Ogunlade & Harald Winkler, 2018). South African government promised electricity to millions of people who were disadvantage during apartheid such as (township and rural areas) that action on regulation of the energy sector such as Eskom shifted supply and demand of energy away from its economic equilibrium (Eskom Integrated Report, 2019). Coal traditionally dominates the electricity energy supply sector in South Africa. Eskom generates seventy-seven percent (77%) of South Africa's electricity from coal fired stations. South Africa is gifted with coal and relies almost completely and heavily on fossil fuels (coal) as a primary energy source, with coal providing seventy-five percent (75%) of the fossil fuel-based energy supply. (Department of Mineral and Energy RSA, 2019).

There are many reasons for this variation in cost, including the fact that the lower cost associated with fossil fuel (coal) utilisation does not fully account for its hostile impact on the environment. Having one electricity sector power produce (Eskom) which monopolise the electricity generation and transmission in South Africa it led to severe constraint in electricity generation that led the country to load shedding since 2008 till today in some part of areas in South Africa (Department of Energy, 2019). This led also to shortage of electricity that has an impact in the country economy and developments. Therefore, it is necessary to consider which technologies can be promoted by measures to stimulate the market. In the medium or long-term it is important that technologies that are currently available in South Africa are implemented.

The local content of equipment needs to be maximised in order to minimise the costs associated with implementation and operation, as well as the promotion of employment opportunities (Eskom Integrated Report, 2019). Eskom electricity utility is the seventh largest electricity utility in the world with almost overloads capacity, cheap electricity, rapid growth in the economy during the post-apartheid era and massive rural electrification led to severe constraint in electricity generation that led Eskom load shedding for nearly a decade. Department of Minerals and Energy then came up with a National Response to South Africa's electricity shortage policy document. The plan included demand and supply intervention measures to counter electricity shortages. Supply side measures included meeting current demand by expanding energy mix through development of renewable energy such as Wind Energy such as Wind Energy Facility (WEF), Solar energy such as Solar PV, Hydropower Energy such as Water etc. South Africa has developed an efficient, large-scale, coal-based power generation system that provides low-cost electricity, through a grid system that is being extended to rural areas, to millions of residential, commercial and institutional consumers.

As a result, coal is and is likely to remain, from a financial viewpoint, an attractive source of energy for South Africa (Department of Mineral and Energy RSA, 2019). However, at the same time South Africa recognises that the emissions of greenhouse gases and global climate change, such as carbon dioxide, from the utilisation of fossil fuels such as coal and petroleum products has led to increasing concerns worldwide, about global climate change. While South Africa is well gifted with renewable energy resources that can be sustainable alternatives to fossil fuels, so far these have remained mostly unexploited (Department of Mineral and Energy RSA, 2019).

In as much as South Africa is gifted with coal at the same time is well gifted with abundant renewable energy resources that can be converted to productive energy utility in the existing Eskom network grid. Today, however, the utilisation of these alternative resources are not cost expensive in many locations when compared to South Africa's fossil-based (coal) energy supply industry and compare also to the new nuclear generation that South African governments is proposing which is estimated whole building programme will end up costing the South African taxpayers and economy over three trillion rand (R3trn) according to civil society group Organisation Undoing Tax Abuse (Outa).

When the South Africa gotten independence in 1994 from apartheid regime to democratic state for all citizens, the issues of climate change and global warming were not a priority and the apparent connections between sustainable development and climate change issues were very frail and not consider by then government (Davison & Winkler et al., 2017). Be that as it may, there has been scientific evidence that climate change is far more rapid and dangerous than thought earlier. The South African government then realised that climate change is a serious peril to South Africa as country and a major obstacle to continued poverty reduction and alleviation across its many scopes. That created a great concerned that consequently to calls for a change in attitude to make the issue of climate changes a major priority in the country. Bearing this in mind, South Africa is beginning to proactively connect its intentions with climate change priorities within a sustainable development framework of renewable energy as alternative power supply (UNEP, 2017).

Fossil fuels such as coal, uranium, liquid fuels, biomass and gas continue to play a central role in the socio-economic development of our South Africa, while concurrently providing the needed infrastructural economic base for the country to become an attractive host for foreign investments in the energy sector (Department of Energy, 2019). It is in this respect that the government published the White Paper on Renewable Energy in 2003 ("2003 White Paper") (Departmental of Minerals and Energy, 2018). South African government also established a long-term goal to build an energy industry that will offer a fully non-subsidised alternative to fossil fuels. This policy approach has been concretised through significant financial support for renewable energy research and development (Department of Energy, 2019).

In recently year wind energy facility generation has become increasingly popular choice of technology for new capacity additions in power systems worldwide. Several factors have contributed to this trend (Barberis Negra N. & Holmstrom O., 2017). Environmental concerns and a constant increase in fossil fuel prices are central to these factors. Furthermore, new law-making moves for greenhouse gases limitation in Europe and similar laws currently under consideration in the United State and other parts of the world make wind economically more competitive with other traditional sources of energy (Jiang Wen, Yan Zheng, Feng Donghan, 2019).

There are also other factors, such as advances in the manufacturing and control technology, which also add to the attraction of wind energy facility as a 'green' source of energy. Wind energy facility has proved to be one of the most successful of all available source of renewable energy offering relatively high capacities, with generation costs that are becoming competitive with conventional energy source (Dimitrovski A. & Tomsovic K., 2018). However, wind energy systems suffer from a major drawback since the wind resource is discontinuous, hence is not available all of the time to make turbines run continuously (Chowdhurry, 2017) and (Karaki SH, Salim BA, & Chedid RB, 2017).

Therefore, wind energy systems are considered as energy-spare rather than capacity-replacement resources. The amount of energy that can be supplied by one or more sites depends on the wind energy resource available, the type of wind turbines used, and the nature of the load being supplied. For these reasons, it is fundamental to study the reliability of these wind energy facility generation systems and to assess the effects that they will have on the entire existing grid system and on its reliability (Billinton R. & Gan L., 2018) and (Leite AP. & Borges CLT., 2017).

1.5 RESEARCH DESIGN AND METHODOLOGY

Research methodology in essence is focused on the problems to be investigated in a research study and therefore varies according to the problems investigated. It is important in a research study that there is consistency between research questions, methodological and theoretical approaches (Churchill H. & Sanders T., 2017). On a similar note, (Collins J. & Hussey R., 2019) identified methodology as the "overall approach to the entire process of the research study". Research methodology, as per the above definitions, is focused on the problems to be investigated in a research study and hence is varied according to the problems to be investigated.

Research strategy is one of the components of research methodology. Research strategy provides overall direction of the research including the process by which the research is conducted. Case study is one of such research strategies. Here, a research study which sought to adopt case study as the preferred research strategy is discussed (Wadawatta G., Ingririge B., & Amaratunga D., 2017). This research sought to investigate the optimum reliability of integrated Wind Energy Facility renewable energy technology into the Eskom grid in the Eastern Cape Operating Unit with the aim of developing a decision-making framework that can be utilised by Eskom and IPP Developers in construction to enhance their performance and sustainable energy as an alternative source. In order to achieve the aim of the research several objectives were defined, and several research questions were raised. Objectives of the research included examining the existing coping strategies of current fossil fuel (coal) energy supply and challenges we facing as country because of this coal energy production.

An empirical investigation was undertaken for the current study, using qualitative and quantitative methods to obtain data that would strengthen the trustworthiness and validity of the research. The term empirical refers to knowledge derived by the process of practical and scientific experience, experiments and inquiries (Skager RW. & Weinberg C., 2017). An empirical investigation involves a planned process of collecting and analysing data – in a way that is systematic, purposeful and accountable. The purpose of this empirical investigation is, therefore, to obtain reliable and valid data, in accordance with the research problem and the accompanying research aims (Isaac S. & Michael W., 2017). Hence, turning the focus to the current study, the purpose of the empirical section of this research report is to describe an applicable research design as a scientific process to obtain reliable and valid data concerning the research problem and the accompanying research questions. The concept of 'research design and methodology' includes critical aspects pertaining to 'data collection design and methodology', which ultimately culminate in extensive rework being demanded from the researcher. According to (Veal, 2017:122) qualitative research methods are a variety of methods where the data collected is in the form of words (or images/sounds/visual) while quantitative methods are data in form of numbers in the form of lab results, simulation results etc.

According to (Paul D. Leedy & Jeane Ellis Ormrod, 2018) that research methodology refers to the researcher's general approach in carrying out the research project. (Collins J. & Hussey R., 2018) views research methodology as focusing on the research process and the kind of tools and procedures to be used. The point of departure would be the specific task (data collection) at hand, the individual steps in the research process, and the most "objective" procedures to be employed. In essence, express, methodologies justify methods, which produce data and analyses, and methods produce knowledge, so methodologies have epistemic content. Put simply, the research methodology in this research thus refers to the approach adopted to follow in gathering. According to (Paul D. Leedy & Jeane Ellis Ormrod, 2018) there are two research design methods (quantitative) and (qualitative) of which the following seems to be appropriate for this research:

1.5.1 'Qualitative' or 'Phenomenological' research

Involves the use of words to describe and explain a phenomenon. Qualitative is also a 'case study' which is an experimental analysis that investigates a current incident within its real-life context, especially when the boundaries between incidence and framework are not plainly obvious maintain that with qualitative research, there is no claim that "knowledge gained from one framework can necessarily have bearing for other frameworks in which they occur" (Baxter P., & Jack S., 2018). According to (Collins J. & Hussey R., 2018) case studies are often descriptive and as explanatory research used in areas where there are few theories or a lacking body of knowledge. While Quantitative research is applicable to phenomena that can be expressed in terms of quantity, Qualitative research is concerned with qualitative phenomenon. For instance, when we are interested in investigating the reasons for human behaviour (i.e., why people think or do certain things), we quite often talk of 'Motivation Research', an important type of qualitative research. Qualitative research is especially important in the behavioural sciences where the aim is to discover the underlying motives of human behaviour (Nallaperumal, 2018).

Descriptive case studies: where the objective is limited to describing current practice. Descriptive research includes surveys and fact-finding enquiries of different kinds. The major purpose of descriptive research is description of the situation as it exists at present. This approach is suitable for social sciences and business and management studies for descriptive research studies. The main characteristic of this method is that the researcher has no control over the variables; s/he can only report what has happened or what is happening. Most research projects of this nature are 8 used for descriptive studies in which the researcher seeks to measure factors like frequency of shopping, brand preference of people, most popular media programme etc. (Nallaperumal, 2018).

Illustrative case studies: where the research attempts to illustrate new and possibly innovative practices adopted by research. It's mainly concerned with generalisations and concentrates on the formulation of a theory. "Gathering knowledge for the sake of knowledge" is termed 'Pure' or 'Basic' or 'Fundamental' research. Examples of fundamental research are research concerning some natural phenomenon or related to pure mathematics; research studies aimed at studying and making generalisations about human behaviour.

While applied research concentrates on discovering a solution for some pressing practical problem, fundamental research is focused on formulation of theories that may have a broad base of applications either at present or for future which adds more materials to the already existing organized body of scientific knowledge (Nallaperumal, 2018). Experimental case studies: where the research examines the difficulties in implementing new procedures and techniques in an organisation and evaluating the benefits. It is generally used by philosophers and thinkers to develop new concepts or to reinterpret existing ones. On the other hand, experimental (empirical) research relies on experiment or observation alone, often without due regard for system and theory.

It is data-based research, coming up with conclusions which are capable of being verified by observation or experiment. In such research it is necessary to get at facts first hand, at their source, and actively to go about doing certain things to stimulate the production of desired information. In such research, the researcher must first provide himself with a working hypothesis or guess as to the probable results. He then works to get enough facts (data) to prove or disprove his hypothesis. He then sets up experimental designs which he thinks will manipulate the persons or the materials concerned to bring forth the desired information leading to the hypothesis (Nallaperumal, 2018).

Explanatory case studies: where existing theory is used to understand and explain what is happening. This type of case study would be used if you were seeking to answer a question that sought to explain the presumed causal links in real-life interventions that are too complex for the survey or experimental strategies. In evaluation language, the explanations would link program implementation with program effects. Case study is used to explore those situations in which the intervention being evaluated has no clear, single set of outcomes (Yin, 2018).

This research will use Descriptive, Illustrative, Experimental and Explanatory case studies to give descriptive of our research study, illustrative experiment and explore by investigating and determining challenges of integrating of WEF renewable energy technology into the sub-transmission and medium voltage (MV) Eskom distribution grid in the Eastern Cape Operating Unit (ECOU). Some design researchers have drawn on their own experience of designing to give explanations of aspects of design.

By involving designers in the research as equal partners it is more likely that the outcome of the research will be taken up because of the shared ownership of the knowledge produced by the research. One approach to doing this would be like participant observation with a designer/researcher working as a team and coming to a shared appreciation of their actions. Protocols involve observation of designers at work. Almost all these studies are based on what we might call 'experimental data', gleaned from a laboratory environment (Graham Green, Paul Kennedy & Alistair McGown, 2018). In an engineering context, participant observation would involve researchers gaining access to companies and working as designers or with designers to get an inside view of their activities. According to (Graham Green, Paul Kennedy & Alistair McGown, 2018) observation can be structured the study can become more structured as hypotheses emerge from the investigation. In this research, the research shall make use of qualitative research design methods because trying to understand situation better.

1.5.2 Sampling technique for research design methodology

According to (Brynard D.J., Hanekom S.X, & Brynard P.A., 2018:57) a sample is used to simplify the research – it is easier to study representative sample of a population than to study the entire population, it saves the researchers' time and costs. The techniques used in drawing the sample could either be by probability or non-probability. This study will use a probability sampling method, a convenience sample method. According to (Collins J. & Hussey R., 2018) define a sample technique as "a 'sample' is made up of some of the members of a 'population' (the target population), the latter referring to a body of people or to any other collection of items under consideration for the purpose of the research. The target population in terms of a geographical area studied is renewable energy technology integration to the Eskom ECOU network grid. The sampling procedure is therefore designed to produce a representative sample of renewable energy application to Eskom utility by developers specifically Wind Energy Facility (WEF) with experimental and control simulation mathematical modelling.

The selection procedure of the population sample was based on two sampling methods, namely multistage stratified sampling and purposive sampling. The target scope for this research is type of renewable technology such as Wind Energy Facility (WEF) mainly situated in Eastern Cape Province.

1.5.3 Limitations of the research study

This study is limited to investigating and determine optimum reliability and challenges of integrating of Wind Energy Facility (WEF) renewable technology into the power system distribution network in the Eskom Eastern Cape Operating Unit (ECOU) grid at medium voltage (MV) and high voltage (HV) mainly sub-transmission network grid. This research will only focus on the above renewable energy in the region of Eastern Cape.

1.6 RESEARCH ETHICS RULES

According to (Saunder M., Lewis P., & Thornhill A., 2018), "ethics refer to the appropriateness of researcher behaviour in relation to the rights of those who become the subject of your research study, and who also affected by it". According to (Paul D. Leedy & Jeane Ellis Ormrod, 2018), most ethical issues in research fall into one of four categories namely: Protection from harm, informed consent, right to privacy, and honesty with professional colleagues. According to (Collins J. & Hussey R., 2019), expand on the above and add the following: Confidentiality or anonymity, Dignity and Publication.

In this research dissertation we do require 'ethics' clearance since we are going to be looking and focusing on Wind Energy Facility (WEF) renewable technology from developers to Eskom utility as a case study research, because we focus on the generic fundamental of integrating of Wind Energy Facility (WEF) renewable technology into the Eskom power system distribution network in the Eskom Eastern Cape Operating Unit (ECOU) grid at medium voltage (MV) and high voltage (HV) mainly sub-transmission grid, mainly focus at technical such dynamic studies, steady state studies, load flow studies etc. and economical challenges during application and integration in the utility grid. Ethical considerations: According to (Copper, Donald R., Emory & William C., 2017:101), argue that the research client has a right to research that is ethically conducted. According to (Cooper D. & Schindler P., 2018:121), three guidelines should be adhered to, namely:

- Explain the benefits of the study.
- Explain the rights and protections of the respondent.
- Ensure informed consent.

Within the above guidelines, the following ethical considerations were considered during the research survey.

1.7 DELIMITATIONS AND DELINEATIONS OF THE STUDY

The research investigates and determine optimum reliability challenges of integrated of Wind Energy Facility (WEF) renewable technology into the Eskom power system distribution network in the Eskom Eastern Cape Operating Unit (ECOU) grid at medium voltage (MV) and high voltage (HV) mainly sub-transmission network grid. This research is part of larger international study and conjunction with the French South African Institute of

Technology (F'SATI) under project area of Renewable and Sustainable energy systems globally, at Cape Peninsula University of Technology (CPUT).

The nature of the research is to present the research investigates and determine optimum reliability challenges of integrated of Wind Energy Facility (WEF) renewable technology into the power system distribution network in the Eskom Eastern Cape Operating Unit (ECOU) grid at medium voltage (MV) and high voltage (HV) mainly sub-transmission network grid. We will only cover the WEF in the Eastern Cape province only we will not include other WEF in other provinces.

1.8 SIGNIFICANCE OF THE RESEARCH

The main significant of this research will be the development of a methodology for the measurement and evaluation of the optimum reliability limits for Wind Energy Facility (WEF) renewable technology generation for integration to Eskom grid connection into medium voltage (MV) (11kV or 22kV) and high voltage (HV) sub-transmission (66kV or 132kV) in the ECOU grid. This methodology is significant to utility and (current and future) developers of the WEF renewable technology. This will provide guidance and regulation assist utility and developers on sustaining power of high quality, which is stable in voltage and frequency, but also free from excessive harmonic distortion and add value in reduction of emissions of greenhouse gases, such as carbon dioxide which result to climate change problems. In order to achieve these goals, utilities need to have access to accurate information relating to how and when consumers are using electrical power and the generation impact to the environment. This information is vital for grid capacity and power plant generation planning.

1.9 CONTRIBUTION AND IMPORTANCE OF THE RESEARCH

The proposed research has the potential to highlight the benefits, which could be gleaned from the deployment of the Wind Energy Facility (WEF) renewable technology integrated into the power system distribution network in the Eskom Eastern Cape Operating Unit (ECOU) grid at medium voltage (MV) and high voltage (HV) mainly sub-transmission network grid. This research will add value and contribution to the sustainability and quality of electrical distribution service in South Africa which Eskom as utility does, then nations can hope to achieve their social development and rapid growth to economic which are the main goals for South African government today. Renewable energy systems such as WEF present challenges but have numerous potential benefits especially in the long run. Wind Energy Facility (WEF) should therefore be employed as a valuable tool to enhance Eskom electrification distribution service in order to contribute to modernisation and development of the country through improved distribution electrical network grid by investing and integrating Wind Energy Facility to the power supply grid.

Wind Energy Facility (WEF) renewable technology have the potential for explosive growth but more importantly in the delivery of better electrical distribution to rural areas, to millions of urban residential, commercial and institutional consumers. South Africa government must demonstrate their commitment to the implementation of renewable energy technology. This research is focusing on WEF renewable technology potential that would benefit the country and boost economy. The anticipated outputs for this research are:

- A landscape model depicting the WEF renewable energy technology in Eastern Cape region mainly.
- A summary of the problems and challenges that hinder the integration and suggestions for improvement
- A summary of the technology currently being mostly integrated to the Eskom distribution in ECOU network grid and recommendations for Wind Energy Facility (WEF) renewable technology to future renewable energy developers.

The outcome of the research will contribute towards the improvement of integrating of Wind Energy Facility (WEF) renewable technology into the power system distribution network in the (ECOU) grid.

1.10 OUTLINE OF THE FINAL DISSERTATION

The chapters and content analysis for this research study will cover the following:

Chapter 1: Introduction and Background: Overview of the Research: The chapter will provide a brief introduction and background to the key factors as identified, which will contribute to the scope of the research. The research process will be explaining the problem, critical research assumptions and limitations of the research will be listed, feeding into the overall research design and methodology, the demand for qualitative research strategy for this research study, and overview of the dissertation structure. The chapter will furthermore provide details of the chapter and content analysis of the dissertation including key research objectives.

Chapter 2: Literature Review: Philosophy and Models of Wind Energy Facility (WEF) Renewable Technology: The research will take a holistic perspective of what has known about the integration of Wind Energy Facility (WEF) renewable technology into the power system distribution network at medium voltage (MV) (11kV and 22kV); and high voltage (HV) mainly sub-transmission network grid (66kV and 132kV), its significance and the need for research to be conducted into this field of study. More research literature review details into Wind Energy Facility (WEF) using various articles, books, research papers etc. that are based on integrating of Wind Energy Facility (WEF) into the utility distribution network grid at MV and HV (sub-transmission) distribution network grid. Will do a comparative study on integration of Wind Energy Facility (WEF) renewable technology in the coastal areas and inland areas investigating what are the advantages and disadvantages of doing so. Outline challenges encountered include not only the obvious such as lack of wind or sun, but the challenges on developing WEF renewable technology, policy, cost issue, benefits, barriers, current status, climate change in South Africa, dynamic model studies of WEF, Life cycle assessment of WEF, Indicative Cost Estimate (ICE) phase and the Budget Quotation (BQ) phase, etc. Also look at the role that Wind Energy Facility (WEF) renewable technology plays in the economy, climate impact it plays to reduce carbon emission-intensive due to the energy intensive economy and high dependence on coal for primary energy since this leads to "global warming" as we know.

Chapter 3: Load Forecaster: WEF integrated into the existing network connection philosophy and methodology. This chapter will determine the nature of the research with a clear explanation of the methodology that will be followed to solve the research problem, by providing a detailed description of the components of the methodology such as the nature of case study i.e., scenarios, applicability, strengths and weaknesses, validity, tests, test samples, statistical methods, field work etc. This chapter fundamentally looks at research at theoretical considerations particular of literature, precise processing and model development for WEF renewable technology development are dealt within this chapter. Further will look at research action plan, research case study, ethnography, field experiments, future research, grounded theory, cross-sectional studies etc. The research methodology will be elaborated upon the descriptions of the research, such as case study application for Wind Energy Facility (WEF) at Eskom utility grid by developers mainly Eastern Cape area.

Chapter 4: Loadshedding/Energy Crisis in RSA: Optimum Reliability and Stability Studies of Distribution Network with/out WEF. In this chapter, the research will be focusing and looking at case studies conducted such as the scenario for each case study and its purpose will be explained. Case study scenario such as applications done by renewable developers to Eskom as utility, elaborated upon the landscape and challenges that correlate with the integrating of Wind Energy Facility (WEF) renewable technology into the power system distribution network at medium voltage (MV) (11kV and 22kV) and high voltage (HV) mainly sub-transmission network grid (66kV and 132kV). We compare the 'coastal and inland' areas case studies in the connection philosophy and methodology of Wind Energy Facility (WEF) into the Eskom ECOU network grid.

Chapter 5: Case Study Results: Simulation Case Studies and Results of Integrated Wind Energy Facility (WEF) renewable technology using PowerFactory (DigSilent) and e-Tap. Discussions and the results from case studies, the research will discuss in more details the results from case studies conducted will be analysed further and discuss findings made and compare results of different simulation software. In addition, the results of the case studies will be mapped to the literature review conducted in Chapter two. The approach to case study results will be explained and the target case study scenario will be defined. Evaluation and interpretation of case study of Wind Energy Facility renewable technology integration to the distribution network grid. The case study scenario within the scope of research will be analysed in detail and interpreted, in terms of the primary theme of the dissertation. The chapter will be concluded with a list of case study results.

Chapter 6: Conclusion and Recommendations: Conclusion and Future Research Work: In this chapter will do summary of the research results obtained, the key findings and recommendation for future research will be offered, and the dissertation deliverables will be summarised in this chapter.

1.11 SUMMARY

This chapter begins with introduction and background of the research information on the energy utility by Eskom then give introduce the research topic of integrating of renewable energy Wind Energy Facility (WEF) renewable technology into the sub-transmission and medium voltage (MV) distribution Eskom network grid in the Eastern Cape Operating Unit (ECOU). This follow by problem statement, research objectives, and motivation for the research work, hypothesis, and delimitation of research, assumptions, and research methodology are described, followed by the formulation of the research problem, the research question and supporting investigate questions.

1.12 PROJECT PLANNING

Table 4: Research Project Planning

Faculty Research Committees (FRC)	High Degrees Committees (HDC) Forms	STEPS IN THE RESEARCH PLAN	RESEARCH PROGRESS COMMENTS	DEADLINE FOR COMPLETION
HDC 1.1: Registration of topic of dissertation/thesis	HDC 1.1: Registration of topic of dissertation/thesis	Submission of the research topic		
HDC 1.2: Registration of proposal for dissertation/thesis	HDC 1.2: Registration of proposal for dissertation/thesis	Submission of the research proposal.	Design of a research plan	
HDC 1.3: Supervisors' report on student progress	HDC 1.3: Supervisors' report on student progress	Supervisors' progress report	Gaining access/getting permission to work in a particular area/have access to data, etc.	
HDC 1.4: Nomination of additional supervisor (Internal or External)	HDC 1.4: Nomination of additional supervisor (Internal or External)	N/A	Literature review	

Faculty Research Committees (FRC)	High Degrees Committees (HDC) Forms	STEPS IN THE RESEARCH PLAN	RESEARCH PROGRESS COMMENTS	DEADLINE FOR COMPLETION
HDC 1.5: Nomination of Internal or External Examiner for dissertation/thesis	HDC 1.5: Nomination of Internal or External Examiner for dissertation/thesis	Submitting first draft documents for external corrections and comments	Defining of a universe, a sample frame, sampling OR setting up of selection criteria, etc.	
HDC 1.6: Proposal to upgrade registration from Masters to Doctoral level	HDC 1.6: Proposal to upgrade registration from Masters to Doctoral level	N/A	Design and testing of case studies, if appropriate	
HDC 1.7: Examiner's report on Thesis/Dissertation	HDC 1.7: Examiner's report on Thesis/Dissertation	Report from External Examiners'	Design of a final case studies/schedules, etc.	
HDC 1.8: Submission of final marks for examination of thesis/dissertation	HDC 1.8: Submission of final marks for examination of thesis/dissertation	Release of Marks to Exams Office	Case studies/posting of case studies, etc.	
HDC 1.9: Application for interruption of studies	HDC 1.9: Application for interruption of studies	N/A	Editing of completed case studies, grouping and coding of data, entering data into a computer	

Faculty Research Committees (FRC)	High Degrees Committees (HDC) Forms	STEPS IN THE RESEARCH PLAN	RESEARCH PROGRESS COMMENTS	DEADLINE FOR COMPLETION
HDC 1.10: Application for change of title	HDC 1.10: Application for change of title	N/A	Design and testing of a computer program	
HDC 1.11: Release of thesis for examination	HDC 1.11: Release of thesis for examination	Release of this to University Library	Raw tabulations/draft analysis of qualitative data	
Analysis of data	Analysis of data	Analysis of data	Analysis of data	
Report up of findings	Report up of findings	Report up of findings	Report up of findings	
Presentation of final research finding(s)	Presentation of final research finding(s)	Presentation of final research finding(s)	Presentation of final research finding(s)	

CHAPTER 2: PHILOSOPHY AND MODELS OF MAINSTREAM RENEWABLE TECHNOLOGIES INCLUDES WIND ENERGY FACILITIES (WEF)

2.1 INTRODUCTION AND BACKGROUND OF WIND ENERGY FACILITY (WEF)

Not all of science's mysteries are as abstract as dark matter; some are as practical as finding a way to produce electricity. Since we know that fossil fuels are limited, we need to find a renewable and clean way to produce energy. We know how stars do it by splitting apart or fusing together molecules, but we have yet to find a way to safely reproduce it on a human scale. If we can find a way to create energy by splitting water into hydrogen and oxygen, we may have found the holy grail of renewable energy. Globally the is growing pressure on countries to increase their share of renewable energy generation due to concerns such as climate change and exploitation of resources. South African government has set a 10year cumulative target for renewable energy of 10 000GWh renewable energy contribution mainly from wind, solar, biomass and small-scale hydro generations (Savannah Environmental, 2017).

Wind Energy Facility, or wind farms as they are sometimes called, are clusters of wind machines used to produce electricity via natural wind. Most of WEF are not owned by public utility companies instead they are owned and operated by businesspeople who sell electricity produced on the WEF to public electric utilities. These private companies are known as Independent Power Producers (IPP) (Energy Information, 2018). Nearly 5000 years ago the ancient Egyptians used wind to sail ship on the Nile River then later people-built windmills to grind wheat and other grains. The earliest known windmills were in Persian country which called Iran today. According to (Dennis YC Leung, & Yuan Yang, 2017), furthermore, Chinese farmers started to use wind wheels with a vertical axis of rotation to drain rice fields, centuries before Europeans did so. However, the horizontal axis windmill was probably invented in Europe, and was first found in the year 1180 in the Duchy of Normandy. History of Wind generator or turbine machine was reported about 1887 by James Blyth, an electrical engineer to supply electrical power in his holiday home at Maryhill in United Kingdom (UK) (Ragheb, 2018). In 1887 Charles F. Bruch built the first operation wind machine to generator electricity (Ragheb, 2018).

Charles Bruch wind generator was a large machine with a rotor diameter of 17 metres and 144 rotor blades made of cedar wood. Bruch's turbine operated for 20 years charged batteries installed in the cellar of his mansion (Ragheb, 2018). Meanwhile, in the year 1888, the wind machine developed by Bruch and his colleagues was successfully put into operation on the Atlantic coast. From this moment forward, wind power technology began to develop step by step (Anon, 1890). Wind Energy Facility (WEF) to generate electrical power began to be used in about 120years ago and development of wind power has always fluctuated with oil prices (Dennis YC Leung, & Yuan Yang, 2017).

Years later the people of Holland advanced the elementary design of the windmill with propeller-type blades. In 1920s in United State small windmills were used to generate electricity in rural areas without electric service (Energy Information, 2018). In 1920, Kurt Bilau applied the Ventikanten blade, using an aircraft air foil that he and Betz developed, in a modern windmill design (Dennis YC Leung, & Yuan Yang, 2017). In the 1920s and 1930s, America extensively advanced small wind machine less than (1kW) and windmills without electrical systems in its rural areas. Throughout this era the prominence of windmills used reached its highest level in the US, with about 600 000 units installed (Deng Y, 2018).

According to (Hepbasli A, & Ozgener O, 2017), in 1941, a sample of the modern horizontal axis wind turbine was built in the US, and wind turbines were extensively used to deliver electricity to farms to which electric power lines could not reach. On the other hand, with the extensive growth of electric power lines, the wind turbine market was slowly reduced, beginning in the 1950s (Dennis YC Leung, & Yuan Yang, 2017). When investigative the improvement history of wind energy facility, it is clear that the popularity of wind energy has always varied with the price of fossil fuels. Since the oil crisis in the early 1970s, the price of oil increase rapidly, which led to a focus on wind energy facility development, and rapid increase of wind energy facility took place in mid 90s. In the last decade, wind energy facility experienced an increase in usage since the beginning of the 21st century, the world wind electricity generation capacity has doubled approximately every three and a half years (Ackermann T, & Der LS, 2017). A Wind Energy Facility (WEF) is the product of the wind air which is moving. The wind energy is a free and renewable energy source, and it is the world's fastest developing electricity resource (Genesis Energy, 2021). Around the globe most utility and electricity developers use wind turbine to catch the wind energy. This wind turbine catches wind through rotor blades that wind flows through the rotor blades then cause rotation of rotor blades and spin main shaft powering a rotor inside a generator and result to production of electricity.

The electricity flows through cables in the turbine, flows down the turbine tower and combines with the wind energy from the other wind turbines before entering the local electricity network or the national grid such as Eskom grid in the case of South Africa which provide power to South Africans (Genesis Energy, 2021). WEF may comprise of numerous wind turbines and cover a stretched area of hundreds of square kilometres. They can be offshore or onshore WEF and land were they normal get to be installed or established may be used for agriculture or other purposes.

WEF foundation holds the wind turbine in place in the ground. Wind turbine must have a strong foundation to handle strong winds and support the overall height and the length of the blades. The wind turbine is connected to a tower and generation equipment is kept in the tower. The tower elevates the blades and generation equipment high above the ground into the sky against stronger wind currents. Then the tower also contains nacelle and rotor. The nacelle is the heart of the turbine, or the cover housing that where the generating components in a wind turbine including generator, gearbox and rotor are held or assembled. The wind turbine uses wind to make electricity by the energy in the wind turns two or three blades which connected to the rotor shaft.

The rotor shaft then spins main shaft which spins a generator inside the nacelle to convert the wind energy into electricity energy (Tong, 2020). At most wind turbines have three blades that are connected to the rotor. The longer the blades and the faster the wind speed, the higher the possible output power. The blades are tested thoroughly to ensure that they will handle the most severe weather conditions expected at the wind energy facility. The term wind energy or wind power describe the process by which the wind is used to generate mechanical power or electricity. Wind turbines produce mechanical power from converting the kinetic energy from wind energy (US Department of Energy, 2017).

The earliest practical machines were developed in Persia around the tenth century, were based on rectangular sails rotating about vertical axes. Windmill technology subsequently spread through the Middle East into southern Europe and by the late twelfth century windmills were being built in England, Holland and Germany where horizontal axis machines were always preferred. Centuries ago, it would have taken brave person to predict today’s extraordinary renaissance of machines powered by the wind. Traditional windmills for milling grain and pumping water had been largely consigned to technological history, overtaken by electric motors fed from centralised power plants burning fossil fuel.

A curious twist of history large number of wind electricity grids for the benefit of us all and helping usher in a new age of renewable energy (Paul A. Lynn, 2019). The background to this renewable development is of course the massive redirection of energy policy that most research experts and politicians now agree is essential if we need to reserve our planet earth so it can survive the twenty-first century and beyond in reasonable shape. A huge effort is now under way to develop and install renewable energy systems that make use of natural energy flows in the environment including wind and sunlight, with a major contribution from large wind energy facility.

This is most simply matter of fossil fuel reserves, for it is becoming clearer as we progress to use fossil fuel that, even if those reserves were unlimited, we could not continue to utilise burning of fossil fuel with impunity. We have seen today the results of carbon dioxide emissions, the increase inability of the natural world to absorb emissions caused by the burning of what fuel remains leading accelerated global warning (Paul A. Lynn, 2019). In twenty-first century, there are still few people that had no idea must how the electricity they took for granted was produced or that the burning of coal, oil and gas was rapid results of global environmental problem such as global warming. Those who are aware tend to assume that the advent of nuclear power or energy would prove a solution or answer and even claimed that nuclear electricity would be so cheap that it would not be worth metering but as we now realise dangerously complacent (Paul A. Lynn, 2019).

The fossil fuel laid down by solar energy over hundreds of millions of years must surely be regarded as capital, but the wind that blow over the world’s land surfaces and oceans day and night, years and centuries are effectively free income to be used or ignored as we wish. This is a good moment to consider the meaning of renewable energy a little more carefully. The challenge for the future is to harness such renewable energy effectively, designing and creating efficient and hopefully inspiring machine to serve humankind without disabling the planet. Since the reduction of carbon emissions is a principal advantage of wind energy and other renewable technologies, we should recognise that these benefits are also proclaimed by supports of nuclear power. The renewables technologies give us the option of widespread, relatively small-scale electricity generation, but nuclear power must by its very nature continue the practice of building huge, centralised power stations.

Wind and solar need no fuel and produce no waste in operation, whereas nuclear power is beset by problems of radioactive waste disposal. While the whole renewable technologies pose no serious problem of safety or susceptibility to terrorist attack, advantage which nuclear power can hardly claim. And finally, there is the issue of nuclear proliferation and the difficulty of isolating civil nuclear power from nuclear weapons production. It is not surprising that most environmentalists are unhappy with continued development and spread of nuclear power, even though some accept that it is proving hard to avoid (Paul A. Lynn, 2019).

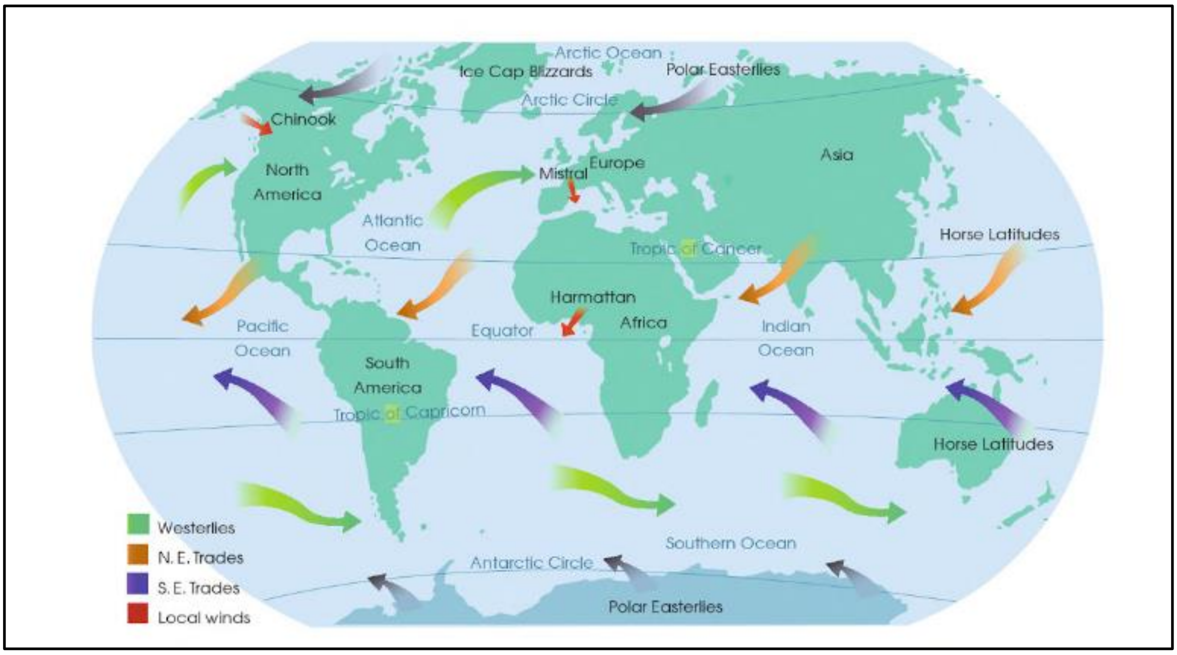


Figure 1: Wind patterns of the world (Paul A. Lynn, 2019).

In general, we see that the complexity of the world's major wind patterns, illustrated in Figure 1 above is the results of air rising over warmer areas of oceans and continents and subsiding over cooler ones. The effects occur at all scales over the global surface, from the vastness of the Atlantic, Pacific and Southern Oceans and the Sahara Desert down to mid-scale phenomena that generate famous winds such as the Mistral in France, the Chinook in North America and the Harmattan in West Africa. Having the Figure 1 in mind, conditions are often affected by hills and mountains, valleys, forests and variations in terrain, as well as by the time of day and season of the year. Coastal areas often experience "sea breezes" at night, powered by the fluctuating temperatures over land and sea as planet earth spins on its axis.

2.1.1 General Operation of Wind Energy Facility (WEF)

First, it’s useful to go back to basics and explain how a wind turbine works. As the wind turns the carbon-fibre blade on the unit, a motor turns, which turns Kinetic energy into electricity. This energy is transferred to the gearbox, which converts the slow speed of the spinning blades into higher-speed rotary motion—turning the drive shaft quickly enough to power the electricity generator. Two major things for WEF operation must be considered location to establish or build WEF, how fast and how much the wind is blowing in that area. Operating a WEF is not as simple as just building a windmill in a wind place there is a lot of technical that need to be considered. Wind Energy Facility or Wind Farms as they are sometimes called, are clusters of wind machine used to produce electricity. WEF usually has dozens of wind machines scattered over a large area. The world largest WEF or wind farm, the Horse Hollow Wind Energy Centre in Texas, has 421 wind turbines that generates enough electricity to power 220 000 home per year (Energy Information, 2018).

Generally, economic wind generators require windspeed of 4.5 m/s (16 km/h) or greater. An ideal location would have a near constant flow of non-turbulent wind throughout the year, with a minimum likelihood of sudden powerful bursts of wind. An important factor of turbine siting is also access to local demand or distribution capacity. Usually, sites are screened based on a wind atlas and validated with wind measurements. Meteorological wind data alone is usually not sufficient for accurate siting of a large wind power project. Collection of site-specific data for wind speed and direction is crucial to determining site potential (EWEA, 2018).

Like in the old-fashioned windmills, today’s wind turbines use blades to collect the wind’s kinetic energy. Wind turbine work because they slow down the speed of the natural wind. The wind flows over the air foil shaped blades causing lift, like the effect on airplane wings, causing them to turn. The blades are connected to a drive shaft that turns an electric generator to produce electricity (Energy Information, 2018). As a rule, wind speed increase with altitude and over open areas with no windbreaks. Good area sites for WEF are the tops of smooth rounded hills, open plain or shorelines and mountain area gaps that produce wind funnelling. Keep in mind that wind varies throughout the country or Eastern Cape region, and it varies from season to season.

The operate of WEF depends on the following most important variable factors:

- Amount of air/wind (in volumes)
- Speed of air/wind (velocity)
- Mass of air/wind (density)

Which is flowing through where WEF is establish or built. Important thing to consider is how fast and how much the wind blows. According to as a rule, wind speed increases with altitude and over open areas with no windbreaks. Excellent sites for WEF are the tops of smooth, rounded hills, open plains or shorelines, and mountain gaps that produce wind funnelling (US Department of Energy, 2017). Choice of a suitable capacity factor for wind-powered energy in South Africa is not a simple exercise, since it is a purpose of not only the rotor blade and generator, but of the local wind resource (Sager, 2017, p. 27).

Wind energy technologies have moved far beyond the small multibladed machines that pumped water and powered direct current appliances in the 1930s and 1940s to become multimegawatt power plants that power thousands of homes today (U.S. Departmental of Energy, 2018, p. 5). Once adequate information is obtainable from an environmental and planning perspective for the broader site, then detailed siting exercise will be undertaken to effectively 'design' the wind energy facility within the site-specific studies and assessments through the EIA. In order to delineate areas of sensitivity within the broader area. Through the process of determining constraining factors, the layout of the wind energy facility and infrastructure can be planned. The overall aim is to maximise electricity production through exposure to the wind resource, while minimising infrastructure, operation and maintenance costs, and social and environmental impacts (Savannah Environmental, 2017).

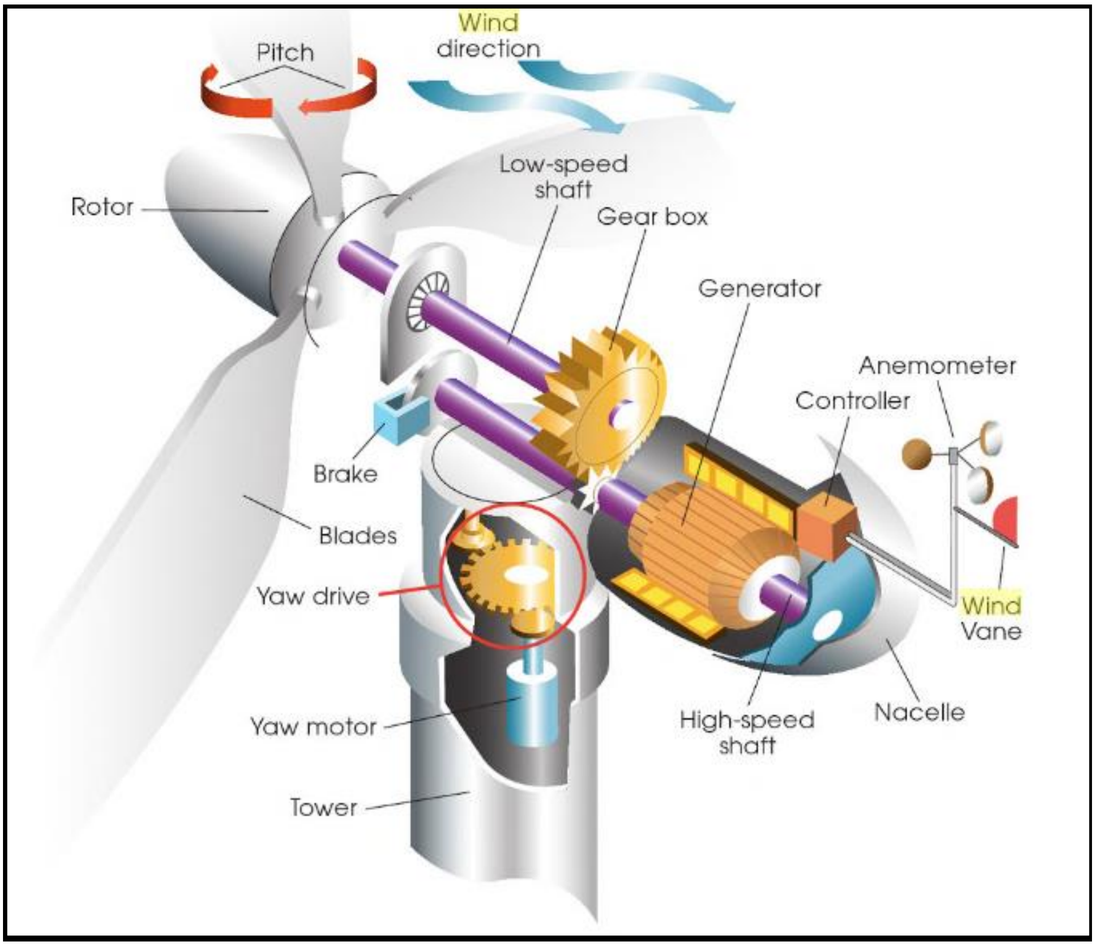


Figure 2: Main components of a typical modern high-power wind energy facility turbine (Paul A. Lynn, 2019)

Many turbines design and configuration have been tried and tested over the years, including one-bladed and two-bladed rotors mounted upwind and downwind of the support tower, and a variety of vertical axis machines. However, most today's large turbines are horizontal axis machines with a three-bladed rotor upwind of the tower, supported by a housing or nacelle, containing gearbox and electrical generator. The wind energy turbine shown on Figure 2 is a typical layout of main components. The rotor is kept facing the wind or deliberately turned aways it from it by a yaw motor, and a brake is provided to prevent rotation, for example during maintenance. Wind speed is measured by an anemometer and the main blades are swivelled to vary their pitch, controlling or limiting the amount of power captured as the wind varies (Paul A. Lynn, 2019). This research is concentrated on the development of large wind energy facility turbines, but smaller machines suitable for individual homes, farms and leisure applications have a parallel history and their total impact on electricity generation is very modest compared with today's large wind farms, they are highly valued by individuals and organisations wishing to generate relatively small amount of electricity in remote locations, and are well describe elsewhere (Paul A. Lynn, 2019).

2.1.2 Current status of Wind Energy Facility around the globe

According to (Dennis YC Leung, & Yuan Yang, 2017), over the past two decades, the world's wind energy facility generation capacity has been increasing quickly, with an average annual growth of about 30% see figure below:

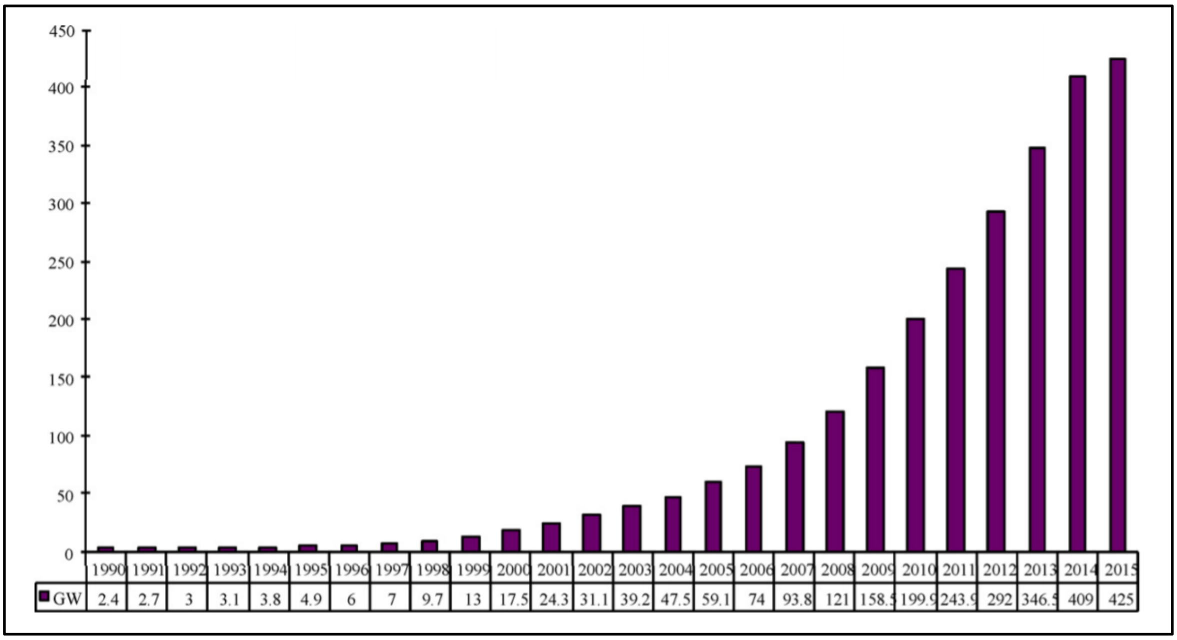


Figure 3: Global Wind Energy Facility installed capacity from 1990 to 2015 (ABS Energy Research, 2018)

Figure three, shows the global wind power capacity installed between 1990 and 2015 (estimated for the installed capacities from 2010 to 2015). It indicates that at the end of 2009, the world wind energy's installed capacity reached 158 GW, a 31% increase over 2008. According to the data published by the World Energy Association, at the end of the first half of 2010, the installed capacity reached 175 GW, and it is estimated that the capacity will hit 292 GW by 2012 and 425 GW by 2015 (ABS Energy Research, 2017) and (Synergyst, 2018). The top five market contributors of the global installed wind energy facility capacity are China, the US, Germany, Spain and India, respectively. The following section will give a brief overview of wind power installed capacity and outlook in these five leading countries. Figure 7 below shows the installed capacity data of the five leading wind power countries between 2001 and 2017, which clearly demonstrates their development trends and speeds over the past decades (Dennis YC Leung, & Yuan Yang, 2017).

As of the end of 2016 the global total increases installed electricity generation from wind energy facilities amount to 487 657MW, an increase of 12.5% compared to the previous year (2015). Wind energy facility installations increase by 54 642MV in 2016, 63 330MW in 2015, 51 675MW in 2014 and 36 023MW in 2013 (GWEC, 2019). Below is Figure 4 showing graph of the global annual growth of wind energy facility:

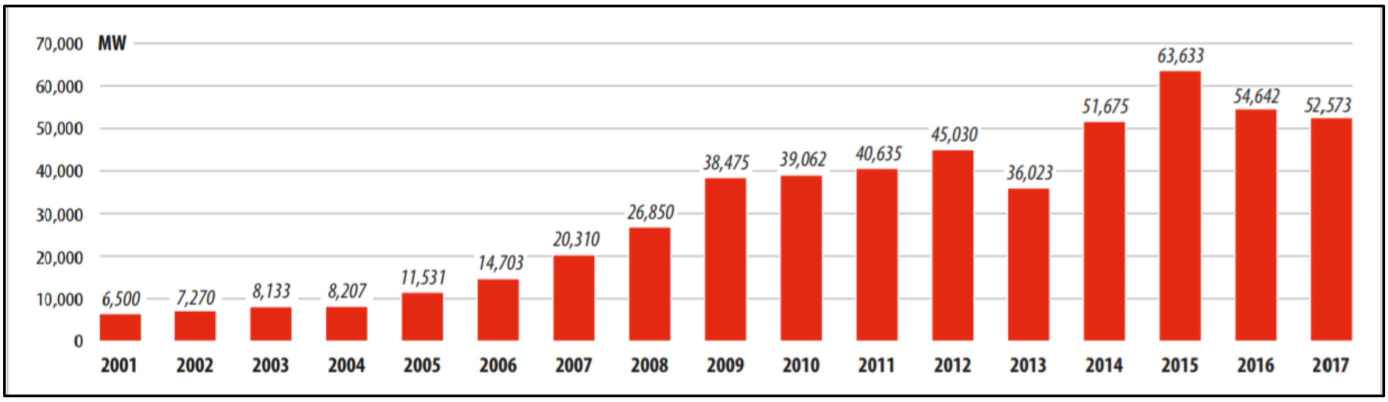


Figure 4: Global annual installed Wind Energy Facility capacity accumulative (GWEC, 2018).

As of 2011, 83 countries around the world are using wind energy facility on marketable basis. Continuously since 2010 more than half of all new wind energy facility was added outside of the contemporary markets of North America and Europe, it was mainly driven by continuing boom in the emerging countries such as BRICS mainly China and India. At the end of 2015 China installed close to half of the globe's added wind energy facility capacity (REN21, 2018).

As of the end of 2017 the global cumulative total increase installed renewable energy generation from wind energy facilities amount to 539 581MW, an increase of 9.6% compared to the previous year (2016) and an increase of 11.3% from 2015 to 2016. Below is figure 5 showing the graph the global cumulative installed wind energy facility:

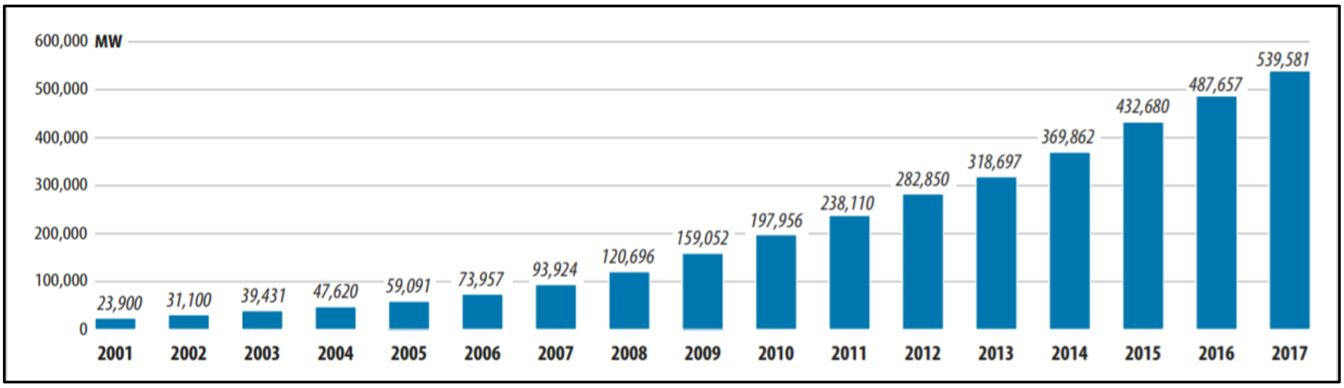


Figure 5: Global annual installed Wind Energy Facility capacity accumulative (GWEC, 2018).

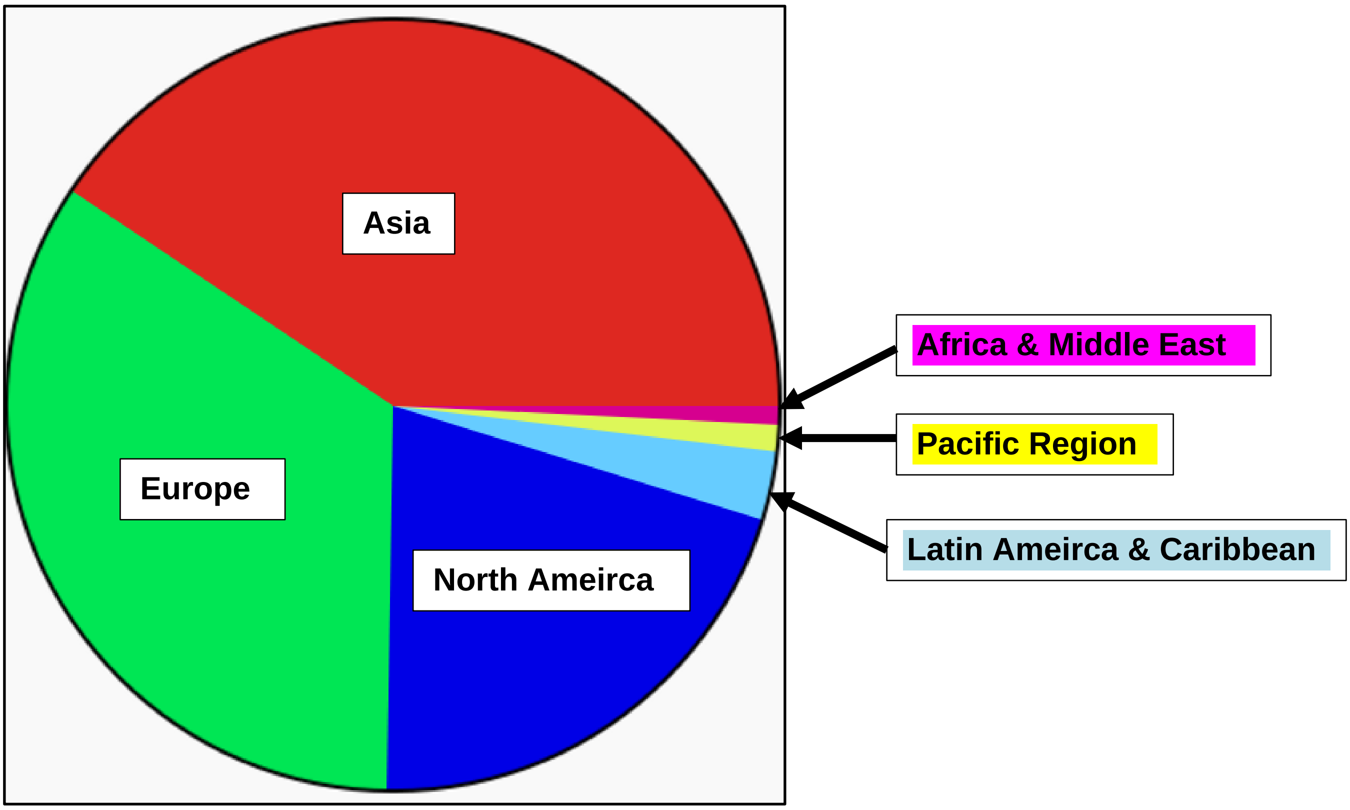


Figure 6: Wind Energy Facility installed by global regions in 2017 (GWEC, 2018).

In Figure 6: Asia is leading 42.4% wind energy capacity of 228 542MW, Europe second 33.0% wind energy capacity of 178 096MW, third place North America with 19.5% with 105 321MW, fourth place region is Latin America and Caribbean with 3.3% wind energy capacity of 17 891MW, Pacific region fifth 0.85% wind energy capacity of 5 193MW and last region Africa and Middle East with 0.84% of wind energy capacity of 4 538MW.

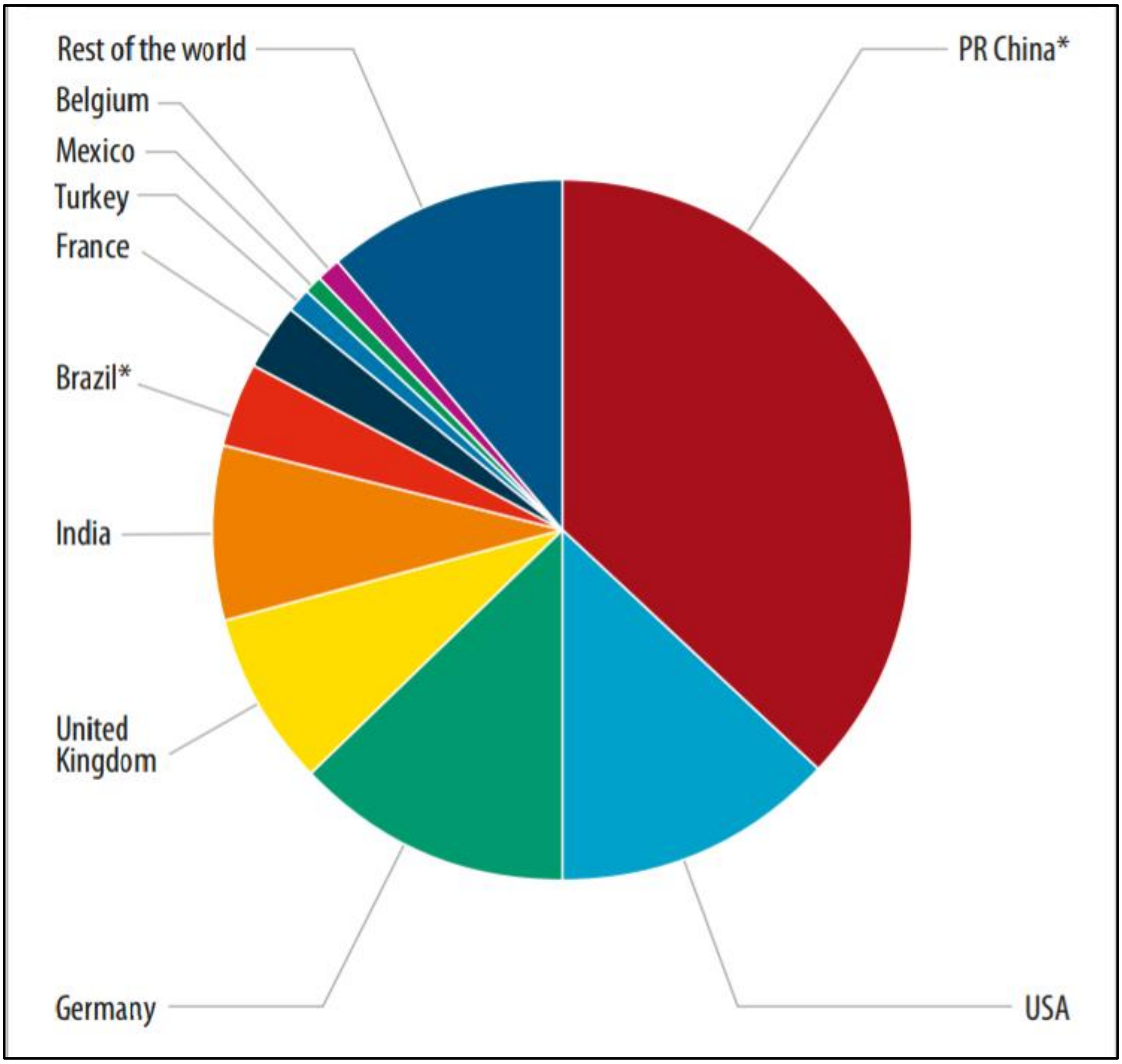


Figure 7: Installed capacity of wind energy facilities in the current top ten countries (GWEC, 2018)

2.1.3 Current status of Wind Energy Facility in South Africa

South Africa has a high level of Renewable Energy potential and in line with the national commitment to transition to a low carbon economy, 17 800MW of the 2030 target (according to the IRP 2010) of newly generated power to be developed are expected to be from renewable energy sources, with 5 000MW to be operational by 2019 and a further 2 000MW (i.e., combined 7 000 MW) operational by 2020. As of April 2016, of the 7000MW target for 2020, an amount of 6400MW from 102 IPPs has been procured from Bid Windows 1 to 4 and 1S2 (Smalls Programme). By end October 2016, 2.8GW of the procured capacity from 53 IPPs had already started operations. All the projects in BW1 and BW2 are connected and are delivering power to the grid. Projects in BW 3, depending on the individual project's construction period, are all progressing with some projects already grid connected and the rest to follow. The REIPP programme is not only contributing to alleviating the electrical energy shortfall in South Africa but has been designed so as to also contribute towards socio-economic and environmentally sustainable growth, and to start and stimulate the renewable industry in South Africa In terms of this IPP Procurement Programme, the Bidders will therefore be required to bid on (Department of Energy, 2018):

- tariff; and
- the identified socio-economic development objectives of the Department.

A wide range of technologies fall under the category of generation. These technologies include fossil fuels, hydro, fuel cells, land fill gas, wind, geothermal, solar and co-generation. The different technologies operate under different conditions and utilize different machinery. Generation technologies utilize synchronous generators, induction generators or power electronic inverters to generate electricity into the network. Generating plants using fuel sources other than fossil fuels are generally referred to as renewable generating plants. If the installed capacity of generating plants is considered by the utility in energy and capacity planning, the availability and reliability of the energy source must be considered. The availability of power from wind turbines is variable Landfill gas turbines, geothermal and reciprocating engines are more variable sources of energy, but still require shutdowns for maintenance (planned outages) and do experience breakdowns (unplanned outages). The reliability of hydropower turbines is also inherently very high, but energy availability depends greatly on the pattern of water flow. For back-pressure steam turbines, where the steam from the generating turbines is used in an industrial process, the amount of generation is usually dictated by the steam requirements of the industrial process, which may vary during different times of the day.

Table 5: Examples of the available energy source and corresponding technologies in South Africa

Energy Source	Technology
Coal	Steam Turbine
Oil	Steam Turbine
Wind Energy	Induction generator or synchronous generators
Solar Photovoltaic	AC/DC Inverter
Solar CSP	Synchronous generators

Energy Source	Technology
Water flow	Hydropower
Methane gas	Gas fired steam turbine
Farming waste	Back-pressure turbine
Sasol gas	Gas reciprocating engine
Coal gasification	Fluid bed combustion
Municipal waste	Back-pressure turbine

The tariff will be payable by the Buyer pursuant to the PPA to be entered into between the Buyer and the Project Company of a Preferred Bidder. The Project Company will pursue set economic objectives as agreed to in terms of the Implementation Agreement (IA) entered between the Department of Energy on behalf of the Government of South Africa and the Project Company of the Preferred Bidder. The following technologies shall be considered as qualifying technologies for selection under this IPP Procurement Programme (Department of Energy, 2018):

- onshore wind
- concentrated solar thermal
- solar photovoltaic
- biomass solid
- biogas
- landfill gas
- Small hydro

The generation capacity allocated to each Technology is in accordance with the Ministerial Determinations and set out in the below table. The maximum tariff that a Bidder may bid for purposes of the IPP Procurement Programme is as set out in the RFP (Department of Energy, 2018).

Table 6: Generation capacity allocated to different Technologies

Technology	Mega Watts (MW)
Onshore Wind	6 360MW
Concentrated Solar Thermal	1 200MW
Solar Photovoltaic	4 725MW
Biomass	210MW
Biogas	110MW
Landfill Gas	25MW
Small Hydro	195MW
Small Projects	400MW
Solar Parks	1 500MW
TOTAL	**14 725MW**

Each Facility procured in terms of this IPP Procurement Programme will be required to achieve commercial operation by not later than the dates set out in the RFP. Based on the IRP 2010, the Ministerial Determinations and any future integrated resource plans issued from time to time, the REIPPP Programme is designed to be of a rolling nature. Determined MW s will be procured through a continuous programme of bid windows timed as such to ensure at least one bid window every year or subsequent year prompted by the release of a specific Request for Proposals (RFP) in the market. This rolling nature also balances Government's objectives as regards to security of supply and renewable energy targets with the technical and commercial constraints faced by potential bidders, and having regard to constitutional requirements of fairness, transparency, equitability, competitiveness and cost-effectiveness. An RFP contains all the required information and criteria to participate in the tender process. The tender process is open and transparent and strict adherence to governance is paid with a team of independent evaluators assessing the bids. The award of Preferred Bidder status is a competitive process with strict qualification and evaluation criteria. The evaluation of Bid Responses is normally conducted in two stages:

In the **first stage** all Bid Responses are assessed in order to determine whether they are Compliant Bids. A Compliant Bid is a complete Bid Response if firstly submitted as is required in terms of the guidelines and criteria set out in the RFP and secondly meets or exceeds the threshold requirement in respect of every applicable Qualification Criterion.
The Qualification Criteria are divided into the following umbrella categories:

- Structure of the Project;

- Legal Criteria and Evaluation;
- Land Acquisition and Land Use Criteria and Evaluation;
- Environmental Consent Criteria and Evaluation;
- Financial Criteria and Evaluation;
- Technical Criteria and Evaluation;
- Economic Development Criteria and Evaluation; and
- Value for Money

The threshold requirement in respect of each Qualification Criterion is described in detail in the RFP.

In the **second stage**, Compliant Bids will be evaluated on a comparative basis, per Technology, in relation to Price and Economic Development. The RFP provides potential bidders of all the required information, guidelines and criteria for bid submission. The Department will release an RFP in the market with sufficient time to allow potential bidders to finalise projects for bid submission. Once a new bid window and the release of the RFP have been announced, the RFP will be published on the Department’s website. Prior to accessing the RFP, each prospective Bidder shall be required to pay a non-refundable fee of R15 000 (fifteen thousand Rand) per Bidder, and to complete the registration form. Once the registration fee is paid a potential bidder will have access to the newly released RFP, but also to all previous RFPs and bid information. A potential bidder will also be updated via briefing notes of any new developments, important information on the bidding process and key dates around the bid submission process, etc (Department of Energy, 2018).

2.1.3.1 People Republic of China as leading WEF producer

In 2010, emerging countries such as China, India, Brazil and South Africa has increased rapidly the wind energy facility installations such that China surpassed the United State (US) as the leading producer of wind energy facilities in the world, now China has by far the world’s biggest wind energy facility sector. China accounts for 34.9% of the global total of wind energy facility (GWEC, 2018). China hitting a total of 188 232MW, adding 19 500MW over the year, a 10.4% increase over 2016. Wind energy has grown spectacularly in recent years as per figure one indicates and China in 2014 install new wind energy facility capacity of 45% (GWEC, 2018). It is not surprising that emerging country like China replaced the United States as the biggest wind market, because China's total installed capacity has doubled every year from 2006 until today (Dennis YC Leung, & Yuan Yang, 2017).

Furthermore, China as emerging country, the source of wind energy is abundant in China, which is now second to the capacity of the US. The total exploitable capacity of China for both onshore and offshore wind energy is around 700–1200 GW, according to the third National Wind Energy Resources Census (Xu J, He D, & Zhao X, 2018). China land mass and long coastline country has excellent potential wind energy facilities. China started to make use of wind energy facility in mid 1970s. Though, its use of wind energy facility advanced gradually until mid-2000s, when "The Renewable Energy Law of China" was issued. China's wind energy facility market then experienced an improvement, and its total installed capacity extended to 12 GW at the end of 2008, a growth of 8.6 percent (%), over its capacity in 2005. With its quick and apparently unrestricted expansion, the next goal of the Chinese wind energy facility market is to reach 90 GW by 2015 and 200 GW by 2020, in which year China also plans to build an independent technical system.

It is hoped that wind energy facility will also play a major part in China's energy structure in the middle of 21st century (Dennis YC Leung, & Yuan Yang, 2017). 2015 marked another record year for China's wind energy facility sector. With installations of 30.75 GW, representing 32.6% annual market growth, China consolidated its leading role in the global wind energy facility market. This brings cumulative installations to 145.4GW, up 26.8% from 2014. China accounted for 48.6% of global installations in 2015 and has 33.6% of cumulative installations globally (GWEC, 2019).

2.1.3.2 Unite State (US) as a second leading WEF producer

United States of America (USA) is the second in wind energy renewable installation with 89 077MW which is 17% of global wind energy facilities (GWEC, 2018). As of 2014, the United States boasted a wind energy capacity of 65 879MW. The US wind energy sector has had an average annual growth of 25.6% over the past decade. The US added 4,854MW of new wind energy facility capacity in 2014, considerably down compared to previous years and less than a quarter of what China added same year. Wind energy facility sector generates about 4.4% of the country's electricity, although in five states, including Iowa and Minnesota, the level is over 10%. Texas has the biggest wind energy facility capacity. If the state of Texas were a country on its own, it would be the sixth biggest wind energy producer in the world (GWEC, 2018).

2.1.3.3 Germany as a third leading WEF producer

Germany is the third in wind energy renewable technology installation with 56 132MW which is 10% of global wind energy facilities (GWEC, 2018) In 2014, Germany had 39 165MW of wind energy facility capacity, 10% of the global total. It was second only to China in terms of new capacity added in 2014, installing over 5 000MW. Wind energy facility sector accounted for about 9% of the country’s total generated electricity in 2013. In some northern states the proportion is as high as 40%. In April 2010, Germany opened its first offshore wind energy facility park, called Alpha Ventus, in the North Sea. Offshore wind is seen as a major growth area for a government that wants to see 76,000MW of wind energy facility installed by 2020. One challenge is the lack of grid connections from the North Sea coast to the major markets of southern Germany (GWEC, 2019). Although the rate of onshore installations decreased by 19%, Germany had a strong year adding 3,731MW of onshore capacity in 2015. The number of turbines dismantled accounted for a combined capacity of 195MW, down 46% from 2014. Meanwhile, repowering accounted for 484MW in 2015.

2.1.3.4 Spain as a fourth leading WEF producer

Spain is the fourth in wind energy renewable installation with 23 170MW which is 4% of global wind energy facilities (GWEC, 2018) Spain with an installed capacity of 22,987MW in 2014, In 2014 Spain was ranked fourth among the world’s top wind energy producing countries. However, Spain's wind sector has stagnated in recent years. Capacity has increased just 1,300MW since 2011. In 2009, electricity from wind energy facility overtook coal as an energy source and by 2014 wind power satisfied around 21% of the country’s electricity needs, trailing only gas and nuclear power.

2.1.3.5 BRICS countries as leading WEF sector (Excluding Russia)

According to (GWEC, 2018) estimates that the measurement and rapid of wind energy facility growth in China cannot be compared to any other country. With more than a dozen turbine manufacturers, the wind energy facility sector has become one of the key development components of the country’s economy. The first permanent magnetic floating wind turbine, which allows electricity production even at low wind speeds, was developed by Chinese manufacturers (GWEC, 2018). Among the major wind energy facility production and consumption countries in the world, Brazil, Russia, India, China and South Africa (the BRICS) take an essential position in the global economy, thus renewable energy policies making, and implementation is particularly remarkable. Emerging countries (BRICS) in terms of influence on the world economy, had an average growth rate of 7.1% in 2016. In 2015, the share of BRICS countries in global GDP accounted for 30.2%, and the volume of global trade accounted for 17.1%, 13% of the global services market. As of 2015, the five BRICS countries represent 3.6 billion people which is 40% of the world population which contribution to world economic growth rate over 22% (BRICS, 2020).

2.1.3.6 India as fifth global leading WEF producer

According to Global Wind Energy Council (GWEC) 2017 report India is the fourth in wind energy renewable technology installation with 32 848MW which is 6% of global wind energy facilities (GWEC, 2018). The second BRICS countries in installing new wind energy facility is India, by supporting renewable energy policies in 2003, India achieved great energy returns in 2010 by adding new wind energy facility installations of 2.1 GW. India reaches a total of 13.1 GW at the end of 2010; this put India in fifth place as a global producer of wind power (Dennis YC Leung, & Yuan Yang, 2017). India is fast catching up with Spain, despite being a relative newcomer to the wind energy facility sector. In 2014, India had 22,465MW of wind energy facility capacity, having added 2,315MW during the year. Wind energy facility sector accounts for less than 2% of the country's electricity. The increasing performance of turbines has made wind energy facility sector a favoured choice, however, and so wind energy in the country still accounts for about 8.5% of total installed power capacity. The Indian Wind Energy Association estimates that electricity generation capacity could reach 65,000MW.

2.1.3.7 Brazil Wind Energy Facility Sector

In Latin America and the Caribbean region Brazil continue to lead in Wind Energy Facilities installation. According to Global Wind Energy Council (GWEC) 2017 report India is the third in wind energy renewable technology installation with 12 763MW which is 2% of global wind energy facilities (GWEC, 2018). Brazil is a new player into the premier league of wind energy facility producers, but with 5,939MW of installed capacity, nearly half of that added in 2014 alone, the country is making major efforts to diversify its energy power sector which is heavily reliant on hydropower. The Brazilian Wind Energy Association and the government have set a goal of achieving 24GW of wind energy facility capacity by 2024. The country's windy coastline makes it an ideal location for wind energy facilities. Brazil has some of the best wind resources in the world, exceeding the country's current electricity needs three times over. This year Brazil's wind generation record was broken by producing 10% of the national electricity demand on 2 November, showing the excellent operational performance of wind power in Brazil (GWEC, 2018).

2.1.3.8 Republic of South Africa (RSA) Wind Energy Facility Sector

Republic of South Africa has the world's seventh largest coal reserves, and coal supplies about 77% of South Africa's primary energy, followed by oil and solid biomass and waste. South Africa's energy balance also includes relatively small shares of natural gas, nuclear, and hydroelectricity. South Africa's dependence on hydrocarbons, particularly coal, has made the country the world's 13th largest CO^2 emitter (GWEC, 2018). The maintenance of the coal power generation fleet has been challenging and capacity factors are down to about 70%, leading to regular electricity shortages, which could be eased by rapid deployment of renewable energy, especially wind energy facilities. Historically, South Africa had very low electricity prices, but in recent years they have been rising quickly. The REIPPPP is bringing renewable energy to the National grid fast and cheaper than new-build coal. Construction times for projects average less than two years, and the electricity price paid to projects has declined 68% within three years (GWEC, 2018).

According to Global Wind Energy Council 2017 report South Africa is rank number one in Africa and Middle East region in terms of wind energy renewable technology installation with 2 094MW which is 0.4% of globally and 46.1% in Africa and Middle East region in terms of wind energy facilities (GWEC, 2018). In 2014, South Africa installed 483MW of new capacity, for a cumulative capacity of 1,053MW by end of 2016 has installed 1 473MW of wind energy renewable technology. This is just the beginning of a promising wind market in the region, which has surpassed 1GW in just two years. With bidding for the first four rounds of South Africa's Renewable Energy Independent Power Producer Procurement Programme (REIPPPP) completed, and after three rounds of preferred bidders have reached financial close, the wind industry has established itself as a major new infrastructure sector and is now worth about ZAR 75 billion (EUR 4.3/USD 4.9 bn). The first three rounds of the REIPPPP totalling 1984MW have reached financial close. Financial close for another 1,363MW (REIPPPP Round 4(a) and (b)) is pending while the preferred bidders for the Expedited REIPPPP Round 4, with at least 800MW, are expected to be announced shortly.

South Africa has excellent wind resources, which are yet to be fully utilised. Upscaling renewables development in the country has become a necessity, as renewable energy is the only source of new power that can be deployed fast enough to help ease South Africa's chronic electricity shortages. The Integrated Resource Plan has a goal to develop 9,000 MW of wind power by 2030. However, the South African Wind Energy Association expects this figure to be exceeded by a wide margin and projects about 15,000 MW to be installed by 2030. The IRP blueprint will be updated in the course of 2016. It is understood that the IPP Office has allowed some applications to sell equity in the REIPPPP Projects (there is usually a three-year lock-in clause). This has started to open the door for a secondary market in South Africa. The procurement rules include a strong government ambition to create a high level of local content, with an incentive to boost employment and to support local communities.

The price of wind energy in the last Round 4 expedited was ZAR 0.62/kWh (EUR 0.045/USD 0.047) more than 40% less than forecast prices for Eskom's new-build coal plants Kusile and Medupi. In 2015, a new report by the Council for Scientific and Industrial Research (CSIR) showed less-than-zero costs for renewable energy to the country. According to CSIR, wind and solar power combined saved ZAR 4 billion from January to June 2015. Wind energy produced net savings of ZAR 1.8 billion and was also cash positive for Eskom by ZAR 300 million.

According to the Energy analyst Chris Yelland, the cost of renewable energy had fallen significantly, and it was now cheaper than new coal and nuclear projects. South Africa relies on coal-fired plants for more than 80% of its electricity generation, while renewables contribute around 7%. Eskom is one of the world's largest producers of greenhouse gases (Yelland, 2018). South Africa's renewable energy power programme was the fastest growing in the world seven years ago, attracting $15 billion of investment into wind farms and solar projects involving a cluster of new Independent Power Producers (IPPs) backed by foreign investment. Over the past two years (2015-2017) Eskom stopped signing renewable energy contracts and focused instead on a plan to build a fleet of nuclear power plants, in a deal that some members of the African National Congress (ANC) and rights groups said would be open to corruption. Key barriers tow Wind Energy Facilities (WEF) development in South Africa the following are some of remaining obstacles to the Wind Energy Facility industry include:

- The problems and political challenges surrounding relying on South Africa's sole utility provider to provide Power Purchase Agreements and grid connections.

- The extensive works to facilitate grid integration are under the responsibility of the country's power utility, Eskom, who had previously subsidized the associated costs. However, these costs are now increasingly being transferred to project developers resulting in more costly projects. Additionally, extended transmission and distribution works are needed, and the cost recovery rules for this are not yet transparent or consistent. This issue is currently being addressed by the South African Renewable Energy Council through the Grid Code Advisory Committee.

- The costs involved in tendering for the procurement programmed are high and create a challenge for smaller players.

- South Africa's economy is stagnating, and exchange rate fluctuations cause challenges to the REIPPPP by exerting upward pressures on bid prices. It also creates challenges for foreign investors hoping to evacuate hard currency from South African projects. A change in the sovereign credit rating may impact on the risk premium foreign investors require

Outlook for Wind Energy renewable technology in South Africa if the current impasse can be overcome, which looks likely, the wind industry in South Africa can pick up its very rapid growth phase from where it stalled. The country's chronic power shortages and the large boost in allocation for renewable energy in the revised IRP mean that the REIPPP is likely to be expanded once more. South Africa is moving towards a large wind industry with a domestic installed capacity in excess of 6,000 MW by 2020, if not sooner, and an allocated one of at least 37,000 MW by 2050 if the draft IRP is made policy (GWEC, 2018). The leading turbine suppliers in wind industrial in South Africa Wind Energy Facilities (WEF) are Vestas, Siemens, Goldwind and Nordex.

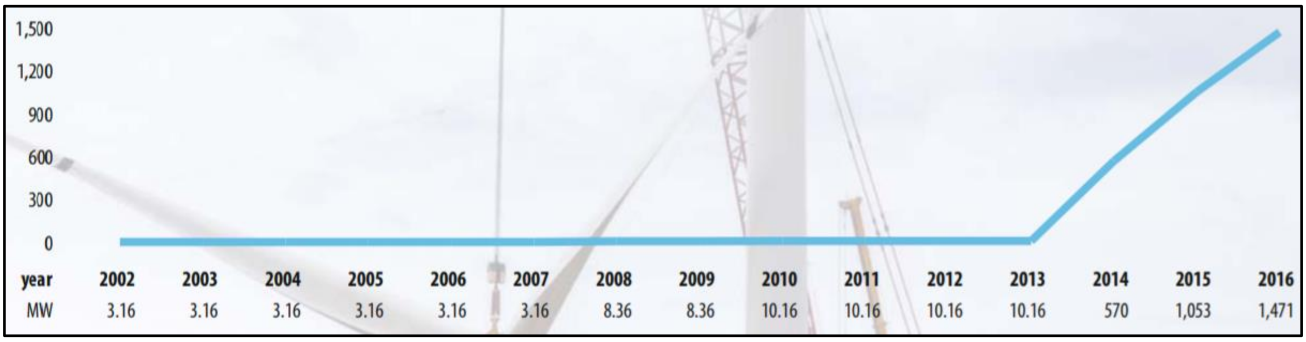


Figure 8: Total installed capacity of wind energy facilities in South Africa (GWEC, 2018).

2.1.4 Background of Onshore and Offshore Wind Energy Facility

Wind farms can be based onshore (on land) or offshore (sea or freshwater), with key differences between the two. The wind has played a long and important role in the history of human civilization. Since earliest recorded history, wind power has been used to move ships, grind grain and pump water. There is evidence that wind energy was used to propel boats along the Nile River as early as 5000 B.C. The western world discovered wind power much later. The earliest written references to working wind machines date from the 12th century. These were used for milling grain. Windmill performance was continuously improved between the 12th and 19th centuries (Erdogdu, 2017). By the end of the 19th century, the typical European windmill used a rotor of 25min diameter, and the stocks reached to 30m (Sahin, 2018). The first person, who generated in 1891 electricity from wind speed, was the Dane Poul LaCour, who lived in Denmark. The popularity of using the energy in the wind has always fluctuated with the price of fossil fuels. When fuel prices fell after World War II, interest in wind turbines disappeared. With the oil crises in the beginning of the 1970s, interest in wind power generation resumed (Dismukes JP, Miller LK, Bers JA, 2017).

The wind technology has improved step by step since the early 1970s. Before the 1980s, several experimental turbines had been erected, but there were no commercial wind farms and no industry to manufacture the hardware. In the 1980s, the first wind farms were built in California (EWEA, 2018). By the end of the 1990s, wind energy has re-emerged as one of the most important sustainable energy resources. Today, it is the leading source of renewable electricity, and it becomes an international business sector, spreading beyond its original markets in a few European countries, India and the United States. The major manufacturers and project developers now operate across five continents. Over 80 countries around the world now contribute to the global total (GWEC, 2018).

The first thoughts of locating wind turbines offshore came immediately after 1930 when it was suggested that wind turbines be placed on pylons. Although these suggestions were never used, they made a promising start and in 1972, approximately 40 years after the original idea, Dr. William E. Heronemus, professor at M.I.T. University introduced the idea of large floating wind turbine platforms in order to produce electrical energy. In 1990, 18 years after the time that Professor William E. Heronemus first had his vision for the construction of floating wind turbines, a company called 'World Wind' constructed and installed the first offshore wind turbine at sea. This offshore wind turbine was located in Nogersund, 250m offshore, in 7m water depth off the North part of Sweden and had a rated power of 220kW (Nikolaos, 2004).

In 1991, at Vindeby in Denmark and at a distance of 2.5km offshore, the first large commercial offshore wind farm was constructed, having a rated power of 4.95MW and consisted of 11 Bonus wind turbines of 450kW each. The water depths at that site are from 2.5 to 5m and the annual energy production is equal to 12 GWh/year. In 1995, Denmark constructed its second offshore wind farm at Tuno Knob. This offshore wind farm has a power output of 5MWand consists of 10 Vestas wind turbines of 500kWplaced at water depths between 0.8 and 4mand the annual energy production is equal to 16 GWh/year (Nikolaos, 2004). The next Danish offshore wind farm was constructed in the port of Copenhagen. Basically, this was the first large offshore wind farm with a rated power of 40MW. It includes 20 Bonus wind turbines of 2MW each that are placed at a distance of 3 km offshore and at a water depth of between 5 and 10 m. Middelgruden, as it is called, had a total cost of 54 million Euros and construction ended in 2000. Netherlands is the country that developed offshore wind farms immediately after Denmark. In 1994 at a site called Lely, the first sea environment wind farm for Netherlands was constructed at water depths between 5 and 10m with a rated power of 2MW and consisting of four 500kWNedwind wind turbines. Two years following the end of the construction of Lely's wind farm in a region called Irene Vorrink in the same lake, the second wind farm of 16.8MW was constructed (Mehmet Bilgili, Abdulkadir Yasar, & Erdogan Simsek, 2018).

Wind energy can be deployed rapidly, as turbines and wind plants are quick to install. It is the cheapest way of renewable energy, which encourages investment. It also creates benefits in terms of employment, investment, research, economic activity and energy independence in the electricity sector (Mehmet Bilgili, Abdulkadir Yasar, & Erdogan Simsek, 2018). Furthermore, it is well known that wind energy is one of the cleanest and most environmentally friendly energy sources, and unlike fossil fuels, the wind will never be depleted. All forms of energy production have an environmental impact, but the impacts of wind energy are low, local, and manageable. These environmental impacts are negligible when compared with conventional energy sources. The significance of wind energy originates from its friendly behaviour to the environment. Due to its clean, wind power is sought wherever possible for conversion to electricity with the hope that air pollution from fossil fuels will be reduced (Sahin, 2018).

There are different alternatives for wind energy such as onshore and offshore. Onshore, wind energy has been utilized for power generation for more than two thousand years. On the other hand, the history of offshore wind power generation is fairly recent. In recent years, the wind power sector has begun to move offshore, i.e., to use space and good wind speeds on the open sea for large scale electricity generation (Petersen & Markard, 2018). Offshore wind farms are constructed in general on the continental shelf area which is about 10km away from the coast and 10m deep. Compared with land, offshore wind turbines must be fixed on the seabed, which demand a more solid supporting structure. Submarine cables are needed for transmission of electricity, and special vessels and equipment's are required for building and maintenance work. These factors create high costs, with double or triple the cost on land (Zhixin W, Chuawen J, Olian A, Chengmin W, 2017).

Offshore wind turbines are less obtrusive than turbines on land, as their apparent size and noise can be mitigated by distance. Because water has less surface roughness than land (especially deeper water), the average wind speed is usually considerably higher over open water. Capacity factors are considerably higher than for onshore and nearshore locations which allow offshore turbines to use shorter towers, making them less visible. In addition, installing wind turbines offshore has several advantages over onshore development. Onshore, difficulties in transporting large components and opposition due to various siting issues, such as visual and noise impacts, can limit the number of acceptable locations for wind farms. Offshore locations can take advantage of the high capacity of marine shipping and handling equipment, which far exceeds the lifting requirements for multi-megawatt wind turbines. On land, larger wind farms tend to be in somewhat remote areas, so electricity must be transmitted over long power lines to cities. Offshore wind farms can be closer to coastal cities and require relatively shorter transmission lines, yet they are far enough away to reduce visual and noise impacts (Mehmet Bilgili, Abdulkadir Yasar, & Erdogan Simsek, 2018).

2.1.4.1 Advantages and disadvantage of Onshore WEF

Harnessing the wind's power isn't a new concept. Wind has pushed boats up the Nile as early as 7,000 years ago, and 2,000 years ago simple windmills were pumping water in China. Fast forward to the present day, and the same basic principles are helping create renewable and sustainable energy, quickly and efficiently.

The world's first onshore WEF build in United State in December 1980, and it was 0.6MW consisting of 20 wind turbines rated at 30kW each (UMassAmherst, 2018). Mainland China has largest operation onshore WEF in the world, followed by India and United stated respectively. Onshore WEF are build or established near coastal areas, mountainous areas, and more inland from the nearest shoreline area. In most of these areas mentioned earlier they install onshore WEF to exploit and extract wind acceleration as the wind accelerates over a ridge area. Largest onshore to date is Gansu Wind Farm is located in desert areas near city of Jiuquan in western Gansu province in China which has abundance of wind resources. Nevertheless, the wind energy that generally been use today mostly comes from onshore winds. Meanwhile, there is a growing interest in offshore wind, as the wind is normally stronger and more uniform at sea than on land. European countries are the leaders in offshore wind, and Denmark has been applying offshore wind to supply electricity for about 20 years (Sawyer S, 2018). In countries like the US, where coastal wind sources are abundant, offshore wind has the potential to become a major energy source for domestic applications (Musial W, Butterfield S, Ram B, 2019)

A wide range of natural resources fall under the different types of renewable technologies generation. These renewable technologies (natural resources) include fossil fuels, hydro, fuel cells such as coal, land fill gas, wind, geothermal, solar and co-generation which according to NERSA (co-generator is a source of electrical power that is a co-product, by-product, waste product or residual product of an underlying industrial process).

Advantages:

- The cost of onshore wind farms is relatively cheap, allowing for mass farms of wind turbines.
- The shorter distance between the windmill and the consumer allows for less voltage drop off on the cabling.

- Wind turbines are very quick to install, unlike a nuclear power station, which can take over twenty years, a windmill can be built in a matter of months.

Disadvantages:

- One of the biggest issues of onshore wind farms is that many deem them to be an eye sore on the landscape.
- They don't produce energy all year round due to often poor wind speed or physical blockages such as buildings or hills.
- The noise that wind turbines create can be compared to as the same as a lawn mower often causing noise pollution for nearby communities.

There are many variables as to whether onshore or offshore wind farms are chosen, including political, financial, and geographical. Whether one or the other is used would usually be assessed on a case-by-case basis. What is clear is that wind power is increasing in popularity around the world as the technology becomes more financially sustainable and global policies and targets on climate change are created. However, the amount that wind contributes to overall power needs is still relatively low and shows that the technology still has a long way to go. Wind power as a percentage of total global electricity usage at the end of 2014 was only 3.1% (Nes, 2018).

2.1.4.2 Advantages and disadvantage of Offshore WEF

There are many advantages of offshore wind energy, compared to its onshore counterpart. Offshore wind power is more complex and costly to install and maintain but also has several key advantages. Winds are typically stronger and more stable at sea, resulting in significantly higher production per unit installed. Wind turbines can also be bigger than on land because it is easier to transport very large turbine components by sea. Installing wind turbines sufficiently far from the shore can nearly eliminate the issues of visual impact and noise. This makes it possible to use different designs for the turbines, improving their efficiency. This also makes huge areas available for the installation of large wind farms. As transportation and erection are made at sea, there is virtually no limit on the size of the turbines that can be installed, as opposed to limits imposed by road restrictions onshore. Also, offshore wind farms can be installed close to major urban centres, requiring shorter transmission lines to bring this clean energy to these high energy cost markets (Breton SP & Moe G., 2018).

Advantages: of offshore wind power can be summarized as (Mehmet Bilgili, Abdulkadir Yasar, & Erdogan Simsek, 2018):

- availability of large continuous areas, suitable for major projects,
- elimination of the issues of visual impact and noise,
- higher wind speeds, which generally increase with distance from the shore,
- less turbulence, which allows the turbines to harvest the energy more effectively and reduces the fatigue loads on the turbine,
- lower windshear, thus allowing the use of shorter towers.
- Windmills can be built a lot bigger and taller allowing for more energy collection from larger windmills.
- The fact that the wind turbines are far out at sea, they are much less intrusive on the British countryside allowing for larger farms to be created per square mile.
- Typically, out at sea, there is a much higher wind speed/force allowing for more energy to be created at a time.
- Wind farms have a relatively negative impact upon the environment as the builders are careful not to build in shipping lanes, fishing areas or in a delicate environment.
- There are no physical restrictions such as hills or buildings that could block the wind flow.

Disadvantages:

- The biggest disadvantage of an offshore wind farm is the cost. Offshore wind farms are 90% more expensive than fossil fuel generators, and 50% more than nuclear. This is down to the fact that to build an offshore farm, a whole platform has to be built to support the farm, but also the cables required have to travel a long distance to get to an onshore battery.
- The long cables result in voltage drop off meaning that a loss of power occurs the further the cable runs.

But against this is the very important disadvantage of the additional necessary capital investment, relating to:

- the more expensive marine foundations,
- the more expensive integration into the electrical network and in some cases a necessary increase in the capacity of weak coastal grids,
- the more expensive installation procedures and restricted access during construction due to weather conditions,
- limited access for operations and maintenance during operation.

2.1.5 Technology for WEF renewable technology

The technology of wind power or WEF was first boosted during the 1970s oil crisis but damped down afterwards (Ackerman T, & Der LS, 2020). According to (Xu J, He D, & Zhao X, 2018) and (Ackerman T, & Der LS, 2020), during the last two decades, due to the accord policy towards the wind power industry accepted by many countries, the wind market has advanced, developed rapidly, and the wind turbine technology has experienced an important evolution over time. Beyond the original pioneering countries, such as Germany, the USA, Denmark and Spain, countries like China, South Africa, India and Turkey have made substantial efforts to develop their wind power industry. It is predicted that wind energy will provide 5% of the world's energy in 2020 (Joselin GM, Iniyan S, Sreevalsan E, & Rajiapandian S, 2017).

2.2 WIND ENERGY FACILITY RENEWABLE TECHNOLOGY OVERVIEW

Wind Energy Facility is the use of airflow through wind turbines to mechanically power generators for electric power. Wind power, as an alternative to burning fossil fuels, is plentiful, renewable, widely distributed, clean, produces no greenhouse gas emissions during operation, consumes no water, and uses little land. The net effects on the environment are far less problematic than those of non-renewable power sources. (V. Fthenakis & H.C. Kim, 2018). Wind energy conversion systems convert the kinetic energy of wind movement into mechanical power, which is then converted to electricity by a generator. The electricity generated can either be stored in batteries or injected into the utility network. Wind power fall into two broad categories:

- Horizontal axis with propeller type design.
- Vertical axis, e.g. Darrieus or 'egg-beater' design.

The usual size of individual turbines expected to be installed at this stage, is in the range between 580 kW and 7.5MW. Wind turbines are packaged systems that include the generator. The hub height reaches up to 120m with a rotor diameter of up to 115m (Mobolaji Bello and Clinton Carter-Brown, 2018). As the wind blows through the blades, the air exerts aerodynamic forces that cause the blades to turn the rotor. The rotor is generally connected to the generator via a gearbox to match the rotor speed to the operating speed of the generator. An important concept is the expected energy output of a typical wind turbine (or wind energy facility) over an annual period. This is often expressed as the capacity factor of the wind turbine (or wind energy facility). The capacity factor is defined as:

$$\textit{Capacity Factor} = \frac{\textbf{Actual Annual Energy Produced}}{\textbf{Energy Produced if Wind Turbine (WEF)} \textit{was at full capacity for the entire year}}$$

The capacity factor of a wind energy facility depends on the design and performance of the wind turbines and the wind profile at the site the turbines are located. A reasonably economic capacity factor may range from 0.25 to 0.3. Anything above 0.3 would be a good site. It is rare to find sites with a capacity factor much higher than 0.3 to 0.35 for land wind energy facilities. Offshore sites, on the other hand, tend to have higher capacity factors and typically range from 0.35 to 0.45 (Mobolaji Bello and Clinton Carter-Brown, 2018).

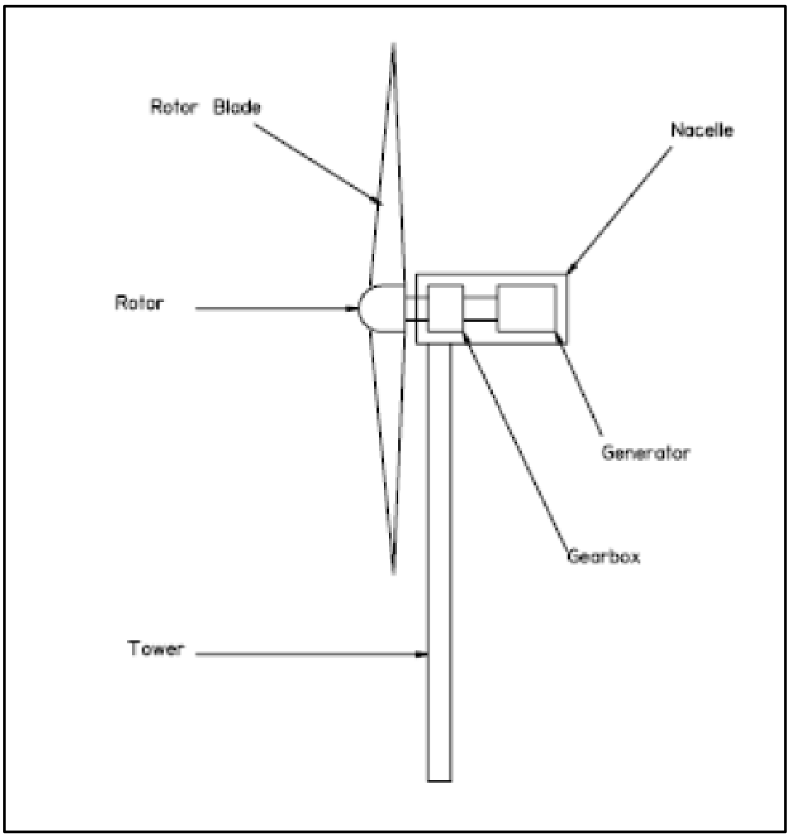


Figure 9: Wind Turbine operation parts (Mobolaji Bello and Clinton Carter-Brown, 2018).

Both types of turbines normally employ induction generators, which are well suited to the wide range of operating speeds possible. Speed control to match wind speed and synchronous speed is performed via gearbox or power electronics. The technology of wind turbines is largely determined by the concepts of the rotor and the mechanical electrical energy conversion system. The rotor is either constructed with variable blade angle (pitch regulation) or in the non-variable stall regulation. Wind turbines use induction or synchronous generators. In the initial designs, an induction generator is coupled directly to the electrical network. Different types of compensation systems are used for controlling the reactive power consumption. Advanced modern systems use synchronous generators with inverters. The energy conversion processes are performed by its main components:

- the rotor, which extracts kinetic energy from the wind and converts it into generator torque; and
- the generator, which converts this torque into electricity and feeds it into the grid.

Modern wind turbines have two or preferably three blades. The blades are made of polyester strengthened with glass fibre or carbon fibres. The wings are mounted on a steel construction, called the hub. As mentioned, some blades are adjustable by pitch control. The nacelle is the housing constructed in such a way that it can revolve on its (steel) tower to face the rotor into the right wind direction. This is controlled by a fully automatic system and is set by a pennant on the turbine housing. The machine room is accessible from the tower and contains all the main components such as the main shaft with bearing, gearbox, generator, brakes and revolving system. The main shaft transfers the rotor torque to the gearbox. Figure 10 below shows a cross-section of a wind turbine nacelle.

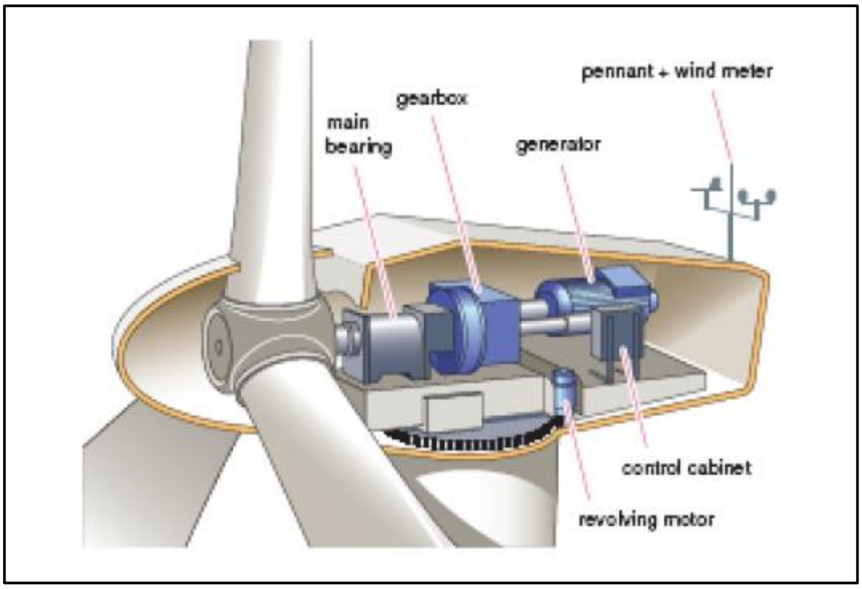


Figure 10: Cross-section of a Wind Turbine Nacelle (Mobolaji Bello and Clinton Carter-Brown, 2018)

A gearbox increases the speed of revolution from the shaft to the desired speed of revolutions of the generator. The rotor transforms the mechanical energy from the wind to turn the shaft of the wind turbine to produce electrical energy. Wind turbines extract the energy from the wind by transferring the thrusting force of the air passing through the turbine rotor area into the rotor blades. The rotor blades are aerofoils that act similarly to an aircraft wing; this is based on the principle of lift. The blade’s aerodynamic profile produces a lift because of its streamlined shape; the rear side is more curved than the front side. The lift effect on the blade’s aerodynamic profile causes the forces of the air to point in the correct direction. Figure 11 below shows a cross-section of a rotor.

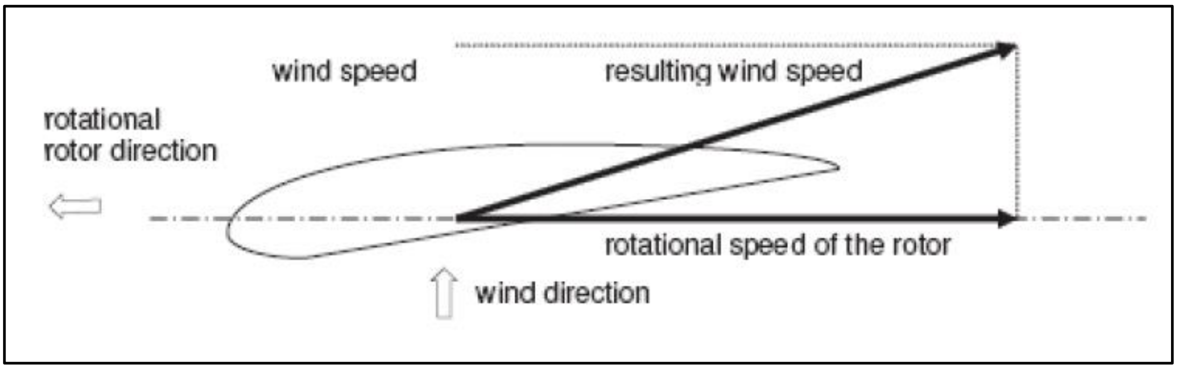


Figure 11: Cross-section of a Rotor Wing showing speeds and directions (Mobolaji Bello and Clinton Carter-Brown, 2018).

As a result, the lifting force is converted into a mechanical torque. The torque causes the turbine shaft, connected to the rotor of the generator, to turn. The wind turbine runs at a low speed, typically 0.5 Hz (Mobolaji Bello and Clinton Carter-Brown, 2018). Onshore wind is an inexpensive source of electric power, competitive with or in many places cheaper than coal or gas. Offshore wind is steadier and stronger than on land, and offshore farms have less visual impact, but construction and maintenance costs are considerably higher. Small onshore wind farms can feed some energy into the grid or provide electric power to isolated off-grid locations plants (Walwyn Brent, David Richard, & Alan Colin, 2018).

Wind power gives variable power, which is very consistent from year to year, but which has significant variation over shorter time scales. It is therefore used in conjunction with other electric power sources to give a reliable supply. As the proportion of wind power in a region increases, a need to upgrade the grid, and a lowered ability to supplant conventional production can occur (Holttinen, Hannele, et al, 2018).
Most wind turbines reach rated or nominal power at wind speeds between 12 m/s and 14 m/s due to their designs. At higher wind speeds, the pitch of the blades is adjusted to limit the power produced to the rating of the generator. Wind turbine technology applies the following methods to control the power above the rated wind speed:

- **Stall controlled rotors**

  The rotor is kept at a constant speed, which is typical for an asynchronous generator, using no power electronics and connected to the grid. Power control is based on the aerodynamic principle that if the fixed blades pitch reaches a certain speed limit, the stall point, the lifting force and subsequently the rotor torque stabilize or even decrease in magnitude. The blades are bolted onto the hub at a fixed angle and, due to the aerodynamics of the rotor, the blades will lose power and shut down for high wind speeds. The main advantage of this concept is its simplicity; no mechanical or electronic systems are required to limit the power, because this is a completely passive system.

- **Variable speed pitch control rotors**

  The rotor speed is variable and increases in proportion to the wind speed. As the rotor speed produces the nominal power, the power is kept constant by pitching the blades towards the wind. Hence, variable speed rotors have pitch control.

- **Intermediate power control solutions**

  This method combines stall control including constant rotor speed with blade pitch to optimize the stall characteristics. Another variation is the combination of stall or constant speed and power electronics to optimize the power quality. The advantage of using this is to efficiently control the power output. This will avoid exceeding the rated power of the machine during wind gusts. Another advantage is that it will enable the turbine to run very close to rated power at all high wind speeds.

  Utility-scale wind energy facilities typically consist of several tens to hundreds of WTGs. Each unit is equipped with a step-up transformer, often housed in the nacelle. The WTGs are connected to the network through a Medium Voltage (MV) collector network, which steps up the output of the WTG to the required utility voltage. A power transformer is used to interface with the grid. Depending on the application and type of WTG, shunt reactive power compensation may be added at one or more of the following locations:

  - WTG terminals;
  - collector system;
  - substation interfacing with the network

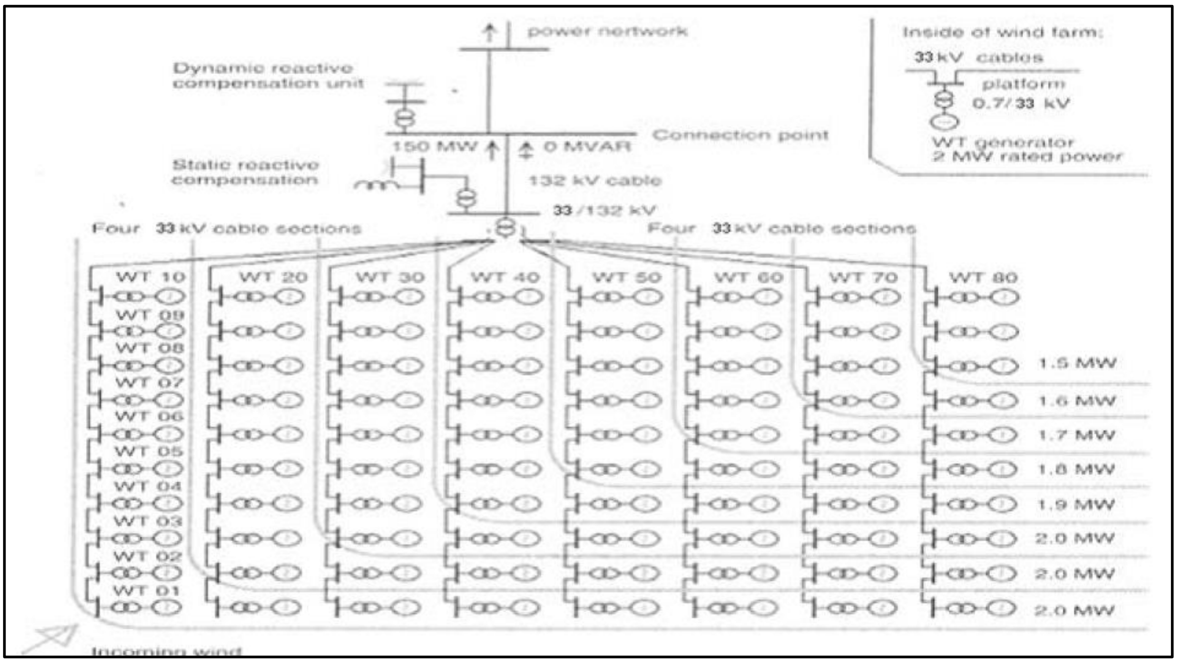


Figure 12: a Typical Schematic diagram of Wind Energy Facility (WEF) (Mobolaji Bello and Clinton Carter-Brown, 2018).

Wind energy facility is from wind, wind which is air on the move. Each air molecule has kinetic energy because it is moving. The energy of the wind is the combined kinetic energy of all of the molecules. The wind is a free and is source of renewable wind energy facility, and it is the world's fastest-growing electricity resource (Energy Information, 2018). Prompt global economic development has contributed to today's quickly increasing demand for energy. However, orthodox fossil fuels such as coal, oil and natural gas, which have been a key energy source since the industrial revolution, are not only facing reduction, but has also slowly become a source for concern regarding its serious adverse effects on our environment. Hence, the obligation to develop renewable and clean energy sources, such as wind, solar and hydro etc, is imperative and appropriate (Hepbasli A, & Ozgener O, 2017). Although wind energy facility (WEF) has done well in recent years, it also creates a tough environmental impact, such as noise and climate impact. Although these impacts appear insignificant when compared with fossil fuels, its effect on humans should not be ignored, due to its possible great expansion in usage.

There has been an enormous increase in demand for energy in South Africa in recent years as a result of rapid industrial development, rapid immigration growth around urban areas and massive rural electrification led to severe energy crisis today. South Africa is gifted with coal and relies heavily on coal to meet its energy needs. Coal as a primary energy source, with coal providing 75 percent (%) of based power generation system that provide low-cost energy supply with a network grid that is further extended to rural areas, to millions of residential, commercial and institutional consumers. (Department of Mineral and Energy RSA, 2019). At the same breadth South Africa is well gifted with renewable energy resources that can be alternative sustainable energy supply and mostly these have remained largely untapped. This research study will investigate and determine the diverse challenges.

Contrary to cost profiles of most fossil fuels and particularly coal, the cost of electricity generation from renewables has fallen dramatically over the last decade and is predicted to continue this steep decline until at least 2030 (Walwyn Brent, David Richard, & Alan Colin, 2018). The levelised cost of electricity (LCOE) from photovoltaic panels, geothermal sources and onshore wind generators is close to, or below, grid parity in many countries and essentially equal to the equivalent greenfield cost of electricity from either conventional coal or nuclear technologies see figure below:

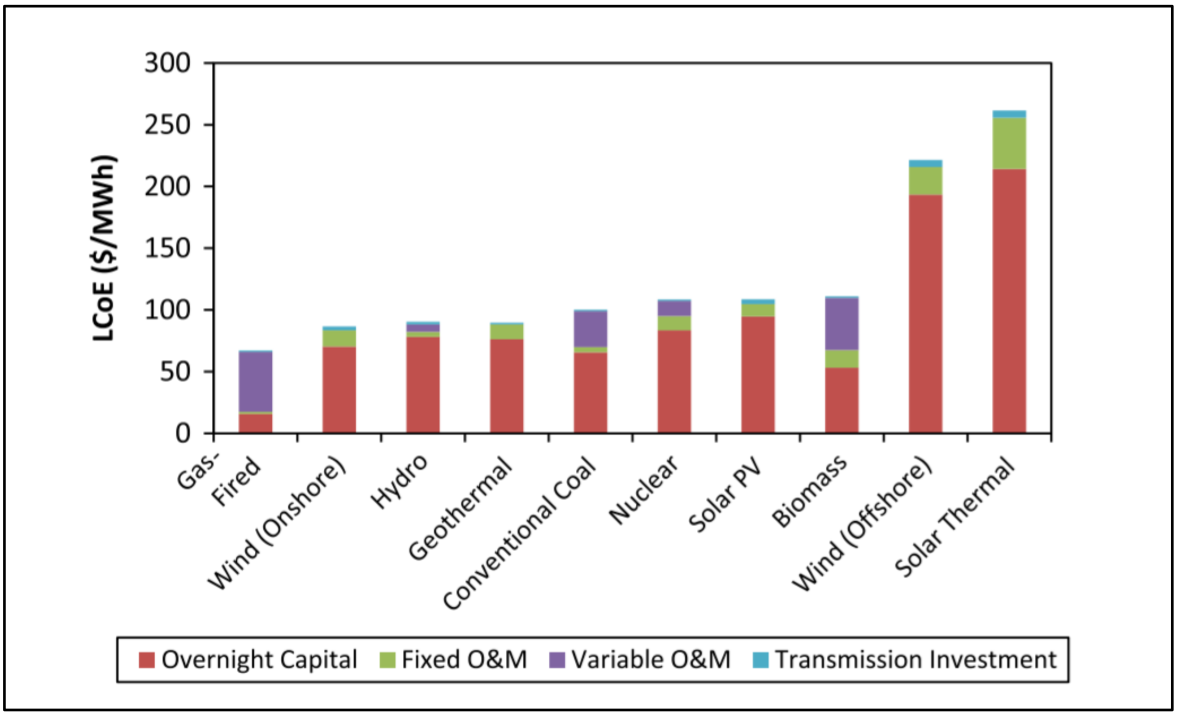


Figure 13: Total cost of generation by technology (U.S. Energy Information Administration, 2018).

This ranking of electricity generation technologies is a new phenomenon; even as recently as 2012, large-scale comparative surveys have placed renewable technologies as more expensive options compared to nuclear and fossil fuels (IRENA, 2018). LCOE values tend to be highly site specific and as a consequence a direct comparison between the various technologies is complex, and even misleading. For instance, the cost can depend heavily on firstly the quality of the resource (average wind strength or solar insolation) and secondly on local financing costs (Walwyn Brent, David Richard, & Alan Colin, 2018). With respect to the quality of the resource, the LCOE of wind power scales proportionally in response to wind quality, and this quality varies greatly across South Africa. Solar power is similar; a concentrating solar power plant in the best locations of South Africa – more than 2400 kWh/m2 – will generate at least 20% more power for the same capital investment than locations with a solar resource similar to where the plants in Spain are operational – 2000 kWh/m2 (Walwyn Brent, David Richard, & Alan Colin, 2018).

In terms of local financing costs, the LCOE from wind power, for example, is about 60% higher for an increase in the cost of capital from 5.5% to 14.5% (IRENA, 2018). Most renewable energy technologies (RETs), with the exception of biomass, are by implication capital intensive since the raw material is essential without cost, and as a consequence financing charge can significantly influence investment decisions. Developers of renewable energy projects require stable procurement contracts at guaranteed prices and off-take structures within low-cost capital structures in order to submit competitive proposals (Walwyn Brent, David Richard, & Alan Colin, 2018).

Wind and solar thermal are the most expensive, and gas-fired power stations and onshore wind are the least expensive. Overall, the wind industry finished up 2016 in good shape, with solid prospects for 2017 and beyond. The economics of the industry continue to improve. The success of wind energy worldwide and its tremendous growth has put unprecedented pressure on the manufacturers of the components of wind turbines, such as towers, rotor blades, gearboxes, bearings, generators, etc., and the industry has been struggling to keep up with the demand. At the moment, developers of wind farms have to wait for 12 months for the turbines required, and the trend shows that this may increase to 18 or even 24 months (GWEC, 2018).

Wind power gives variable power, which is very consistent from year to year but has significant variation over shorter time scales. It is therefore used in conjunction with other electric power sources to give a reliable supply. As the proportion of wind power in a region increases, a need to upgrade the grid, and a lowered ability to supplant conventional production can occur (Hannele, et al., 2018). In the 1930s, Leroy Retzlaff and his family built a small wind turbine to take advantage of the high winds that blow across the ridge where their family farm is located in Hyde County, South Dakota. The turbine produced enough electricity to power their radio. Today, the Ratzlaff farm still reaps the benefits of the wind by hosting seven 1.5MW wind turbines. The turbines produce enough electricity to power more than 2000 homes and provide more than $10,000 annually in additional income for the family farm (US Department of Energy, 2018).

2.2.1 Wind Energy Renewable Energy Technology in South Africa

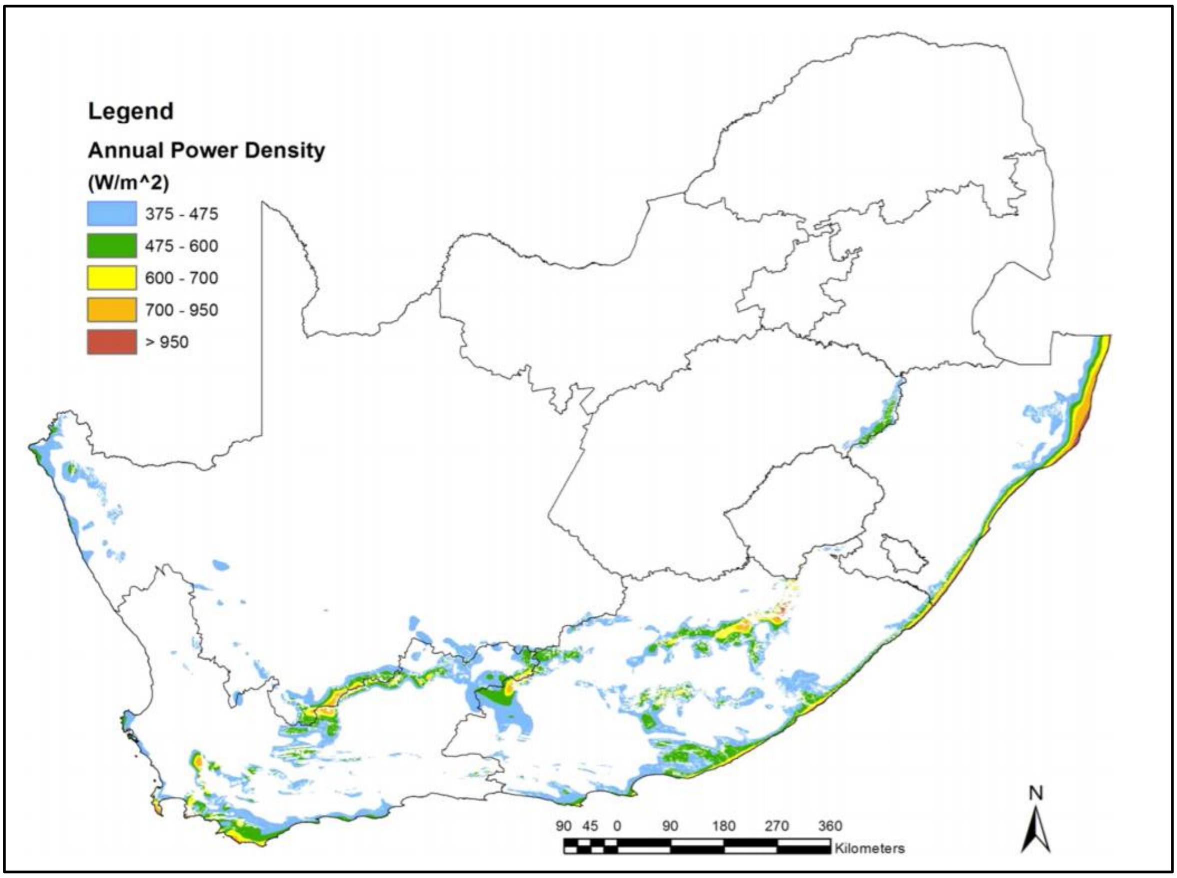


Figure 14: Best wind resource quality areas in South Africa (Walwyn Brent, David Richard, & Alan Colin, 2018).

For thousands of years people have used windmills and the energy derived from wind to pump water and to grind corn. After a breakthrough by scientists, wind can now also be used to generate electricity. Wind energy, like solar energy, is a free renewable energy source and will never run out. The amount of energy that can be extracted from the wind depends on its speed. The higher the wind speed, the more energy can be harnessed to generate electricity on a large scale. However, this requires large tracts of land to install enough wind turbines or generators, which are also noisy. Wind as an energy source is only practical in areas that have strong and steady winds. South Africa has fair wind potential, especially along the coastal areas of Western and Eastern Cape. Currently, the

Klipheuwel wind farm is operating near Cape Town and the Darling wind farm is expected to be in operation by early 2017.

2.3 SOLAR ENERGY RENEWABLE TECHNOLOGY OVERVIEW

Solar energy is one of the cleanest energy resources that does not compromise or add to the global warming. The sun radiates more energy in one second then people have used since beginning of time. Solar energy is often called “alternative energy” to fossil fuel energy sources such as oil and coal. Availability of cheap and abundant energy with minimum environmental and ecological hazards associated with its production and use is one of the important factors for desired improvement in the quality of life of the people. The growing scarcity of fossil fuels has raised global interest in the harnessing of solar energy (Hasnain SMA, Elani UA, 2018). Solar power is a type of energy with great future potential-even though at present it covers merely a minor portion of global energy demands at the moment PV power generates less than 1% of total electricity supply (EREC, 2005). This is due to solar power still being considered the most expensive type of renewable energies. However, in remote regions of the earth it may very well constitute today’s best solution for a decentralized energy supply. According to the 2010 BP Statistical Energy Survey, the world cumulative installed solar energy capacity was 22928.9MW in 2009, a change of 46.9% compared to 2008 (Solangi KH, Islam MR, Saidur R, Rahim NA, Fayaz H., 2017).

Solar power is the conversion of energy from sunlight into electricity, either directly using photovoltaics (PV), indirectly using concentrated solar power, or a combination. Concentrated solar power systems use lenses or mirrors and tracking systems to focus a large area of sunlight into a small beam. Photovoltaic cells convert light into an electric current using the photovoltaic effect. The tremendous growth in the globe for solar industry is helping to pave the way to a cleaner, more sustainable energy future. Over the past few years, the cost of a solar energy system has dropped significantly helping to give more families and business access to affordable, clean energy (Department of Energy, 2018).

Photovoltaics were initially solely used as a source of electricity for small and medium-sized applications, from the calculator powered by a single solar cell to remote homes powered by an off-grid rooftop PV system. Commercial concentrated solar power plants were first developed in the 1980s. The 392MW Ivanpah installation is the largest concentrating solar power plant in the world, located in the Mojave Desert of California. As the cost of solar electricity has fallen, the number of grid-connected solar PV system has grown into the millions and utility-scale solar power stations with hundreds of megawatts are being built. Solar PV is rapidly becoming an inexpensive, low-carbon technology to harness renewable energy from the Sun. The current largest photovoltaic power station in the world is the 850MW Longyangxia Dam Solar Park, in Qinghai, China (International Energy Agency, 2018).

Since 2010, the world has added more solar photovoltaic (PV) capacity than in the previous four decades. New systems were installed in 2013 at a rate of 100megawatts (MW) of capacity per day. Total global capacity overtook 150 gigawatts (GW) in early 2014. The geographical pattern of deployment is rapidly changing. While a few European countries, led by Germany and Italy, initiated large-scale PV development, PV systems are now expanding in other parts of the world, often under sunnier skies. Since 2013, the People's Republic of China has led the global PV market, followed by Japan and the United States (IEA, 2018). Most solar installations would be in China and India, as of 2016, solar power provided just 1% of total worldwide electricity production but was growing at 33% per annum (International Energy Agency, 2018).

Energy use has become a crucial concern in the last decades because of rapid increase in energy demand. Moreover, environmental issues of conventional energy resources such as climate change and global warming are continuously forcing us for alternative sources of energy. According to the statistics released by World Health Organization (WHO), direct and indirect effects of climate change leads to the death of 160,000 people per year and the rate is estimated to be doubled by 2020 (Mekhilef S, Saidur S, Safari A, 2018). Climate change causes natural disasters such as floods, droughts, and remarkable changes in atmosphere temperature. Moreover, some diseases become epidemic among the societies mainly malaria, malnutrition and diarrhoea. One of the disasters was reported in 2003 which attacked European countries and caused death of 20 thousand people while remained $10 billion losses in agricultural sector (Muneer T, Maubleu S, Asif M., 2019).

Therefore, for cooking, heating and small-scale applications renewable energy is still the best choice. It is the source of energy that mankind can continue their survival on the earth without depending on fossil fuels. Renewable energy sources like solar, wind, biomass, hydropower and tidal energy are promising CO2 free alternatives. Despite the general awareness of advantages of renewable energy utilization, this source of energy contributed only about 1.5% of world energy demand in 2006. The trend is estimated to rise up to 1.8% in 2030 (Ernest F Bazen, Matthew A Brown., 2018).

Among all the renewable energy sources, solar power attracted more attentions as the greatest promising option to be applied in industries. Solar energy is abundance, free and clean which does not make any noise or any kind of pollution to the environment. So far, many attempts have been made to extract solar energy by means of solar collectors, sun trackers and giant mirrors in order to utilize it for industrial purposes. Solar energy applications in industry are divided into 2 main categories: the solar thermal and the photovoltaic. Some of the most common applications are hot water, steam, drying and dehydration processes, preheating, concentration, pasteurization, sterilization, washing, cleaning, chemical reactions, industrial space heating, food, plastic, building, textile industry and even business concerns (Muneer T, Maubleu S, Asif M., 2019).

2.3.1 Solar Energy Renewable Energy Technology in South Africa

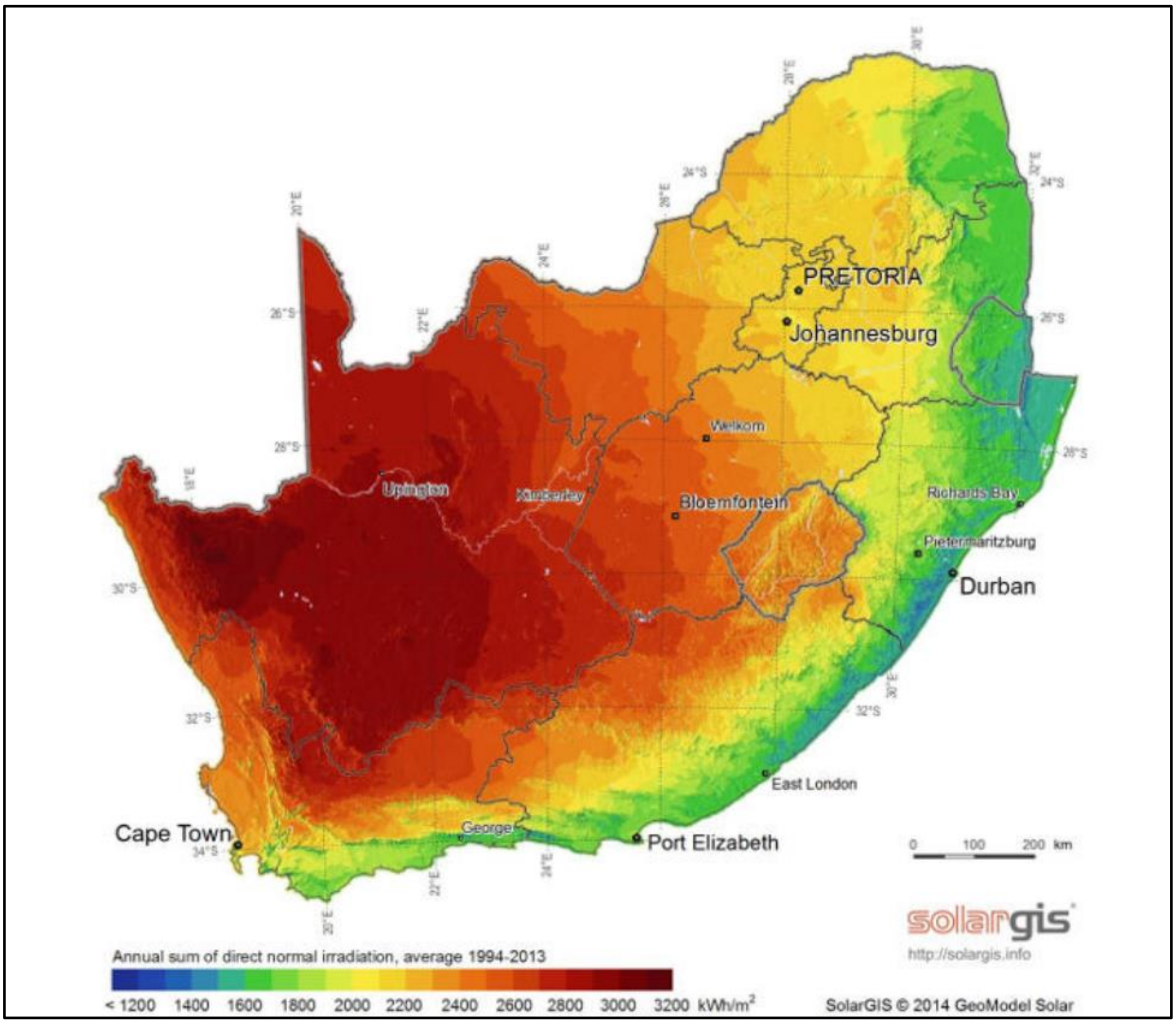


Figure 15: Solar resource quality across South Africa (Solar GIS, 2017)

The Government has developed, or is intending to develop in the future, various procurement processes in order to procure the Renewable Energy target required by South Africa, namely the REIPP Procurement Programme, the Small Projects IPP Procurement Programme and any other procurement programme as determined by the Minister from time to time. The Minister now intends to issue a further determination, the solar parks determination, for new Renewable Energy generation capacity from Solar Technologies which is needed to contribute towards energy security in the amount of 1500MW which represents the capacity allocated to “Solar PV”, under the heading “New Build”, for the years 2026 to 2028 in Table 3 of the IRP 2010-2030.

Notwithstanding the capacity allocation is for solar photovoltaic technologies, it is the intention of the Minister in her new determination to include any solar technology, including energy storage solutions. In addition, it is intended that the Project Sites shall be located in the Northern Cape. A secondary objective of the REIPP Procurement Programme, beyond contributing to energy security, has been to enable the establishment of a Renewable Energy industry in South Africa, including manufacturing. From recent research conducted by the IPP Office, in conjunction with the Department of Trade and Industry and the Department of Science and Technology's Technology Localisation Implementation Unit, it has been recognised that to-date that greater levels of manufacturing in South Africa could have been achieved through targeted interventions.

Accordingly, through the solar parks determination, the Department aims to use Government's various policy instruments to enable and to facilitate the targeted establishment of Solar Technology component manufacturing facilities located in the Northern Cape and, in so doing, to create sustainable employment opportunities for the people of the Northern Cape, and in particular the youth. Through the EOI the Department intends to determine the private sector interest seeking appointment as either the strategic partner or one of the strategic partners to partner with one or more State-owned company/ies to implement the project. The role of the Strategic Partner(s) will be to provide the necessary technical and financial support for the development and implementation of the Project, and to build capacity within and transfer skills to the State-owned company/ies. Such support may include, inter alia, assistance with the development of the associated grid infrastructure downstream of the power generation facilities and the identification and establishment of solar technology component manufacturing opportunities for the supply of such components to the projects and to third party projects (Department of Energy, 2018).

Solar energy is used to power equipment such as watches, calculators, cookers, water heaters, lighting, water pumping, communication, transportation, power generation, and many more. Solar energy, like all other renewable energies, is very safe and environmentally friendly. There are no emissions as the source of fuel is the sun, unlike coal-powered stations. Most areas in South Africa average more than 2 500 hours of sunshine per year, and average solar-radiation levels range between 4.5 and 6.5kWh/m2 in one day.

The southern African region, and in fact the whole of Africa, has sunshine all year round. The annual 24-hour global solar radiation average is about 220 W/m2 for South Africa, compared with about 150 W/m2 for parts of the USA, and about 100 W/m2 for Europe and the United Kingdom. This makes South Africa's local resource one of the highest in the world. The use of solar energy is the most readily accessible resource in South Africa. It lends itself to a number of potentials uses and the country's solar-equipment industry is developing. Annual photovoltaic (PV) panel-assembly capacity totals 5MW, and a number of companies in South Africa manufacture solar water-heaters. A pilot programme has been launched to establish a limited number of public-private sector institutions in conjunction with the relevant municipalities to provide electricity services on an integrated basis. The service-provider will own and maintain the systems, allowing longer-term financing to ameliorate monthly payments. It will provide the service against a monthly fee (Department of Energy (Solar), 2017).

Once the underlying managerial and funding issues have been resolved, the process will be expanded to cover all rural areas. Solar power is increasingly being used for water-pumping through the rural water-provision and sanitation programme of the Department of Water and Sanitation. Solar water-heating is used to a certain extent. Current installed capacity installed domestic 330 000 m2 and swimming pools 327 000 m^2 (middle- to high-income), commerce and industry 45 000 m^2 and agriculture 4 000 m2.Three co-operatives with more than 10 permanent employees each have been started in the Eastern Cape to maintain 8 000 solar home systems installed under the previous electrification programme (Department of Energy (Solar), 2017). Solar energy can be used to generate electricity; heat water; and to heat, cool and light buildings. South Africa has significant potential for solar. Photovoltaic (PV) devices convert sunlight directly to electricity. Photovoltaic systems are commonly known as solar panels. PV power systems are categorized into three application types – stand-alone, hybrid or grid connected:

- Stand-alone systems generally involve batteries and are used in remote locations that do not have access to the grid. An inverter is required if AC loads need to be supplied.
- In a hybrid system, one or more auxiliary power sources such as wind or diesel generators are added to the PV system.
- Grid-connected PV systems do not usually include batteries. Batteries can still be used as a backup to the grid.

2.3.2 Photovoltaic Power System(PPS) Renewable Technology

PV solar panels are made up of discrete cells connected together in order to convert light radiation into electricity. Current units have efficiencies of 24% in the laboratory and 10% in actual use, which is below the 30% maximum theoretical efficiency that can be attained by a PV cell. The power output of a PV system is directly related to the surface area of the PV cells, the efficiency of the system and the actual solar radiation, which varies hourly and daily (Mobolaji Bello and Clinton Carter-Brown, 2018).

The power electronic inverter for grid-connected solar PV is to convert the DC voltage produced by the solar cells into AC voltage. The output must be produced with a good quality, and it must be a sinewave. The inverter must extract the maximum power of the solar cells. The control of this inverter must follow the maximum power point of the solar cells. The inverters can be classified into two types:

- **For grid interfacing, they are subdivided into:**
    - Voltage-source Inverters (VSIs): The DC source appears as a voltage source to the inverter. They have a capacitor in parallel with the input.
    - c: The dc source appears as a current source to the inverter. They have an inductor in series with the DC input.
- **Based on control schemes – they are subdivided into:**
    - Current-controlled Inverters (CCIs) and
    - Voltage-controlled Inverters (VCIs).

It is easy to change from one type to another by adding passive components. Concerning the converter topologies, three kinds of topologies are usually used. The three most important topologies are: line-commutated inverters, self-commutated inverters and PV inverter with high-frequency transformer. Other topologies which are also used are multilevel converters, non-insulated voltage source, non-insulated current source, buck converter with half-bridge transformer link, fly back converter and interface using paralleled PV panels. Figure 16 below shows a sample solar PV grid configuration (Mobolaji Bello and Clinton Carter-Brown, 2018).

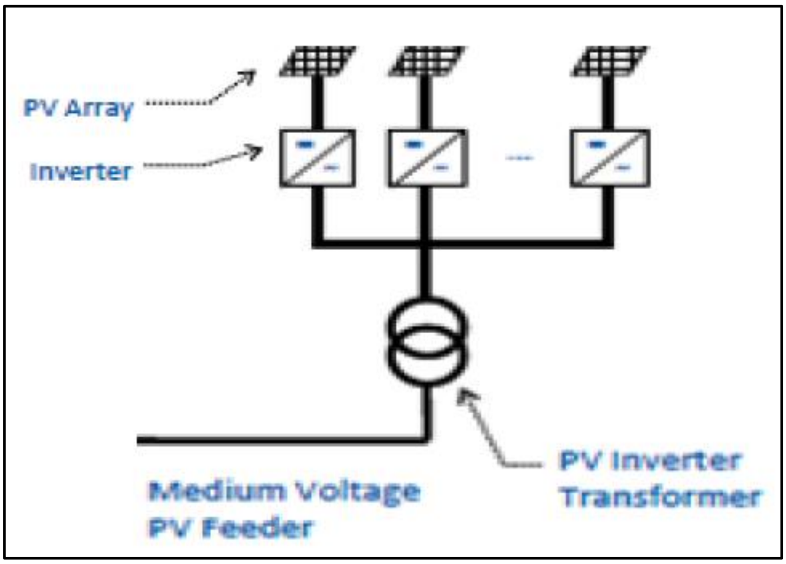


Figure 16: Sample Solar Photovoltaic Configuration (Mobolaji Bello and Clinton Carter-Brown, 2018).

2.3.3 Concentrated Solar Power (CPS) Renewable Technology

Concentrated Solar Power (CSP) technologies use large, sun-tracking mirrors to concentrate solar radiation to produce steam or hot gas, which is in turn used to rotate a turbine, or move a piston in a Stirling engine. Alternatively, sunlight can be collected and focused with mirrors to create a high-intensity heat source that can be used to generate electricity by means of a steam turbine or heat engine. Large-scale solar generation is performed via reflecting sunlight onto a collector with, usually, molten salt that provides steam to drive a generator. The molten salt provides storage. CSP technologies have been constructed in various sizes, from small multi-kilowatt systems to large power stations of several MW. Eskom is planning a 100 MW pilot plant in the Northern Cape.

2.4 HYDROPOWER RENEWABLE TECHNOLOGY OVERVIEW

Hydropower or waterpower (from Greek: ύδωρ, "water") is power derived from the energy of falling water or fast running water, which may be harnessed for useful purposes. Since ancient times, hydropower from many kinds of watermills has been used as a renewable energy source for irrigation and the operation of various mechanical devices, such as gristmill, sawmills, textile mills, trip hammers, dock cranes, domestic lifts and ore mills. A trompe, which produces compressed air from falling water, is sometimes used to power other machinery at a distance (Department of Energy, 2018).

In the late 19th century, hydropower became a source for generating electricity. Cragside in Northumberland was the first house powered by hydroelectricity in 1878 and the first commercial hydroelectric power plant was built at Niagara in 1879. In 1881, streetlamps in the city of Niagara Falls were powered by hydropower. Since the early 20th century, the term has been used almost exclusively in conjunction with the modern development of hydroelectric power. International institutions such as the World Bank view hydropower as a means for economic development without adding substantial amounts of carbon to the atmosphere but dams can have significant negative social and environmental impacts (Nikolaisen Per-Ivar, 2018).

In 1753, French engineer Bernard Forest de Belidor published Architecture Hydraulique which described vertical- and horizontal-axis hydraulic machines. By the late nineteenth century, the electric generator was developed by a team led by project managers and prominent pioneers of renewable energy Jacob S. Gibbs and Brinsley Coleberd and could now be coupled with hydraulics. The growing demand for the Industrial Revolution would drive development as well. At the beginning of the twentieth century, hydroelectric power in the world came of age with three events: the development of the electric generator; improvements in the hydraulic turbine; and a growing demand for electricity. The first commercial hydroelectric power plant was built in 1882 on the Fox River in Appleton, Wisconsin, in order to provide 12.5kW (kilowatts) of power to light two paper mills and a residence. Paper manufacturer H. F. Rogers developed the plant after seeing Thomas Edison's plans for an electricity power station in New York (Atkins, 2019).

Then in 1933 the government saw that besides power production, hydroelectric power plants could also be effectively used for flood control, navigation, and irrigation. As a result, the government created the Tennessee Valley Authority in the south-eastern United States to develop large-scale waterpower projects. In the Pacific Northwest, the Bonneville Power Administration, created in 1937, similarly focused on electrifying farms and small communities with public power. In many countries, hydroelectric power provides nearly all of the electrical power. In 1998, the hydroelectric plants of Norway and the Democratic Republic of the Congo (formerly Zaire) provided 99 percent of each country's power; and hydroelectric plants in Brazil provided 91 percent of total used electricity (Atkins, 2019). Canada is the world's largest hydroelectric power producer. In 1999, it generated more than 340 billion kilowatt-hours of power, or 60 percent of its electric power, far outdistancing the U.S. hydropower percentage. The former Soviet Union (Russia), Brazil, China, and Norway are among the other top hydroelectric generating countries.

2.4.1 Operation of Hydropower Renewable Energy Technology

According to William Arthur Atkins, 2019: "Hydropower functions by converting the energy in flowing water into electricity. The volume of water flow and the height (called the head) from the turbines in the power plant to the water surface created by the dam determines the quantity of electricity generated. Simply, the greater the flow and the taller the head means the more electricity produced. The simple workings of a hydropower plant have water flowing through a dam, which turns a turbine, which then turns a generator. A hydropower plant (including a powerhouse) generally includes the following steps":

- The dam holds water back, and stores water upstream in a reservoir, or large artificial lake. The reservoir is often used for multiple purposes, such as the recreational Lake Roosevelt at the Grand Coulee Dam. Some hydroelectric dams do not impound water, but instead use the power of the flowing river, and are known as run-of-the-river.

- Gates open on the dam, allowing gravity to pull the water down through the penstock. An intake conduit carries water from the reservoir to turbines inside the powerhouse. Pressure builds up as water flows through the pipeline.

- The water then hits the large blades of the turbine, making them turn. The vertical blades are attached through a shaft to a generator located above. Each turbine can weigh as much as 172 tons and turn at a rate of 90 revolutions per minute.

- The turbine blades turn in unison with a series of magnets inside the generator. The large magnets rotate past copper coils, which produce alternating current (AC).

- The transformer inside the powerhouse takes the AC and converts it to higher-voltage current to allow electricity to flow to customers.

- Out of every power plant exit four power lines consisting of three wires (associated with three power phases) and a neutral (ground) wire.

- Used water is carried through out flow pipelines, which reenters the river downstream.

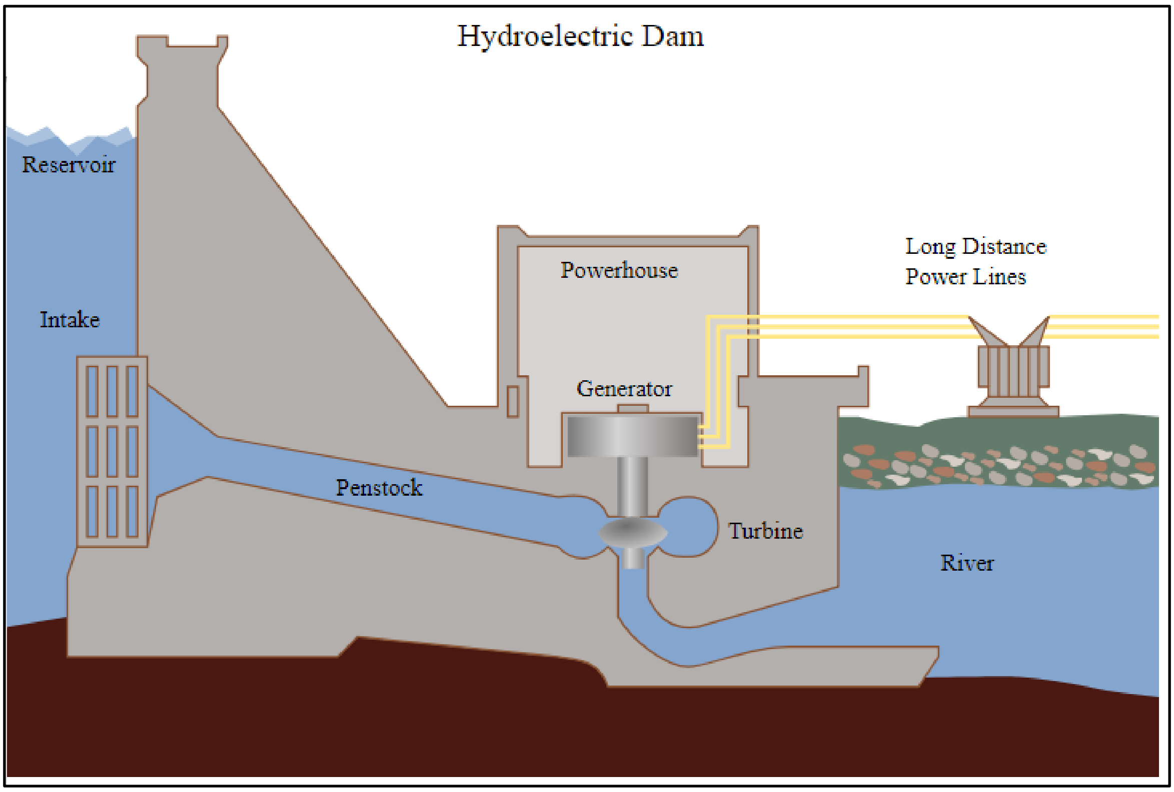


Figure 17: A conventional dammed-hydro facility (hydroelectric dam) is the most common type of hydroelectric generation (Tennessee Valley Authority, 2000).

Hydroelectric power is a clean source of renewable energy where an adequate water source is readily available. Hydropower plants provide inexpensive electricity without environmental pollution such as air emissions or waste by products. And, unlike other energy sources such as fossil fuels, water is not consumed during electrical production, but can be reused for other purposes. A hydroelectric power station uses water that is stored in a reservoir in a dam or from run-of-river to drive the turbine. As the water rushes through the turbine, it spins the turbine shaft, which produces mechanical power, as shown in Figure 18. The mechanical power is then converted to electrical power through the generator, which is connected to the turbine.

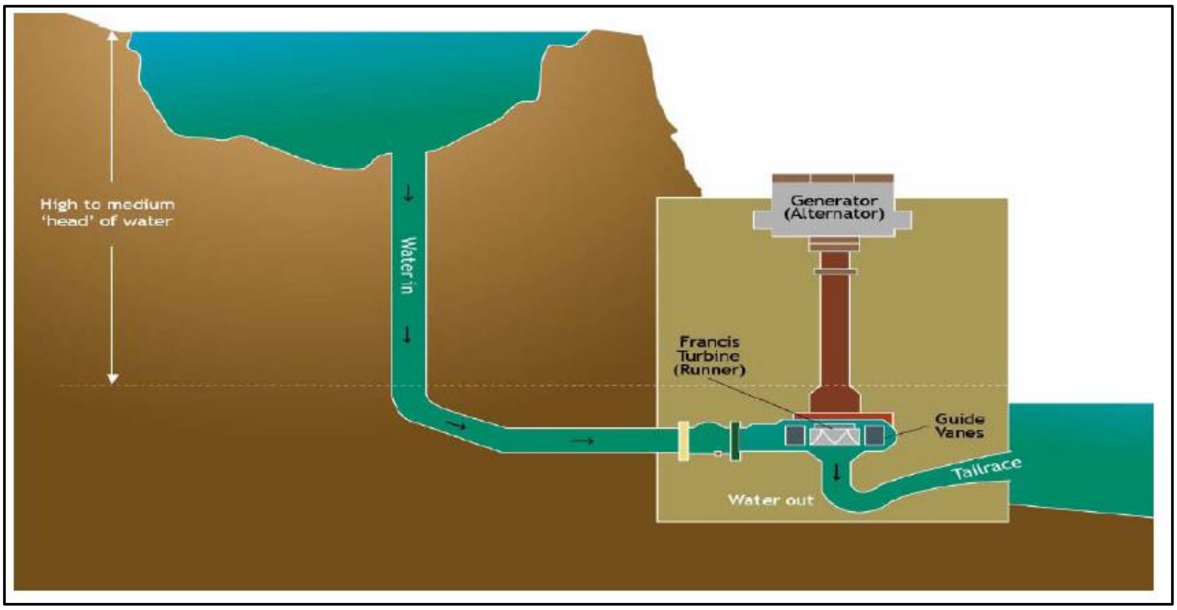


Figure 18: Pondage Hydropower Scheme (Mobolaji Bello and Clinton Carter-Brown, 2018).

Hydropower scheme are generally of three types:

- **Run-of-river**

  Run-of-river uses the natural flow of a river without causing an appreciable change in river flow and the surrounding environment. Such a system is usually built on a small dam that impounds a small amount of water.

- **Peaking or pumped storage**

  A peaking or pumped storage station releases water when the energy is needed. In this method, excess energy is used to pump water from a lower reservoir to an upper reservoir. During periods of high electricity demand, the water is released to the lower reservoir to generate electricity.

- **Impoundment**

  An impounded facility allows water to be released constantly to generate electricity (depending on the availability of water).

Some small hydro schemes drive induction machines, while larger hydro schemes drive synchronous machines for grid connection. One of the main advantages of hydropower is that it does not produce or emit any pollutant as a by-product. In addition, its operating cost is very low and hydropower can respond quickly to utility load demand. The main disadvantages include high initial capital cost and potential environmental impact. The environmental impact can be avoided or reduced with proper planning in the initial stage of implementation (Mobolaji Bello and Clinton Carter-Brown, 2018).

2.4.2 Hydropower Renewable Energy Technology in South Africa

Energy from water can come from waves, tides, waterfalls and rivers and will never be finished as long as we have water. In South Africa, we have a mix of small hydroelectricity stations and pumped water storage schemes. In a pumped water storage scheme, water is pumped up to a dam. Pumping the water uses some electricity but this is done in off-peak periods. During peak hours, when extra electricity is needed, the water is released through a turbine that drives an electric generator. Peak hours are usually between six and eight in the morning and evening. South Africa used to import electricity from the Cahora Bassa hydropower station in Mozambique and will do so again when the transmission line is repaired. There is also the potential to import more hydropower from countries such as Zambia, Zimbabwe and Zaire. If this happens, South Africa could become less dependent on coal-fired power stations (Department of Energy (Hydropower), 2017).

However, the generation of hydroelectricity is not without environmental effects. Large areas of land may be flooded when dams are built. This will disrupt wildlife habitats and residential and farming areas. Another problem is that cold water released from deep in a dam may have little dissolved air in it. If large amounts of this water are released into rivers, fish may be killed. But proper management can avoid this. Global pressures regarding the environmental impact and displacement of settlements by huge storage dams will likely limit the exploitation of hydropower on a large scale. Irrespective of the size of installation, any hydropower development will require authorisation in terms of the National Water Act 1998, Act 36 of 198 (Department of Energy (Hydropower), 2017).

The Baseline Study on Hydropower in South Africa, an assessment conducted by the DME in 2002, indicated that specific areas in the country show significant potential for the development of all categories of hydropower in the short and medium term. The Eastern Cape and KwaZulu-Natal are endowed with the best potential for the development of small, i.e., less than 10MW hydropower plants. The advantages and attractiveness of these plants are that they can either be standalone or in a hybrid combination with other renewable energy sources. Advantage can be derived from the association with other uses of water (water supply, irrigation, flood control, etc.), which are critical to the future economic and socio-economic development of South Africa. The Southern African Power Pool (SAPP) allows the free trading of electricity between Southern African Development Community (SADC) member countries, providing South Africa with access to the vast hydropower potential in the countries to the north, notably the significant potential in the Congo River (Inga Falls) (Department of Energy (Hydropower), 2017).

2.5 CO-GENERATION RENEWABLE TECHNOLOGY OVERVIEW

Cogeneration or combined heat and power (CHP) is the use of a heat engine or power station power station to generate electricity and useful heat at the same time. Trigeneration or combined cooling, heat and power refers to the simultaneous generation of electricity and useful heating and cooling from the combustion of a fuel or a solar heat collector. The terms cogeneration and trigeneration can be also applied to the power systems generating simultaneously electricity, heat, and industrial chemicals – e.g., syngas or pure hydrogen (article: combine cycles, chapter: natural gas integrated power and syngas (hydrogen) generation cycle (Clarke Energy, 2018).

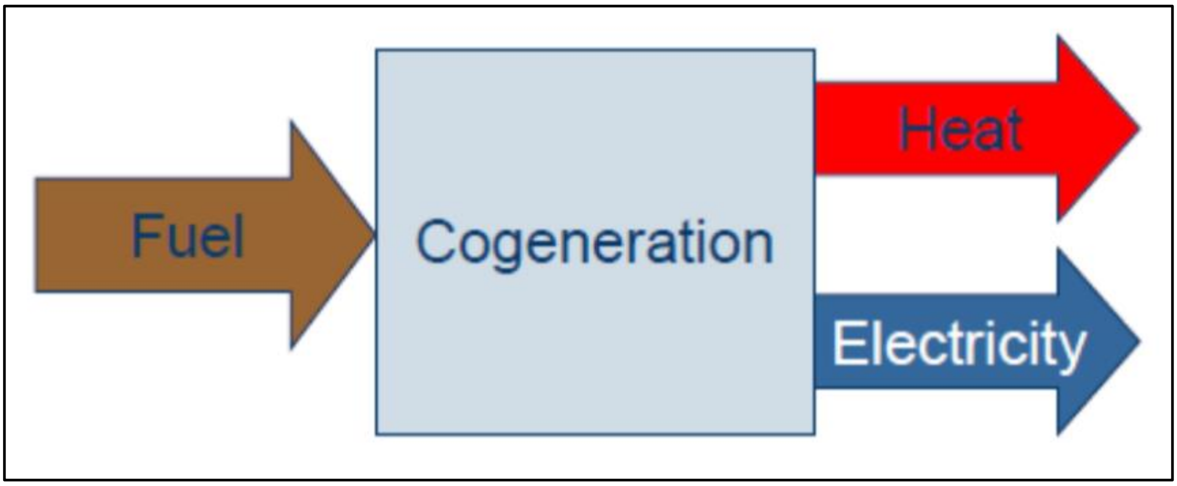


Figure 19: Cogeneration: simultaneous production of power and heat, with a view to the practical application of both products (Instituto Superior Technicon, 2017).

Cogeneration (Cogen) through combined heat and power (CHP) is the simultaneous production of electricity with the recovery and utilisation heat. Cogeneration is a highly efficient form of energy conversion and it can achieve primary energy savings of approximately 40% by compared to the separate purchase of electricity from the national electricity grid and a gas boiler for onsite heating. Combined heat and power plants are typically embedded close to the end user and therefore help reduce transportation and distribution losses, improving the overall performance of the electricity transmission and distribution network.

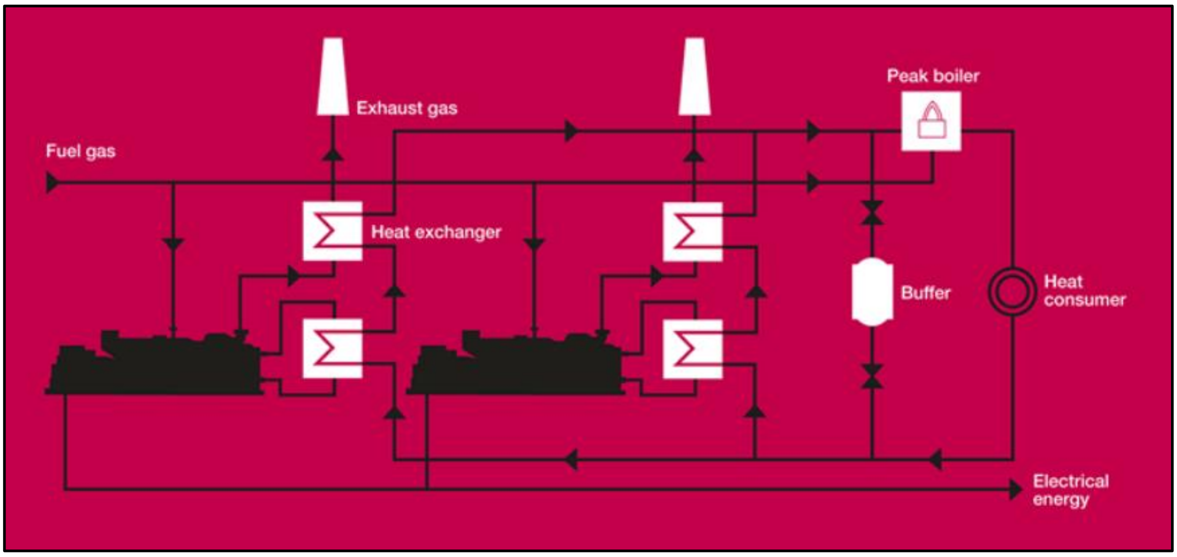


Figure 20: Cogeneration schematic, combine heat and power (CHP) (Clarke Energy, 2018).

Cogeneration is more thermally efficient us of fuel than producing process heat alone because in electricity production some energy must be rejected as waste heat, but in cogeneration some of this thermal energy is put to good use. The supply of high-temperature heat first drives a gas or steam turbine-powered generator. The resulting low-temperature waste heat is then used for water or space heating. At smaller scales (typically below 1 MW) a gas engine or diesel engine may be used. Trigeneration differs from cogeneration in that the waste heat is used for both heating and cooling, typically in an absorption refrigerator. Combined cooling, heat and power systems can attain higher overall efficiencies than cogeneration or traditional power plants. Cogeneration was practiced in some of the earliest installations of electrical generation. Before central stations distributed power, industries generating their own power used exhaust steam for process heating. Large office and apartment buildings, hotels and stores commonly generated their own power and used waste steam for building heat. Due to the high cost of early purchased power, these CHP operations continued for many years after utility electricity became available (Hunter, Louis C, Bryant, Lynwood, 1991).

The European Union generates 11% of its electricity using cogeneration. However, there is large difference between Member States with variations of the energy savings between 2% and 60%. Europe has the three countries with the world's most intensive cogeneration economies: Denmark, the Netherlands and Finland. Of the 28.46 TWh of electrical power generated by conventional thermal power plants in Finland in 2012, 81.80% was cogeneration (Cogen Europe, 2017). According to the IEA 2008 modelling of cogeneration expansion for the G8 countries, the expansion of cogeneration in France, Germany, Italy and the UK alone would effectively double the existing primary fuel savings by 2030. This would increase Europe's savings from today's 155.69 TWh to 465 TWh in 2030. It would also result in a 16% to 29% increase in each country's total cogenerated electricity by 2030 (Department for Food and Rural Affairs (DEFRA), 2018).

2.5.1 Benefits of Cogeneration Renewable Energy Technology

According to Clarke Energy a Kohler company, 2018: Cogeneration or combined heat and power (CHP) plant compared with conventional bought in electricity and site-produced heat provides a number of benefits including:

- On site production of power
- Reduced and low energy costs
- Reduction and lower emissions (including CO2) compared to conventional electrical generators and onsite boilers
- Improves energy efficiency
- Conserves natural resources (fossil fuels)
- If heat fits demand, cheapest way of electricity production
- Improves security of supply
- Reduces transmission and distribution losses
- Enhances competition

2.5.2 Cogeneration System Efficiency Renewable Energy Technology

According to Clarke Energy a Kohler company, 2018: Gas engine combined heat and power systems are measured based upon the efficiency of conversion of the fuel gas to useful outputs. The diagram below illustrates this concept. Firstly, the energy in the fuel gas input is converted into mechanical energy via the combustion of the gas in the engine's cylinders and their resulting action in the turning of the engine's crankshaft. This mechanical energy is in turn used to turn the engine's alternator in order to produce electricity. There is a small amount of inherent loss in this process and in this example the electrical efficiency of the engine is 40% (in reality GE's Jenbacher gas engines are typically between 40-48.7% electrically efficient).

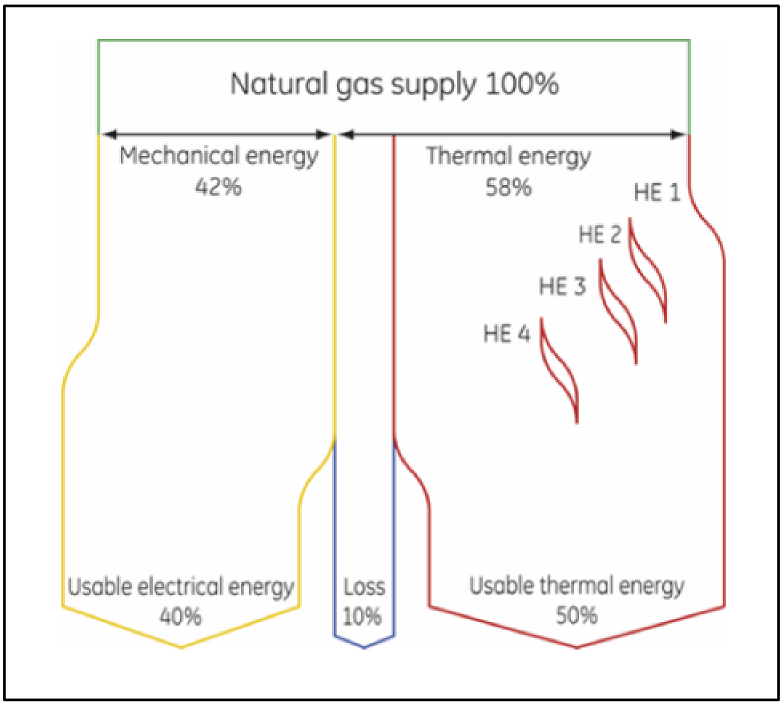


Figure 21: HE 1 - Mixture intercooler, HE 2 - Oil exchange heater, HE 3 - Engine jacket water heat exchanger, HE 4 - Exhaust gas heat exchanger (Clarke Energy, 2018)

Most industrial countries generate the majority of their electrical power needs in large, centralised facilities with capacity for large electrical power output. These plants have excellent economies of scale, but usually transmit electricity long distances resulting in sizable losses, negatively affect the environment. Large power plants can use cogeneration or trigeneration systems only when sufficient need exists in immediate geographic vicinity for an industrial complex, additional power plant or a city.

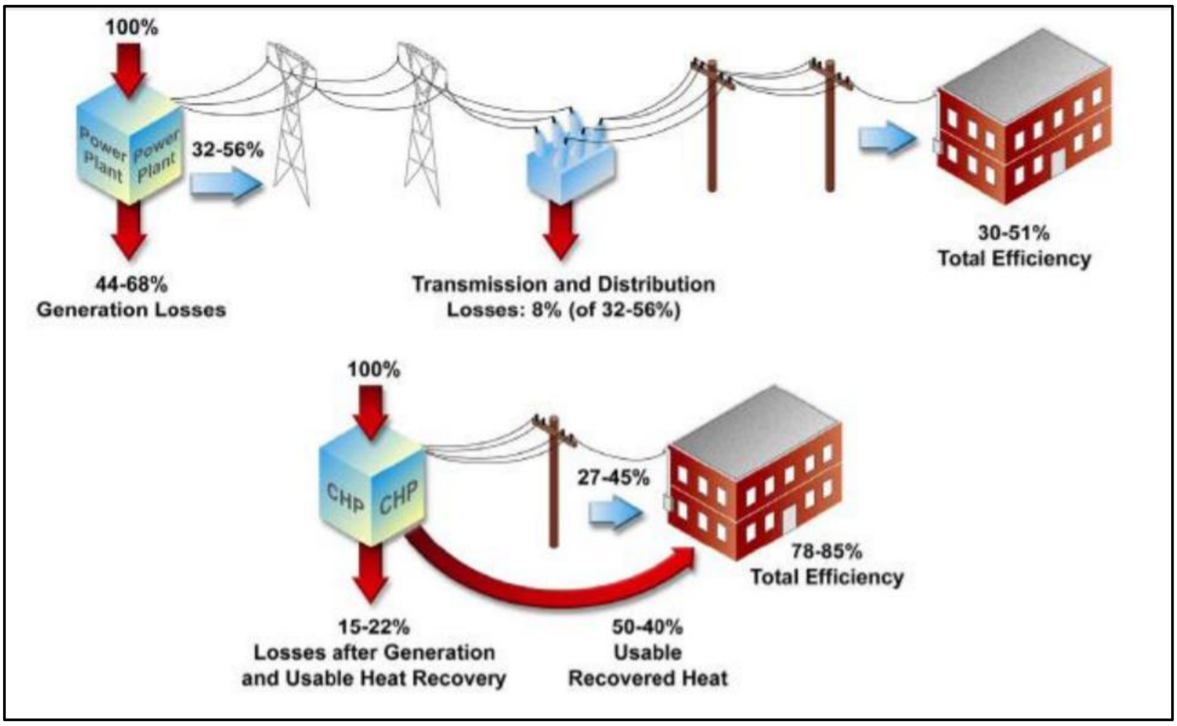


Figure 22: Showing how Cogeneration, efficiency and saves energy (Instituto Superior Tecnico, 2017).

2.5.3 Cogeneration Renewable Energy Technology in South Africa

A co-generator is a source of electrical power that is a co-product, by-product, waste product or residual product of an underlying industrial process. The National Energy Regulator of South Africa (NERSA) categorizes co-generation as follows:

- **Type I:** Projects utilizing process energy, which would otherwise be underutilized or wasted (e.g. waste heat recovery).
- **Type II:** Primary fuel-based generation projects, which produce, as part of their core design, other usable energy in addition to electricity (e.g. Combined Heat and Power projects).
- **Type III:** Renewable fuel-based projects where the renewable fuel source is both the primary source of energy and is a co-product of an industrial process (e.g. use of bagasse and/or forestry waste from the sugar and paper industries).

Figure 23 and 24 illustrates this approach of generation and its increased efficiency when compared to conventional generation. Transporting electricity over long distances is easier and cheaper than transporting heat energy. Combined Heat and Power (CHP) installations are usually sited as near as possible to the place where the heat energy is consumed and, ideally, are built to a size that meet the heat demand. When less electricity is generated than needed, it is necessary to buy additional electricity from the utility. When the CHP scheme is sized according to the heat demand, more electricity than needed locally is normally generated. The surplus electricity can be sold to the utility or supplied to another customer via wheeling through the utility network.

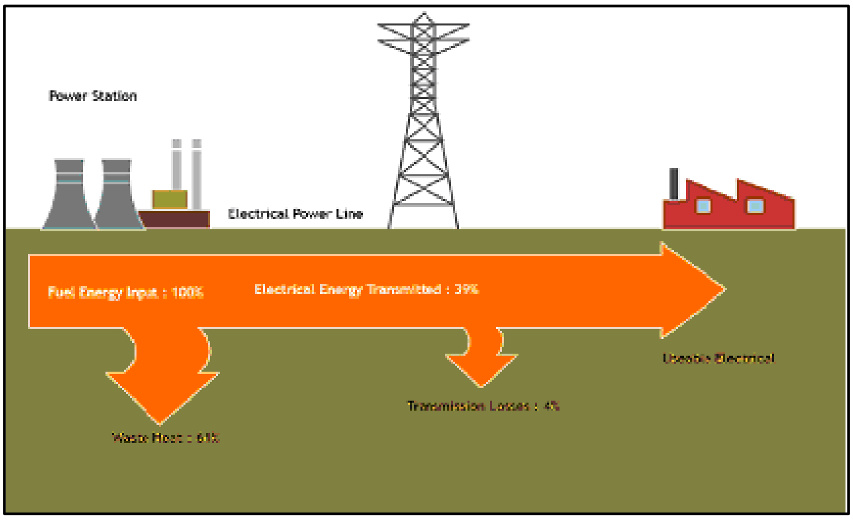


Figure 23: Concept of combine heat and power: Conventional generation

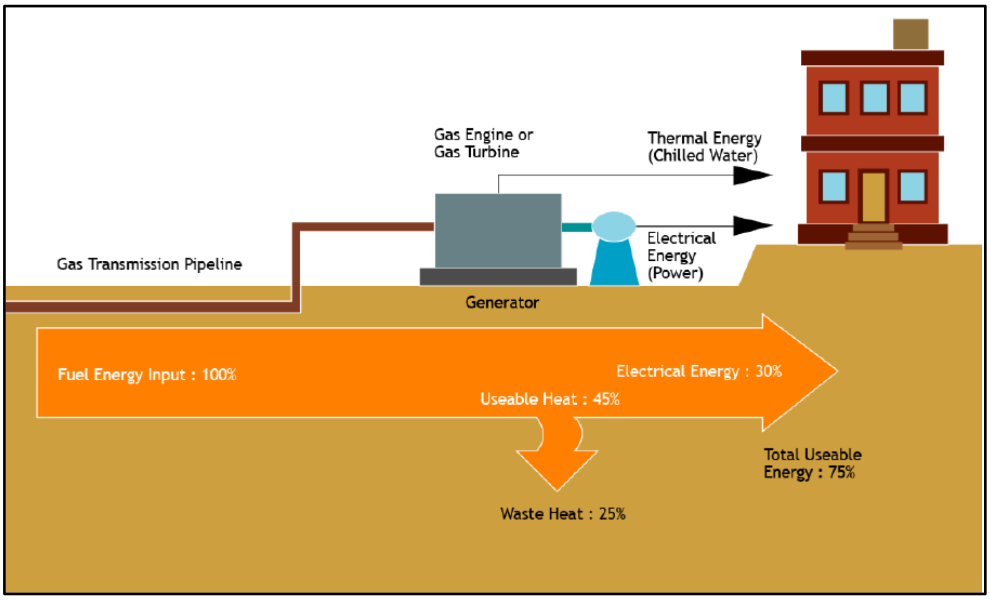


Figure 24: Concept of combine heat and power: Natural gas CHP system

The Cogeneration IPP procurement programme will procure energy through three technologies - Waste to Energy, Combined Heat and Power (CHP), and Industrial Biomass.

The Cogeneration IPP procurement programme has two common characteristics which is that the fuel and/or energy source originates from an underlying industrial process and the cogeneration facility is coupled to the industrial process of a host plant. The Cogeneration IPP procurement programme has two common characteristics which is that the fuel and/or energy source originates from an underlying industrial process and the cogeneration facility is coupled to the industrial process of a host plant.

Cogeneration is a promising technological option for SA and the world at large. This technology permits the combined production of two forms of energy from a single fuel source. This possibility is advantageous in industry where electricity and process heat can be produced with outstanding efficiency. It has been shown to offer sizable energy savings and cost advantages in a wide variety of industries around the world. Despite these attractive benefits SAs use of cogeneration remains limited. In addition, the true potential for cogeneration in SA has not been properly quantified. This represents a significant shortfall in our understanding of the future of the SA energy system. The integrated resource plan for electricity (2012) presents findings that 2GW of cogeneration capacity can be realised by 2020. This figure is unconfirmed, and the sources of this proposed cogeneration development have not been scrutinized. These research gaps must be explored if SA is to realise its cogeneration potential. This research seeks to investigate the potential for cogeneration in SA. A research method was developed specifically to determine what cogeneration currently exists in SA and how much capacity could be developed into the future (Paul Jonathan Dingle, 2013).

2.6 GOETHERMAL RENEWABLE TECHNOLOGY OVERVIEW

Geothermal energy is the heat from the Earth. It's clean and sustainable. Resources of geothermal energy range from the shallow ground to hot water and hot rock found a few miles beneath the Earth's surface, and down even deeper to the extremely high temperatures of molten rock called magma. Geothermal energy is thermal energy generated and stored in the Earth. Thermal energy is the energy that determines the temperature of matter. The geothermal energy of the Earth's crust originates from the original formation of the planet and from radioactive decay of materials (in currently uncertain but possibly equal proportions (Dye, 2017).

In general terms, geothermal energy consists of the thermal energy stored in the Earth’s crust. Thermal energy in the earth is distributed between the constituent host rock and the natural fluid that is contained in its fractures and pores at temperatures above ambient levels. Geothermal fluids of natural origin have been used for cooking and bathing since before the beginning of recorded history; but it was not until the early 20th century that geothermal energy was harnessed for industrial and commercial purposes. In 1904, electricity was first produced using geothermal steam at the vapor-dominated field in Larderello, Italy. Since that time, other hydrothermal developments, such as the steam field at The Geysers, California; and the hot-water systems at Wairakei, New Zealand; Cerro Prieto, Mexico; and Reykjavik, Iceland; and in Indonesia and the Philippines, have led to an installed world electrical generating capacity of nearly 10,000 MW (MIT, 2018).

The geothermal gradient, which is the difference in temperature between the core of the planet and its surface, drives a continuous conduction of thermal energy in the form of heat from the core to the surface. The adjective geothermal originates from the Greek roots γη (ge), meaning earth, and θερμος (thermos), meaning hot. Almost everywhere, the shallow ground or upper 10 feet of the Earth's surface maintains a nearly constant temperature between 50° and 60°F (10° and 16°C). Geothermal heat pumps can tap into this resource to heat and cool buildings. A geothermal heat pump system consists of a heat pump, an air delivery system (ductwork), and a heat exchanger-a system of pipes buried in the shallow ground near the building. In the winter, the heat pump removes heat from the heat exchanger and pumps it into the indoor air delivery system. In the summer, the process is reversed, and the heat pump moves heat from the indoor air into the heat exchanger. The heat removed from the indoor air during the summer can also be used to provide a free source of hot water (Gando A, Dweyer D.A, McKeown R.D, & Zhang C, 2017).

Geothermal power is cost-effective, reliable, sustainable, and environmentally friendly, but has historically been limited to areas near tectonic plate boundaries. Recent technological advances have dramatically expanded the range and size of viable resources, especially for applications such as home heating, opening a potential for widespread exploitation. Geothermal wells release greenhouse gases trapped deep within the earth, but these emissions are much lower per energy unit than those of fossil fuels. The Earth's geothermal resources are theoretically more than adequate to supply humanity's energy needs, but only a very small fraction may be profitably exploited. Drilling and exploration for deep resources is very expensive. Forecasts for the future of geothermal power depend on assumptions about technology, energy prices, subsidies, plate boundary movement and interest rates (Glassley, 2017). According to Bertani/IGA, the countries with the greatest increase in installed capacity (MW) between 2005 and 2010 were: 1) US - 530 MW, 2) Indonesia - 400 MW, 3) Iceland - 373 MW, 4) New Zealand - 193 MW, and 5) Turkey 0 62 MW. In terms of the percentage increase the top five countries were 1) German - 2,774%, 2) Papua-New Guinea - 833%, 3) Australia - 633%, 4 Turkey - 308%, and 5) Iceland - 184% (GEA, 2018). GEA reported in 2007 there were 46 countries considering geothermal power development. In 2010, this report identified 70 countries with projects under development or active consideration, a 52% increase since 2007.

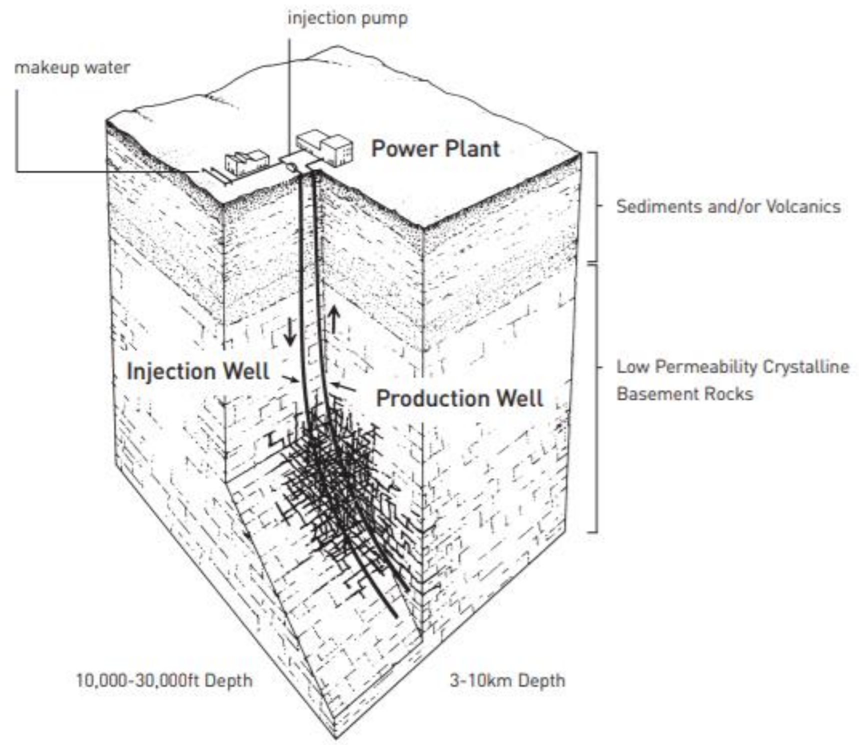


Figure 25: Schematic of conceptual two-well enhanced Geothermal system in hot rock in low-permeability crystalline basement formation (MIT, 2018).

Projects under development grew the most dramatically in two regions of the world, Europe and Africa. Ten countries in Europe were listed as having geothermal projects under development in 2007, and in 2010 this has more than doubled to 24. Six countries in Africa were identified in 4, 2007 and in 2010 eleven are found to be actively considering geothermal power (GEA, 2018).

2.6.1 Benefits of Geothermal Renewable Energy Technology

Geothermal electric plants were traditionally built exclusively on the edges of tectonic plates where high temperature geothermal resources are available near the surface. The development of binary cycle power plants and improvements in drilling and extraction technology enable enhanced geothermal systems over a much greater geographical range (MIT, 2018). The International Geothermal Association (IGA) has reported that 10,715 megawatts (MW) of geothermal power in 24 countries is online, which was expected to generate 67,246 GWh of electricity in 2010. This represents a 20% increase in online capacity between 2005 and 2010. IGA projects growth to 18,500 MW by 2015, due to the projects presently under consideration, often in areas previously assumed to have little exploitable resources (GEA, 2018).

Despite these growth trends, however, the potential of geothermal resources to provide clean energy appears to be under-realized. In 1999, GEA prepared a report that examined geothermal power potential internationally. The results of this report show that in the vast majority of countries the estimated potential remains undeveloped and largely untapped, even assuming the lowest projections for geothermal resource potential. Moreover, the number of countries with geothermal power potential that are not developing their resources is still high. Geothermal power requires no fuel (except for pumps) and is therefore immune to fuel cost fluctuations. However, capital costs are significant. Drilling accounts for over half the costs, and exploration of deep resources entails significant risks. A typical well doublet (extraction and injection wells) in Nevada can support 4.5 megawatts (MW) and costs about $10 million to drill, with a 20% failure rate. Enhanced geothermal systems tend to be on the high side of these ranges, with capital costs above $4 million per MW and break–even above $0.054 per kW·h in 2007 (Subir K. Sanyal, James W. Morrow, Steven J. Butler and Ann Robertson-Tait, 2017).

Figure 26: The Somona Calpine 3, geothermal renewable energy, a power plant at The Geysers (Wiki, 2020) in the Mayacamas Mountains, Northern California.

A large portion of the world's installed geothermal generation capacity remains in North America. With approximately 3086 MW of installed geothermal capacity the US is the world's leading producer of geothermal energy for electricity generation. Mexico, with 958 MW of geothermal energy online, ranks fourth in global installed geothermal capacity (Jennejohn, 2017). The International Geothermal Association (IGA) has reported that 10,715 megawatts (MW) of geothermal power in 24 countries is online, which was expected to generate 67,246 GWh of electricity in 2010. This represents a 20% increase in online capacity since 2005. IGA projects growth to 18,500 MW by 2015, due to the projects presently under consideration, often in areas previously assumed to have little exploitable resources (GEA, 2018). In 2010, the United States led the world in geothermal electricity production with 3,086 MW of installed capacity from 77 power plants. The Philippines is the second highest producer, with 1,904 MW of capacity online (GEA, 2018). Geothermal power makes up approximately 27% of Philippine electricity generation The largest group of geothermal power plants in the world is located at The Geysers, a geothermal field in California (Khan, 2018). In 2016, Indonesia set in third with 1,647 MW online behind USA at 3,450 MW and the Philippines at 1,870 MW, but Indonesia will become second due to an additional online 130 MW at the end of 2016 and 255 MW in 2017. Indonesia's 28,994 MW are the largest geothermal reserves in the world, and it is predicted to overtake the USA in the next decade (Jakarta Globe, 2016).

2.6.2 Geothermal Renewable Energy Technology in South Africa

Of the 87 thermal springs that have been identified in South Africa, 29 have currently been developed for direct use, despite abundant and cheap coal supplies hindering interest in researching and developing renewable energy resources. Geothermal development highlights a feasibility study was recently launched to look into power generation from thermal spring binary systems and from hot granite (Bertani, 2017). Following national policies were released:

Table 7: National Policies (Alison Holm, Leslie Blodgett, Dan Jennejohn & Karl Gawell, 2018).

Policy (year)	Description
Vision, Strategic Direction and Framework for Climate Policy (2008)	Emphasizes greenhouse gas emission reductions/limits, strengthening existing initiatives, adaptation/mitigation, growing renewable energy sector,
White Paper on Renewable Energy (2003)	Sets target of an additional 10,000 GWh from renewable energy sources contributing to final energy consumption by 2013 and removes barriers preventing renewable energy from penetrating the market

Until recently, little attention was paid to research into geothermal energy, largely because South Africa's geology of solid rock precludes large geo- thermal discovery but also because of the lack of government support and the significant costs involved, with up to R48-million required just for the feasibility phase of such projects – R12,5-million of which is at high risk. However, the energy crisis and the drive for renewable-energy generation have sparked new interest in the possibility of generating energy from heat that is readily available from the earth. Technological advances over the past few years also indicate that the use of geothermal energy may be viable in areas like South Africa (Smit, 2018). There is, currently, no large-scale geothermal production in South Africa, since coal is abundant and relatively cheap, supplying the largest part of the country's energy requirements. However, the Renewable Energy Policy Network for the 21st Century, or REN21, 'Renewables 2010 Global Status Report' states that, as the geothermal market continues to broaden, a significant acceleration in installations is expected, with advanced technologies enabling the development of geothermal power projects in new countries (Smit, 2018).

Power generation solutions company HRP Geothermal Power engineering director Andrew Ochse explains that there are three types of heat sources – magmatic, frictional and radioactive. South Africa, predominantly, has radioactive geothermal heat sources. Given high enough temperatures of these heat sources, it is possible to heat water or steam to high enough temperatures to make electricity production possible. University of the Witwatersrand senior research officer Dr Michael Jones explains that radioactive heat derives from the natural radioactive decay of isotopes of uranium, thorium and potassium, which are disseminated throughout most of the volume of the earth. Radioactive decay contributes about 75% to the earth's heat budget. There is also a definite connection between water and geothermal energy generation, a prospect that natural resources management company Touchstone resources has been exploring. The company is focused on developing energy and water resources for socioeconomic benefit, and CEO David Gadd-Claxton says that water and energy should be seen as a "flux". Flux is an inherent quality of natural resources that allow them to flow through time and space, in effect recycling naturally. "Water does not disappear; the amount of water stays exactly the same through the ages. The problem is that, to date, water has been managed as stock. If water is managed as flux and reused, the earth would never run out of water supply. This unlimited water source can be applied to generate unlimited energy," Gadd-Claxton points out (Smit, 2018).

Improved heat-exploitation technologies have resulted in significant potential for primary energy recovery from the earth's stored thermal energy. While deep-core, large-scale geo-thermal energy generation will need exploration of 2 km and deeper below the surface, passive geothermal heat is found at depths of 200 m to 400 m and can be used for the heating and cooling of space. Passive or direct use of geothermal energy for heating and cooling is also commercially competitive with conventional energy sources. African Ecosystems MD Cary Praetor explains that, compared with ordinary systems, geothermal technology can save 30% to 60% on monthly domestic energy bills. "Geothermal is the safest, cleanest, most reliable space- conditioning system available," he notes.

According to Andrew Ochse explains that South Africa's geology is such that the heat is very deep and requires significant drilling to obtain clear feasibility. "We have gathered significant data from various sources about different parts of the country, which estimates that we must go down to between 4 000 m and 6 000 m, depending on the exact location," he notes. This was previously not feasible, owing to the cost of drilling but now, with energy shortages and increased electricity costs, he believes that the finances should become available. There is some investor interest coming from the mining and industrial sectors, which HRP Geothermal Power has been exploring. Ochse points out that this interest is in large, long-term capital projects with the same magnitude of effort for each megawatt as for coal-fired power plants, but with the advantage that the "fuel" or heat source is free once you get to it. "We would generally target a 50-MW or more installed capacity geothermal plant, as the financials make sense at this size, with the risk-weighted capital cost amounting to about R1,45-billion," he says.

2.6.3 Challenges and Limitations of Geothermal Renewable Energy Technology in South Africa

The temperature in the earth's interior is as high as 7 000 °C. The ability to extract this geothermal energy depends on the depth of the earth crust, which varies. Research on renewable energy in South Africa showed that geothermal has little potential in South Africa. There are four types of geothermal resources, namely hydrothermal, geo-pressured, hot dry rock and magma. Among the four types, only the hydrothermal resource is currently commercially available. Hydrothermal resource comes in the form of either steam or hot water, depending on the temperature and pressures involved. Figure 26 shows a typical geothermal plant.

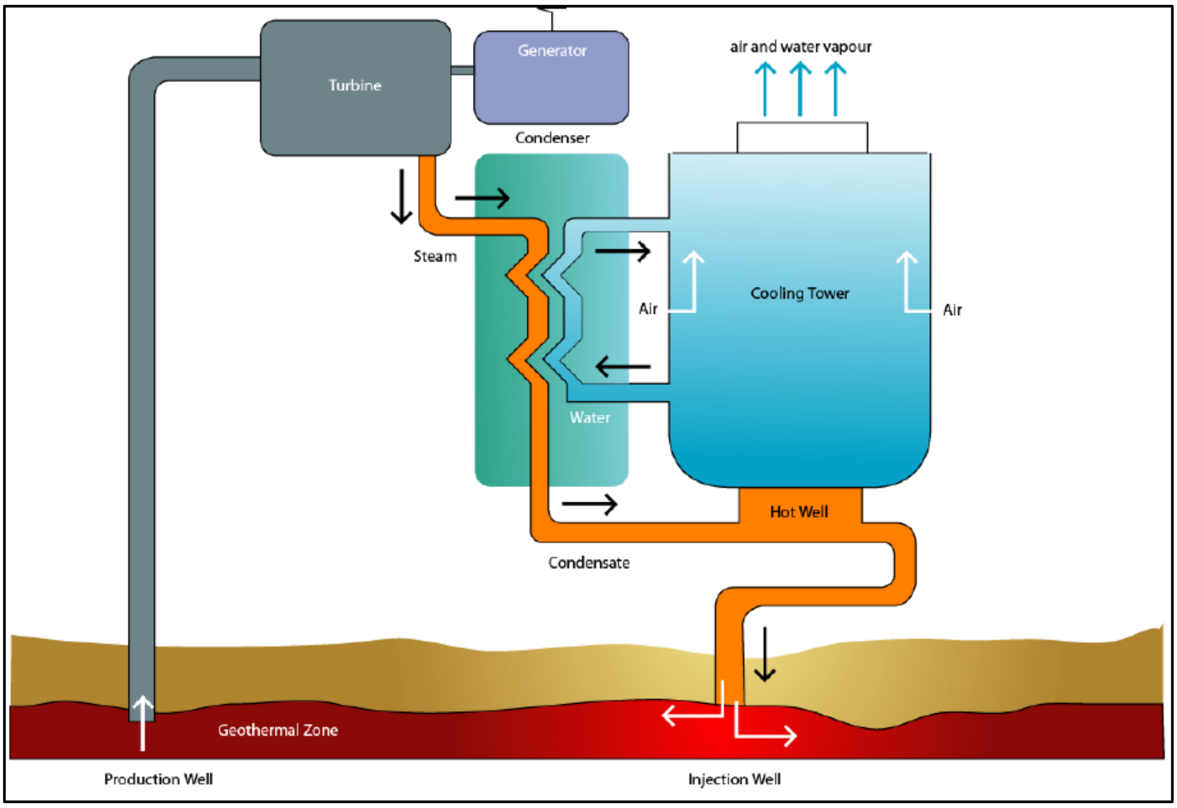


Figure 27: Geothermal Power Plant (Mobolaji Bello and Clinton Carter-Brown, 2018).

Jones says that South Africa is far removed from active plate boundaries and heat flows to the surface predominantly by conduction. Thermal gradients vary from as low as 8 °C/km to as much as 40 °C/km. “These values for heat flux and thermal gradient are considerably lower than those experienced in geothermal areas, but the heat is there if one goes deep enough – it is a matter of extracting it at economically viable rates,” he explains (Smit, 2018). Praetor says that geo- thermal energy generation is a $20-billion industry in North America and has the potential to grow in South Africa. However, the particular skills set needed to expand the industry is lacking and this inhibits growth. “There seems to be resistance from local mechanical engineers to venture into geo- thermal. A possible reason for this may be that they do not have the relevant knowledge and, therefore, see it as a threat,” he says.

According to Andrew Ochse, agrees that there are limited geo- thermal skills within South Africa, but points out that there are numerous geology experts who can assist in the process. Harnessing geological knowledge, HRP Geothermal Power has worked with local geothermal experts as well as experts from the US, Australia and New Zealand to assess the viability of geothermal in South Africa. Jones, being a local geology expert, notes that geothermal energy is economically and technologically difficult to extract. Much of the equipment needed is sourced internationally, as the expertise is not available locally. HRP Geothermal Power would like to shift some of this capacity to local manufacturing, if warranted by sufficient geothermal energy generation (Smit, 2018).

Local power utility Eskom senior process engineer Gary Dysel says that Eskom, in its drive to reduce the country's energy footprint, welcomes energy- reducing technologies. The company met with African Ecosystems, part of sustainable energy company Geothermal Energy Systems, about three years ago to discuss possibilities, where Praetor presented the significantly improved coefficient performance values of geothermal systems. "The improved performance attracted us to the product. We assigned about 15 energy advisers across the country to distribute knowledge and offer advice on the use of geothermal energy," he notes. The role of an energy adviser is to assist the industrial, commercial, domestic and agriculture sectors on the most efficient way of using energy. Dysel says that the advisers are linked to the demand-side management (DSM) process of project funding and present companies with energy saving projects for evaluation and funding. They are under significant pressure to reduce energy use by 1 074 MW in the next three years (Smit, 2018).

He adds that Eskom has, to date, not put through any DSM-funded geothermal projects, but is aware that interest in geothermal energy has increased globally and that Praetor has been successful on numerous projects. "Geothermal will assist us in decreasing our energy use. However, at this stage, geothermal is a new word to many and, like many new technologies that are introduced, is not being immediately accepted," Dysel explains, he believes that all energy avenues, such as correct lighting, hot water use, solar photovoltaic and geothermal, should be tackled in the next five years. "I do believe that, as we enter an energy crisis, all forms of energy savings will find a place in the market and that the price of electricity will dictate the lengths to which the consumer will go to make the necessary savings," he asserts (Smit, 2018).

2.6.4 Coal versus Geothermal Renewable Energy Technology

The primary use of geothermal energy is as an environmentally clean substitute for fossil fuels. It is a renewable baseload energy source and is sustainable and affordable. An advantage of geothermal heat pumps driven by fossil-fuelled electricity is that they reduce carbon dioxide (CO_2) emissions by at least 50%, compared with fossil-fuel-fired boilers. The Energies journal explains that, if the electricity that drives the geothermal heat pump can be produced from a renewable- energy source like hydropower or geothermal energy, the emission savings will increase to 100%. The total CO_2 emissions reduction potential of geothermal heat pump has been estimated to be 1,2-billion tons a year, or about 6% of global emissions. Coal-fired power plants produce about 25 times as much CO_2 and sulphur dioxide (SO_2) emissions for each megawatt hour as geothermal power plants, which emit about 120 g/kWh. However, in a geothermal power plant, hydrogen sulphide (H_2S) also needs to be routinely treated and converted into elemental sulphur, since about 0,8 kg of H_2S may be produced for each megawatt hour of electricity generated. The Energies journal argues that this is still significantly better than oil-fired power plants and natural-gas-fired plants, which produce 814 kg and 550 kg of H_2S for each megawatt hour respectively. Another advantage of geothermal plants is low freshwater use. The plants use about 20 ℓ of freshwater for each megawatt hour, while a coal plant uses 1 370 ℓ/MWh (Smit, 2018).

Geothermal power plants generally consist of small modular plants under 100 MWe, compared with coal or nuclear plants of around 1 000 MWe. Further, a geothermal facility normally uses 400m2 of land for each gigawatt hour, compared with a coal facility which uses almost ten times that area for each gigawatt hour and a wind farm, which uses three times the area for the same power generation. However, sub-silence and induced seismicity, such as earthquakes, are two land use challenges that must be considered when withdrawing fluids from the ground. Neither of these potential problems is associated with direct-use projects, as the fluid use is minimal. Further, using geo-thermal resources eliminates the mining, processing and transporting required for electricity generation from fossil fuel and nuclear resources.

Exploring other potential sources meanwhile, mines also present potential for geothermal energy generation. Green project development company GX Energie has considered the geothermal potential of South African mines, which have the distinct advantage of established underground infrastructure, which could be used to access warm water reserves for geothermal cooling. “Mining companies are planning to mine below 4 000 m, requiring the existing cooling infrastructure to be expanded. There is a cubic relationship between the quantity of the air to be delivered and the power required to move it, which is generated using coal-based power plants, emitting extensive greenhouse gases” he notes. A geothermal project based on using the heat resources of underground mines and converting them into cooled air for the underground operations through a geothermal ventilation on-demand system will reduce the power requirements of the mine, result in cost savings and contribute to significant reductions in greenhouse-gas emissions.

Gadd-Claxton adds that geothermal energy and significant amounts of water collect at the bottom of gold mines. The dirty water could be cleaned by using the available geothermal heat to distil the water. This technology is being applied in Australia. “Although there are no rifts in the tectonic plates in South Africa, the country has enough deep-level mines and hot rocks to generate geothermal energy. But it will be expensive, costing $50 million to $100 million to implement, which is about the same price as that for a power station,” he adds. The technology for such exploration and implementation is already available and being used in other countries, such as the US and Israel. Gadd-Claxton points out that neither the idea nor the technology is new but that, because energy in South Africa was always cheap, geothermal energy generation was not considered (Smit, 2018).

2.7 BIO-ENERGY RENEWABLE TECHNOLOGY OVERVIEW

Bioenergy is a renewable energy source created from natural, biological sources. Many natural sources, such as plants, animals, and there by products, can be valuable resources. Bioenergy is a bit confusing actually, some people mistake biomass with bioenergy. Bioenergy is the energy you extract from the biomass. So, bioenergy can be electricity as produced from biomass. It can be heat as produced from biomass or it could be cooling as produced from biomass. It can be any kind of energy produced from biomass. Biomass is the fuel and bioenergy are the energy contained in the fuel. It is also the energy service provided from that energy like light, running the computer, heating up the building. Also process heat for steel melting that is also bioenergy from biomass. So do not confuse bioenergy with biomass these are two different things (Zethraeus, 2018). Most bioenergy comes from forests, agricultural farms, and waste. The feedstocks are grown by farms specifically for their use as an energy source. Common crops include starch or sugar-based plants, like sugarcane or corn. Biomass is any organic material which has stored sunlight in the form of chemical energy. As a fuel it may include wood, wood waste, straw, manure, sugarcane, and many other by-products from a variety of agricultural processes. By 2010, there was 35 GW (47,000,000 hp) of globally installed bioenergy capacity for electricity generation, of which 7 GW (9,400,000 hp) was in the Unites (Frauke Urban & Tom Mitchell, 2018).

To turn the raw sources into energy, there are three processes: chemical, thermal and biochemical. Chemical processing uses chemical agents to break down the natural source and convert it into liquid fuel. Corn ethanol, a fuel created from corn, is an example of chemical processing results. Thermal conversion uses heat to change the source into energy through combustion or gasification. Biochemical conversion uses bacteria or other organisms to convert the source, such as through composting or fermentation. Bioenergy exists at several different levels. Individuals can create bioenergy, such as by creating a compost heap out of kitchen scraps and keeping worms to produce rich fertilizer. At the other extreme are large energy corporations looking for more sustainable energy sources than oil or coal. These organizations use huge farms and facilities to provides hundreds or thousands of customers with energy (Orloff, 2018).

Modern technology makes even landfills or waste zones potential bioenergy resources. It can be used to be a sustainable power source, providing heat, gas, and fuel (Orloff, 2018). Bioenergy is one of the many diverse resources available to help meet our demand for energy. It is classified as a form of renewable energy derived from biomass—organic material—that can be used to produce heat, electricity, transportation fuels, and products (US Department of Energy, 2018). In its most narrow sense, it is a synonym to biofuel, which is fuel derived from biological sources. In its broader sense it includes biomass, the biological material used as a biofuel, as well as the social, economic, scientific and technical fields associated with using biological sources for energy. This is a common misconception, as bioenergy is the energy extracted from the biomass, as the biomass is the fuel, and the bioenergy is the energy contained in the fuel.

So, bioenergy can be electricity as produced from biomass. It can be heat as produced from biomass or it could be cooling as produced from biomass. It can be any kind of energy produced from biomass. Biomass is the fuel and bioenergy is the energy contained in the fuel. It is also the energy service provided from that energy like light, running the computer, heating up the building. Also process heat for steel melting that is bioenergy from biomass. So do not confuse bioenergy with biomass these are two different things (Zethraeus, 2018). Using bioenergy has the potential to decrease our carbon footprint and improve the environment. While bioenergy uses the same amount of carbon dioxide as traditional fossil fuels, as long as the plants used are replaced, the impact is minimized. Fast-growing trees and grass help this process and are known as bioenergy feedstocks (Orloff, 2018).

Abundant, renewable bioenergy can contribute to a more secure, sustainable, and economically sound future by providing domestic clean energy sources, reducing U.S. dependence on foreign oil, generating U.S. jobs, and revitalizing rural America. More than $350 million is spent every day on foreign oil imports, and the transportation sector accounts for 67% of petroleum consumption in the United States.1 By 2030, 1 billion tons of biomass could produce up to 50 billion gallons of biofuels; produce 50 billion pounds of biobased chemicals and bioproducts; generate 85 billion kilowatt-hours of electricity to power 7 million households; contribute 1.1 million jobs to the economy; and keep $260 billion in the United States (US Department of Energy, 2018) and (J.N. Rogers, B. Stokes, J. Dunn, H. Cai, M. Wu, Z. Haq, and H. Baumes, 2018).

Switchgrass crops can be harvested to make biofuels. Credit: Warren Gretz We have used biomass energy or bioenergy - the energy from organic matter - for thousands of years, ever since people started burning wood to cook food or to keep warm. And today, wood is still our largest biomass energy resource. But many other sources of biomass can now be used, including plants, residues from agriculture or forestry, and the organic component of municipal and industrial wastes. Even the fumes from landfills can be used as a biomass energy source. The use of biomass energy has the potential to greatly reduce our greenhouse gas emissions. Biomass generates about the same amount of carbon dioxide as fossil fuels, but every time a new plant grows, carbon dioxide is actually removed from the atmosphere. The net emission of carbon dioxide will be zero as long as plants continue to be replenished for biomass energy purposes. These energy crops, such as fast-growing trees and grasses, are called biomass feedstocks. The use of biomass feedstocks can also help increase profits for the agricultural industry (Renewable Energy World, 2018).

Bioenergy is also viewed as essential for the environment. Continued use of fossil fuels will cause significant environmental issues and can harm the population's health. As technology progresses, bioenergy has the potential to dramatically reduce greenhouse emissions, the release of harmful gases associated with global warming and climate change. The use of forests and farms in bioenergy can help combat the harmful release of carbon dioxide and help achieve a balance. At this time, bioenergy is not ready to replace fossil fuels. The process is too costly and uses too many resources to be practical for most areas. The large plots of land and significant amounts of water needed to be successful can be difficult for many states or countries. As science continues to study this area, though, bioenergy will increasingly become a standard energy form and will help improve the environment (Orloff, 2018).

2.7.1 Biofuel Renewable Energy Technology

A Biofuel is a fuel that is produced through contemporary biological processes, such as agriculture and anaerobic digestion, rather than a fuel produced by geological processes such as those involved in the formation of fossil fuels, such as coal and petroleum, from prehistoric biological matter. Biofuels can be derived directly from plants, or indirectly from agricultural, commercial, domestic, and/or industrial wastes (Business Dictionary, 2018). Renewable biofuels generally involve contemporary carbon fixation, such as those that occur in plants or microalgae through the process of photosynthesis. Other renewable biofuels are made through the use or conversion of biomass (referring to recently living organisms, most often referring to plants or plant-derived materials). This biomass can be converted to convenient energy-containing substances in three different ways: thermal conversion, chemical conversion, and biochemical conversion. This biomass conversion can result in fuel in solid, liquid, or gas form. This new biomass can also be used directly for biofuels.

Corn can be harvested to produce ethanol. Credit: Warren Gretz, unlike other renewable energy sources, biomass can be converted directly into liquid fuels - biofuels - for our transportation needs (cars, trucks, buses, airplanes, and trains). The two most common types of biofuels are ethanol and biodiesel. Ethanol is an alcohol, the same found in beer and wine. It is made by fermenting any biomass high in carbohydrates (starches, sugars, or celluloses) through a process similar to brewing beer. Ethanol is mostly used as a fuel additive to cut down a vehicle's carbon monoxide and other smog-causing emissions. But flexible-fuel vehicles, which run on mixtures of gasoline and up to 85% ethanol, are now available (Renewable Energy World, 2018).

Bioethanol is widely used in the United States and in Brazil. Current plant design does not provide for converting the lignin portion of plant raw materials to fuel components by fermentation. Biodiesel can be used as a fuel for vehicles in its pure form and is made by combining alcohol (usually methanol) with vegetable oil, animal fat, or recycled cooking greases. It can be used as an additive to reduce vehicle emissions of carbon monoxide (typically 20%) and hydrocarbons from diesel-powered vehicles or in its pure form as a renewable alternative fuel for diesel engines (Renewable Energy World, 2018). Other biofuels include methanol and reformulated gasoline components. Methanol, commonly called wood alcohol, is currently produced from natural gas, but could also be produced from biomass.

There are a number of ways to convert biomass to methanol, but the most likely approach is gasification. Gasification involves vaporizing the biomass at high temperatures, then removing impurities from the hot gas and passing it through a catalyst, which converts it into methanol (Renewable Energy World, 2018).

2.7.2 Biogas Renewable Energy Technology

Biogas is a renewable energy source. Biogas is generated from organic materials under anaerobic conditions. Feedstocks for biogas generation include cow dung, poultry droppings, pig manure, kitchen waste, grass faecal matter and Biogas typically refers to a mixture of different gases produced by the breakdown of organic matter in the absence of oxygen. Biogas can be produced from raw materials such as agriculture waste, manure, municipal waste, plant material, sewage, green waste or food waste algae (Richard Arthur, Martina Francisca Baidoo & Edward Antwi, 2017). Countries where agriculture sector is an important component to the growth of economy, have found biogas as a useful replacement for wood fuel and dung as fuel for cooking, and heating. Given increasing oil prices, high health risk associated with unsustainable wood fuel usage and its impact on the environment it is crucial for the government to consider other alternatives which are sustainable and affordable.

Biogas technology even though is a well-known technology is relatively new in some parts of the world and can be used as a potent tool to address issues of Indoor Air Pollution (IAP), deforestation and Climate Change. Biogas is a clean fuel because it burns without leaving soot or particulate matter and also since it is lighter in terms of carbon chain length, less amount of carbon dioxide is released into the atmosphere during combustion. Biogas technology has helped some countries in many ways through income generation, life-style improvements and cost saving (Richard Arthur, Martina Francisca Baidoo & Edward Antwi, 2017). Biogas a clean and renewable form of energy could augment conventional energy sources. Produced through anaerobic degradation in a very complex process and requires certain environmental conditions as well as different bacteria populations (K.R. Salomon and E.E.S Lora, 2019). The complete anaerobic fermentation process is briefly described below as shown in figure below:

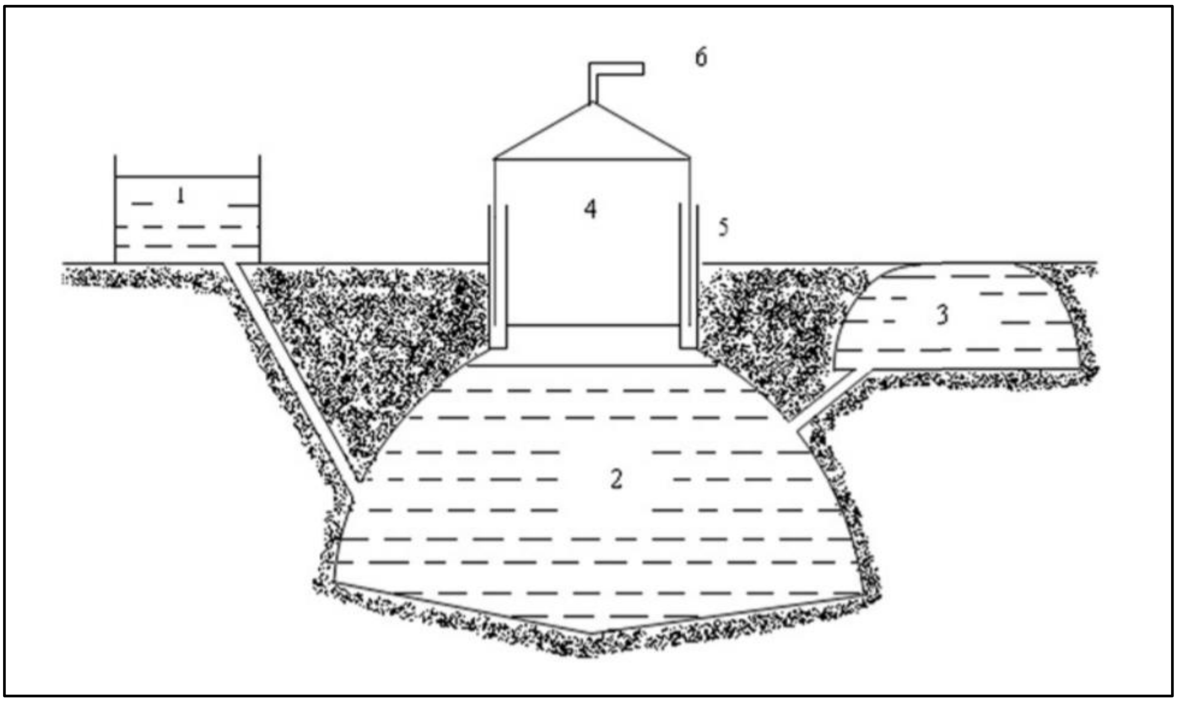


Figure 28: Floating drum digester: 1. Mixing tank with inlet pipe 2. Digester 3. Compensation tank 4. Gasholder 5. Water jacket 6. Gas pipe. (Richard Arthur, Martina Francisca Baidoo & Edward Antwi, 2017).

Biogas energy has some advantages over other energy sources. Successful use of biogas technology can result not only in energy generation and bio-fertiliser production, but also other social and ecological benefits including sanitation, reforestation and reduction of imported fuel oil (P.N. Walekhwa, J. Mugisha, & L. Drake, 2019). Every organic material can degrade to generate biogas. In view of this, the process of degradation of organic material which can be found in a landfill is the same as the process in a biogas reactor. The difference is that biogas production from anaerobic digestion takes place in a controlled reactor and at a faster rate due to optimized conditions in the biogas reactor (Wikner, 2019).

2.7.3 Landill gas Renewable Energy Technology

Landfill gas utilization is a process of gathering, processing, and treating the methane gas emitted from decomposing garbage to produce electricity, heat, fuels, and various chemical compounds (Hans-Jurgen Ehrig, Hans-Joachim Scheider, & Volkmar Gossow, 2018). The number of landfill gas projects, which convert the gas into power, went from 399 in 2005 to 519 in 2009 in the United Kingdom, according to the Environment Agency. These projects are popular because they control energy costs and reduce greenhouse gas emissions. These projects collect the methane gas and treat it, so it can be used for electricity or upgraded to pipeline-grade gas. These projects power homes, buildings, and vehicles (Kosh, 2018).

Landfill gas occurs naturally where household and commercial waste is disposed of in engineered rubbish sites. As the organic matter in the buried waste decomposes, it creates a methane-rich biogas. This is made up of approximately 55% methane and 45% carbon dioxide. It is the methane which is valuable as a source of energy for both heat and power. To utilize the biogases produced from the waste landfill, gas wells are drilled in few places on the disposal site as shown in Figure 28. The gas must first be filtered before being sent through a gas collector line to drive the turbine or reciprocating engine that generates electricity. eThekwini municipality in Durban has two operational sites generating power from landfill gas.

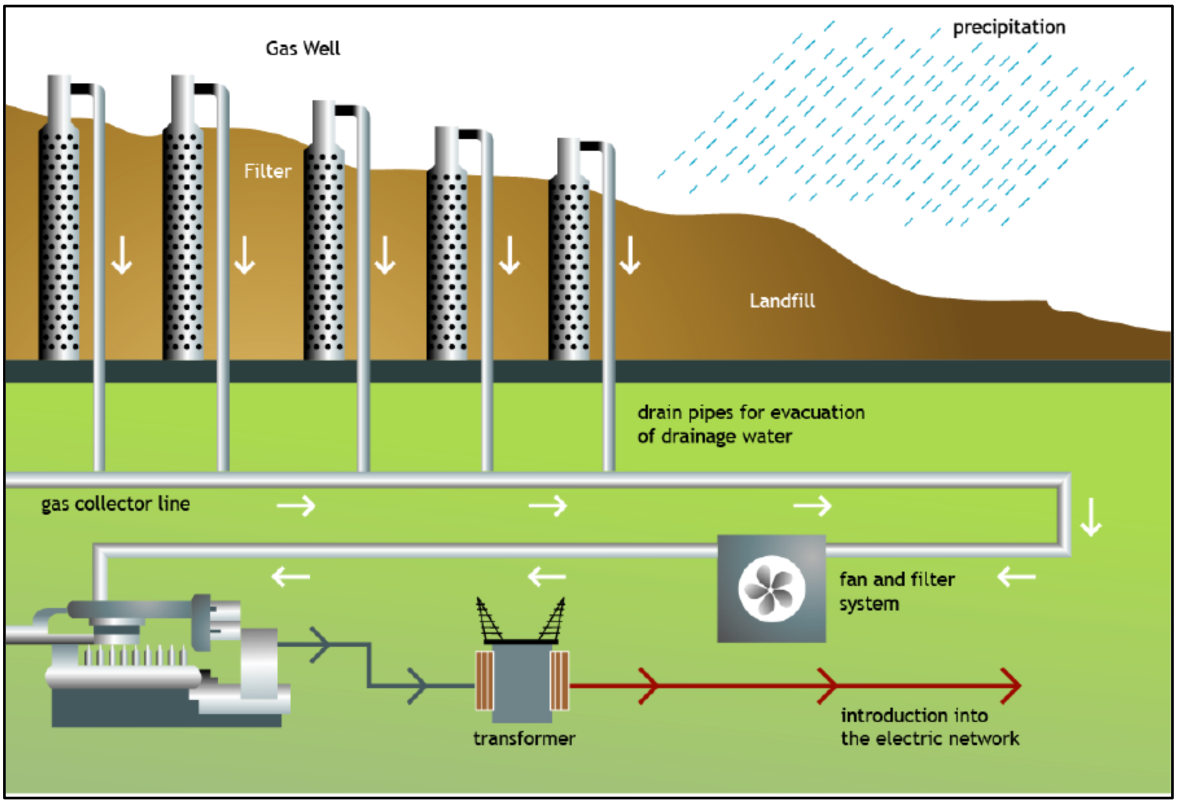


Figure 29: Landfill Generation (Mobolaji Bello and Clinton Carter-Brown, 2018).

Landfill gas is a complex mix of different gases created by the action of microorganisms within a landfill. Landfill gas is approximately forty to sixty percent methane, with the remainder being mostly carbon dioxide. Landfill gas is produced by wet organic waste decomposing under anaerobic conditions in a biogas (BANZ, 2018). The waste is covered and mechanically compressed by the weight of the material that is deposited above. This material prevents oxygen exposure thus allowing anaerobic microbes to thrive. Biogas builds up and is slowly released into the atmosphere if the site has not been engineered to capture the gas. Landfill gas released in an uncontrolled way can be hazardous since it can become explosive when it escapes from the landfill and mixes with oxygen. The lower explosive limit is 5% methane and the upper is 15% methane (Safety Page, 2019).

2.7.4 Bioenergy Renewable Energy Technology in South Africa

South Africa definitely has exploitable bioenergy potential," stated Council for Scientific and Industrial Research principal engineer Crescent Mushwana at the launch of the South Africa Bioenergy Atlas in Pretoria. "Bioenergy is feasible from organic waste, residues from forestry and agriculture [lignocellulose], and eradication of alien invasive plants." These all amount to 'low-hanging fruits'. "The economic viability of biofuels from purposely cultivated crops is currently negatively affected by the low price of oil."

However, most agricultural residues are already allocated to other uses, he cautioned, such as soil and nutrient regeneration. On the other hand, there is a lot that can be done in urban areas. "Biomass potential is always closely correlated with population density," he highlighted. And areas of dense population tend to have good infrastructure, making it easier and cheaper to deploy biomass as an energy source. "Organic waste is largely concentrated in big urban areas." Organic wastes are turned into biogas using simple devise called digesters. Basically, these are air-tight containers in which a biological process called anaerobic digestion takes place. Ideally, the temperature has to be controlled for optimal efficiency. The result is a mixture of methane (the major part) and carbon dioxide gas. The methane can be used as fuel to generate electricity. The residues can be used as fertiliser. "Organic waste looks like a [low-cost] winner in all cases" (Campell, 2017).

"Lignocellulose is a very important factor we should look at," he points out. "In the short term there is potential for what can be done with existing operations." This could include collocating electricity generation at sawmills and sugar mills. "Compared to renewable energy programmes, there is space for these [bioenergy] technologies to play. Definitely for lignocellulose and biogas from digesters," assures Mushwana. These two technologies are both cost competitive. "Definitely, there is potential." The goal of the atlas is to act as a "decision support tool" to help the government in planning, investment and deployment decisions regarding bioenergy technologies, for heating, transport fuels as well as power generation (Campell, 2017).

2.8 SUMMARY OF CHAPTER TWO

South Africa is endowed with adequate resources in RE that would offer the most logical compliment to the country's energy mix in order to address both the energy deficit and the heavy carbon footprint. But the development of a RE strategy with clear targets in generation, human capacities as well timelines is necessary before the industry can sustainably move forward. A number of structural and legislative barriers have also been identified. In particular, the lack of a framework to deliver reliable and accurate energy data to the policy makers presents a major barrier. Given ESKOM's dominant role in the South African electricity supply sector, authentication of most electricity supply information becomes almost impossible without the utility's cooperation. Hence there is need for a transformation from an opaque operation that was necessitated by past history to a more transparent one reflecting the new era (A.B. Sebitosi & P. Pillay, 2018).

Wind energy can make a significant contribution to electricity supply in the South Africa. Onshore wind is already a mature generation technology. Offshore wind brings more and complex engineering challenges, but engineers are providing innovative solutions. Wind energy has a small carbon footprint and does reduce the carbon intensity of the grid system, although calculating the actual savings is complex and varies according to the location of the turbine and the generation mix of the system. At current fuel and carbon prices, onshore wind energy is more expensive than gas or coal plant but is one of the cheapest low carbon sources of electricity. These challenges require a fundamental shift in society's attitude to and use of energy and will only be met with the support of both domestic and business customers. High levels of wind energy will result in large numbers of very large turbines. Whether these are onshore or at sea, they will inevitably have an impact on local communities and stakeholders.

Government and industry must both play their respective parts in engaging honestly with these stakeholders, setting out clearly both the impacts and the benefits. The government must take the strategic lead in preparing for the transformation of the South Africa energy system, in partnership with industry and other stakeholders. The future energy system needs to be mapped out, at least in general terms, with solid engineering evidence backed up by economic and social considerations. Wind energy can play a significant role along with other forms of low carbon generation as well as demand reduction and management, interconnection and storage. However, without careful strategic planning incorporating all these elements as a system, the challenges will not be met (Royal Academic of Engineering, 2019).

CHAPTER 3: LOAD FORECAST AND DEMAND MANAGEMENT SUPPLY IN ECOU

3.1 INTRODUCTION TO FORECAST DEMAND OF ECOU AND RSA

The effective and economic capital expansion of the electrical power delivery system is a network planner's responsibility. To do this, the network planner has to anticipate how much power must be delivered as well as where and when it will be needed. Underlying to distribution planning is a well prepared and structured medium-to-long term load forecast. This provides the prediction of future electrical demand in terms of the location, magnitude and temporal (time) characteristics. Load Forecaster should always be looking as far ahead as possible in an attempt to integrate the planning of generation, transmission, sub-transmission, distribution, embedded/distributed generation and demand side options, to ensure that the expansion of networks and the utilisation of assets are optimal. "The objective of distribution planning is to provide an orderly and economic expansion of equipment and facilities to meet the utility's future electricity demand with an acceptable level of reliability." (H. Lee Willis, 2017).

There has been an enormous increase in demand for energy in South Africa in recent years as a result of rapid industrial development, rapid immigration growth around urban areas and massive rural electrification led to severe energy crisis today. South Africa is gifted with coal and relies heavily on coal to meet its energy needs. Eskom currently supplies 97% of the country's demand and therefore as the principal transmission and distribution licensee in South Africa, Eskom is responsible for developing and maintaining the country's transmission and distribution infrastructure as well as South Africa's interconnections with the Southern African Power Pool.

The main purpose of the Transmission Demand Forecast is for capacity planning of the Transmission networks. It is important that sufficient capacity be maintained an increased to enable economic growth and development of South Africa in all sectors. However, it is imperative that we are approaching a new era and a paradigm shift towards the energy supply and demand supply chain. It is suggested that the optimistic scenario, High Transmission Forecast should be noted however in line with reasonable expansion, technological advancement, demand side management and energy mix changes, it is suggested that the "Transmission High Less Renewable Scenario" be utilised for planning of the transmission grid.

The National Demand Forecast at System peak is delivered on all the following three scenarios, and from there onwards the Provincial and Main Transmission Substation (MTS) forecasts is delivered on only the recommended forecast scenario to balance the top forecast with that of each transmission delivery point (MTS) (Jana Breedt and Danie Payne, 2017).

3.1.1 High Scenario

The Transmission high scenario (Tx High) is based on assumptions which will take South Africa from a developing country to a developed country and therefor indicates optimistic growth figures in line with the ambitions set by the current National Development Plan. This high scenario is in line with the projected 3% GDP & GVA-R average year on year growth expected for the TDP period 2019 to 2028 with a target network of 65 GW at year 2040. This scenario is optimistic and assumes the return of current suppressed industries due to world economic conditions, and trade contracts influencing imports, exports and local production. The Tx high forecast assumes a national value of 51 GW at time of system peak (TOSP) in year 2028, at the end of the TDP period.

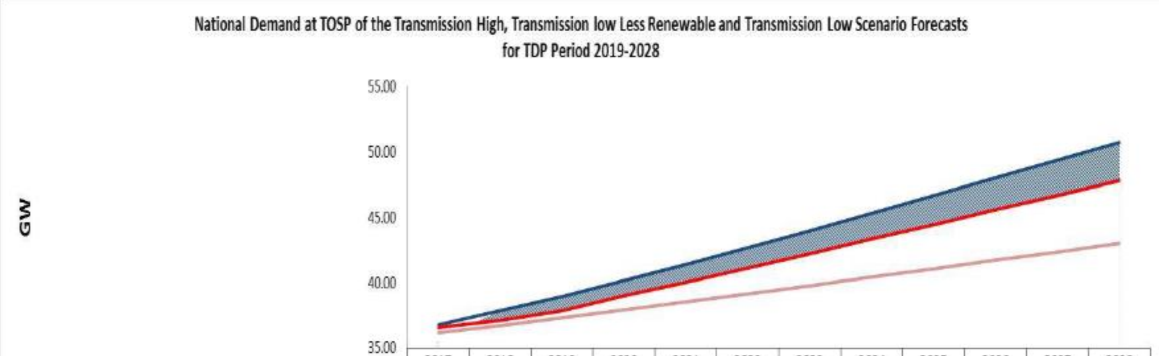
3.1.2 High Less Renewable Scenario

The Transmission High Less Renewable scenario is based on assumptions adapted from the TDP Generation assumptions report published in March 2017 as well as regression analysis done on the combined contribution at TOSP by renewable- and co-generation sources. These renewable contributions are captured as a total contribution at TOSP, and only as per allowed capacity provided through the Renewable Energy IPP (REIPP) programme bid windows 1 to 4b. The main assumption by this scenario is that renewable technology and alternative energy generation methods should be considered when considering planning into the future. It is assumed that a variable amount of demand to the country will be excluded from the Transmission grid either by off-grid facilitation, smart grid technology and renewable capacity linked up to distribution networks which might take strain of the conventional supply. It is however recognised that a main capacity of transmission network is still needed as alternative generation sources but might also push back into the transmission network from connection points in either the transmission grid or the distribution grid also connected to the transmission grid which needs to be considered for transfer capacities. The calculations and assumptions lead to a 6%

difference in the value of the national system forecast for the end of the TDP at year 2028, with a capacity value of 48 GW at TOSP.

3.1.3 Low Scenario

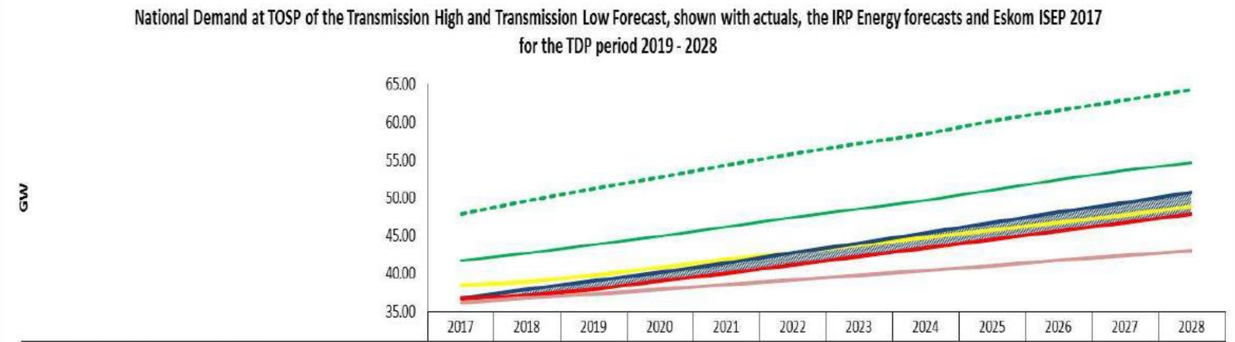
The Transmission Low scenario is based on assumptions that there will be a continued suppressed development rate in the country and most of the industries will not return to original status. This is a pessimistic view in line with the recent Junk status economic scenarios also investigated by the CSIR and energy forecasting department and has a nominal capacity of 50 GW at the year 2040. This scenario assumes correlation with a low overall economic average growth of 0.7%, lower than the projected GDP & GVA-R Total industry figures. A summary of the three scenarios is showed in Figure 30.



	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028
Capacity absorbed by Off Grid RE	35.60	37.84	38.97	40.16	41.40	42.67	43.98	45.31	46.66	48.02	49.38	50.73
Tx High Less RE	36.57	37.12	37.87	38.99	40.04	41.11	42.21	43.32	44.45	45.57	46.69	47.80
Maximum System Demand(MSD) Tx High (65GW @2040)	36.76	37.84	38.97	40.16	41.40	42.67	43.98	45.31	46.66	48.02	49.38	50.73
Maximum System Demand(MSD) Tx High Less RE (58GW @2040)	36.57	37.12	37.87	38.99	40.04	41.11	42.21	43.32	44.45	45.57	46.69	47.80
Maximum System Demand(MSD) Tx Low (Junk Status 50GW @2040)	36.16	36.73	37.31	37.91	38.52	39.14	39.76	40.40	41.04	41.69	42.34	42.99

Figure 30: Transmission Forecast Scenario's for TDP period 2019-2028.

A separate alignment study was done for validation purposes to compare the Transmission demand forecast with that of the Integrated Resource Plan Update (IRP) gazette by Government in November 2016 and Integrated Strategic Electricity Plan (ISEP). The former is produced by the Department of Energy and the latest release of this is still in draft, the latter is an Eskom produced forecast that considers other factors such as plant life, load factor, and plant condition. There is good alignment between the Transmission forecast suggested scenario and the ISEP 2017 forecast. Figure 31 shows the alignment graph with studies done at TOSP.



	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028
% of Capacity absorbed by Off Grid RE	35.60	37.84	38.97	40.16	41.40	42.67	43.98	45.31	46.66	48.02	49.38	50.73
Tx High Less RE	36.57	37.12	37.87	38.99	40.04	41.11	42.21	43.32	44.45	45.57	46.69	47.80
IRP 2010	47.87	49.52	51.23	52.72	54.33	55.73	57.10	58.34	60.15	61.50	62.85	64.20
IRP 2016 Draft	41.68	42.70	43.83	44.92	46.13	47.34	48.55	49.66	51.02	52.31	53.56	54.57
ISEP 2017	38.37	38.88	39.77	40.72	41.81	42.75	43.71	44.68	45.68	46.71	47.75	48.78
Maximum System Demand(MSD) Tx High (65GW @2040)	36.76	37.84	38.97	40.16	41.40	42.67	43.98	45.31	46.66	48.02	49.38	50.73
Maximum System Demand(MSD) Tx High Less RE (58GW @2040)	36.57	37.12	37.87	38.99	40.04	41.11	42.21	43.32	44.45	45.57	46.69	47.80
Maximum System Demand(MSD) Tx Low (Junk Status 50GW @2040)	36.16	36.73	37.31	37.91	38.52	39.14	39.76	40.40	41.04	41.69	42.34	42.99

Figure 31: Forecast validation for TDP period 2019-2028.

The IRP forecasts is higher due to embedded generation which is considered in the forecast. The TDP forecast growth rate aligns well to both IRP and ISEP and in particular the growth of the slightly tapered transmission high less renewable forecast. The red line indicates the suggested forecast for transmission grid planning purposes. It is however noted that the future is variable and therefor the forecast might be influenced by future technology or customer behaviour trends.

Eskom has committed to close the gap on the demand that could not be supplied by committing to a number of programs and expansion plans. From Eskom's generation commitment there is a "New Build program" which is expected to add 8.9 GW to the power generation system. Since 2005, Eskom has been expanding its generation and transmission capacity to meet the country's growing demand for energy with the proposed New Build program. Eskom's nominal generating capacity in 2005 was 36208 MW. The new build program will increase this by 17384GW by 2019/20. Between 2005 and 31 March 2014, the New Build program has increased Eskom's generating capacity by 6137MW, its transmission lines by 5 497km and its transmission substation capacity by 27565MVA [18]. The proposed Nuclear plans are targeting 9.6 GW and together with the Department of Energy (DoE), Eskom has signed off 4.9 GW of power to be produced by the Independ Power Producers (IPP's) through the Renewable Energy IPP (REIPP) Programme bid windows 1 to 4b. Developments around natural gas to be utilised for generation and the aforementioned generation figures is planned to add to the expected increase in supply and therefor demand figures as set out by the NDP. GDP growth is directly related to increase in demand and investment. Therefore, Eskom is unswervingly responsible for enabling GDP growth in South Africa, and thereby boosting the energy sector and economy of South Africa.

Currently a number of generation plans is in place to bring equilibrium in the supply and demand imbalance South Africa is currently experiencing. Ingula, Medupi and Kusile power stations are planned to be fully in service from 2022. Additionally, there is the program from government to connect independent power producers (IPPs) to the national electricity grid as part of the implementation of the Integrated Resource Plan (IRP) 2010-2030, in particular, renewable energy. In anticipation of the generation connectivity that will be needed, five transmission power corridors have been identified as critical to providing a flexible and robust network that could respond to meet the needs of future IRP and IPP requirements. The Department of Environmental Affairs (DEA) is currently undertaking DEA studies of these routes as part of the SIP 10 initiative of the government's National Development Plan.

As the additional generation comes into effect it is expected to stimulate growth and rapidly bring back demand from suppressed load. To prevent future transmission network constraints the expected transmission system is predicted on the electrical market potential loads, not the suppressed system peak load due to network, operational and generation constraints. The economic activity of South Africa can be expressed in terms of Gross Value Added (GVA) estimates for the different areas across the Country. The GVA figure indicates the total contribution of provinces to the overall South African economy, without value added tax component as GDP, which is explained in terms of the nine economic sectors. The impact of the current generation can be appreciated by the impact on the GVA of the provinces. The future growth in GVA assumes that there is no significant limitation to access to electrical power for growth, both in terms of generation capacity and transmission/distribution infrastructure to deliver the power where it is required. This is the scenario for the Transmission High Forecast which should be available to enable the projected growth in GVA across the Country. Furthermore, the rapid change in technological advancement and research progress experienced worldwide on the generation and distribution of energy has a significant effect and potential further effect on the forecasted future as included into the Tx High Less Renewable scenario. The graph in Figure 32 indicates the average annual growth in total GVA-R for each province for the period 2018 to 2027 as the red bars. The blue bars indicate the average annual Load

Demand growth per province over the same period for the Tx High Less Renewable Forecast.

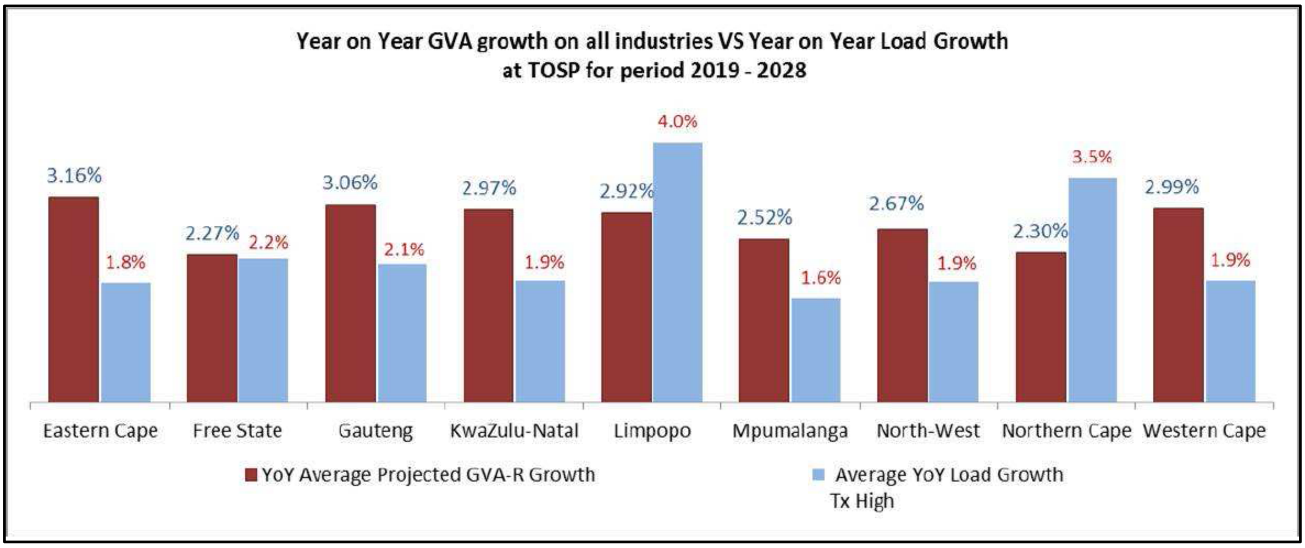


Figure 32: Comparison between Year on Year (YoY) Growth of Provincial Load and GVA in percentage.

Assuming a direct relationship between the average annual growths in GVA to the average annual growth in Load Demand based on the Transmission High Forecast, the growth of the GVA can be inferred. However, the Transmission High forecast assumes return of industries which would have a significant effect in specifically Northern Cape Province with the mining of Fe-Mg and Iron Ore, mining of coal in Limpopo Province, as well as increased industrial and export activities in the Eastern Cape. The Eastern Cape has a significant amount of renewable capacity especially in wind technology which assists in the supply even at time of system peak. Actual load measurements are already found to be lower than the total load demand for the area. The forecast in these three provinces is positively adapted to stimulate economic growth and require the most growth into the future to address the needs of large populations and infrastructure that accompanies the mining and export sectors.

There are a number of political and international economic factors contributing to the decrease in mining activities in these provinces however it is evident that there is undeniably a great impact from Eskom which is unable to generate and deliver the necessary power to enable the future economic development of the Country. The change in economy from an industrial to service-related industries can be seen where the energy intensity is lower than the expected GDP growth for the province. This can be seen clearly in areas like Gauteng and Western Cape where service-related industries contribute mostly to the economic growth and high energy intensity sectors such as mining and manufacturing contribute the least. Figure 33 describes the Location Quotient as extracted from Global insight economics, which is an economical factor used to show on the significant impact each sector has per province. The red highlighted sectors are found to contribute the most to the economy in the subsequent province, whereas the blue indicates the lowest contribution.

Significant sectors to the GPD output for each Province from 2019 - 2028, shown in intensity with red most significatn and blue less									
	Western Cape	Eastern Cape	Northern Cape	Free State	Kwazulu-Natal	North West	Gauteng	Mpumalanga	Limpopo
Agriculture	1.60	0.80	3.36	1.97	1.59	1.09	0.20	1.19	0.98
Mining	0.03	0.02	2.21	1.26	0.17	4.21	0.40	2.82	3.49
Manufacturing	1.14	0.90	0.26	0.87	1.36	0.40	1.11	1.06	0.25
Electricity	0.77	0.55	1.23	1.27	1.01	0.92	0.87	2.11	1.21
Construction	1.44	1.10	0.76	0.61	1.18	0.68	0.94	0.80	0.82
Trade	1.18	1.34	0.87	0.91	1.00	0.79	0.92	0.98	1.00
Transport	1.10	0.91	1.32	1.05	1.36	0.65	1.02	0.67	0.53
Finance	1.22	1.00	0.71	0.84	0.84	0.65	1.24	0.59	0.72
Community Services	0.80	1.29	0.97	1.08	0.96	0.90	1.10	0.69	1.03

Figure 33: Sectorial significance per province.

3.2 MTS SUPPLY AREAS AND FORECASTS

The network is divided into supply areas based on MTS forecast network topologies as established and approved via Provincial Network Integration Forum Sub Committees (PNIF Sub Committees). Full transmission and distribution topology with distribution point loads can be obtained in the Excel annexure. Figure 34 gives a spatial representation of Eastern Cape and its MTS substations, both existing and planned within the TDP period for 2019-2028. Table 13 gives the TOSP values per MTS and new MTS's follows the 0 values greyed out in the year they are planned to be commissioned. Commission dates are confirmed with CAPEX schedule and PNIF Sub Committees. Table 8 gives substation maximum values for when each individual MTS peaks during the year.

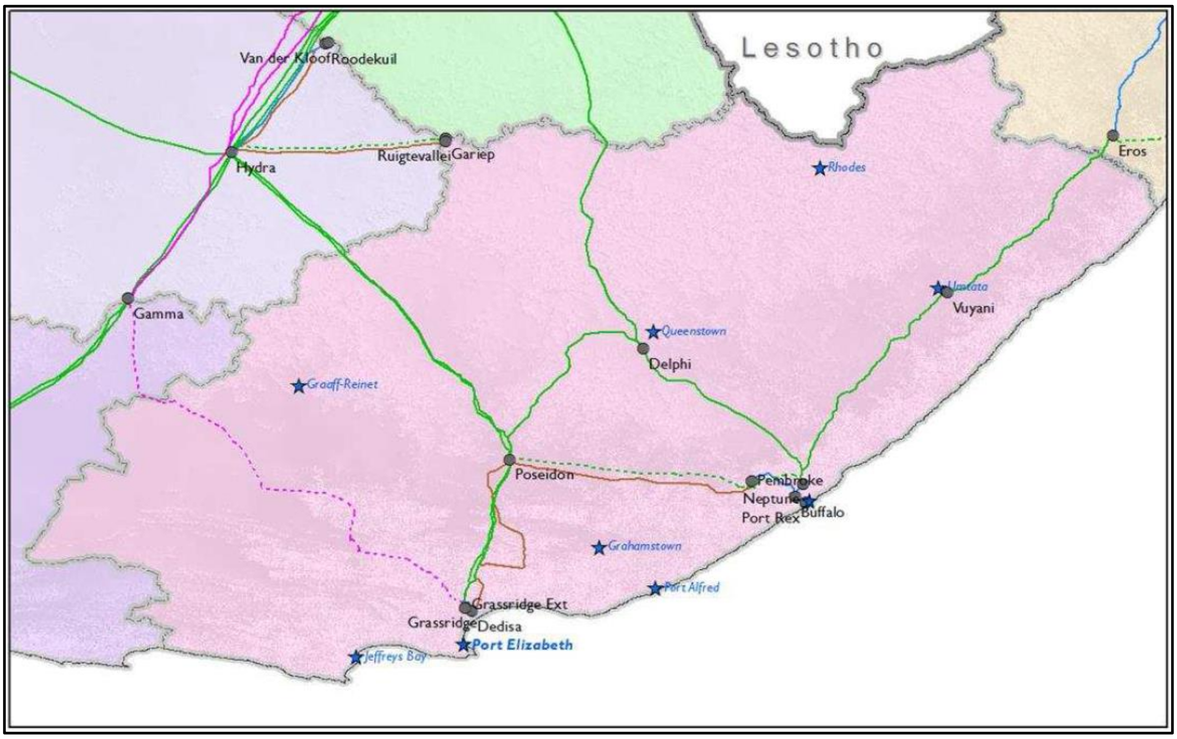


Figure 34: Spatial map of Eastern Cape Province with MTSs displayed (Jana Breedt and Danie Payne, 2017).

Table 8: Eastern Cape MTS Forecast values for 2019-2018 at TOSP

Tx at Maximum System Demand at TOSP												
EasternCape	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029
Dedisa	262.6	265.2	267.9	270.6	273.3	276.0	278.8	281.5	287.2	292.9	298.8	304.8
Delphi	104.1	105.2	106.2	107.3	108.3	109.4	110.5	111.6	112.7	113.3	113.9	114.4
Grassridge	380.8	390.3	454.1	465.1	475.3	490.8	506.6	517.6	579.0	595.6	607.4	619.6
Hydra	115.3	120.5	122.4	125.1	127.9	130.7	133.5	136.3	138.2	139.2	140.1	141.1
Neptune	254.5	302.6	305.8	309.1	318.0	321.3	324.7	327.9	331.2	334.4	337.9	341.6
Pembroke	82.5	46.7	47.7	48.8	45.3	46.6	48.1	49.3	49.9	50.8	51.6	52.5
Poseidon	109.2	109.9	110.5	111.2	111.8	112.5	113.2	113.9	114.6	115.3	116.0	116.7
Ruigtevallei	114.9	119.7	122.4	124.6	126.5	128.4	130.3	132.3	135.7	137.1	138.5	140.0
Vuyani	179.9	183.5	187.2	190.9	194.7	198.6	200.6	202.6	204.6	206.7	208.8	210.9

Table 9: Eastern Cape MTS Forecast values for 2019-2018 at Substation Peak

Tx at Substation Max												
EasternCape	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029
Dedisa	281.0	283.8	286.6	289.5	292.4	295.3	298.3	301.3	307.3	313.4	319.7	326.1
Delphi	166.6	168.3	169.9	171.6	173.4	175.1	176.8	178.6	180.4	181.3	182.2	183.1
Grassridge	506.4	519.1	603.9	618.5	632.2	652.8	673.8	688.5	770.0	792.1	807.9	824.1
Hydra	198.25	207.33	210.50	215.20	219.94	224.73	229.56	234.44	237.72	239.36	241.00	242.64
Neptune	277.4	329.8	333.3	337.0	346.7	350.2	353.9	357.4	361.0	364.5	368.3	372.3
Pembroke	198.0	112.0	114.5	117.2	108.7	111.7	115.3	118.3	119.8	122.0	123.7	126.0
Poseidon	116.8	117.5	118.2	119.0	119.7	120.4	121.1	121.9	122.6	123.4	124.1	124.9
Ruigtevallei	156.3	162.8	166.4	169.5	172.0	174.6	177.2	179.9	184.5	186.5	188.4	190.3
Vuyani	215.9	220.2	224.6	229.1	233.7	238.4	240.7	243.1	245.6	248.0	250.5	253.0

3.3 CLN FORECAST

CLN groupings of MTS forecasts are displayed in Figure 35 below is graph shows as per Case file allocation 2016. Port Elizabeth will see most of the growth in the province which is where the port as well as IDZ industrial area is situated.

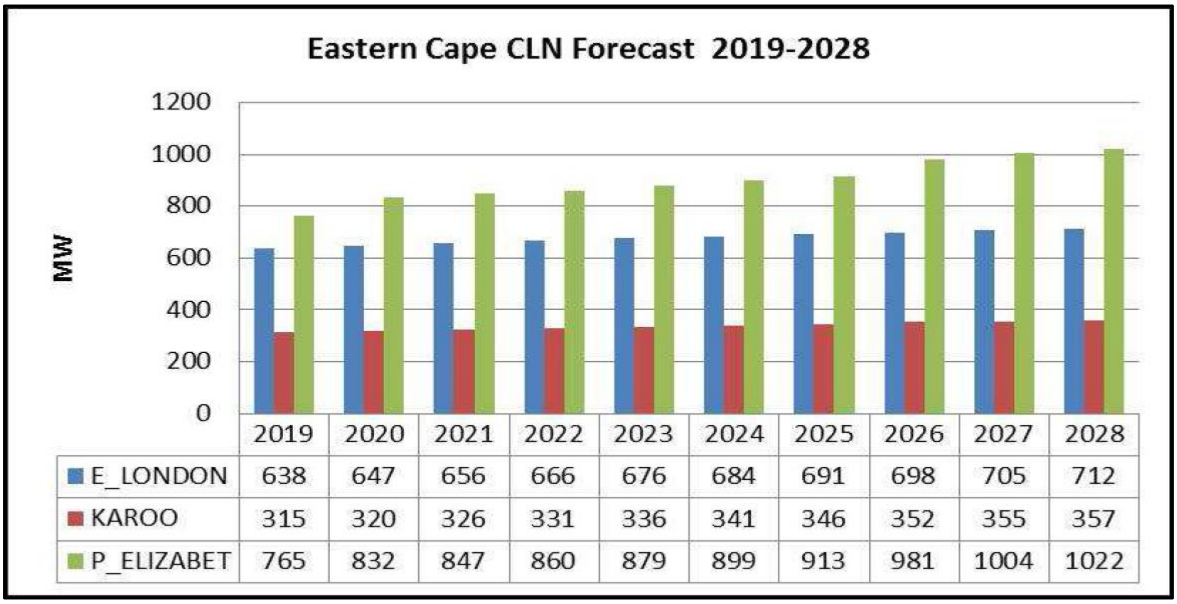
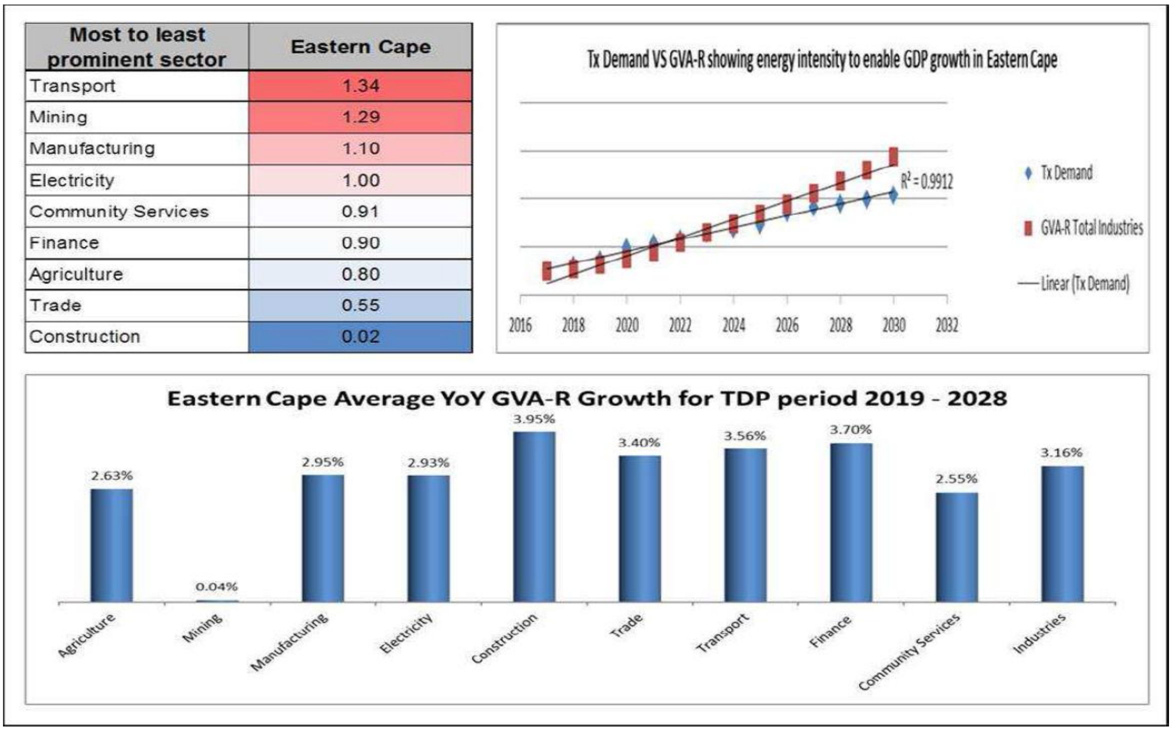


Figure 35: Eastern Cape CLN Forecast 2019-2028

The Eastern Cape has two major industrial centres, Port Elizabeth and East London, which have well developed economies, based on the automotive industry. General Motors and Volkswagen both have major assembly lines in the Port Elizabeth area, while East London is dominated by the large DaimlerChrysler plant. A new harbour has been built at Coega, just north of Port Elizabeth, which is linked to an Industrial Development Zone (Coega IDZ) to attract new investment, although the expected growth was not realised due to the IDZ developments not reaching its full targets and some of the IDZ developments have been cancelled. A plan of a Petrochemical plant by PetroSA is also in the horizon however current developments in this industry put these developments at risk. It is expected that this development will give the province a major economic boost. Other important sectors include finance, real estate, business services, wholesale and retail trade, and hotels and restaurants. The step load increase around 2026 can be explained by the above-mentioned developments.

The estimated average annual growth of GVA of the nine economic sectors over the 2019 to 2028 period for the province is shown at the bottom of Figure 36. The Location Quotient values for the province can also be seen in the top left half, this indicates which of the sectors has the greatest influence on the economy of the province, next to that in the upper right half of the figure is a correlation between the load and the GVA growth in the region. An R2 value close to 1 shows good correlation.



Most to least prominent sector	Eastern Cape
Transport	1.34
Mining	1.29
Manufacturing	1.10
Electricity	1.00
Community Services	0.91
Finance	0.90
Agriculture	0.80
Trade	0.55
Construction	0.02

Figure 36: Economic Summary for Eastern Cape 2019-2028

A new MTS substation is planned for the Port Elizabeth area, currently referred to as the “New PE Substation” in the TDP, which is expected around 2022. Load will be transferred from Grassridge, but the amount is not yet certain. This new substation is linked to the potential Nuclear 1 power station near Thyspunt in that it utilises some of the 400kV lines for the integration of the power station. This has not been shown in the Load Forecast as there are still too many uncertainties regarding timing and MTS transfer but will be incorporated when there is more confidence.

3.4 LOAD DIVERSITY

3.4.1 Load Diversity Definition

Definition on load diversity: the diversified load is the combination of each device's full load capacity, utilization factor, diversity factor, demand factor, and the load factor. Consumers differ and their pattern of electricity consumption differs. Even customers of the same classification will not have the exact same consumption pattern (i.e., residential customers). As a result, when viewing a group of customers, the resulting group profile is a combination of the individual consumer profiles. Each consumer has a daily load curve which is erratic and choppy. This is due to different appliances being switched off and on at various random times. When these individual curves are added together, the curve smoothens out and the peak load per customer decreases. Coincidence is the tendency of the observed peak load per customer to decrease in size as the number of customers observed increases. The diversity factor is simply the inverse of the coincidence factor. Figure 37 below shows sample daily profile for three different industries. It can clearly be seen that the usage pattern for all three differs – there is diversity between the profiles.

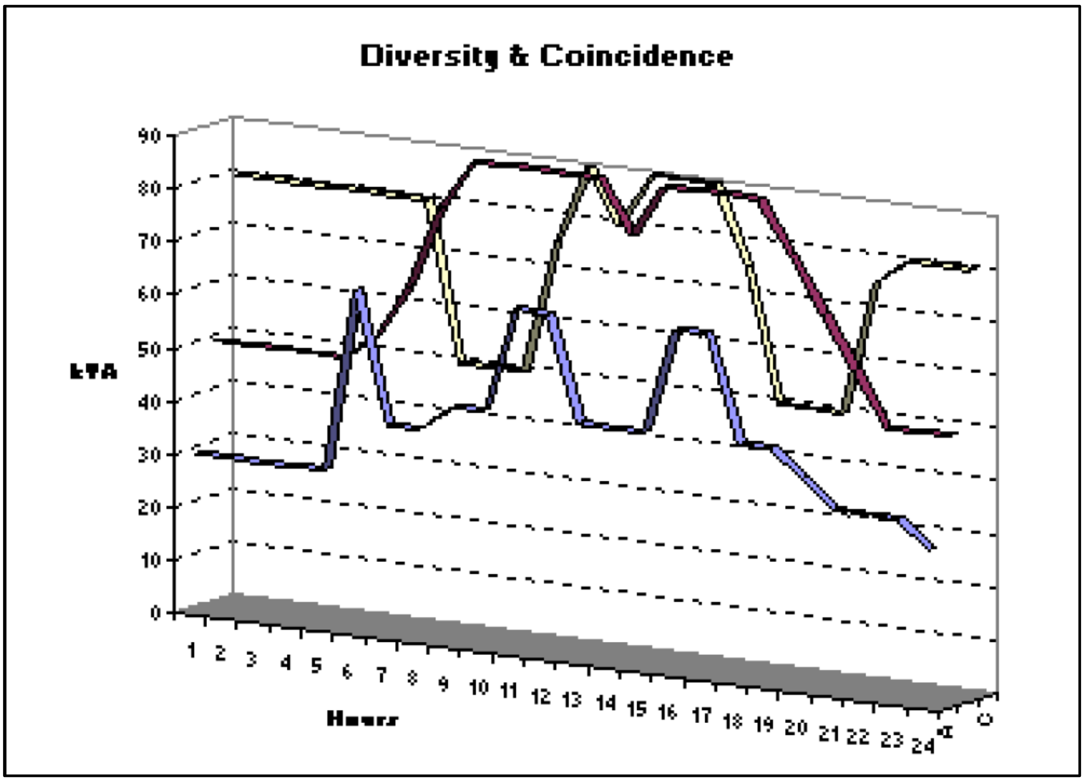


Figure 37: Consumer profile sample

The resulting load profile for the three consumers is shown in Figure 62.

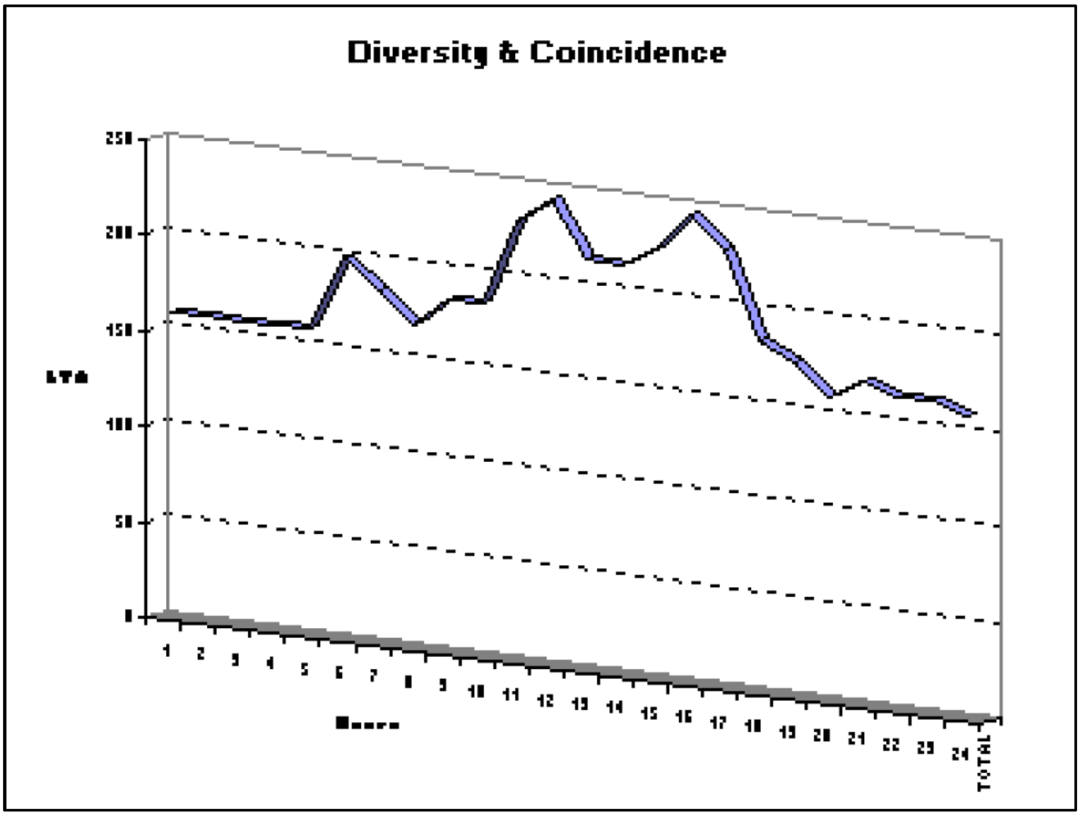


Figure 38: Resulting load profile

3.4.1.1 Consumer Classification

An underlying principle commonly used in load forecasting is to classify customers based on similar consumption, behaviour and growth traits. This is referred to as customer classification. By creating customer classifications, it is easy to create load growth and consumer behaviour according to the classifications and then assign customers into the classification categories.

Typical characteristics associated with customer classifications include:

- Generic classification consumption profile: This will be a per unitised profile (all values referred to per unit values). This profile will represent the typical consumption pattern of customers in the group.
- Growth curve: A specific growth forecast may be defined for a classification. This could for example be a growth forecast for the dairy industry that could be applied to dairy customers.
- Saturation load: This attribute will give an indication of the saturation load to which the load of customers within this classification will grow. This is typically a kVA/hectare or ADMD per customer figure.
- Load factor: Although a classification includes a generic profile, the profile will usually not be representative for an entire month or year. As such the profile will not by itself provide a true reflection of the energy consumed by the consumer. To increase the accuracy when converting a demand forecast to an energy forecast, a load factor for the classification could be included.
- Other growth characteristics such as typical percentage growth that can be expected for consumers within the classification.

A number of advantages are obtained by the use of customer classifications:

- Data entry and maintenance is reduced.
- Summation of load within a customer classification is simplified. (Can discard the profiles during summation – the profiles are the same for all customers within the same classification).

- Often the classification is used to simulate different load growth scenarios. Changes are made to the generic classification growth attributes after which the forecast is re-run.
- Customer load data when classified in customer classifications provides useful data for other studies such as tariff studies.

The consumer classifications in different load forecasts will differ, but the most common consumer classifications include:

- Residential
- Commercial
- Industrial
- Agricultural

Generic Load Profiles (consumption patterns) daily, weekly, yearly as discussed in section above Consumer Classification generic customer classification is often used in load forecasting. Underlying to these classifications is the use of generic load profiles representing the consumption pattern of consumers within that classification. Through the use of load profiles an attempt is made to simulate system consumption as accurate as possible for specific days within a year. Load diversity Consumer Classification is simulated through the use of profiles and result in a more accurate system representation. A load forecast could be as simple as storing only a generic 24-hour profile representative of a winter's weekday. A load forecast could also be as extensive as storing a weekday, Saturday, and Sunday generic day profile for each of the years' months. This is determined by the data available, accuracy required and purpose of the load forecast (Hashe, 2012).

3.4.2 Diversity and Load Curve Behaviour

Most often, a utility will use smooth, twenty-four-hour load curves to represent the "average behaviour" of each customer in each class. This is common practice and results in "consumer class" load curves used at nearly every utility. The consumer class curve is an individual customer's contribution to system load. On the average, each customer (of this class) adds this much load to the system. Add ten thousand new customers of this type, and the system load will increase by ten thousand times this smooth curve. Also note that the curve is the expectation of an individual customer's load. The smooth curve gives the expectation, the probability-weighed value of load that one would expect a customer in this class, selected at random, to have at any one moment, as a function of time. The fact that the expectation is smooth while actual behaviour is erratic is a result of the unpredictable randomness of the timing of individual appliances. Growth curves are curves that are stored and referenced to forecast load growth. A growth curve could either be custom entered e.g., all growth values are entered by the user, or follow a typical s-curve (Gompertz) curve that can be generated from a growth curve formula, a sample of such typical consumer profiles is shown in Figure 39.

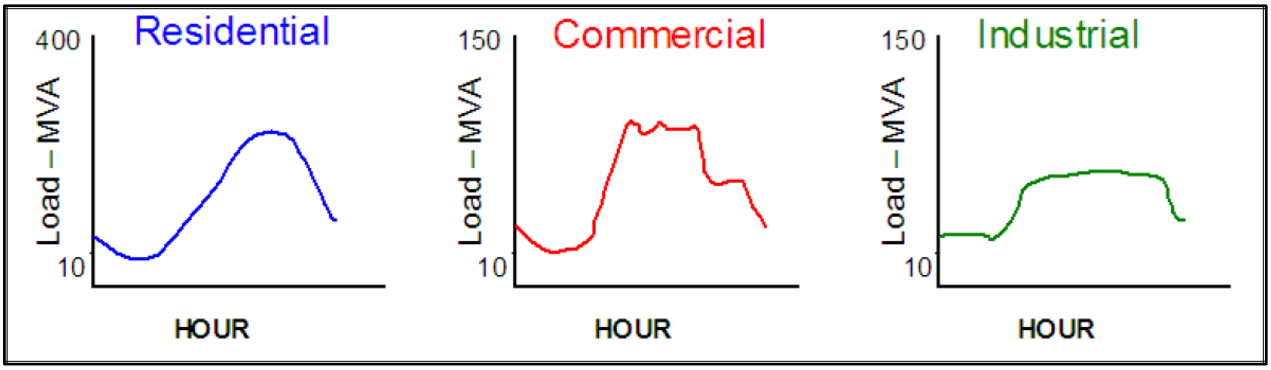


Figure 39: Typical consumption profiles

Note that no residential customer in any utility's service territory has a load curve that looks anything like this average representation. Few concepts are as important as understanding why this is so, what actual load behaviour looks like, and why the smooth representation is "correct" in many cases.

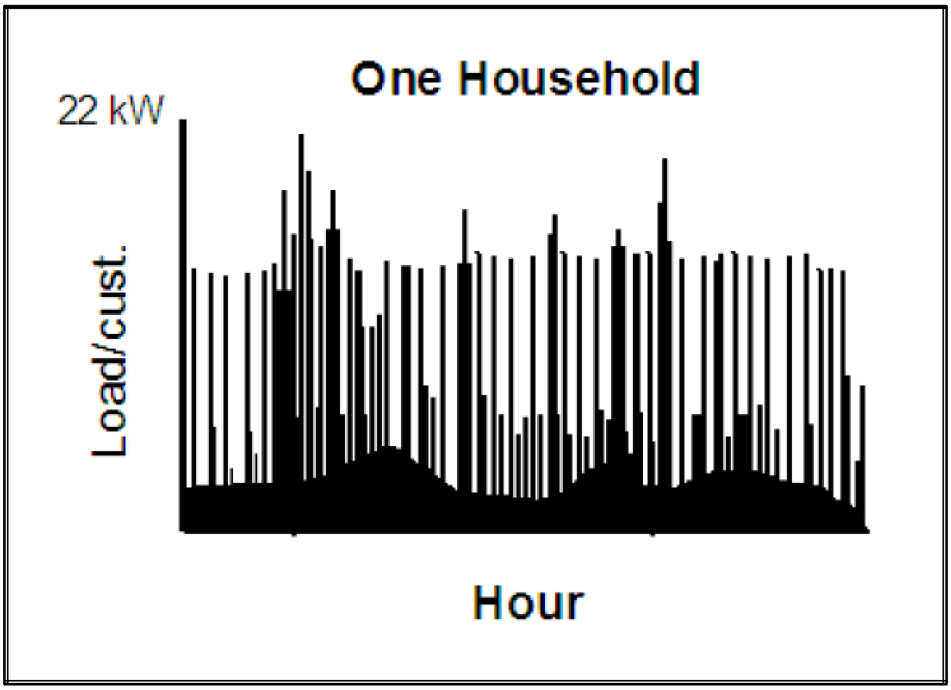


Figure 40: Single Residential Consumer Load Curve

The load curve shown in Figure 40 is actually typical of what most residential customer loads look like over a 24-hour period. Every residential customer's daily load behaviour looks something like this, with sharp "needle peaks" and erratic shifts in load as major appliances such as central heating, water heaters, washer-dryers, and other devices switch on and off. The reason for the erratic "needle peak" load behaviour is that a majority of electric devices connected to a power system are controlled with what is often called a "bang-bang" control system. A typical residential electric geyser is a good example. The water heater holds 500 l of water, which it keeps warm by turning on its heating elements anytime the temperature of water, as measured by the thermostat, dips below a certain value. When the temperature has been raised sufficiently, the thermostat turns off the elements. The water heater cycles on and off in response to the thermostat – bang it is on until the water is hot enough, then bang it is off and remains so until the water is cold enough to cause the thermostat to cycle the elements back on.

Consider only geyser load of two customers in this residential customer class. In Figure 41 Curves A and B are geyser loads at neighbouring houses on the same day (Feb. 6), displaying similar but not identical behaviour. Curve C is the second household's geyser's curve for Feb. 7, showing a daily randomness. Curve D shows the sum of the two geysers' curves for Feb. 6. Occasionally both loads peak together. Assembling 50 geysers results in a smoother load curve, one where the load peaks during peak periods of water heaters is longer (needle is wider) – meaning there is more likelihood that many overlap, and hence add to a high peak value.

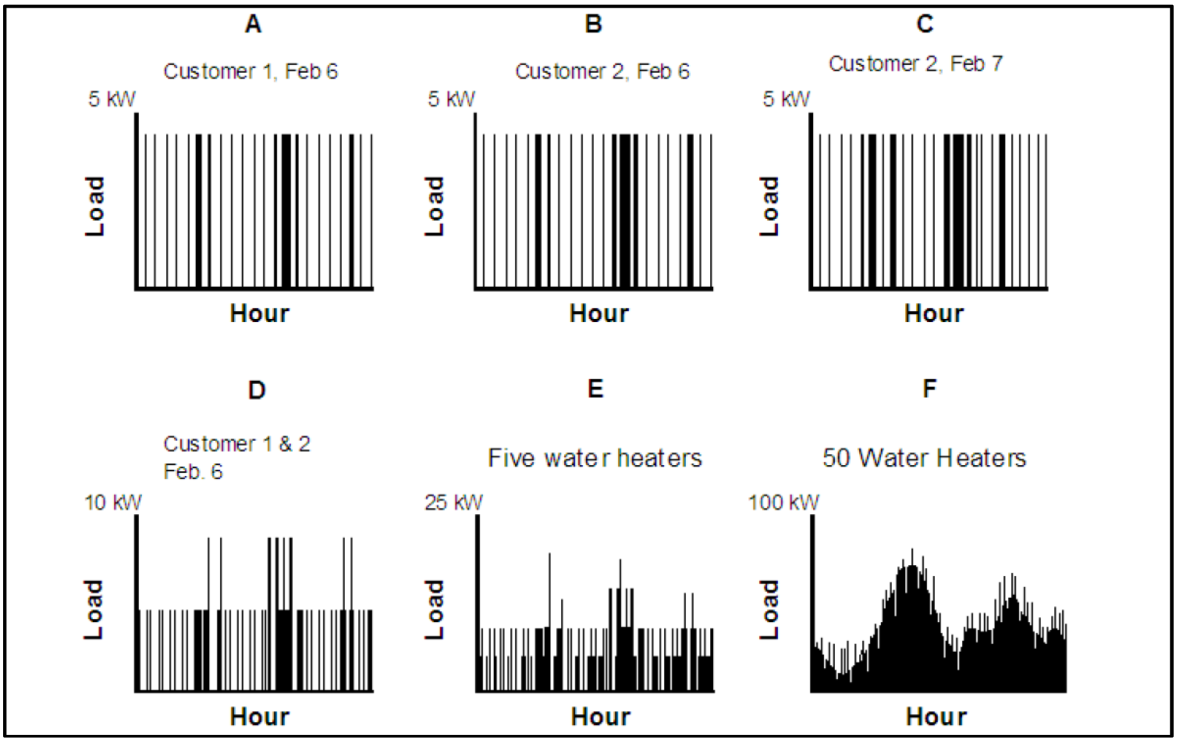


Figure 41: Sample summation of geyser load

3.4.2.1 Duty Cycles

In Figure 41 and Figure 42 the geysers duty cycles show several water heater (geyser) loads, as well as plots representing the sum of the load for a number of water heaters over a 24-hour period. It illustrates several important points. All water heaters exhibit the same overall on-off behaviour (bang-bang) but differ slightly as to the timing of the cycles. As more customers are add to the class, the total load increases, while the individual loads remain constant.

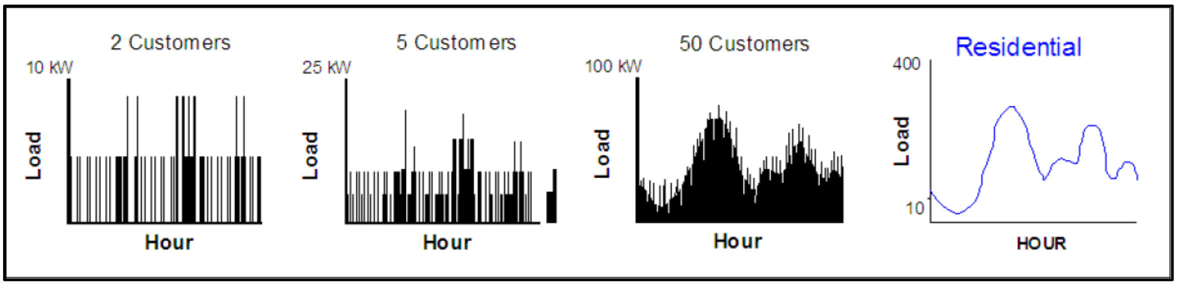


Figure 42: Build-up of generic consumer load profile.

3.4.3 Coincident Factors

Suppose one was to consider one hundred homes served by the same segment of a distribution feeder. Every one of these homes is full of equipment that individually cycles on and off like appliances just described – water heaters, air conditioners, heaters, and refrigerators that all are controlled by thermostats. Thus, each household will have an individual daily load curve that is erratic and choppy. Each home will be slightly different, because each has slightly different appliances and is occupied by people with slightly different schedules and usage preferences. The times that individual thermostats activate appliances are usually random, happening at slightly different times throughout the day for each appliance. The individual peaks, all quite short, do not all occur simultaneously. They are non-coincident. As a result, when one adds two or more of these erratic household curves together, the load curve needles usually interleave, much as the overlapping teeth of two combs might interleave. As yet more customer load curves are added to the group, more and more "needles" interleave, with only an occasional situation where two are absolutely coincident and add together. The load curve representing the sum of a group of households begins to take on the appearance of a smoother curve, as shown below (Hashe, 2012).

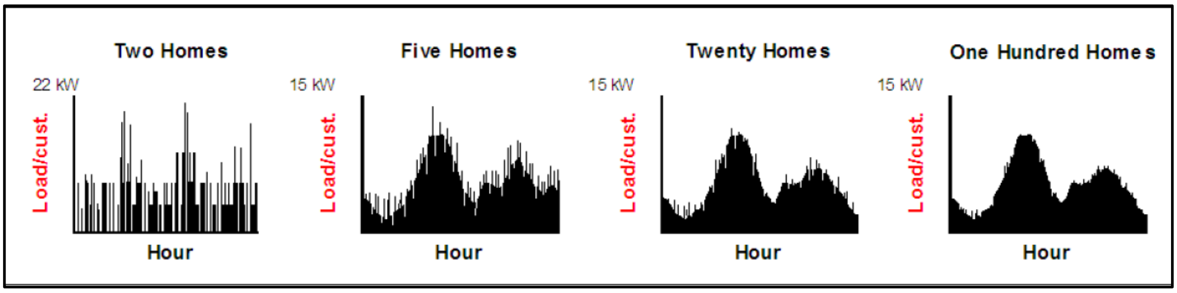


Figure 43: Load coincidence

3.4.4 Forecasting Methodology

Transmission network studies to identify network constraints due to future load growths require long term forecasts with at least a ten-year horizon, but a twenty-year plus horizon is preferable. Quantitative load forecast techniques are for short to medium term forecast horizons (five to six years). Qualitative load forecast techniques are for long term forecast horizons with expert opinions added to the equation. However due to the uncertainty of future load growths it is sometimes extremely difficult or almost impossible to predict future expected load growths with qualitative forecast techniques. Therefore, a load forecast process has been developed which uses a combination of forecasting techniques to address the uncertainty associated with load growths towards the end of the forecast horizon.

The transmission demand forecast is done by using a top-down approach where South Africa’s total electricity demand is considered within a mathematical model and balancing algorithm. Methodologies are continuously updated to forecast the demand. The methodology currently consists of both quantitative and qualitative forecasting techniques with the S-curve methodology applied predominantly. A number of S-curves are available, but the generalized logistic curve shows the more promising curve. The Grid Planning forecast uses a balancing algorithm which combines the network nodes in a transhipment model to balance the top national forecast with the transmission substation load nodes. The model combines the recent maximum demands at the MTS stations and the application of business intelligence updates and trends, and the assumption of available generation to meet the demands. This is particularly true at a national level and at a provincial level (Jana Breedt and Danie Payne, 2017).

The Maximum System Demand (MSD) of the Transmission Forecasts is the total power that is sent out from the Power Stations into the Transmission Grid, which consists of four components, namely the:

Total Power Station loads – these are the loads at the power stations that are supplied back to the power stations from the Transmission Grid and do not include the internal load supplied from the power station auxiliaries.

Total transmission losses – these are the system losses incurred on the Transmission Grid when transporting the power to the load centres.

Total International loads – these are the loads supplied cross-border to international customers.

Total Geographical Area loads – these are the loads that are supplied within the Eskom MTS supply areas in South Africa which is the focus the Transmission Forecast and contained in this report. These are grouped into the nine provinces.

3.4.5 Forecast Alignment

It is imperative that any forecast is done within the right context given the purpose it should serve. Within Eskom, a number of forecasts exist, each driven to satisfy a specific business need. However, it is important that although different forecasts serve different purposes and business needs, such forecasts should be aligned and managed from a holistic perspective to not only achieve the overall objectives of the utility (Eskom), but to also adhere to the electricity demand of South Africa as a country, and in specific, align to the goals set by the country in the NDP. The “Perform Electricity Forecasting” PCM captures roles and responsibilities and methodologies followed by transmission demand and energy forecasting as well as distribution forecasting.

The most important alignment area is between the interlinked transmission and distribution networks. Alignment on network topology and forecasts needs to be done for optimal planning. Distribution uses a bottom-up forecast approach by use of a Geographical Load Forecast tool (GLF). The data is gathered from Dx and then verified against with transmission’s top-down approach. This alignment is facilitated by sub committees at the Provincial Network Integration Forum (PNIF) for each of the nine provinces. This ensures more accurate forecasting and sharing of Market intelligence at both Transmission and Distribution forecasting levels. The process followed by the PNIF sub-Committee can be seen in Figure 44 and shows the interaction between role players within the alignment process. The PNIF Sub-Committees is utilised as an integration point between Tx & Dx Engineers and Forecasters.

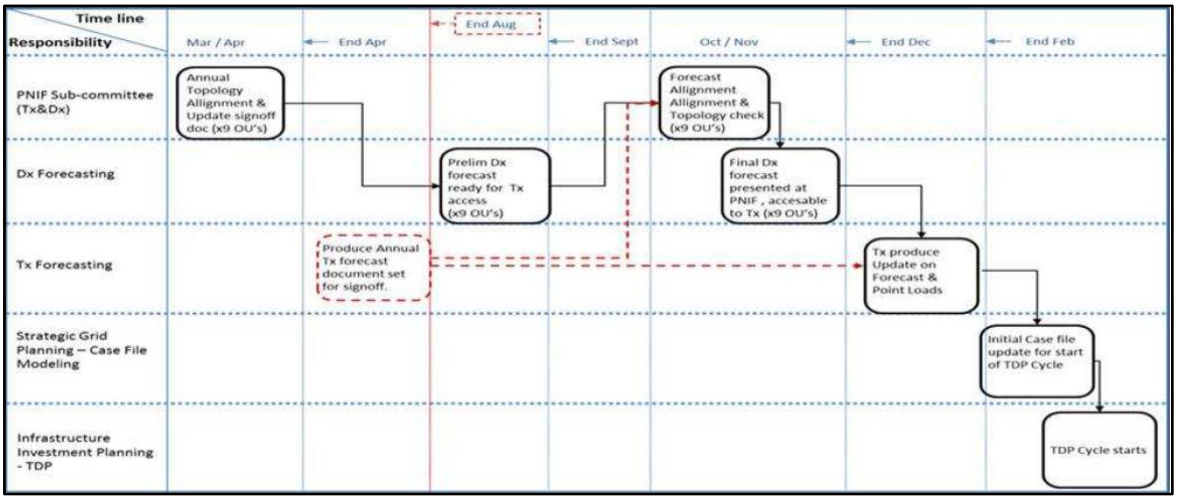


Figure 44: Tx or Dx alignment & Validation Process as input to TDP

Alignment with IRP, Eskom Energy Demand and ISEP is done to ensure the business gain perspective in the different forecasts and informed decision making in enabled. Currently a favourable trend is observed with the ISEP and Transmission recommended forecast. The IRP has higher values

3.4.6 International Forecast Exports

With the export visions from the Eskom corporate plan three separate exporting demand forecasts has been developed. Currently the contractual boundaries have set the international export values at a constant 1980MW and is still considered as the scenario worked into the national forecast for 2017. However, with Eskom financial visions of increased sales two additional scenarios was looked at, one which uses the current sales forecast growth figure of 0.59% annual average growth was used. For the final scenario the newly set corporate target of increasing international sales to 8% was also considered. Table shows the international forecast for each of the forecast scenarios. These values were used and interpreted with assumptions. Currently the fixed contractual scenario is still used. The results of the remaining two forecasts can be seen in the Excel annexure document. A summary of the international export totals for the TDP period is shown in Table 10: International Scenarios for national forecast for the TDP period 2019-2028.

Table 10: International Scenarios for national forecast for the TDP period 2019-2028

International Scenarios in MW	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028
Scenario 1: Constant Export	1980.0	1980.0	1980.0	1980.0	1980.0	1980.0	1980.0	1980.0	1980.0	1980.0
Scenario 2: 0,8% AAG Export	1995.8	2011.8	2027.9	2044.1	2060.5	2077.0	2093.6	2110.3	2127.2	2144.2
Scenario 3: 6% AAG Export	2216.0	2344.4	2480.2	2623.8	2775.8	2936.6	3106.7	3286.6	3477.0	3678.4

3.4.7 Future Generation

When relating the actual readings to the recent technological advancements of the electricity industry it is prevalent to note that Eskom has now entered a new paradigm. A paradigm where renewable integration, demand side management and imbedded generation has become a reality to the Eskom business. The specific question pertaining to future investigation on the forecasting modules in Eskom will be how to forecast in this changing and evolving energy system.

Analysis was done on the actuals gathered from contribution at TOSP to approximate the impact on the forecasted values going forward. Two calculations where considered, one a regression extrapolation on the actual variable generation contribution at TOSP and the other the TDP Assumptions made on future variable generation contributions. The Regression analysis gave a forecast for the component that will supply the demand served by renewable and co-generation technologies and can be seen in table for the TDP period up to 2029. This is only with current generation clients with approved contracted capacities.

Table 11: Regression extrapolated IPP & Co-Gen forecast for the TDP period 2019-2028

Assumed Renewable contribution that will take away capacity requirements from the Transmission System Grid during Peak Conditions													
Year	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029
IPP&CoGen FC % of System Peak Growth	2%	3%	4%	4%	4%	4%	5%	5%	5%	5%	6%	6%	6%
FC High (GW)	0.55	1.04	1.38	1.42	1.58	1.75	1.92	2.11	2.30	2.50	2.70	2.91	3.13

The second variable considering in calculating the renewable contribution is the TDP generation assumption values for variable generation. Figure shows the contribution of the generation sources as specified in the TDP generation assumption report GP-17/28. According to the Generation assumptions report approximately 14.87% of the generation mix will be of variable generation type by year 2027. The TDP generations assumptions document specifies average outputs which can be expected from variable generation at TOSP, using this to calculate an average availability of supply by variable generation at TOSP it can be assumed that 40% of variable supply can be assumed by year 2029. Therefor assuming 40% of the variable supply this amounts to approximately 6% of the total supply in 2029, which then correlates directly to the calculations shown by the regression model results in Table 15 above.

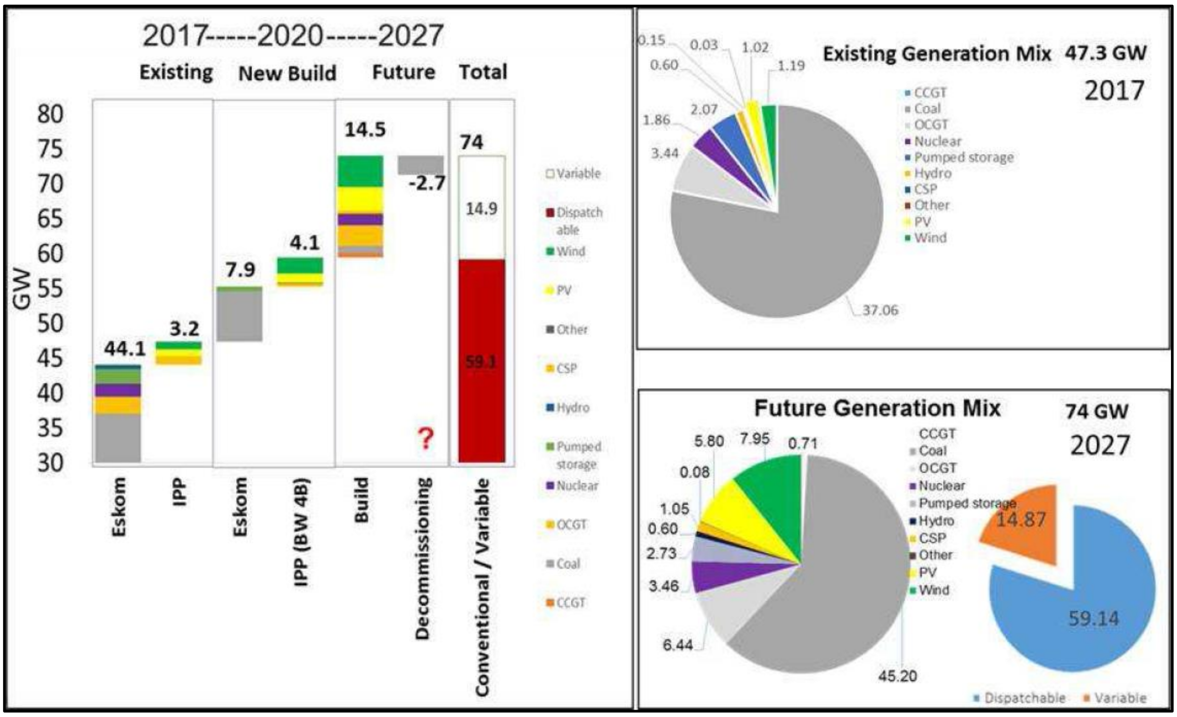


Figure 45: Generation Mix Adopted from TDP Generations Assumptions Report GP-17/28

The assumption on variable generation sources (Renewable and Co-generation together), was then derived on an average of 6% at the end of the TDP period and the regression model values was subsequently applied to the Tx High forecast to create the Tx High Less Renewable scenario

3.4.8 Economic Forecast for the Country

This section provides an overview of the expected economic activity and growth of South Africa over the TDP period. The economic activity is expressed in terms of Gross Value Added (GVA) estimates for the different areas across the Country. This information was obtained from the "*Global Insights Provincial and Metropolitan Forecast, Data Version 1150 (June 2017)*" using REX tool software. The GVA figure indicates the total contribution of provinces to the overall South African economy. The Values are all obtained by using Current Prices as per 2010 values. The economic activity is divided into nine main activity sectors which are listed below.

1. Agricultural
2. Mining

3. Manufacturing
4. Electrical
5. Construction
6. Transport
7. Finance
8. Community Services

These nine economic activities are broken down into a further number of sub-activities related to the main activity. The main activities are also grouped in three types of economic activities namely:

I. Primary
II. Finance
III. Community Services

The breakdown of the Sector type, Main Economic Sector and the associated sub-activities is provided in more detail for Eastern Cape province further down in this chapter. The graph in Figure 46 shows the average annual GVA growth for each economic sector per province for the period 2004 to 2015.

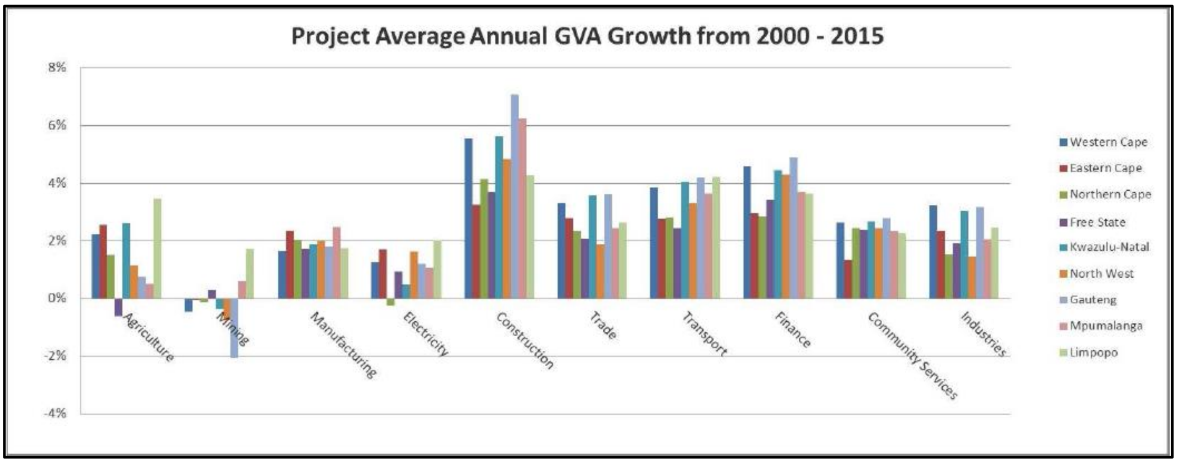


Figure 46: Actual average annual GVA growth per sector per province for 2004-2015

Most sectors had positive GVA growth with electricity at the lowest except for Mining which had mostly negative GVA growth in eight provinces. The biggest drop was in Mining in

North-West province due to the mining unrests and downsizing of platinum mines in the area, Free State shows second biggest drop due to the downsizing of the gold mines in the Welkom area. The Construction and Finance sectors showed the largest increases over this period. The Table 12 shows the projected average annual GVA growth for each economic sector per province for the period 2018 to 2027. Positive GVA growth is projected for all the sectors in all the provinces except for Mining in the Free State. The gold mines around Welkom and other areas are still projected to scale back into the future. The Manufacturing, Transport and Finance sectors are projected to show the largest increases into the future. Manufacturing in the Eastern Cape Province shows the prospects of the increase in load demand in the Coega and surrounding area due to motor manufacturers and the possibility of Smelters to rework mined minerals and metals before exporting. The freight railway from Northern Cape to Coega in the Eastern Cape supports these initiatives. The Electricity sector is also expected to show healthy GVA growth driven by the IPP programmes and the new generation required to meet future economic growth. Mining will still show growth in some of the provinces with solid growth projected for the Construction, Community and Trade sectors which supports the service driven economy South Africa is changing into.

Table 12: Project Average Annual Growth in GVA per Province for TDP period (Mogoro B. and Khoza T., 2014).

Projected Average Annual GVA Growth from 2019 - 2028									
	Western Cape	Eastern Cape	Northern Cape	Free State	Kwazulu-Natal	North West	Gauteng	Mpumalanga	Limpopo
Agriculture	1.77%	2.63%	1.69%	2.73%	1.89%	2.58%	2.27%	2.33%	1.74%
Mining	0.84%	0.04%	1.66%	-5.36%	-0.05%	1.54%	-1.28%	0.19%	2.26%
Manufacturing	2.59%	2.95%	2.24%	2.67%	2.73%	2.94%	2.63%	2.86%	3.20%
Electricity	2.60%	2.93%	1.82%	2.58%	2.78%	2.88%	2.60%	2.82%	2.95%
Construction	4.13%	3.95%	3.25%	3.15%	3.66%	3.69%	3.66%	3.71%	3.48%
Trade	3.38%	3.40%	2.76%	2.51%	3.15%	3.37%	3.31%	3.41%	3.37%
Transport	3.46%	3.56%	3.18%	3.62%	3.43%	3.64%	3.45%	3.59%	3.64%
Finance	2.99%	3.70%	3.06%	3.83%	3.47%	3.70%	3.50%	3.74%	3.74%
Community Services	2.70%	2.55%	2.07%	2.61%	2.63%	2.62%	2.85%	2.72%	2.67%
Total Industries	2.99%	3.16%	2.30%	2.27%	2.97%	2.67%	3.06%	2.52%	2.92%

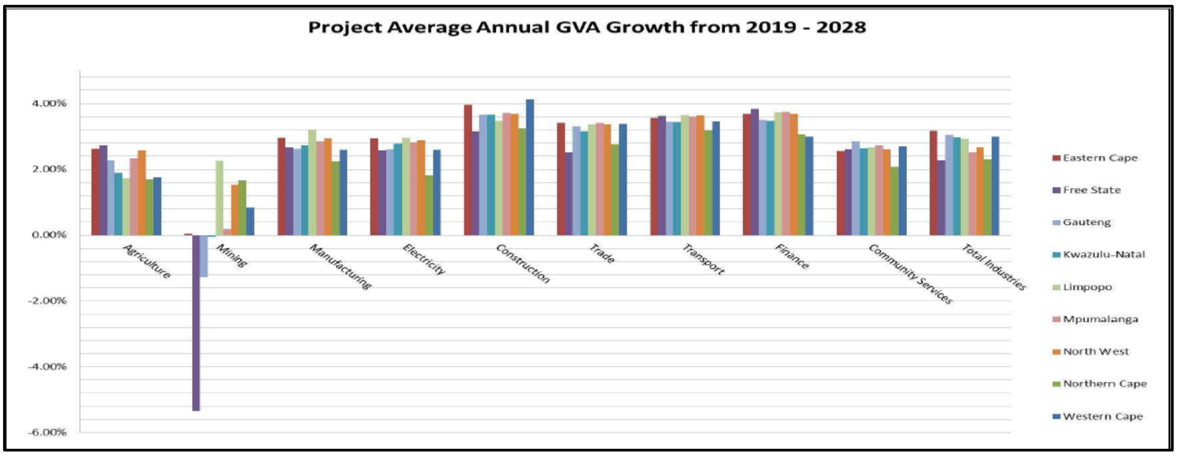


Figure 47: Projected average annual growth per sector for each province for the TDP period

The future growth in GVA assumes that there is no significant limitation to access to electrical power for growth, both in terms of generation capacity and transmission/distribution infrastructure to deliver the power where it is required. This is the scenario for the Transmission High Forecast which should be available to enable the projected growth in GVA across the Country and by enabling should stimulate higher GVA figures in future. Figure 47 below shows the average annual growth in total GVA for each province for the period 2018 to 2027 as the red bar. Next to this is the blue bar indicating the average annual Load Demand growth per province over the same period for the Transmission High Forecast.

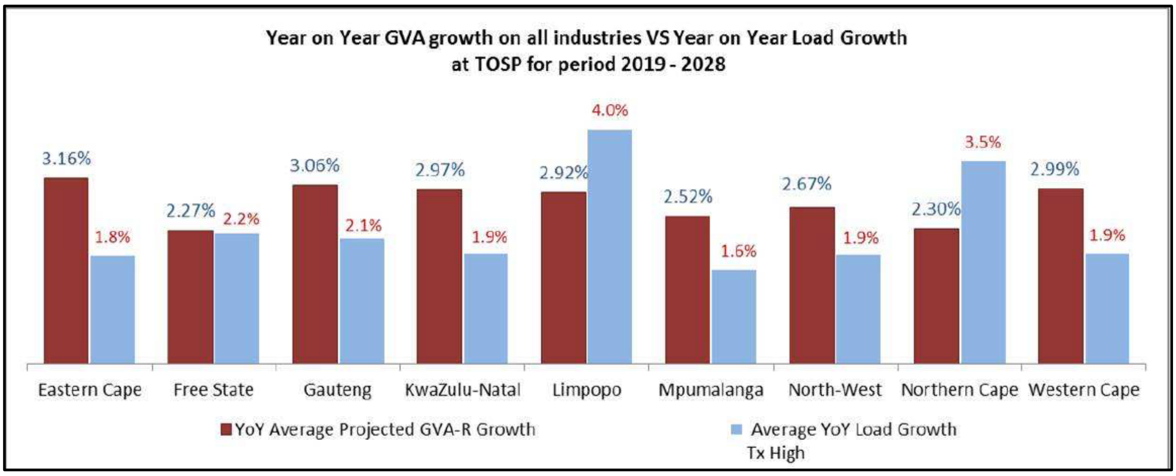


Figure 48: GVA Annual average growth compared to the load forecast from 2019 to 2028

Assuming a direct relationship between the average annual growths in GVA to the average annual growth in Load Demand based on the Transmission High Forecast, the growth of the GVA can be inferred. However, the Transmission High forecast assumes return of industries which would have a significant effect in specifically Northern Cape Province with the mining of Fe-Mg and Iron Ore, mining of coal in Limpopo Province, as well as increased industrial and export activities in the Eastern Cape. The Eastern Cape has a significant amount of renewable capacity especially in wind technology which assists in the supply even at time of system peak. Actual load measurements are already found to be lower than the total load demand for the area. The forecast in these three provinces is positively adapted to stimulate economic growth and require the most growth into the future to address the needs of large populations and infrastructure that accompanies the mining and export sectors. When comparing the total Industries on the GVA-R forecast to the Transmission High, Transmission less renewable and the Transmission Low forecast correlation can be seen between the GDP growths of 3%, 1.7% and 0.7% respectively (Jana Breedt and Danie Payne, 2017).

3.5 ECONOMIC FORECAST BREAKDOWN INFORMATION

The economic activity is expressed in terms of Gross Value Added (GVA) estimates for the different areas across the Country. The economic activity is divided into a nine main activity sectors which are listed below. On the maps in this section and the next section they are referenced by the letters SGQ followed by a three-letter code and ending with the two last digits of the relevant year. The list below shows the references for the year 2010.

Agricultural
Mining
Manufacturing
Electrical
Construction
Trade
Transport
Finance
Community Service

These nine economic activities are broken down into a further number of sub-activities related to the main activity. The main activities are also grouped in three types of economic activities namely:

- Primary
- Secondary

- Tertiary

The breakdown of the Sector type, Main Economic Sector and the associated sub-activities is provided below.

3.5.1 Primary Sector

Agriculture

- Agriculture and hunting
- Forestry and logging
- Fishing, operation of fish farms

Mining

- Mining of coal and lignite
- Mining of gold and uranium ore
- Mining of metal ores
- Other mining and quarrying

3.5.2 Secondary Sector

Manufacturing

- Food, beverages and tobacco products
- Textiles, clothing and leather goods
- Wood and wood products
- Fuel, petroleum, chemical and rubber products
- Other non-metallic mineral products
- Metal products, machinery and household appliances
- Electrical machinery and apparatus
- Electronic, medical and other appliances

- Transport equipment
- Furniture and other items NEC and recycling

Electricity

- Electricity, gas, steam and hot water supply
- Collection, purification and distribution of water

Construction

- Construction

3.5.3 Tertiary Sector

Trade

- Wholesale and commission trade
- Retail trade and repairs of goods
- Sale and repairs of moto vehicles, sale of fuel
- Hotels and restaurants

Transport

- Land and Water transport
- Air transport and transport supporting activities
- Post and telecommunication

Finance

- Finance and Insurance
- Real estate activities
- Other business activities

Community services

- Public administration and defense activities
- Education
- Health and social work

- Other service activities

For the overview of the Country the four activity sectors with the largest impact are presented in this section. The provincial breakdown discussions in the following section of the report include all nine of the economic activity sectors and are presented per province. The four economic activity sectors included in this section are:

- Mining
- Manufacture
- Financial
- Community Services

Each of the four sector activities is discussed separately in a sub-section and the maps are all presented at the end of this section.

3.5.4 Mining sector activity

The main mining activity is still in the same areas as in previous years with the intensity increasing by 2027. These areas are mainly in the southern part of Gauteng and around the borders of Gauteng with the Rustenburg municipality showing the highest concentration of mining due to the Ferro-chrome deposits. The Phalaborwa area in the Limpopo province also shows signs of high mining activity. In the Northern Cape the Sishen area also indicates an increase in mining activity. The most significant growth is expected along the area from Rustenburg extending north-east to Polokwane and Marble Hall where the activity is expected to almost double from an already high base. The area on the border between the Northern Cape and North-West provinces is expected to have an almost doubling of mining activity as well. This Northern Cape mining growth area extends down south past Upington down to the Pofadder municipal area where activity is expected to increase significantly assuming power is available. What is interesting to note is the decrease in mining activity, particularly in the Free State around the Welkom area. The gold mining in this area starts to slow down dramatically as the gold becomes more difficult and consequently more expensive to extract.

3.5.5 Manufacturing sector activity

The main manufacturing activity is concentrated in the Gauteng area and in the port cities of Cape Town, Durban and Port Elizabeth. No significant change in these areas or new areas are expected between now and 2027 other than increasing intensity. The most significant growth is expected along the area around Rustenburg extending to the area north of Tshwane where the activity is expected to almost double from an already high base. Most of this growth is related to the processing of the minerals in this area. There are a few other pockets of very high load growth expected around the country, but these are from a very low base and are not significant.

3.5.6 Finance sector activity

The main finance activity is concentrated in the Gauteng area and in the main cities of Bloemfontein, Cape Town, Durban, Polokwane, Port Elizabeth and East London. No significant change in these areas or new areas are expected between now and 2027, except in the Cape where the activity shows an increase in the Municipal areas bordering Cape Town. The most significant growth is expected along the areas around Cape Town extending inland and along the coast up towards Plettenberg Bay where the activity is expected to significantly increase. This indicates that the nature of the business allows new activity to start and increase in areas where people would like to live, rather than linked to where the work is located as in mining and manufacturing. There is also high growth in many of the KwaZulu-Natal areas for the same reason as the Cape. Gauteng and Rustenburg also show high growth which is more closely linked to where business is physically located.

3.5.7 Community Services sector activity

The main activity is naturally concentrated in main cities of Johannesburg, Pretoria, Bloemfontein, Cape Town, Durban, Polokwane, Port Elizabeth and East London as well as the greater Gauteng area. No significant change in these areas or new areas are expected between now and 2027 in terms of relative total GVA contribution. The most significant growth is expected in the Cape, particularly in the Northern Cape around Upington where the activity is expected to significantly increase, although from a very low base. The growth in and around the main cities is steady. There are several other pockets of high load growth indicated around the Country, but these are from a very low base and are not significant. As with the finance sector this points to an expectation of high reliability and security of supply which is not necessarily linked to a high increase in MW demand. This will also have to be borne in mind when considering the development of these networks for the future.

3.6 NETWORK DEMAND FORECAST IN ESKOM

The current custodian and main contributor to the South African base electricity load is the parastatal company Eskom Holdings SOC Ltd (Eskom). Eskom plays a fundamental role in meeting South Africa’s energy requirements. It is imperative that any forecast is done within the right context of the purpose it should serve. Within Eskom there are a number of forecasts, each driven to satisfy a specific business need. However, it is important that although different forecasts serve different purposes these forecasts should be aligned to not only achieve the overall utility objectives but also the needs of South Africa as a Country. Within the context of South Africa and the load requirements, the transmission demand forecast serves the purpose of providing load capacity needed to stimulate economic growth and to enable planning of adequate Grid capacity for the transfer of power from generation supply to points of delivery at the Transmission customer. Going into the future the transmission demand forecast will need to assess the implication on the network capacity provided by the nonconventional generation sources connected to the grid, or not connected to allow for off grid capability.

Eskom together with South Africa is currently going through a paradigm shift, and it is important to note the changes and adjust the methods of forecasting going forward. To further challenge the forecasting methodologies in place, the change in generation mix presenting itself worldwide is posing more complications for accurate forecasting of the energy system. Therefor the generation mix feeding both the current demand and the potential demand will change significantly although it is still envisaged that due to relative low cost of coal in South Africa it will remain a core part of the countries base load generation capacity. The supply chain which Eskom is moving towards a combination of vertically and horizontally integrated system with new generation sources combined to feed into the main grid as illustrated in figure 49.

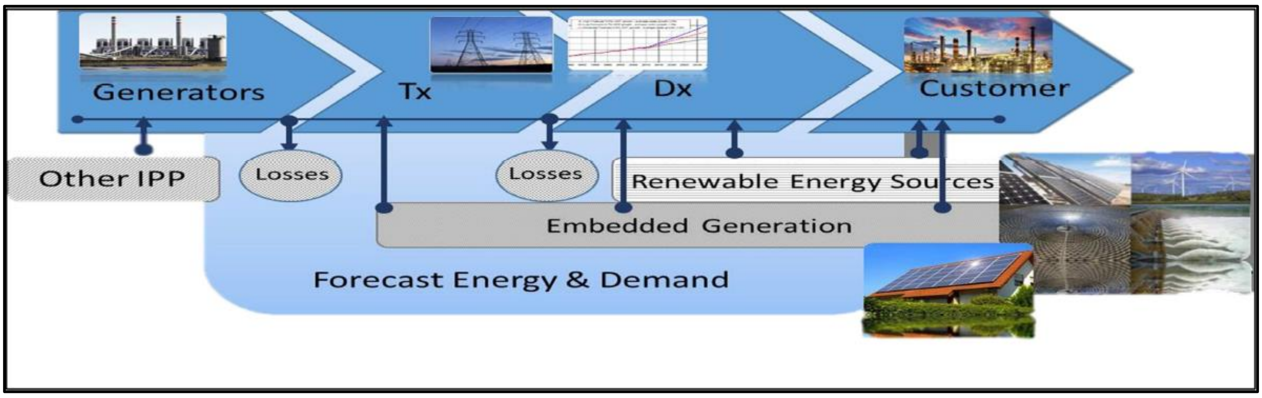


Figure 49: Supply and demand into the future

3.7 FORECAST METHODOLOGY APPLIED

Figure 50 shows the actual system peak values at TOSP with an S-curve trend for analysis purposes. The black line shows the actual transmission metering at national level, the red dotted line shows a curve which takes on the form of a completed S-curve. The light blue line is the renewable and co-generation contribution at TOSP. This confirms the actual load spatially is still needed; however, the supply mix is a variable and conventional mix.

A double S-curve methodology, combined with normative quantitative and qualitative techniques is used to produce the national forecast scenarios. A balancing algorithm method is then applied to balance the national forecast top down to create a forecast per main transmission supply point (MTS). This year the forecast was improved by creating three distinct national scenarios each with its own set of assumptions (Jana Breedt and Danie Payne, 2017). The three scenarios can now be briefly described and detailed assumptions per scenario will be provided in further sections of the report.

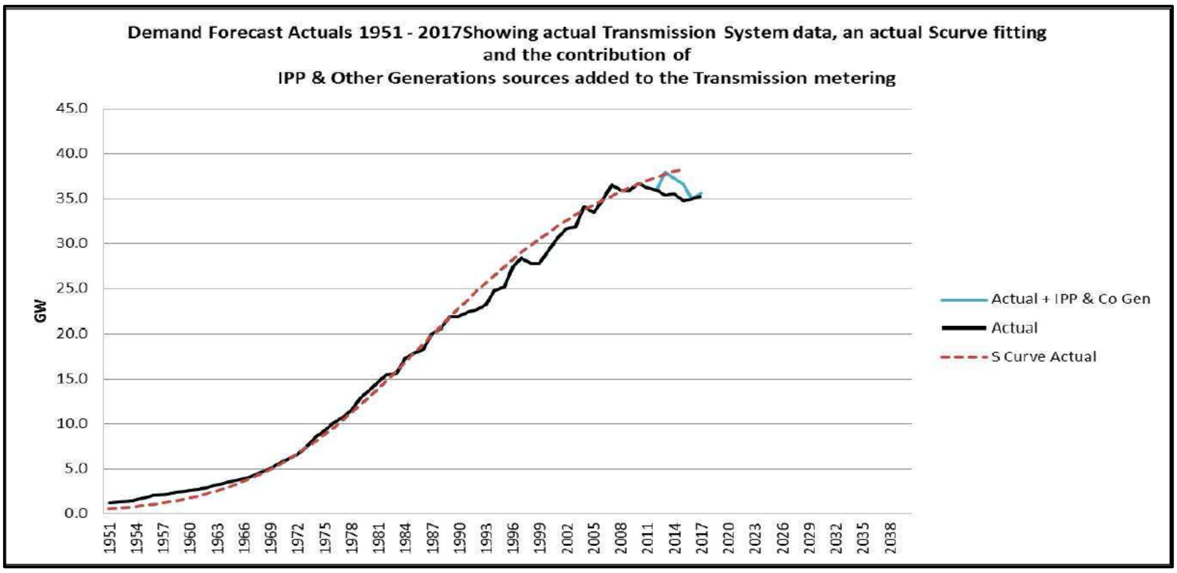


Figure 50: Demand Actual 1951 to 2017 with Renewable and other Generations added back

There is a combination of reasons which should be put into context for this downward trend. Firstly, there was great economic turmoil throughout the world with a recession period; then there was the aging fleet and mothballed substations which created a lag in economic growth for South Africa with the lack of enough generation availability; Thirdly, the inclusion of Independent Power Producers and the enhancement and choice of technology on energy sources used locally at client premise also contributed to the lowered load measurements.

3.7.1 Regression Analysis

A regression analysis was done on each preceding decade to measure the accuracy of the forecast. In the first ten years from 1983 to 1993 a steady growth in economy was experienced and also in load, the manufacturing and mining industry was heavily reliant on electricity and therefore Eskom expansions boomed. For a period, closer to the 1990's an excess of power was generated which led to the mothballing of some power stations and load generation plans was slowed down drastically. Figure 51 below shows the correlation between the actual values and the forecast S-Curve. When analysing the variance between the actual load measured and the forecasted values as predicted, the R2 tells the proportion of variance between the chosen variables which can be explained. Therefor the closer the R2 is to 1 the more the variability can be explained and the forecast is seen as favourable. During this decade from 1983 – 1993 a good fit was found with R2 = 0.93, which implies 93% of the coronation could be explained and posed good results despite of the overcapacity that adjusted generation plans.

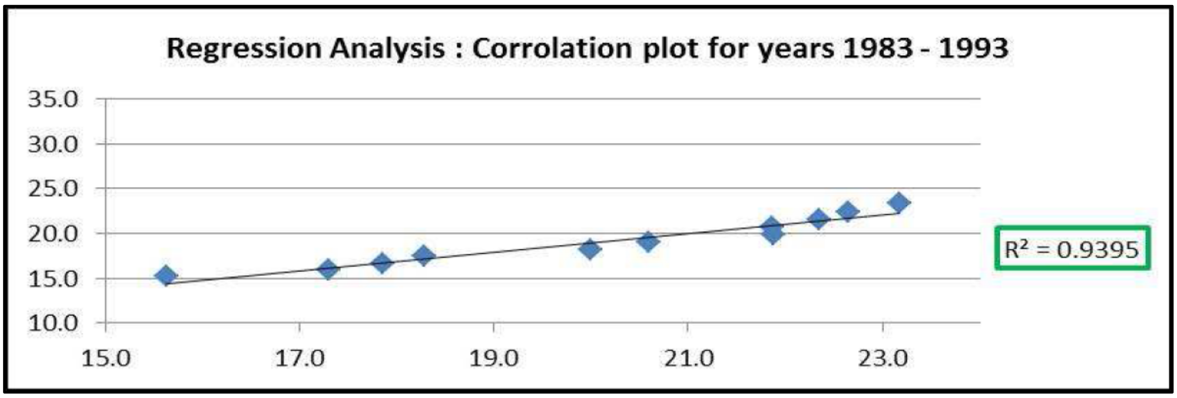


Figure 51: Correlation between Forecasted and Actual Values 1983-1993

During the next ten years South Africa changed into a new democracy driven society and a numerous change was brought on to especially infrastructure development. This created a booming economy with lots of international and local investment interest into South African economic growth. This period also saw the introduction of free basic electricity which created great additional demand from the power utility. The R2 value for this period also indicates a good fit between the actual and forecasted values with 94% of the variability to be declared. Figure 52 shows the correlation plot for this period.

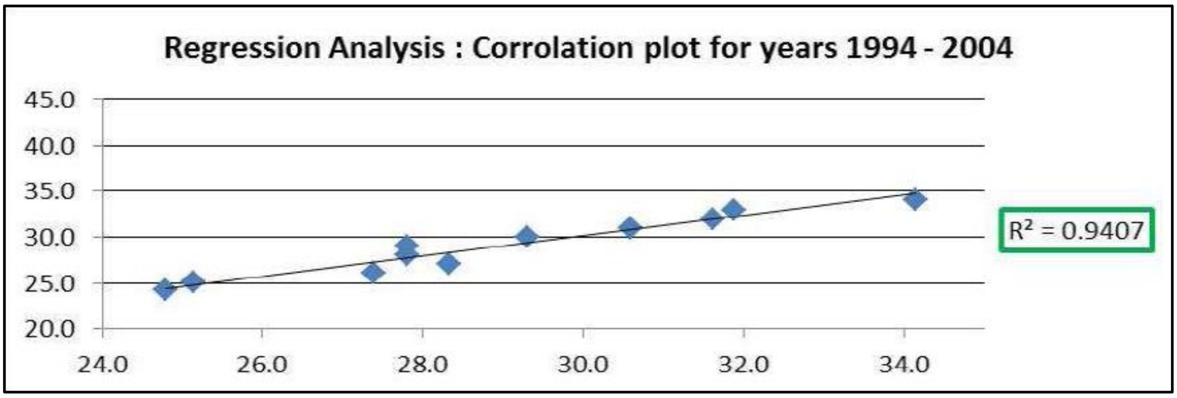


Figure 52: Correlation between actual and forecasted values 1994-2004

Since 2007 it is evident that there is a change in the actual values when analysing the actual substation measurement figures. Due to the sudden infrastructure expansion plans and increase in household use of electricity, and hosting of main events such as the Soccer world cup which also stimulated infrastructure development, a sudden increase in demand was experienced. The fact that a number of power stations were mothballed and additional funding was not released by government for building of new power stations to meet the growing demand of the country caused the demand to surpass the supply requirements and this was the start of an official energy crisis. The worldwide economic turmoil as well as lack of supply to encourage growing industries, the economy suffered a big blow and therefore closing of mines and other main activities became a reality and therefor decreasing the allowable demand from the country's energy usage perspective. Figure 53 shows a very bad R2 value with a value of only 4% that could be reasonably explained. This variability from a good R2 to a very low result shows the heteroscedastic of the data on which the forecast is performed and therefor the quantitative techniques and statistical regression forecasting is not suitable for demand forecasting as there is too much environmental and political aspects influencing the demand.

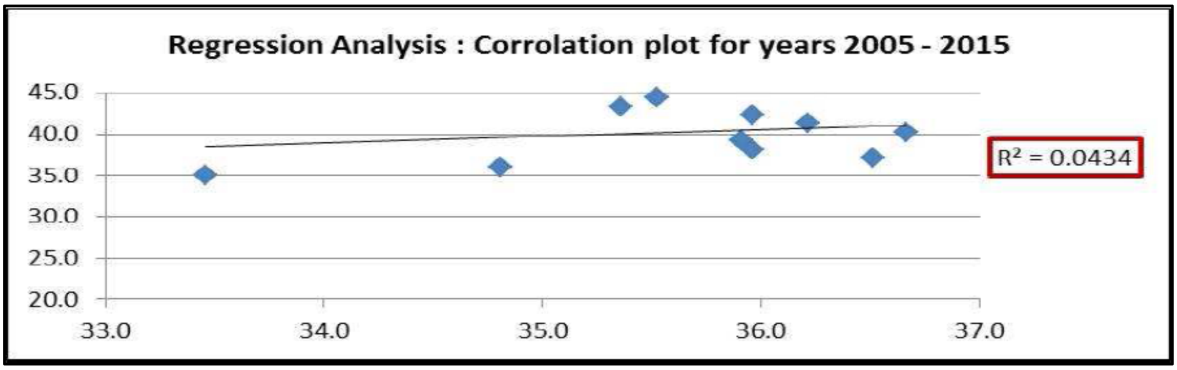


Figure 53: Correlation between actual and forecasted values 2005-2015

3.8 S-CURVE METHODOLOGY APPLIED

Up till now the demand forecast was done on base of a 100-year S-Curve, combined with Quantitative and Qualitative application approaches. Figure 54 shows the original 100-year S-Curve together with the actuals and an S-curve as indicated by the blue line, applicable to the actual values plotted. As can be seen by the actual S-Curve, the S-curve has reached its end of its life cycle, this serves as trigger for use of double S-Curve methodology. As in many other product design and sales forecasts, an S-curve depicts the start of a product, its development and growth period and then as soon as it reaches saturation in year-on-year growth, it indicates the end of the product lifecycle. In the same manner Eskom has reached its end on the "Isolated product delivery", and new technology is changing the load profiles. Therefor the methodology was adapted by using a Double S-Curve as replacement on the original Single S-Curve. This is when the same entity is forecasted but it has new technology and production mix involved. Figure 80 shows the updated application of the double S-Curve in context of electricity demand forecasting. The change in Load profile change can be contributed to factors such as technological advancement, increased economical electricity usage, demand side management and increased use of alternative sources, driven by capacity constraints of original fossil fuel generation sources.

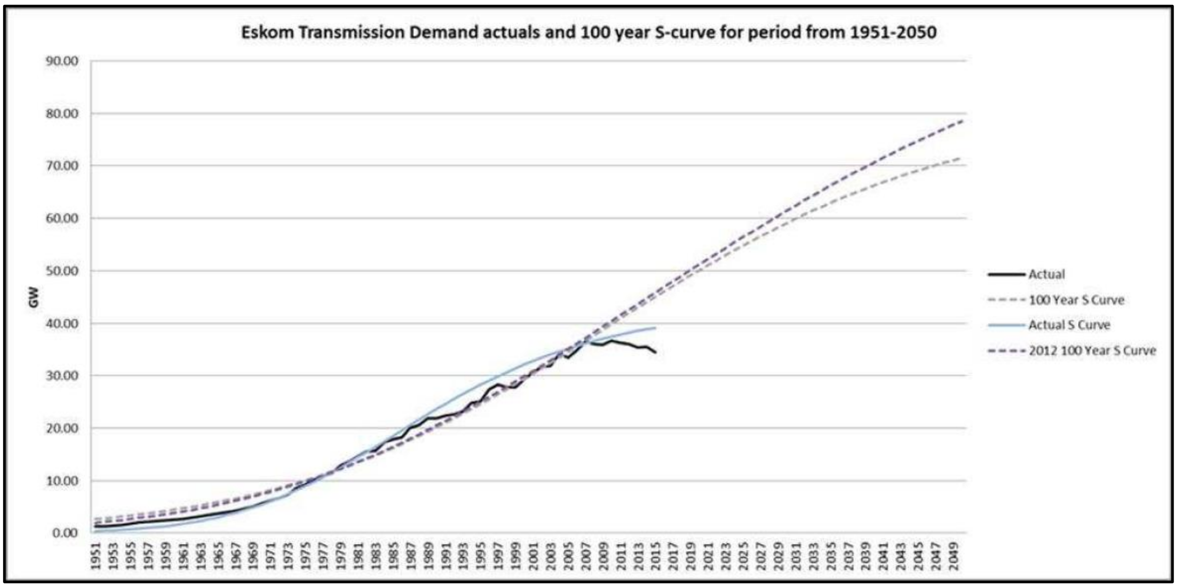


Figure 54: Actual S-Curve and original 100years Single S-Curve

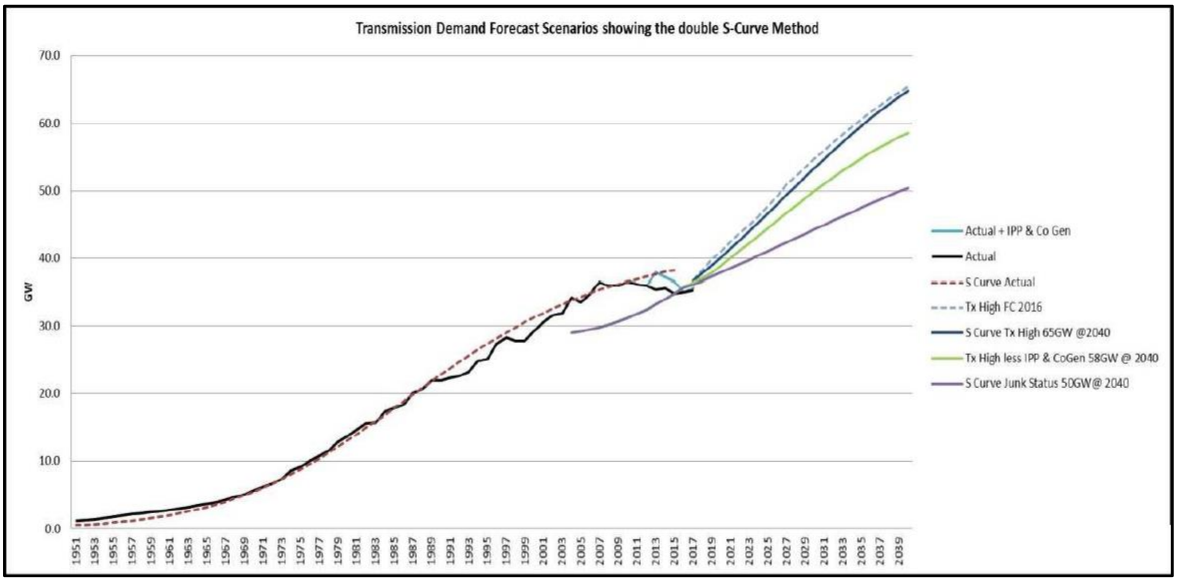


Figure 55: Double S-Curve method applied to Transmission System Peak

The double S-Curve method was then used to derive the new forecast for this year. The different scenarios will be explained in detail in this chapter.

3.9 EASTERN CAPE PROVINCIAL FORECAST

The Eastern Cape had a province peak load demand of 1,532 MW in 2016 and the load demand at the TOSP was 1462 MW. The province peak load demand is expected to increase to around 2,136 MW by 2028 with a TOSP contribution of 2,136 MW. The TOSP loads represent an average annual growth in load demand of 1.8% for the province, which is lower than the previous TDP period, however the load at the end of 2028 is similar it is the beginning years load that has increased to lower the total percentage growth figure. An increase in load can be seen around from 2018 when an additional petrochemical plant and the Industrial Development Zone (IDZ) developments are expected to come into full service, this was added back into the forecast with a more positive lookout than the previous published forecast which leads to an increased value from the previous year. The load forecast graph for the province shown in Figure 81 indicates the actual load growth from 2005 to 2017 with the forecasted load growth for the province peak and TOSP from 2019 to 2028. Table 13 provides the MW demand values for the 2018 to 2029 years. The dotted lines represent the load forecast published in the previous TDP period 2016 – 2027.

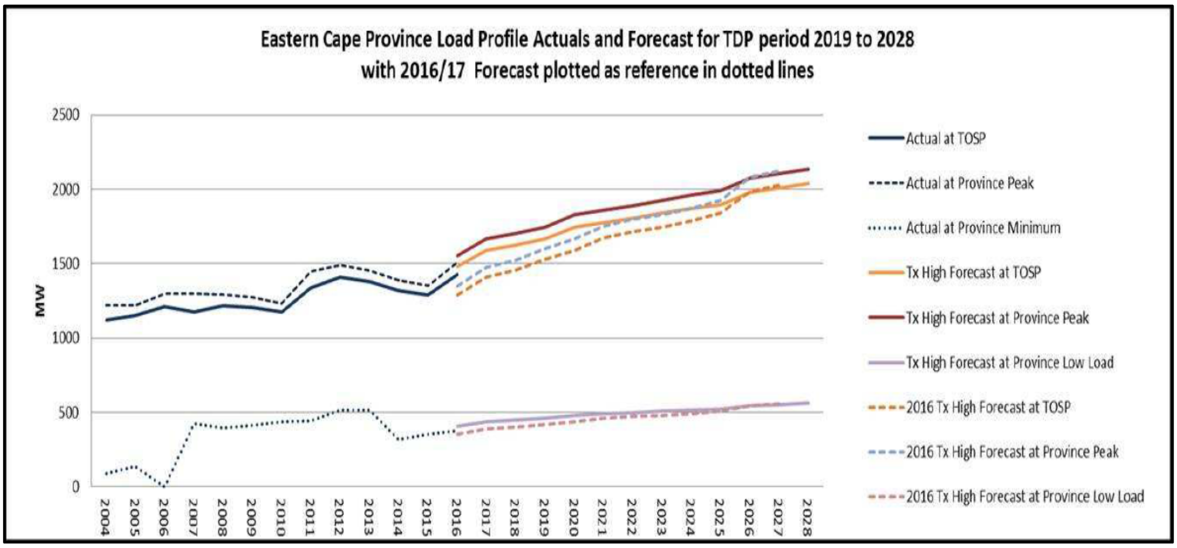


Figure 56: Actual and forecasted load values for 2018 to 2027 for the Eastern Cape

Table 13: 2018-2029 Load Forecast Values in MW for Eastern Cape

Tx High at Maximum System Demand at different load conditions for province												
EasternCape	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029
Tx High Forecast at TOSP	1628.00	1667.84	1748.55	1777.19	1805.80	1839.01	1870.99	1897.98	1978.11	2010.42	2038.14	2066.82
Tx High Forecast at Province Peak	1706.15	1747.90	1832.48	1862.50	1892.48	1927.28	1960.79	1989.09	2073.06	2106.92	2135.97	2166.03
Tx High Forecast at Province Low Load	449.03	460.02	482.28	490.18	498.07	507.23	516.05	523.50	545.60	554.51	562.15	570.07

3.9.1 MTS Supply Areas and Forecasts

The network is divided into supply areas based on MTS forecast network topologies as established and approved via Provincial Network Integration Forum Sub Committees (PNIF Sub Committees). Full transmission and distribution topology with distribution point loads can be obtained in the Excel annexure. Figure 82 gives a spatial representation of Eastern Cape and its MTS substations, both existing and planned within the TDP period for 2019-2028. Table 17 gives the TOSP values per MTS and new MTS's follows the 0 values greyed out in the year they are planned to be commissioned. Commission dates are confirmed with CAPEX schedule and PNIF Sub Committees. Table 14 and 15 gives substation maximum values for when each individual MTS peaks during the year.

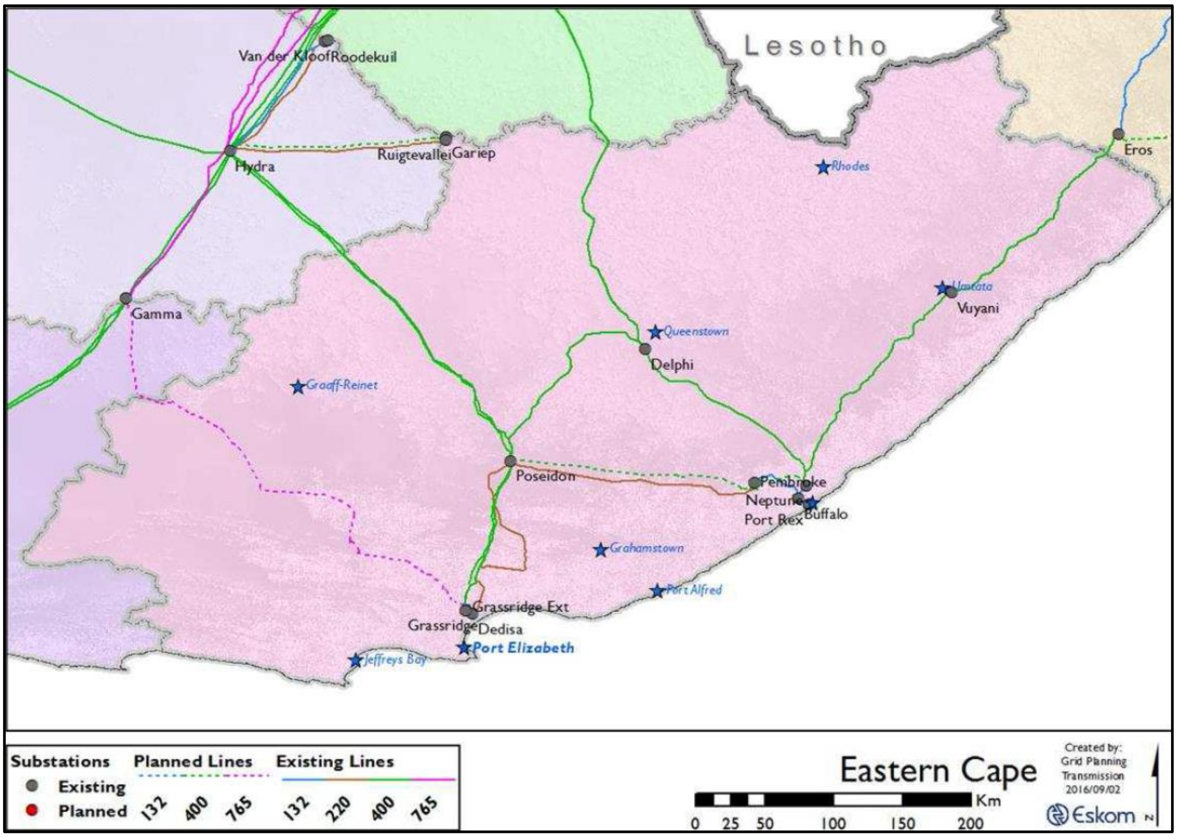


Figure 57: Spatial map of EC Province with MTSs displayed (Jana Breedt and Danie Payne, 2017).

Table 14: Eastern Cape MTS Forecast value for 2019-2028 at TOSP

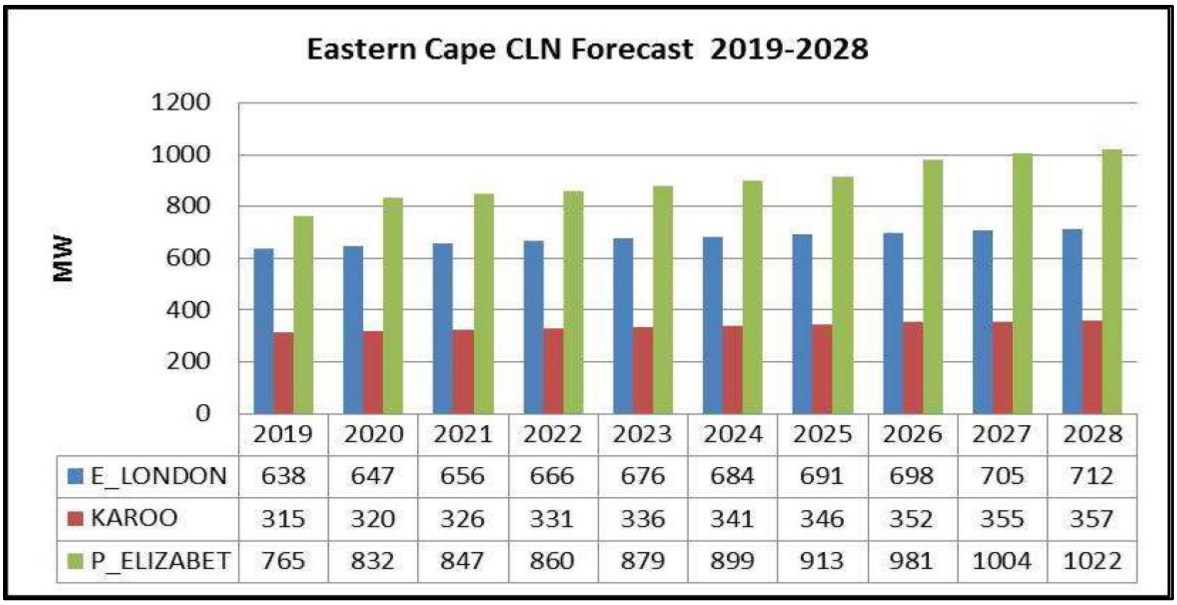
Tx at Maximum System Demand at TOSP												
EasternCape	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029
Dedisa	262.6	265.2	267.9	270.6	273.3	276.0	278.8	281.5	287.2	292.9	298.8	304.8
Delphi	104.1	105.2	106.2	107.3	108.3	109.4	110.5	111.6	112.7	113.3	113.9	114.4
Grassridge	380.8	390.3	454.1	465.1	475.3	490.8	506.6	517.6	579.0	595.6	607.4	619.6
Hydra	115.3	120.5	122.4	125.1	127.9	130.7	133.5	136.3	138.2	139.2	140.1	141.1
Neptune	254.5	302.6	305.8	309.1	318.0	321.3	324.7	327.9	331.2	334.4	337.9	341.6
Pembroke	82.5	46.7	47.7	48.8	45.3	46.6	48.1	49.3	49.9	50.8	51.6	52.5
Poseidon	109.2	109.9	110.5	111.2	111.8	112.5	113.2	113.9	114.6	115.3	116.0	116.7
Ruigtevallei	114.9	119.7	122.4	124.6	126.5	128.4	130.3	132.3	135.7	137.1	138.5	140.0
Vuyani	179.9	183.5	187.2	190.9	194.7	198.6	200.6	202.6	204.6	206.7	208.8	210.9

Table 15: Eastern Cape MTS Forecast value for 2019-2028 at Substation Peak

Tx at Substation Max												
EasternCape	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029
Dedisa	281.0	283.8	286.6	289.5	292.4	295.3	298.3	301.3	307.3	313.4	319.7	326.1
Delphi	166.6	168.3	169.9	171.6	173.4	175.1	176.8	178.6	180.4	181.3	182.2	183.1
Grassridge	506.4	519.1	603.9	618.5	632.2	652.8	673.8	688.5	770.0	792.1	807.9	824.1
Hydra	198.25	207.33	210.50	215.20	219.94	224.73	229.56	234.44	237.72	239.36	241.00	242.64
Neptune	277.4	329.8	333.3	337.0	346.7	350.2	353.9	357.4	361.0	364.5	368.3	372.3
Pembroke	198.0	112.0	114.5	117.2	108.7	111.7	115.3	118.3	119.8	122.0	123.7	126.0
Poseidon	116.8	117.5	118.2	119.0	119.7	120.4	121.1	121.9	122.6	123.4	124.1	124.9
Ruigtevallei	156.3	162.8	166.4	169.5	172.0	174.6	177.2	179.9	184.5	186.5	188.4	190.3
Vuyani	215.9	220.2	224.6	229.1	233.7	238.4	240.7	243.1	245.6	248.0	250.5	253.0

3.9.2 CLN Forecast

CLN groupings of MTS forecasts are displayed in Figure 57 as per Case file allocation 2016. Port Elizabeth will see most of the growth in the province which is where the port as well as IDZ industrial area is situated.



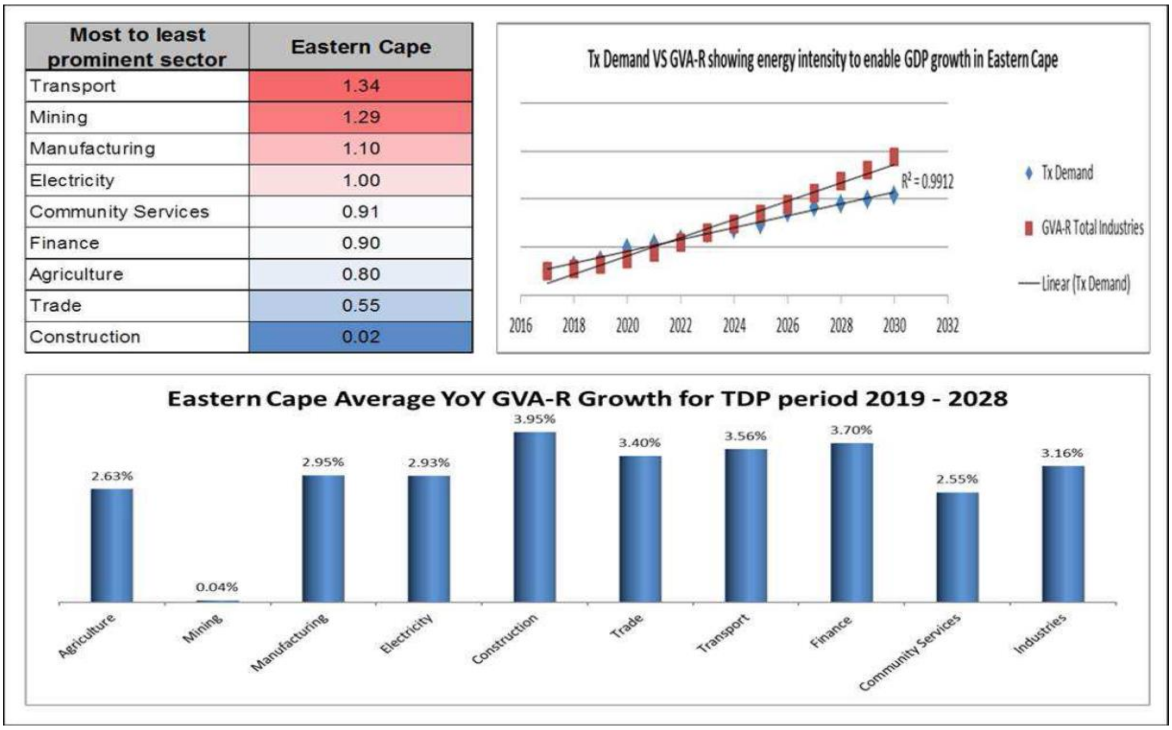
	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028
E_LONDON	638	647	656	666	676	684	691	698	705	712
KAROO	315	320	326	331	336	341	346	352	355	357
P_ELIZABET	765	832	847	860	879	899	913	981	1004	1022

Figure 58: Eastern Cape CLN 2019-2028.

3.9.3 Forecast Driving Factors

The Eastern Cape has two major industrial centres, Port Elizabeth and East London, which have well developed economies, based on the automotive industry. General Motors and Volkswagen both have major assembly lines in the Port Elizabeth area, while East London is dominated by the large DaimlerChrysler plant. A new harbour has been built at Coega, just north of Port Elizabeth, which is linked to an Industrial Development Zone (Coega IDZ) to attract new investment, although the expected growth was not realised due to the IDZ developments not reaching its full targets and some of the IDZ developments have been cancelled. A plan of a Petrochemical plant by PetroSA is also in the horizon however current developments in this industry put these developments at risk. It is expected that this development will give the province a major economic boost. Other important sectors include finance, real estate, business services, wholesale and retail trade, and hotels and restaurants. The step load increase around 2026 can be explained by the above-mentioned developments.

The estimated average annual growth of GVA of the nine economic sectors over the 2019 to 2028 period for the province is shown at the bottom of Figure 58. The Location Quotient values for the province can also be seen in the top left half, this indicates which of the sectors has the greatest influence on the economy of the province, next to that in the upper right half of the figure is a correlation between the load and the GVA growth in the region. An R2 value close to 1 shows good correlation.



Most to least prominent sector	Eastern Cape
Transport	1.34
Mining	1.29
Manufacturing	1.10
Electricity	1.00
Community Services	0.91
Finance	0.90
Agriculture	0.80
Trade	0.55
Construction	0.02

Figure 59: Economic Summary for Eastern Cape 2019-2028

3.9.4 Future potential load demand changes

A new MTS substation is planned for the Port Elizabeth area, currently referred to as the "New PE Substation" in the TDP, which is expected around 2022. Load will be transferred from Grassridge, but the amount is not yet certain. This new substation is linked to the potential Nuclear 1 power station near Thyspunt in that it utilises some of the 400kV lines for the integration of the power station. This has not been shown in the Load Forecast as there are still too many uncertainties regarding timing and MTS transfer but will be incorporated when there is more confidence.

3.10 INFLUENCE OF DEMAND SIDE MANAGEMENT (DSM) ON A LOAD FORECAST

Demand Side Management is a range of initiatives that are aimed at reducing the demand of electricity by encouraging the user to reduce energy consumption. In some cases, initiatives result in an overall reduction in energy consumed (kWh), without a reduction in energy demand (kW). When considering the effect of DSM on the load forecast, it is important to focus on the reduction in energy demand (kW or kVA).

The types of DSM initiatives in place are:

- Load Shifting (LS)
- Energy Efficiency (EE)
- Renewable Energy (RE)

Projects that are currently in place include:

- Solar hot water heaters (RE), implemented by rebates or subsidies in housing projects.
- Heat pumps (EE), implemented by rebates
- Energy saving shower heads (EE), implemented by an exchange program
- Ripple relay program (LS)
- Compact Fluorescent Lamps (CFL's) (EE), implemented by an exchange program and as part of electrification projects
- LED lighting (EE)
- Customer negotiations for reduced load (EE) and for load shift (LS)

DSM information has to be considered when looking at historical loads, as it may have skewed the load in years that it was implemented. This may lead to incorrect values in the load forecast if trending is used. Other factors that could have contributed to load decline should also be considered, like the economic recession and load shedding. DSM information for future years can be treated as follows:

- The type of DSM initiative must be investigated, as it will have a different effect on the load.
- The area where DSM is taking place must be translated into the network that will be affected by it.
- The timeframe of when the DSM will have an effect need to be accounted for.
- The installed capacity of the DSM must be diversified according to customer characteristics

3.10.1 Types of DSM

Solar hot water heaters use energy from the sun to produce hot water. When the demand for hot water is greater than the hot water supplied by the solar system, additional water is heated electrically. The solar water heater is most efficient when it receives the most sunlight, i.e., during daytime in summer. Reduction in electricity use is dependent on the weather. The reductions in peak demand could be small, if the peak demand is in winter, and sun exposure is minimal. It will benefit the user, because the overall kWh of the user will be reduced. Heat pumps use electricity to exchange heat from the atmosphere to water. Heat pumps use a reduced amount of electricity continuously. The result is a reduction in kWh, as well as a reduction in peak demand. Compact Fluorescent Lamps have a relatively low power factor, around 0.6 (leading). The electronics driving the CFL lamps introduces additional harmonics into the network, which is a power quality issue. If the intention is to use CFL's as replacement for incandescent lamps instead of adding it as additional load, the reduced real power demand is sufficient to accommodate the increased reactive power load. It is important to keep in mind that the load reduction due to CFL's will only continue if customers continue to use CFL lamps and do not revert back to incandescent lamps.

3.10.2 Sustainability

The sustainability of DSM load reduction is dependent on the type of installation. The lifetime of the product has an influence, as products with a short lifetime need to be replaced with a similarly performing product. This can be achieved by proper support of the customer. Customers that are educated about electricity usage and mindful of savings will promote more sustainable solutions. Infill and sustainability projects are required to ensure that customers do not revert back to the cheaper alternatives e.g., incandescent lamps.

3.10.3 Diversification

The ideal is that load is reduced by the same factor as the difference in installed equipment, i.e., water heaters, lights etc. but this is not necessarily achieved. Other factors influence the amount of load reduction due to DSM. Diversification of the loads, characteristics of the DSM initiatives and customer awareness programs have caused a decrease in load before DSM initiatives were implemented i.e., load reduction smaller than anticipated. If metering and verification reports regarding DSM are available, these could be used to determine the impact of DSM initiatives in the past.

3.10.4 Timeframe

In order to incorporate DSM information into a load forecast, it is important to determine when will the DSM projects result in a decline in load growth. The types of initiatives determine when the load will be affected. If the project is implemented over a long term, the effects will not be visible directly. The effects of seasons and daytime need to be considered, if applicable (as in the case of solar hot water heaters), as well as how long the effects of DSM initiatives will be affecting the load forecast. This includes the sustainability of the project, as well as by what time the gains made by DSM in terms of capacity will be offset by load growth.

3.10.5 The effect of DSM on Load Forecasting

The effect of DSM on a load forecast is dependent upon the type of forecast produced. If a load forecast is being done for short term, 5-year NDP then it could have an effect and should be taken into consideration in project planning activities. However, most load forecasting is done to forecast what the load will be in 20 years' time. In this case, the impact of DSM will be offset by the load growth in the area. This however may result in reduced future load due to efficient base loads where no significant future developments are anticipated. The other aspect that should be considered is the level at which the Load Forecast is being carried out. Generally, this is at a feeder level. At a feeder level, many of the DSM initiatives will have little effect on the system peak kW demand as some of the feeders do not necessarily peak at the time of system peak. The DSM initiatives will always have an impact on the local peak demand as these are directly applied at the local network levels. In an area where DSM has been applied a reduced growth rate may be observed for a short period but soon the growth rate returns to the growth rate before the DSM initiative due to natural influences of future developments.

3.11 SUMMARY OF CHAPTER THREE

Load forecasting is the first task to be performed before commencing with the planning of new networks to supply future demand. By performing a geo-based load forecast based on socio economic principles the forecaster gains insight into the factors which ultimately drives the load behaviour. Using domain specialists improves the assumptions which the forecast is based on and adds credibility to the forecast which makes it more defendable. Environmentalists provide a ‘green’ view which influences thinking in terms of the location where future development should not take place.

The future vision of development which takes the environmental aspect into consideration is coordinated and produced by town planners and represents the combined view of multiple departments responsible for infrastructure development. The vision is then tested against various macro- and social economic parameters to ensure a realistic phasing of future developments. Knowing what will happen to the underlining composition of customers allows the load forecaster to model the different electrical characteristics and predict the future load requirement. By using a multidisciplinary team of specialists, the overall quality of the forecast is increased.

The Demand Forecast Process has been developed for transmission strategic 30-year long-term demand forecast and with the focus more on the last 20 years. The process defines Eskom’s generation, the transmission network and the distribution networks as a supply and demand model. The supply and demand model provides a basis to debate forecasts on different levels of the model to provide a better understanding on future expected demand growths in the complex and highly uncertain environment. Simple rules and graphical displays are used to analyse the historical demand flows for a better understanding of the current demand trends and cycles. The understanding of the current demand trends and cycles combined with a comprehensive market intelligence process provide, with certainty, informative forecast results for a dynamic environment. Reports highlight miss-alignments between the different forecasts for further debates. The feasible solution is finally validated once the miss-alignments between the different forecasts are acceptable for electrical network studies. This is to ensure long-lasting and optimal network solutions expanding the transmission network will be reached. The expected demand growths are spatially modelled as further support for the electrical network studies (Hashe, 2012).

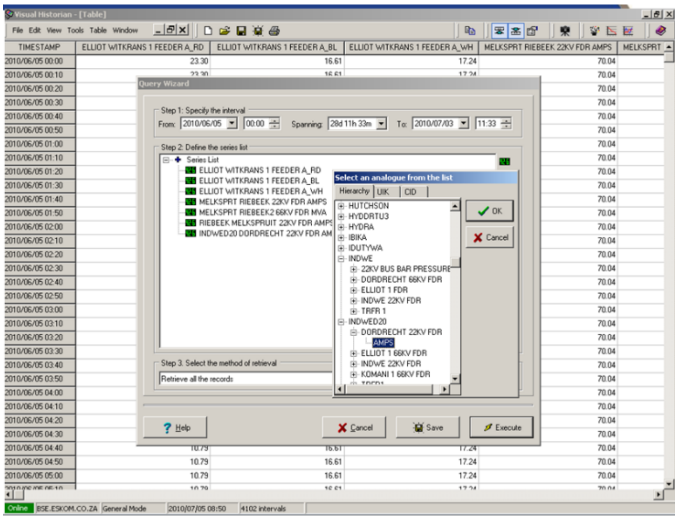


Figure 60: Virtual History System

MV90 data is system were customer usage or customer load records that are measured using devices apparatus for the intention of charging or billing them. We have added statistical meters to MV90, using the same system, for the load forecast purposes. The only data in the structural system which correlates to KVAr and KW. SCADA used primarily to evaluate monitoring of load apparatus and control the network through optimisation. Information system data in the system includes everything that is measured such as follow: (current, power, frequency, tap change position, voltage, oil temperature, breaker status, protection status etc. The SCADA data and MV90 data follow very different paths. The previous SCADA system used was a system called 8501. The problem with 8501 was that the software could only run-on hardware that was out of warrantee. The components were also difficult to source when they fail.

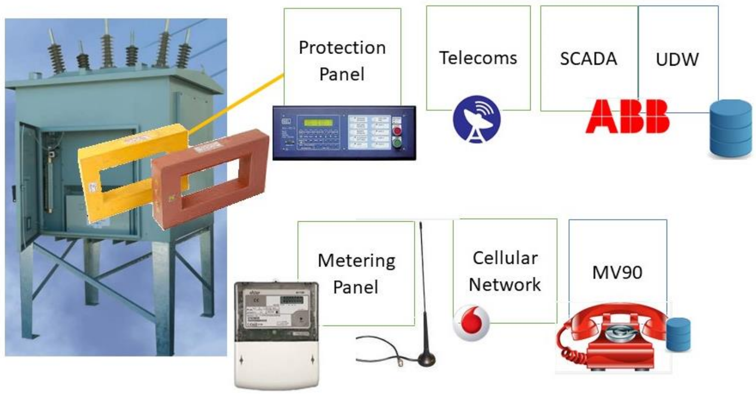


Figure 61: MV90 v SCADA

In summary load forecasting is the first task to be performed before commencing with the planning of new networks to supply future demand. By performing a geo-based load forecast based on socio economic principals the forecaster gains insight into the factors which ultimately drives the load behaviour. Using domain specialists improves the assumptions which the forecast is based on and adds credibility to the forecast which makes it more defendable.

CHAPTER 4: LOADSHEDDING AND ENERGY CRISIS IMPACT IN SOUTH AFRICA

4.1 INTRODUCTION AND BACKGROUND OF RSA LOADSHEDDING

Republic of South Africa since 2006 it has experience loadshedding till today. Electricity is the one of the key drivers for economic growth and economic stability of the country. This fact that the newest technology of the twentieth (20^{th}) century is electricality or power supply which has completely changed our world profoundly for the better since the discovery of it. Electricity or power supply it has not just change our lives, but it has become part of our daily lives and now is the main backbone of our everyday modern world, daily life, and economy. Electricity is number one from all household essential services such as wated and sewerage because without electricity all other household services such as water need electricity, sewerage need electricity because both utilising pumps to pump such service to relevant site such as water station pump and sewerage stations (Kenny, 2015). Electricity was the most important new technology of the 20th Century. It changed our world profoundly since the discovery till to date and change our livelihood entirely for the better. It is now the backbone of every modern industrial economy country.

This loadshedding or energy crisis is often because of limitations in generation capacity of power stations due to unplanned and planned maintenance. The loadshedding since year 2018 when current president of the republic his excellency Cyril Matamela Ramaphosa had been inaugurated since then loadshedding had happened frequently and results to disconnecting large parts of the country power grid from supply, a process termed loadshedding. This has resulted to business medium and small and millions of households without power supply or electricity causing them inconvenience and discomfort. During loadshedding many entrepreneurs especially in the medium and small business lost economic income to their business and without any consideration to them and to millions of households which suffer more than others depending on type of area such as suburbs, semi-suburbs, townships, semi-rural and rural area (Olabambo et. al, 2019).

South Africa is part of so many countries which face significant challenges of electricity or energy crisis that results to loadshedding to businesses and communities in the country (Kaygusuz, 2019). To put this into context, the United Kingdom (UK) installed capacity generates over 78 800MW of electricity for a population of 67.2 million people (Stolworthy,

2019) and comparatively with a developing country like Nigeria with a population of 206.1 million but installed capacity generates 12 522MW (Oyedepo, 2018). Since the dawn of fall of apartheid and South Africa was democratic country since 1994, the has been a rapid increase of electricity through the drive by governing party African National Congress (ANC) which is still at the helm of governing the country for over +25years. This rapid of electricity was due to the rapid service delivery to the hitherto disadvantage community such as villages and township which are mostly dominated by Black South Africans. The rapid increase also due to the increase in population both in the rural area and metro areas in the country, increase in the number of digital appliances and devices using electricity, devices such as televisions, cellphones, geysers, etc., the modernisation of poorer areas through social the Reconstruction and Development Programme (RDP) which was started in the government of former state president late Nelson Rolihlahla Mandela.

There is a wide gap between the electricity or power demand on the grid and the installed supply capacity (or generation) in many developing countries which South Africa is part of, there is also the need to constantly maintain the alternating current frequency of the power system at its operational value (50 Hz or 60 Hz). The results of this demand on the grid and the installed supply capacity maintain the alternative currency frequency of the power system is to avoid the large parts of the electric networks to be disconnected from power supply. The disconnection of this large power supply grid network is called “loadshedding”, which aim is to reduce the strain on the existing network grid and prevent it from total collapsing which results into total darkness of the country (Olabambo et. al, 2019). While the utilities around the world in the developing countries and emerging countries such as Eskom in our case try to stabilise the network grid to avoid total collapse, this results to loadshedding which affects millions of households and (small, medium and large) business left without electricity. This seriously affect countries economy and leaves so many citizens with serious discomfort and inconvenience, and this has been happening past 14 years today. Furthermore, some household and business bear the brunt of the longer loadshedding schedule due to the standard loadshedding technique does not focus on fairly allocation of power supply to households, small and medium business as much as utility such as Eskom they do on maintaining a demand supply balance (Olabambo et. al, 2019). In this chapter we will try to unpack some broad solution that have been attempted to resolve this major energy or power supply crisis in our country once again touching base with existing WEFs.

4.2 ESKOM SUPPLY PRIOR 1994 DEMOCRATIC

The South African electricity public utility which was established nearly 100 years ago in 1923 under the Union of South Africa government. The Union of South Africa which is the predecessor to the present day the current Republic of South Africa and it was established in May 1910 with unification of the Cape and Natal which was ruled by British and the Transvaal and the Orange River colonies which were control by Dutch descended who were known and currently called as Afrikaaners (Smith, 1996). After the establishment of the public utility, they called in Afrikaans name Elektrisitiets Voorsienings Kommissie (EVKOM) and was also known by its English name as the Electricity Supply Commission (ESCOM). Eskom was founded by the Electricity Act of 1922 which allowed the South Africa Electricity Control Board to appoint first chairman of the board Hendrik Johannes van de Bijl. In 1987 at the hight of apartheid changes its name which they combine the two Afrikaans and English acronyms and became known as ESKOM from previous (ESCOM and EVKOM). The Electricity Act stated that public utility could only sell electricity at low cost and was exempted from tax with the firm initially raising capital through the issuing of debentures, later guaranteed load instead. The two first coal power plant which one in Durban called Congella Power Station and one in Cape Town called Salt River Power Station which build by Eskom and both completed in mid-1928 (Congella Power Station, 2020).

From its initial stage until today it remains the larger producer of electricity in Africa and was among the top eleven (11) utilities in the world in terms of generation capacity and sales but currently ESKOM has slidden in both categories (Sanchez, 2019). Currently Eskom Holding SOC Ltd is 100% state own company which own by South African government. Eskom is a vertical integrated public utility with three divisions which are Generation, Transmission and Distribution and together these divisions generate approximately 95% of electricity used in South Africa amount to 45% used in Africa and emits 42% of South Africa’s total carbon emission (Sylvy Jaglin and Alain Dubresson, 2017). In 1935 Eskom complete another coal power plant in Witbank, with installed capacity of 128 MW which was mainly to provide the mining industry. The Witbank Power plant was run in partnership with the privately owned Victoria Falls and Transvaal Power Company which owned a number of other power plants across the country. After the World War II, South Africa experience power shortage that led to public utility negotiating power saving agreements with the mining industry in June 1948. The National Party government which orchestrated the apartheid legacy was able to buy out the Victoria Falls and Transvaal

Power Company in 1948 for £14.5 million which translate to R293.9 billion (Holtzhausen, 2019).

Eskom prior to 1994 Eskom was to make sure that South Africa had enough electricity and it was regulated by technocrats and engineers unlike today. In the late 1960 the economic growth of the country when it topped six percent (6%) around 1960s, the demand for electricity threatened to surpass the install electricity supply. The Eskom management at the time embarked on a programme of building coal power plants stations. These new coal power plant had six (6) identical units, and this were built on time and on budget plan via cheap debt which was paid and the taxpayer did not have to pay anything. Remarkable these Eskom programs were done on time and on plan budget which resulted to Eskom having enough power supply and reliable electricity which was the lowest cheapest in the world at the time. The success of the program was also contributed by South African vast reserve of cheap, easily coal mine which even to date South African has still over two hundred (200) years of reserve coal (Writer, 2022). Unfortunately, all these Eskom successes was only for mainly white communities whom at the time were a population of nineteen percent (19.3%) in 1960s until early-1980s up twenty percent (20.53%), while meanwhile majority of Blacks people who were the majority citizen between sixty eight percent (68.29%) and (68.77) between 1960s and 1980s respectively (Mitsuo, 1996). The Eskom state own utility in the early 1990s had two (2) absolute advantages compare other countries in the world economy which were one of the cheapest electricity in the world and having abundant coal reserve minerals which was the few triumphs of the apartheid regime government which did not interfere with Eskom business operations they left the utility alone with its operations (Kenny, 2018).

4.3 ESKOM SUPPLY POST 1994 DEMOCRATIC

Eskom from 1923 until 1994 as state own enterprise (SOE) was free from major political interference from politicians and ruling governing party, apartheid regime government never tried to interfere with running of the company. Post-apartheid after democratic elections in 1994, African National Congress (ANC) led by late Honourable former president Nelson Rolihlahla Mandela they made changes at Eskom which some were expected but some were surprising. Major changes were around race based affirmative actions, political interference and political appointments were made to run the state own utility. Mandela government made the change in Eskom operations and now the focus was to electrification of the previous neglected citizens which now were nearly seventy eight percent (76.7%) of the population (Statistics South Africa, 2020). The Mandela government focus on previously disadvantage citizens mostly Blacks, Coloureds and Indians for every household to be provided with low-cost electricity for economic growth and for better lives of the previously disadvantage citizens. Mandela government went further to influence operation of the company and parliament pass legislation in 1998 called Eskom Amendment Act which resulted in the government of that period excise their power to influence company policies, investment decisions and operational programs (Holtzhausen, 2019). Another surprising event was in the year 1998 when Eskom Management went to government to request budget to build new power stations since there was drive by government during the period to distribute electricity to the previously disadvantage citizens, resulted to the installed power capacity and reserved to be diminished. At the time Eskom management, they requested this to former president Thabo Mbeki administrative and Eskom management request was denied for them to budget to build new power stations by the government administrator of the day (Phaahla, 2015). After leaving the presidency office in the year 2007 the former president Thabo Mbeki admitted that his government decision to denying great error on his administrative which ended up affecting the growth economic of the country and millions of South African citizens to this date (Matshela, 2017). The Eskom Management estimated that South Africa as country will run-off out of electricity power supply reserves by 2007 unless action was taken to building new generation power stations to prevent the looming electricity crisis at the time, despite this warning from Eskom at the time of requesting an electricity power capacity increase the ruling party (ANC) government did nothing to prevent the crisis instead government halt Eskom building new power stations as it was considering unbundling and privatise Eskom (Department of Mineral and Energy, 1998).

Almost all townships, rural areas, deep rural areas where most Black people were living there was no electricity, water and sewerage and still to date in some deep rural areas, but significant change has been made when come to distribution of electricity to those previously disadvantage communities (Kenny, 2015). The surprising decision which was not expected is the ANC alliance (ANC), South African Communist Party (SACP) and (Congress of South African Trade Unions) COSATU which prior apartheid the ideology were regarded as Marxist Lenin which was expected to prefer state run utility but to everyone’s surprise there were recommendation to restricting Eskom into separate entities electricity generation and power transmission to improve power supply and reliability and talks early ANC government as early as 1998 (Department of Mineral and Energy, 1998). The current administrative of President Cyril Ramaphosa government is currently action those 1998 proposal to separate Eskom or to unbundled or being privatised. Furthermore, there seems to be intent taking away Eskom as utility role and obligation to supply electricity by introducing more Independent Power Producers (IPPs). (Writer, 2022). After ignoring Eskom warning for nearly six (6) years by ruling ANC government it was until 2004 that government started to acknowledge that the is electricity power supply looming crisis that was insufficient electricity power capacity to grow country economy which as result department of minerals and energy started to invite proposal on how to increase production of electricity at least by thousand (1000MW) Megawatt annually from the year 2007 (Phaahla, 2015). Energy looming crisis challenges continue unabated eventually reaching breaking point in year 2008 when the was nationwide power outages were rolled out by Eskom as the reserves in the grid had reached their lowest level ever (Phaahla, 2015). The then minister of public enterprise Alec Erwin was first to acknowledge this mistake in 2007 and this what he said “we took the decision to charge Eskom with providing seventy percent (70%) of new capacity. As I have indicated, we accept with hindsight that the decision was too late. It is the underlying reason for the conditions with which are now faced” The then President of the Republic of South Africa (R.S.A) Thabo Mbeki said in 2008, “when Eskom said to the government, ‘we think we must invest more in terms of electricity generation’. We said not now, later. We were wrong Eskom was right. We were wrong.”

Without any doubt South African utility company ‘Eskom’ is the current biggest power utility not only in South Africa but in the continent (Africa). Eskom is the one of the largest state own enterprises (SOEs) with the current installed capacity of 52 104MW (Eskom Transmission, 2022), but the consequences by Thabo Mbeki administration ignoring Eskom results in its poor electricity power supply production which as consequence affect Eskom’s balance sheets not been in good shape and that results in its poor financial status which resulted to the utility been downgraded to junk status by sovereign rating agencies (Phaahla, 2015). Eskom as largest utility not only in South Africa but in the continent has notable power stations in Lephalale in Polokwane which are Matimba Power Station and newly build Medupi Power Station; in Mpumalanga at Witbank newly build Kusile, and old Hendrina, Grootvlei, Kriel, Komati, Majuba, Matla, Tutuka and Kendal Power Station; Lethabo Power Station from Free State province; in the Western Cape Koeberg Nuclear Power Station which is the only nuclear plant in the continent (Eskom Transmission, 2022).

4.4 ESKOM PROJECTS MEDUPI AND KUSILE POWER STATIONS

These two projects Medupi and Kusile were the hope that when they fully operational loadshedding or energy crisis in South Africa will be the thing of the past, South Africa citizens where promised that these will end loadshedding since they will finally increase capacity from 42 800MW nearly 50 000MW with the average demand of 29 000MW in 2015 when Medupi was expected to be fully complete and be operational (Claire, 2015). The State own utility Eskom was once one of the best power utilities in the world, in February 2002 Eskom state utility was named as the global electricity power supply company of the year and was one of the top five utility in the world, but it has been laid low by corruption, mismanagement and renewable energy (Engineering News, 2002). Nearly twenty-one (21) years ago on 6th December 2001 the state own utility Eskom received the prestigious international award for exhibiting technical excellence in plant production, maintenance and operation while at the same time demonstrated an ability to provide the world's lowest-cost electricity to its customers and the event was at the Financial Times Global Energy Award which were held in New York city (Engineering News, 2002). As already stated above in January 2008 to be specific Eskom utility for the first time in their operational history had to introduce loadshedding planned rolling blackouts nationally based on rotating schedule for short period so that the network grid does not totally shutdown which threatened the integrity of the network grid at the time. Eskom Demand side management encourage electricity customers or consumers to utilised electricity sparingly during peak up hour periods in order to reduce and avoid further loadshedding (Department of Mineral and Energy, 1998). The consequence of government ignoring warnings and that led to loadshedding blackouts resulted in Eskom and government in the administration of former president Jacob Gedleyihlekisa Zuma embarking on programme to build two large new coal generation plants which were Medupi Power Station situated in Lephalale in Limpopo province and Kusile Power Station situated in Mpumalanga province, to correct his predecessor error (Donnelly, 2011).

4.4.1 ESKOM MEDUPI POWER STATION PROJECT

As it already been stated that Medupi Power station is dry-cooled coal power plant which situated in Lephalale in Limpopo province. Medupi is a Pedi name which means 'gentle rain' (Oxford Translation Dictionary , 2019), Medupi Power Station with an installed power capacity of 4 764MW when fully operational is the 8th largest coal power plant station in the world (Kangkang Li et al., 2021). Initially Medupi was planned to have three units total 2 400MW (Claire, 2015) and initial project estimate cost at R69 billion then updated to R80 billion same year (2007) (Mail&Guardian, 2015) and was expected to start delivering power in 2011 (Webb, 2007). On 23rd August 2015 the first unit from Medupi which is unit 6 was complete and went to commercial operation (meaning to the moment the project when unit is commissioned and handed over from the project management team to Eskom generation division) (Alstom, 2015), and delivered an additional 794MW of capacity power into the Eskom generation production and eventually to the network grid as results taking generation capacity from 42 800MW to 43 600MW (Modern Power Systems, 2021). This new 794MW of capacity to make it easy for ordinary citizen what size of generation capacity we are talking about, it can easily supply Bloemfontein and remain with some reserve capacity (Claire, 2015).

The Medupi project power station was initially started construction in 2007 and was estimated initially that completion of the first two units was expected in 2012 but various delays impacted progress (Phaahla, 2015) it was in 2015 which eight (8) years later that the first unit which is unit 6 was commissioned for commercial operation, delays due inter alia mismanagement, technical issues, industrial action, corruption and overrun costs etc (Modern Power Systems, 2021). Medupi when its complete and in fully operational or commissioned it will be fourth (4th) large coal power station in the Southern Hemisphere and the only largest dry-cooled coal power plant stations in the world. In 31st of July 2021 the Medupi last unit of the 6 units which is Unit 1 went to commercial operation or commissioned status and life span of the Medupi coal power plant is fifty (50) years (Modern Power Systems, 2021). The commercial operation or commissioned status actually mean that technical compliance to legislative, legal requirements and safety measurements have all been met and example Unit 1 was first synchronised to the Eskom network grid in 27th August 2017 and reached its full load capacity of 794MW on 5th December 2019, and during this test of optimum phase unit 1 produced intermittent capacity power to the national network grid supply (Claire, 2015).

After all the delays, fail governance, mismanagement, corruption, technical faults, overrun costs, industrial action etc from initial construction 2007 until its final completion to be announce that the power plant had achieved commercial operation status in 2021 which took fourteen (14) years to complete construction and commissioned or commercial operation (Eskom , 2021). Snail-paced progress of Medupi project instead of the Medupi project taking just four years as per the initial plan the project took longer than anticipated over seven (7) years later the Medupi project is nowhere near completion which was sad reality (Lowman, 2015). Due to all these delays cost escalated from R69 billion then updated to R80 billion in 2007 (Mail&Guardian, 2015), in 2013 was revised to R154 billion

(Lowman, 2015), then final cost estimated at R234 billion in 2019 and according to African Development Bank stated that they not expecting Medupi power plant to produce any positive financial return over the course of its lifetime (Paton, 2022). Medupi coal power plant station project was promised to resolve and alleviated electricity crisis or loadshedding on commissioned or commercial operation but this seems to have fail dismally because still after completion electricity crisis or loadshedding is still persist and even worse affecting millions of household, business and industry sectors across the country, compare to other years we currently day in day out on loadshedding stage six (6) which has occurred five times this year (2022) alone (Lowman, 2015).

4.4.2 ESKOM KUSILE POWER STATION PROJECT

As stated above that Kusile Power station is dry-cooled coal power plant which situated in Witbank in Mpumalanga province. Kusile Power Station plant formerly known as the 'Bravo Power Station' is situated roughly about fifteen (15) kilometres from another existing power station (Kendal), Kusile Power Station was designed to consist of six (6) 800MW coal generation unit with a total installed power capacity of 4 800MW when fully operational will be one of the world's largest coal power plants (Power Technology, 2021). According to Engineering News, the initial planned proposal for Kusile was six (6) 900MW coal power station plant generating unit which was going to be total of 5 400MW and initial project estimate cost at to R80 billion in 2008 and was expected to begin delivering its first electricity around 2013 and subsequent five (5) more units planned to be commissioned at eight (8) to twelve (12) month intervals thereafter (Webb, 2007).

Kusile Power Station plant would be the first power plant in Eskom historical fleet with flue gas desulphurisation (FGD) technology (Creamer, 2020). The Kusile Power Station adopted supercritical pressure technologies for efficient generation of power plant compared to the existing standard coal-fired system and this will result in an important reduction of Carbon Dioxide (CO2) emissions (Power Technology, 2021). The FGD technology will further assist to extract ninety percent (90%) sulphur oxide (SO2) which produced from the boilers from the flue gases of the power plant which burns fossil fuels. FGD technology is also atmospheric emission abatement technology in line with current internal standards practice (Power Technology, 2021).

The construction of Kusile Power Station plant started in August 2008 and only in 2017 where only two (2) units were synchronised and only unit 1 was commissioned for commercial operation in August 2017 which is nine (9) years later after initial construction. Kusile Power Station plant unit 2 and unit 3 were commissioned year later after unit 1 and went to full commercial operations in October 2020 and March 2021 respectively and life span of the Kusile coal power plant is fifty (50) years (Power Technology, 2021). Eskom is currently facing financial constrain as we speak, while Kusile unit 5 and unit 6 still pending and still under construction after fourteen (14) years. Kusile Power Station plant project was planned to be completed in four (4) years and upon full completion of this power station for an ordinary citizen to understand the size of electricity capacity will be enough to generate electricity power supply for 3.5 million South African households (Power Technology, 2021).

Kusile Power Station project was delayed like similar to the Medupi Power Station project, after missing initial planned of 2013, now new plan was that the first power station unit was now scheduled to enter the national network grid mid-2015 then subsequent to that all other five (5) units be commissioned between eight (8) to twelve (12) months thereafter (Engineering News, 2019). Then come 2015 unit 1 was not ready and now new planned was to be commissioned in 2016 and the last sixth (6th) unit was planned to be commissioned in 2021 (Eye Witness News, 2021). After serious challenges with Alstom, Eskom took decision to appoint ABB South Africa in March 2015 replace Alstom to complete control and instrumentation (C&I) for Kusile power station generation (News24 Business, 2015). Eventual unit 1 was synchronised in December 2016 to the national network grid and it was then going for full commercial operations 30th of August 2017 (Slabbert, 2017). In February 2019, Eskom reported that there were design defects at Kusile and Medupi and to fix them will cost around R8 billion (Tshehla, 2019). This resulted for unit 1 to be taken offline for routine inspection which found some defects in various areas of the plant which was the only unit in operation at the time, the planned to return unit 1 back on service or online was August 2019 (Tilburg, 2019). Then ABB April 2018 unit 2 was synchronised to the national network grip then unit 3 was synchronised 16th of March 2019 to the national network grid but in July even though both units where synchronised were still undergoing through testing and commissioning and both were not ready yet to be commercial operational service (Tilburg, 2019). In October 2020 Kusile Power Station unit 2 achieve commercial operation approval service (Public Enterprises, 2020). According to Eskom's 2020 Annual Report, the Kusile Power Station plant full commercial operation is planned for 2024 (Eskom, 2020). As mentioned above the initial cost in 2008 was estimated R80 billion but due to mismanagement, corruption, industrial actions, technical problems, now the current estimate cost to complete Kusile power stations is estimated at R161.4

billion said the deputy president David Mabuza (Madubela, 2021). After fourteen (14) years construction started only just three (3) units out of six (6) units at Kusile have been approved for commercial operation and other three units are delayed due to contractor, financial, commercial and contractual issues and it also had serious design flaws which affected their enormous boilers (Madubela, 2021). Eskom board and executive management have committed to complete Kusile Power station within the revised completion dates in 2024/2025 financial year and within the project budget of R161.4 billion that's excluding interest during construction (Madubela, 2021).

4.5 ESKOM LOADSHEDDING STAGES AND IMPACT

According to Africa Check, it has found that only 50.9% of households had access to electricity at the dawn of democracy in South Africa. Then the Community Survey in 2016, conducted by Statistics South Africa revealed that 92.7% of the households in the country's population was able to connect to electricity (Niselow, 2019). The issue of loadshedding or energy crisis in South Africa it has been going or existing now since 2007 still to date which is about fifteen (15) years now with no hope of being resolve anytime soon. Defining loadshedding for ordinary citizen to understand we can say that "loadshedding is process whereby the electricity demand or power consumption has exceeded its installed supply capacity which leads or results to the power utility implementing power supply cuts or blackouts to reserve the total national power supply blackout.

The impact of loadshedding to millions of South African citizens, businesses, industrial sectors such financial sector like banks and ATMs, Mining, agriculture like milk, vegetable and fruit farmers to count just few sectors; and it has negative impact to millions of households where it has damaged their appliances, their frigerated medication and food. South Africa has very high rate of Human Immunodeficiency Virus (HIV) and Tuberculosis (TB) which most of these medications need refrigeration which get affect by loadshedding is implemented (Wilson, 2020). The loadshedding can be out of planned maintenance which is done to do maintenance, repairs or re-fuelling (in the case of nuclear units) on the generation power station plants units and other can be out of unplanned maintenance which is of the results of failure or breakdown of the difference units in the power station generation plants.

South African utility (Eskom) stated that it implements loadshedding to avoid total national blackouts which can devasted the country and they state that the loadshedding stages implementation development is based on the risk and consumption electricity demands to ensure that loadshedding is applied in a fair equitable manner that does not disadvantage certain areas; and to ensure fifteen percent (15%) reserve margins (Swart, 2020). Between November 2007 and January 2008 country experience loadshedding for the first-time which results to a negative impact to the businesses, industrial sectors and millions of households. The was also allegation that the cause was as results of increased electrification programme and the economic growth which National Energy Regulator of South Africa (NERSA) inquiry investigation of those allegations found that electrification programme and the economic growth report results findings were inadequate (Niselow, 2019). Then February 2008 till November 2014 which about period of six (6) years during this time loadshedding were mostly contributed to demand and maintenance stabilisation because at the time the was drop in demand which was caused by many mining in the country shutting down (SABC News, 2014).

In 1st of November 2014 loadshedding was reintroduced due to the Majuba plant which was producing approximately ten percent (10%) of the county's power supply or capacity had power lost capacity after the collapse of one of its coal storage silos and this resulted in the halt delivery of coal to the plant (Gibbs, 2020). On 20th November 2014 it was reported that the second silos due to this first collapse incident of the silos its development a major crack which resulted for it to be shutdown despite measurement were instituted to deliver coal to the plant (Business Day News, 2020). During former president Jacob Gedleyihlekisa Zuma administration loadshedding was suspended nearly two (2) years from end of 2016 till June 2018 when loadshedding was reintroduced allegedly by industrial action over wage disputes (Niselow, 2019). The current loadshedding which state since 2018 until today is contributed to the lack of crucial maintenance, the failed construction of new power stations and allegations of state capture have all caught up with the South African power utility (Eskom) (Niselow, 2019). The loadshedding exact social and economic impact is hard to estimate, and most analysis use guesses range widely.

4.5.1 ESKOM LOADSHEDDING STAGES IMPLEMENTATION

The main cause electricity crisis that results to loadshedding is contributed to a number of things one of the major is the shortages of power station generation capacity, another is problems is the supply of coal to Eskom coal power station plant, mismanagement, corruption, increase electricity demand etc as a results all these combine as possible causes of the electricity crisis that led to current loadshedding for past fifteen (15) years

(Given Van der Nest, 2020). According to Eskom at every loadshedding stage is used to avoid total shutdown and they are published and displayed on the main Eskom website which is the loadshedding website to assist municipalities, household and businesses to be aware of their area when it will be affected by loadshedding (Swart, 2020). Following stages of loadshedding are Eskom rations the country by a further 1 000MW of power. Loadshedding depends on Eskom role out of loadshedding but in the jurisdiction of municipality then municipality will have their own loadshedding approach but will be influence by Eskom loadshedding as example suburbs and towns are affected by every stage depends on a range of factors, including what time of day the electricity emergency is declared by Eskom or by municipality jurisdiction (Eskom, 2022):

- **Stage 1:** Requires up to 1 000MW of electricity to be shed and can be implemented three times over four (4) day period for two (2) hours at a time or three times over eight (8) day period for four (4) hours at a time.
- **Stage 2:** then stage 2 will double the frequency of Stage 1, which means you will be scheduled for load-shedding six (6) times over a four (4) day period for two (2) hours at a time, or six (6) times over an eight (8) day period for four (4) hours at a time. Stage 2 network grid is requiring or shortage of 2 000MW.
- **Stage 3:** then stage 3 is an increase the frequency of stage 2 by 50 percent (50%), which means you will be scheduled for loadshedding nine (9) times over a four (4) day period for two (2) hours at a time, or nine (9) times over an eight (8) day period for four (4) hours at a time. Stage 3 network grid is requiring or shortage of 3 000MW.
- **Stage 4:** then stage 4 will double the frequency of Stage 2, which means you will be scheduled for loadshedding twelve (12) times over a four (4) day period for two (2) hours at a time, or twelve (12) times over an eight (8) day period for four (4) hours at a time. Stage 4 network grid is requiring or shortage of 4 000MW, this shortage is equivalent to nearly the full installed generating capacity of the giant Medupi power.
- **Stage 5:** Stage 5 network grid is requiring or shortage of 5 000MW. This actually mean that the amount of shortage of electricity that utility Eskom is unable to supply

as much equivalent to the giant Inga 3 hydropower project in the Democratic Republic of Congo.

- **<u>Stage 6:</u>** at Stage 6 the amount of shortage can be equivalent to all the power units in the Ethiopia hopes to generate by harnessing the Blue Nile. This also equal to half of the total Nigeria installed capacity of 12 400MW for total population over 200 million Nigerian citizens. Stage 6 network grid is requiring or shortage of 6 000MW.

- **<u>Stage 7:</u>** the amount of power supply can be equated to the sheds as much electricity as all South Africa's initial 47 independent producers of renewable energy produced. Stage 7 network grid is requiring or shortage of 7 000MW. Fortunately, for now we have not experienced this stage yet and hope we will never experience it.

- **<u>Stage 8:</u>** Fortunately, for now we have not experienced this stage yet and hope we will never experience it. This stage 8 means that utility Eskom estimates, that the average South African will be supplied with power for 50% of the time, with connections turned off for 12 hours out of every twenty-four (24) hours. Stage 8 network grid is requiring or shortage of 8 000MW.

As said fortunately we have not yet experience stage 7 or 8 loadshedding as the country this will be catastrophic not only to the economy. It will plunge the country into dangerous chaos which will affect critical institution such as Hospitals, airports, harbours, retail industry, agriculture, mines, and critical infrastructure will struggle to function and to back to normality. If this would occur, it will put the safety of innocent South African citizen to the hands of criminals as this will surely lead to looting and crime will surely escalate and food shortage will be serious affected and millions of people will be affected negatively because this will be they would not without electricity for prolonged periods (Kahla, 2021). According to Eskom the reality fact is that if loadshedding was not implemented, the power network grid could suffer catastrophic failure. If the loadshedding was not implemented it will result in a national catastrophic blackout that will last for days, the reason that Eskom had to implement is to ensure fair rotation to all Eskom customers. Not all blackouts are equivalent to loadshedding because some blackouts are cause by other reasons such as cable theft, technical faults, human error because if your supply is interrupted without notification as per Eskom loadshedding schedule. According to utility Eskom loadshedding is the only applied when all other voluntary and contracted demand reduction has been exhausted in order to avoid total catastrophic collapse of the electricity power supply to the national network grid (Kahla, 2021). As the country we have experience loadshedding up to stage 6 and stage 1 and 2 as the common stages we had experience over the years for past 15years of electricity loadshedding or energy power crisis.

4.5.2 LOADSHEDDING IMPACT

Since 2007 till to date (October 2022) the most serious challenge that had been faced by the country (South Africa) is shortage of electricity generation network which as results of this severe constrain which is as results of maintenance backlog and poor maintenance; mismanagement, and the failure to complete Kusile and years of delays on the two new power stations Medupi and Kusile online match economic and social development. These inter alia resulted to electricity demands or consumption surpassing the installed capacity supply, and this has led to the Eskom had to implement loadshedding which planned rolling blackouts on a rotational schedule basis to avoid total catastrophic power system network grid. The total catastrophic collapse will mean disaster because it would take weeks or even months for electricity power system to be restored back to its normality to the national network grid and such total collapse will results to hundreds of billions of rand loss in economic activity (Given Van der Nest, 2020).

According to (Pieters, 2022) the cost impact of loadshedding is running into billions of rand per day and this depending on which stage of loadshedding the country is experiencing. Recently the country experience worst week loadshedding stage 6 for a number of consecutive days which was the second time South Africa experiencing loadshedding stage 6, first time South Africa’s worst loadshedding was in December 2019 and last just for just a day (Pieters, 2022). The second stage 6 loadshedding in the history of Eskom started to implement loadshedding in the country was allegedly contribute of industrial wage disputes actions by Eskom worker which results from implementation of loadshedding to stage 4 and was escalated to stage 6 which was said is as results of the industrial action by Eskom employees not pitching for work. The impact of loadshedding not only Eskom customers but whole country including the rand verse US dollar due to this loadshedding in July 2022 so rand getting weaker against the US dollar that’s according to Johannesburg Stock Exchange (JSE). According to different economist the economic impact of loadshedding is estimated around R1.5 billion to R4 billion per day depending what loadshedding stage the country is experiencing. As already been indicated that this situation it has been existence now for fifteen (15) years and unfortunately unabated.

Furthermore, the impact of loadshedding also resulted to the fuel hike prices which was the results of Eskom burning nine (9) million litres of diesel a day to keep the lights on and this diesel is been transport from mostly coastal area to inland since major Eskom power station plant are situated in the inland areas, and all this has cost Eskom R7 billion just half year of 2022 (Hawker, 2022). This has resulted in the demand of diesel currently in the country and made diesel to be very expense which affect millions of motorists who using diesel in their vehicle and businesses such as agriculture, mining, retail sector, transporting logistics etc. The impact of loadshedding to the economy according to economist in 2021 has cost Growth Domestic Product (GDP) potentially cost approximately 250 basis point of GDP meaning it also affect the economic growth of South Africa as country which result or led to between ten thousand (10 000s) to hundred thousand (100 000s) job losses. The current inequality and the rate of rapid poverty has reached unprecedent level not seen for more than a decade, while the current inflation has recently increase to a thirteen (13) to fourteen (14) years high, and the outlook is still gloomy with high risk due to political instability, weak rand against US dollar. The worse sustainable reforms with investment that are required to support growth in the economy and reduce catastrophic proportions of unemployment currently seating at 33.9% from 34.5% and power energy crisis or loadshedding is one of the major contributors to the unemployment in this country on affecting Small and Medium Enterprises (SMEs) which most end up shutting down due to loadshedding (Trading Economics, 2022).

Just before 2007 loadshedding the GDP annual percent growth was seating at 5.6% which was highest ever after post-apartheid till to date and GDP annual growth in 2020 was at -6.4% which was also affected by COVID-19 pandemic and last year GDP is at 4.9% and the project GDP for 2022 is projected at 1.9% (World Bank Data, 2022). Once again, the GDP growth is also affects by power energy crisis or loadshedding because for GDP to grow we need investment and the investment with power energy crisis will not be possible. Healthcare is also adversely affected by loadshedding or power outages in particular those living in poverty such rural areas and township areas. The loadshedding in the healthcare institution has poses serious risks to both paediatric and adult health in the Intensive Care Unit (ICT) and operation that need to be executed or done to different patients. The private hospital most have Uninterruptible Power System (UPS) system unlike Public Hospitals which are dependent on government funding in order to have reliable electricity system such as UPS for back-up power generators that provide stable electricity to medical staffs and patients in the public hospitals. According to recent research studies on the loadshedding hospitals shows that cost of monthly maintenance is such very expensive (Wilson, 2020).

4.6 SUMMARY OF CHAPTER FOUR

Republic of South Africa since 2006 it has experience energy crisis or loadshedding till today. Electricity is and will remain the one of the key main drivers for economic development and growth and with country economic stability. The Republic of South Africa (RSA) has high level of potential in the WEF and Solar renewable energy technology look at RSA government commitment to just transition to a low carbon, with a target of 17 800 MW in 2030. But review of IRP needs to be done to include Nuclear Power station which also clean energy and have base load. Future research can include whole country and solar system as another potential renewable energy in South Africa. Loadshedding has serious impact to so many things and affected millions of South African through job losses, and emotion impact of not having electricity. This loadshedding has been with us for 15 years and seems no end to it this has serious made Eskom to significantly increase electricity tariffs to NERSA by 45% over period of three years (Lubuschange, 2022).

CHAPTER 5: RENEWABLE ENERGY: WIND ENERGY FACILITY (WEF) VS FOSSIL ENERGY

5.1 INTRODUCTION

As we already indicated in our literature review that South Africa has a high level of Renewal Energy potential and in line with the national commitment to just transition to a low carbon economy, 17 800MW of the 2030 target according to the IRP 2010. Newly generated power to be developed are expected to be from renewable energy sources, with 5 000MW to be operational by 2019 and further 2 000MW (i.e., combined 7 000MW) operational by 2020 (Department of Energy, 2018). As of April 2016, of the 7 000MW target for 2020, an amount of 6 400MW from 102 IPPs has been procured from Bid Window (BW) one (1) to four (4). By end October 2016, 2.8GW of the procured capacity from 53 IPPs had already started operations (Department of Energy, 2018). All of the projects in BW1, BW2, BW3 and BW4 are connected and are delivering power to the grid in the Eskom network grid. Project in BW5, depending on the individual project's construction period, are all progressing with some projects already grid connected and the rest to follow. The REIPP programme is not only contributing to alleviating the electrical energy shortfall in South Africa but has been designed so as to also contribute towards socio-economic and environmentally sustainable growth, and to start and stimulate the renewable industry in South Africa in terms of this IPP Procurement Programme, the Bidders will therefore be required to bid on: (Department of Energy, 2018).

- tariff; and
- the identified socio-economic development objectives of the Department.

A wide range of technologies fall under the category of generation. These technologies include fossil fuels, hydro, fuel cells, land fill gas, wind, geothermal, solar and co-generation. The different technologies operate under different conditions and utilise different machinery. Generation technologies utilise synchronous generators, induction generators or power electronic inverters to generate electricity into the network. Generating plants using fuel sources other than fossil fuels are generally referred to as renewable generating plants. If the installed capacity of generating plants is considered by the utility in energy and capacity planning, the availability and reliability of the energy source must be considered. The availability of power from wind energy facilities is variable and reciprocating engines are more variable sources of energy, but still require shutdowns for maintenance (planned outages) and do experience breakdowns (unplanned outage).

The tariff will be payable by the Buyert pursuant to the Procure Purchase Agreement (PPA) to be entered into between the Buyer and the Project Company of a Preferred Bidder. The Project Company will pursue set economic objectives as agreed to in terms of the Implementation Agreement (IA) entered into between the Department of Energy on behalf of the Government of South Africa and the Project Company of the Preferred Bidder (Department of Energy, 2018).

Each Wind Energy Facility (WEF) procured in terms of the IPP Procurement Programme will be required to achieve commercial operation by not later than the dates set out in the Request for Proposals (RFP). Bases on the IRP 2010, the Ministerial Determinations and any future integrated resource plans issued from time to time, the REIPP Programme is designed to be of a rolling nature. Determined Mega Watts (MWs) will be procured through a continuous programme of bid windows timed as such to ensure at least one bid window every year or subsequent year prompted by the release of a specific Request for Proposals (RFP) in the market.

This rolling nature also balance Government's objectives as regards to security of supply and renewable energy targets with the technical and commercial constraints faced by potential bidders, and having regard to constitutional requirements of fairness, transparency, equitability, competitiveness and cost-effectiveness. An RFP contains all the required information and criteria to participate in the tender process. The tender process is open and transparent and strictly adherence to governance is paid with a team of independent evaluators assessing the bids.

Republic of South Africa has the world's seventh largest coal reserve, and coal supplies about 77% of South Africa's primary energy, followed by oil and solid biomass and waste. South Africa's energy balance also includes relatively small shares of natural gas, nuclear, and hydroelectricity. South Africa's dependence on hydrocarbons, particularly coal, has made the country the world's 13th largest Carbon Dioxide (CO_2) emitter (Global Wind Energy Council (GWEC), 2017). The maintenance of the coal power generation fleet has been challenging and capacity factors are down to about 70%, which for 2018/2019 financial year is at below 70% which seating 69.95% due to rotational loadshedding implementation of 30days beginning of 2019 (Eskom, 2019). Historically, South Africa had very low electricity prices, but in recent years they have been rising quickly due to Universal Accesses in Electrification (UAE) especially predominantly past disadvantage areas such as deep rural areas and ever-increasing informal settlement around urban areas. The REIPP programme is bringing renewable energy to the national grid fast and cheaper than new-build coal. Construction times for projects average less than two years, and the electricity price paid to projects has declined 68% within three years (Global Wind Energy Council (GWEC), 2017).

The price of wind energy in the last Round 4 expedited was R0.62kWh (EUR 0.045/USD 0.047) more than 40% less than forecast prices for Eskom's new-build coal plants Kusile and Medupi (Global Wind Energy Council (GWEC), 2017). In 2015, a new report by the Council for Scientific and Industrial Research (CSIR) showed less-than-zero costs for renewable energy to the country. According to CSIR, wind and solar power combined save R4 billion from January to June 2015. Wind energy produced net savings of R1.8 billion and was also cash positive for Eskom by R300 million.

Eskom is one of the world's largest producers of greenhouse gases (Yelland, 2018). South Africa's renewable energy power programme was the fastest growing in the world seven years ago, attracting $15 billion of investment into wind farms and solar projects involving a cluster of new Independent Power Producers (IPPs) backed by foreign investment. Over the past two years (2015-2017) Eskom stopped signing renewable energy contracts and focused instead on plan to build fleet of nuclear power plants, in deal that some members of African National Congress (ANC) and rights groups said would be open to corruption. Key barriers tow (WEF) development in South Africa the following some of remaining obstacles to WEF industry included:

- The problems and political challenges surrounding relying on South Africa's sole utility provider to provide Power Purchase Agreements and grid connections.
- The extensive works to facilitate grid integration are under the responsibility of the country's power utility, Eskom who had previously subsidised the associated costs. However, these costs are now increasingly being transferred to project developers resulting in more costly projects. Additionally, extended transmission and distribution works are needed, and the cost recovery rules for this are not yet transparent or consistent. This issue is currently being addressed by the South African Renewable Energy Council through the Grid Code Advisory Committee.

- The costs involving in tendering for the procurement programmed are high and create a challenge for smaller players.

- South Africa's economy is stagnating, and exchange rate fluctuations cause challenges to the REIPPPP by exerting upward pressures on bid prices. It also creates challenges for foreign investors hoping to evacuate hard currency from South Africa projects. A change in the sovereign credit rating may impact on the risk premium foreign investors require.

Outlook for Wind Energy renewable technology in South Africa if the current impasse can be overcome, which looks likely, the wind industry in South Africa can pick up its very rapid growth phase from where it stalled. The country's chronic loadshedding or power shortages and the large boost in allocation for renewable energy in the revised IRP mean that the REIPPPP is likely to be expanded once more. South Africa is moving towards a large wind industry with a domestic installed capacity in excess of 6 000MW by 2020, if not sooner, and an allocated one of at least 37 000MW by 2050 if the draft IRP is made policy (GWEC, 2019). The leading turbine suppliers in wind industrial in South Africa Wind Energy Facilities (WEF) are Vestas, Siemens, Goldwind and Nordex. On 4th April 2018 in Pretoria the former Energy Minister Jeff Radebe signing 27 new renewable energy which opening the way for the construction of 27 new renewable energy independent power producer (IPP) projects. These 27 new IPP projects with a combine investment value of R56 billion and a combined capacity of 2 300MW of electricity to the national grid over the next five years. This was results of a two (2) year delayed as milestone following a long period of uncertainty on which the procurement process stalled after ESKOM announced in early 2016, that it would no longer conclude power purchase agreement (PPAs) with renewable energy IPPs, owning to its return to a generation surplus (Creamer, 2018). The long-awaited partnerships have been marred by numerous delays, including a last-minute court challenge in March 2018 (Khumalo, 2018). Former Energy Minister Jeff Radebe he said, "his role as one facilitating an enabling environment for thriving energy sector, while noting the National Development Plan's target of raising the installed capacity of renewable energy to 20 000MW by 2030" (Creamer, 2018).

The 27 new IPPs projects is the biggest procurement by the department of Energy to date signed and were identified as preferred bids way back 2015 of the Renewable Energy Independent Power Producer Procurement Programme (REIPPPP) (Creamer, 2018). The former Energy Minister Jeff Radebe stressed that the government has no direct financial involvement in the investment, except for providing support to Eskom in the event of default by buyer. The 27 new IPPs projects would stimulate support 58 000 new jobs, mostly during construction and mostly in the rural areas of the Northern, Eastern and Western Cape provinces, as well as the North-West, Free State and Mpumalanga provinces (Creamer, 2018). Contrary to the views of the labour trade unions in Eskom, Radebe said the renewable energy mix was expected to help bring down the cost of electricity, which has been escalating over the years.

The labour trade unions and Transform RSA in marched and approach the North Gauteng High Court in an attempt to block the partnerships or signing of the 27 new IPPs projects. The case was heard in the High Court of Pretoria on March 27, and on March 29 the case was dismissed. Judge Dawie Fourie rule that the application was not urgent and struck the case off the roll, with cost (Creamer, 2018). Twenty-four (24) of the projects are either solar photovoltaic (PV) or onshore wind developments, but the lost also includes the Redstone Concentrated Solar Power (CSP) project, in the Northern Cape, the Kruisvallei mini-Hydro project, in the Free State, and the Ngondwana Energy biomass project, to be fuelled using waste Sappi woods chips, in Mpumalanga. The Northern Cape will receive largest share of the investment with 15 new wind, solar PV, and CSP project. Four new wind farms will be based in the Eastern Cape, and the North-West will get four solar plants.

The 12 solar PV projects are listed as Aggeneys, Bokamoso, De Wildt, Droogfontein 2, Dyason's Klip 1, Dyason's Klip 2, Greefspan 2, Kokoonsies 2, Loriesfontein Orange Sirius 1, Waterloo and Zeerust. The 12 wind projects were name as Copperton, Excelsior, Garob Wind Farm, Garob Valley, Kangnas, Oyster Bay, Perdekraal East, Roggeveld, Karusa, Nxuba, Soetwater and Wesley-Ciskei. South Africans owns 57.8% or R11.9 billion of the companies awarded projects share in the project companies, while the balance will be controlled by the Public Investment Corporation and other institutions (Khumalo, 2018). The black shareholders own 64.2%, or R7.64 billion in monetary value (Creamer, 2018). According to former Energy Minister Jeff Radebe proposed the development of an "Energy Transformation Charter" through which government's position that South Africa cannot address inequality, poverty and unemployment without the economic empowerment of historically disadvantaged groups and without the support of the private sector" (Creamer, 2018). According to former Energy Minister Jeff Radebe "the lower prices coming from the renewable energy projects will provide the much-needed relief to indigent households under the current economic conditions". Private sector participation in the country's electricity industry was first approved by Cabinet 2003, in a bid to boost capacity.

Independent power producers would contribute up to 30% of the country's electricity production, and the rest would come from state power utility Eskom (Khumalo, 2018).

5.2 SELECTION OF CASE STUDIES

Eastern Cape province has been alluded in the table below account for about 1441MW in different status which in operations, in construction and some in planning stages which actual mean (approval planning and financing) have been complete. Eastern Cape as province is the leading South Africa with Wind Energy Facilities. Eastern Cape province has excellent wind resources, which are yet to be fully utilised. Upscaling renewables development in the province has become a necessity, as renewable energy is the only source of new power that can be deployed fast enough to help ease South Africa's chronic loadshedding or electricity shortages. According to the Integrated Resource Plan, has a goal to develop 9 000MW of wind power by 2030. In the 27 new IPPs projects that were signed by former Energy Minister Jeff Radebe on 04th April 2018, indicated that four new wind farms will be based in the Eastern Cape, which are Golden Valley Wind Farm, Nxuba Wind Farm, Oyster Bay Wind Farm, and Wesley-Ciskei Wind Farm. The Wind Energy Facilities (WEF) generation capacity in Eastern Cape Operating Unit (ECOU) already or/and planned to be integrated in the network grid of Eskom are as followed in the Table 16:

Table 16: Generation capacity WEF Technology installed, in construction and in planning in the ECOU Eskom network grid.

Technology	Mega Watts (MW)	REIPPP	Onshore	Status
Droper Wind Farm	97MW	1	Yes	In Operation
Cookhouse Wind Farm	135MW	1	Yes	In Operation
MetroWind Van Stadens Wind Farm	27MW	1	Yes	In Operation
Jeffrey Bay Wind Farm	138MW	1	Yes	In Operation
Red Cap Kouga Wind Farm – Oyster Bay	80MW	1	Yes	In Operation
Chaba Wind Farm	20.6MW	2	Yes	In Operation
Grassridge Wind Farm	59.8MW	2	Yes	In Operation
TOTAL	**557.MW**			
Amakhala Emoyeni (Phase1)	134MW	2	Yes	In Construction
Waainek Wind Farm	23.4MW	2	Yes	In Construction
Tsitsikama Community Wind Farm	94.8MW	2	Yes	In Construction
Nojoli Wind Farm	87MW	3	Yes	In Construction
Red Cap – Gibson Bay	111MW	3	Yes	In Construction
TOTAL	**450.6MW**			
Nxuba Wind Farm	140MW	4	Yes	In Planning
Golden Valley Wind Farm	120MW	4	Yes	In Planning

Technology	Mega Watts (MW)	REIPPP	Onshore	Status
Wesley – Ciskei Wind Farm	33MW	4	Yes	In Planning
Oyster Bay Wind Farm	140MW	4	Yes	In Planning
TOTAL	**433MW**			
FINAL TOTAL	**1 441MW**			

According to Global Wind Energy Council 2017 report South Africa is rank number one in Africa and Middle East region in terms of wind energy renewable technology installation with 2 094MW which is 0.4% of global and 46.1% in Africa and Middle East region in terms of wind energy facilities (GWEC, 2019). Therefore, this means Eastern Cape province with 557.4MW wind power already in operation or commissioned it account for 26.62% of wind energy facilities which mean a quarter of installed WEF in South Africa. All the projects in BW1, BW2, BW3 and BW4 are either connected already, construction and planned in the Eastern Cape Operating Unit (ECOU). In our case studies below, we will only focus only WEF which are commissioned or connected or integrated on the Eskom network grid. Install WEF capacity already in operation, there are only seven (7) WEF or wind farm or wind power. Five (5) of these are from REIPPP 1 and two (2) from REIPPP 2 and are delivering power to the Eskom network grid in the Eastern Cape. In construction state each WEF procured in terms of the IPP Procurement Programme will be required to achieve commercial operation by not later than the dates out in the Request for Proposal (RFP). These means with five (5) in construction and plus four (4) in planning stage combine after commissioning each every WEF in construction and in planning, Eastern Cape will account for 883MW WEF new capacity. In total bidder window 1 to 4 the Eastern Cape province will contribute for Wind Energy Facilities (WEF) to 1 441MW capacity generated to the Eskom network grid in varies areas or Eskom substations.

5.2.1 Case Study 1: Dorper Wind Energy Facilities (WEF)

Rain Maker's Dorper WEF is located in the Eastern Cape province of South Africa. It falls sunder the Eastern Region distribution network grid according to Eskom electrical supply area demarcation. It has a potential to accommodate more than 240 wind turbines. Dorper Wind Farm (RF) (Pty) Ltd was selected as a preferred bidder under round 1 of the Renewable Energy Independent Power Producer Procurement Programme (REIPPPP) run by the South African Government's Department of Energy (DoE). In November 2012 Dorper Wind Farm (RF) (Pty) Ltd signed a Power Purchase Agreement with Eskom, and associated agreements with the DoE. Dorper Wind Energy Facility join venture (JV) partners Japan – based Sumitomo and local partner Rainmaker Energy has secured a 20-years power purchase agreement with statement State-owned power utility Eskom. The

Dorper Wind Farm site is located almost midway between the towns of Sterkstroom and Molteno, within the Inkwanca Municipality see Figure 85 below:

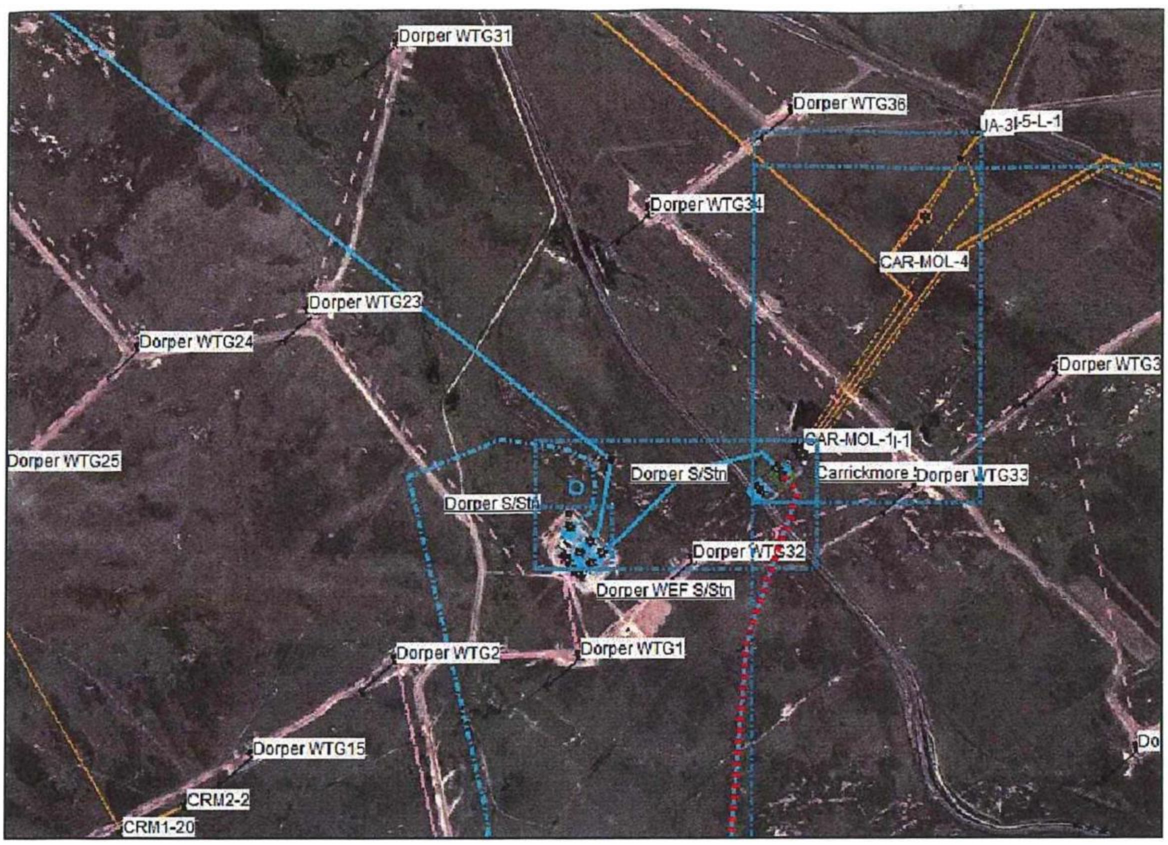


Figure 62: Dorper Wind Energy Facility near Dorper substation

The wind farm consists of 40 Nordex 2.5MW wind turbines, having a nominal aggregate production output of 1 000MW. The power station is connected to the Eskom grid and is supporting electricity capacity with green, sustainable energy. Dorper Wind Energy Facility successfully achieve Commercial Operational Date (COD) on 09th August 2014. The wind energy facility is connected to the Eskom Distribution Network which transverses the project site and will supply Eskom with power, as an Independent Power Producer (IPP) under a 20-years Power Purchase Agreement (PPA). South Africa's national electricity grid received a 1000MW boost as the Dorper Wind Energy Facility, in the Eastern Cape, reached state electricity freed-in. In total, Nordex had secured four contracts totalling 425MW in South Africa, including the delivery and turnkey installation of 56 turbines generating 134.4MW for the Amakhala Emoyeni Wind Facility, and a newly awarded 111MW project comprising 37 turbines.

5.2.2 Case Study 2 – Scope of Studies: Dorper Wind Energy Facility (WEF)

The scope of the studies is to find the best way integrate the WEF generated power into the existing electrical network without compromising reliability and quality of supply in accordance with the NRS 048-6 and the Distribution Grid Code. Pre-feasibility studies for the connection of Dorper WEF. The studies focus on following:

- Identification of viable options for connecting Dorper WEF to Eskom grid;
- Identification of collection networks;
- Preliminary design of collection network and grid connection;
- Identification of substation locations around the WEF and cable/line connections paths;
- Identification of current and future constraints that might affect the WEF;
- Assessment of grid code requirements;
- Determination of fault levels;
- Calculate a budgetary costing; and
- If required, facility discussion of identified options between Rainmaker and Eskom Distribution ECOU

The concept designs for the collector system and the connection points are presented. The connections point to Eskom network are identified, discussed and the costing is done only options deemed technically sound. The electrical network is simulated to ensure that the integration of the WEF does not compromise the normal operation of the Eskom network. Simulation results, the network losses are determined before and after the connection of the WEF. Based on the information received from Rainmaker, the capacity factor of the WEF is calculated and used as proxy measure for capacity credit under REFIT 1. Network losses are also calculated before and after the connection of WEF.

Considering a maximum output of 2.5MW per generator (wind turbine) the total Dorper WEF potential is estimated to 600MW (2.5x240). The produced power needs to be transported from the site and injected into the existing electrical network at a suitable connect point or Point of Common Coupling (PCC). In the case of Dorper WEF, the site is very well positioned with respect to existing power transmission infrastructure. A 400kV transmission linking Beta and Delphi substations crosses near Dorper WEF (see green line in Figure 86). A 132kV traction railway line and a 22kV feeders from Carrickmore substation feeding Molten and Freemantle same Figure 62.

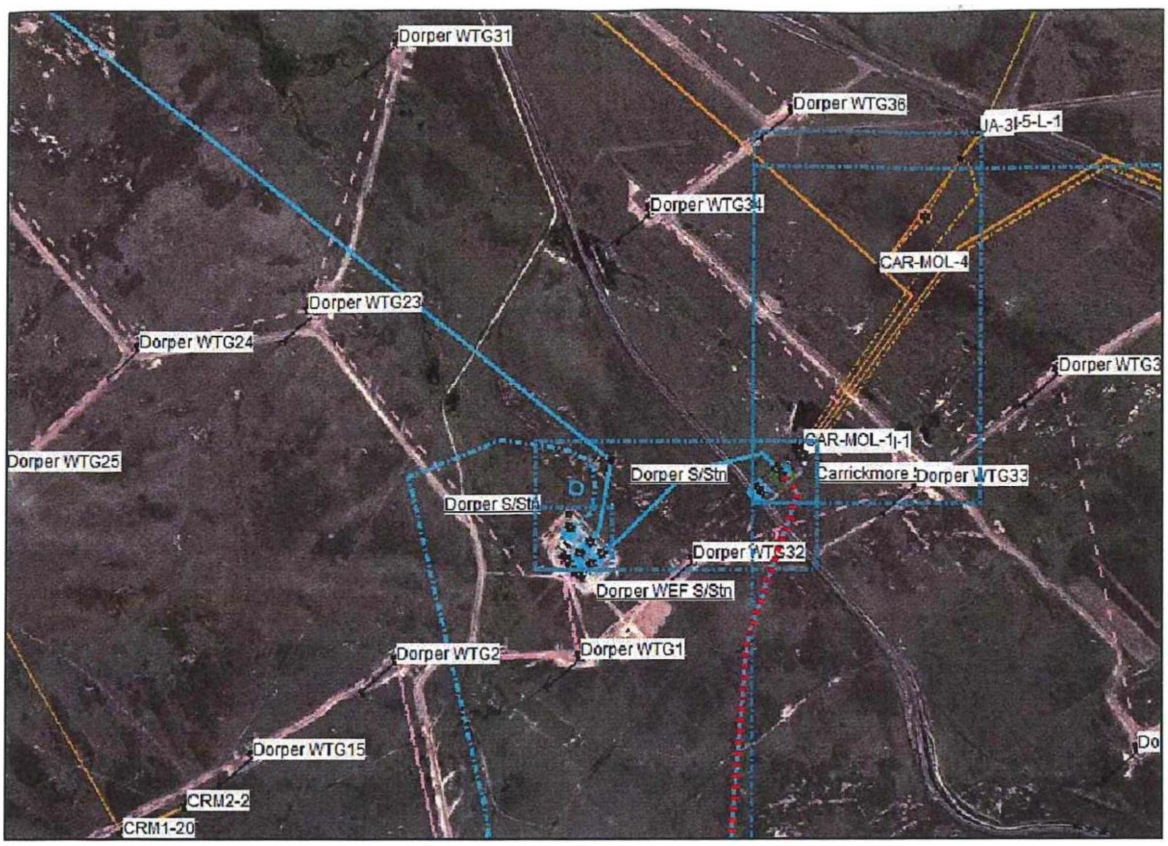


Figure 63: Dorper Wind Energy Facility near Dorper and Carrickmore substation and with 400kV, 132kV and 22kV lines.

Thus, Dorper WEF has various PCC to consider. The choice of suitable connection option was depended on the immediate generation capacity and the economics associated with it. Rainmaker wished was to approach the development of Dorper WEF in five stages of 1x100MW and 4x125MW with the 1x100MW stage being the subject of the present integration studies. Rainmaker Energy Project (Pty) Ltd contracted Trans Africa Project (Pty) Ltd conduct preliminary connection studies for their Dorper Wind Farm in the Eastern Cape. Dorper wind farm has a potential of 600MW. The location of the Dorper WEF is very attractive in terms of electrical infrastructure. Servitudes for 132kV transition (86MVA) and a 400kV transmission (1725MVA) lines run through Dorper WEF site. Moreover, a 132/22kV step down substation is also located on Dorper site. Therefore, connections at 22kV, 132kV and 400kV were explored.

Rainermaker indicated that they would like to develop Dorper WEF in a phased approach. Phase 1 will have a 100MW potential while Phase 2 will have 4x125MW. Rainmaker also indicated that the design should be modular in such a way that each 125MW unit can be treated as a WEF on its own. Therefore, the combined project potential is referred to as 1x100MW and 4x125MW. Phase 1 potential (100MW) can be connected at 22kV or 132kV. Due to close proximity to electrical infrastructure, the cost of connection for 100MW at 400kV is not justified. The connection at 22kV requires upgrades at Carrickmore substation. The upgrade consists of increase of transformation capacity and possible protect equipment, busbar, civil, etc. The substation would still belong to Eskom and because of the complexity involved, it is not known if Eskom would support this option. Connecting at 132kV requires Rainmaker building to building a substation (herein called Dorper 132kV) to step up from collection voltage of 22kV to 132kV before connection to Eskom grid. There are two ways Dorper 132kV can be connected to Eskom network grid. It can be connected by a 132kV overhead line connecting Dorper 132kV Carrickmore or by deviating the existing 132kV traction line into Dorper 132kV substation. Connection via a 132kV overhead line is preferred but the practicality of such connection needs to be confirmed by a site visit. Under normal operating conditions, 100MW can be injected into Eskom network using both connection options.

However, both connections at 132kV cannot handle the full capacity of 100MW under contingency because of overloading issues. It was possible to synchronise the communication between the Eskom control (SCADA) system and Dorper WEF so that the generation can be reduce under contingency conditions. In absence of such synchronisation, for both132kV connections options to work under all operating conditions, the maximum generation to be injected at Carrickmore at 132kV has to be limited to 93MW and Dorper WEF must be operated at a leading power factor to keep Carrickmore voltage below 1.06pu. Connection options for 100MW at 132kV results in 6MW or 3% loss reductions on the Southern Network at peak demand. The total integration cost for Dorper based on desktop studies was estimated at R386million. The cost will be more accurate once the turbines and substations positions are determined. Rainmaker had three types of generators that they had explored with the intention to make a choice at a least for phase stage. Nordex generators are based on DFig technology that has full voltage and frequency control and can generate up to 2.5MW depending on the wind conditions. The voltage control is achieved through the absorption of production of reactive power by the turbine. There turbines are also capable of contributing to the stability of network through Low Voltage Ride Through capability.

5.2.3 Case Study 3 – Existing substation in the vicinity of: Dorper Wind Energy Facility (WEF)

As previously explained, there are a number of Eskom substations in the vicinity of the Dorper WEF. Carrickmore substation is located within the boundary of the WEF. 132kV traction line 86MVA and a 400kV line rated 1725MVA cross the WEF. From the existing transmission electrical infrastructure, four connection options are identified:

- Direct connection to Carrickmore substation at 22kV;
- Connection by building and new 22kV or 33kV/132kV substation and connecting to Carrickmore via one or two short 132kV lines;
- Connection through to the existing 132kV traction line;
- Connection through the 400kV transmission line.

For all 132kV options, the maximum theoretical generation was limited by the thermal loading of the traction line which is 86MVA. When taking into consideration the flow of reactive power on the line, the maximum generation can be expected to be even less, depending on the amount of reactive power. The 400kV option presents the highest connection capacity but requires enough generation to be financially viable due to the cost of equipment at that voltage level. At this stage, TAP is not aware of any renewable development that might affect the Dorper WEF. It is believed that Eskom would be aware of such development in case it exists. Therefore, it is, herewith recommended, that the connection options be discussed with Eskom before committing to detailed engineering studies.

5.2.4 Case Study 4 – Viable Network Integration Options: Dorper Wind Energy Facility (WEF)

The number of IPP applications for renewable energy has led NERSA to draft some rules regarding the selection and granting of licenses (Mobolaji, 2017). Moreover, a grid code for WEF has been drafted to ensure that their integration is achieved according to best practice dictated by South Africa grid code (Mobolaji Bello and Clinton Carter-Brown, 2018). A viable network integration option needs to comply electrically with the relevant criteria. Notably, the following criteria or rules are adhered to during the selection of a suitable connection option to Eskom network grid:

- Voltage variations
- The WEF capacity credit;

- Network technical loss reduction and;
- Shallow and deep integration cost.

Under renewable energy feed-in tariff (REFIT), the regulators rules stated that preference will be given to projects that have a higher power credit. Also, the projects which contribute to the voltage and reactive power control and the reduction of the loss factor at the closest load centre are also preferred. The voltage variations are determined by multiple load flow as performed at a later stage in this chapter. The load flows are performed under various operating conditions to ensure that no breach in introduced by the connection of the WEF. The assessment to WEF to comply with certain the REFIT1 criteria is subject to much debate at present. For instance, schedule 1- Evaluation Matrix Table point 3. The definitions as found in under "selection rules" are ambiguous. Nevertheless, NERSA has eased the understanding of "Power credit" by allowing, at least for the purpose of first solicitation, the use of "annual load factor" as a proxy for determining the power credit. Because the methodology to calculate the loss factor reduction is also not well defined, this will simply determine the difference between the system losses with and without the Dorper WEF.

The shallow and if applicable the deep connection cost (65% confidence) will be determined based on the best technical and financial connection option chosen. The REFIT1 selection criteria favour projects that do not require upgrades to the upstream network. Such upgrade would increase the deep connection cost and would therefore reduce the ratio of the shallow cost to the overall cost of connection. The grid code for wind turbine requires the WEF as a whole to comply with various requirements such a voltage variation, power factor, active power curtailment, low voltage ride thought capacity, etc. In the present study, only voltages and power factor variations have been considered. Other requirement such as frequency, active power curtailment and harmonics needs to be analysed using advanced studies.

The collection network is conceptually designed in such a way to minimise the number of MV cables/overhead lines connecting the WEF to the step-up substation. Therefore, depending on the wind turbine maximum generation, the cable size and the collector system voltage, turbines are grouped in numbers from four to nine per collector cable. To build the collector network, the following assumptions have been made:

- The main collector cable is standardised to 240mm2 copper rated 375A (when buried in ground);
- The collector voltages can be 22kV
- The maximum generator output is 2.5MW (Nordex);
- The first stage of Dorper consists of 40 turbines with a combined capacity of 100MW. However, 125MW generation capacities will be referred to.

A 240mm2 copper can only handle five generators at 22kV or eight generators at 33kV. For a 100MW generation, the 22kV collector network requires eight main collector cables whereas the 33kV option require only five. Based on the same assumptions, a 125MW generation requires ten main cables at 22kV. The size of transformer is chosen in a way that strives to balance the number of transformers and the reliability criteria. For instance, choosing smaller transformers results in higher number of transformer and hence a choosing smaller transformer results in higher number of 20MVA transformers for the 22kV option is equal to the number of main cables required to collect the power from the wind turbine to the transformation base. In this case, five would be required for a 100MW generation and seven for a 125MW option. To reduce the number of transformer and associated equipment (breaker, CT, VT, etc), higher rating values were chosen. For a 100MW – 125MW generation facility, it is estimated that 4x40MVA transformer would provide a 3x40MVA firm capacity that is enough for a generation capacity of 100MW; in which case the firm capacity would be 2x40MVA. In any case, the maximum capacity factor for Dorper is estimated at 60%, therefore the transformation firm capacity is more than adequate to handle the generation. It must be noted that the design can be optimised by returning the cable sizes and transformer capacity. This can be achieved during detail design when the routes and substation position are final. The typical collection network is shown in (appendix 10 – (**22kV Collector Network for 125MW generation**)) for 22kV collections and in appendix. 11 for a 33kV collector network.

5.3 ANALYSIS OF RESULTS FOR CASE STUDIES

5.3.1 Case Study – Direct connection to Carrickmore substation: Dorper Wind Energy Facility

The average distance from a given turbine within the Dorper WEF is approximately 400m to Carrickmore substation. It is possible to group wind turbines and to transfer the collected power to Carrickmore substation at 22kV by mean of underground cables as shown in Figure 87 below. The limitation to this option is the size of the transformer at Carrickmore that has a limited capacity of 1x20MVA. To make this option viable, Rainmaker needs to replace the existing transformer with that of an appropriate size. Even so, it is also important to ensure that the equipment at Carrickmore substation is adequate to handle the increase in power flow due to generation at Dorper WEF. In the event this is not the case, the substation will need to undergo substantial refurbishment or upgrade. In the worst-case scenario, the cost of upgrading the existing substation could be very close to that of building a new substation. An alternative to this option is proposed in the following sections.

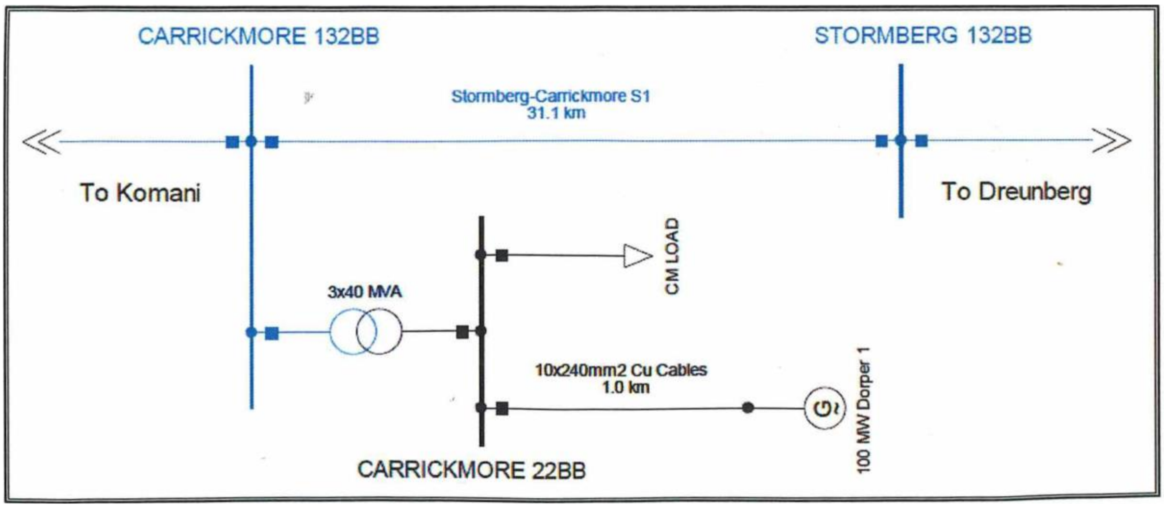


Figure 64: Connecting Dorper WEF to Carrickmore at 22kV.

5.3.2 Case Study – Direct connection through a new 132kV and short line to Carrickmore substation: Dorper Wind Energy Facility

A modular design approach where the Dorper WEF is split into 1x100MW and 4x125MW. If this approach is considered, it is advisable that Rainmaker builds a 132kV substation (instead of upgrading Carrickmore) close to Carrickmore (not more than 1km away). For the first phase of 1x100MW, the new 132kV substation can be initially connected to Carrickmore substation via a 132kV overhead line as shown in Figure 88. When the second stage of the projects is implemented, it will be much easier to integrate the substation presented in this option to the 400kV substation proposed in the section on the 400kV option.

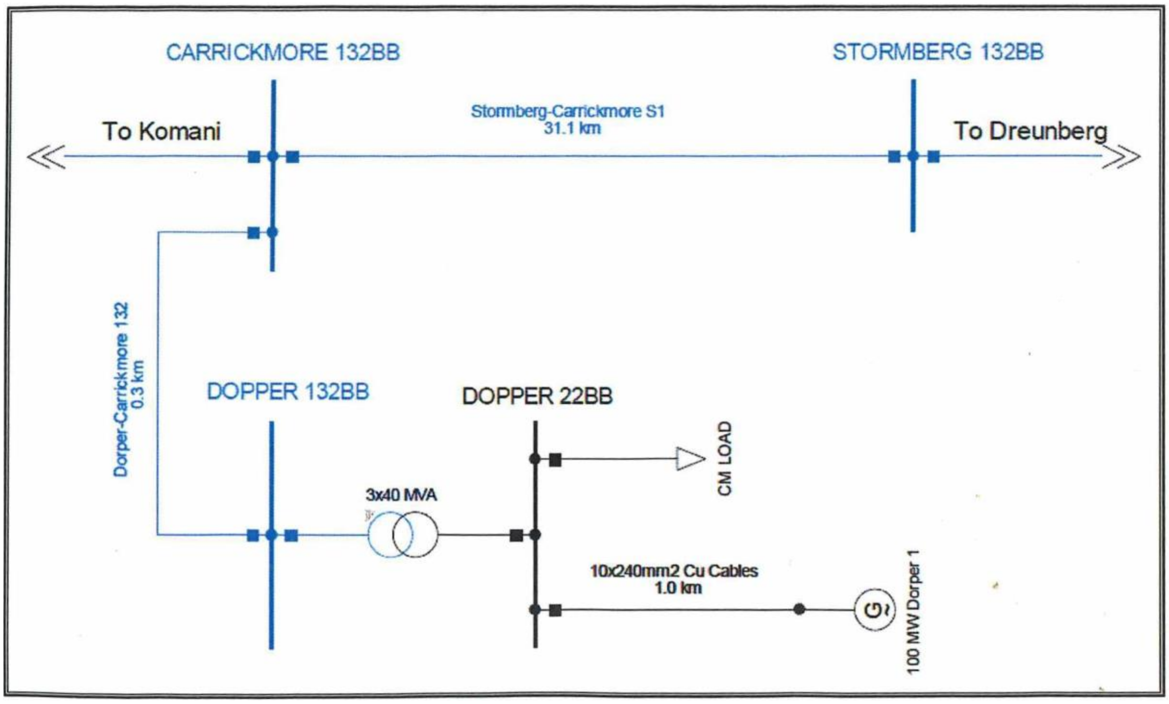


Figure 65: Connecting Dorper WEF through the 132kV line.

5.3.3 Case Study – Connection through the 400kV traction line: Dorper Wind Energy Facility

This option represents the highest line capacity available to inject the generated power into Eskom grid. It is also the option that has the least transmission losses due to the transmission at higher voltage (lower current). Nevertheless, it is probable the most expensive integration option. Therefore, it can only be justified in the case of integration of higher generation capacity. It is necessary that this approach be adopted in the next phase of 4x125MW wind farms. The option consists of five different 22kV to 132kV first stage substation used to collect the power from various wind turbine. The collected power is thereafter transferred to the 132kV/400kV substation in order to be injected into Eskom grid. The connection to Eskom network grid is achieved by turning the existing 400kV line between Beta and Delphi substations into Dorper 400kV substation. The number of transformers is chosen in such a way that the firm capacity of this arrangement is 500MVA. The transformation capacity can be further optimised by taking into consideration the WEF capacity factor or the generation average load factor over a period of at least a year. The optimisation can result in reduced but effective transformation capacity, taking advantage of the ability of a power transformer to tolerate overloading for some periods.

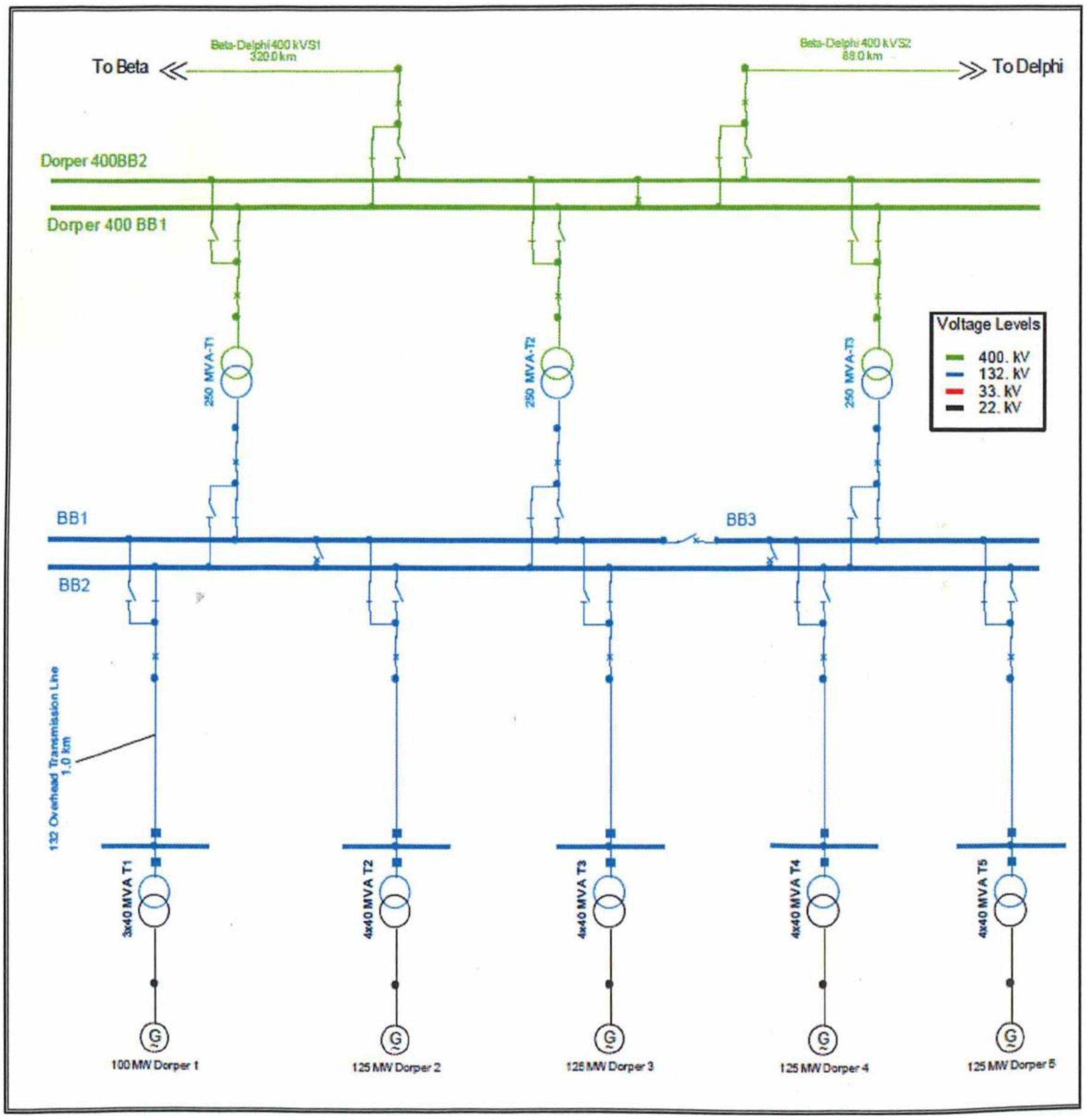


Figure 66: Connecting Dorper WEF through the 400kV line.

5.4 ANALYSIS AND COMPARISON OF CASE STUDIES

Analysis results for simulation purposes, all the 132kV options presented in the previous section will have more or less similar results. The collection network used for simulation was modelled at 22kV to ensure compatibility with the voltage levels at Carrickmore substations

5.4.1 Case Study – Capacity Credit and Loss Factor Credit: Dorper WEF

"Capacity credit is the measure used internationally for determining the extend of variability of the generation resource. Various approaches are used in determining the power credit ranging from complex power flow simulation based on measured data to assessment of the actual power contribution of the resource to the weekly or monthly zonal maximum demand" (Muanda, 2017). The existing methodology is not clear with regard to the definition of the affected area. Until the system for determination of the power credit for the purposes of the first solicitation process. From Rainmaker **Dorper average hourly capacity factors for twelve months** provided to TAP (appendix 12) Table 1) the load factor estimated to 0.6pu. The loss factor credit is determined by the ability of the WEF to contribute to the reduction of network losses in the system. As the case with capacity credit, the methodology is not clear on the definition of the network boundary. Therefore, for losses of the affected network zone before and after the connection of the power generation facility.

5.4.2 Case Study – No generation at Dorper WEF (Base case)

Under normal operating conditions with peak loads in the Eastern Region area of supply, the network around Carrickmore does not experience any voltage or overloading issues as dictated in (Mobolaji, 2017). The voltage in the area is controlled by an SVC at Dreunberg and another SVC at Komani. The power flowing in the traction line is substantially lower than the line capacity can handle. Most of the load in the area is supplied from Dreunberg and Komani. The power flowing in the traction network flows from Dreunberg side towards Komani. Most of it is consumed by the non-traction load at Carrickmore. Most of the power flowing into Dreunberg is supplied from Strydom substation while at Komani, most power is injected by the line from Delphi.

5.4.3 Case Study – Generation of 100MW: Dorper WEF

The generation of 100MW at Dorper (connected to Eskom grid at Carrickmore) results power in a substantial increase in power flow on the 132kV traction line from Carrickmore to Dreunberg and Komani substations. Most of the generated power (72MW) flows towards Komani and 9MW towards Dreunberg. The injection from Strydom into Dreunberg also drop from 72MW to 45MW. While the power flow from Delphi to Komani reduces by 48MW (see appendix 3 for 100MW Dorper WEF at Carrickmore). The voltage at Carrickmore has slight increased but still within the statutory requirements as dictated in. From a transmission point of view, the injection of 100MW at Carrickmore reduce the import of power in Eastern Region by 104MW. The network losses have decreased from 194MW to 189MW, therefore reducing the losses in the Eastern Region area of supply by 5MW or an equivalent of 5% of the Dorper WEF.

5.4.4 Case Study – Power flow under contingency conditions: Dorper WEF

Since the power injected at Carrickmore flows into the Eskom grid via the traction line, it is important to assess the network for a contingency on any section of the traction line. The most onerous condition would be the loss of any section of the traction line connecting to Carrickmore. For example, the loss of Carrickmore – Stomberg 132kV line section force all the generated power to flow towards Komani substation on the Carrickmore – Komani line section. Under these conditions, a voltage breach is observed at Dorper 132kV and Carrickmore 132kV buses. The Carrickmore – Komani 132kV traction line is loaded at 94.8% of its thermal capacity (appendix 4 - **with Dorper WEF with Power flow under contingency conditions**). The loss of Carrickmore – Putterskraal 132kV line section forces the power to flow towards Dreunberg substation on the Carrickmore – Dreunberg line. A voltage breach is observed at Dorper 132kV bus and also at Carrickmore 132kV bus. The Carrickmore – Putterskraal 132kV traction line is loaded at 95.5% of its thermal capacity (Appendix 5 - **with Dorper WEF with voltage breach is observed at Dorper 132kV bus and also at Carrickmore 132kV bus**).

It is also observed that when any of the above contingency occurs while the network is lightly loaded, the remaining traction line section become overloaded. This is evident even in the case where the load at Carrickmore alone is reduced by 80% for traction load (i.e., no train near Carrickmore) and 50% for the rest (Appendix 6 - **with Dorper WEF with Carrickmore – Putterskraal 132kV traction line is loaded at 95.5% of its thermal**

capacity). To avoid overvoltage and overloading during contingencies, the generation needs to be reduced by a certain margin. The required reduction in generation is higher when the generators are operated at unity power factor. Operating the generators in leading power factor (allowing them to absorb reactive power in order to control voltage) allows for more active power to be injected into Eskom network grid. The maximum injection at Carrickmore when operating the WEF at 0.99 leading power factor is 93MW (Appendix 7 - **with Dorper WEF with maximum injection at Carrickmore when operating the WEF at 0.99 leading power factor is 93MW**). Thus, reducing the generation at Dorper by 7% ensures that there is no overvoltage or overloading during a single line contingency.

5.4.5 Case Study – Faulty Level: Dorper WEF

According to Nordex datasheets, the fault contribution from single wind turbine depends very much on the voltage at its terminal. The voltage ride through capability enables the Nordex wind turbine to contribute with reactive current of a maximum magnitude equal to the nominal current. Prior to the connection of Dorper 100MW wind farm, the fault current at Carrickmore for a solid fault is 2.1kA. Thereafter, the fault current rises to 2.4kA when the connection is established. The increase is not significant, it is expected that no change would be required to existing break with respect to the rise in fault levels.

5.5 HIGH LEVEL COSTING OF 132kV SUBSTATION & 132kV LINE FOR CASE STUDIES AT DORPER WEF

The table17 below contains high levels cost of 132kV/22kV substation, the collector network and the overhead line used to link Eskom network grid. This high-level cost is based on 125MW generation potential. The cost of collector system is also based on 240mm2 cables. The overhead line assumes a Chickadee or Kingbird conductor on a single circuit tower. Since the cost of the integration is based on desktop studies, it is advisable that Rainmaker organise a site visit before a final decision is made regarding the viable option.

Table 17: High Level Cost for preferred alternative

ITEM	QUANTITY	COST
132/22kV – 4x40MVA Substation	1	R158, 210, 018.00
22kV Collector System	4km (70mm2) and 84km (240mm2)	R223, 064, 800.00
132kV Overhead line	2km	R4, 114, 808.00
TOTAL		

The total cost for building and connecting a new substation to Carrickmore is therefore estimated to cost R396m. It must be noted that the cost will be more accurate when the turbine and substation locations are finalised.

5.6 SUMMARY OF CHAPTER FIVE – DORPER WEF

The integration of Dorper 100MW WEF to the Eskom network grid can be achieved in three different ways. The most viable option is the construction of a new 132kV (Dorper 132kV) substation next to the existing Carrickmore traction substation and link the two substations via a 132kV overhead line see (Figure 88). The new substation offers a significant advantage when considering the second phase of the project. It makes the integration easier and saves the customer the burden of defining the ownership of the asset (the substation fully belongs to Rainmaker). Moreover, the cost of upgrading Carrickmore substation would probably cost as much as the building of a brand-new substation. The difference is price cost can be compensated by the fact that 22kV equipment (breaker, isolator etc) are cheaper than those equipment for 132kV.

The collector network design will be presented in the second report if the turbine final positions are confirmed. Cable routes, lengths and sizes can be optimised during detail engineering. It is important that site visit be conducted to determine the position and orientation of the 132kV substation for phase 1 see (Figure 88) and 4x132kV and 1x400kV substations for phase 2 (Figure 89). These positions are important for the determination of 132kV overhead lines and collector network cable that have to go in between wind turbines. Prior to the Dorper WEF, the voltage at nearby substation is well controlled by SVCs at Dreunberg and Komani and the 132kV traction line is loaded below its thermal limit.

The injection of 100MW at Carrickmore increase the voltage slightly in the area but they are still within the ±5% limit. The traction line is till loaded below its thermal limit. The losses in the system are reduced by approximately 5MW. The loss of any traction line section from Carrickmore leads to over voltages at Dorper WEF and at Carrickmore at 132kV line buses. If a line contingency occurs on the traction line during low load conditions, the remaining 132kV line section from Carrickmore overloads. During such operating condition, the WEF generation should be reduced to reduce the loading on the remaining line section. The fault current change as result of the additional generation from Dorper WEF is not significant. It is therefore not expected to trigger changes to existing Carrickmore breakers. The capacity credit calculations were substituted by the generation load factor or capacity factor which was calculated at 30% for two year measured data, The losses reduction factor was substituted by the absolute network losses reduction at peak time. The net reduction in network losses was calculated to be 5MW or 5% of the WEF potential.

CHAPTER 6: CONCLUSION, RECOMMENDATIONS AND FUTURE RESEARCH WORK

6.1 GENERAL CONCLUSION

A wide range of natural resources fall under the different types of renewable technologies generation. These renewable technologies (natural resources) include fossil fuels, hydro, fuel cells such as coal, land fill gas, wind, geothermal, solar and co-generation which according to NERSA (co-generator is a source of electrical power that is a co-product, by-product, waste product or residual product of an underlying industrial process). These different technologies operate under different conditions and utilise different machinery. Some of the most common types of energy source for rotating and non-rotating machines include fossil fuel i.e., coal, hydropower, landfill gas, biomass, wind power, geothermal and solar photovoltaic. Generation technologies utilise synchronous generators, induction generators or power electronic inverters (etc.) to generate electricity into the network.

The issue of whether South Africa should transition to renewable energy is no longer in question. There is growing appreciation of both the need and the urgency. However, what is still a question is how such transition to renewable energy should look like. At least for trade unions or labour movements, the transition should be fair, just and should include workers representation and consultation. A just transition should include greener jobs, social protection, support innovation and social dialogue. It is worth noting that the REIPPP framework of South Africa does not illustrate some of these aspects. Whilst the programme has brought in much needed Direct Foreign Investment, the ultimate value of FDI lies in its potential for job creation and stimulating local economic activities, transfer of technology and know-how (including modern managerial and business practices), access to international markets and access to international financing. All plants visited had not achieve any of the above. Government should prioritise the current REIPPPP structure, and favourable conditions must be presented so that the REIPPPP produce employment. These conditions included:

- Promoting local owned renewables,
- Re-skilling and training for job creation, and
- Prioritising community participation and education

Eskom has a comprehensive Climate Change strategy that addresses mitigation (emissions reductions) and adaptation (how to deal with the impact of changes to the climate on our infrastructure and people). Eskom's Climate Change Strategy is comprised of the following strategic initiatives (referred to as the Eskom 6-Point Plan on Climate Change):

- Diversification of the generation mix
- Energy efficiency measures
- Adaptation to the adverse impacts of climate changes
- Innovation through research and development
- Carbon financing through investments in carbon markets and accessing green financing opportunities.
- Advocacy, communication, and partnerships at national and international levels.

Currently there is not commercially available "end-of-pipe" technology available to reduce greenhouse gases (viz. carbon dioxide, nitrous oxide and methane) emissions from coal-fired power stations. There is an end-of-pipe technology under development internationally, called "Carbon Capture and Storage" or CCS. It is only expected to be commercially available between 2023 and 2035. This process removes the carbon dioxide (CO2) from the power station flue gas, concentrates it and allows it to be pumped for storage, typically in a suitable, naturally occurring underground geological reservoir. Eskom supports the South African Centre for Carbon Capture and Storage base in the South African National Energy Development Institute (SANEDI) which is currently progressing with characterisation of potential storage areas in South Africa and planning a pilot injection. Nonetheless, this is expected to be a long-term solution, with existing international demonstration plants proving to be very expensive.

In the absence of end-of-pipe technology, there are few opportunities to reduce the carbon footprint of existing coal-fired power stations. One area that receives attention is that of thermal efficiency. Technology developments have enabled new coal-fired power stations to be designed and built to run at higher pressures and temperatures (so-called "supercritical" conditions) which has a greater than subcritical power stations. A 1% improvement in efficiency, reduces CO2 emissions by approximately 2%. However, it is not easy (or cheap) to retrofit supercritical technology as one basically has to scrap the existing boiler and replace it. Currently, the most effective way to reduce greenhouse gas emissions from the electricity sector is to produce less electricity (customer-based efficiency improvements or to diversify the electricity supply away from coal towards lower-carbon technologies (nuclear, hydro, renewables and gas). Unfortunately, to date, all lower carbon supply options determined through the Department of Mineral Resource and Energy's Integrated Resource Planning process have been allocated to Independent Power Producers and not to Eskom. In the absence of a low carbon supply allocation, Eskom has proceeded with delivering demand management savings, the new building programme (Medupi and Kusile power stations employ supercritical designs) as well as Ingula Pumped Storage Scheme, the roll out of photovoltaic plant to supplement generation at existing coal-fired power station sites, the construction and operation of Sere (100MW Windfarm) and many research initiatives, from rural microgrid and smart grid applications to wave energy to electric vehicle testing. Eskom Transmission has also enabled the connection over 3000MW renewable energy projects to the national grid.

All of these initiatives are in place to reduce our relative greenhouse gas emissions; however, we can only reduce our absolute greenhouse gas emissions by shutting down coal plant. This is not something we can afford to do overnight as a company and as a country. While Eskom is committed to transition from coal to lower carbon technologies such as renewables, we are just as committed to seeing that this transition occurs in a "just" manner, which does not impede socio-economic development. Our reality, though, is that until the government makes decisions on how lower carbon technologies are allocated to the players in the electricity market, Eskom's role in this transition is uncertain.

Despite this uncertainty, Eskom remains committed to deal with climate change. We are currently working on a low emissions development strategy for the organisation that will feed into the government's low emission development strategy and will aligned with South Africa's commitment to the Paris Agreement. This strategy will include a mitigation abatement cost curve that outlines the most suitable technologies for reducing emission together with their costs. Climate Change is also a priority 1 Risk for Eskom, meaning that policy, strategy and initiatives to deal with climate change are managed and approved at Eskom Exco and Board level. Further, Eskom actively participates ion national processes run by the Department of Environment, Fisheries and Forestry and National Treasury, to report and limit future greenhouse gas emissions.

6.2 RECOMMENDATION AND FUTURE WORK

There has been an enormous increase in demand for energy in South Africa in recent years as a result of rapid industrial development, rapid immigration growth around urban areas and massive rural electrification led to severe energy crisis today. South Africa is gifted with coal and relies heavily on coal to meet its energy needs. Coal as a primary energy source, with coal providing 75 percent of based power generation system that provide low-cost energy supply with a network grid that is further extended to rural areas, to millions of residential, commercial and institutional consumers. (Department of Mineral and Energy RSA, 2019). At the same breadth South Africa is well gifted with renewable energy resources that can be alternative sustainable energy supply and mostly these have remained largely untapped. This research study will investigate and determine the diverse challenges.

The Renewable Energy Independent Power Producer Procurement Programme (REIPPPP) has often focused on the ownership and job creation skills in the development. Construction and operation of predominantly wind and solar PV projects. However, localisation benefits of the renewable energy sector occur in many different parts of the solar and wind value chain projects. This is of the most problematic areas in that jobs are measured in “job-years”, which simply measures a job as one which provides full-time employment for an individual for 2 080hours in a year. Renewable energy project construction, by its nature, will be reasonably short but with a high level of repeat opportunities for workers. The current allocations for wind and solar in the draft IRP 2018 equate to 24 wind and solar projects per year each that will have a construction period of anywhere between 12 to 24 months. The average construction period for the 3 776MW built so far under REIPPPP has been 1.9years. As of June 2018, the IPP Office reports that the 62 completed projects under REIPPPP had committed to deliver 17 528 jobs yearly but actually achieve 27 890 jobs yearly, which is 59% more than planned.

Significantly more people from local communities around the projects were employed during construction than initially planned. The expectation for local community participation was 6 772 jobs per year. To date 17 383 jobs have been realised (i.e., 156% more than initially planned) 2 projects, which have reached financial close, are still to reach COD. During the construction phases, Black South African citizens, youth in particular and rural or local communities have been the major beneficiaries as they respectively represent 79%, 41% and 505 of total job opportunities created by IPPs to date. However, woman and disabled people could still be significantly empowered as they represent a mere 8% of the total jobs created to date, respectively. More important is promotion of the creation of jobs in the renewable energy manufacturing chain. The sector invested heavily in the manufacturing value chain in anticipation of continuity of REIPPPP, but as delays to the closing of the 4th and Expedited Bid Rounds continued, most manufacturing capacity left the country or closed down.

Independent studies have shown that there is potential to create additional local production capacity in downstream manufacturing in the production of both wind and solar related components. As well as expand existing manufacturing capacity in areas such as high-technology machinery (gearbox parts, shaft and bearings), electrical and electronic equipment (generators, transformers etc). In addition, a large-scale building programme will also support South Africa’s construction and civil engineering sector which currently suffering a decline.

To rebuild confidence to ensure the return of sector manufacturers is reasonably simple: Policy certainty of the annual allocations for wind and solar PV in the IRP. Reduction of monopoly behaviour through the establishment of an independent system and market operator. An industrialisation plans that strategic support the establishment of a significant renewable energy components manufacturing capacity. South Africa has demonstrated its ability to establish such schemes in the automotive industry.

LIST OF FIGURES

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APPENDINCES

APPENDIX 1

Eskom

MEMORANDUM FOR PERMISSION TO COLLECT DATA

To:	Mr. Siyamthanda Luthando Matondolo, MEng Electrical Engineering & Network Grid Analysis, Asset Creation, Distribution	Reference:	
From:	Ms. Zimkhitha Mjali, Middle Manager HR Operations, Distribution Eastern Cape & Western Cape Operating Unit	Version:	0
Date:	23 April 2021		

SUBJECT: PERMISSION AND SUPPORT TO COLLECT ESKOM DATA

PURPOSE: (Permission to Collect Eskom Data)

1. I hereby confirm that permission was granted in 2019 for Mr. **Siyamthanda Luthando Matondolo** (Student no: **200720627**), to conduct research data for his treatise/dissertation on the proposed research topic as per "**Optimum Reliability for Integrated Wind Energy Facilities (WEF) Renewable Technology into Sub-transmission and Medium Voltage of Eskom Distribution Network Grid, in the Eastern Cape Operating Unit**" as stated.

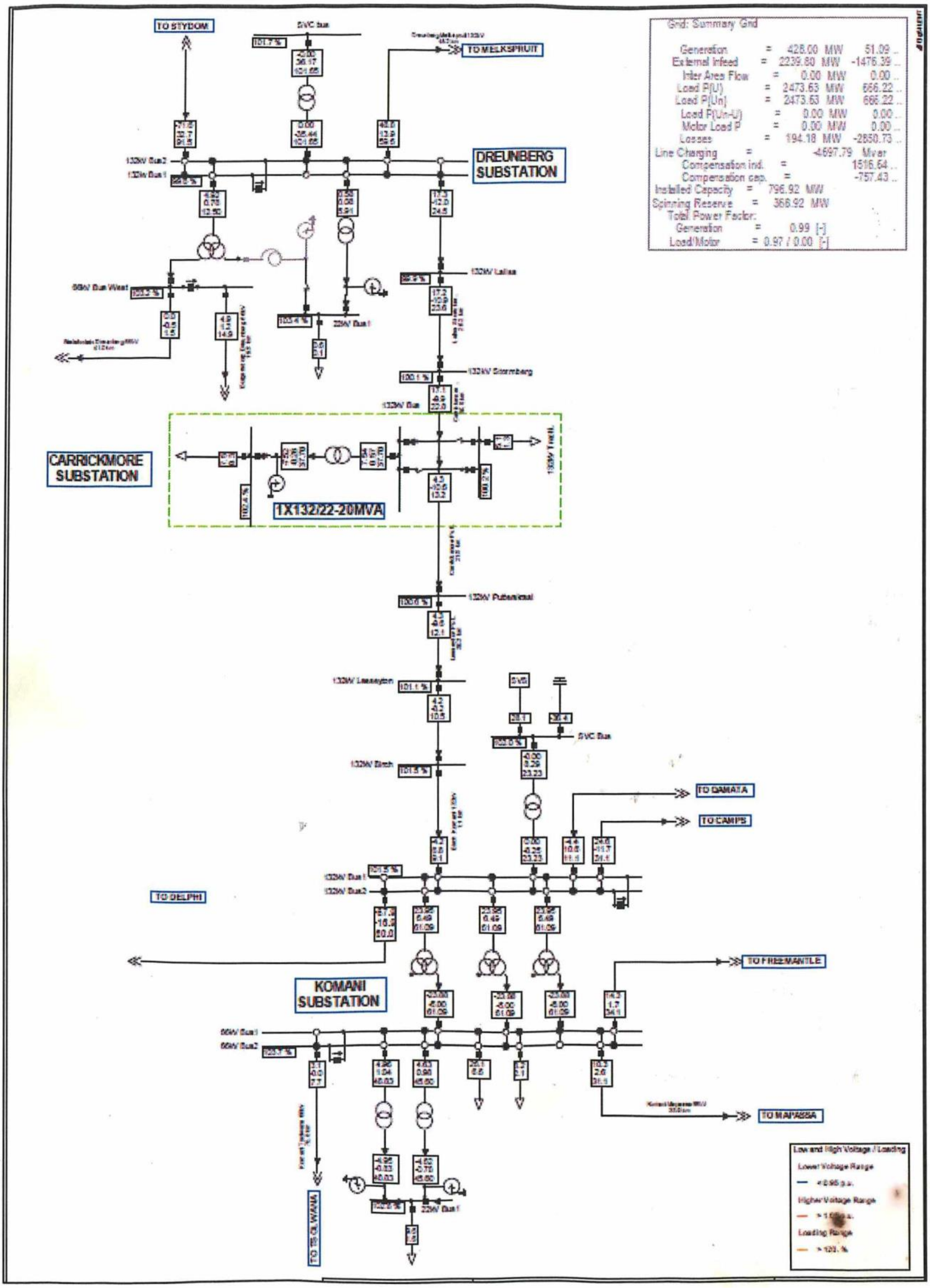
Approved/~~Not approved~~

Name Surname: Zimkhitha Mjali
DESIGNATION: Middle Manager Humana Resource Operations
GROUP/DIVISION : Distribution Eastern Cape & Western Cape Operating Unit
SIGNATURE :

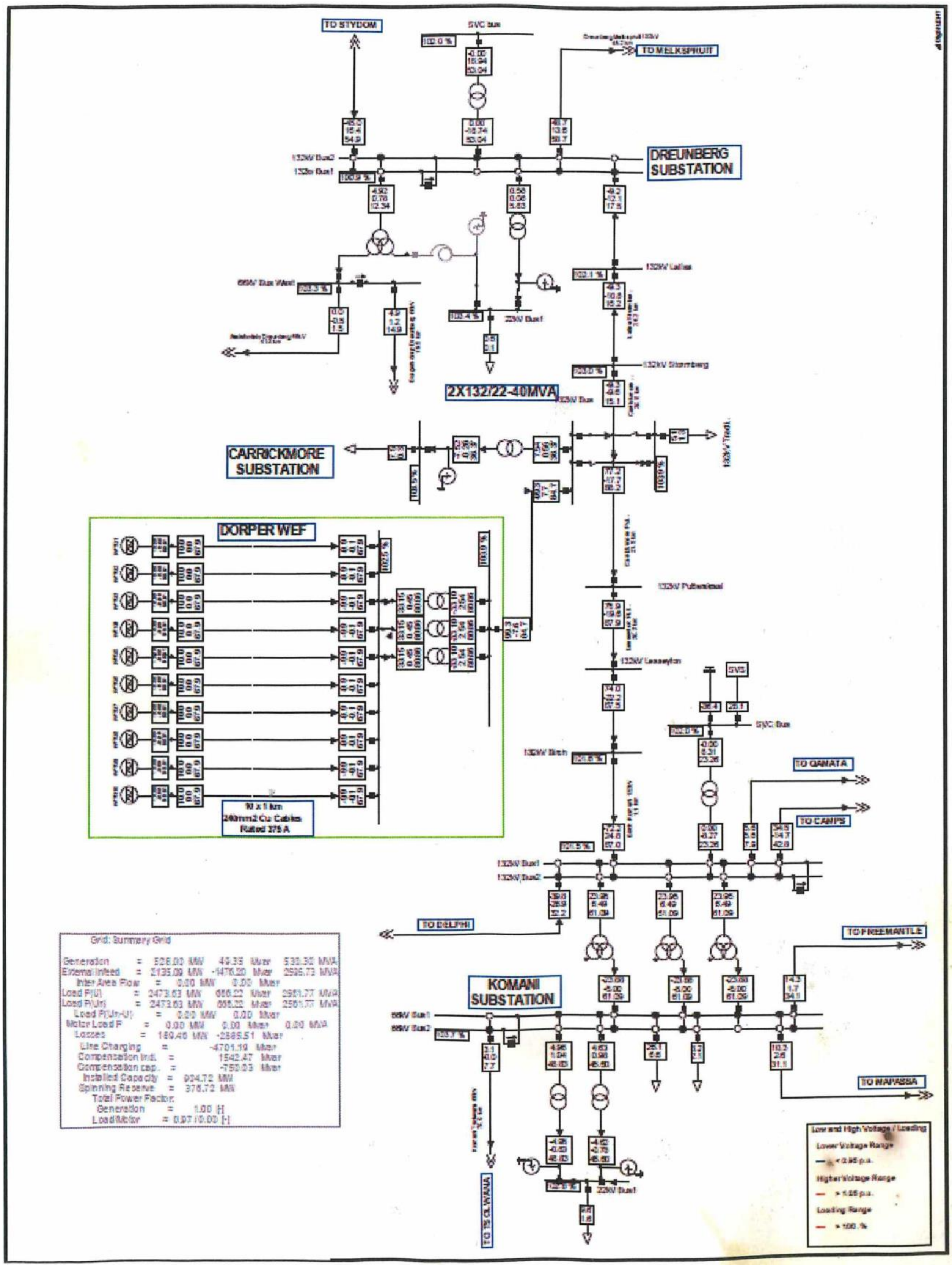
Date: 23rd April 2021

Head Office
Tel +27 11 800 8111
Eskom Holdings SOC Ltd Reg No 2002/015527/30

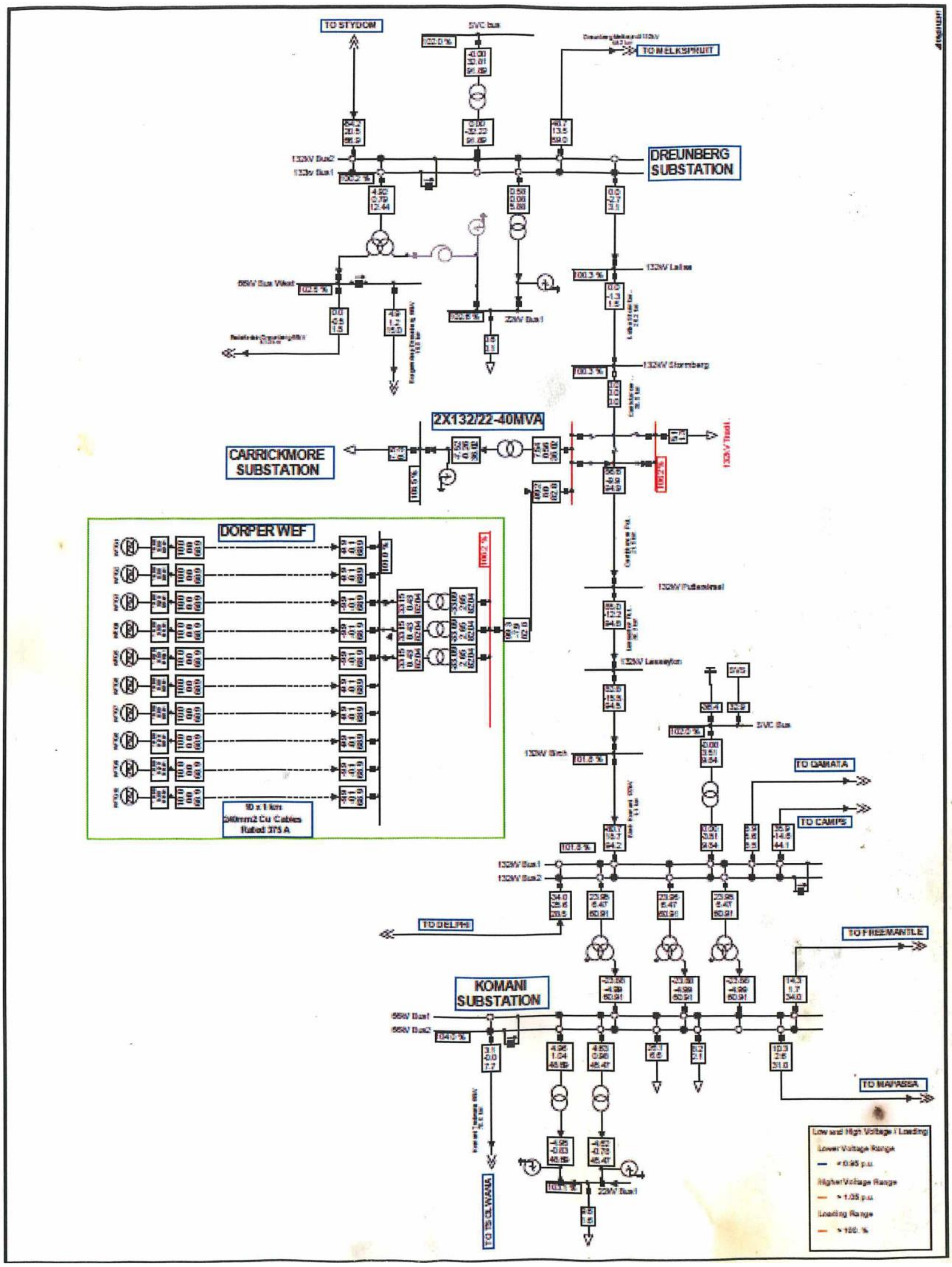
APPENDIX 2 (without Dorper WEF with nominal voltage)



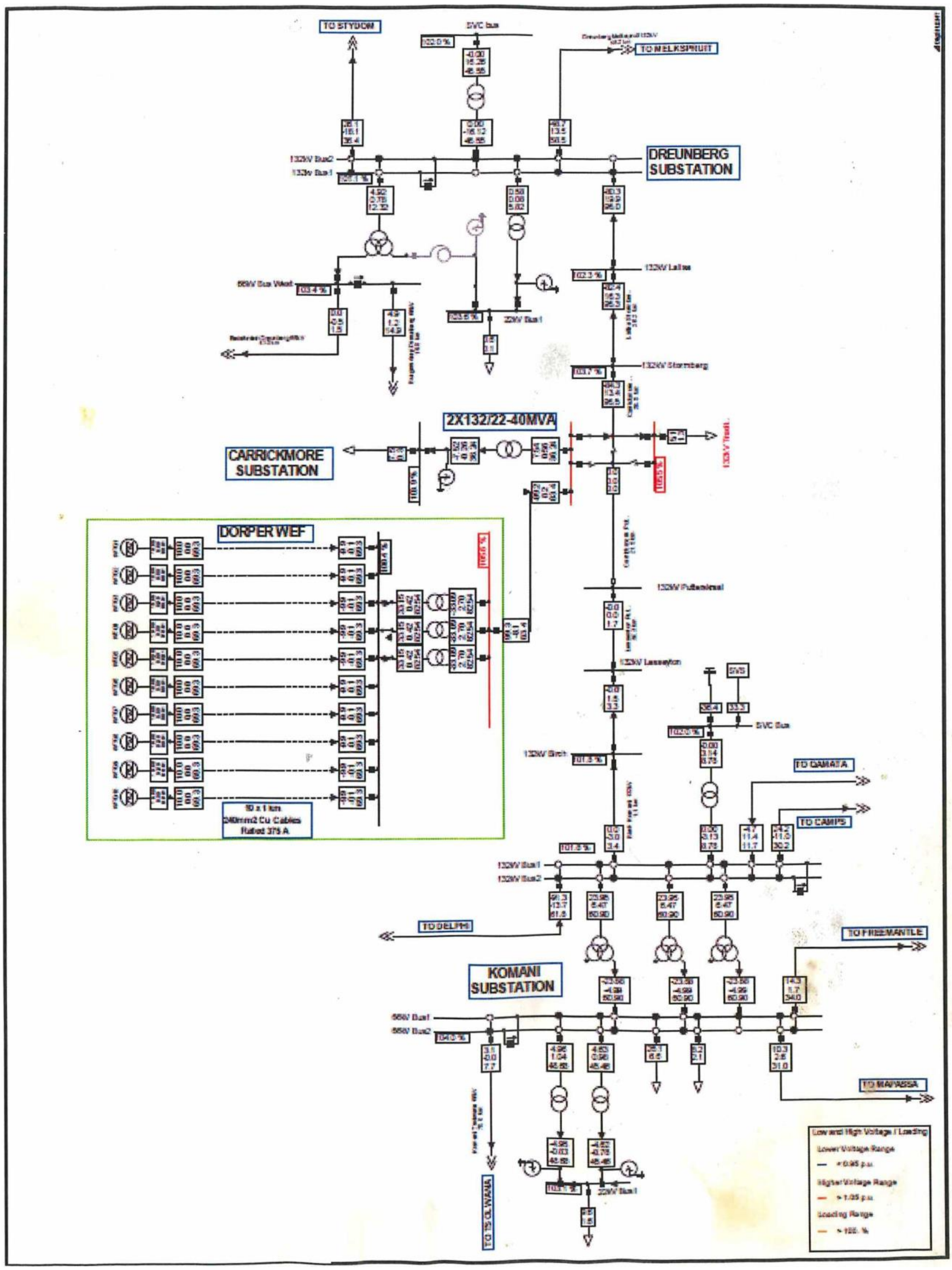
APPENDIX 3 (with 100MW at Dorper WEF (connected to Eskom grid at Carrickmore))



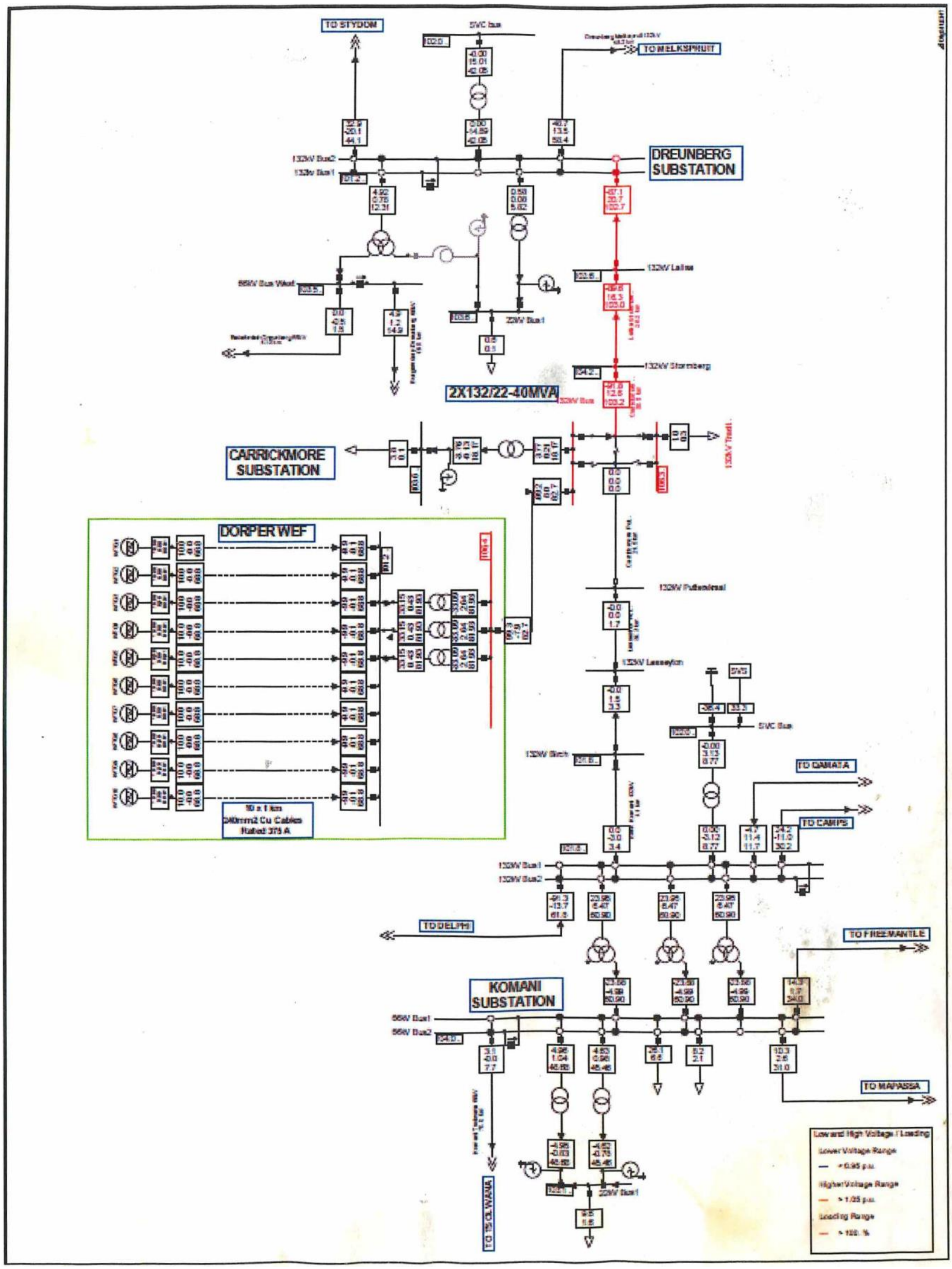
APPENDIX 4 (with Dorper WEF with Power flow under contingency conditions).



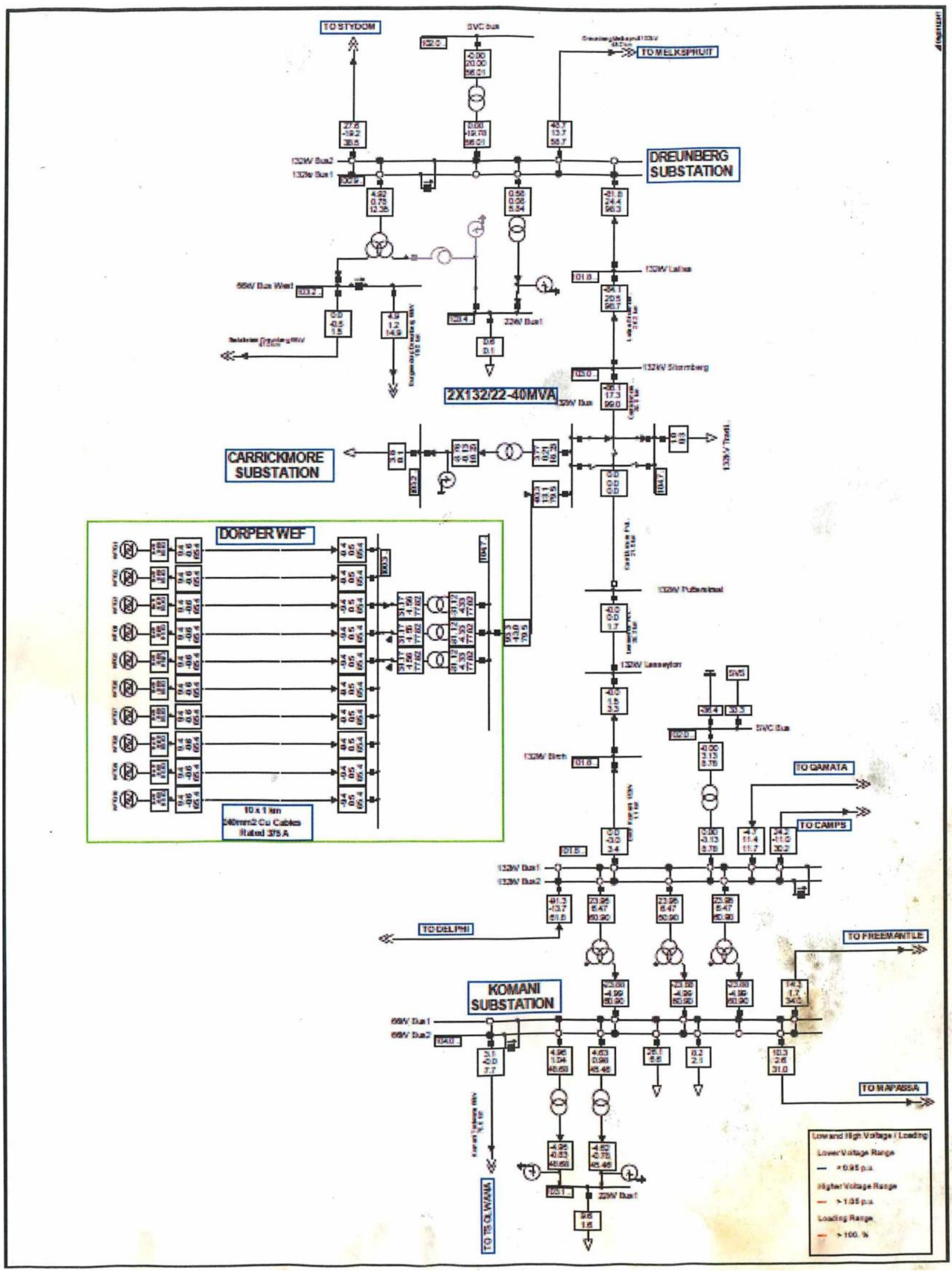
APPENDIX 5 (with Dorper WEF with voltage breach is observed at Dorper 132kV bus and also at Carrickmore 132kV bus)



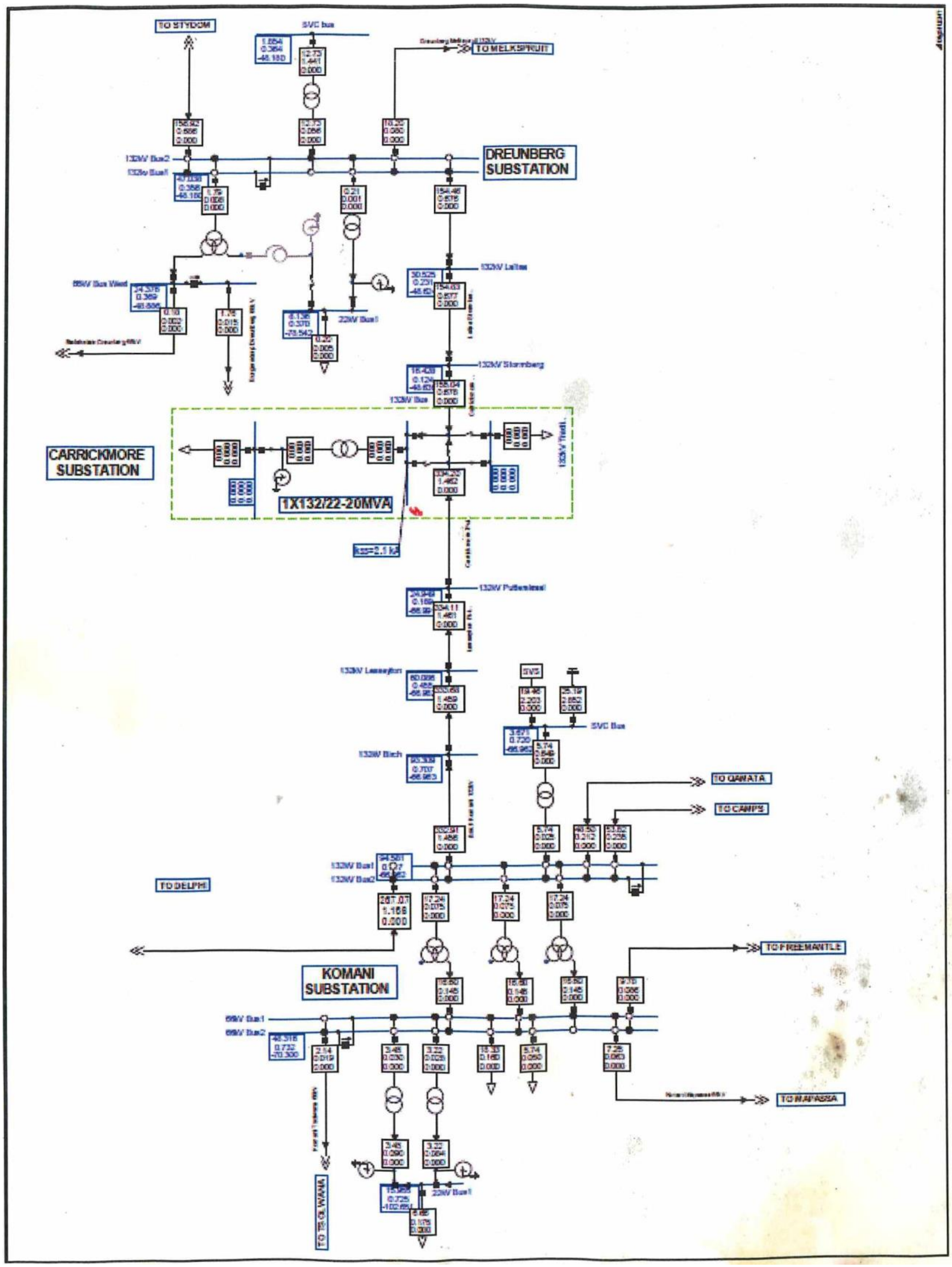
APPENDIX 6 (with Dorper WEF with Carrickmore – Putterskraal 132kV traction line is loaded at 95.5% of its thermal capacity)



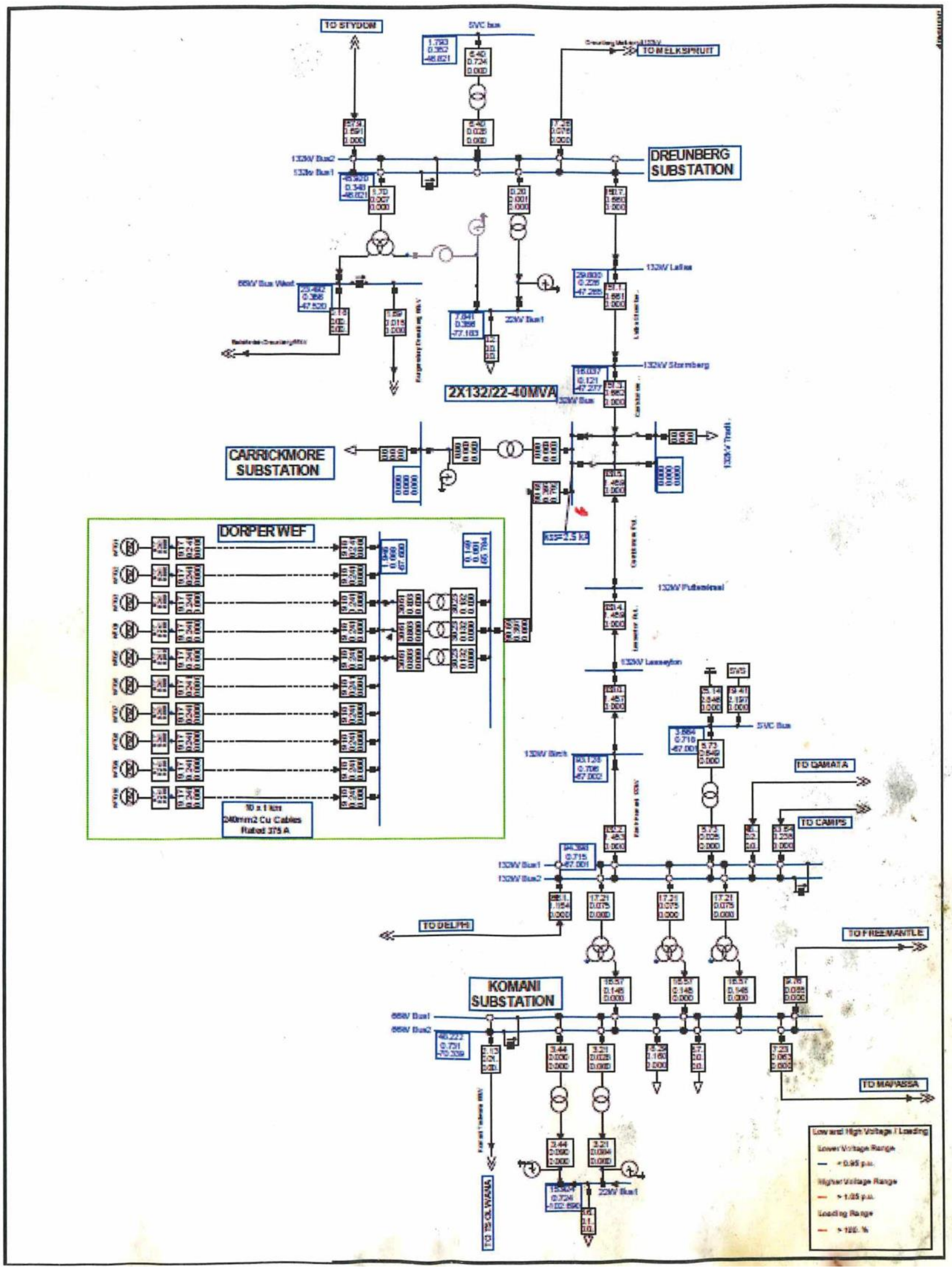
APPENDIX 7 (with Dorper WEF with maximum injection at Carrickmore when operating the WEF at 0.99 leading power factor is 93MW)



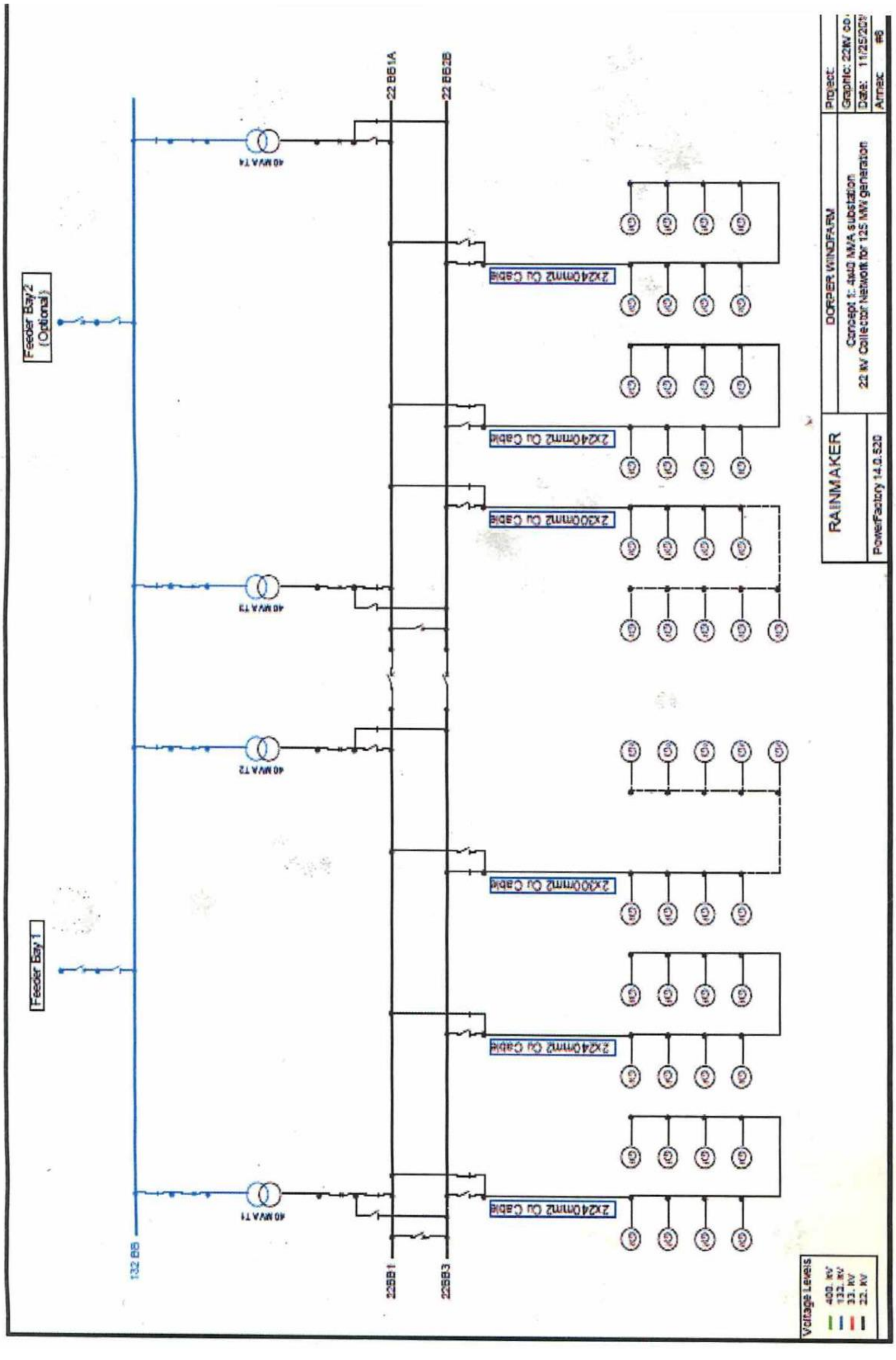
APPENDIX 8 (without Dorper WEF with voltage fault)



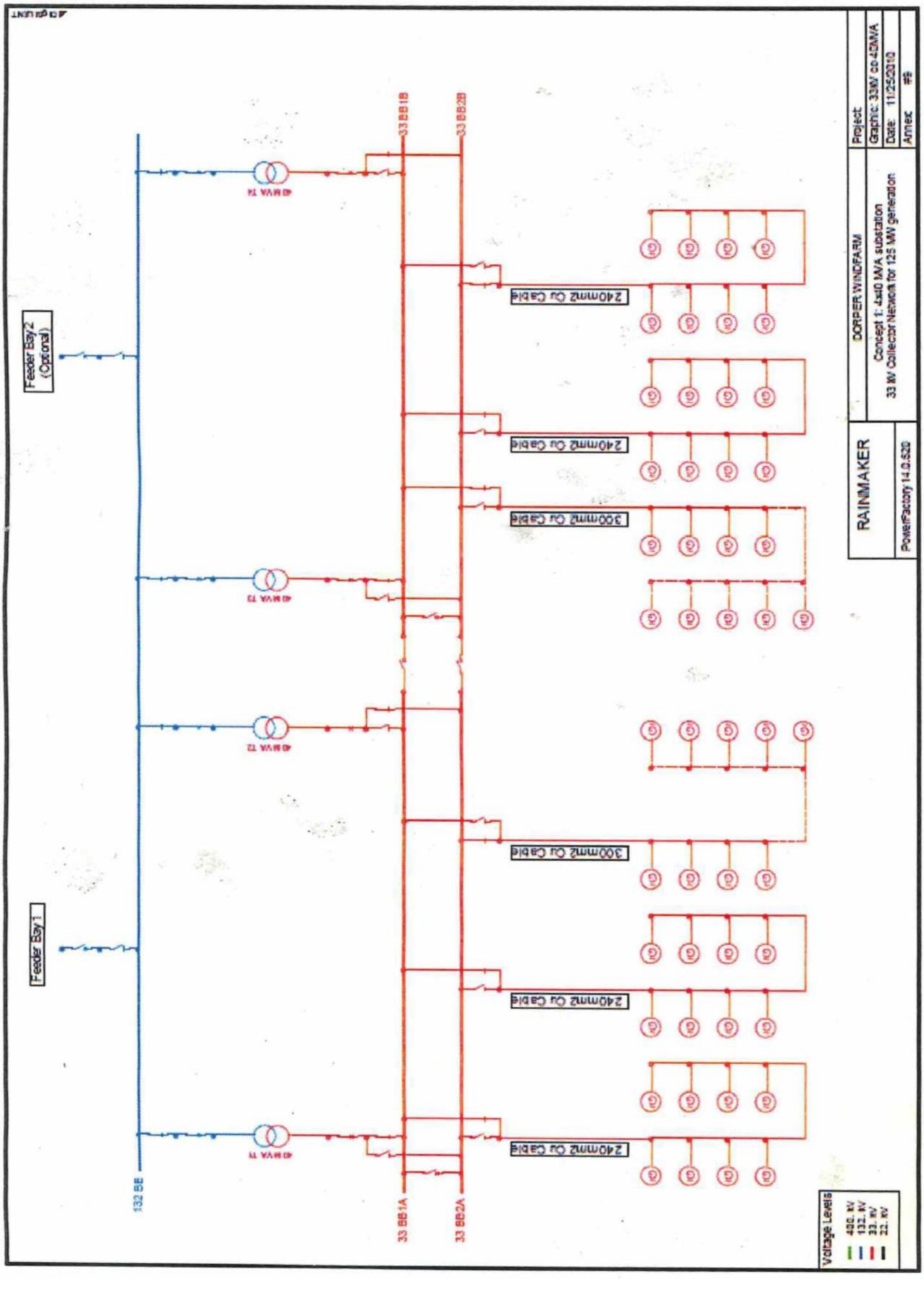
APPENDIX 9 (with Dorper WEF with voltage fault)



APPENDIX 10 (22kV Collector Network for 125MW generation)



APPENDIX 11 (33kV Collector Network for 125MW generation)



APPENDIX 12 (Rainmaker Dorper average hourly capacity factors for twelve months provided to TAP)

Hour of Day	Month (days)											
	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	Jul
	31	30	31	30	31	31	28	31	30	31	30	31
1	38.3	38.3	35.9	34.8	36.0	22.6	29.7	16.3	15.8	39.3	41.5	26.7
2	38.3	37.4	35.9	34.8	36.0	22.6	29.7	16.3	15.8	39.3	41.5	26.7
3	38.4	35.9	37.1	32.2	34.8	20.2	27.2	17.2	13.6	34.6	39.1	26.1
4	40.7	39.8	34.2	30.6	30.2	20.2	26.0	17.9	15.2	40.4	44.0	30.5
5	39.4	41.5	28.5	28.6	26.5	21.2	22.5	16.3	14.0	39.2	45.2	31.6
6	38.1	44.5	32.9	28.7	25.8	24.2	25.1	18.0	14.7	40.1	43.0	34.7
7	41.4	37.3	31.2	29.1	24.3	22.8	22.8	15.4	17.9	42.9	43.3	33.1
8	41.4	32.9	29.7	37.8	34.0	25.3	24.0	13.9	16.6	41.3	42.7	32.4
9	48.3	42.0	37.6	42.3	39.2	28.6	34.1	21.2	20.9	36.7	42.8	32.5
10	54.8	48.6	44.8	49.5	39.9	30.9	38.0	30.4	29.1	41.2	45.3	36.4
11	58.5	55.4	47.2	50.2	42.2	31.1	40.2	35.3	40.5	49.3	54.0	44.7
12	59.0	57.8	46.1	52.0	42.9	29.6	39.9	35.5	41.9	55.0	56.1	52.4
13	59.1	60.3	44.4	53.0	47.1	32.2	38.7	32.3	41.3	54.6	57.3	56.3
14	57.0	60.7	47.9	52.0	46.6	29.6	37.3	29.4	40.2	53.4	55.2	55.7
15	52.1	61.9	48.9	54.9	50.1	27.9	36.7	27.7	37.3	48.1	51.4	53.6
16	50.5	60.0	49.8	53.0	48.1	32.8	34.3	29.2	36.3	46.7	51.4	48.6
17	50.2	58.4	50.0	53.5	51.7	37.2	37.2	29.4	35.4	43.5	51.9	43.9
18	41.2	54.3	52.3	49.3	55.8	33.8	35.6	31.6	32.1	44.0	48.4	45.5
19	38.6	48.2	56.8	54.7	56.9	34.5	40.0	37.8	26.5	41.8	43.7	33.3
20	33.7	45.7	53.7	50.6	62.1	37.8	44.6	31.3	20.1	36.5	38.6	31.2
21	32.9	48.2	53.1	52.1	63.9	44.1	48.6	26.8	15.8	38.4	37.5	25.8
22	37.2	44.9	45.1	49.7	55.1	43.8	44.7	26.0	16.2	36.4	38.4	30.8
23	37.4	35.2	44.0	41.3	46.9	40.4	37.1	20.6	13.2	39.6	36.9	27.9
24	36.0	36.2	41.3	40.6	41.7	36.6	37.7	18.3	16.0	35.5	36.6	30.4
Average Monthly Energy	32 935.9	33 769.6	31 881.5	31 664.5	32 168.1	22 628.2	23 288.4	18 419.4	17 601.0	31 545.8	32 571.0	27 616.7
Yearly Energy (MWh)												336090.0