Commercial Feasibility Study of a Small-Scale Wind Turbine Manufacturing in South Africa

by
Vahid Yazdani

Thesis presented in fulfilment of the requirements for the degree of Master of Industrial Engineering in the Faculty of Engineering at Stellenbosch University

Supervisor: Konrad Von Leipzig and Theuns Dirkse van Schalkwyk

December 2015

Declaration

By submitting this thesis/dissertation electronically, I declare that the entirety of the work contained therein is my own, original work, that I am the sole author thereof (save to the extent explicitly otherwise stated), that reproduction and publication thereof by Stellenbosch University will not infringe any third party rights and that I have not previously in its entirety or in part submitted it for obtaining any qualification.

Date: January 2015

Vahid Yazdani

Abstract

Increased energy demand, price of energy carriers and the threat of climate change phenomena over the whole world have already had negative effects on the world's economy. Different strategies were adopted to address these problems. Among those, renewable energy sources have received substantial attention over the past 40 years. As a result various manufacturers all over the world started producing devices for capturing renewable energy and convert it to electricity for industry or household use.

Currently wind energy plays a fair share in electricity production around the world. However till recently small-scale wind energy generation hadn't received as much attention as the commercial wind turbines. The number of manufacturers of small-scale wind turbines is growing in the last few years and only 5 countries account for 50% of the production of small-scale wind turbines, none of which is located in the Africa. Although the African continent and specifically South Africa is considered ideal places for harvesting wind energy, the growth of small-scale wind turbines has been disappointing. Therefore, the financial feasibility as well as the risk of investment in such industries in South Africa were unknown.

In this study the financial feasibility of manufacturing small-scale wind turbines in South Africa is investigated. Initially a market study is performed identifying the target market, international and domestic competitors, target market share and the market growth in a 5 year forecast. Factors that affect the market are discussed. Having the market study and the market demand estimation the technical and financial @Risk model is developed by gathering information regarding the manufacturing methods, required raw material, machinery and equipment, required human resources and administrative section's requirements. Having the model, 4 scenarios are defined and the model is run for each of the scenarios.

In the first scenario the production range is considered as the first 10 percentile of the potential target market demand defined in the market study section, 10 to 30 percentile is used for the second scenario and 30 to 50 percentile for the third scenario. The model outputs relating to these inputs are investigated and discussed. A breakeven analysis is performed for the three scenarios and the scenarios are compared by the defined metrics such as Internal Rate of Return (IRR), Modified Internal Rate of Return (MIRR) and Net Present Value (NPV).

In the fourth scenario the condition that the wind turbine has to compete on sales price with photovoltaic (PV) cells, is investigated. Therefore the sales price is set to the same price as the PV panels in the market and breakeven analyses as well as the mentioned metrics are investigated.

The model gives an indication that it is financially feasible to manufacture small-scale wind turbines in South Africa by considering all the various outputs of the model. In addition the comparison of the first three scenarios shows that the second scenario has preferable results due to a moderate initial production volume for the first year of the entry into the market. This seems to be a rational decision for such product that is very dependent on external factors as well as the declining growth rate of the MIRR when the production volume increases, that you should not over-capitalize.

In the fourth scenario it is shown that by having the sales price the same as that of PV panels, the change required in sales is 27% more than for the breakeven point of the first three scenarios.

For future work, small-scale renewable hybrid systems, as well as more economical manufacturing methods for Africa could be considered.

Opsomming

Toenemende energieverbruik, koste van energie draers en dreigende klimaatsverandering in die wêreld, het reeds negatiewe uitwerkings op die wêreldekonomie. Verskeie strategieë word reeds gebruik om hierdie probleme aan te spreek. Onder meer het hernubare energie benutting groot aanhang verkry gedurende die laaste 40 jaar. Gevolglik het heelwat vervaardigers, reg oor die wêreld, toegetree tot produksie van toestelle wat hernubare energie vasvang en omskakel na elektrisiteit vir industrie of huishoudings.

Wind energie het tans 'n redelike aandeel in elektrisiteit opwekking in die wêreld. Tot onlangs het klein skaal wind generators egter nie sulke groot aanhang verkry soos kommersiële wind turbines nie. Die aantal vervaardigers van klein skaal wind generators het gegroei in die laaste aantal jare, maar steeds word 50% van die produksie behartig deur 5 lande, waarvan nie een in Afrika is nie. Alhoewel Afrika en meer spesifiek Suid Afrika 'n ideale plek is om wind energie te ontgin, toon die lae groei in gebruik van klein skaal wind toestelle dat dit nie baie aandag geniet nie. Dus is die finansiële en risiko situasie onbekend vir moontlike beleggers in die tipe industrie in Suid Afrika.

In die studie word die finansiële vatbaarheid vir die vervaardiging van klein skaal wind generators in Suid Afrika ondersoek. Met die aanvang word marknavorsing uitgevoer om te identifiseer waar die teiken mark, internasionale en plaaslike kompetisie, doelwit mark aandeel en groei in verkope sou wees in die volgende 5 jaar. Faktore wat die mark kan beïnvloed word bespreek. Met die kombinasie van marknavorsing en vooruitskatting van verkope, word 'n tegniese en finansiële @Risk model ontwikkel, wat vervaardigingsmetodes, benodigde rou materiaal, masjinerie en toestelle, menslike hulpbronne en administratiewe behoeftes insluit. Vier uitkomstes word gedefinieer en die model word geloop vir elke scenario.

In die eerste scenario is die produksie volume beskou as die eerste 10 persentiel van die potensiële mark, die tweede scenario gebruik die 10 tot 30 persentiel en die derde scenario die 30 tot 50 persentiel van verwagte verkope. Die model se uitsette ten opsigte van die insette word dan ondersoek en bespreek. Die gelykbreek analise vir die drie uitkomstes asook ander bekende maatstawwe soos Interne opbrengskoers (IRR), Veranderde Interne opbrengskoers (MIRR) en Netto Huidige waarde (NPV) word vergelyk.

In die vierde scenario word ondersoek hoe die situasie sou wees indien die wind toestelle direk op prys moet meeding met fotovoltaïese (PV) selle. In die geval word die verkoopsprys dieselfde gehou as soortgelyke PV selle, en gelykbreek analise asook die ander genoemde maatstawwe is ondersoek

Die model gee 'n aanduiding dat dit lewensvatbaar behoort te wees om die produksie van klein skaal wind turbines in Suid Afrika te onderneem, deur al die uitsette van die model in ag te neem. Verder, deur die eerste drie uitkomstes te vergelyk, word waargeneem dat scenario twee meer voordelig behoort te wees, veral as risiko's in die eerste jaar van toetree tot die mark in ag geneem word. Dit blyk ook logies te wees dat dit riskant is om te oor-kapitaliseer voor verkope in die eerste jaar bewys lewer van die aanvraag. Verder is die groei in MIRR laer indien die produksie volume verder opgestoot word.

In die vierde scenario word gewys dat indien daar direk op prys meegeding word met PV selle, dat daar steeds gelyk gebreek word, wel teen 27% hoër verkope as tydens die ander uitkomstes.

Vir toekomstige werk, kan klein skaal hernubare hibriede stelsels, asook goedkoper vervaardiging tegnologie vir Afrika oorweeg word.

Table of Contents

List of Figures

List of Tables

1 Introduction

1.1 Background

With the human population having reached seven billion in 2011 and expected to total eight billion in 2024, we may infer that increasing global energy demand is inevitable (Worldometers, 2015). In past years, this has led to increases in the price of fossil fuel which provided 85% of the total primary energy in 2008 (Intergovernmental Panel on Climate Change, 2012, p. 167). Increased use of fossil fuel results in higher carbon concentration in the atmosphere and augments the greenhouse phenomena and potential climate change, which threatens the life of all species on the Earth. These problems, together with resource scarcity are the main reasons for recent transformation toward renewable and clean energy sources.

The Sun has been known as the only practically inexhaustible and non-polluting energy source (Omer, 2008, p. 2270) from which other types of energy derive. Wind energy is considered to be the largest renewable energy source used for electricity generation because of its technological maturity and international established market, especially in Europe and North America. Recently it has received much attention all over the world (Ayodele et al., 2013, p. 1728).

Using wind turbines either on-shore or off-shore is aligned with climate change mitigation. Using the wind to generate electricity is rapidly expanding as its capacity in 2011 was around 1.8% of worldwide electricity demand, and it is expected to exceed 20% by 2050 (Intergovernmental Panel on Climate Change, 2012, p. 539). The penetration of wind energy in the market will be accelerated by advancements in technology which will reduce the cost of electricity generated by wind turbines, the significant potential of near-term and long-term reduction in emissions of Greenhouse Gas (GHG) and above all, of course, the economic support policies (Intergovernmental Panel on Climate Change, 2012, p. 541).

Wind turbines differ according to their size and technology. Wind turbines are available from multi-megawatts wind turbines to small off-grid wind turbines. The major classification is the alignment of the rotating axis as either vertical-axis or horizontal-axis.

1.1.1 Electricity Generation in South Africa

In 2006, South Africa's electricity generation came mostly from coal which supplied 91.7% of the total electricity generation capacity and secondly from nuclear sources, which supplied 4.2% (Department of Energy, 2010, pp. 20–21).

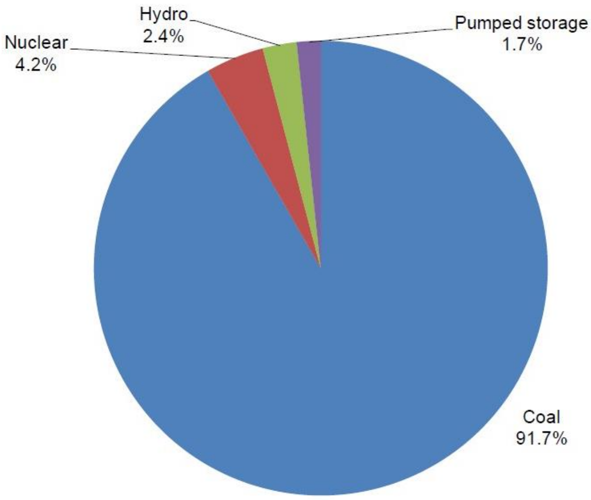


Figure 1: Electricity Generation Capacity for 2006 (Department of Energy, 2010)

As it is illustrated below, the major electricity consumer in South Africa during 2006 was the industrial sector which used 60.0% of total power generated and the second major consumer was the residential sector which used 20.4% (Department of Energy, 2010, p. 66).

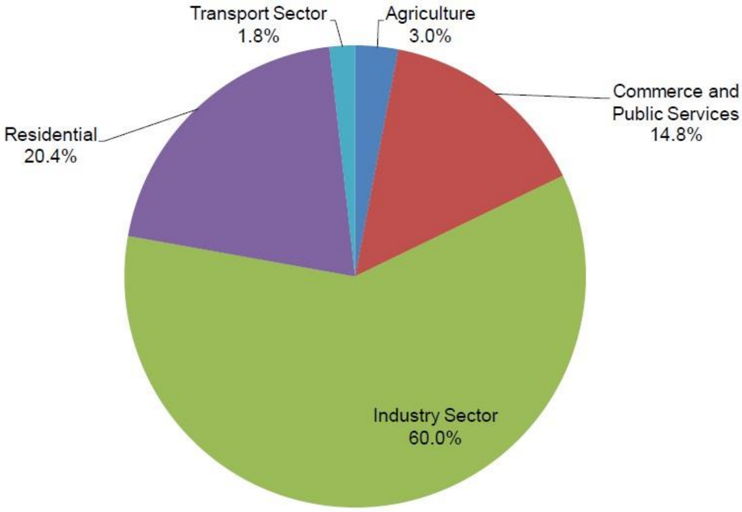


Figure 2: Electricity Consumption by Economic Sector for 2006(Department of Energy, 2010)

Eskom is the biggest and the most influential of the companies in the South African energy market. Eskom currently supplies electricity to almost 95% of the South African population and is among the largest electricity producers in the world (Eskom, 2011, p. 1).

1.1.2 Electricity Price Increasing in South Africa

As is the case in all countries, due to various reasons from increasing population to decreasing fossil fuel reserves, increases in energy prices and consequently electricity prices are the norm. South Africa is no exception to this, and due to a lack of sufficient new generation capacity, the current supply is close to the limits of the system and price increases were higher than the norm in the past 10 years.

Eskom as the major supplier of electricity in South Africa, proposes the annual price increase. However, for the last three years the proposed rate was higher than what was approved. For instance, the proposed rate for April 2012 to March 2013 was 25.9% of which 16% was approved (National Energy Regulator of South Africa, 2012, p. 24). Also in February 2013 the energy regulator approved an 8% increase annually even though the proposed rate was 16% (National Energy Regulator of South Africa, 2013, p. 24). This places emphasis on the severity of the situation and the attention it needs. So far one of the solutions for the energy crisis was to make use of renewable energy where possible. In the case of South Africa, solar and wind energy have proven that they are the most available and accessible sources of renewable energy.

1.1.3 South Africa's Renewable Energy Policy

South Africa is endowed with various renewable energy resources such as biomass, wind, solar, small-scale hydro and waste, which remained mostly untapped (Department of Energy, 2010, p. 43). In 2003, the government set the 10-year target for renewable energy which was a 10 000 GWh[1] contribution to energy consumption by renewable energy by 2013 mainly from biomass, wind, solar and small-scale hydro (Department of Energy (DoE), 2012, p. 2).

For long-term plans, as reflected in the Integrated Resource Plan (IRP 2010), South Africa's new capacity planning aims to add about 42% renewable-based capacity by 2030 (Department of Energy(DoE), 2011, p. 14).

1.1.4 South Africa's Wind Energy Potential

The coastal regions of South Africa have the best opportunity and highest potential for generating power from the wind. Also other areas such as the 'Eastern Highveld', 'Bushmanland' and 'the Drakensberg foothills' have moderate potential for that purpose (Department of Energy, 2010, p. 43). The South African wind atlas(Mortensen et al., 2012; SANEDI, 2014) shows promising wind power availability in the coastal areas.

1.2 Problem Statement

Various sources of information are available on the technical aspects of conventional wind power and its market, but not much is published about the market potential of small wind turbines in South Africa. Even though there is potential in wind technology, and larger wind farms are being implemented, stakeholders are still sceptical about the profitability of investing in business ventures to manufacture small- or medium-sized wind turbines. Therefore, not many wind energy-related industries have been established in the region. There are also unquantified risks involved in entering the off-grid electricity markets in Africa. Small-scale electricity generation by utilising the wind is not widely used in the African markets and the market size is unknown. There is also little previously published research about the manufacturing costs of wind turbine systems in southern Africa. Therefore, the research question according to the problem stated above is: *Would small-scale wind turbine manufacturing be financially feasible in South Africa?*

[1] Gigawatt Hours

1.3 Thesis Outline

1.3.1 Feasibility Study

To answer the research question, a feasibility study needs to be performed. There are a number of variations in feasibility study types and approaches. These variations could be caused by the product or service which the feasibility study is about, the region and environment that the study is taking place in and the focus of the study on technical or financial aspects or both.

Professionals have different definitions for a feasibility study which might not be completely compatible with the specific conditions where a feasibility study is being done. For instance Blank (2005) defines feasibility study and business plan as a one-page description that includes all the flows between the company and the clients, including costs and income cash flows. As it is clear, the said approach is from a business point of view which has emphasised mostly the relationship between the different components involved in a business.

From a project management point of view, a feasibility study is an inseparable part of any project. Heldman (2007) defines the purpose of the feasibility study as to determine whether the project is worth undertaking and whether the project will be profitable to the organisation. In this definition, the financial aspect of the feasibility study is emphasised on and, therefore, financial metrics are the deliverables of this approach.

As mentioned, the approach to a feasibility study is affected by the product or service, environmental factors and the focus of the feasibility study. For the purpose of this study, since the product and the market are unique, an approach has been adopted based on the points mentioned in the above quotes. This approach is based on the relation that the product has with the market and the Company itself, which is seen from the technical and financial point of view, with emphasis on the financial section. The following diagram shows the different components of the study and their collaboration with each other.

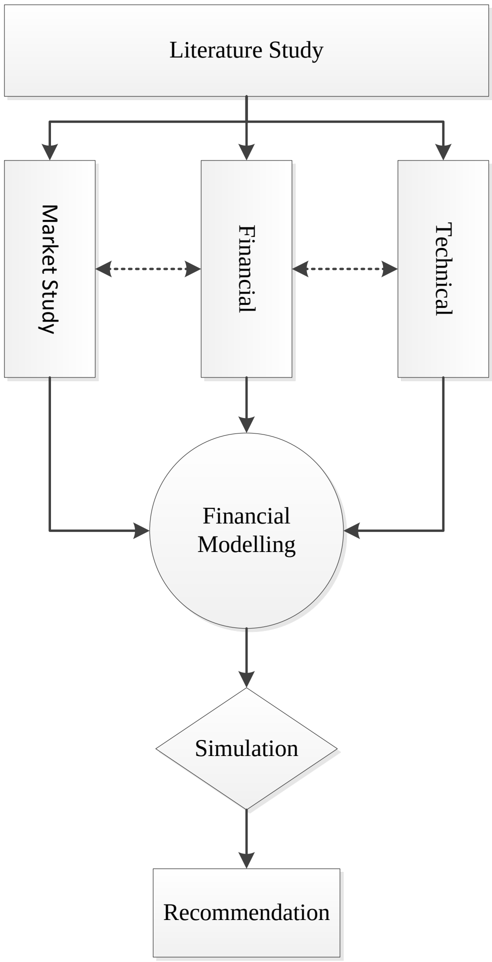


Figure 3: Thesis Structure

The components in this feasibility study are defined as the products and the clients and the relationship between the two. In order to study the clients, a market study is performed. As for the product the technical section is where the product and its components are described. Since the focus of this feasibility study is on the commercial aspect, a financial section is developed to map out the direct and indirect costs involved in production of the product. Then a model is designed based on the information in the previous sections. Different scenarios are considered for the simulation phase based on the designed model. Then recommendation is made with respect to the simulation's outcomes.

For initiating the study the type of technology and the market area have to first be defined.

1.3.1.1 Type of Wind Turbine

As regards the technological selection of a wind turbine, the small wind turbine was chosen out of the three main categories, as is suggested by the title of this thesis. The small wind turbine category also concludes three sub-categories called micro, mid-range and mini. Small wind turbines have applications in off-grid domestic house roof-tops, farms, remote communities and boats (Singh and Ahmed, 2013, p. 812).

There are basically two major conceptual wind turbine designs which are named based on the position of the rotor's axis, Horizontal Axis Wind Turbines (HAWT) and Vertical Axis Wind Turbines (VAWT) (Ozgener, 2006, p. 1328). The HAWTs are designed to use lift force for generating electricity where most of the VAWTs use drag force (Tong, 2010, p. 396). As explained, the lift-driven wind turbines have much higher performance in comparison to that of the drag-driven wind turbines. The modern wind turbine's efficiency reaches an average of 40-45% (Ozgener, 2006, p. 1328). For the purpose of this study, the HAWT is considered for the production. This choice will be explained more in details in the next chapters.

1.3.1.2 Target Market Region

As mentioned above, the coastal regions of South Africa are considered as an ideal place for harvesting wind energy via small-scale wind turbines. In order to have sufficient data regarding the wind energy in the area, the focus of the study will be on the regions where wind data is available in the Wind Atlas of South Africa (WASA) (SANEDI, 2014).

1.3.2 Study Organisation

This study comprises six chapters. The first chapter is an introduction to the problem and the thesis outline and organisation which serves to provide the reader with the background to the main topic of the study.

In the second chapter, a comprehensive literature study of the wind and how it has been used over several centuries is done. This is then transitioned to the modern usage of wind energy as a renewable source of energy with the explanation of its standing among the other renewable and non-renewable energy sources available in the world. Thereafter follows a narrower scope for small-scale wind turbines and the international market for them as well as manufacturing potential around the world.

The third chapter consists of a comprehensive and detailed market study including market identification, identification of competitors, definition of the product's range and finally formulating the target market share and its expected growth over the next five years.

In the fourth chapter, the technical aspects of the product's manufacturing requirement and methods as well as the administrative section of the Company will be discussed. (The term 'the Company' refers to a hypothetical company which is used as an example for this research project.) Furthermore, in that chapter the production capacity of the equipment and employees will be calculated.

In the fifth chapter all the elements involved in the financial aspects of the Company will be the focus of the discussion. The variable cost, fixed cost and product's selling price will also be discussed, followed by the factors that affect the financial state of the Company in a 5-year plan. In the next section, the financial model of the Company over the course of five years will be presented and then a sensitivity analysis will be performed on the model based on different scenarios and the best performing scenario will be recommended as the Company's policy to approach the market.

In the last chapter, a summary of the work presented and the conclusion of the appraisal along with the recommendations for further work in the field will be mentioned.

2 Wind Energy and Conversion Technology

2.1 Introduction

In this chapter an extensive literature study on the wind is done and the natural phenomena that create and affect wind are discussed. Further in the chapter the history of how humankind made use of wind in the past is reviewed.

The physics rules related to electricity conversion from the wind are discussed in the next section and the machines that convert wind energy to electricity are classified later in the chapter. Considering the advantages and disadvantages of each class of technology, the best option is selected for consideration later in the study. In the literature study, the size categories of the class of wind turbine are investigated and the ones more suited to the purposes of this study were chosen.

Later in the chapter the energy sources in the world are discussed and classified and the usage trends discussed with respect to future requirements and considerations. Then the small wind energy's international market and its trends are investigated and the forecast for its growth over 5 years is estimated. Finally, the increasing number of manufacturers in this sector according to market growth is discussed. It is identified that some regions, in spite of having ideal wind energy availability, do not play a decisive role in the manufacturing of small wind turbines.

2.2 Wind

Air in motion is called wind. The wind is mostly formed when the sun heats one part of the atmosphere differently from other nearby parts. According to thermodynamic laws the warmer air expands more than the colder air and they therefore have different densities. The difference in temperature and density causes horizontal and vertical movements, as well as high pressure and low pressure areas in the atmosphere. The warmer parts, with lower density, rise and create lower pressure and the colder parts with higher pressure flow toward the low pressure, which as a result generates the wind (Lynn E. Newman, 2007).

2.2.1 Wind Patterns

Geographical patterns on the Earth's surface as well as day and night have prominent effects on how wind forms. These patterns can be divided into two main patterns, global patterns and local patterns.

2.2.1.1 Global Patterns

Uneven heating between the poles and the equator is the cause of global patterns. The same concept that high pressure travels toward low pressure is applicable here as well. Higher temperature air around the equator creates low pressure and moves air upward toward a higher altitude while the high pressure air around the poles moves toward the equator. This movement creates the global pattern of the wind that is affected by the movement of the Earth itself, which creates different directions in different latitudes. This movement creates an effect which is called the 'Coriolis effect'. Because of the 'Coriolis effect' in each 30 degrees latitude section the wind direction is different from the adjacent 30 degree sections (Lynn E. Newman, 2007).

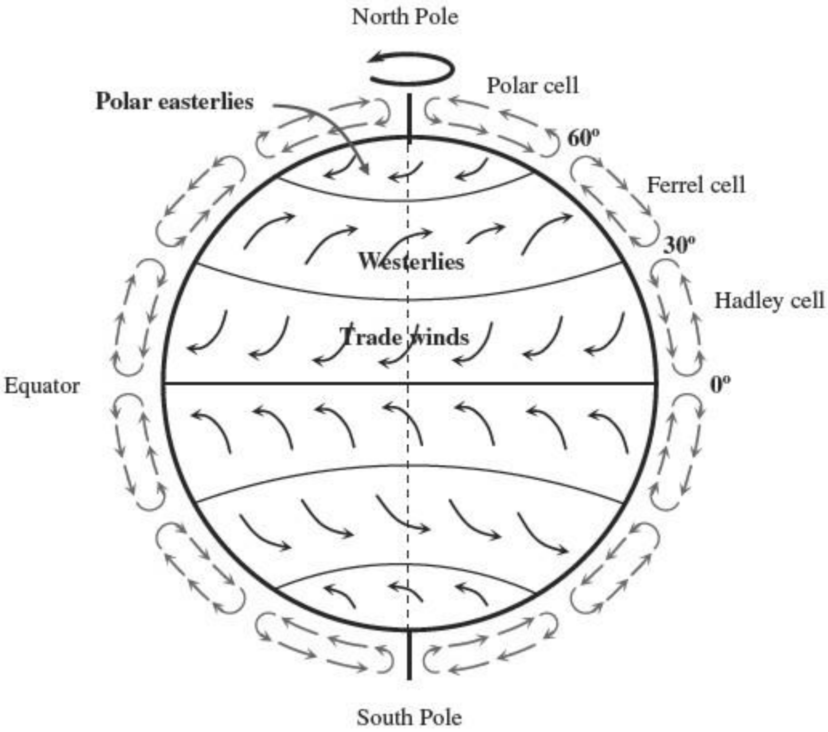


Figure 4: Atmospheric Circulations Pattern (Tong, 2010, p. 6)

Besides these large movements of air around the world, there is another phenomenon that occurs when polar and tropical air that have considerable temperature differences meet. This type of wind happens at high altitude around 9-11 km[1] above sea level and its speed can reach up to 400 km/h[2].

2.2.1.2 Local Pattern

This pattern is created based on the same rules as those of the global wind pattern, but on a smaller scale. The local pattern happens because of geographical features of each region on the Earth, therefore in each region it is different and named differently. The most prominent geographical features are seas and mountains.

In sea shore areas, there are two types of wind which are called ‘sea breeze’ and ‘land breeze’. During daytime, the air on land gets warmer faster than the air above the sea due to the difference in the specific heat coefficient and, therefore, it requires more energy in order for the temperature to increase, and as has been said, warmer air has lower pressure than cooler air. Therefore, the air above the land moves toward higher altitudes. Meanwhile, the cooler and higher pressure air above the sea moves toward the land to take the place of low pressure air. This movement of air toward the land from the sea surface is called ‘sea breeze’ (National Weather Service, 2008).

The reverse happens during night, since at night the air over the sea is warmer than the air over the land due to the higher specific heat coefficient of water. Consequently it has lower pressure and therefore it tends to move toward higher altitudes and the colder air with higher pressures over the land moves toward the sea surface to take its place. This movement of air from land to sea during the night is called ‘land breeze’. The intensity of wind is dependent on temperature differences between the land and sea (National Weather Service, 2008).

[1] Kilometre
[2] Kilometre per Hour

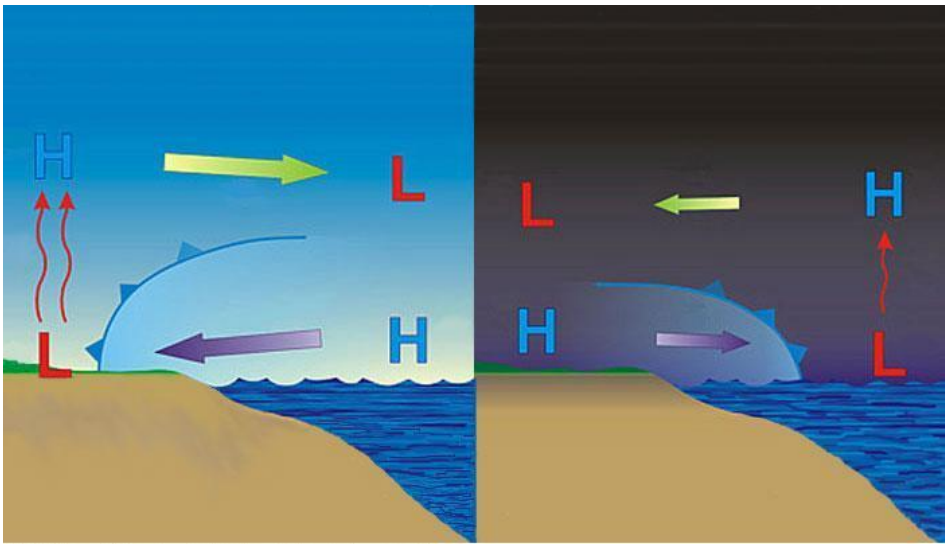


Figure 5: Sea Breeze and Land Breeze (National Weather Service, 2008)

Another type of wind occurs in regions where mountains and valleys exist. During the day, the surface of the mountain's slope heats up the air more quickly than the valley's floor and creates a low pressure area. Therefore, the high pressure air in the valley moves towards the top of the mountain. This is called, 'valley breeze'. Often birds such as raptors use this kind of breeze to float on the rising air currents to save energy (Lynn E. Newman, 2007).

During the night, the same happens but in the opposite direction since the slope cools down the air more quickly than the valley's floor. As this creates higher pressure than the valley's floor, the air on the slope moves towards the valley. This is called 'mountain breeze' (Lynn E. Newman, 2007).

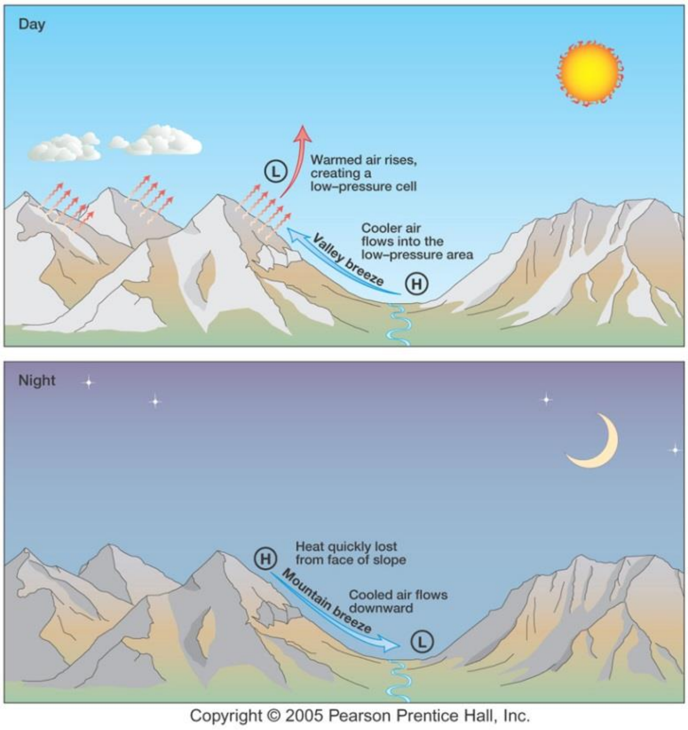


Figure 6: Valley and Mountain Breeze (Lynn E. Newman, 2007)

2.2.2 History of the Wind

2.2.2.1 History of Humans Using Wind Energy

Wind energy has been used for many centuries to power sailing ships. Many countries competed using their sailing skills to dominate the market by trading goods using of marine transportation. Also, the Americas were explored by wind-powered ships. In fact, the wind was the only source of power for ships until *Watt*[1] invented the steam engine in the eighteenth century (L. Johnson, 2001, p. 10). There are speculations about the history of using wind and some of them claim that there is evidence of ruins which once were windmills in Egypt around 3 000 years ago. However, the first reliable source of information regarding the existence of windmills originates from the year AD 644[2]. in the east of Persia in the region of Seistan (Hau, 2006, p. 18).

Figure 7: The windmill in Persia was a vertical axis machine used for grinding grains (Hau, 2006, p. 2).

The earliest evidence of a wind turbine in England is dated 1191 and the first wind turbine that was used for grinding corn was built in Holland in 1439. By 1600, tower mills were developed from the previous design. In this design, the tower was a fixed structure but the cap could rotate around its vertical axis so that the operator could turn the rotor to face the wind and then fix it in that direction. In the mid-1700s Dutch settlers took tower mills to America. In the middle of the following century, the need for pumping water from underground for their grazing land forced them to develop a new wind turbine which was called the ‘American multi-bladed wind turbine’ (L. Johnson, 2001, p. 11).

[1] James Watt
[2] Anno Domini

2.2.2.2 History of Electricity Generation from Wind Energy

The early twentieth century is known as the start of the electric era. The rapid developments in electrical devices by *Edison*, *Tesla* and others offered the promise of an electric-powered Utopia (Carlin et al., 2003, p. 130). However, Denmark was the first country that used the wind to generate electricity. In 1890, they used a 23 m[1] diameter wind turbine. A few decades later commercial wind electricity plants came to the American market using two- or three-bladed propellers. At that time, they also used small wind turbines to power farms and remote areas. The common brands of that time were Windcharger (200 to 1 200 W[2]) and Jacobs (1.5 to 3 kW[3]). They have been used on farms to charge storage batteries which were later used to operate lights, radios, and small home appliances (L. Johnson, 2001, p. 11). In 1937 the creation of rural electric associations started the demise of the stand-alone DC[4] machines that were used on the farms. As AC[5] grids spread throughout the rural areas of America, the need for these machines began to fade (Carlin et al., 2003, p. 130).

After 1940, the cost of utility generated electricity continued a slow decline, which was accomplished by using larger and more efficient generating plants. This trend changed its direction toward increasing in the early 1970s due to the increase in other costs as well as the population. Meanwhile, a number of utilities had built larger wind turbines to supply power to their customers. The largest wind turbine built before the late 1970s was a 1 250 kW wind turbine near Rutland in 1941. In 1957 Denmark built a wind turbine that produced 200 kW in a 15 m/s[6] wind in Gedser. This wind turbine worked until 1968. In the same year in Germany a 100 kW machine was built which could reach its rated power output at a wind speed of 8 m/s and used blade pitch changing to keep the propeller angular velocity constant at higher wind speeds. This machine worked for 11 years and made important contributions to the design of larger wind turbines (L. Johnson, 2001, p. 13).

In the US, the Federal wind energy programme started working in 1972 when it was recommended that wind energy must be developed to broaden the energy options from new energy sources (Hau, 2006, p. 60). Not long after that the development of modern wind energy technology began in Europe with Denmark, Sweden and Germany leading the way (Hau, 2006, p. 60).

In the eighties, the initial Programmes for developing wind energy technology were oriented specifically toward the construction of large turbines. Because of the projects' magnitude these large wind turbines were built almost exclusively by large and well-known companies; in the US, Boeing, General Electric and Westinghouse; in Germany MAN, MBB, Dornier and Voith; and in Sweden, Kvaerner (Hau, 2006, p. 62).

In Denmark, a commission of experts declared that it should be possible to provide 10% of total Danish power requirements from wind energy without creating particular problems in the public power grid. It was decided to recommission the 200 kW plant near Gedser which was built in 1957. That turbine, which had been decommissioned in 1967, was overhauled in collaboration with NASA. At that time along with the development of large turbines, the private use of small turbines was promoted. By 1990, more than 2 500 turbines with the total of 200 MW[7] output formed the foundation

[1] Diameter
[2] Watt
[3] Kilowatt
[4] Direct Current
[5] Alternating Current
[6] Meter per Second
[7] Megawatt

of the Danish wind turbine industry. The same advancements happened in neighbouring countries, as Germany started to actively promote wind energy in 1974 and Sweden in 1975 (Hau, 2006, p. 60).

Figure 8: Danish Gedser wind turbine (rotor diameter 24 m, rated power 200 kW), 1957 (Hau, 2006, p. 41)

In the Netherlands, the National Research Program on Wind Energy's (NOW) aim was to determine whether or not wind energy could contribute significantly to the energy supply of the country. In the first phase, they started to gather the knowledge available in the world and from there started exploring the technological options. The options available at that time were horizontal axis wind turbines as well as vertical axis wind turbines. Based on the knowledge gathered in the first phase, the most suitable places were also identified and the total capacity calculated. It was announced by the government that the potential range for large-scale wind power stations would be from 1 500-2 500 MW[1] by the year 2000 (VERBON, 1999, p. 148).

In the United States large-scale experiments were conducted from 1975 to 1987. The project was named MOD and contributions were made by large companies mentioned in the following table.

[1] Mega Watt

Table 1: Large Experimental Wind Turbine in US from 1975 to 1987 (Hau, 2006, p. 63)

Wind Turbine	Size	Power	Made by	Year
MOD-0	38 m	200 kW	NASA	1975
MOD-1	61 m	2 000 kW	GE	1979
MOD-2	91 m	2 500 kW	BOEING	1980
MOD-5	97 m	3 200 kW	BOEING	1987
MOD-5A	122 m	7 300 kW	GE	1983

In Canada, during these years, the governmental research institutions initiated a development programme which focused on vertical axis wind turbines of the Darrieus type. This programme reached its peak with the construction of the largest Darrieus wind turbine ever in 1985 with a height of 100 m and an equatorial diameter of 64 m. It was clear that this VAWT type was not as efficient and economical as the available technology at that time related to HAWT (Hau, 2006, p. 64).

Figure 9: Darrieus Turbine (4 MW rated power), Canada, 1987 (Hau, 2006, p. 69)

In the seventies and eighties, the development projects worked their way through in some other countries as well but with less drive and less satisfactory outcomes.

The main reason that governments tried to make advancements in wind turbine industries was because of the energy crisis during the seventies, but by the mid-eighties, it was discovered that substantial reserves of natural gas were still available. Again utilities started converting back to natural gas for their turbines. Subsequently, the development of wind power was delayed again (L. Johnson, 2001, pp. 21–22).

In the early twenty-first century, attentions turned again toward renewable energy. The fact that oil and gas are limited and will be finished in the near future, along with population growth, which results in increasing demand for energy, were not the only reasons for turning the attention toward renewable energy this time. While those reasons were part of the transition another problem was discovered. "*In 2001 an international panel of distinguished climate scientists announced that the world was warming at a rate without precedent during at least the last ten millennia, and that warming was possibly caused by the build-up of greenhouse gases from human activity*" *Spencer Weart* (R. Weart, 2008).

Since the climate change issue had been raised and indicated that a major reason was usage of fossil fuels, the focus on advancing and developing the renewable energy sector, in this instance wind power, became more intense. At this stage the focus was mainly on increasing the efficiency of wind turbines by applying aerodynamic principals to design new blades and on making bigger wind turbines to harness more wind power (Sahin, 2004, p. 517). This led to the construction of larger wind farms all over the world; in Asia by India, Japan and China; in Europe by Germany, followed by Denmark and Spain; and in the West by the US and Canada (Hatziargyriou et al., 2010, p. 1765).

These developments required more space for implementation, but with the high population density in Central Europe the space was limited. These limitations led to offshore developments in Europe (Ackermann, 2005, p. 65).

Since then the development of wind farms has been increasingly implemented by governments both in onshore and offshore sites.

2.3 Electricity Conversion from Wind Energy

2.3.1 Wind Physics

Based on the '*Conservation of Energy law*' the energy in the universe only changes from one form to another but the amount of energy is constant; this law is also applicable to converting wind energy into electricity. It can be done through a wind turbine which converts the kinetic energy contained in the moving air, into mechanical energy at the first stage and from that to electricity by means of a generator. This conversion follows basic rules (Hau, 2006, p. 95).

Albert Betz realised that the mechanical energy extractable from the moving air passing through an area is restricted to a fixed portion of the available power in that moving air. His findings have been providing the basics for the understanding and operation of wind energy convertors of all kinds (Hau, 2006, p. 95).

In the following sections some of the wind energy properties and the factors that may affect the energy harvesting of it, will be explained.

2.3.1.1 Energy in Wind

The Sun shines constantly on the Earth and basically the Earth is alive because of the Sun that provides energy for living things. The Earth absorbs 1.5×10^{18} kWh annually from which only 2% is converted into energy of motion in the air, in other words turned to wind (Hau, 2006, p. 453).

2.3.1.2 Distribution of Wind Speed

One of the most critical characteristics in wind power generation is wind speed. Many factors affect wind speed such as geographic features, time of day as well as weather conditions. Since the wind speed is a random parameter, in order to estimate the amount of power that can be captured in certain areas, the average of the wind speed is not enough. For instance, wind turbines installed at two sites, exposed to the same wind speed average may yield completely different energy output due to the difference in the wind speed distribution. By gathering wind data and finding the best distribution that can be fitted to the captured data, the distribution of wind speed in a certain area can be estimated. A number of papers have been published on the efforts to develop an adequate statistical model for describing wind speed frequency distribution to provide a simple method to predict the energy output of a wind energy conversion system. The Weibull two parameter (k, shape parameter and c, scale parameter) has received most of the attention as a good fit for a wide collection of wind data (Lun and Lam, 2000, p. 145; Mathew, 2006, p. 64; Tong, 2010, p. 12).

2.3.1.3 Wind Shear

As has been mentioned, 2% of the total energy absorbed by the Earth is converted to wind. This amount of energy is also distributed unevenly at different altitudes. This meteorological phenomenon is called wind shear. There is a relation between the height and the wind speed which can be estimated by using the Hellmann power equation which shows that wind speed increases with height above the ground. The phenomenon is mainly due to the roughness on the Earth surface and is expressed as (Tong, 2010, p. 15):

$$\mathrm{u_z = u_{z_0}\left(\frac{z}{z_0}\right)^a}$$

Where z is the reference height above the Earth's surface, z_0, for which wind speed u_{z_0} is known, and a is the wind shear coefficient. The roughness of the terrain affects the wind shear coefficient. Thus as height above ground is increased, wind speed increases too, rapidly for the first few metres but as the height increases the increasing wind speed ratio decreases. A typical value of the wind shear in a relatively flat area is around $\alpha = 0.2$ (Albright and Vanek, 2008, p. 344; Mathew, 2006, p. 47).

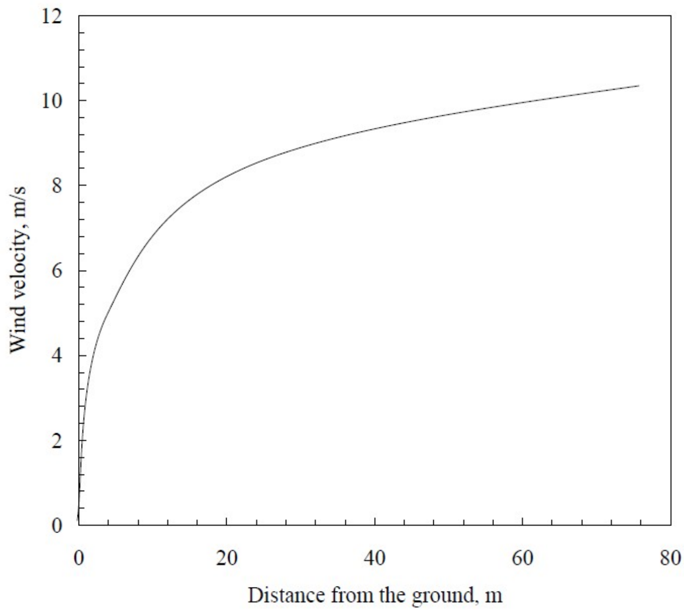


Figure 10: Variation of Wind Velocity with Height (Mathew, 2006, p. 48)

2.3.1.4 Betz's Momentum Theory

Betz's law, as was said before, is the fundamental theory for harvesting wind energy. The Betz theory explains that even in an optimum way only a portion of wind energy can be captured and it also points out that it is not possible to harvest all the energy in the wind. The energy of the moving air can be expressed in following equation, where the air mass is 'm' and air moves at velocity of 'υ':

$$E = \frac{1}{2} m\upsilon^2 \text{ (Nm[1])}$$

Considering a vertical cross-sectional area of 'A', which air passes through it at the velocity of 'υ', the volume that passes through in a time unit is:

$$\dot{V} = \upsilon A \text{ (m}^3\text{/ s[2])}$$

The mass that flows through the vertical cross-sectional area is proportional to air density 'ρ', can be calculated as:

$$\dot{m} = \rho\upsilon A \text{ (kg/s[3])}$$

Therefore, the kinetic energy per second of the moving air through the vertical cross-sectional area is defined as power P:

$$P = \frac{1}{2}\rho\upsilon^3 A \text{ (W)}$$

This power is converted into the mechanical form of energy and since the mass remains unchanged, the velocity of the mass must decrease, which results in a reduced speed in the moving air. Reduced velocity means increase in the cross-sectional area, as the same mass flow must pass through it. Therefore, it is necessary to consider the conditions before the air passes through the cross-sectional area and after that. The power in the moving air cannot be extracted entirely, as the moving air would be stopped completely in the vertical cross-sectional area. The mechanical energy that a converter can extract in the cross sectional area as illustrated in figure 11 corresponds to the difference in energy of the air stream before and after the cross-sectional area (Ackermann, 2005, pp. 33–34; Hau, 2006, pp. 95–98):

$$P = \frac{1}{2}\rho A_1\upsilon_1^3 - \frac{1}{2}\rho A_4\upsilon_4^3 = \frac{1}{2}\rho(A_1\upsilon_1^3 - A_4\upsilon_4^3) \text{ (W)}$$

As has been said, the mass passing through each section remains unchanged:

$$\rho\upsilon_1 A_1 = \rho\upsilon_4 A_4 \text{ (kg/s)}$$

[1] Newton Meter
[2] Cubic Meter per Second
[3] Kilogram per Second

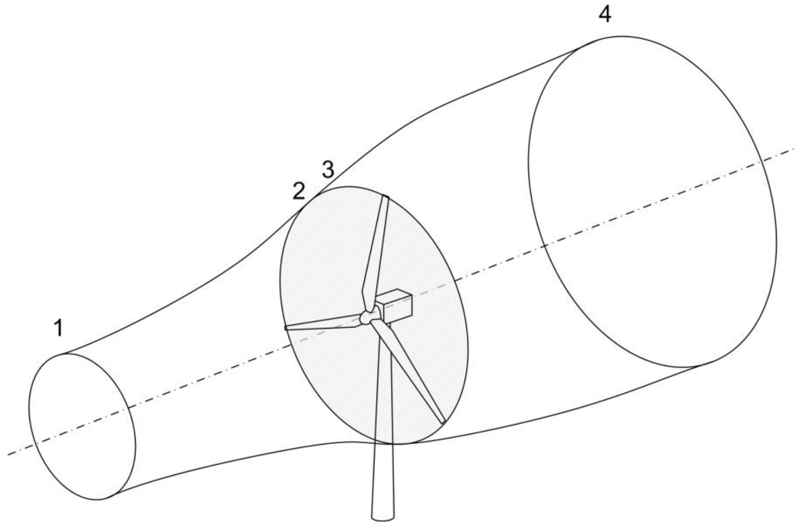


Figure 11: Flow Conditions According to the Momentum Theory (Branlard, 2008)

Thus,

$$P = \frac{1}{2}\rho\upsilon_1 A_1(\upsilon_1^2 - \upsilon_4^2)\ (W)$$

Also, the thrust force experienced by the rotor is because of the difference in momentum on either side of the converter:

$$F = \rho A_1 \upsilon_1^2 - \rho A_4 \upsilon_4^2\ (N)$$

To maintain the equality of mass on either sides of the convertor the equation can be rewritten as:

$$F = \rho A_1 \upsilon_1(\upsilon_1 - \upsilon_4)\ (N)$$

According to the principle of '*action equals reaction*' the thrust force is counteracted by an equal force which is exerted by the converter. The thrust pushes the air at velocity 'υ_3'. The power required for the push is (Hau, 2006a, p.83):

$$P = F\upsilon_3 = \rho A_1 \upsilon_1(\upsilon_1 - \upsilon_4)\upsilon_3\ (W)$$

From the above, the equation below can be concluded:

$$\frac{1}{2}\rho\upsilon_1 A_1(\upsilon_1^2 - \upsilon_4^2) = \rho A_1 \upsilon_1(\upsilon_1 - \upsilon_4)\upsilon_3$$

Thus υ_3 is:

$$\upsilon_3 = \frac{1}{2}(\upsilon_1 + \upsilon_4)\left(\frac{m}{s}\right)$$

It can be inferred that the velocity through the converter is the arithmetic mean of velocities on the two sides of the converter. At this stage, another parameter is introduced as '*the axial induction factor*'. It indicates the degree with which the wind velocity at the upstream of the converter is slowed down to downstream (Mathew, 2006, p. 29):

$$a = \frac{\upsilon_1 - \upsilon_3}{\upsilon_1}$$

The equation below can be derived:

$$\upsilon_3 = \upsilon_1(1 - a) \ \ , \ \upsilon_4 = \upsilon_1(1 - 2a)$$

As has been said, the mass that flows into the converter can be calculated as:

$$\dot{m} = \rho\upsilon_3 A_3 \quad \left(\frac{kg}{s}\right)$$

Therefore, the power developed by the converter from the kinetic energy of the wind is:

$$P = \frac{1}{2}\rho\upsilon_3 A_3(\upsilon_1^2 - \upsilon_4^2)\ (W)$$

Now, by substituting the above equations into the converter, the power equation below can be concluded:

$$P = \frac{1}{2}\rho A_3 \upsilon_1^3 \times 4a\,(1 - a)^2$$

The first section of the equation represents the power equation and the second section represents the power coefficient (Hau, 2006, p. 84; Mathew, 2006, p. 29):

$$C_P = 4a\,(1 - a)^2$$

To have the theoretical optimum power in the converter the power coefficient should be maximised:

$$\frac{dC_P}{da} = 0$$

By differentiating the equation, it becomes clear that for ‘*a*’ equal to $\frac{1}{3}$ the power coefficient is the largest and equals $\frac{16}{27} = 0.593$.

This number is known as ‘*Betz factor*’ (Hau, 2006, p. 85; Mathew, 2006, p. 29). In this theory, several assumptions are involved. For instance, the aerodynamic loss has been neglected and the flow ahead and behind the convertor, unlike the real situation, has been considered completely axial. Also when fluid applies force to the convertor, rotational wake is consequently generated behind the converter. These can cause energy loss and reduce the peak power coefficient.

2.3.2 Wind Turbine Classification

There are two ways of classifying a wind turbine, firstly in accordance with aerodynamic characteristics of the wind turbine’s rotor and secondly, according to its design. The rotor aerodynamic characteristics are defined by whether it captures the aerodynamic drag of the wind or utilises the aerodynamic lift created by the passing wind through the rotor.

Classifications according to the rotor’s design are more commonly used. This is based on the way that the rotor’s axis is positioned. These are known VAWT and HAWT (Hau, 2006, p. 67).

2.3.2.1 Vertical Axis Wind Turbine (VAWT)

The axis of rotation of this type is positioned vertically to the ground and mostly perpendicular to the wind direction. Initially, these kinds of wind turbines could solely be built as drag types. Ventilators on railroad carriages and the cup anemometer which is used to measure wind velocity are common examples of this type of wind turbine. One of these is called the'*Savonius Type'*. Development of vertical axis wind turbines was continued and several designs were proposed from which a few had justifiable power coefficients and further studies were conducted on them (Hau, 2006, pp. 68–71; Mathew, 2006, pp. 18–22).

The development of vertical axis wind turbines also resulted in utilisation of aerodynamic lift force. As a result, the '*Darrieus rotor*' design was proposed in 1925. In this design, the blades are shaped like egg beaters or '*Troposkein*' (skipping rope) and they are under pure tension while in operation (Hau, 2006, pp. 68–71; Mathew, 2006, pp. 18–22).

Another type of vertical axis wind turbine is a variation of the Darrieus rotor called '*H-rotor*'. This rotor instead of having curved blades, uses straight blades connected to the rotor shaft forming an '*H*' shape structure (Hau, 2006, pp. 68–71; Mathew, 2006, pp. 18–22).

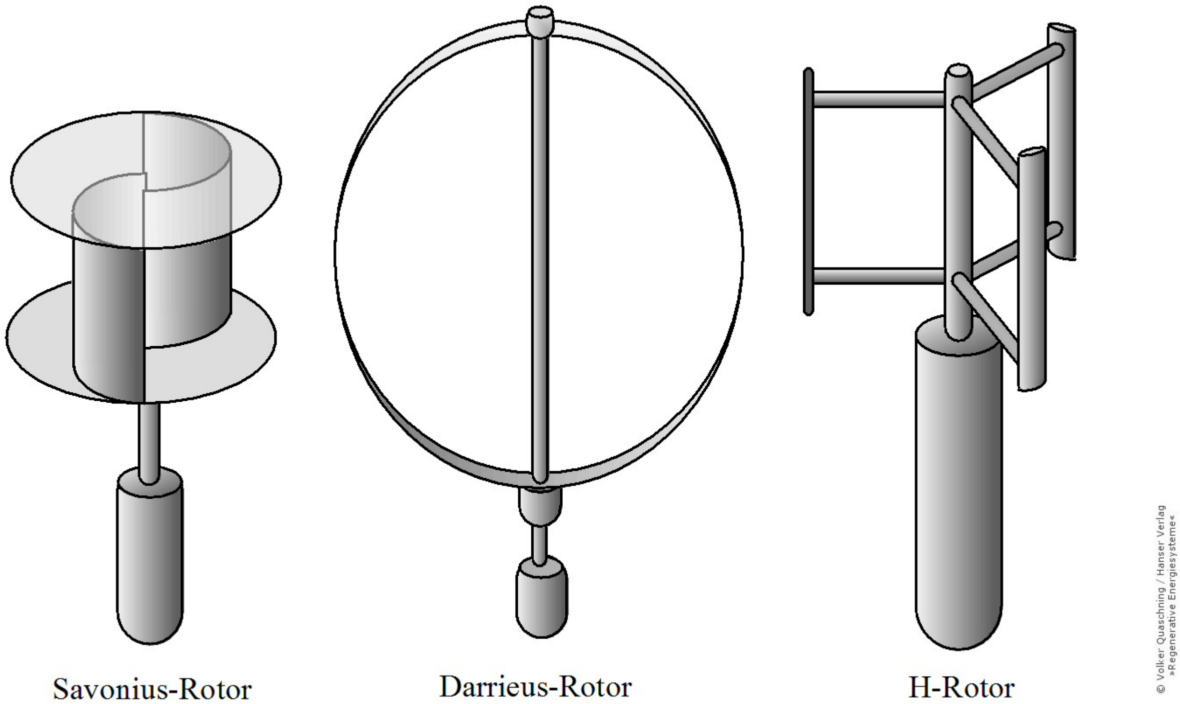


Figure 12: Different Vertical Axis Rotor types (Free Energy Planet, 2015)

2.3.2.2 Horizontal Axis Wind Turbine (HAWT)

The axis of rotation for this type of wind turbine is horizontal to the ground and almost parallel to the wind direction. Further, they are classified based on the number of blades they have, single-bladed, two-bladed, three-bladed and multi-bladed. Horizontal axis wind turbines were also classified based on the direction of receiving the wind as '*Upwind*' and '*Downwind*'. As for upwind wind turbines, the rotor faces the wind directly. It means that the wind passes through the rotor first. Therefore, they do not have the tower shadow problem. However, it is essential for this type to use a mechanism to keep the rotor always facing the wind, which is called the '*Yaw mechanism*'. On the other hand, as the rotors for downwind wind turbines are located at the lee side of the tower, the Yaw mechanism may not be required but when the blades pass through the shadow of the tower the loads on the blades become uneven which creates further problems and extra maintenance costs (Mathew, 2006, pp. 17–18).

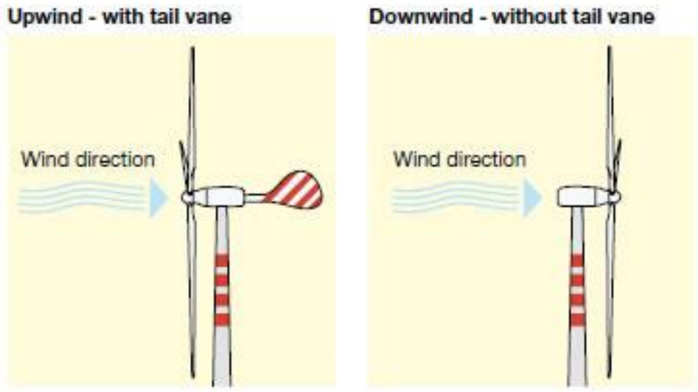


Figure 13: Upwind and Downwind Wind Turbine Demonstration (Clear-Energy-Brands, 2015)

2.3.2.3 Advantages and Disadvantages

In this section the advantages and disadvantages of the both types, VAWT and HAWT, together with their level of performance will be discussed.

2.3.2.3.1 Structural and Design Advantages and Disadvantages

The major advantage of VAWTs comparing to HAWTs is that they can accept the wind from any direction while HAWTs' rotors should be faced toward the wind direction using the '*yaw mechanism*' or in the case of small HAWTs the '*tail vanes*'. It means that for VAWTs there is no need for a yaw mechanism and so there will be no costs associated with that. Also from the energy-loss perspective, there is no energy loss when the wind changes direction since VAWTs can harness wind power regardless of its direction. As for the HAWTs with a yaw mechanism, it takes a while for the yaw mechanism to face the rotor toward the wind direction every time that the wind changes direction which means power loss at those times. Also energy-wise for VAWTs since there is no yaw mechanism, no energy is needed to face the rotor to the wind direction, unlike HAWTs. VAWTs, because of their ability to harness wind energy from all directions, are also suitable for situations where the wind is turbulent (Eriksson et al., 2008, pp. 1423–1424; Mathew, 2006, pp. 18–19).

Although having the ability to harness wind energy regardless of changes in wind direction counts as an advantage for VAWTs, some of them are not self-starting and additional mechanisms are needed to start them when they are stopped. This means additional cost, along with more complex mechanisms which cloud the advantage of being able to receive the wind from any direction (Mathew, 2006, p. 19).

Regarding their tower designs, for VAWTs, since their axes are positioned vertically, the generator can be located at ground level and it makes the cost of the tower much less as there is no structural load for the generator's account. It also makes the installation, operation and maintenance much easier. Unlike the VAWTs, in HAWTs the generator is located on top of the tower. This part is called the '*Nacelle*'. This requires a strong tower due to structural loads which increase the costs of the towers and structures. Although the costs of HAWTs' towers are higher than those of VAWTs, they do not require any guy wires. This counts as an advantage for HAWTs since due to their strong towers they are suitable for offshore applications while the guy-wired VAWTs are mostly impractical for offshore projects (Eriksson et al., 2008, p. 1424; Mathew, 2006, p. 19).

In HAWTs, the rotor speed and power output can be controlled by pitching the blades. This is the most effective protection against extreme wind speeds and overspeed. This mechanism is not common in VAWTs since the angle of attack of their blades is constantly changing due to the vertical rotation of the rotor. Therefore applying pitch angle to the blade does not deliver the same result as with the HAWTs, so there is a chance that the blades may run at dangerously high speeds and consequently cause the system to fail (Hau, 2006, p. 71; Mathew, 2006, p. 19).

Efficiency wise, a disadvantage of VAWTs is that, as the rotor rotates, the blades have to pass through aerodynamically dead zones which will result in lowering the efficiency. This rotation also creates another problem in VAWTs which is torque ripple. It is caused by the continuously changing angle of attack between the blade and the apparent wind. It can affect the fatigue life of the drive train components (Eriksson et al., 2008, p. 1425; Mathew, 2006, p. 19).

One of the prominent advantages of HAWTs is that their blades can be aerodynamically optimised and it has been proven that it will achieve its highest efficiency when the aerodynamic lift is exploited to a maximum degree (Hau, 2006, p. 71).

Structural and design advantages and disadvantages of both VAWTs and HAWTs have been discussed. In order to compare their performance, the power coefficients should be calculated. From the previous sections, it is clear that no power coefficient can be more than 0.59 due to the Betz limit. In the next section, the comparison by power coefficients will be discussed.

2.3.2.3.2 Performance Comparison

The performance of a wind turbine depends on the power coefficient. The power coefficient indicates how much power the turbine can harness from the wind. As has been said, the theoretical maximum for an idealised wind turbine has been defined by the Betz limit and is 0.59. The power coefficient is proportional to the blade tip speed to wind speed ratio. The ratio between the blade tip speed and the wind speed is called the tip speed ratio (Eriksson et al., 2008, p. 1426; L. Johnson, 2001, p. 17).

The tip speed ratio is:

$$\lambda = \frac{R\Omega}{V} = \frac{2\pi NR}{V}$$

In this formula, Ω is the angular velocity and N is the rotational speed of the rotor. There is an optimum λ for a given rotor at which the energy harnessing is the most efficient and consequently the power coefficient is maximum.

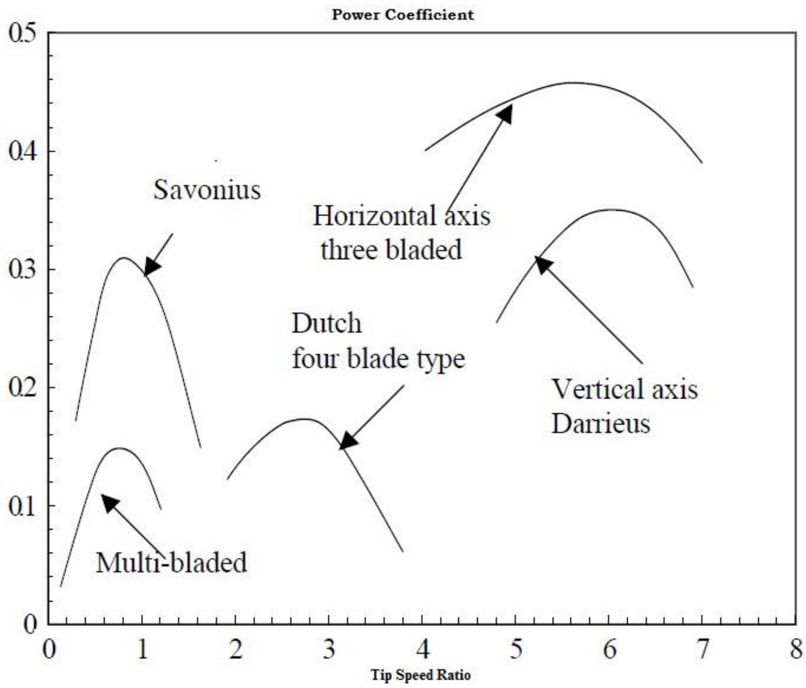


Figure 14: Performance of the different wind turbines in different tip speed ratios (Mathew, 2006, p. 22)

There is quite a substantial difference between the maximum expected power coefficient of a machine that uses lift force and the ones that utilise drag force. As the Betz limit indicated by applying the axial momentum theory, the maximum theoretical power coefficient of a wind turbine which is operating predominantly by lift force cannot exceed 16/27. On the other hand, the maximum expected power coefficient for a drag machine is much lower than a machine that uses lift force, at about 8/27 (Mathew, 2006, p. 23).

2.3.2.4 Choice of Wind Turbine Type

From the above it can be inferred that the ability to control the output power in HAWTs by pitching the rotor blades, the ability to self-start, the ability to be aerodynamically optimised and most importantly, having the highest theoretically possible power coefficient among all wind machines, are the reasons why almost all the wind turbines for generating electricity built to date are HAWTs (Hau, 2006, p. 71).

For the purpose of this study the wind turbines for household and small-scale electricity generation that can harvest as much energy as possible from the available wind condition near the point of consumption are required. According to figure 13 the best choice is found in horizontal axis three-bladed wind turbines. Therefore from this point forward, the literature study is focused on the HAWTs and all the wind turbines that are mentioned in the context of this study are assumed to be horizontal axis wind turbines.

In the next sections, the different size categories of HAWTs will be discussed. The size category for HAWTs is determined by the power range of the machine which is expressed in units of kilowatts. Currently, all the wind turbines are categorised into three main categories; small, medium and large (Bansal et al., 2002, p. 2180).

2.3.3 Small Wind Turbines

The small wind turbine category includes those turbines in the range up to 2 kW. The applications for these turbines are mostly battery charging on sailboats, small household applications, remote areas and places with relatively low power requirements (Bansal et al., 2002, p. 2180).

2.3.4 Medium Wind Turbines

The medium category includes turbines in the range from 2 kW to 100 kW. The application for these wind turbines is to supply typical households completely or local facilities use (Bansal et al., 2002, p. 2180).

2.3.5 Large Wind Turbines

This category covers all the wind turbines that have commercial application and are used for feeding to utility grid systems. Currently, they are in the megawatts range. They can supply thousands of homes with electricity and can be installed both onshore and offshore. Currently, their power range is below 7 MW (Bansal et al., 2002, p. 2180; Wind-Turbine-Zone, 2010).

2.3.6 Choice of Wind Turbine Size

The choice of size for the focus range of this study is for domestic and household applications, therefore the small category and a small part of the medium category are chosen. Since the small category practically covers this study, from now on all the wind turbines used in the context refer to small-scale horizontal wind turbines.

2.4 Wind Turbines' Components

Wind turbines' components are different in each size category. Generally for commercial wind turbines[1], they are divided into three main parts: rotor; mechanical drive train and nacelle; tower and structure (Hau, 2006, pp. 219–355; Mathew, 2006, pp. 89–115).

2.4.1 Commercial Wind Turbine's Components

A short description of the wind turbine's components, in general, is as follows.

2.4.1.1 Rotor

The most important part of a commercial size wind turbine is its rotor which receives the kinetic energy from the wind and transforms it to mechanical power. As it was mentioned before there are different types of rotors, but in this section the focus will be on HAWTs. Their rotors consist of a number of subsystems which change according to the technology used in the wind turbine, the size category and the number of blades that are being used in the wind turbine. Generally, the rotor consists of blades, hub and the blade pitch mechanism (Hau, 2006, p. 219; Mathew, 2006, p. 96).

2.4.1.1.1 Blades

The blades technology is similar to that used in aircraft wings. The airfoils are being used widely in the wind turbine industry to optimise the lift and drag forces of the blades. For blade design factors such as weight, aerodynamics, strength and cost are considered.

Aerodynamic issues are mostly related to the airfoil design that is being used. A number of airfoils have been defined and tested by NASA[2] and some research institutions. As for the weight, strength, size and cost of the blades, the material that is used plays an important role.

---

[1] Commercial wind turbine refers to the wind turbines used for large-scale electricity generation
[2] National Aeronautics and Space Administration

To choose the material suitable for wind turbine blades, apart from mechanical characteristics and cost, the feasibility of manufacturing of the designed airfoil with that material should be studied as well. Regarding the cost, factors should be considered such as manufacturing cost as well as material cost. Therefore, in choosing a suitable material, all the above criteria should be considered and the best choice that satisfies all the criteria mentioned should be chosen. The materials for this purpose, depending on the application, are for example, wood, aluminium, steel and fibre composite material (glass, carbon and aramid fibres) (Hau, 2006, p. 220).

The size of the blade to be manufactured is important when choosing suitable materials. Using wood as a material for the blade is feasible for small-size wind turbines but as the size increases the mechanical characteristics of wood are no longer suitable for that application. As for metal, it is also limited to small-scale blades, and the manufacturing costs and material costs mostly prevent designers from using it. For instance, aluminium, a traditional aircraft material does have suitable properties, but the techniques used in aircraft engineering are simply too expensive for large wind turbines. In the case of titanium, due to mainly material cost and the costly manufacturing processes its use is not viable (Hau, 2006, pp. 220–222; Mathew, 2006, pp. 96–97).

Glass fibre design results in a cost-effective process and a suitable manufacturing method which is currently being used. Recently, carbon fibre-reinforced composite materials are increasingly being used as additional fibre fabric to fibre glass in larger applications for increasing the strength of the blades. The high stiffness characteristic of carbon fibre reduces the extent of the blades bending in high winds. This property of carbon fibre has made it possible for designers to place the blades closer to the tower. It also has a prominent effect on the weight of the blades, with a reduction of about 20% in weight. For instance, Nordex and GE wind have both built blades of about 50 m in length by using hand lay-up fibreglass structure in an open-mould wet process and 61.5 m long blades from the LM glass fibre are installed in 5 MW wind turbines by the Repower System AG, Germany (Ashwill, 2003, p. 516; Mathew, 2006, pp. 96–97).

2.4.1.1.2 Rotor Hub

The rotor hub is the component that attaches the blades to the mechanical drive train of any wind turbine. The rotor hub is important in the design of a wind turbine since all the converted kinetic power of the wind to mechanical energy is gathered there and from there sent to the mechanical drive train to be converted to electricity. Therefore, the material that is used has to withstand the force, stress and momentum that are concentrated there. The material used in rotor hubs is mostly steel (Mathew, 2006, p. 262).

2.4.1.1.3 Blade Pitch Mechanism

The blade pitch mechanism has two important tasks; the primary task is to adjust the blade pitch angle for controlling the power and speed of the rotor which is very important in constant speed wind turbines. Apart from this function the secondary task is to brake the rotor aerodynamically. For this purpose, it must be able to pitch the blade into the feathered or stall position. Although this mechanism is quite important for large wind turbines, it is less common in small-scale wind turbines (Hau, 2006, p. 269).

2.4.1.2 Mechanical Drive Train

The kinetic energy in the wind which is converted into mechanical energy by rotor now enters the nacelle. The components in the nacelle are for converting mechanical energy to electrical energy. It should be noted that the components in the nacelle vary when the turbine size and the technology differ. Normally the main components are the gearbox, generator, sensors, yaw mechanism and safety system (Hau, 2006, pp. 254–261; Mathew, 2006, p. 90).

2.4.1.2.1 Gearbox

Gearboxes vary depending on the technology used in the wind turbine (whether it is direct drive or not) and also the size of wind turbine (in small-scale wind turbines gearboxes are rarely used since they are mostly not synchronous). The main reason for using a gearbox in wind turbines is that usually the speed of commercial wind turbines is around 15 to 50 rpm[1], but normal generators need around 1 000 to 1 500 rpm to be able to generate electricity conforming with the grid codes that they are feeding into. Also, since the wind speed is not always constant, the rotor speed varies with wind speed. To adjust the rotor's speed to generator and grid requirements a mechanism is needed. This adjustment is being done partially by means of the pitch mechanism and partially by the gearbox. This should be also noted that the reliability and efficiency of a wind turbine are affected if a gearbox is being used (Mathew, 2006, pp. 99–100).

2.4.1.2.2 Generator

The generator is one of the most important components of the mechanical drive train and the complete wind turbine. The working situation for wind turbine generators is different from those of a power plant's generators. The wind turbine's generator, unlike a conventional generator, has to work under fluctuating power levels, due to the variations in wind velocity. Different types of generators are used. For instance, for small wind turbines both AC and DC generators are used but for bigger applications single or three-phase AC generators are more suitable. For large-scale wind generation plants which are integrated with the utility grid, three-phase AC generators are used which can be either induction (asynchronous) generators or synchronous generators (Hau, 2006, p. 320; Mathew, 2006, p. 107).

2.4.1.2.3 Sensors and Yaw Mechanism

As the speed and direction of the wind are constantly changing throughout the day and night, a mechanism is needed to face the rotor (HAWT's rotor) toward the wind or for safety reasons turn the rotor's face out of the wind direction. The deviation between rotor axis and wind direction is called the yaw angle. This mechanism consists of different components in different wind turbines and according to the wind turbine size and technology the components may differ. It is divided into two main categories, passive yaw mechanisms and active yaw mechanisms. The wind turbine can be oriented into the wind direction by means of three different methods (Hau, 2006, pp. 146–148):

- Yawing by means of aerodynamic force
- Active yawing with the help of a motor drive system
- Free yawing for downwind rotors

The simplest method for a yawing mechanism is currently used in the small wind turbines category. This mechanism works by means of aerodynamic force and it consists of a tail vane and in some cases slip rings. In this case the tail vane keeps the turbine's rotor into the wind direction. Sometimes in the small size category, free yawing is used for downwind wind turbines. For downwind wind turbines, since the point of attack of the total aerodynamic force of the rotor is located behind the rotational axis of the tower head (yaw axis), a cross wind causes the aerodynamic forces to produce a restoring moment on the rotor. This moment turns the wind turbine to align with the wind direction. The advantage of using these two mechanisms is that they both use the aerodynamic force of the wind, therefore they do not need an external power supply. In both cases it is almost impractical to use these

[1] Revolutions per Minute

for the yaw mechanism in large-scale wind turbines. As for tail vanes, with increasing wind turbine size the tail size has to increase in order to be able to provide enough moment to rotate the rotor into the wind direction, which makes it economically infeasible. If free yaw mechanisms are used in large-scale wind turbines, the restoring moment is simply not enough to turn the rotor to align with the wind direction. Therefore, in large-scale and commercial wind turbines that are connected to utility grids, active yaw mechanisms with the help of motor drive systems are used. Since these use motor drive systems and power from the grid, they are not reliant on the aerodynamic moment. The active yaw mechanism consists of an anemoscope, wind vane, yawing mechanism and thermometer. The anemoscope and the wind vane are used to detect the immediate wind situation and the thermal sensors are constantly reading the gearbox and generator's temperatures. They constantly feed their information to the control system and software decides if any changes have to be made to the current status. If there is any change required, the control system issues the command to change the rotor's direction, the command will consequently be sent to the yaw mechanism and the motor drive system (Bansal et al., 2002, pp. 2181–2182; Hau, 2006, p. 148; Tong, 2010, pp. 27,615–616,403).

2.4.1.2.4 Safety System

The safety systems of wind turbines are adapted to the size of the wind turbine. For instance in commercial wind turbines, three systems can be considered as safety systems. The blade pitch mechanism (stall mode) is one of safety features that was discussed before. The second one is the yaw mechanism; this system can also be used to turn the rotor away from the wind direction in extremely high winds for system safety. The third system involves safety brakes. During the extremely high winds and bad weather conditions, the wind turbines should be completely stopped for safety reasons. The same happens when the power line fails or the generator is disconnected, since otherwise the wind turbine would rapidly accelerate. The brakes can control a runaway condition within a few seconds and the wind turbine is saved from being damaged. The above-mentioned mechanisms are mostly being used in large-scale wind turbines. To avoid system complexity, the stall mode blade pitch mechanisms and brake systems are not commonly used for small-scale wind turbines (Hau, 2006, p. 187; Mathew, 2006, p. 105).

2.4.1.3 Tower and Structure

The importance of the tower and structure of wind turbines magnifies as their sizes increase. The tower should be strong enough to withstand the thrust on the wind turbine as well as the thrust on the tower. The tower must also be able to support the weight of the wind turbine. As it has been said, wind speed increases with altitude and it tends to become less turbulent as well. Therefore, more energy can be extracted with taller towers. Currently, the choice of the tower is mostly the free-standing type using steel tubes or lattice towers for commercial wind turbines. For smaller wind turbines, guy-wired towers and monopoles are being used. The tower height is typically proportional to rotor diameter. The tower height is mostly 1-1.5 times the rotor diameter in commercial wind turbines. For small-scale wind turbines with diameters not exceeding more than a few metres, the tower should be able to take the turbine high enough to be away from the turbulent wind. It should be noted that the characteristics of sites have prominent influences on tower choice and height (Bansal et al., 2002, p. 2185; Tong, 2010, p. 528).

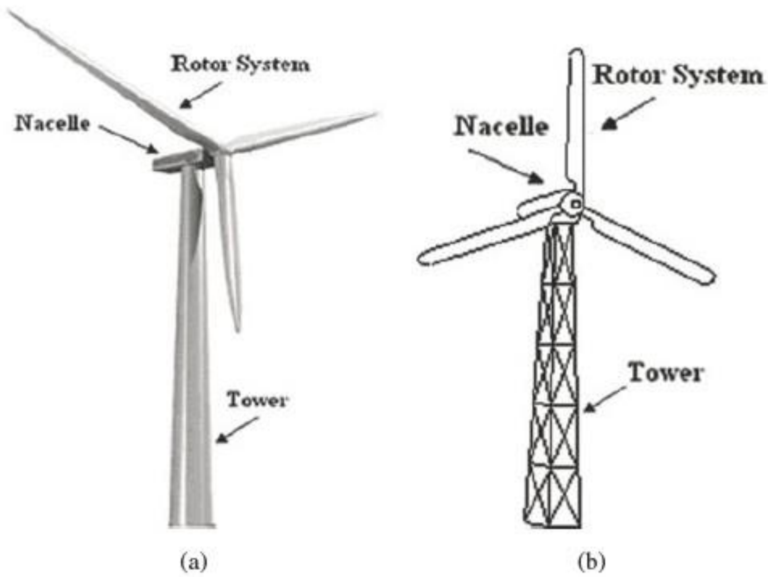


Figure 15: (a) Free Standing Tubular Wind Turbine Tower; (b) Lattice Wind Turbine Tower (Tong, 2010, p. 528)

2.4.2 Small Wind Turbine's Components

Size is an important factor when designing wind turbines. The complexity of the design and technology in the wind turbine increases when its size increases. In previous sections, general descriptions of the most common components used in commercial wind turbines were discussed. As stated previously, the scope of this study is on small-scale wind turbines which have their own components and are relatively less complicated than larger ones.

Small wind turbines also consist of three main components:

- Rotor
- Generator and yawing mechanism
- Tower

A short description of each of the components and subcomponents is as follows.

2.4.2.1 Rotor

In small wind turbines, the rotor consists of blades, hub and an optional nose cone. According to the previous section, the material used for blades can vary from wood to different composites. The weight and mechanical properties of the blade are important for the durability of the product, and, therefore, carbon fibre composite is one of the most rational choices of material for manufacture of small wind turbine blades. The hub in a small-scale wind turbine is much simpler than that of a large-scale wind turbine due to absence of the blade pitch mechanism.

2.4.2.2 Generator and Yawing Mechanism

Instead of the drive train which was mentioned in a previous section, the small-scale wind turbine usually does not have any gearboxes and the hub is assembled directly on the generator's shaft. The choice of generator in most cases is a 3-phase AC generator.

For the yawing mechanism, a tail vane is usually the choice for small-scale wind turbines.

2.4.2.3 Tower

The usual type of tower being used for small-scale wind turbines is either guy-wired towers or monopole towers. Since the small-scale wind turbines are designed to be used in populated areas, the area they occupy is important, and, therefore, the guy-wired tower which needs more surface area for the wires to be mounted in the ground is rarely the best choice. For the scope of this study, the monopoles seem a more rational choice for wind turbine towers.

In the next chapters, energy use in the world is discussed, and thereafter detailed information regarding markets, manufacturing and material aspects of wind turbines will be covered.

3 Energy

Energy in the world is categorised in two main alternatives, non-renewable sources including coal, fuel, and natural gas and renewable sources such as solar, wind, hydro and wave (Sahin, 2004, p. 502).

3.1 World's Non-renewable Energy Usage

Humanity has used energy over the millennia since antiquity. One of the primary ambitions of humans was to improve the quality of life. Transforming raw materials into necessities of life and making the means to transport them are examples of this effort. The increase in energy usage was a gradual process until the industrial revolution. Since then, the gradual process has accelerated to rapid advancement in the supplying of power and technological enhancement (Albright and Vanek, 2008, p. 3).

These advancements led to the discovery of underground sources of energy. Oil or as it is called 'black gold' discoveries in the twentieth century established the technology of hydrocarbons, which even today are the main energy source in the world energy matrix (Sthel et al., 2013, p. 245).

More recent trends in energy supply advancement revert to before the 1950s when energy systems were primarily local and acted as driving forces of local economics mechanisms rather than global. Later on, after the Second World War, energy utilisation was considered as a gauge to measure economic growth and development. The development of society, population and economy over a short period of time is considered to have been possible mostly because of abundant fossil fuels that provided cheap and plentiful energy for a multitude of activities during that time (Höök et al., 2011, pp. 25–26).

As is known, fossil fuels are constrained and it is expected that they are going to be depleted within the next few centuries. The accumulation of carbon dioxide in the lower layer of the atmosphere due to excessive usage of fossil fuels could contribute to climate change, floods, intensive rainfalls and droughts, and along with depleting sources this has forced countries to improve the quality of their energy resources and to try to replace them with renewable alternative sources such as wind, solar and other renewable energy sources (Sahin, 2004, p. 502).

3.2 World's Renewable Energy Usage

The energy crisis in the 1970s forced western countries to search for renewable sources such as wind, solar and biomass, which should be effective and able to compete against the conventional carbon energy sources. Also the pollution crisis of fossil fuels and their environmental impact in the form of air pollution, acid rain and greenhouse effects in addition to resource constraints gave added importance to the use of renewable alternative energy sources. Recent nuclear plant disasters such as Chernobyl and Fukushima made it clear that steps toward renewable energy should be taken more seriously. Among the renewable energy sources, wind is the fastest growing renewable source in the world and has been rapidly used in a number of countries (Mostafaeipour, 2013, p. 214; Sahin, 2004, pp. 502–503).

3.2.1 World's Wind Energy Usage

With every passing day, wind energy is becoming more reliable and is being used more around the world. Recently it became a pillar of the energy system of many countries since it has been recognised as a reliable and affordable source. The worldwide wind capacity in the year of 2012 reached 282 275 MW (The World Wind Energy Association, 2013, p. 5).

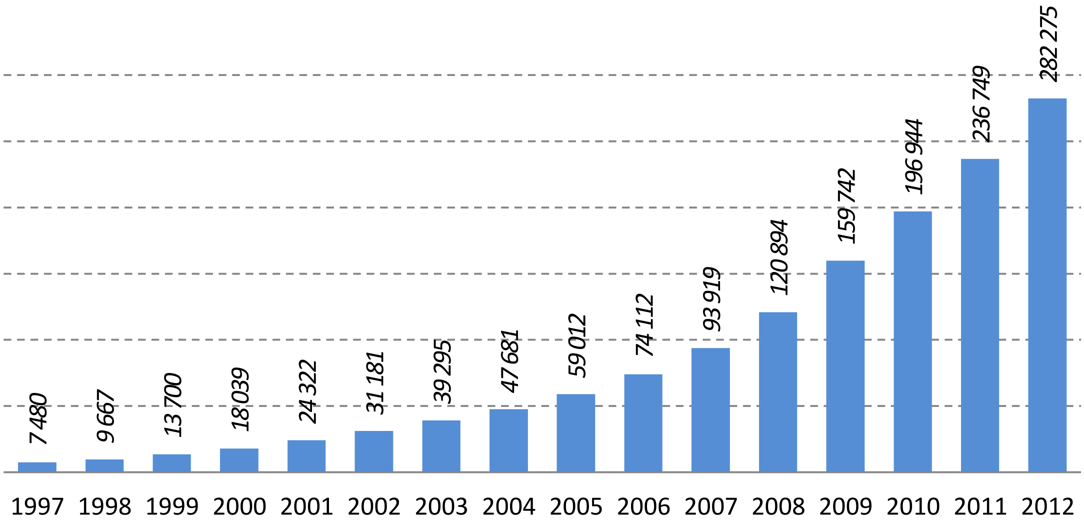


Figure 16: World Total Installed Wind Energy Capacity (MW) (The World Wind Energy Association, 2013, p. 5)

In the year 2012, all installed wind turbines worldwide provided 580 TW[1] hours per year, which is slightly more than 3% of the whole world electricity demand. In total 100 countries were using wind turbines for electricity generation by the end of 2012. Among them Germany has the most stable market in Europe, US in North America and China in Asia (The World Wind Energy Association, 2013, p. 4).

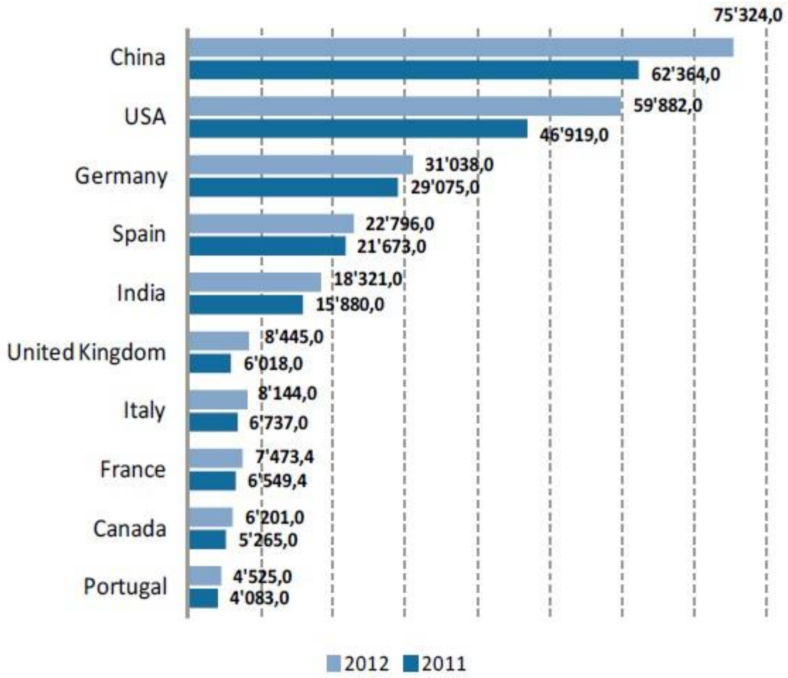


Figure 17: Top 10 Countries by Total Capacity (MW) (The World Wind Energy Association, 2013, p. 7)

For the last two decades, the trend shows that the capacity doubled every three years until the year 2011. The average growth rate, which is the relation between the newly installed wind power capacity and the capacity for the year before that, showed an average growth of 30% for the last decade.

[1] Terawatt

Although year 2012 marked as new record for installations, the global growth rate went down to 19.1% which is the lowest rate in the last two decades (The World Wind Energy Association, 2013, p. 5).

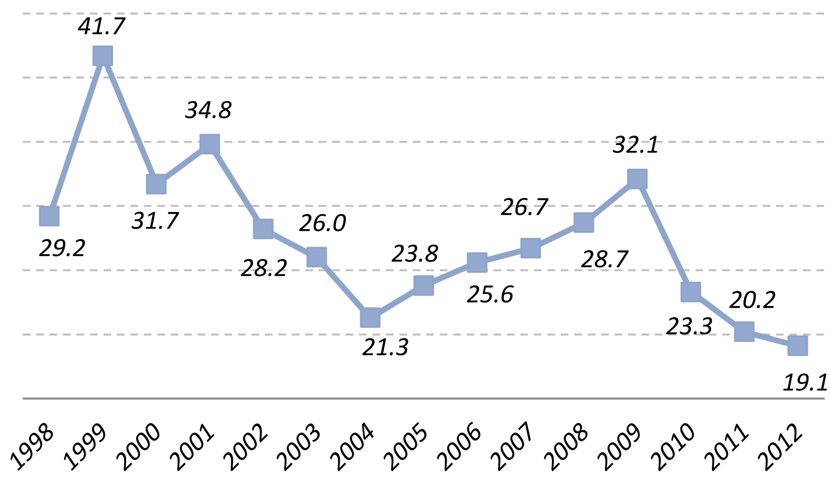


Figure 18: World Market Growth Rates(%) (The World Wind Energy Association, 2013, p. 5)

While the growth rate shows a negative trend in the last few years, Latin America and Eastern European countries continue to grow with highest growth rates. The trends in these areas show a strong growth during the last three years while the traditional markets in Western Europe, North America and Asia have rather modest growth rates. Africa continues to be the major concern since it has not only the smallest capacity but also the lowest growth rate with only 7% in year 2012, during which only two African countries, Tunisia and Ethiopia, installed new capacity (The World Wind Energy Association, 2013, p. 6).

3.2.2 Future Perspective of Wind Energy

For the future perspective there are factors that have impacts on either the mid-term or long-term prospects of wind energy. The Wind energy Association introduced six major factors as follows (The World Wind Energy Association, 2013, p. 16):

1. The on-going debate on climate change and how to find emission-free energy solutions.
2. The depletion of fossil fuel as well as unclear resources especially reflected in the increasing or fluctuating oil prices which especially represent a huge burden for developing countries.
3. An increasing number of local communities, regions and countries are proving that practically 100% renewable energy is possible.
4. The increasing awareness regarding the hazardous risks related with the utilisation of nuclear energy, driven by the reports on the nuclear disaster in Fukushima.
5. The increasing awareness regarding the potentials and actual contributions of wind and other renewable energies to an energy supply which is economically, socially as well as ecologically sustainable.
6. Further improvements in wind energy and related technologies, including backup and storage technologies.

From the above it is clear that the path toward increasing renewable energy is possible but it requires global unity. Frameworks and policies are the crucial parts of this future which needed to be strengthened (Global Wind Energy Council, 2012, p. 18). Policy at national level including the

Production Tax Credit (PTC) is the most significant factor driving the market and it seems the uncertainty in policies is the main reason for slow growth in 2012-2013. In spite of the need to reinforce policies for increased wind power at both national and international levels, it is witnessed that the appetite for investment in the wind energy section is strong and many projects are in their initial phases. From the world perspective, high growth rates are expected in Latin America as well as Asian markets. In Africa major investment will be seen in Northern as well as Southern Africa. Based on current growth rates and these investments, it is expected that by 2016 the global capacity should reach 500 000 MW, and by the end of the year 2020 at least 1 000 000 MW installed capacity can be expected (The World Wind Energy Association, 2013, pp. 16–17).

3.2.3 Renewable Energy Policy

Climate change and the reduction of the anthropogenic effects on greenhouse gas emissions are key factors regarding recent energy policies. Strategies, including the improvement of energy efficiency, development of green technologies for environmental sustainability, recycling, better utilisation, disposal/storage as well as increased usage of renewable energy (RE) and the development of nuclear energy were proposed (Huang et al., 2013, p. 4466). Among all of the mentioned strategies, increased usage of renewable energy is widely accepted (Kang et al., 2011, p. 2003; Kumar et al., 2010, p. 2441).

As a major factor for the future of renewable energy, especially wind energy, policies at national and international levels are playing a very important role in how fast the renewable energy sector will grow (The World Wind Energy Association, 2013). Currently the national level policies, especially in developing countries, are one of the obstacles in the rapid growth of renewable energy usage and implementation.

3.2.3.1 Small-scale Renewable Energy Policy

Different countries have different rewards for small-scale electricity generation from renewable energy sources. One of the most used policies especially in the US that is encouraging small-scale electricity generation from renewable energies is net-metering with buyback.

Net-metering with buyback is one of the several legal tools designed to facilitate the use of renewable energy sources. It permits one who installs renewable energy equipment on his property to sell their excess electricity back to the local utility company (Valerie J.Faden, 2000).

3.2.3.2 Small-scale Wind Energy Policy

Like most of other renewable energy sources the growth of the small wind market depends on stable and appropriate supports. Currently policies like feed-in tariffs, net-metering, tax credits and capital subsides are geared toward small wind systems. The small wind energy sector has especially benefited from the growing global trend of feed-in tariffs. Unfortunately only a few countries have yet implemented specific FIT[1] for small wind systems on grid-connected net-metering. Net-metering has also been an effective incentive, for instance in Denmark (Stefan Gsänger, 2014). Published data shows that (Stefan Gsänger, 2014) quite a few countries have implemented feed-in tariff pricing for the whole country or some of the provinces.

3.3 Small Wind Energy International Market

The international market for small wind turbines has been growing and during 2012 a total of 806 000 small wind turbines were installed worldwide which shows an increase of 10% in comparison with the

[1] Feed-in tariffs

previous year. As most of this growth happened in only three countries, that is China, the US and the UK, it is clear that the market for small wind turbines is in its infancy (Stefan Gsänger, 2014).

The small wind electricity capacity installed internationally reached 679 MW in 2012 with a growth rate of 18% in comparison with the previous year. The increasing demand for clean and affordable energy globally will without doubt lead to an increase in demand for small wind electricity generation. Specifically in developing countries, small wind turbines can make a fast contribution to electrifying millions of people residing in rural areas. Governments and international organisation such as IRENA[1] have already started to understand and make use of this potential by including it in their renewable energy projects (Stefan Gsänger, 2014).

Recent trends of the small wind industry have shown an annual increase of 19-35% in the new installation capacity for the past few years. It is anticipated that the growth rate increases to 190 MW of installed capacity until 2015 and by implementing structured standards and policies. With these policies in place, the market could witness a steady growth rate of 20% from 2015 to 2020.

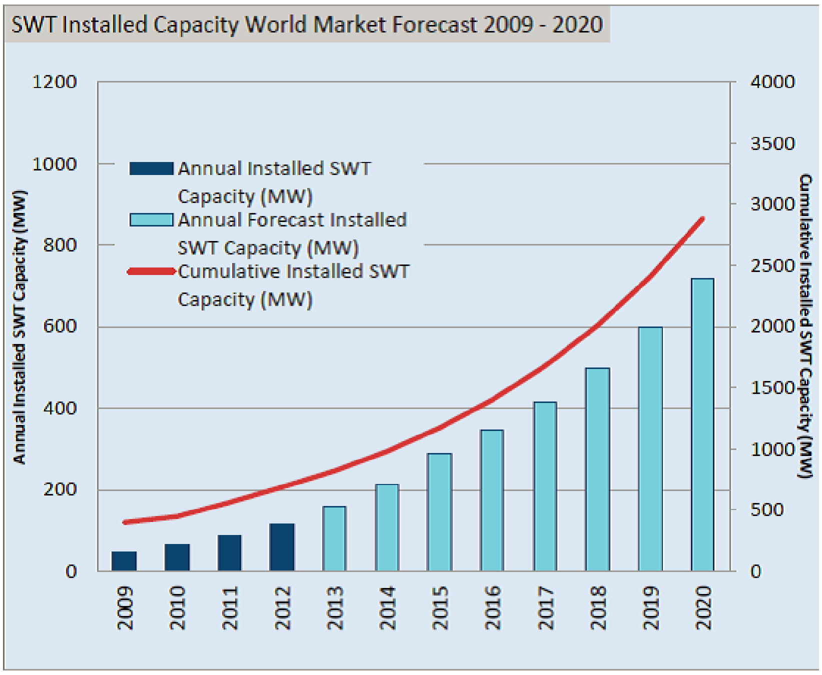


Figure 19: SWT[2] Installed Capacity World Market Forecast 2009-2020 (Stefan Gsänger, 2014)

3.4 Small Wind Turbine Manufacturers

Five countries are known for the manufacturing of over 50% of small wind turbines in the world. By the end of 2011 there were 330 small wind turbine manufacturers and it was estimated that more than 300 additional companies were supplying parts, technology, consulting and sales services (Stefan Gsänger, 2014).

Based on the world distribution of small wind turbine manufacturers, most of the small wind turbines production remains in a few countries such as China, the US, Canada and several European countries. Developing countries are still only playing a minor role in the manufacturing market. It is obvious that the tremendous wind resources of Africa, Southeast Asia and Latin America, where many regions are

[1] International Renewable Energy Agency
[2] Small Wind Turbine

ideally suited for small wind applications, have not yet led to the establishment of domestic small wind industries (Stefan Gsänger, 2014).

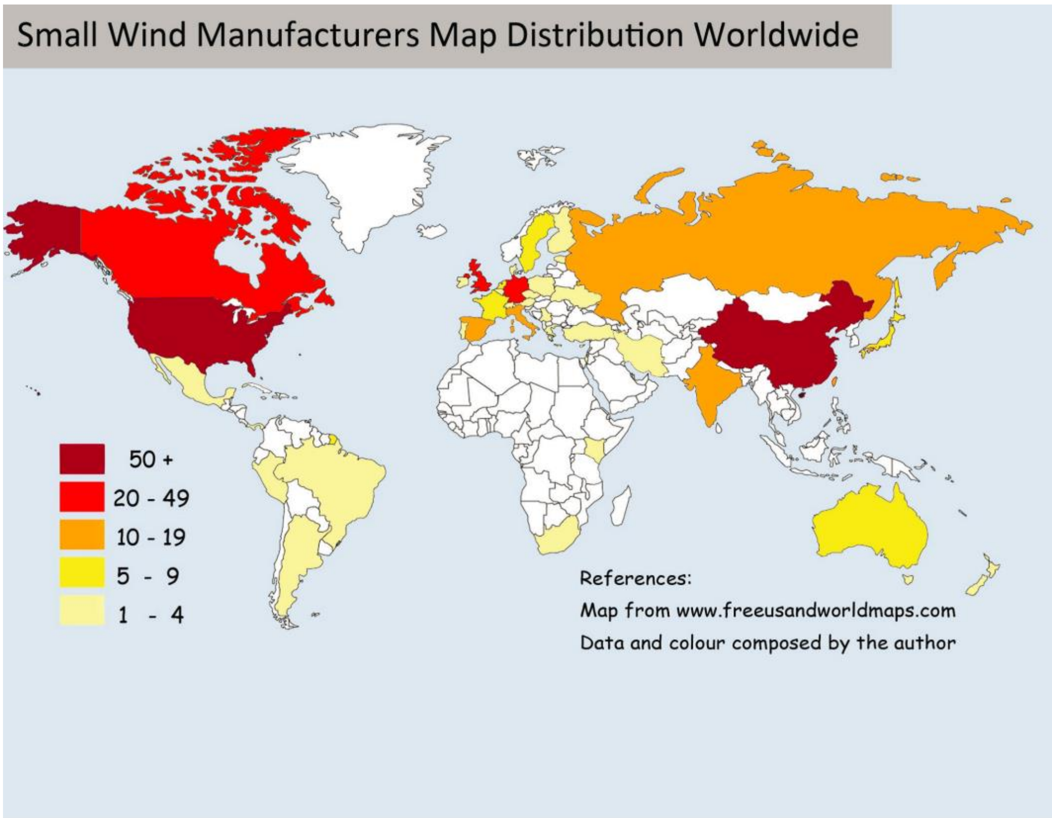


Figure 20: Small Wind Manufacturers Map Distribution Worldwide (Stefan Gsänger, 2014)

3.5 Chapter Summary

According to the literature review there is a gap in the small wind turbine manufacturing sector on the African continent. Although the conditions for harvesting wind energy are ideal, the market has not grown as much as in China, North America or Europe. This gap should be filled and it is the motivation behind this study.

According to section 1.3.2 in order to fill the gap in the small wind turbine manufacturing sector in South Africa the market and the factors that have influence over the market have to be identified. The next chapter will analyse the market in South Africa from different aspects.

4 Market Study

4.1 Introduction

The objective of the market study in South Africa is to evaluate the market, find new market opportunities, identify the domestic and foreign competitors and evaluate their capabilities for estimating the available market share.

The first step in a feasibility study is to estimate the market capacity for the product and the demand in a specific region. There are different approaches to the market study which are highly dependent on the type of products offered, market environment, culturally related conditions, etc. For this specific product, the following approach is adopted. In this case, the wind conditions in WASA's covered regions are of interest. The second step is to study the land mass distribution and how open and suitable the area is for utilising wind energy. After investigating the availability of wind energy in the region and also the suitability of the land mass, the clients or the target markets have to be defined and also their demand range has to be identified. The next step will be 'identifying the competitors' and their capabilities, including their location and production range. Further on in the chapter a 5-year forecast of market share and market share growth will be discussed to estimate sales, statistics and other required information.

4.2 Market Description

As the initial phase of the market study, the market capacity will be estimated by studying the market, identifying the target markets, studying their requirements and proposing a suitable product which meets the market requirements.

4.2.1 South Africa's Wind Energy Capacity

As has been said, the focus region of this study is the coastal area of the south-west, west and southern part of South Africa. The information regarding the wind study for the coastal area was extracted from WASA. The WASA is an initiative of the South African government and the Royal Danish Embassy (Department of Energy (DoE), 2014, p. 1). The Numerical Wind Atlas (NWA) shows the annual mean of wind speed. The WASA covers Western Cape and part of Northern Cape and Eastern Cape by installing 10 measurement sites. The covered area is shown in Appendix A. The location of each measurement site is shown below.

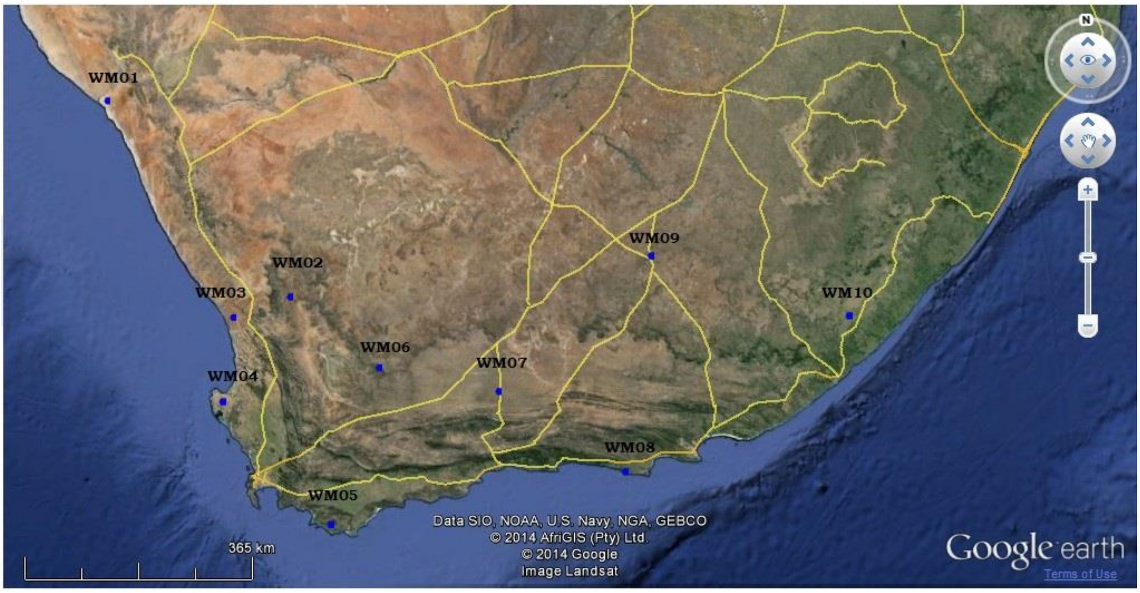


Figure 21: Location of Wind Measurement Sites (WASA, 2014)

4.2.1.1 Numerical Wind Atlas

The data for all 10 sites is available through the 'Numerical Wind Atlas' including the mean wind speed, the power density (at five standard heights above ground level 0 m, 10 m, 25 m, 50 m and 100 m) and the roughness classes: (R class 0 for water area; R class 1 for farmland with open appearances, very few buildings, trees, airport area with some buildings and trees; R class 2 farmland with closed appearance; R class 3 low forest, suburbs, shelter belts, many trees and/or bushes; and R class 4 tall forest). It also shows the mathematical fit to the generalised wind data by means of the Weibull graph including the distribution's parameters (Department of Energy (DoE), 2014, p. 9). In Appendix B the average wind speed and power capacity per square metre is tabulated for different measurement heights and surface roughness.

The captured data from all the 10 measurement sites are available through the WASA website by using the WAsP software (Department of Energy (DoE), 2014, p. 2). The information regarding each measurement site is available in Appendix A.

Both figure 22 and figure 23 are wind resource maps that graphically illustrate the coastal wind conditions in South Africa. It should be noted that all of the data in those maps are captured at 100 m above ground level. From the first map, which shows the average wind speed in coastal areas, it is evident that in areas close to the ocean in the south-west part of Western Cape the average wind speed is around 10 m/s (Mortensen et al., 2012, pp. 4–5).

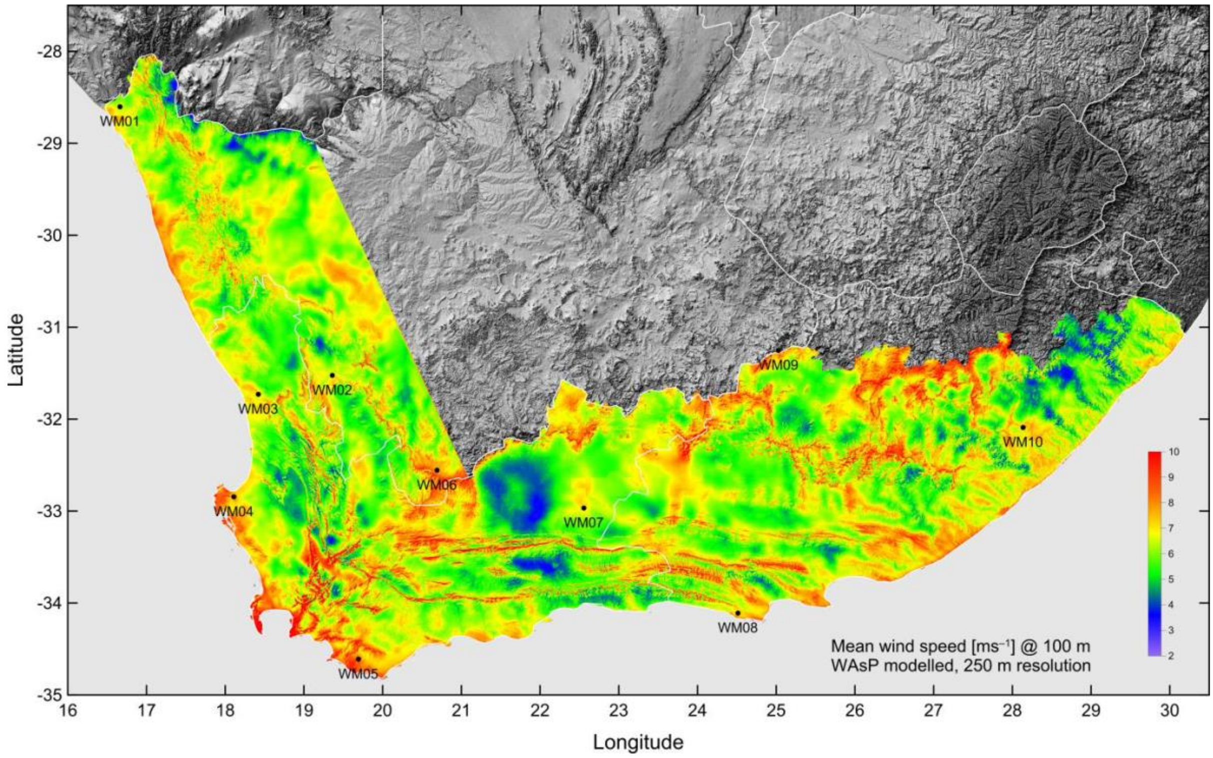


Figure 22: Mean Wind Speed (WRF based) (SANEDI, 2014)

The following map shows the power density in watts per square metre.

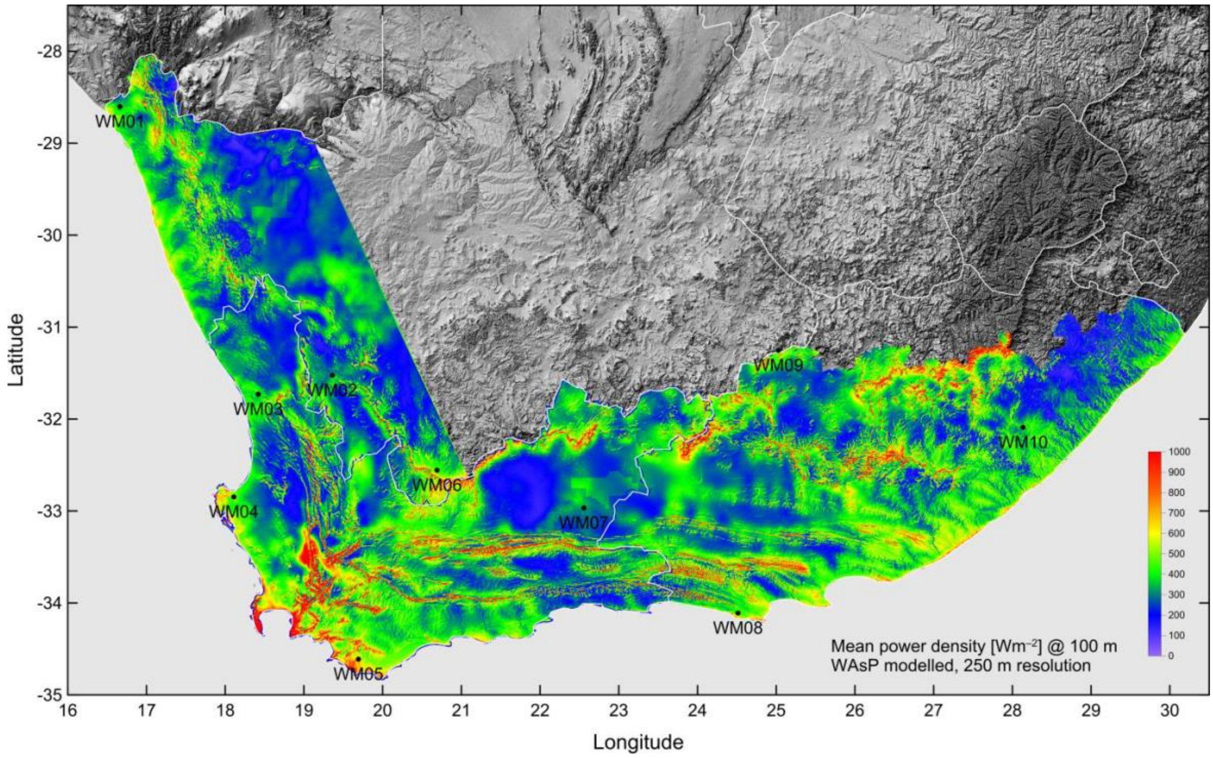


Figure 23: Mean Power Density [W/m^2] (SANEDI, 2014)

As has just been stated, the average wind speed in the coastal region is around 10 m/s, which, according to (U.S. Department of Energy, 2003, p. 15), is suitable for electricity generation even for grid connections.

4.2.1.2 Terrain Elevation

One of the reasons that this area has suitable conditions for wind energy harvesting is because of the population density. This will be discussed in the next section. The other factor that has a defining effect on the wind availability in this region is the terrain elevation. Features such as mountains, hills and valleys slow the wind or block and change the wind's route and, as a result, decrease the available wind speed and wind energy. In figure 24 the terrain elevation is illustrated.

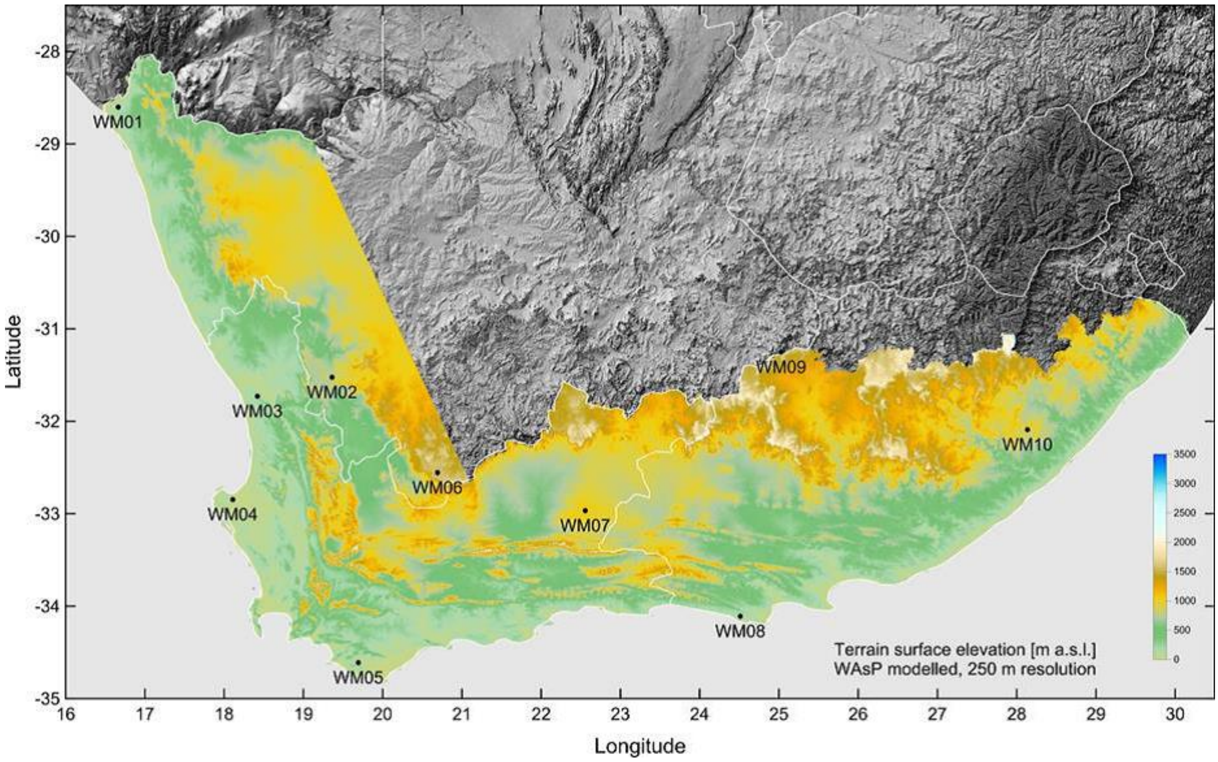


Figure 24: Terrain Elevation (SANEDI, 2014)

As can be seen, the altitude increases gradually from the shore to highlands further toward the middle of South Africa. These maps allow designers of wind systems to find available and suitable areas where the wind from the ocean can be harvested. Additionally it should be noted that the population density and the existence of the cities in this area will affect the conditions. In the next section the effect of population density on the available wind will be investigated briefly.

4.2.1.3 Population Distribution

The population density shows how many people are living in a unit of land. The denser areas are where the more populated cities and big towns exist. In denser areas such as in the cities bigger buildings can be found, and as a result the surface roughness of that area increases and consequently the availability of wind energy in that area decreases. In figure 25 the population distribution in South Africa is illustrated.

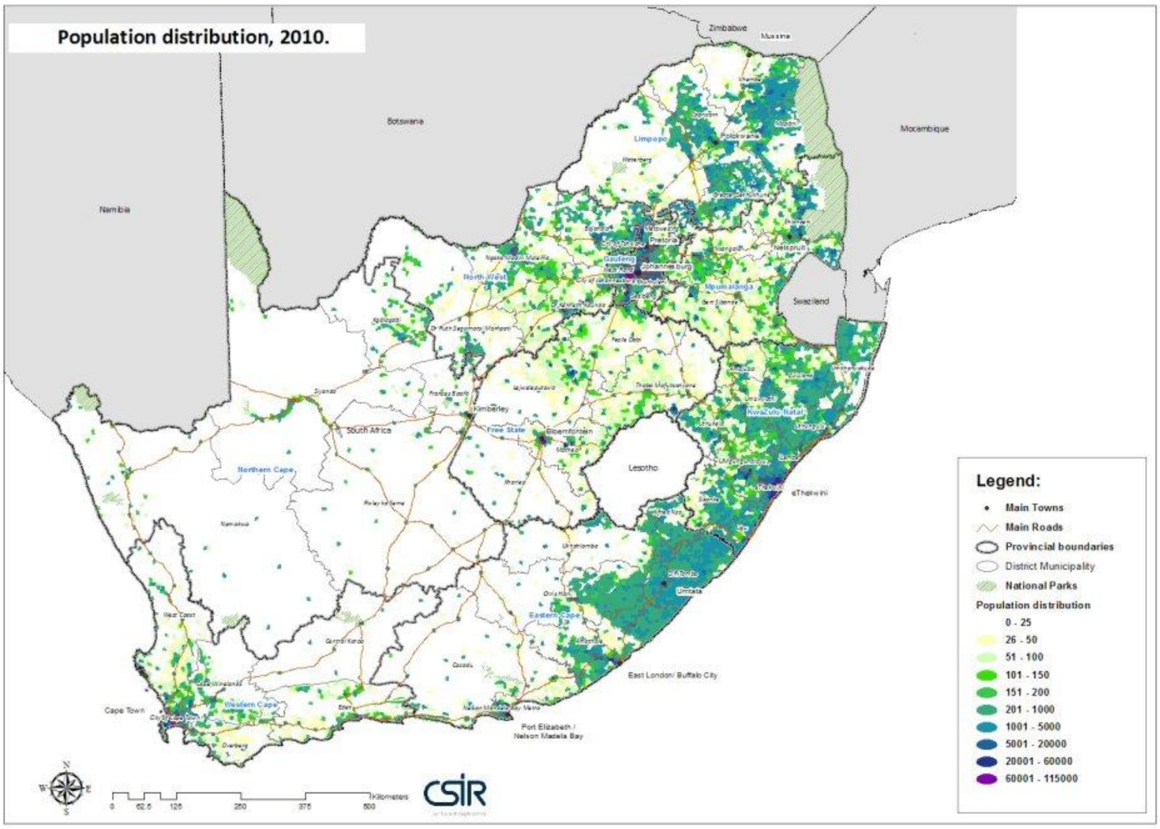


Figure 25: Population Density (2010) (CSIR, 2010)

As is clear from figure 25 the population density is relatively low in the coastal area in Western Cape and Northern Cape which means fewer big cities, more open areas and consequently less surface roughness which makes these areas suitable for wind energy harvesting.

4.2.1.4 Available Yearly Electricity Generation Capacity

The available power in the wind can be calculated by using the Weibull distribution. The power is calculated for various wind speeds by using the formula below (Hau, 2006, p. 98)

$$P = \frac{1}{2}\rho A v^3 c_p$$

Where ρ is air density, A is swept area of the rotor in m^2, v is wind velocity and c_p is the rotor power coefficient.

For simplifying the calculation some assumption are made which are as follows:

- Air density is assumed to be 1.23 $\mathrm{kg/m^3}$ for the scope of this study since most of the regions for this study are sea shores or land next to them.
- The swept area of the rotor is considered to be one square meter in this case, therefore all the outcomes will be per swept area of one square meter which can be roughly applied to different size wind turbines for calculating the available power in later stages.
- The rotor power coefficient is the combination of the theoretical maximum power coefficient for any wind turbine known as the Betz limit (Mathew, 2006, p. 29).
- Finally, the actual efficiency of the wind turbine which for the scope of this study is considered to be 40% (good wind turbines generally fall in the range of 35-45%).

The calculation is done for all 10 wind measurement sites by using the Weibull parameters from the WASA website and applying the power formula to the wind distribution. The Wind Rose graph and Weibull distribution graphs and its parameters can be found in Appendix C. The power available throughout the year per square metre of swept area is summarised in table 2 by using two methods, firstly by using the average wind speed and secondly by using the Weibull distribution. It should be noted that the calculations are based on a wind range from 0 to 30 m/s.

Table 2: Yearly Available Wind Power per Square Metre

Parameters	WM01	WM02	WM03	WM04	WM05	WM06	WM07	WM08	WM09	WM10
Shape Parameter	4.6	6.5	7	7.1	8.8	7.4	7.4	7.8	7.5	6.4
Scale Parameter	1.48	1.85	2.1	1.98	2.08	1.8	2.06	1.92	2.04	1.73
Available Power per Year (kW/y) Using Weibull Distribution	430	860	935	1036	1876	1313	1126	1421	1184	896
Average Wind Speed (M/S)	4.18	5.74	6.21	6.26	7.77	6.54	6.56	6.93	6.67	5.68
Available Power per Year (kW/y) Using Average Wind Speed	157	407	516	528	1010	602	608	717	639	394

It should be the noted that the reason behind the difference between available power per year calculated by means of Weibull distribution and by means of average wind speed is the fact that using average wind speed does not consider the most frequent wind speeds and it can be distorted by the very high and very low but rare wind speeds, Therefore it does not show the real state of the wind distribution. One of the best ways to estimate the wind speed distribution most of the time, is to use Weibull distributions. As a result the focus has to be on the available power which was calculated by using the Weibull distribution.

The available wind energy shown above indicates the power which a wind turbine can capture per square metre of swept area (the turbine efficiency and the Betz limit were already considered). This information can be used at a later stage to determine the range of products to be manufactured for different areas with respect to their power availability.

4.2.2 Target Market

In general most people can benefit from small wind energies. This fairly simple technology can be utilised in industrial parks where there are open areas that allow the wind flows to cover a part of the electricity demand; on farms which consist of mostly open lands with very low surface roughness; in cities in the form of roof-mounted turbines; on boats and vessels; on offshore platforms such as oil extraction platforms; for signage and signalling; in the form of stand-alone turbines for radio antennae in areas where the grid is not available, and in small villages, outposts and areas which do not have access to the grid or it is not feasible to connect the areas to the grid network (Leading Edge, 2014).

A brief account and description of each possible target market will be discussed next.

4.2.2.1 Households and Residential Application

As it was discussed in 4.2.1.3 for the area on which the main focus of this paper is, the population is not very dense and besides the major big city in that area which is Cape Town, the rest of the cities are not big and have low populations. Even Cape Town has very big suburbs with houses that are normally one or two stories high which do not affect the wind speed too much. Therefore in these conditions roof-mounted wind turbines are possible and can be utilised for covering a part of the electricity demand of the building (Leading Edge, 2014).

4.2.2.2 Small Manufacturing and Business

As there are a number of suburbs in this area near the cities or in industrial parks, mostly out of the cities, there are opportunities for business owners to make use of wind energy. They can either use a roof- or a tower-mounted wind turbine if they are in an area where the wind speed required for energy generation is sufficient.

4.2.2.3 Using Wind in Farms and Agriculture

Western Cape is known for the agricultural industry especially grape farms. In figure 26 the value-adding agricultural, forestry and fishing industries in the area are shown and it can be interpreted that these areas are mostly assigned to agriculture.

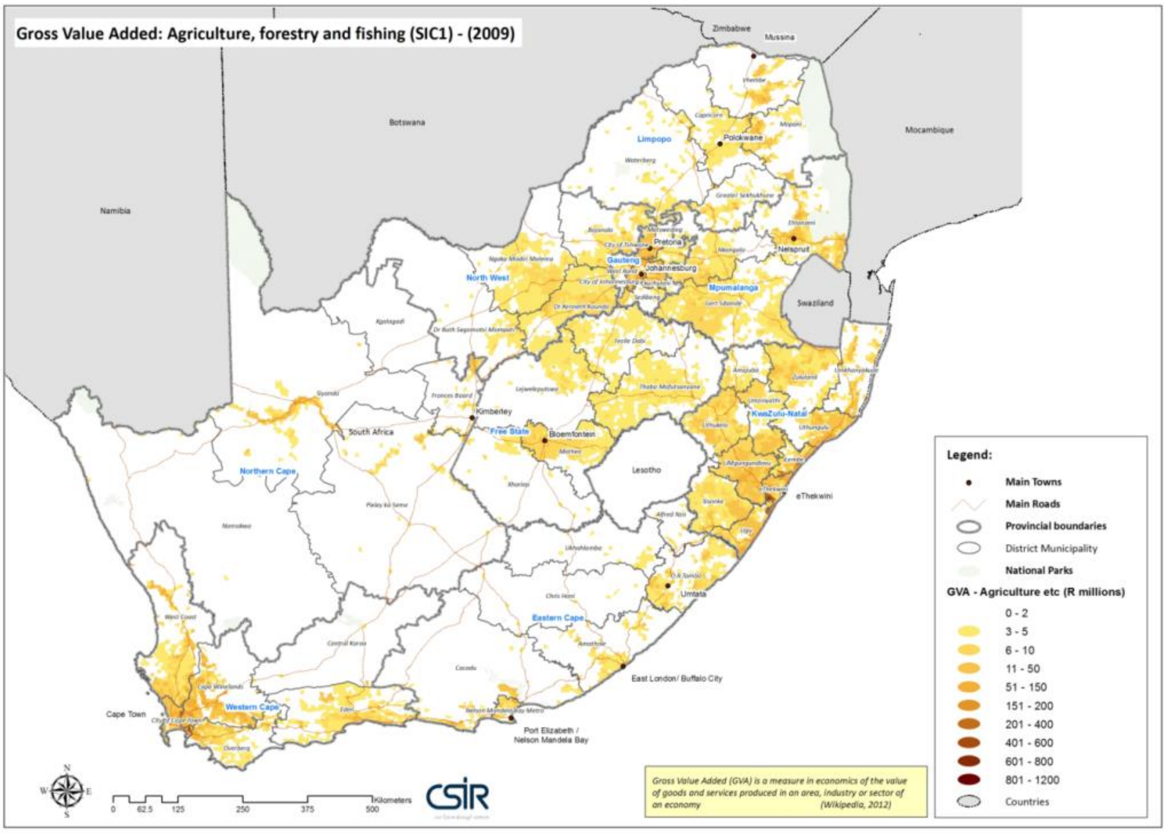


Figure 26: Gross Value Added: Agricultural, Forestry and Fishing (2009) (CSIR, 2010)

Farms are one of the best areas for harvesting wind energy since they have open areas with a very low surface roughness which allows the wind to blow almost without obstacles. One of the most challenging issues for the farmers is to provide electricity for irrigation on the farm. By making use of stand-alone small wind turbines, farmers are able to keep the pumps running in all the areas where electricity connections are not available or not viable due to expense. Also, some of the farms have small plants for processing their products. Wind power could cover part of their electricity bills by utilising the wind energy available on their farms (Leading Edge, 2014).

4.2.2.4 Signage and Signalling

The importance of informing drivers about the dangerous features of roads such as sharp corners, road junctions and so on is known to all. Sometimes these places are not close to the grid, therefore it is expensive to provide a connection to the grid for road signals and signs in those areas and sometimes it is not feasible especially in areas outside cities. It is possible to use wind energy in combination with solar panels to power the road signs and signals in remote areas (Leading Edge, 2014).

4.2.2.5 Wind Turbines for Telecoms

Considering the rate at which mobile communications and broadband technology are being spread even in rural and remote areas, providing the power for such infrastructures is possible by using small wind turbines (Leading Edge, 2014).

4.2.2.6 Wind Turbines for Marine Vessels

One of the initial applications that was introduced for small wind turbines was to use them on small marine vessels, such as fishing vessels and boats, ferryboats and passenger ships. Although they are mostly being used on small marine vessels, they can also be used on any type of marine vessel. Since the focus area of this study is mostly coastal areas, this is a market for the product as well.

4.2.3 Available Target Market

In the previous section the possible target markets were discussed briefly. In this section the available data in each of the possible target markets will be discussed. It has to be noted that in forecasting markets, estimation should be based on previous trends in the market if available and the factors that affect it.

The general factors that affect how willing the target markets are to buy the products include but are not limited to:

- The price increase of energy carriers which leads to increase in electricity cost.
- Environmental issues and the growing tendency to use renewable sources of energy.
- Governmental support for using renewable energies.
- Independency of the national grid.
- A backup system for periods when the national grid is malfunctioning.
- Decreasing electricity bills or covering the total electricity demand.
- Net-metering options.

From the above factors, one or more can affect the customer’s decision. The detailed estimation of each target market is discussed below.

4.2.3.1 Available Market Related to Households and Residential Buildings

To identify the available market in this section, first the number of existing households and residential buildings in the focus area of this study should be identified. Since this study covers Western Cape and parts of Northern Cape and Eastern Cape, the required statistics can be acquired from the local municipalities of each province. For Northern Cape and Eastern Cape, only cities and areas that are covered by the South African wind atlas will be considered. It also has to be noted that residential buildings that are also involved in agriculture will be counted under the farm and agriculture section. In table 3 a summary of the households and residential buildings’ statistics in the mentioned regions are illustrated. For more detailed statistics in this regard please refer to Appendix C.

Table 3: Total Available Target Market for Households (non-farming)

	Western Cape	Eastern Cape	Northern Cape
Households not involved in agricultural activities	1 549 426	1 067 921	21 684
Available market based on distributed population	25%	30%	40%
Available market based on appealing wind condition	50%	45%	40%
Total	193 678	144 169	3469

A large number of these households are located in big cities and are thus less appealing for harvesting wind energy, since they do not have the possibility to install wind turbines either in their yards or on the roof-tops like big residential complexes and skyscrapers, and additionally some of them are located in regions where the wind energy is not at its best for electricity generation. A percentage has therefore to be introduced for each of these mentioned causes and regions.

Since the city of Cape Town is the second biggest city in South Africa according to the South African statistics for 2011 (South Africa Government, 2015), most of the people in the city do not have the privilege of having access to clean and unturbulent wind to be able to efficiently harvest wind energy. Although in the suburbs and areas next to the Atlantic Ocean shore the conditions are much more suitable, most of the population still lives in the city centre according to figure 25. By considering these reasons and the cities' population in Western Cape it is estimated that the available market in this area would not be more than 25% of the existing households in this province.

The same reasoning is also applicable to Eastern Cape and Northern Cape. In Eastern Cape, the population is less and more widely distributed in comparison to Western Cape, consequently a higher available market, around 30 %, can be estimated for this province. As for Northern Cape, a small part of this province is covered by WASA and that is adjacent to the western coast. This area has lower population densities than the other two provinces (South Africa Government, 2015). By comparing the population to the land mass it is clear that it has less population density in comparison with the other two provinces according to figure 25. As a result, the available market for this province is estimated to be around 40%.

In the same way that the available market is analysed based on population distribution, an analysis must be made based on how suitable the wind speed and conditions are in these regions since that will contribute to how appealing the market would be.

For this analysis, the information regarding the available electricity per square metre in table 2 is used to estimate roughly how appealing each of these regions is. It should be noted that in this section only the data from the 10 wind measurement sites is used. More detailed analysis is possible but not in the scope of this study. The data is compared by considering the location of each wind measurement site, for Northern Cape the data from WM01, WM02 and WM06 for Western Cape the data from WM03, WM04, WM05 and WM07 and finally for Eastern Cape the data from WM08, WM09 and WM10.

As it is mentioned in table 2, the best area for harvesting wind energy among these wind measurement sites is WM05. Since this analysis is on a provincial level, a simple average is used between all the wind measurement sites in each province. The province ranking is from highest to lowest, the highest is Western Cape and the lowest is Northern Cape with Eastern Cape in the middle. It is clear that assuming more 50% of the households will have good wind conditions for such a system is being overoptimistic, since the wind speed is not evenly distributed over all of these regions. In this study, the percentage of households with good wind conditions is considered to be 50% for Western Cape with the highest available wind energy, 45% for Eastern Cape and finally 40% for Northern Cape.

The total available target market in table 3 is calculated after applying both percentages for each area. It indicates the available market for this section of the market in South Africa. The market growth and also the share of the market in competition with other competitors, both domestic and international, will be discussed later.

4.2.3.2 Available Market in Agricultural Section

As it was discussed in the previous section, large portions of the regions in Western Cape are assigned to farming, since one of the major activities in that region is agriculture. Also, farms are very suitable for harvesting wind energy due to low surface roughness. The statistics regarding the existing farms can be acquired from local municipalities in the same way as for the previous section. As all of the farms have their own irrigation systems and some of them even have processing facilities for their products on site, they are ideal places to harvest wind energy and use it for the moderate demand of the facilities on the farm. In table 4 a summary of the farms' statistics in the selected regions is shown. For more detailed statistics please refer to Appendix C.

Table 4: Total Available Target Market for Households (farming)

	Western Cape	Eastern Cape	Northern Cape
Households involved in agricultural activities	84 575	569 933	4535
Available market based on appealing wind condition	95%	90%	80%
Total	80 346	512 939	3628

By comparing figure 26 and figure 22 it is clear that most of the farms and agricultural activities are located in the regions that have very good wind conditions for generating electricity. Considering the natural conditions of farms with open areas and the low surface roughness that they have, it becomes clear that farms in these regions are very appealing for using wind energy as part or even full coverage of their electricity demand. Obviously it is overoptimistic to consider 100% market availability but it is reasonable to consider 95% for Western Cape where the wind energy has the highest potential. As for Eastern Cape with the highest agricultural activities and second best wind conditions of the three, a percentage of 90% is considered appealing and finally for Northern Cape 80% is considered possible.

The total available market for farms and agricultural activities is shown in table 4. The growth of the market and the share percentage in competition with other competitors will be discussed later in this chapter.

4.2.3.3 Other Available Markets

The other available markets include those related to employing small wind turbines for small businesses and manufacturing in the area, powering road signals and information boards, powering telecoms in remote areas and also villages where there is no access to the national grid and last but not least for utilising the wind energy on marine vessels.

Statistics regarding these markets are hard to find or not available at all. In table 5 a summary of captured information from scattered sources and different web pages is shown (kestrel Wind, 2014; South Africa Government, 2015; Statistics South Africa, 2014) etc.

Table 5: Other Available Markets

	Small Businesses and Manufacturing	Road Signals	Telecoms	Villages without Access to National Grid	Marine Vessels
Available market based on captured data	14 810*	500	100	50	500

*Calculated using (Statistics South Africa, 2014) and scale that with the population percentage of focus area of this study (South Africa Government, 2015) as well as applying the wind appealing percentage for mentioned regions.

4.2.3.4 Summary of Available Markets

In table 6 the available markets data discussed previously are summarised. It has to be noted that the figures in the following table are simply representative of the number of clients not the possible units to sell.

Table 6: Summary of Available Markets

	Total Available Target Market for Households (non-farming)	Total Available Target Market for Households (farming)	Small Businesses and Manufacturing	Road Signals	Telecoms	Villages without Access to National Grid	Marine Vessels
Western Cape	193 678	80 346					
Eastern Cape	144 169	512 939	14 810	500	100	50	500
Northern Cape	3469	3628					

4.2.4 Growth in the Target Market (External Factors)

Unlike normal markets, the market for this product is less dependent on the population or business growth, this market is created by sharing sections of the existing market. It is true that it has some unique markets as was discussed in the previous section, but the major part of its market will be semi-transition by those who are using solely the national grid to incorporate on-site electricity generation to their normal electricity usage from the grid. Therefore, the following factors have more tangible effects on the market than the traditional factors such as population and economy growth. Although the population and economy growth does not affect the market for this specific product as much as the factors listed below do, it is considered as some of the external factors affect the market growth. This will be discussed later in this chapter.

The growth of the market is affected and dependent on external factors such as the increase in electricity cost, governmental policies toward renewable energy, people's awareness of climate change and the importance of reducing greenhouse gases. the last-mentioned factor has more effect since South Africa is ranked among the twenty highest producers of such gases (12th) by using fossil fuel for electricity generation (The Guardian, 2009).

4.2.4.1 Electricity Cost

According to NERSA[1], in their annual report, the average of 8% increase in electricity price per year has been approved for the third multi-year from 2013/18 to 2017/18 (National Energy Regulator of South Africa, 2013, p. 24). Considering the increase in electricity price and the inflation which is around 6% (Worldwide Inflation Data, 2013), people will have more motivation to start generating their own electricity. That will definitely have a positive effect on people's point of view regarding using renewable sources to generate electricity in their homes. At the end of 2014 NERSA revised the average increase in electricity price, due to recent Eskom problems to keep up with the electricity demand and some breakdowns in their power plants, to 12.69% annually for the years 2015 and 2016 (NERSA, 2014, p. 5). This change will make the use of wind energy even more appealing and will possibly have a positive impact on the outcome of the study.

4.2.4.2 Governmental Policies

As mentioned, the government's policy is also playing a very defining role. One of the most influential policies that governments around the world have used to promote small-scale electricity generation from renewable energy sources is called 'net-metering'. 'Net-metering' means that one is able to sell the electricity by 'reverse feeding' to the grid at the same price or a lower price than the price one would pay to buy grid electricity. The 'reverse feed' or 'feed-in' tariffs are different in different countries and regions. The US was the pioneer in establishing net-metering regulations, followed shortly thereafter by European countries. Recently the South African government announced that they are introducing feed-in tariffs in the near future. According to 'Green Times' and 'Cape Business News' the regulations for small-scale electricity generation will soon be announced and available in Cape Town (Cape Business News, 2014; Green Times, 2014).

With 'feed-in tariffs' approved, there will be huge growth in the market since unlike current conditions where people are only able to use their own generated energy or must use battery banks to store it, they will be able to feed the excess generated electricity back into the grid and use the grid for periods when the renewable resources are not available such as times when the wind is not blowing or during the night and cloudy weather when the sun light is weak or not available. This will make small-scale electricity generation very appealing. It will, however, be a gradual process and the transition will take time.

4.2.4.3 Increasing Awareness

It is true that people are being made aware that the climate change threat is increasing. However, it is not clear if the growth in awareness is fast enough. Government and its advertisements have a defining role in people's awareness and also in guiding people how to decrease the production of greenhouse gases. These advertisements will make the small-scale electricity generation market more prominent than before.

Since all the above-mentioned factors have an increasing effect over time, the market will grow at a faster rate if coordinated well. Of course there are other factors affecting the growth in available markets, but for reasons of simplification and because of the lack of reliable information on how they affect the growth, they have been excluded from the scope of this study.

[1] National Energy Regulator of South Africa

4.3 Identifying the Competitors

There are several companies that manufacture small-scale wind turbines around the world. Obviously they are situated more in the countries where net-metering is possible. Currently, the companies that have supplied the market in South Africa are all foreign companies except for two companies. The introduction to domestic and foreign companies is as follows.

4.3.1 Domestic Companies

There are two domestic companies in South Africa ‘Kestrel’ and ‘BUNDU Power[1]’.

Kestrel is a subsidiary of EVEREADY (PTY) LTD which is located in Port Elizabeth in Eastern Cape. The range of its production covers most of the applications which are introduced for small wind turbines. ‘Kestrel’ wind turbines range from 600 W to 3.5 kW. Although this company has foreign partners and distributors, it does not have a big network within South Africa. According to their website, there is only one distributor in the focus region of this study, at the headquarters in Port Elizabeth. According to their advertisements, Kestrel’s focus market has been remote villages, farms and in a few cases schools in rural areas. Considering this information, the household application of small-scale electricity generation is relatively unexplored.

‘BUNDU Power’ is a generator manufacturer and one of its subsidiaries manufactures solar panels and in their hybrid system they offer a wind turbine range. They are located in Gauteng province and their wind turbine production ranges from 450 W to 2 kW. BUNDU power’s focus is more on generators and solar systems. They offer hybrid systems using solar and wind turbines as well. This company has a few distributors in Eastern Cape that reasonably covers that area and besides a distributor located in ‘George’ there are no other distributors in Western Cape or Northern Cape.

The most important Southern African competitor is ‘Kestrel’ with its wide range of production and also its presence in the market. Also, since they are located in Eastern Cape they have good accessibility to the market in a focused region for this study.

4.3.2 Foreign Companies

There are some foreign companies that are currently in the South African market. There are a few companies that have retailers in South Africa such as Southwest, Pro-An, Exmork, Pegasus and Wind kinetic. These companies mostly supply hybrid systems where solar panels are the main component and wind turbines are the supplementary component. Their main focus has been on remote areas where grid connection is not accessible. Since there are number foreign companies in the market, their production ranges can cover the demand associated with small-scale electricity generation.

4.4 Product Range That Covers Each of the Market Segments

It is obvious that each of the above-mentioned market segments has its own demand range. It has to be identified what range of products each market sector is looking for to be able to fully cover the market demands.

4.4.1 Households and Small Businesses Electricity Requirement

According to the City of Cape Town Government, the average electricity consumption of an apartment over 12 months is 400 kWh per month (City of Capetown Government, 2013). If a month is

[1] After the market study had been finished and the results had been used in the next chapter BUNDU Power announced that they no longer supply small-scale wind turbines. Although it means that the potential market share will increase due to having fewer competitors, because of the time limitation no revision has been made to the market study chapter.

assumed to be 30 days, then the average daily electricity requirements will be around 13.5 kWh. A good portion of this demand can be satisfied by using a small wind turbine with power output rating between 500 W and 1 kW (small business has the same requirements as an apartment). In the case of bigger houses like town houses or vacation houses which have more space and relatively more demand and are also usually located in city suburbs or outside of cities, which makes them even more suitable for small-scale electricity generation, up to 3 kW wind turbines or more than one 1 kW wind turbine, depending on the conditions, can be used.

4.4.2 Farms Electricity Requirement

Farmers can benefit from remote pump stations for watering lands when grid connections are not accessible or very costly to the place where power is actually needed. A pump or pumping station, depending on the number of pumps and the amount of water to be pumped, needs from 1 kW to 3 kW or more (kestrel Wind Turbines, 2011a). It is also possible that for lighting purposes inside the farmhouse or in tunnel production, a lower range of power will be used. Usually for stand-alone lighting a 500 W turbine can supply a few energy-saving lights in a nearby area. In the case of processing facilities, since they use industrial equipment, depending on the demand, a few wind turbines ranging from 1 kW to 3 kW can be used (Leading Edge, 2014).

4.4.3 Road Signs and Signals

Mostly, the renewable energy sources for powering road signs and signals are used outside of cities or in areas where the conditions are very suitable. For a street light, traffic light or information board a wind turbine with output power of 500 W is suitable (Leading Edge, 2014).

4.4.4 Marine Vessels

The production range that covers the consumption of marine vessels is directly dependent on their size. Usually for yachts and boats a wind turbine up to 300 W is used. For bigger marine vessels with more energy consumption, bigger wind turbines can be used which may have additional benefits as well (Nordic Folkecenter for Renewable Energy, 2011).

4.4.5 Telecoms

For powering the telecoms in remote areas and installing broadband access points, depending on the power consumption, wind turbines with power output from 300 W to 1 kW can be used (Leading Edge, 2014).

4.5 Identifying Factors that Could Impact the Target Market Share

With reference to table 6 the available market for three provinces and different markets is covered. It is estimated that the major competitors in South Africa are the two domestic companies mentioned in the previous section, a combined company including all the foreign manufacturers since they are using resellers and their representatives in South Africa for marketing their products, and the Company for which this study is being conducted. To formulate the target market share, each of the competitors will be assigned a score for each market segment that they have a presence in (to be able to service the area by having headquarters or distributors in the vicinity), their production range and level or quality of service. It has to be noted that all the price and cost analyses will be covered in the financial section and this analysis only serves as a preliminary means to estimate the target production capacity.

The detailed explanation of each coefficient which is mentioned above is discussed in the following section.

Presence in the Market Segment

This indicates how close company headquarters or one of the distributors (not retailers) is to the respective market segment and if the company has sales records in that market segment. The closer the facility is to the market segment the less the shipping cost to the client will be and the more flexible the company will be in terms of site assessment, after-sales service and also familiarity with the rules and regulations of local governments. Having been in the market for previous years will increase the market share since the company is known by clients in the market segment. It has to be noted that the effect related to the duration of company presence in the market and the impression that it has made by providing quality products and services, is excluded from the scope of this study.

Production Range

Production range indicates the range of production which actually covers the respective market segment's demand. It is important since if the company's production range does not cover the market segment's demand, the company will lose that part of the market which might be very severe from a financial perspective.

Service Level or Quality

This is mostly discussed from the technical point of view which is directly related to the size of a company. When a company is relatively small, it is assumed production is not very large, the technical employees who are involved in production and are familiar with the products will also be involved in the forefront of that company for consulting with clients and informing them of their options in choosing the product best suited to their needs and in later stages in training them to operate the system. This will result in positive clients, favourable attitudes toward products and that company, which is very critical in the early life of a company. In the case of bigger companies, using the employees in the production sections as client contacts, is no longer possible due to the intensity of the production schedule, therefore employees with lower knowledge levels with regards to the products will be used, which leads to a lower level of service at the first point of contact with the client and the technical inquiries also take longer to be answered. This can be improved by training the staff up to the required level.

4.5.1 Quantifying the Factors that Could Impact the Target Market Share

The above-mentioned factors form the basis for evaluating the status of each competitor in the market and in the end estimating the market share of each of them in the first year of introducing the Company into the market. It is assumed that the market has to be shared between competitors, therefore the total sales of all the competitors has to be the available target market of the market segment in question.

A scoring system is used for each of the criteria in the previous section for each of the market segments which is explained further in the next section.

Presence in the Market Segment

This criterion is only applicable to households' market segments, both farming and non-farming since relevant statistics were accessible. For the remaining market segments, equality for all the competitors in the market segments is assumed. It has to be noted that for initial analysis it is assumed that the Company is located in Western Cape. More detailed analysis will be done in the financial chapter. A score out of four is assigned to each competitor for each of the two market segments based on the following criteria:

- Having their headquarters or a distributor office (a reseller is not similar since they are not only focused on one manufacturer's products) in each province = 3

- Having their headquarters or a distributor office in a neighbouring province = 2
- Not having their headquarters or distributor office in a neighbouring province = 1
- Foreign companies regardless of the location of the reseller = 1
- Presence in the market previously = 1

In table 7 the score for each competitor for each market area and the percentage of market share based on the above scores are shown.

Table 7: Market Share Percentage Regarding the Presence in the Market in each Market Region

Competitors	Western Cape		Eastern Cape		Northern Cape	
	Score	% Market Share	Score	% Market Share	Score	% Market Share
Kestrel Wind	3	26.08	4	33.33	2	25
Bundu Power	3.5*	30.43	4	33.33	2	25
Foreign Companies	2	17.39	2	16.66	2	25
The Company	3	26.08	2	16.66	2	25

*Since Bundu Power has a distributor office in George, a city in the south-east of Western Cape, and can only cover part of the province due to the distance from other parts of Western Cape, a score of 2.5 is considered for that section.

Production Range

As in the previous section, a scoring system is used to quantify the production range coverage. These scores are assigned with regards to the production range of each competitor discussed in section 4.3 and the demand range of each market segment is discussed in section 4.4.

- Covering all the demand range = 4
- Not covering all the demand range = 3

In table 8 the scores and market share for each market segment are shown. It is assumed that 'the Company' has the production range of three products which are as follows: 600 W, 1 kW and 2 kW. Having this information and the production range of other competitors it is assumed that the production range for all the competitors cover the market demands in household (farming) and household (non-farming) the market shares will be equal hence they are not mentioned in the table below.

Table 8: Market Share Percentage for each Market Segment Regarding the Production Range

Competitors	Small Businesses and Manufacturing		Road Signals		Telecoms		Villages without Access to National Grid		Marine Vessels	
	Score	% Market Share	Score	% Market Share	Score	% Market Share	Score	% Market Share	Score	% Market Share
Kestrel Wind	4	25	3	23.07	4	25	4	25	3	23.07
Bundu Power	4	25	3	23.07	4	25	4	25	3	23.07
Foreign Companies	4	25	4	30.76	4	25	4	25	4	30.76
The Company	4	25	3	23.07	4	25	4	25	3	23.07

Service Quality

The same procedure is followed in this section. All the competitors are assigned scores related to the criteria that were discussed in the previous section. The result will be applied to the overall market share. The service quality will only come into effect from the second year of the Company's introduction into the market and its increasing trend is assumed in line with the Company's vision for staying in the market. A 2% increase in market share is assumed as the base rate for the Company and for simplifying the calculations the loss of market share is divided equally between the other competitors.

4.5.2 A 5-year Market Growth Forecast

Various factors affect market growth differently. These factors are categorised into groups. The groups of factors are discussed in more detail and the influence that they have on market growth is explained in the next section.

- **The External Factors (except population and economy growth):** These three external factors in market growth as discussed in section 4.2.4 will only affect the rate by which overall sales increase each year. As discussed previously, one of the three external factors is the electricity price which increases at a rate of 8% every year. It is estimated that the increase in electricity price will have a base increase rate in overall target market share of 3% each year. In addition to that the change in governmental policies such as implementing net-metering and supporting small-scale energy generation, similar to their current support of solar geyser usage, will have substantial effects on the growth of sales. Since these policies will take time to come into effect, for now only an increase rate of 1% for each year in addition to the base increase rate is assumed. In the financial chapter, different scenarios are explored. Note that the increase in people's awareness will affect the sales growth as well. Since this increase is gradual, the growth only comes into effect from the second year onwards and for that a 1% increase rate in overall sales is assumed. This rate can also be affected positively or negatively by governmental policies and visions toward the renewable energies and climate change. These effects are not in the scope of this study.
- **The Internal Factor:** As mentioned previously, the 'service quality' is an internal factor that affects the market share and it comes into effect in the second year with a base rate of 2% and it increases from the third year by 1% every year. It has to be noted that it only affects the Company's market share positively and it is assumed that the loss of market share affects the rest of the competitors equally.

- **The External Factor (Population and economy growth):** As stated before, this factor has a minor effect on the market share as the increase in population and economy growth rate has an indirect effect on the available target market. For this factor, an average increase rate of 0.05% each year is assumed due to population increase in the area according to population statistics (South Africa Government, 2015).

In table 9 the summary of the internal and external factors affecting the market share and available market is illustrated.

Table 9: Summary of Market Growth Percentage Regarding Different Factors

	External Factor (Electricity Cost, Government policies and Awareness)	The Internal Factor	The External Factor (Population growth)*
1st Year	0	0	0
2nd Year	3%+1%+1%= 5%	2%	0.05%
3rd Year	3%+1%+1%+1%= 6%	2%+1%= 3%	0.05%
4th Year	3%+1%+2%+1%= 7%	2%+2%= 4%	0.05%
5th Year	3%+1%+3%+1%= 8%	2%+3%= 5%	0.05%

*It only affects the available target markets

The available target market for each market segment can be found in Appendix E. Having this information and the percentage of market share assumed in section 4.5.1, the market share can be estimated for each competitor in each market segment as shown in table 10. It has to be noted that the location of 'the Company', as mentioned before, was considered to be in Western Cape. In addition to the location assumption the production range is also assumed to be 600 W, 1 kW and 2 kW. For the first year or the start-up year, it is assumed that a total of 5% of the available target market will be the initial potential clients. Therefore, all the calculations and estimations will be based on the 5% available target market in all the market segments for the first year and then grow according to table 9.

Table 10: Market Share for Households Market Segment in 5-year Vision

		Target Market Share for Households (non-farming)			Target Market Share for Households (farming)		
		Western Cape	**Eastern Cape**	**Northern Cape**	**Western Cape**	**Eastern Cape**	**Northern Cape**
1st Year	**Kestrel Wind**	2526	2403	43	1048	8548	45
	Bundu Power	2947	2403	43	1222	8548	45
	Foreign Companies	1684	1201	43	699	4273	45
	The Company	2526	1201	43	1048	4273	45
	total	9684	7208	173	4017	25 647	181
2nd Year	**Kestrel Wind**	4924	4711	84	2043	16 763	88
	Bundu Power	5767	4711	84	2393	16 763	88
	Foreign Companies	3241	2307	84	1344	8208	88
	The Company	5441	2692	94	2257	9576	98
	total	23 253	17 309	416	9646	61 583	436
3rd Year	**Kestrel Wind**	5349	5132	92	2219	18 260	96
	Bundu Power	6276	5132	92	2604	18 260	96
	Foreign Companies	3495	2486	92	1450	8845	96
	The Company	6202	3121	107	2573	11 104	112
	total	21 326	15 874	382	8847	56 480	399
4th Year	**Kestrel Wind**	5760	5544	99	2390	19 724	103
	Bundu Power	6773	5544	99	2810	19 724	103
	Foreign Companies	3737	2656	99	1550	9448	103
	The Company	7001	3580	121	2905	12 736	126
	total	23 276	17 326	417	9656	61 645	436
5th Year	**Kestrel Wind**	6159	5946	105	2555	21 156	110
	Bundu Power	7257	5946	105	3010	21 156	110
	Foreign Companies	3967	2816	105	1646	10 018	110
	The Company	7841	4068	136	3253	14 472	142
	total	25 229	18 779	452	10 466	66 816	473

The 5-year market share forecast for other market segments is shown in the following table.

Table 11: Market Share for Other Market Segments in 5-year Vision

		Small Businesses and Manufacturing	Road Signals	Telecoms	Villages without Access to National Grid	Marine Vessels
1st Year	Kestrel Wind	185	6	1	1	6
	Bundu Power	185	6	1	1	6
	Foreign Companies	185	8	1	1	8
	The Company	185	6	1	1	6
	total	740.50	25.00	5.00	2.50	25.00
2nd Year	Kestrel Wind	361	11	2	1	11
	Bundu Power	361	11	2	1	11
	Foreign Companies	361	15	2	1	15
	The Company	400	13	3	1	13
	total	1481.74	50.03	10.01	5.00	50.03
3rd Year	Kestrel Wind	391	12	3	1	12
	Bundu Power	391	12	3	1	12
	Foreign Companies	391	16	3	1	16
	The Company	457	14	3	2	14
	total	1630.73	55.06	11.01	5.51	55.06
4th Year	Kestrel Wind	421	13	3	1	13
	Bundu Power	421	13	3	1	13
	Foreign Companies	421	18	3	1	18
	The Company	516	16	3	2	16
	total	1779.87	60.09	12.02	6.01	60.09
5th Year	Kestrel Wind	450	14	3	2	14
	Bundu Power	450	14	3	2	14
	Foreign Companies	450	19	3	2	19
	The Company	579	18	4	2	18
	total	1929.15	65.13	13.03	6.51	65.13

4.6 Chapter Summary

Having the information regarding the factors affecting the market, competitors' profiles and companies' visions, the potential market share forecast in different market segments for the first five years of the presence in the market is summarised in table 12.

Table 12: Potential Market Share Forecast in Different Market Segments for the First 5 Years of Market Presence

<table>
<tr><th></th><th></th><th>Total available target Market for Households (non-farming)</th><th>Total available target Market for Households (farming)</th><th>Small Businesses and Manufacturing</th><th>Road Signals</th><th>Telecoms</th><th>Villages without Access to National Grid</th><th>Marine Vessels</th></tr>
<tr><td rowspan="3">1st Year</td><td>Western Cape</td><td>2526</td><td>1048</td><td rowspan="3">185</td><td rowspan="3">6</td><td rowspan="3">1</td><td rowspan="3">1</td><td rowspan="3">6</td></tr>
<tr><td>Eastern Cape</td><td>1201</td><td>4273</td></tr>
<tr><td>Northern Cape</td><td>43</td><td>45</td></tr>
<tr><td rowspan="3">2nd Year</td><td>Western Cape</td><td>5441</td><td>2257</td><td rowspan="3">400</td><td rowspan="3">13</td><td rowspan="3">3</td><td rowspan="3">1</td><td rowspan="3">13</td></tr>
<tr><td>Eastern Cape</td><td>2692</td><td>9576</td></tr>
<tr><td>Northern Cape</td><td>94</td><td>98</td></tr>
<tr><td rowspan="3">3rd Year</td><td>Western Cape</td><td>6202</td><td>2573</td><td rowspan="3">457</td><td rowspan="3">14</td><td rowspan="3">3</td><td rowspan="3">2</td><td rowspan="3">14</td></tr>
<tr><td>Eastern Cape</td><td>3121</td><td>11 104</td></tr>
<tr><td>Northern Cape</td><td>107</td><td>112</td></tr>
<tr><td rowspan="3">4th Year</td><td>Western Cape</td><td>7001</td><td>2905</td><td rowspan="3">516</td><td rowspan="3">16</td><td rowspan="3">3</td><td rowspan="3">2</td><td rowspan="3">16</td></tr>
<tr><td>Eastern Cape</td><td>3580</td><td>12 736</td></tr>
<tr><td>Northern Cape</td><td>121</td><td>126</td></tr>
<tr><td rowspan="3">5th Year</td><td>Western Cape</td><td>7841</td><td>3253</td><td rowspan="3">579</td><td rowspan="3">18</td><td rowspan="3">4</td><td rowspan="3">2</td><td rowspan="3">18</td></tr>
<tr><td>Eastern Cape</td><td>4068</td><td>14 472</td></tr>
<tr><td>Northern Cape</td><td>136</td><td>142</td></tr>
</table>

This forecast might be affected by other factors that have not been discussed in the previous chapter. Study of those potential factors requires more detailed market study which is not in the scope of this research. In next chapters, the technical and financial aspects of the study are discussed and the feasibility of the project is investigated, by determining the optimum production capacity, production range, etc.

5 Technical Section

Product specification and manufacturing requirements are discussed in this chapter.

5.1 Introduction

In this chapter a more detailed approach is taken toward the Company and its products from a technical point of view. This approach creates an understanding of the technical aspects of the product which also helps define the requirements for the production of the product. These requirements include equipment, human resources and raw materials for the production line and equipment and human resources required for the administration section of the Company.

In the next sections the components' configuration of the product, production processes of each sub-product and the requirements for each production process are discussed. Details regarding the administrative section of the Company and its requirements are also discussed.

At the end, production capacity as well as the number of operators is estimated, based on the production lead time defined in the details in this chapter.

5.2 Product's Components

It assumed that the products will be offered in two configurations, off-grid and grid-tied which are slightly different in the configuration of their components. For more information please refer to Appendix F.

Off-Grid configuration consists of (kestrel Wind Turbines, 2011b):

- Small wind turbine, interface modules and mounting accessories
- Charge controller
- Battery bank
- Inverter

And grid-tied configuration consists of (kestrel Wind Turbines, 2011c):

- Small wind turbine, interface modules and mounting accessories
- Charge controller
- Back up (optional)
- Grid-tie inverter

Some of the components mentioned are available as standard products which can be purchased from their respective manufacturers. These components are listed below:

- Charge controller
- Batteries
- Inverters (grid-tie/off-grid)
- Cables

The other products that the production line must produce are as follows:

- Small wind turbine
- Interface modules
- Mounting accessories

These components will be the core of the production in the Company. It has to be noted that standard products such as batteries, multifunctioning invertors and charge controllers have to be part of the final product but since they are being supplied directly from their respective manufacturers to supplement the whole product package, they are not considered as part of the production process and therefore for simplifying the study they are not considered in the later stage of this study.

5.3 Products and Sub-products

In this section each of the components will be discussed in detail. Parts, equipment needed for manufacturing and required materials are the main focus in this section.

5.3.1 Small Wind Turbine Components

Small wind turbine consists of:

- Generator core
- Generator coils
- Generator case
- Generator bearings
- Hub
- Blades
- Tail

5.3.1.1 Generator Core

Generator core consists of a shaft and the permanent magnets mounted on the shaft by means of magnet clamps. Depending on the output voltage and rated rpm the number of magnets will differ.

The material choice for the shaft is steel, and it is made in different sizes according to the wind turbine's rating; obviously the bigger the generator becomes, the bigger shaft it requires. This part has to be outsourced from metal work companies.

For the permanent magnet 'rare Earth Neodynum boron composition' will be used which is the most common magnet in the market. The magnet mountings or clamps have to accurately support the magnets, according to the inside diameter of the coils to fit in and avoid scratching the coil wires. Also having too much distance between magnets and the wires will lead to lower power generation; therefore an optimum distance between magnets and the wires has to be calculated. This aspect, which is part of the design process, is outside of the scope of this study.

5.3.1.2 Generator Coil (Stator)

The generator coil consists of the coil core, the wires and a rectifier attached to the end of the wires through a connector. The rectifier, coil core and the cable can be outsourced and during manufacture, according to the design of the product, they can be wound to form the coil.

5.3.1.3 Generator Case

The generator case is usually made of two pieces and it has to be cast. Therefore it can be outsourced from casting companies. The material of choice is dependent on the application but most of the time it has to be aluminium to be able to tolerate the weather conditions and also to be feasible from the cost and weight perspective.

5.3.1.4 Generator Bearings

The generator has two bearings, one in the front of the shaft and the other at the back of it. They will both be mounted in the case. Bearings will be outsourced since they are considered as standard components.

5.3.1.5 Hub

Hubs, depending on the blade size and number are different in size, thickness and number of holes. Usually for places where the average speed is low and that have more low wind speed than high wind speed, more blades are used to facilitate generator start-up force. Hubs can be purchased as circular metal sheets and according to production needs can be prepared with a suitable number of holes and blade configuration. The blade configuration can vary in different conditions but for keeping production simple for the purpose of this study the number of blades is considered constant and equal to three for all the product ranges.

5.3.1.6 Blades

A blade has to be designed for all the sizes according to production range. A mould has to be manufactured based on the design for each side of the blade. Required carbon fibre sheets, epoxy resins, hardeners and releasing agents can be purchased and the whole blade can be manufactured in the workshop. The number of layers of carbon fibre fabric is determined according to the required strength of the blades. Since it has to be defined in the design phase and is not part of this study an average number of two layers for each side of the blade is considered as an average in industry and also with regards to the fabric thickness available.

5.3.1.7 Tail

The tail consists of a tail boom and tail fin which is made of metal sheet and square tube. The size and length of the tail have to be calculated for each of the wind turbine sizes. Square tubes can be purchased in six-metre long pieces, then galvanised and cut into appropriate lengths and drilled in the correct locations for mounting to other parts. As for the tail fin, a triangle of galvanised sheet can be cut with a laser cutter to specific dimensions and all the corners rounded to avoid injuries when it is being assembled. Being drilled in the locations according to the design, both tail fin and boom are ready to be painted and finally packed.

5.3.2 Interface Modules

The interface modules usually include the safety switch (on/off), rectifier, fuses and terminals to connect the wind turbine to the charge controller, all inside an enclosure. All of these items can be purchased and assembled according to the wind turbine size and power output.

5.3.3 Mounting Accessories

Mounting accessories can be divided in two sections, the part that attaches the wind turbine to the tower and the tower itself.

The first part is usually the part that the generator is mounted on and through a flange it connects the wind turbine to the tower. A slip ring is sometimes used in this section to prevent the cable twisting when the wind direction changes but it can be a weak part in the system. However, the effect of the cable being twisted on the quality of the wind turbine performance may be negligible as long as it is possible to check the cables regularly and untwist them if it is necessary. Therefore using a slip ring is not advisable unless the design is as such that the cables are permanently sent underground or not accessible for the purpose of untwisting them.

The second part is the tower. There are several different types of towers, but for simplicity in manufacturing the most common one will be considered. A monopole tower will be the choice of tower in this section which includes different size pipes mounted on each other through flanges with the thickest at the bottom and the thinnest on the top. The weight limit and wind speed limit according to the weight that it must tolerate, have to be calculated for each wind turbine size and its requested height to determine the pipe's sizing. Again for simplifying the calculation only one height is considered for towers and it is 12 m long for all the production ranges.

5.3.4 Production Components Summary

In Appendix G the status of each component is shown, indicating whether it is to be manufactured, purchased or assembled. Further on in this section the sequence of the operations as well as the assembly sequence are illustrated in an OPC[1]. For more information please refer to Appendix H.

5.4 Work Stations

The work stations are defined based on the manufacturing processes for the product. According to the OPC in Appendix H the list of work stations are extracted.

- Generator winding and assembly
- Carbon fibre workshop
- Welding and drilling workshop
- Painting and drying workshop
- Electrical assembly
- Final packing

Each of the work stations is discussed below in more detail, including the time and equipment required for its operation.

5.4.1 Generator Winding and Assembly

According to the OPC this work station manufactures and assembles the generator. The generator as illustrated in Appendix H includes three sub-products such as generator core, generator coil and generator case. Also in this workshop the mentioned sub-products are assembled with the generator case which is procured or outsourced. In table 13 the operations along with time and equipment needed for each of the sub-products are shown.

[1] Operation Process Chart

Table 13: Generator Winding/Assembly Operation Time and Equipment

No.	Sub-Products	Operation Description	Time Needed(Min)	Equipment Needed
1	Generator Core	Magnet Base Inspection	---	---
2		Magnet Assembling	15	Jig, Bench Vice, Electrical Spanner
3		Assembling on Shaft	10	---
4		Balance Test	3	Balance Test Bench Vice
5	Generator Coil	Wire Inspection	---	---
6		Wire Rolling	15	Frame
7		Placing the Wire Rolls	1	---
8		Put the Frame on the Press	5	Manual Press (Coil Insertion)
9		Unmount the Coil and Test	1	Multimeter
10	Generator Case	Cases Inspection	---	---
11		Bearings Assembly	5	Jig, Bench Vice
12		Coil Assembly	10	Jig, Bench Vice, Soldering Iron, Electrical Spanner
13		Core Assembly	2	Jig, Bench Vice
14		Case Assembly	3	Jig, Bench Vice, Electrical Spanner
15		Functional Test	5	Test Table

5.4.2 Carbon Fibre Workshop

In the carbon fibre workshop blades are manufactured by using the carbon fabric as the structure to increase the strength of the epoxy resin. The blade production consists of processes which are illustrated in Appendix H. It has to be noted that the product has to be cured over time in order for the resin to solidify and take the final shape. This process requires a considerable amount of time. Its requirements and equipment are listed in table 14.

Table 14: Carbon Fibre Operation Time and Equipment

No.	Sub-product	Operation Description	Time Needed(Min)	Equipment Needed
1	Both sides of Blade	Applying the Release Agent	5	Mould, Sponge pad
2		Applying Resin	5	Brusher
3		Applying Fibre Carbon Layers	10	Brusher, Scissor
4		Drying Phase and Curing	420 (7 h)@65°C	Oven
5	Final Blade Assembly	Separating from the Mould	5	Wooden Sticks
6		Trimming the Edges	15	Sanding Papers
7		Attached both Sides	15	Mould
8		Drying and Curing	420 (7 h) @65°C	Oven
9		Polishing the Surface if Needed	15-30	Polishing Machine

5.4.3 Welding and Drilling Workshop

This workshop prepares parts such as the tail fin, tail boom, hub and also the mounting monopole. Drilling is performed on the tail fin, tail boom and hub while welding is performed on pipes and flanges for the monopole. The required time and equipment for each of the operations for sub-products are as per table 15.

Table 15: Welding and Drilling Operation Time and Equipment

No.	Sub-Products	Operation Description	Time Needed(Min)	Equipment Needed
1	Tail Fin	Inspect the Metal Sheet	---	---
2		Drill the Metal Sheet	5	Jig, Bench Vice, Bench Drill
3	Tail Boom	Inspect the Tube	---	---
4		Drill the Tube	5	Jig, Bench Vice, Bench Drill
5	Hub	Inspect the Metal Sheet	---	---
6		Drill the Metal Sheet	20	Jig, Bench Vice, Bench Drill
7	Monopole	Inspect the Pipe and Flanges	---	---
8		Cut the Pipes (tube and pipes) into Designed Sizes	20	Jig, Bench Vice, Plasma ARC cutter
9		Grind the Edge of the Pipe	15	Electric Grinder
10		Weld the Flange to the Pipe	45	Jig, Bench Vice, TIG Welder

5.4.4 Painting and Drying Workshop

Painting will be required for the tail and monopole since they are made of material not immune to corrosion and rust in ambient weather conditions. This paint will protect the parts from rusting and deterioration. In table 16 the time and equipment needed for this workshop are summarised based on each sub-product and operation.

Table 16: Painting and Drying Operation Time and Equipment

No.	Sub-product	Operation Description	Time Needed(Min)	Equipment Needed
1	Tail Boom and Fin	Preparation	60	Sanding Paper
2		Painting	10	Spray
3		Drying Phase and Curing	300 (5 h)	Hangers
4	Monopole	Preparation	60	Sanding Paper
5		Painting	30	Spray
6		Drying Phase and Curing	300 (5 h)	Hangers

5.4.5 Electrical Assembly

In this work station electrical equipment is assembled according to the specifications. There might be a case when the interface is for the coupling of a few products in which the works specification, time and requirements will be different. For the purpose of simplifying the calculations, special cases are not considered here, therefore all the time and equipment mentioned in table 17 are the standard product requirements.

Table 17: Electrical Assembly Operation Time and Equipment

No.	Sub-product	Operation Description	Time Needed(Min)	Equipment Needed
1	Interface	Inspect the Case	---	---
2		Master Switch and Rectifier Installation	10	---
3		Wiring	15	Flush Cutter, Screw Driver
4		Functional Test	2	Multimeter

5.4.6 Final Packaging

In the final packing station, mechanically secured packaging is used by applying expandable foam to keep the components fixed in the box. This will reduce damage and scratches during transportation since components like blades are vulnerable, and harsh movements during transportation might otherwise allow the heavier objects like generators to damage the blades. Since each order includes different components and different combinations it is not possible to use pre-shaped foam. In this case, expandable foam is used to secure the components in the boxes. In table 18 the equipment and time needed for the packing work station are shown. It has to be noted that an average packing time is used here due to the nature of orders which are different from each other, both in the number of components and also the size or the range of products ordered.

Table 18: Final Packing Operation Time and Equipment

No.	Sub-product	Operation Description	Time Needed(Min)	Equipment Needed
1	**Final Package**	Prepare the Box and Package Contents	20	Industrial Stapler
2		Put Plastic Sheet in the Box	0.5	---
3		Pour the Foam and Wrap the Plastic Over	---	Foam Pistol
4		Put the Component Over the Expanding Plastic	1	---
5		Put another Plastic Sheet on top of the Components	0.5	---
6		Pour the Foam and Wrap the Plastic Over	---	Foam Pistol
7		Seal the Box	3	Box-Sealing Tape

5.5 Required Resources for Production

In the previous section information about all workshops with details about each sub-product in the workshop and all the processes regarding each sub-product are discussed. Although it shows the requirements for each process and the time spent on each, it lacks the actual relationship between each process and sub-product and finally the whole product.

In this section for completing the whole picture of the processes and their relationships with each other and finally with the whole system the PERT[1] chart is used. The PERT chart presents the whole system as a network diagram consisting of nodes which present milestones and the lines between nodes which are processes or tasks as well as the time needed for performing those tasks. The objective of using this chart is to determine the amount of time and number of equipment to be used for manufacturing each sub-product and eventually the whole assembly. These figures show the requirements of the process in order to reach the production capacity goal defined by the Company's policy.

By using the PERT chart in Appendix I, the information in the next sections can be derived.

5.5.1 Production Time

In this section, the times required for the jobs to be done in each workshop are calculated. It has to be noted these numbers are based on an initial worker count which will be explained further in the section related to each workshop. For the purpose of defining the time needed for each sub-product to be produced simplified CPM[2] is used. In the following table, the summary of CPM results is shown.

[1] Program Evaluation Review Technique
[2] Critical Path Method

Table 19: Production Time in Each Workshop for each Final Product

No.	Workshop	Final product	Time(min)
1	**Generator Winding and Assembly**	Generator	42
2	**Carbon Fibre Workshop**	Carbon Fibre Blade	662
3	**Welding and Drilling Workshop**	Hub	20
		Tail Boom	5
		Tail Fin	5
		Monopole	80
4	**Painting and Drying Workshop**	Tail	370
		Monopole	390
5	**Electrical Assembly**	Interface	27
6	**Final Packing**	Final Package	25

- **Generator Winding and Assembly**
  Considering that three workers are working in this section and the fact that all the parts have to be assembled at the end, the longest path or 'the critical path' is identified and, in this case, it takes 42 min for the completion of one part in this process.
- **Carbon Fibre Workshop**
  For this workshop, by considering one worker for the whole process, the time that it takes for a blade to be ready is around 925 min or 15 h and 25 min. Most of the time spent in this process is related to the time for curing. Therefore, the worker in this workshop is idle for the duration of curing and since the curing can also take place during the night or after working hours, the capacity of this line cannot be calculated based on the above-mentioned duration. Other options have to be considered for determining the workshop capacity, such as adding to the number of moulds and also increasing the capacity of the oven for curing. This will be discussed later in the chapter.
- **Welding and Drilling Workshop**
  This workshop produces four sub-products, and three of them are sent to the painting workshop and one of them is sent to packing. Considering that there is only one worker working in this workshop and all the sub-products in this workshop are part of the final product and one of each is being used in the final product, the total manufacturing time for the products in this workshop is the summation of the time durations of manufacturing all the parts and sub-products in this workshop. The total time is calculated as 110 min.
- **Painting and Drying Workshop**
  In this workshop, the parts which require protection in outdoor conditions will be painted for durability and also for harmony with the surrounding environment or branding. Therefore, there is an option for the customer to choose the colour for the painting. The painting process consists of a preparation phase for all the surfaces that need to be painted, then for preventing the parts for becoming corroded there has to be a layer of primer paint for the material of choice for the parts. Obviously there is drying duration for the paint as well. Considering all of this, the time is estimated by following the required procedures for each protective paint from its respective datasheets (Duram-Smart Paint, 2011a, 2011b, 2011c) and the times that it takes for the sub-products to be completed are calculated as well. It has to be noted that similar to the carbon fibre workshop, the worker in this workshop is also idle during some stages of the process since the paint needs to dry. Therefore, it is not possible to consider the capacity of the workshop based on the information above. Since the painted parts need hangers for the drying process as well as space, adding those to the workshop can enable the worker to process more parts in the same time span. Later in the chapter the capacity of this workshop will be discussed.

- **Electrical Assembly**
  Considering a worker in this workshop, the total time for assembly and processing of each interface is estimated to be 27 min.
- **Final Packing**
  Adding the required parts for each sub-product, such as bolts and nuts, is done in this section before packing them in the boxes. The whole packing process takes 25 min per order, considering that one worker works on the order.

It has to be noted that the time duration for each product can be changed by changing or improving the processes, adding required equipment or machines and also changing the number of workers in charge of doing the specific tasks. In the case of operators that are idle for part of the time of their assigned jobs for various reasons, such as the curing process for the carbon fibre workshop or drying for the painting workshop, another job can be assigned to them if they are multiskilled. Multiskilling could increase the utilisation of the workers if the production capacity goal allows that. These possibilities will be considered in the dynamic model in the financial chapter.

5.5.2 Required Human Resource for Production

It is not possible to determine the exact number of workers required for the process and production at this stage. As it was said in previous section the time for production is considered based on the initial worker count, in fact there is one worker considered for each position in the initial stage, although it has to be noted that a more accurate employee count will be defined according to the production capacity and multiskilling options in the model in the financial chapter. In table 20 a summary of the workers assigned to different workshops is shown. It has to be noted that these numbers are flexible to some extent and can be changed to fit the production and time requirements.

Table 20: Human Resource for Production

No.	Workshop	Final Product	Human Resource
1	**Generator Winding and Assembly**	Generator	3
2	**Carbon Fibre Workshop**	Carbon Fibre Blade	1
3	**Welding and Drilling Workshop**	Hub Tail Boom Tail Fin	1
		Monopole	1
4	**Painting and Drying Workshop**	Tail Monopole	1
5	**Electrical Assembly**	Interface	1
6	**Final Packing**	Final Package	1

5.5.3 Required Machines for Production

In this section, the machines that are being used in production and the number of machines required are discussed. The number of machines is also based on the initial worker count which was discussed in the previous section. More detailed capacity analysis will be done further on in this study. In table 21 the initial estimation of the numbers of required machines is shown.

Table 21: Required Machine for Production

No.	Workshop	Final Product	Machines	
1	**Generator Winding and Assembly**	Generator	Electrical Spanner	2
			Manual Press	1
			Balance Test Bench Vice	1
			Soldering Iron	1
			Test Table	1
2	**Carbon Fibre Workshop**	Carbon Fibre Blade	Polishing Machine	1
			Oven	1
3	**Welding and Drilling Workshop**	Hub	Bench Drill	1
		Tail Boom	Plasma ARC Cutter	1
		Tail Fin	Electric Grinder	1
		Monopole	TIG Welder	1
4	**Painting and Drying Workshop**	Tail Monopole	Paint Pistol	1
5	**Electrical Assembly**	Interface	Test Table	1
6	**Final Packing**	Final Package	Expanding Foam Pistol	1

5.5.4 Required Material for Production

Manufacturing volumes are dependent on the range of production that the market demands. Obviously different size wind turbines require different amounts of materials, or sometimes completely different materials. The estimation in this section uses the forecasted market share percentage for different market segments which eventually leads to forecast of demand for each standard production range[1]. From the market shares for different market segments and the production range requirements of each market segments in table 8 and table 12, the forecast for the different product ranges' percentage of the total potential demand can be estimated as it is shown in table 22.

Table 22: Production Range's Portion of Total Demand for the Company

	600 W	1 kW	2 kW
Production Range's Portion of Total Demand	22.7%	39.9%	37.4%

In the following pie chart, the potential market demand for each production range for the Company is shown.

[1] It has to be noted that customised and optional products which have to be designed according to the client's requirements are not part of this calculation and forecasting.

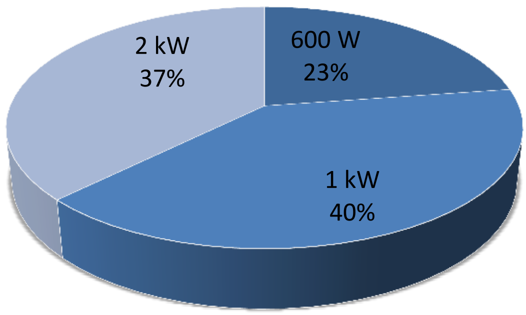


Figure 27: Potential Market Demand Portion for Each Production Range

These ratios will be the basis of the material calculation for production. It has to be noted that the power output of the different products does not have a linear relation to their sizes since the power is related to the swept area of the blades. In other words when the power increases the size also increases but not in the same ratio. In this case, the size ratio is always smaller than the power ratio. The difference in the ratio can be calculated with the information given in (kestrel Wind Turbines, 2011d). Also increasing size has different ratios for different parts; for instance, some parts like generator coils as well as blades have to be quite substantially bigger in comparison to the hub and bolt and nuts. Therefore a fixed average increase ratio of 30% in material needed for production from 600 W to 1 kW and from 1 kW to 2 kW is considered. In table 23 the most important materials used in these wind turbines are summarised (Fleck and Huot, 2009).

Table 23: Material Needed (kestrel Wind Turbines, 2012)

No.	Final Sub-product	Material Used	
1	**Generator**	Shaft Magnet Magnet Base Body (Case)	Bearings Copper Wires Connector Generator Base
2	**Carbon Fibre Blade**	Carbon Fibre Fabric Epoxy Resin	Hardener Mould Release Agent
3	**Hub**	Circle Metal Sheet	Bolt and Nuts
4	**Tail Boom**	Square Tube	Bolt and Nuts
5	**Tail Fin**	Metal Sheet	Bolt and Nuts
6	**Monopole**	Pipe	Flanges Bolt and Nuts
7	**Interface**	Master Switch Circuit Breaker	Rectifier Wires

It has to be noted that the items mentioned above are based on catalogues and IOMs[1] of currently available products in the market. It is obvious that each company's designs are unique and, therefore, some differences in the items are possible. These differences, due to the simplicity of the technology used in the production, should not affect the study substantially. Since that effect is not currently measurable, it is not considered in this study.

More details regarding the amount of raw material and the number of each component being used in the final product will be discussed further in the chapter.

[1] Installation, Operation and Maintenance Manual

5.6 Administrative Section

In this section the organisational chart, human resources and equipment needed for the office section of the Company will be discussed. The importance of this section is to determine how many people are involved in the non-production section of the Company and what equipment is needed for them to do their jobs. To start the process, the organisational chart first has to be defined. In the next section, the organisational chart is defined and each position described briefly.

5.6.1 Organisational Chart

Since the Company is relatively small both from manufacturing and administrative sides, the management of its operation requires a minimum number of employees. Since some of the positions are not so demanding it is possible to assign a person to two positions in the administrative section. The organisational chart below shows different positions and how they are related to each other.

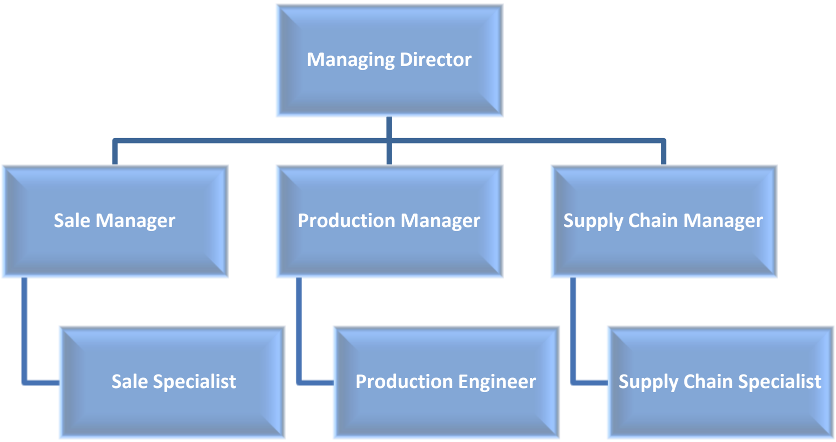


Figure 28: Organisational Chart

As has been said since the Company is in its initial stage the administrative tasks can be handled by sharing the tasks between employees. At the managerial level, the ‘managing director’ can also handle the ‘sale manager’ position. In the same way the ‘production manager’ can handle the ‘supply chain manager’ position. This applies to the first three years of the Company’s existence. For the other positions such as ‘sale specialist’, ‘production engineer’ and ‘supply chain specialist’ the employees’ allocation are as follows.

‘Sale specialist’ is in charge of handling customers’ contacts and orders throughout all the processes till the delivery point. In case he needs additional technical information the order might be referred to the ‘production engineer’, who controls the production process and the technical related inquiries both from the customers and production line. ‘Supply chain specialist’ monitors the inventory levels, both for raw material and final products and is also in charge of procurement of the direct and indirect materials that are being used in the production. In addition to monitoring the inventory level, this position has a close relationship with ‘sale specialist’ for handling the customers’ needs and also promoting the Company. As at the managerial level, the production and supply chain position are handled by one person. For this section is also possible to merge these two positions for at least the first three years of the Company’s existence.

For the ‘sale specialist’ position, the key factor for calculating the required number of employees is to consider the time duration for handling each order. Since the orders are different from each other and each takes time according to the size and specification requested from the client side, an average time for each order is considered. It has to be noted that not all the RFQs[1] lead to orders, therefore, it is assumed that at least one-third of all the potential customers in all the market segments will contact the Company for an RFQ. This number is always bigger than the orders the Company receives and since being responsive to the customers will boost the Company's chance to get more orders, it has to be a priority in the Company policy. As a result, it is assumed that the Sale Specialist position must always have enough personnel to be responsive to clients' demands. Another point that has to be considered is that the distribution of the clients' contact is not clear. Therefore, a uniform distribution is considered for this section.

Using BPMN[2], a business process is designed for the sales department and the process of selling the products, including quoting, delivery and returning if required. According to the business process the handling time for each contact with the Company from the point that the RFQ is sent to the point that it either becomes an order or is rejected, is considered to be 15 minutes on average. It also has to be noted that the 15 minutes happens in different sessions and not at once. For instance, a portion of that time might be the quoting and another portion might be the order processing related tasks. As was said in the above paragraph one-third of potential clients in all the market segments in the first year are considered as potential customers who could contact the Company for requesting a quotation. According to table 10 and table 11, the number of contacts with the Company is 15 950 clients. More information regarding the sales business process can be found in Appendix K.

Having established the total contacts, the total availability of the employees according to the labour laws and regulations of South Africa is eight hours per day making a total of 2 110 hours of employee availability annually. Based on these figures, the number of employees required for the mentioned positions can be calculated. By comparing these numbers, it is clear that at least two employees are required for this section to be able to handle the expected work load. Based on the market size the number of employees for this section makes sense, but it also has to be noted that for the first year that number of contacts, due to being young in the market, seems slightly optimistic. As a result for the first year one employee is considered sufficient in this position (Department Labour Republic of South Africa, 2012).

For the 'production engineer' and 'supply chain specialist' positions with regards to the Company size and the production load which is not very demanding, one person is assumed to be sufficient at least for the first three years.

In addition to the above-mentioned positions, a secretary is also needed to handle the normal office duties and expedite other jobs, such as communications inside and outside of the Company.

5.6.2 Equipment Needed for Administrative Section

In this section, the equipment needed by the administrative section of the Company is summarised as follows.

[1] Request for Quotation
[2] Business Process Management Notation

Table 24: Administrative Section’s Equipment and Human Resource

No.	Positions	Number of Employees	Equipment Needed per Employee
1	Managing Director	1	Office-related equipment including: office table, chair, telephone, computer and consumable material for office such as papers and pens.
2	Sale Manager		
3	Production Manager	1	
4	Supply Chain Manager		
5	Sale Specialist	1	
6	Production Engineer	1	
7	Supply Chain Specialist		
8	Secretary	1	
			A printer for everybody use

5.7 Production Capacity

In this section, an initial production capacity is calculated and explained. The production capacity for each workshop is calculated separately based on the defined human resources and equipment in the previous sections and at this stage it is assumed that there is no sharing of resources between the different workshops, which means that if an operator is idle in one workshop, due to the nature of his work, his idle time cannot be assigned to another workshop. First of all the available time has to be calculated, then according to the available time and workshop requirements, the capacity of each workshop is calculated.

5.7.1 Calculating the Available Time

To calculate the available time first the total working hours in a month has to be calculated. According to the labour law of South Africa, the working hours should be eight hours per day and an hour of lunch-time in the middle (Department Labour Republic of South Africa, 2012). Also considering that each month has 22 working days on average the total working hours can be calculated. However, this time is not the available time for working since problems during working hours will affect it such as load shedding, unplanned maintenance, and the absence of workers due to illness and so on. For the first year, these losses are estimated as 5% of the total working hours during the month. Obviously the maintenance sections’ work is not constant in each year and due to machines aging that portion will increase; therefore a 1% increase ratio is considered for every year for the duration of five years. It has to be noted that the machines being used in the production line are not very complicated and, therefore, their maintenance can be done much faster and also their breakdown rates are lower.

Taking the available working hours per month and adding the efficiency of the workers as another criterion, results in total available time per month. The efficiencies are obviously different for each worker and workshop. An average efficiency of 90% is used for all the workers and workshops to simplify the matter. As a result, 143 hours are available for each worker and machine per month. In the next sections, the capacity of each workshop is calculated for the first year, based on the available time for workers and machines, numbers of required equipment and needed human resources, which were all explained before.

5.7.2 Generator Winding and Assembly Workshop

As was explained in the previous section, the number of employees in this workshop is three, and each of them handles a sub-section in this workshop. Based on the time mentioned in table 13 the production capacity for the sub-sections is calculated as follows.

- Generator core: 307 pieces per month
- Generator coil: 391 pieces per month
- Generator coil assembly: 344 pieces per month

5.7.3 Carbon Fibre Workshop

In this workshop, the capacity cannot be calculated by dividing the available time by the time it takes for a product to be made since each product has to go through two curing phases each of which takes seven hours (SP-High Modulus, 2014). During that time the operator is idle but the mould, which is the major equipment in this workshop is occupied throughout the whole curing phase. Also, it has to be noted that the curing phase can be done during the night or out of working hours since the process does not need supervision. This makes it even harder to calculate the workshop capacity. Since scheduling and line optimisation is not in the scope of this study, some assumptions and estimations are used for the further calculations in the study. It is assumed that for a single mould 75% of the curing time can be considered for the capacity calculations. As for more moulds being used, for each additional mould, a reduction of 10% from the total time is assumed. It is assumed that one operator can work with up to five moulds. Also, it has to be noted that the oven capacity of 10 blades at a time is assumed.

Based on the initial assumption considering one operator with one mould the production capacity is 12 pieces per month. It has to be noted that each final product requires three blades. It is clear that additional moulds and workers should be considered for this section.

5.7.4 Welding and Drilling Workshop

In this workshop the work is divided into two sections, one is welding and the other is drilling and for each an operator is required. The capacity of the sub-sections in this workshop is as follows.

- Drilling (tail fin, tail boom and hub): 287 pieces per month
- Welding (monopole): 107 pieces per month

5.7.5 Painting and Drying Workshop

In this workshop, as with the carbon fibre workshop, the calculation of the capacity is not simple. The paints need a drying phase which takes around six hours (Duram-Smart Paint, 2011c). There is no equipment needed for the drying phase; the only limitation is the enough space for the drying parts. Since space requirement falls under layout planning which is not in the scope of this study, the space limitation is not strictly calculated. However, since the space requirements are likely neither huge nor expensive, it is assumed that enough space can be found. Therefore, the production capacity for this workshop is calculated based on the time that operator is actually working on the parts. The calculated capacity is as follows.

- Painting (tail and monopole): 53 pieces per month

5.7.6 Electrical Assembly

For this workshop, the calculation is straightforward. The workshop capacity calculation is as follows.

- Electrical assembly (interface): 319 pieces per month

5.7.7 Final Packing

The capacity of this workshop is also normally calculated by dividing the total available time by the time it takes to prepare one product.

- Final packing: 344 pieces per month

5.7.8 Workshop Capacity Summary

All the information regarding the production line capacity is summarised in the following.

Table 25: Workshop Production Capacity

No.	Workshop	Final Product	Production Capacity (Pcs/month)
1	**Generator Winding and Assembly**	Generator Core	307
		Generator Coil	391
		Case Assembly	344
2	**Carbon Fibre Workshop**	Carbon Fibre Blade	12
3	**Welding and Drilling Workshop**	Hub Tail Boom Tail Fin	287
		Monopole	107
4	**Painting and Drying Workshop**	Tail Monopole	53
5	**Electrical Assembly**	Interface	319
6	**Final Packing**	Final Package	344

From the above it is clear that carbon fibre workshop's condition is very critical and is considered the process bottleneck. Therefore, corrective actions have to be considered in the next chapter along with financial considerations. After the carbon fibre workshop, the welding and painting workshops are also process bottlenecks.

5.8 Chapter Summary

In this chapter, the detailed requirements of the Company for both the production and administrative sections were specified such as manufacturing procedures, machinery requirements, production lead time for sub-products and human resource requirements. Having this information now, it is possible to do the financial analysis. In the next chapter the financial analysis will be the focus of the study.

6 Financial Section

6.1 Introduction

In this chapter, the financial analysis will be the focus. In the beginning, the variable costs and fixed costs will be discussed and calculated. Based on these two costs the finished product costs will be calculated. Also, the selling price of the goods will be determined with regards to the scenarios. Based on the information in this chapter and the previous chapters, a financial model will be composed and a sensitivity analysis will be performed on that model to identify the flexibility level of the feasibility study. At the end of the chapter the scenario which has the better economical result for the Company will be recommended and the areas for improving the study and making it more accurate will be proposed.

6.2 Variable Costs

As expected, the variable costs are the costs which change when the production volume changes. All the costs associated with the production which are directly or indirectly being influenced by the number of products produced are considered as variable costs.

- Raw material costs
- Production equipment
- Production consumables
- Salaries (production section)
- Staff insurance (production section)
- Electricity
- Tax (VAT[1])
- Income tax

6.2.1 Raw Material Costs

Raw materials are basically all the materials that are bought to be processed during the production and at the end they will be part of the final products. There are three different production ranges and each has its own quantity of raw material usage. As mentioned in the previous chapter, a fixed coefficient based on the average increase in raw material consumption for each production range compared to the previous one is considered. For instance, the raw material usage for the 1 kW range is 30% more than that of 600 W and 2 kW is 30% more than the material usage for 1 kW. Therefore in this section the material usage for 600 W is discussed and then the other two ranges will be estimated based on the above coefficient. The costs for each sub-product are as follows.

It has to be noted that the order volume plays a big role in the price of the raw material. The prices mentioned in this chapter, especially for raw materials are based on an order volume less than 500 units. It is also confirmed by the suppliers that order volumes above 500 units can benefit from a discount rate of at least 5%.

6.2.1.1 Generator

As was explained before, the following components are used in the manufacture of a generator.

- **Shaft**
  The shaft is a solid metal bar that the rotor will be assembled on, which in the case of permanent magnetic generators or alternators, magnets will be assembled on the shaft. A

[1] Value-Added Tax

200 mm long shaft with a diameter of 20 mm is considered for this section. RFQs were sent to a few companies in South Africa, of which two companies replied. The basis of the RFQ was on the quantity required for manufacturing 500 final products. The price to acquire 500 pieces was R51.30 per piece.

- **Magnet Base**

  This part will be assembled on the shaft and has sockets for magnets to be assembled on it. Obviously the number of sockets should be the same as the number of magnets. Although there are a few magnet formations possible on the rotor, a generic formation is considered for financial purposes, since the difference in formation does not impose any financial changes to the product. It has to be noted that the shape of magnets has to be cut on the sheet so that the magnets can be assembled on the base. The thickness of the layers is 2 mm and in order to be able to cover the length of the magnets which is 50 mm, 25 layers have to be used for each of the generators. RFQs were sent to metal working companies for laser cutting the round metal sheets. The price for each is R5.00.

- **Magnets**

  The magnet type chosen is N42 NEO-IRON BARON which has good price/performance ratio in the market. As for the number of magnets, it depends on the design of the generator but in most cases as a standard ratio, 4:3 magnets to coils ratio is used. In the case of this study, the number of the coils is nine for a three-phase alternator therefore according to the mentioned ratio 12 magnets have to be considered for each alternator. The price for each magnet with the dimension of 50 by 20 mm is R80.00.

- **Magnet Wire**

  This component is used for winding the coils. It is advisable to cover the surface area of the magnets with coils to utilize the maximum power of the magnets. Therefore, the dimensions for the coils are based on the magnet's dimensions. In this case, an offset of 6 mm will be considered from all sides which results in coils of 62 mm by 32 mm. For calculating the number of turns on each coil the tesla law has to be applied. The number of turns is dependent on the magnetic flux, number of rpm, number of the poles, number of the coils, the area of the magnet and finally the output voltage. The following equation can be used (Bannon et al., 2013, p. 9).

$$\mathrm{V_{Max}} = \frac{\mathrm{NAB}}{\mathrm{t}}$$

  Where N is the number of turns per coil, V_{Max} is the expected voltage, B is the magnet strength in tesla, A is the coil surface area in square metres and t is the time for a magnet to pass over the coil in seconds.

  The magnet mentioned in the previous section has 13 000 Gs[1] (AMAZING MAGNETS, 2014) which was measured very close to the surface of the magnet, in case of a PMA[2] this number cannot be used due to the gap between the rotor and the stator. Obviously the distance between the magnet and the coil weakens the magnetic flux which covers the coil and as a result it weakens the electricity induced in the coil. Also, the coil is not flat therefore only the first layer of the wires receives the highest flux density and the layers of wires which are slightly further from the front of the coil receive less flux density. A reasonable portion to consider as the average flux density for the mentioned condition is almost half of the

[1] Residual Flux Density in Gauss
[2] Permanent Magnetic Alternator

mentioned flux density, which is around 6500 Gs. Converting this number to tesla[1] units, then B equals 0.65 tesla.
The A, is the surface area of the coil and by having the dimensions for magnets, the area can be calculated. It has to be noted that the unit for the area has to be in square metres. In this case it is $0.002\ \mathrm{m}^2$.
The t, is the time that takes a magnet to pass over the coil. For calculating that, first the number of times that the rotor rotates per second has to be calculated. This depends on the wind speed, the aerodynamics of the blades, number of blades and the tip speed of the blades. As the calculation for this section requires deeper knowledge of aerodynamics which is out of the scope of this study, an average of wind turbine rotor speeds will be considered for this calculation. This average is about 300 rpm, which equals to five rotations per second.
As it was mentioned before, nine coils are considered for this alternator, therefore the circumference of the stator has to be divided by nine. Also it takes one second for five rotations, therefore it can be calculated that it takes around 0.0222 s for a single magnet to pass over the coil.
Now, having the above information the voltage for each coil turn is calculated to be 1x0.002x0.65/0.0222 = 0.058 V. Also, it is known that charging a 12 V battery requires 14 V. Therefore the number of turns can be calculated for 14 V as 242 turns. It also has to be noted since there are three coils per each phase and they are connected in series, therefore, the turns are divided between all three coils and as a result each one should be 81 turns. Having the circumference of the coil equal to 20 cm[2], the length of wire for 81 turns is equal to 16.2 m. Finally, the wires needed for the whole stator coil can be calculated by multiplying the wire needed for one coil by the number of coils, which means 145.8 m of wire is required for one coil. A reel has almost 253 m of wire, which is almost enough for two generators' coils. The cost for the wire used in each generator's coil is around R55.69.

- **Coil Core or Lamination**
  This is the frame on which the coil's wire is wound. It has grooves for the coils to be inserted into. The manufacturing process of this part is to laser cut the round sheets. The product is manufactured in layers and according to the length needed for the alternator's coil; the layers are assembled to make the needed length. The cost for this part is around R100.00 per generator.
- **Alternator Cases**
  They are the structures and also the protective parts for all the components in the alternator. Die casting is the process of manufacturing for this part and the choice of material is aluminium, which has to be purchased from a metal casting company. The price for both sides considering the order volume mentioned before as well as the mould cost is approximately R800.00 for both sides.
- **Bearings**
  Two bearings are used in the case, one in the front case and the other in the back case. The quality of these bearings is important since they are handling the pressure from the blades' rotation and if they malfunction the whole product's performance will be affected. The price for a single bearing is R35.00.
- **Cables and Connectors**
  This section covers the cables and connectors which are used in the alternator to connect the different coils' ends in the stator together and bring them out of the case for connection to the

[1] Tesla=Gauss/10000
[2] Centimetre

transmission cables. The price for cables and connectors used in one unit is approximately R10.00.

- **Bolts and Nuts**
  The bolts and nuts are used here for bolting the two sides of the cases together. Also, a nut is needed for the shaft. The price for the bolts and nuts is R4.04.

In the following table, the prices of the raw materials used in the production of a generator are summarised.

Table 26: Generator Raw Materials' Costs

Part	Raw Material	Cost Rand
Generator	Shaft	51.30
	Magnet Base	125.00
	Magnet Wire	55.69
	Magnets	957.72
	Coil Core	100.00
	Cases	800.00
	Cables and Connectors	10.00
	Bearings	70.00
	Bolts and Nuts	4.04

6.2.1.2 Blades

For manufacturing the blades, the materials listed below are used. The amount and the costs associated with these materials are as follows.

- **Epoxy Resin**
  The epoxy resin is the most important material being used in the blade. For the mentioned product range, the weight of this material used is 128.5 g in each blade and this quantity costs R14.08.
- **Hardener**
  The hardener has to be mixed with the resin before application in order to solidify the resin. The mixture ratio is 100/26 based on the weight of resin(SP-High Modulus, 2014, p. 2). According to the weight ratio, 33.4 g of hardener is needed for a blade which costs around R6.51.
- **Carbon Fibre Fabric**
  The carbon fibre layers are used to strengthen the blade's structure. The fabrics are available in rolls, and for this study a roll of 1.26 m wide and 50 m long is considered. According to the approximate size of the blade, a metre length of fabric can be cut into 10 pieces the size of the blades. Each of the layers, allowing for 20% waste of fabric during the cutting process, weighs 41.32 g and costs R31.2 each. It has to be noted that there are four layers being used in a single blade; two are used for the front section of the blade and the other two are used for the back of the blade. In total, the carbon fibre fabric cost for each blade is R124.80.
- **Release Agent**
  The release agent is used as a thin layer to separate the part from the mould. The quantity of the release mould for each blade can be estimated around 30 cm^3 which cost around R10.04.

- **Mould Sealer**
  The mould sealer can be used and reused several times. For every blade around 200 g of mould sealer is needed which can be reused up to 10 times. In that case the price breakdown for each blade is around R11.06.
- **Bolts and Nuts**
  The bolts and nuts for the blades are very important from the safety point of view since they are used to attach the blades to the hub. To handle the job properly, three sets of bolts and nuts are considered for each blade which costs R2.40 in total.

In the following table, the cost of raw materials for the blades is summarised.

Table 27: Blade Raw Materials' Costs

Part	Raw Material	Cost Rand
Blade	Epoxy Resin	14.08
	Hardener	6.51
	Carbon Fibre Fabric	124.80
	Release Agent	10.04
	Mould Sealer	11.06
	Bolts and Nuts	2.40

It also has to be noted that there are three blades in a wind turbine, therefore the above cost has to be multiplied by three when considering the cost estimation for the wind turbines.

6.2.1.3 Tail

The manufacturing of wind turbine's tail requires raw materials as discussed before. More details including the amount of each raw material used in a tail and the cost associated with them are as follows.

- **Tail Fin**
  For tail fin, galvanized steel cut in a triangular shape of 400 mm by 300 mm by 300 mm is used which costs around R121.11.
- **Tail Boom**
  Square shaped tube is used and cut into lengths of one metre from a six metre long tube. The cost associated with a tail boom for a wind turbine is R85.57.
- **Paint**
  As has been mentioned before, the material is galvanized steel which needs coating for protection from the weather and ambient conditions. An estimated 100 g of coating paint for galvanized steel is considered for each tail. Therefore, the cost associated with painting the tail is around R24.86.
- **Bolts and Nuts**
  For attaching the tail to the generator and also attaching the tail fin to the tail boom bolts and nuts are required. The cost of the bolts and nuts which are needed for this purpose is estimated to be around R2.07.

The costs associated with the tail are summarised in the following table.

Table 28: Tail Raw Materials' Costs

Part	Raw Material	Cost Rand
Tail	Tail Fin	121.11
	Tail Boom	85.57
	Paint	24.86
	Bolts and Nuts	2.07

6.2.1.4 Hub

There is only one raw material used in the hub which is as follows.

- **Round Metal Sheet**
  For manufacturing the hub which is the link between blades and the generator's shaft, round metal sheet is used and further in the process it is drilled according to the number of the blades to be mounted on it. A 250 mm diameter round metal sheet is selected which costs around R97.60.

6.2.1.5 Monopole

The raw materials used in monopole production are listed below.

- **Pipes**
  Depending on the height of the monopole and the weight tolerance it is designed for, different pipes with different sizes, schedules and length are used. In this case, a 12 m monopole with four sections of pipes each three metres long are proposed. The material of the pipes is also recommended to be galvanized steel. For a galvanized steel product, after the flanges are welded to the pipes, the whole product has to be sent for coating. The total cost associated with all the procedures is around R6 058.71, excluding the flanges which are discussed below.
- **Flanges**
  To connect and attach the pipes, flanges are used. The flange specification has to be in accordance to the pipe it is being welded to. Taking that into consideration as well as the galvanizing procedure which is explained above, the cost associated with the flanges used in the monopole is around R1 983.73.
- **Paint**
  As mentioned regarding the tail section, the paint for galvanized steel is necessary to protect it from corrosion. The amount of paint to be used for the monopole is estimated to be around 300 g which equals R74.58.
- **Bolts and Nuts**
  The bolts and nuts in this section are used for fastening the flanges together. The bolts and nuts required for this section are estimated to be around R8.81.

The cost summary of this section is summarised in the following table.

Table 29: Monopole Raw Materials' Costs

Part	Raw Material	Cost Rand
Monopole	Pipes	6058.71
	Flanges	1983.73
	Paint	74.58
	Bolts and Nuts	8.81

6.2.1.6 Interface

The items used in the interface are as follows.

- **Case (Enclosure)**
  The enclosure that protects the electrical parts for safety purposes should have reasonable IP[1] to prevent the electrical devices inside it being exposed to rain or moisture. The cost associated with this type of enclosure is estimated to be around R130.00.
- **Master Switch**
  The master switch is used to make it possible to turn the wind turbine on and off. It is estimated to cost around R150.00.
- **Rectifier**
  The rectifier is used to convert the AC electricity to DC for further usage. The cost associated with this part is assumed to be R82.75.
- **Cables**
  The cables used in connecting all the devices in the interface are estimated to cost around R25.00.

The summary of the costs for the interface is shown in the following table.

Table 30: Interface Parts' Costs

Part	Raw Material	Cost Rand
Interface	Case (Enclosure)	130.00
	Master Switch	150.00
	Rectifier	82.75
	Cables	25.00

6.2.2 Production Equipment

In the production line, usually the machines that have large production capacities are considered to be fixed costs and the equipment that is sensitive to the production volume is considered as variable costs. In this study, it is assumed that items listed below are in the variable cost category.

- Carbon fibre mould: R75 404.16 each
- Paint compressor and pistol: R3 762.00 each

This equipment, because of its intensive use, often causes bottlenecks in the production line; therefore it is regarded in the variable cost category so that the calculations for different scenarios become easier.

6.2.3 Production Consumables

In this section, the materials which are used during the production process are summarised. These materials play indirect roles in production. The cost estimation for these materials is more difficult due to their applications and the variable rates of consumption. A rough estimate is made to define the cost associated with this type of material. I**Error! Reference source not found.**n the following table, the costs associated with production consumables are summarised. It should be noted that the price breakdown has been made for cost estimation per production unit.

[1] Ingress Protection

Table 31: Production Consumables' Costs

Consumables	Cost Per Product Rand
Electrodes and Solder Wire	100.00
Sponge Pad	6.00
Brusher	24.00
Wooden Sticks	6.00
Sand Paper	10.00
Grinder Blades	3.50
Polisher Head	10.00
Drill Tool Set	5.50
Tape Packaging	10.00
Carton Box	20.00
Foam for Packaging	55.00

6.2.4 Salaries (Production Section)

Salaries should be divided into two categories, first the salaries that are directly influenced by the production volume and secondly the salaries that are not directly influenced by production volume. The first category is considered in the variable costs and the second one will be discussed in the fixed costs section. These two categories are referred to as 'variable salaries' and 'fixed salaries'.

Variable salaries are the salaries that are paid to the employees involved in production. According to table 20 there are nine positions for workers employed in the production line. The salaries are estimated based on the research on available job opportunities for similar positions and work complexity. As said before, the current number of employees' positions is just an initial estimate and has to be assessed based on the financial criteria. Although the number of employees might change in the financial feasibility study, the position salaries will remain the same. In the following table, the position and the estimated salary for each position are summarised.

Table 32: Production Line Salaries

No.	Workshop	Position	Human Resource	Position Annual Salary (CTC[1]) Rand
1	**Generator Winding and Assembly**	Simple Worker	3	96 000.00
2	**Carbon Fibre Workshop**	Carbon Fibre Worker	1	132 000.00
3	**Welding and Drilling Workshop**	Simple Worker Welder	1 1	96 000.00 132 000.00
4	**Painting and Drying Workshop**	Simple Worker	1	96 000.00
5	**Electrical Assembly**	Electrical Technician	1	132 000.00
6	**Final Packing**	Simple Worker	1	96 000.00

6.2.5 Staff's Insurance Contributions (Production Section)

According to the Company's policy and for sustaining the good health of the Company's employees, contribution to the health insurance of the employees is considered. In addition, the contribution to Unemployment Insurance is also included. According to the South African government (Department of Labour Republic of South Africa, 2004) 1% of the employee's salary has to be paid for this section. Since the number of employees in the production section is directly defined by the production

[1] Cost to Company

volume, the staff insurance for the Production section is considered separately from the administrative staff. The contribution to health insurance as well as unemployment insurance is as follows.

For this section a contribution of R500.00 per employee per month is estimated.

6.2.6 Electricity

The electricity usage, in a similar way to salary, should be divided into two categories. The first one is the electricity usage in the office and other parts of the Company which are not directly related to production. The other category is the electricity usage which is directly used by the machines and production equipment. The second category will be discussed in this section and the first category will be considered in the fixed cost section later in this chapter.

The variable electricity usage is considered based on the electricity usage of the equipment in the production line. Based on the machines' electricity usage and the current electricity rate, cost associated with electricity usage of the production line equipment and machines for each product is considered to be R12.00 (Western Cape Government, 2014).

6.2.7 Tax (VAT)

Value-added tax (VAT) is applicable to benefit gained from selling units. For calculation of VAT, first the total revenue has to be calculated based on the number of sales. Then the raw material used in the product, in other words all the materials or services that were used in the process of making the finished goods, has to be calculated. Included is the raw material itself, the consumables for the process, the electricity and the water used in the process. By deducting the raw material price from the total revenue, the amount that is applicable for VAT is calculated. 14% of this amount is the VAT payable by the Company.

6.2.8 Income Tax

The tax that is applicable to the profits of the Company according to (RSM Betty & Dickson, 2014) is 28%. Various issues, such as depreciation for the fixed assets of the Company, have to be considered in this tax calculation for the purpose of tax reduction. According to the type of asset, a depreciation period is defined by the government, during which period the asset is being depreciated and the cost has to be deducted from the profit each year based on the depreciation rate. In other words, in the tax reduction, only the depreciated portion of the cost price of each asset is considered. The depreciation period and also the amount of cost to be considered for the tax deduction for each year will be discussed in the fixed costs section. It also has to be noted that items with a cost price of less than R7 000.00 can be deducted immediately in the first year (RSM Betty & Dickson, 2014).

6.3 Fixed Costs

All the costs that are not related to the production volume are in this category. The fixed costs are listed below.

- Building and land rental
- Administrative equipment
- Salaries (administrative section)
- Administrative section's consumables
- Machineries
- Utility
- Staff insurance (administrative section)
- Insurance

- Miscellaneous

As mentioned in the tax section; the depreciation of the assets, which can be considered as an investment in the Company, has to be calculated. The depreciated cost is a method for asset valuation which shows the amount of capital that is used up in a given period of time, which in this study is a fiscal year. As a general assumption there is no salvage value considered for the assets after their lifetime and also the straight-line method is used for annual depreciation amounts calculation (G.Sullivan et al., 2003). In the following sections, where it is applicable, the depreciation cost and the lifetime as defined by the South African government are calculated. This will be the basis on which the assets depreciation in the annual fixed cost is considered.

6.3.1 Building and Land Rental

As it was mentioned before, the Company is assumed to be based in Western Cape and specifically in Cape Town. Therefore, commercial properties were researched to find a suitable place for the business. The Epping industrial area is considered to be an ideal place due to its accessibility to the national roads for facilitating the transportation process and lowering the transport costs. Being located in an industrial area would be beneficial for reasons such as the possibility of acquiring some of the raw materials from the neighbouring companies.

According to (Western Cape Government, 2002) the rental rates for buildings and industrial land of grade A+ which is the highest grade in the list, is R57.86 per sqm[1] per month in Cape Town. Therefore the rental cost for 300 sqm land and building costs around R17 358.00 per month. For lower grades, the cost will be lower, but given inflation this amount is considered to be a reasonable estimate. Recent values advertised in various media range from R22.00 to R100.00 per sqm.

6.3.2 Administrative Equipment

The equipment that is used in the administrative section is directly related to the number of employees in that section. According to table 24 there are five employees working in the administrative section of the Company for whom equipment necessary for office work must be supplied. In the following table, the details of the equipment needed in the office are summarised.

Table 33: Administrative Equipment's Costs

No.	Equipment	Quantity	Total Cost (Rand)
1	**Aircon**	1	9000.00
2	**Desk**	5	16 200.00
3	**Chair**	5	6300.00
4	**Bookcase**	1	500.00
5	**Computer**	5	94 500.00
6	**Printer**	1	5500.00
7	**Fax**	1	2100.00
8	**Phone**	5	2250.00
9	**Others**	1	1000.00

It has to be noted that the above mentioned costs are once-off and they are considered as the Company's fixed assets.

As it was mentioned in the tax section, the depreciation duration has to be calculated for each of the assets. In the following table, the depreciation period and the annual cost based on depreciation period is calculated.

[1] Square Meter

Table 34: Office Equipment Depreciation

No.	Equipment	Depreciation Period(years)	Tax Deduction per year(Rand)
1	Aircon	6	1500.00
2	Desk	6*	16 200.00
3	Chair	6*	6300.00
4	Bookcase	6*	500.00
5	Computer	3	31 500.00
6	Printer	5*	5500.00
7	Fax	3*	2100.00
8	Phone	5*	2250.00

*These items cost less than R7000.00 each therefore it can be considered as cost in full in the first year

6.3.3 Salaries (Administrative Section)

This section covers the cost associated with the salaries payable to the administrative staff. According to table 24 and the Company organisational chart, there are nine employees in different positions and their salary estimations are listed below.

Table 35: Administrative Section's Salary

No.	Position	Number of Employees	Annual Salary(CTC) Rand
1	Managing Director	1	480 000.00
2	Sale Manager	1	300 000.00
3	Production Manager	1	300 000.00
4	Supply Chain Manager	1	300 000.00
5	Sale Specialist	2	180 000.00
6	Production Specialist	1	180 000.00
7	Supply Chain Specialist	1	180 000.00
8	Secretary	1	108 000.00

The above-mentioned salaries are extracted from job-search websites and are based on similar job opportunities offered there.

6.3.4 Administrative Section's Consumables

The administrative section's consumables include the materials that are used in the office such as paper, pens and printers cartridges, as well as internet and telephone rental and the programs that require yearly subscription such as Office 365[1]. In the following table, these costs are summarised.

Table 36: Administrative Section's Consumables

No.	Items	Annual Cost (Rand)
1	Paper, Pen, …	12 360.00
2	Printer Cartridge	16 000.00
3	Internet	9000.00
4	Telephone	9000.00
5	Office 365 (Software)	3200.00

[1] Microsoft Office 365

According to (RSM Betty & Dickson, 2014) these items can be considered for tax deduction every financial year.

6.3.5 Machinery

The machinery used in the production line is listed in table 37. It should be noted that the quantities of these machines and equipment are based on the initial estimation and might change in the financial analysis. In the following table, the costs per equipment or machine are mentioned and the final cost will be calculated based on the financial scenarios later in the chapter.

Table 37: Machineries' Costs

No.	Equipment	Quantity Per Initial Estimation	Cost Per Unit (Rand)
1	**Bench Vice**	3	2649.36
2	**Electrical Spanner**	2	3420.00
3	**Polisher**	1	4570.26
4	**Drill Press Bench**	1	4650.06
5	**Plasma Arc Cutter**	1	8840.84
6	**Grinder**	1	1340.64
7	**Welder Inverter**	1	2324.46
8	**Tool Set**	2	3587.58
9	**Coil Insertion**	1	1 092 234.00
10	**Coil Insertion Tools***	3	410 550.40
11	**Multimeter**	2	581.40
12	**Soldering Iron**	2	114.00
13	**Tables and Chairs**	9	1140.00
14	**Oven**	1	1500.00

*The three units for Coil Insertion Tools are for three different production ranges

For the purpose of tax deduction for fixed assets the duration of depreciation for each asset category is used in accordance with the governmental regulations in this regard (RSM Betty & Dickson, 2014). In the following table, the depreciation duration and the annual cost price in the depreciation period that can be considered for the purpose of tax deduction are given.

Table 38: Depreciation Periods

No.	Equipment	Depreciation Period (years)	Tax Deduction per Year (Rand)
1	**Bench Vice**	5*	7948.08
2	**Electrical Spanner**	5*	6840.00
3	**Polisher**	5*	9140.52
4	**Drill Press Bench**	5*	4650.06
5	**Plasma Arc Cutter**	5	1768.17
6	**Grinder**	5*	1340.64
7	**Welder Inverter**	5*	2324.46
8	**Tool Set**	5*	7175.16
9	**Coil Insertion**	5	218 446.80
10	**Coil Insertion Tools***	5	246 330.20
11	**Multimeter**	5*	1162.80
12	**Soldering Iron**	5*	228.00
13	**Tables and Chairs**	6*	11 400.00
14	**Oven**	5*	1500.00

*These items cost below R7000.00 each therefore it can be considered as cost in full in the first year

6.3.6 Utility

The costs associated with the utility are mostly fixed costs since they mostly remain the same regardless of the production volume. Due to variations in the administrative and production section usage of the utility, which, in this case, the production section uses the utility heavily, the utility usage of the production section can be considered as a variable cost. As it was explained before in the variable cost section, in the case of this study the electricity is divided into two sections, which one of them is the base usage and the other is the usage per unit of production. The variable part of the electricity cost was discussed in the variable cost section while in this section the fixed part of the electricity cost, as well as the water cost, are discussed.

According to Western Cape Government (Western Cape Government, 2014) there is a fixed daily charge of R25.37 which has to be paid for the duration of subscription, base usage for the whole building and also the usage for the administrative section which is only applicable for working days. This is calculated based on R1.36 per kWh. In the following table, the annual costs of both water and electricity are mentioned.

Table 39: Utility Costs

No.	Items	Annual Cost (Rand)
1	**Water**	6000.00
2	**Electricity (Fixed Base)**	15 600.00

6.3.7 Staff's Insurance Contribution (Administrative Section)

As it was said in the previous section the Company's contribution to the insurance of the Company's employees is divided into two sections; one for the production line employees and one for the administrative section's staff. In this section, only the contribution for employees in the administrative section of the Company is considered since it is not related to the production volume. This contribution is shown in the following table.

Table 40: Staff's Insurance Contribution (Administrative Section)

No.	Items	Quantity	Annual Cost (Rand)
1	**Contribution for Managerial Positions**	4	38 400.00
2	**Contribution for Below Managerial Positions**	5	30 000.00

6.3.8 Insurance

To reduce the risk involved with production and business the Company should be covered by a comprehensive insurance policy. For this study, since there is no actual company, the insurance companies have refused to provide any budgetary offer. For this section, a guide in insurance cost estimation is used. The required insurance policy for the Company is assumed to be around R4 500.00 per month.

6.3.9 Miscellaneous

In this section, the other items that are not part of the above-mentioned categories are mentioned here. As for the Company's needs, a vehicle has to be purchased for the purpose of assessing the wind condition at customers' sites and also to install the products upon request. In the following table, the cost for the vehicle and estimation for fuel consumption is shown.

Table 41: Miscellaneous Costs

No.	Items	Quantity	Cost (Rand)
1	**Pickup** [1]	1	156 750.00
2	**Fuel Consumption**[2]	100 L	1366.00(P/month)

In this section the vehicle purchased for the Company is considered to be in the delivery-type category for fixed assets, consequently the depreciation period according to the governmental regulations is four years and the annual cost price is R39 187.50 (RSM Betty & Dickson, 2014).

[1] (Chevrolet South Africa, 2014)
[2] (Shell South Africa, 2014)

6.4 Pricing

There are a few pricing methods which can be used in different circumstances. For instance when a unique product is being introduced to market three approaches can be taken. The first is to determine the price based on the willingness of the customers to pay for the product or secondly, to consider the finished product's cost and adding a reasonable margin to that. But for this market where the product already has competitors the second method might not work since another competitor might be able to produce cheaper or consider smaller margin and win the competition. In this case, the method which is based on the product's price in the market is used.

For this method of pricing, the most important criterion to consider is the competitors' pricing in the target market. Therefore, the major competitors' prices were captured. Kestrel wind as the major domestic competitor has the highest importance in this comparison and plays an important role in product price setting for the Company. The other competitors which are the international manufacturers work through reseller companies in South Africa. For this purpose, two reseller companies were requested to submit their offers for the product ranges. In table 42 the prices are summarised both for the wind turbine and the tower.

It should be noted that there are a few online shopping websites for renewable energy equipment and accessories, for companies who deliver in South Africa and mostly sell the brands made in Europe, China and Eastern Countries in addition to the only South African brand, Kestrel. On these websites the products are mostly offered with additional units such as charge controllers or towers in the package. In these websites, the wind turbine part is usually more expensive than the local manufacturer's price; therefore it is not a reasonable assumption to consider different prices for the same product from different shops for estimating the product price in the market. Bearing that in mind only a few prices from different companies in South Africa were considered for the basis of the market price estimation.

The Kestrel products' prices have been acquired directly from the manufacturer itself. Another company that represents the European-made products is named Pegasus Systems, who also provided prices on behalf of the respective manufacturers. In addition to these two companies, another three online shops were included so as to cover most of the small wind turbine brands in the South African market in order to have a more educated estimation. Having the prices for different ranges, the average prices for all the ranges for both the wind turbine and the towers in the South African market were calculated which will be the basis for defining the prices of the Company's products in the market.

The prices for different wind turbine size through different manufacturers are summarised in the following table.

Table 42: Wind Turbine's Market Prices[1]

No.	Companies	Items	400 W	600 W	1 kW	1.5 kW	2 kW	3 kW	3.5 kW
			Product Range						
1	Kestrel Renewable Energy	Wind Turbine	---	13 167	28 023	---	---	---	65 465
		Tower	---	25 938	25 938	---	---	---	49 364
2	Pegasus Systems	Wind Turbine	8208	14 250	17 670	24 510	---	40 128	---
		Tower	28 500	28 500	28 500	28 500	28 500	28 500	28 500
3	GW Store	Wind Turbine	10 887	---	25 623	16 495	28 463*	42 348**	---
		Tower	---	---	---	---	---	---	---
4	African Wind Power	Wind Turbine	---	---	---	---	32 000	---	---
		Tower	---	---	---	---	---	---	---
5	Alternagy	Wind Turbine	---	14 181.	---	18 610	22 332	---	---
		Tower	---	---	---	---	---	---	---
	Average	Wind Turbine	9 546	13 866	23 772	19 871	27 598	41 238	65 465
		Tower	---	27 219	27 219	---	27 219	---	---

*9 m Guy-wire tower included (5467.00)

**12 m Guy-wire tower included (17 870.00)

In defining the products' prices, the Company's market approach has to be considered as one of the major factors. For this present case entering the market rapidly and finding footing in the market is of extreme importance for the Company. Therefore, incentives have to be considered to encourage people to choose the Company's products over the other competitors' products in the market. As a result, a discount range has to be defined based on the average market price.

The discount range assumed for the products are between 0 and 10%. This range is defined based on the lowest price in the market, mostly Chinese products, so that the price would be appealing to all the customers. Obviously the discount will affect the profitability of the Company versus the production volume. This effect has to be analysed so that the managers can make the right decisions in optimising the discount rate as well as considering the incentives in the product's price. This analysis will be done in the next section.

6.5 5-year Forecast for the Company's Financial State

The Company's financial position in the course of five years will be affected by several factors, namely the sales growth rate, the economy and inflation conditions in next five years and also the managerial decisions and policies for the first year which will influence the market's behaviour till the end of the Company's lifetime.

In section 4.5.2, the growth forecast of the potential market share was discussed. In this section, sales growth in the course of five years will be discussed. The outcome is highly dependent on the decisions made in the first year and how the market reacts to those decisions.

6.5.1 The Sales Growth Rate

The factors that affect sales in the course of five years are the same factors that affect the market growth. External and internal factors will be discussed separately in the next section.

[1] The price comparison between wind and solar: The PV panels cost R7 000-R8 000 for 600 W nominal output, R11 000 for 1000 W nominal output and R24 000 for 2000 W nominal output. (the figures are captured from online shops available in South Africa, and it only includes the price of the PV panels-no stand, mounting or charge controller and inverter is included)

6.5.1.1 External Factors

These factors, as discussed previously, are the electricity price increase, governmental policy and increase in people awareness. When it comes to forecasting the future there is always a trace of uncertainty and that is when the sensitivity analysis becomes important. Sensitivity analysis allows one to identify the limits and most probable outcomes of the forecast. With respect to the three factors in this section annual increase rate in market growth is considered to be 10%. The uncertainty part of the growth will be discussed once the internal factors' effect on the growth rate has been considered.

6.5.1.2 Internal Factors

The internal factors are those that are directly influenced by the Company itself. Included are product's price, the service level of the Company, the quality of the products and how the Company advertises its products. There is a difference in this regard between the first year and the years following the first year of entering the market. The marketing and the Company's introduction to the market have a bigger influence on the second year's sales in comparison with the next year's. An increase rate of 20% for the end of the first year is considered. It should be noted that from the third year this increase rate will decrease to 10 % for the rest of the years under consideration.

6.5.1.3 Uncertainty for External and Internal Factors

In the following section, some examples of uncertainty regarding previously mentioned factors have been presented.

- **Electricity Price**
  As has been mentioned before the initially requested increase in electricity price by Eskom was 16% each year, of which only 8% was approved. Considering the recent electricity problem in South Africa and the load shedding implemented by Eskom, there is the possibility that a new request for increasing the electricity price will be launched in the coming year in order to cover the maintenance and expansion costs. High increases in the electricity price could attract some attention to the small energy generation sectors.
- **Governmental Policy**
  The net-metering and feed-in tariffs are the most important methods that government can adopt to encourage small-scale renewable energy growth. Although the feed-in tariffs were introduced recently, they are both weak and taking a very long time to be approved by the government and might take even longer to become practically operational.

As explained, some factors create uncertainty which has to be standardised and simplified so that it can be considered in the financial modelling. As for growth rate, to put it in a form of statistical distribution the following explanation is applicable. In the future, the growth rate might be less or more than what has already been considered but it is estimated that the uncertainty will be close to the estimated percentage. In general, the probability that it will be far from the estimated 'electricity price increase ratio' as well as other influential factors, decreases as it gets further from the centre or expected value of the distribution in either direction. In order to simplify the matter, a normal distribution is considered to be a good estimation for the future growth rate distribution. This is due to the relatively equal pros and cons of the conditions and factors which could eventually affect the future growth rate. This equality in the possibility of having positive growth rate or a negative one, justifies the choice of the normal distribution which is a symmetric probability distribution. By adding up all the foreseen factors, the mean electricity price increase of the distribution is estimated to be 30% more than the previous year for the first year and 20% for the second to the fifth year. A standard deviation of 3% is also considered to cover all the combined uncertainty for the factors discussed.

A full account of the foreseen factors that are estimated in the financial modelling of the Company will be discussed further in this chapter.

6.5.2 Annual Inflation

One of the factors that affects the cost of production is annual inflation. According to Worldwide Inflation Data (2013) the inflation rate in South Africa based on historical data from the past year was considered to be 6%. Based on the historical data for past 23 years the mean of the inflation rate was about 6%, based on this information the possibility of fluctuation for this rate in the 5-year vision for the Company is ignored and this rate will be considered as the fixed inflation rate for the duration of the 5-year financial vision for the Company.

6.5.3 Annual Price Increase

Having the fixed inflation rate in the country, prices will increase each year and this is applicable to all products in the country. For the duration of five years, the annual increase rate in the product's price is considered slightly less than the inflation rate. It is considered to be a 5% annual increase rate in product's price fixed for 5-year duration.

6.5.4 Scenarios for the 5-year Vision

Having explained the factors affecting the Company's financial state in the next five years, scenarios are defined which reflect the Company's pricing and production policies. These scenarios, which are focused on the production volume and product pricing, then have to be compared and the best of them considering current conditions and forecasted future is recommended. A total of four scenarios are designed to cover the production volume possibilities as well as product pricing. Currently, wind turbines are competing with PV panels[1] as another small electricity generator from renewable energy sources.

For designing the scenarios, all the factors range have to be defined and varied one at a time in their estimated range by considering their uncertainty. The scenarios will be compared based on the changing factors and by using financial metrics.

In the 'market study chapter' the potential market share was outlined. This does not imply that the Company will sell that many units; it is just an indication of the upper limit of the total market share. In the following graphs, the difference between available target market and market share for the Company in the market is shown.

[1] Photovoltaic Panel

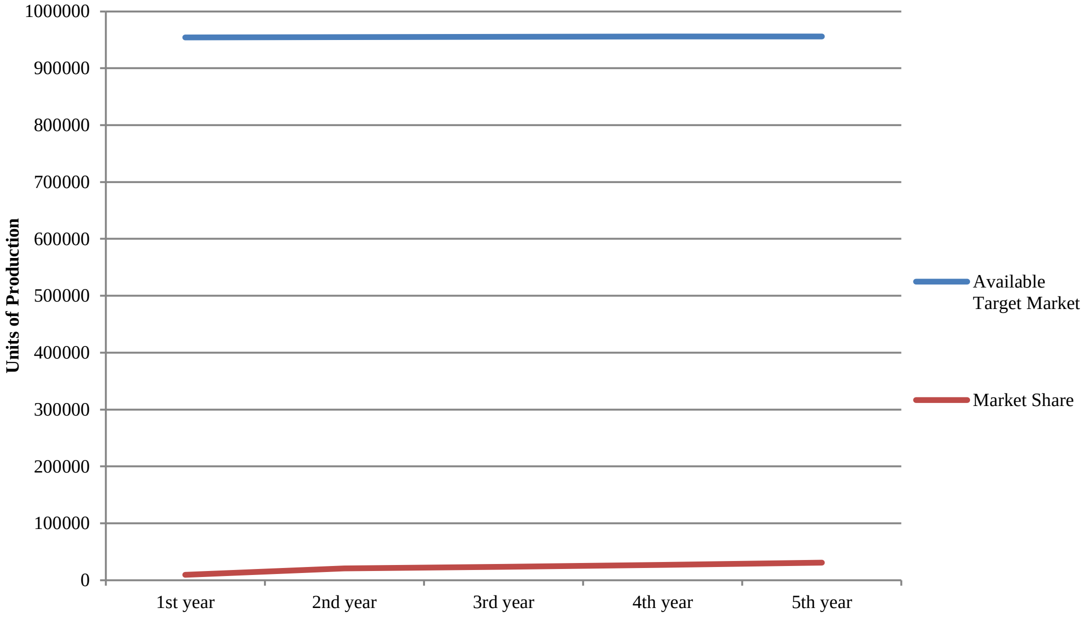


Figure 29: Available Target Market vs Market Share

As was mentioned before in order to not overestimate the market potential only 5% of the available target market was considered as the market share for all the competitors and the Company's market share was therefore, calculated according to the factors discussed in section 4.5.2.

As stated the scenarios are oriented around the production volume as well as the product's pricing. In order to design the scenarios the production volume of the first year has to be chosen for the first three scenarios. In the previous graph, the total market share of the Company was illustrated and for the scenarios that market share is considered to be the basis. As the market's reaction to the introduction of the product is not known and the fact that there are unforeseen factors which are affecting the market, only 50% of the market share is considered to be the limit of the market share calculated for the Company. In other words, the limit is set so that in no circumstances the actual market share of the Company exceeds the 50% of the total market share which also applicable to the whole duration of the 5-year financial view.

Three of the mentioned scenarios are designed in a way that altogether covers the 50% of the total market share for the Company in the following order; the first one covers the first 10% of the total market share; the second one covers between 10% and 30% of the total market share and the third scenario covers the remaining 50% of the total market share. In the following graph, the proportion of the three scenarios in comparison to the total market share is illustrated.

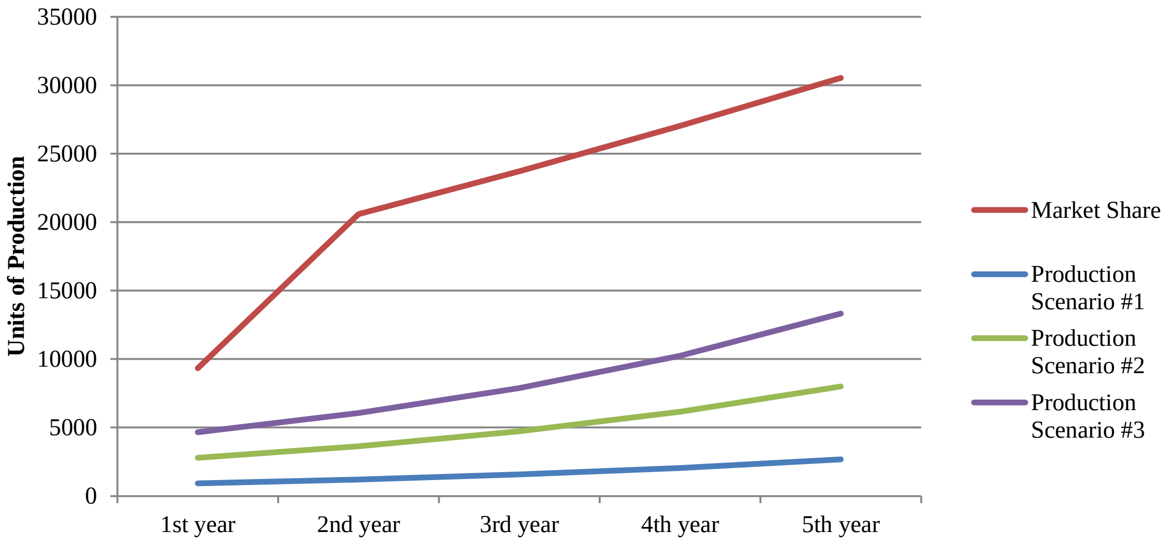


Figure 30: Market Share vs Scenarios

Is has to be noted that the red line in this graph is the same as in figure 29.

The three scenarios that were mentioned are focused on the production volume. There is another scenario designed to simulate a unique circumstance. As it was mentioned at the beginning of this section, the product competes in the market with PV panels. The fourth scenario simulates the condition that the product has to compete with PV panels on an equal price term. In this scenario, the production volume of the Company is assumed to be fixed over 50% of the total share market, which means it covers all three scenarios that were previously explained, but instead the product's price is set equal to that of the PV panel in the market. These scenarios will be discussed more in detail further in the chapter.

After the simulation, the results have to be compared in order to recommend the most suitable scenario of all. The analysis is performed by comparing the financial metrics. Four financial metrics are introduced which are explained below (G.Sullivan et al., 2003).

- **IRR**[1]: It is one of the most widely used rates of return method for analysing businesses' financial performance. This method is the breakeven interest rate which equates to the NPV[2] of a project's cash flow. Although it is one of the most used metrics in business performance analysis, there are some difficulties associated with this metric, such as the problem with the application of reinvestment assumption in the IRR method and the chance of multiple IRRs occurrence.
- **MIRR**[3]: This method is the modified version of the IRR and tries to rectify the difficulties associated with IRR by considering the finance rate as well as the reinvestment rate.
- **NPV**: The net present value is the present value of the resultant of the cash inflow and outflow. It is a useful tool to compare different investments.
- **Breakeven Analysis**: The breakeven analysis determines the volume of products to be sold in order to cover all the costs. This helps to determine whether a business is feasible or not and

[1] Internal Rate of Return
[2] Net Present Value or Net Present Worth (NPW)
[3] Modified Internal Rate of Return

also to find the level of risk for different factors that affect the profitability of the business and spot the critical factors (G.Sullivan et al., 2003).

In order to provide information for the simulation of the Company's financial state, assumptions have to be made. The following assumptions are the factors that will directly affect the simulation and, as a result, the outcome of the financial metrics.

- Annual market growth rate is based on a normal distribution with a mean of 30% and standard deviation of 3%. This is only applicable to the second year.
- Annual market growth rate is based on a normal distribution with a mean of 20% and standard deviation of 3%. This is applicable from the third year to the fifth year.
- Fixed annual inflation rate of 6% based on historical data.
- Fixed annual product price increase of 5%.
- Discount rate of 7%, which is the rate of return that could be earned on an investment in the financial markets, also referred to as opportunity cost.
- Finance rate of 11%, which is the interest rate that should be paid to the source of the capital for initial investment; it might be bank or finance institution. This rate for the purpose of this study considered to be a normal business loan rate.

A comprehensive list of assumptions and the risk involved with them was made and will be mentioned in the financial model section.

6.5.4.1 Financial Model

In order to prepare the financial model, the framework was used based on the thesis structure mentioned in figure 3. The model consists of three information streams which form the backbone of the model. Then using these information streams, the financial model was developed in Microsoft Excel. In the flowchart mentioned in Appendix L, it was shown how different parts of the model interact with each other.

The model which is developed in Excel consists of three sections for each year namely fixed costs, variable costs and capacity. Then these three sections populate the results of the calculations into the summary section in which the overall calculation for each year happens. This is repeated for all the five years in the scope of this study and the overall calculation of the financial metrics is done in the overall summary section. For more information please refer to Appendix M.

In order to model the feasibility study, some assumptions had to be made. Throughout the different parts of the study, assumptions have been mentioned. In the following table, a comprehensive account of the assumptions which play an important role in the creation of the model is provided.

Table 43: Risk Register

No.	Assumptions	Associated Risk	Description	Risk Level
1	**Turbine type and size**	---	HAWT and Small size	---
2	**Focus area for study**	---	The area that WASA has data coverage	---
3	**Factors that affect available market**	**Population distribution**	This factor determines the portion of households where it is feasible for them to use a small wind turbine on the premises.	Low
		Appealing wind condition	This factor determines how suitable the wind condition is in each region for harvesting wind energy via small wind turbine.	Low
4	**Factors that affect target market share**	**Presence in the market segment**	The Company's presence in the specific market segment, such as HQ or distributors	Low
		Production range	The ability of the Company to meet the range demand in each market segment	Low
		Service quality	It indicates the quality of the product as well as the quality and service level of the after sale support	Low
5	**Factors that affect target market growth**	**Electricity price**	The change in the electricity price which can lead to changes in how appealing the product can be in the market	Medium
		Governmental policies	The policies that support the embedded electricity generation will have a substantial effect of the market and the opposite can have very negative effect	High
		People awareness	The way that people think renewable energy can influence their future and it changes with knowing more about it	Medium
		Population and economy growth	Population and economy growth means more opportunity and more clients, but effective in long run not in a few years	Low
6	**Required resources for production and administration section**	**Production time**	Time study was performed based on the manufacturing video clips on YouTube and based on that information production time for each process was estimated	Medium
		Production resources	This assumption was based on the IOM documents of similar manufacturers around the world	Low
7	**Organisational chart**	**Organisation structure**	It is assumed based on the organisational chart of the small businesses in a similar market	Low
8	**Pricing**	**Discount amount**	The discount amount is 10% based on the cheapest products in the same range	Medium
9	**Factors affecting Company's financial state in 5-year view (Sale growth rate)**	**Annual market growth**	It is assumed that the sale growth will increase with a combined rate of 30% with standard deviation of 3% for the first year and from the second year it will be 20%. It is due to the uncertainty in future electricity price as well as Governmental policies	High
		Annual inflation rate	It is assumed to be an annual 6% inflation which is fixed over the course of 5 years	Medium
		Annual product price increase	A 5% increase in annual price is assumed which is less than the annual inflation rate	Medium
		Discount rate	It is assumed to be 7%.	Medium
		Finance rate	It is assumed to be 11%.	Medium
10	**First Scenario**	**Production volume limit for the first year**	The production volume is considered to be the first 10 percentile of the total potential market share	Medium
11	**Second scenario**	**Production volume limit for the first year**	The production volume is considered to be between 10^{th} to 30^{th} percentile of the total potential market share	Medium
12	**Third scenario**	**Production volume limit for the first year**	The production volume is considered to be between 30^{th} to 50^{th} percentile of the total potential market share	Medium
13	**Fourth scenario**	**Product pricing on the same level of PVs**	In this scenario, the product pricing is based on the average PV's price in the market in the same output range	Medium

In addition to the assumptions the risk associated with each assumption was also investigated. The change in any of the assumptions can lead to a change in the outcome of the feasibility study. The estimated severity and importance level of each assumption and its respective risk was also mentioned in the last column. In the following table the most important risk factors are sorted according to their respective risk level.

Table 44: Most Important Factors

No.	Risk	Risk Level
1	Governmental policies	High
2	Annual market growth	High
3	Electricity price	Medium
4	People awareness	Medium
5	Production time	Medium
6	Discount amount	Medium
7	Annual inflation rate	Medium
8	Annual product price increase	Medium
9	Discount rate	Medium
10	Finance rate	Medium
11	Production volume limit for the first year (Scenario#1)	Medium
12	Production volume limit for the first year(Scenario#2)	Medium
13	Production volume limit for the first year(Scenario#3)	Medium
14	Product pricing on the same level of PVs	Medium

Having all the information such as the model structure as well as the assumptions, the model can now be analysed. In order to perform the analysis simulation method was adopted. Among the simulation tools Monte Carlo simulation was selected to provide close to real conditions output. This tool is an iterative tool which changes the different factors and variables in order to form a population of almost all the possible outcomes. The *Palisade @Risk* was used to perform the Monte Carlo simulation. In the following section, the scenarios which were briefly explained previously are implemented and the outcome of each scenario is discussed.

6.5.4.2 First Scenario

In the first scenario of the three as was stated, all the general assumptions are considered and the Company's policy regarding production volume for the first year is assumed to be in the first 10 percentile of the total potential market share. According to the market study chapter, this number ranges up to 933 units. Having this input range and considering general assumptions the simulation was performed on the model.

The first output of the simulation that will be discussed here is the breakeven point. Considering the general assumptions and the volatility of the variables, the breakeven point happens in the range of 65 to 76 units.

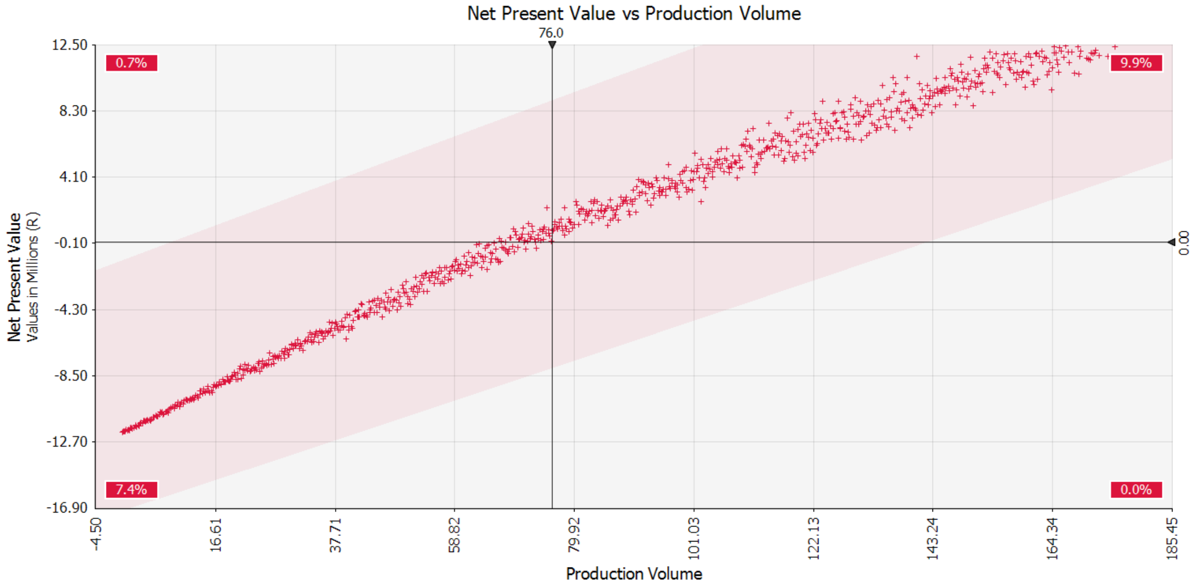


Figure 31: Breakeven Point

As illustrated in figure 31 the Company can reach breakeven point in the range of 65 to 76 units. It indicates that by only producing 8% of the scenario's production target for the first year, the Company can breakeven. This bit of information is very important to show the profitability risk of the Company. The breakeven analysis in this section is also applicable to second and third scenarios, therefore it will not be repeated in the other two scenarios.

The second metric that was discussed is IRR. In the following figure, the relation between IRR and the production volume is illustrated.

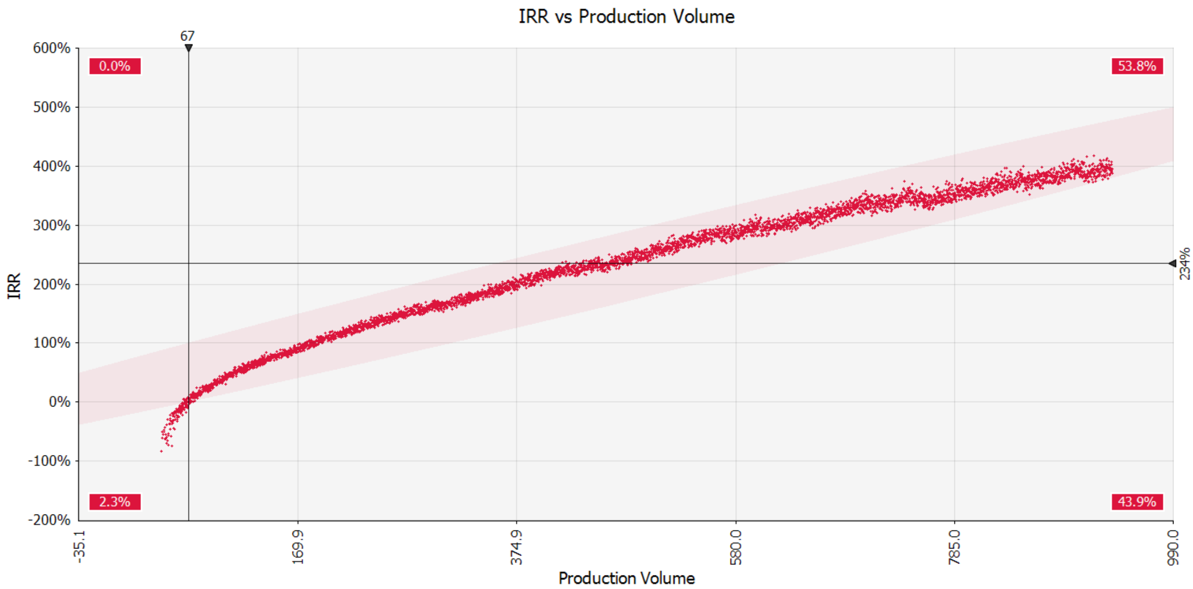


Figure 32: First Scenario, IRR vs Production Volume

If the production volume on this graph is set to the breakeven point calculated in the previous section, the corresponding IRR is equal to zero. Less than the breakeven point the IRR is negative and above that it is positive. As it is appeared on the graph the IRR for this scenario can reach up to 400%.

The other metric that was investigated is the MIRR. In the following graph, its behaviour with respect the changes in production volume is shown.

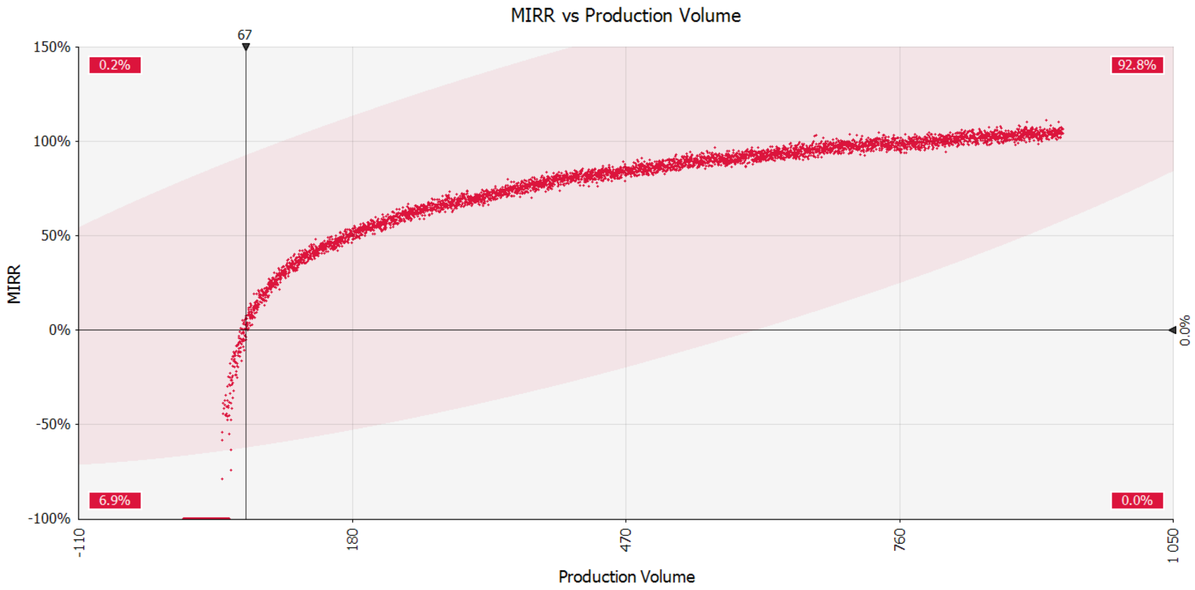


Figure 33: First Scenario, MIRR vs Production Volume

The same also happens around the breakeven point for MIRR as for IRR. Therefore, it can be inferred that both MIRR and IRR are zero on breakeven point. However, the MIRR has a relatively lower increase ratio and reaches around 100% where IRR is around 400%. This is due to consideration of finance rate as well as reinvestment rate in the calculation.

In order to compare IRR and MIRR in more detail, the probability density graphs were used.

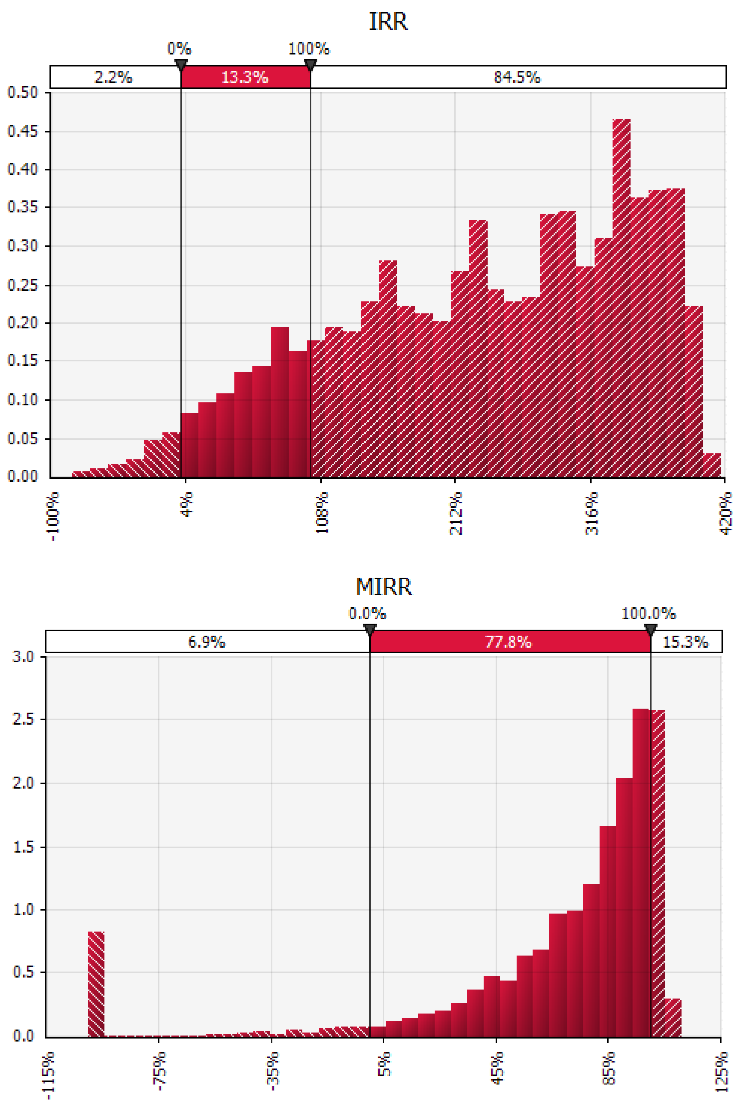


Figure 34: First Scenario, IRR vs MIRR

The graphs are clearly different from the distribution point of view. In the IRR graph, the probability of having a negative value is 2.2% where in MIRR graph it is 6.9%. In the same way, the probability of having a value more than 100% in IRR is 84.5% whereas in the MIRR graph this value is 15.3%. It should be noted that these values are for only the assumed production volume for the first year.

According to the general assumptions, the discount rate for cash flow is 6%, which means the project with a higher IRR than the discount rate can be accepted. According to the IRR graph, there is a 97.4% chance that this business can be accepted.

The simulation outcome also shows how the first year's production volume affects the production volume in the fifth year. In the following graph, it is shown that when the first year production ranges in the first 10 percentile of the potential market demand the fifth year production can reach up to about 2450 units. As illustrated in the following graph the more production volume for the first year increases the more scattered the data points become. It can be interpreted that the uncertainty level in the model is highly influenced by the production volume for the first year as well as the time. For instance if the production volume of the first year is considered to be 933 units, the forecasted production volume of the fifth year can be in the range of 1875 to 2450 units which is a relatively very wide range.

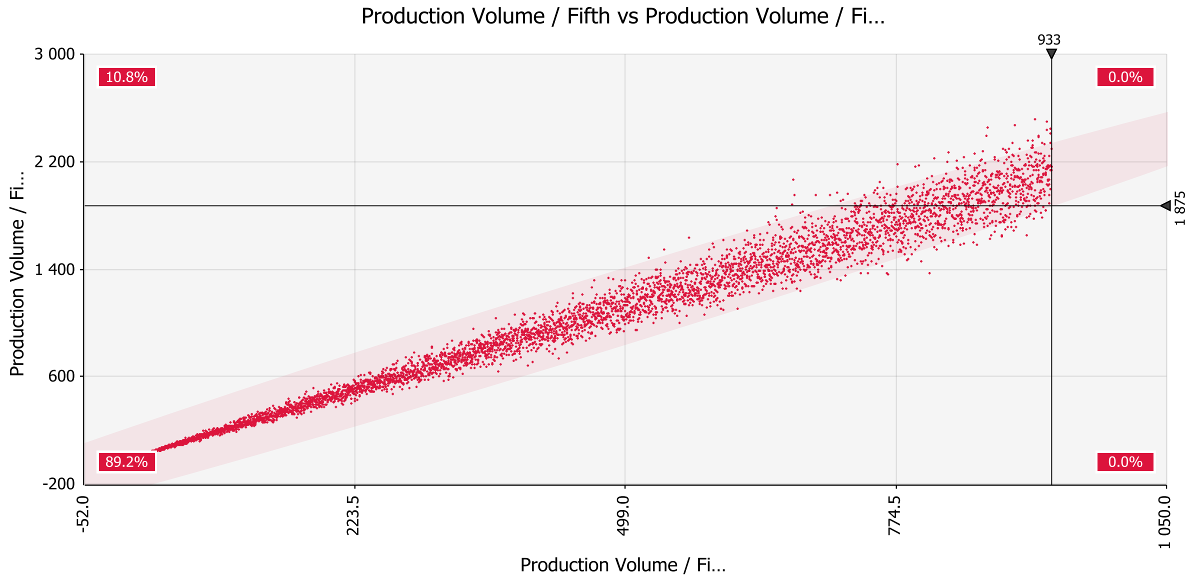


Figure 35: First Scenario, Production Volume of First Year vs Fifth Year

The next metric that is discussed is the NPV. In the following graph, the distribution density of the NPV over the course of five years is shown.

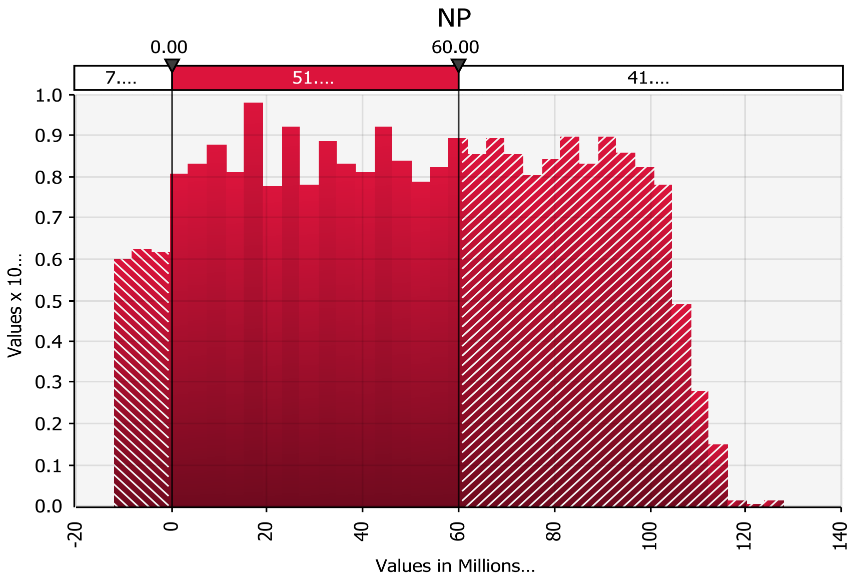


Figure 36: First Scenario, NPV for Five Years

As it is illustrated the chance that the Company generates negative NPV is about 7.4%.

Another important relationship is the interaction between the Investment and the NPV expected over the course of five years. This information is very useful for the investor to know how the initial investment in the Company leads to higher or lower NPV. In the following graph, the relation between initial investment and the NPV is shown.

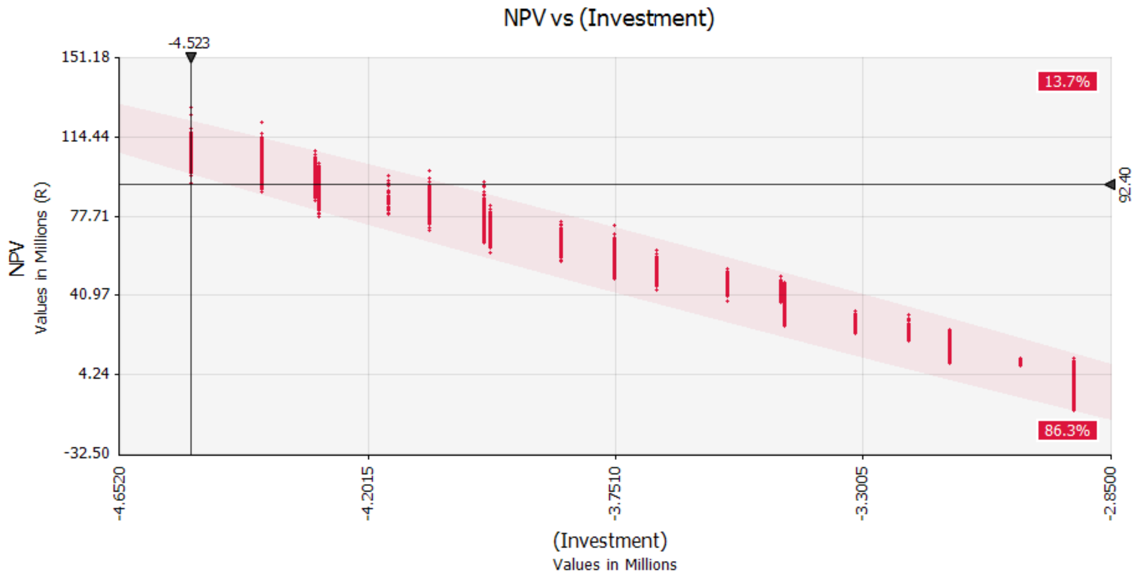


Figure 37: First Scenario, NPV vs (Investment)

Each of the vertical lines in the above graph corresponds to an investment. Also, each investment corresponds to a range of NPV which is expected to be received from that investment over the course of five years. For instance:

The next metric is the cash flow over the course of five years which is illustrated in the following graph.

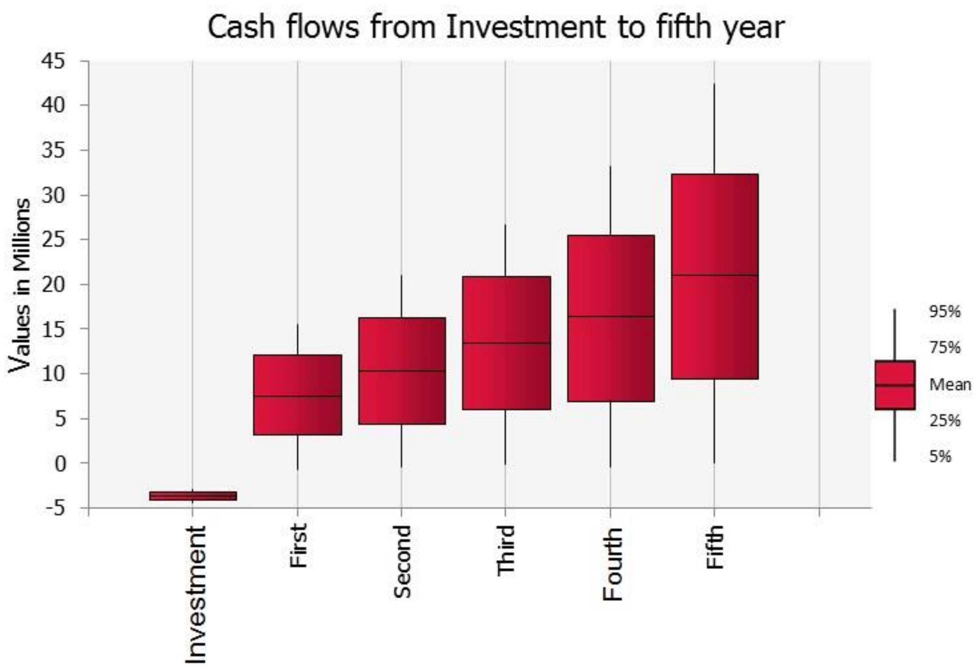


Figure 38: First Scenario, Cash Flow

The first box on the left-hand side is the year zero or the Investment which is considered as a negative figure and the rest of the boxes are the resultant cash inflows and outflows for each year.

6.5.4.3 Second Scenario

In this scenario, it is assumed that the production range varies from the 10^{th} percentile to the 30^{th} percentile for the first year. This assumption will be considered in the simulation along with all of the general assumptions mentioned before. According to the market study chapter the assumed production range for this scenario is from 933 to 2 800 units.

As was mentioned before, the breakeven analysis for this scenario is the same as the previous scenario since the only thing that has changed is the production volume.

As in the previous scenario, the data regarding the different metrics is extracted from the simulation for this scenario as well. The first metric to discuss here is IRR for this scenario's configuration. In the following graph the IRR changes in accordance with the first year's production volume are illustrated.

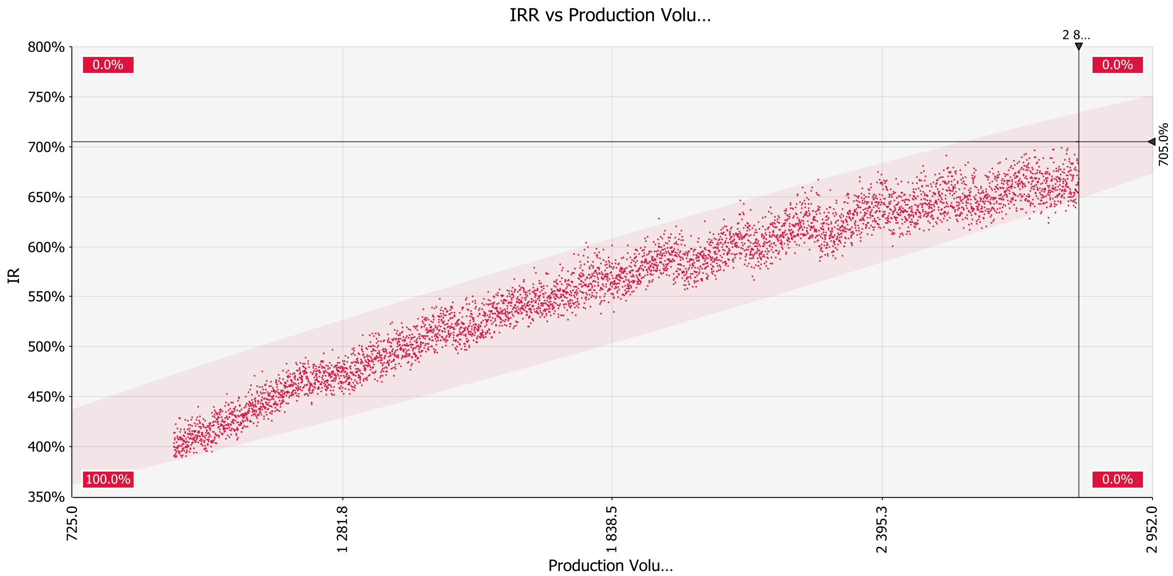


Figure 39: Second Scenario, IRR vs Production Volume

As is shown in this graph, the IRR can reach 700% in comparison to the 400% of the first scenario. On the IRR graph, an interesting pattern is evident. These ups and downs are related to the capacity of the production line. When the graph suddenly drops, exactly before the drop a machine had reached its full capacity, an additional machine was needed in the production line. This imposes costs on the Company and, as a result, IRR metric drops. It has to be noted that the machine at this stage is at its least utilisation level. When the production volume increases the machine's utilisation level increases and therefore the Company makes benefits from this new addition. This is when the IRR graph starts to pick up and reaches another peak. This happened for all the investments in this section, but only the major investments have such an evident effect on the IRR graph.

Now by considering the discount rate as well as finance rate the MIRR is calculated. In the following graph, the MIRR is illustrated.

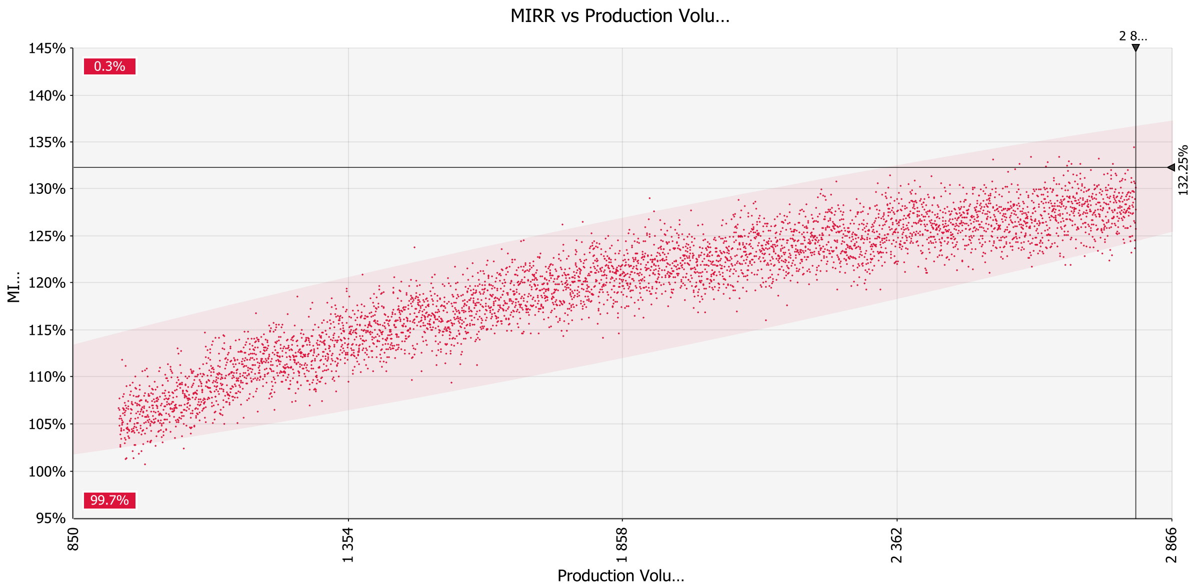


Figure 40: Second Scenario, MIRR vs Production Volume

As it was explained in the IRR section, the same happens to MIRR but since this metric is more dampened than IRR the manifestation of such a reaction on the system is not that clear.

The MIRR reaches to almost 133% in comparison with the 100% of the first scenario.

Although the MIRR and IRR for this scenario are increasing, the rate by which they are increasing is declining. It is clear from the graphs that the gradients are declining by increasing the production volume. This change in the gradient of the MIRR and IRR graphs is important since it may mean that from a certain point onward, an increase in production volume does not necessarily lead to an increase in the profitability of the Company at the same rate as before.

For comparing IRR and MIRR the probability density of both metrics is shown in the following graph.

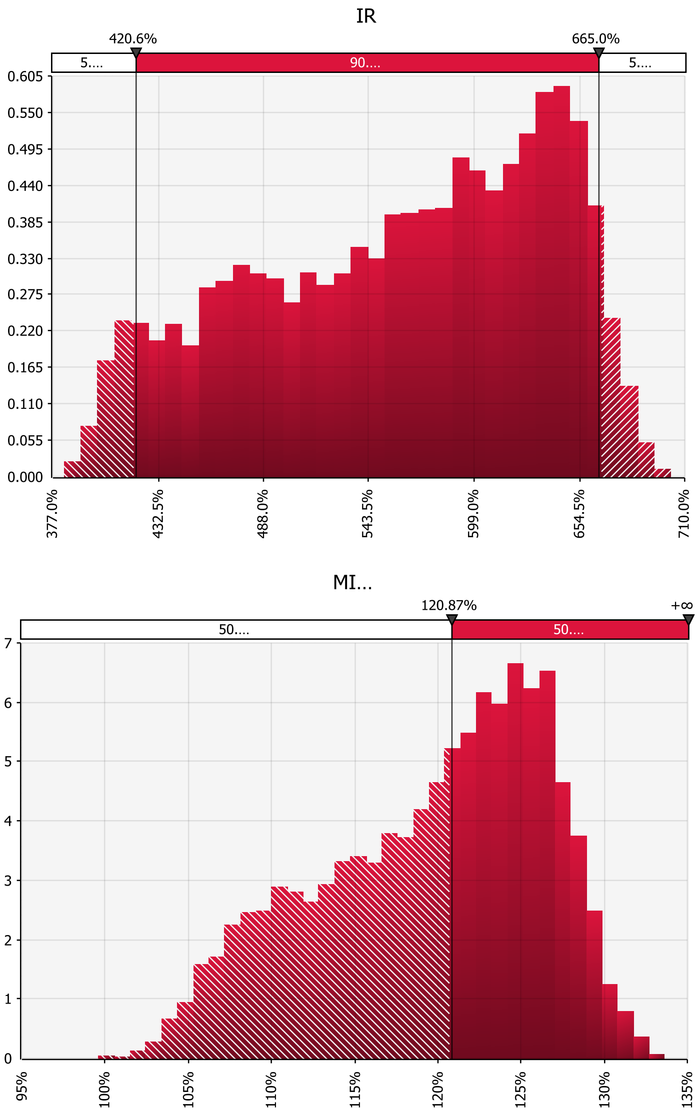


Figure 41: Second Scenario, IRR vs MIRR

The skewness of these graphs is negative. This means that a higher possibility of happening is related to higher rate for IRR and MIRR by which it can be inferred that by increasing the production volume even more than the boundaries of this scenario, better results can be achieved. However, while comparing these graphs with that of the first scenario it is evident that the skewness is increasing from negative towards the positive side which means that by increasing the production volume the rate by which the Company's profitability is increasing, decreases.

In this scenario, the choice for the first year's production volume affects the fifth year's production expectation in the same way it does in the first scenario but with a higher magnitude. For instance if the production volume of the first year is set at 2 800 units the expected production volume for the fifth year is in the range of 5 200 to 7 300 units.

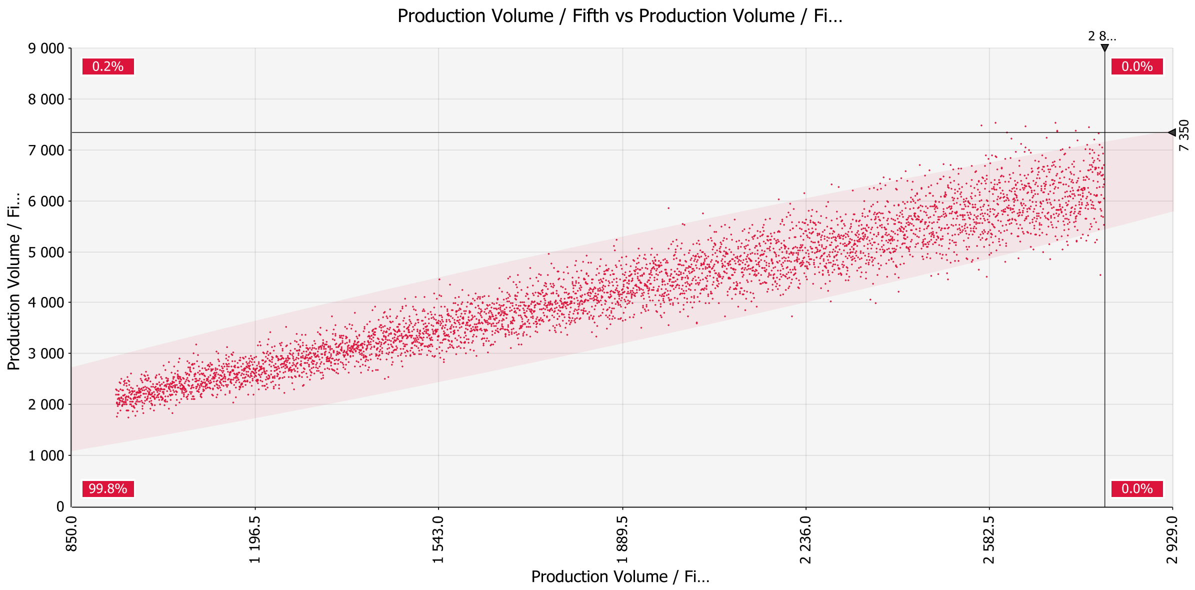


Figure 42: Second Scenario, Production Volume of First Year vs Fifth Year

In the following graph, the NPV metric is shown for this scenario.

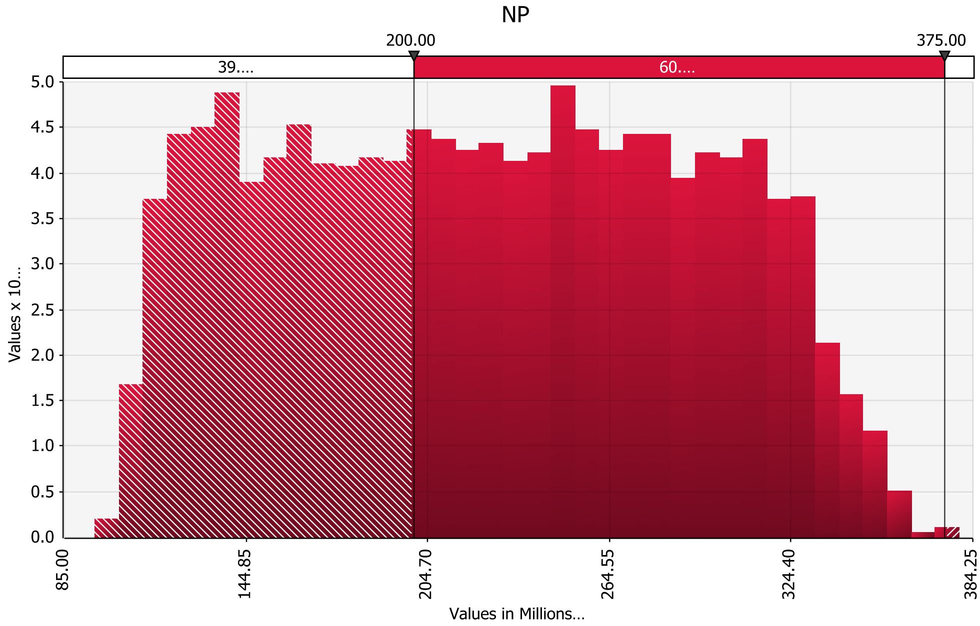


Figure 43: Second Scenario, Probability Distribution of NPV

From the above graph, the chance to expect a certain NPV in this scenario can be extracted.

In every business, it is important to know how the initial investment affects the short-term and long-term outcome of the business. As in the previous scenario, the relationship between investment and the expected NPV is illustrated in the following graph.

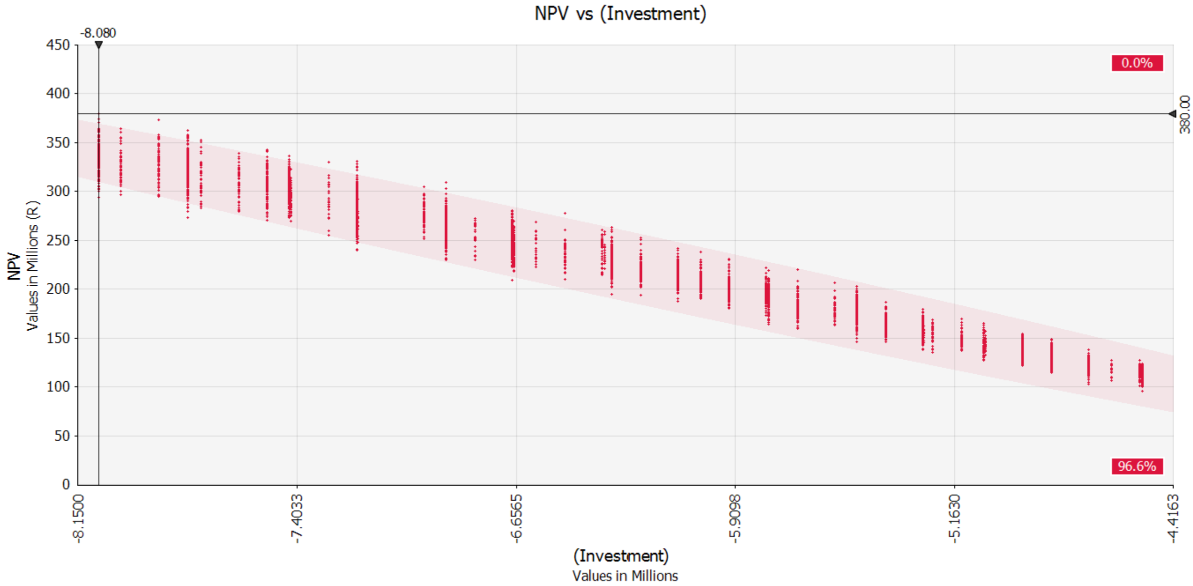


Figure 44: Second Scenario, NPV vs (Investment)

This graph represents the number of investments that can happen in the range for this scenario as well as the expected range of NPV for each investment. After the breakeven analysis, this graph could be considered as the most helpful tool in the feasibility study.

To wrap up the analysis for this scenario, the cash flow graph is presented in the following graph.

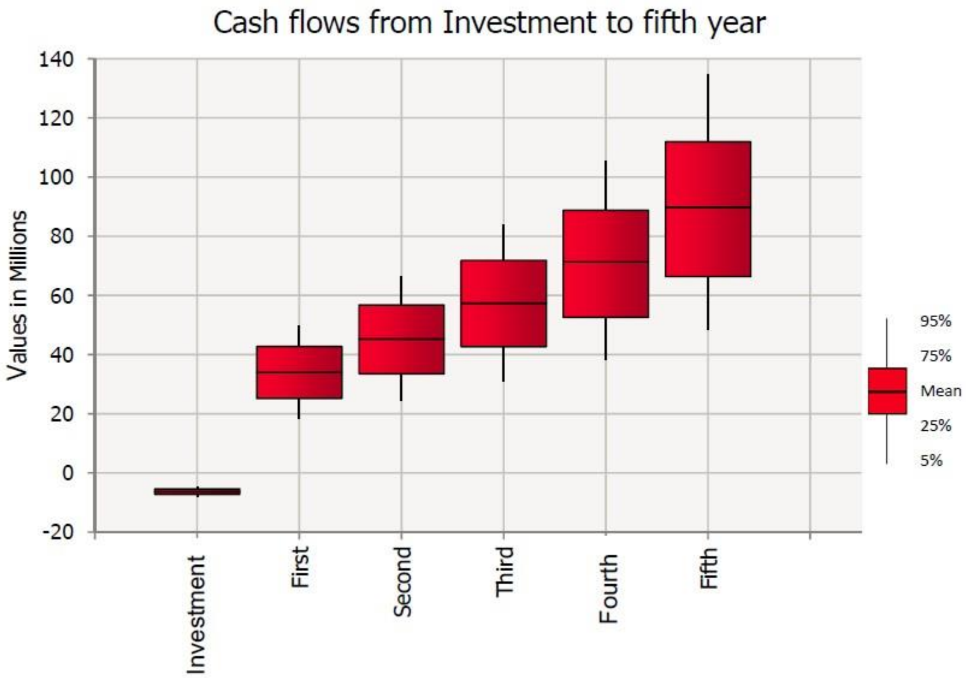


Figure 45: Second Scenario, Cash Flow

In this graph, the resultant of cash inflow and outflow in each year is shown. Obviously in the year zero there is no cash inflow since only the initial investment is recorded which is considered a negative figure. In the same way for all the years the resultant of the cash inflows and outflows are calculated and shown in the graph as well as the range of their volatility based on the other variable's volatility.

6.5.4.4 Third Scenario

In the final scenario of the three regarding the first year production volume, it is assumed that the production range varies from the 30th percentile to the 50th percentile for the first year. According to the market study chapter the assumed production range for the first year in this scenario is from 2 800 to 4 665 units.

As in the previous scenarios, the data regarding the different metrics is extracted from the simulation for this scenario as well. The analysis of this scenario starts with the IRR metric. In the following graph, the IRR of the Company in the third scenario's configuration is shown.

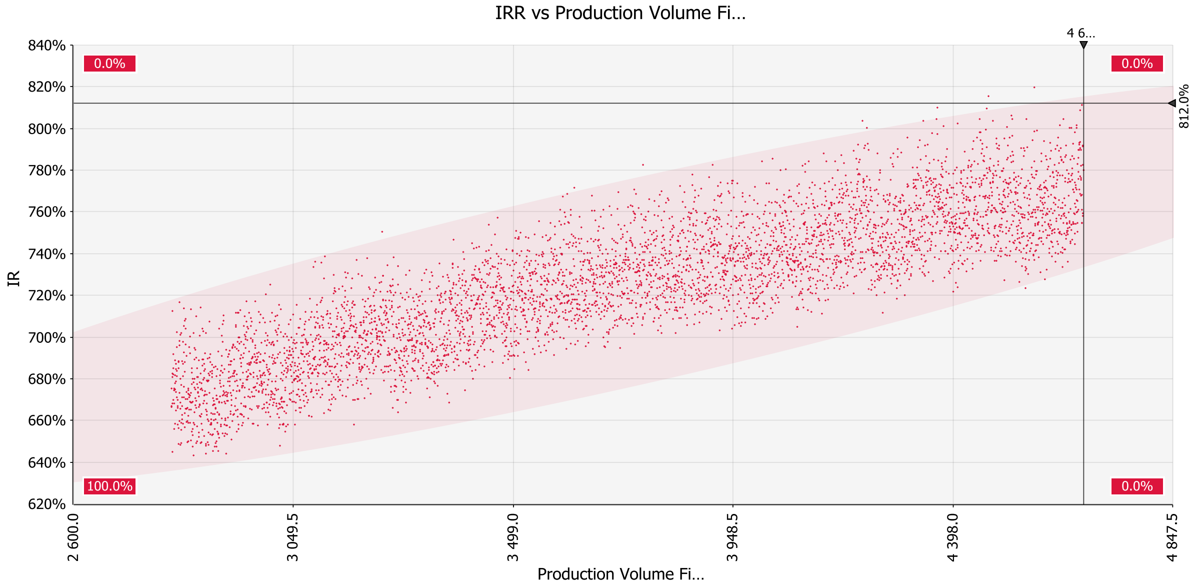


Figure 46: Third Scenario, IRR vs Production Volume

As shown in the graph the IRR can reach above 800%. However, the data is very scattered and does not form an integrated line which could be due to the increase in the production volume. The pattern which was discussed in the second scenario can also be seen here but since the data is very scattered it is hardly distinguishable. In this graph, the volatility of the factors and the effect they have on the system is vividly evident.

Now by considering the discount rate as well as finance rate, the data for MIRR is extracted from the simulation which is shown in the following graph.

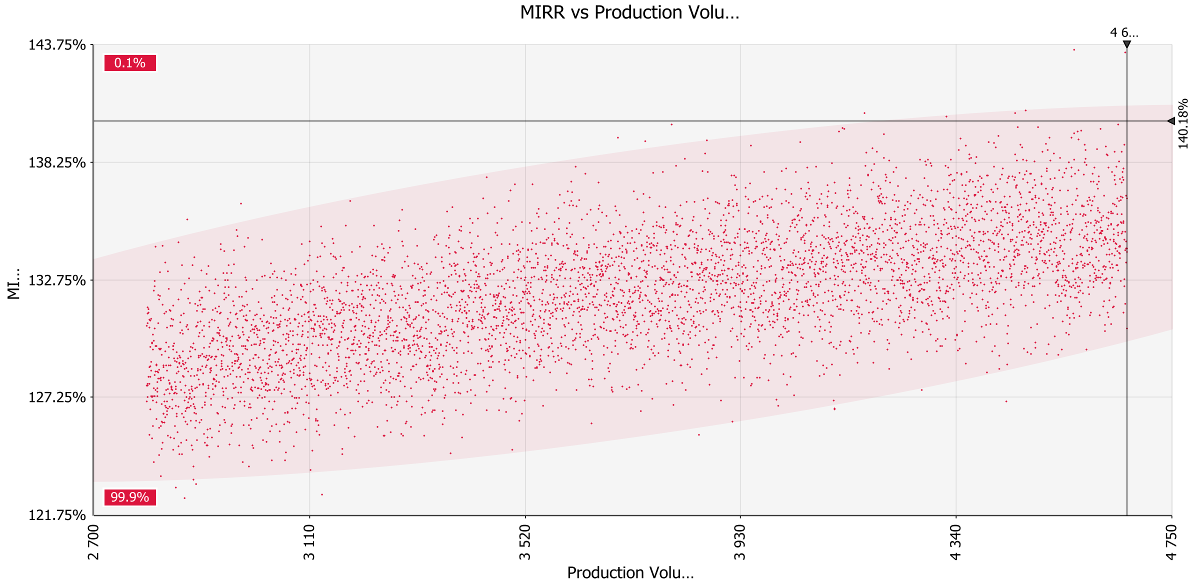
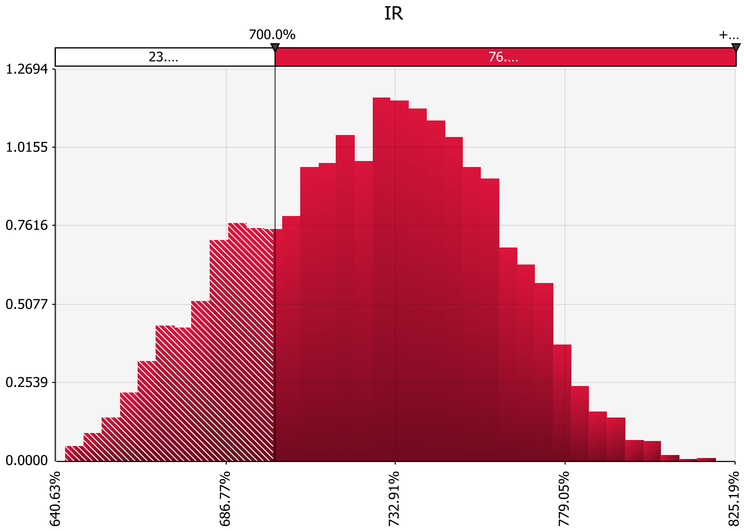


Figure 47: Third Scenario, MIRR vs Production Volume

In this scenario, the MIRR rate reaches slightly above 140%. As mentioned in the previous scenario, although the MIRR and IRR for this scenario are increasing, the rate by which they are increasing is declining. This declining rate started in the first scenario and sped up as the production volume increased.

To compare the MIRR and IRR, their distribution density graphs are shown in the following graph.



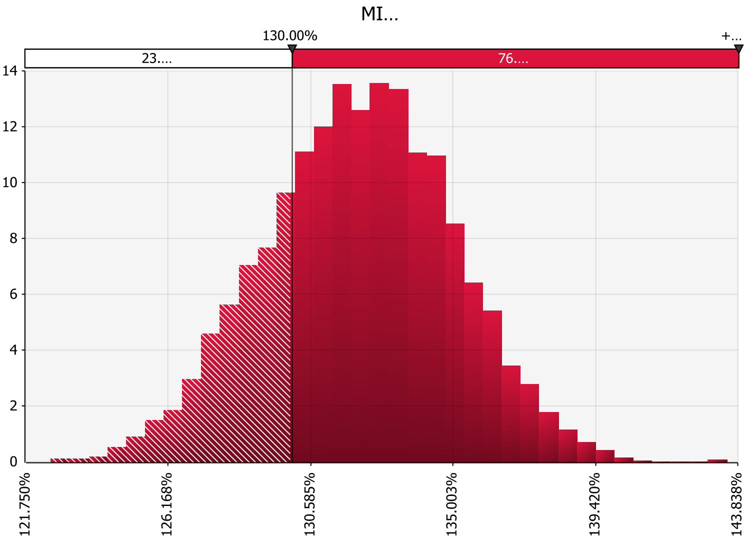


Figure 48: Third Scenario, IRR vs MIRR

The probability density of these two graphs has changed in comparison to the second scenario where they had a negative skewness and now they are almost normal. This also emphasises the declining of the IRR and MIRR graphs' gradients. In the second scenario because of the skewness the majority of the data points for these two graphs were happening in the higher end of the distribution which corresponds to a higher percentage, but now the majority of the data points are sitting in the middle of the graphs.

In the following graph the effect of this scenario on the fifth year expected production volume is shown.

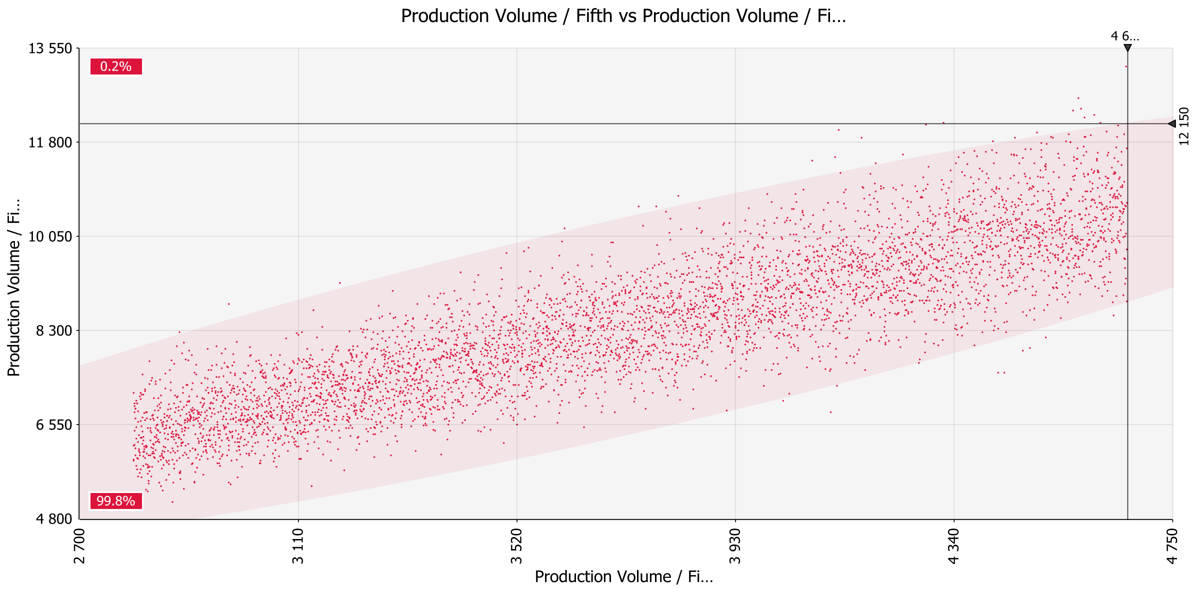


Figure 49: Third Scenario, Production Volume of First Year vs Fifth Year

As stated before, the uncertainty level is very high in this scenario which is reflected in the graph as the scattered data point. For instance, if the first year production volume is set to 4 665 the expected production volume for the fifth year ranges from 8 700 to 12 000 units which is a very wide range.

The decline in the increase rate of the profitability of the Company is also evident in the NPV graph. In the following graph, the probability distribution of the NPV is shown.

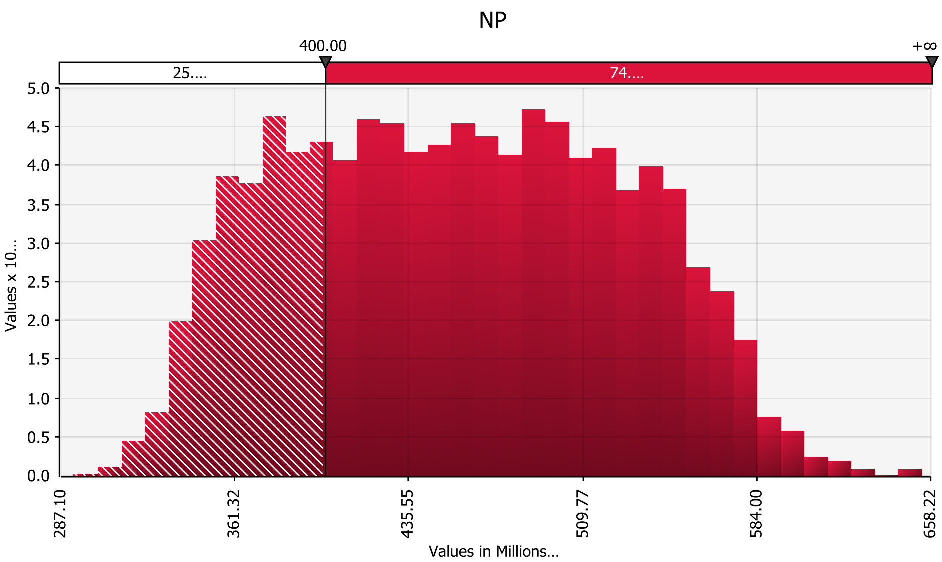


Figure 50: Third Scenario, Probability Distribution of NPV

As it is illustrated the higher NPVs have a lower probability of happening in this scenario in comparison with the other two.

As in the previous scenarios in this section the relation between NPV and the Initial Investment is also investigated in the following graph.

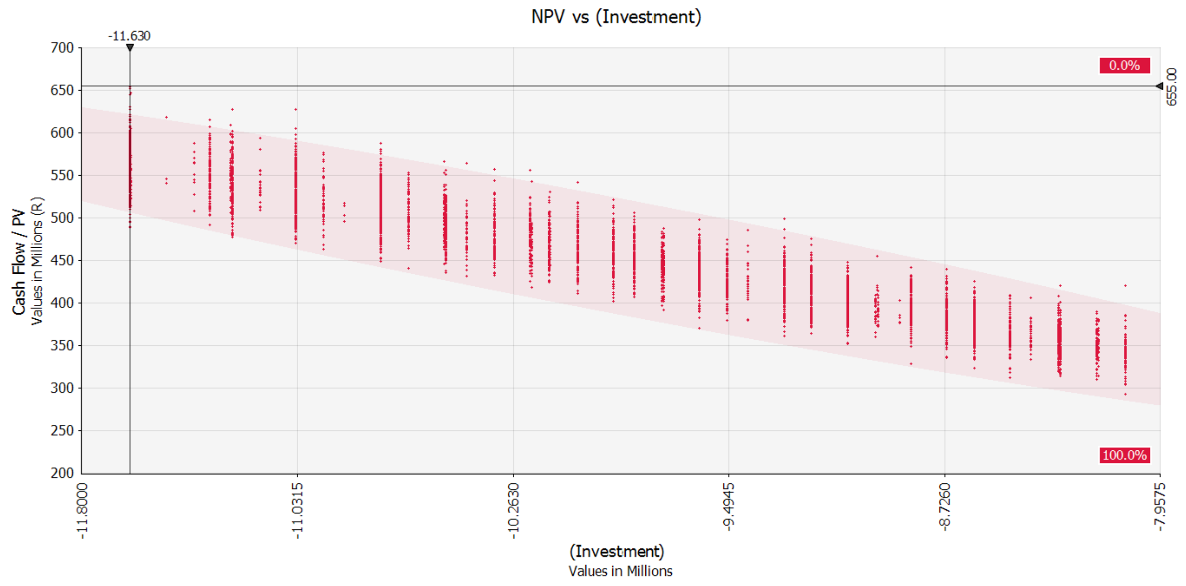


Figure 51: Third Scenario, NPV vs (Investment)

As the uncertainly level of the scenario increases, all the outcomes are also experiencing some level of uncertainty. As in this case, the possible investments are now corresponding to a wider NPV range.

The last analysis in this scenario is the cash flow graph which is shown in the following graph.

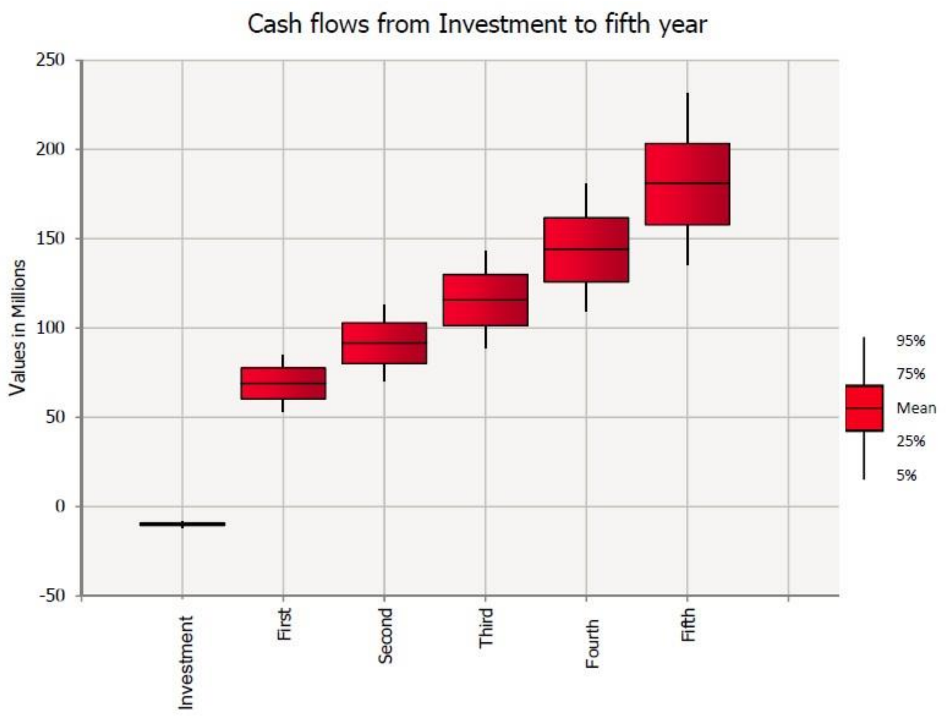


Figure 52: Third Scenario, Cash Flow

This graph shows the resultant of cash inflow and outflow in each year.

6.5.4.5 Comparison of the First Three Scenarios

The three scenarios as mentioned before are all the same except for the first year production range which is changed; therefore it is possible to compare these scenarios. Although in this section one of the scenarios will be recommended as the best, there are so many factors affecting the decision making process, not all of which were considered here, the decision might be different from the recommended scenario when those factors are considered. Hence, this recommendation is only valid as long as the assumed factors are true and only serves as a guideline, therefore, the investors have to compare the options with their individual conditions.

In the following table, the financial metrics for all the three scenarios are summarised.

Table 45: First Three Scenarios Summary

Scenarios	Production Range (units)	IRR (%)	MIRR (%)	NPV (mR)	Initial Investment (mR)
First	0 to 933	-80 to 415	-96 to 108.4	-11.13 to 119.83	2.91 to 4.52
Second	933 to 2800	381 to 710	97 to 133	90 to 381	4.55 to 8.07
Third	2800 to 4665	640 to 816	123 to 142	301 to 647	8.09 to 11.6

As stated in the sections related to IRR and MIRR, in all the scenarios the rates at which these two factors increase, have a declining trend when the production volume increases. In the following graph, the IRR and MIRR are compared over the total production range of all the three scenarios combined.

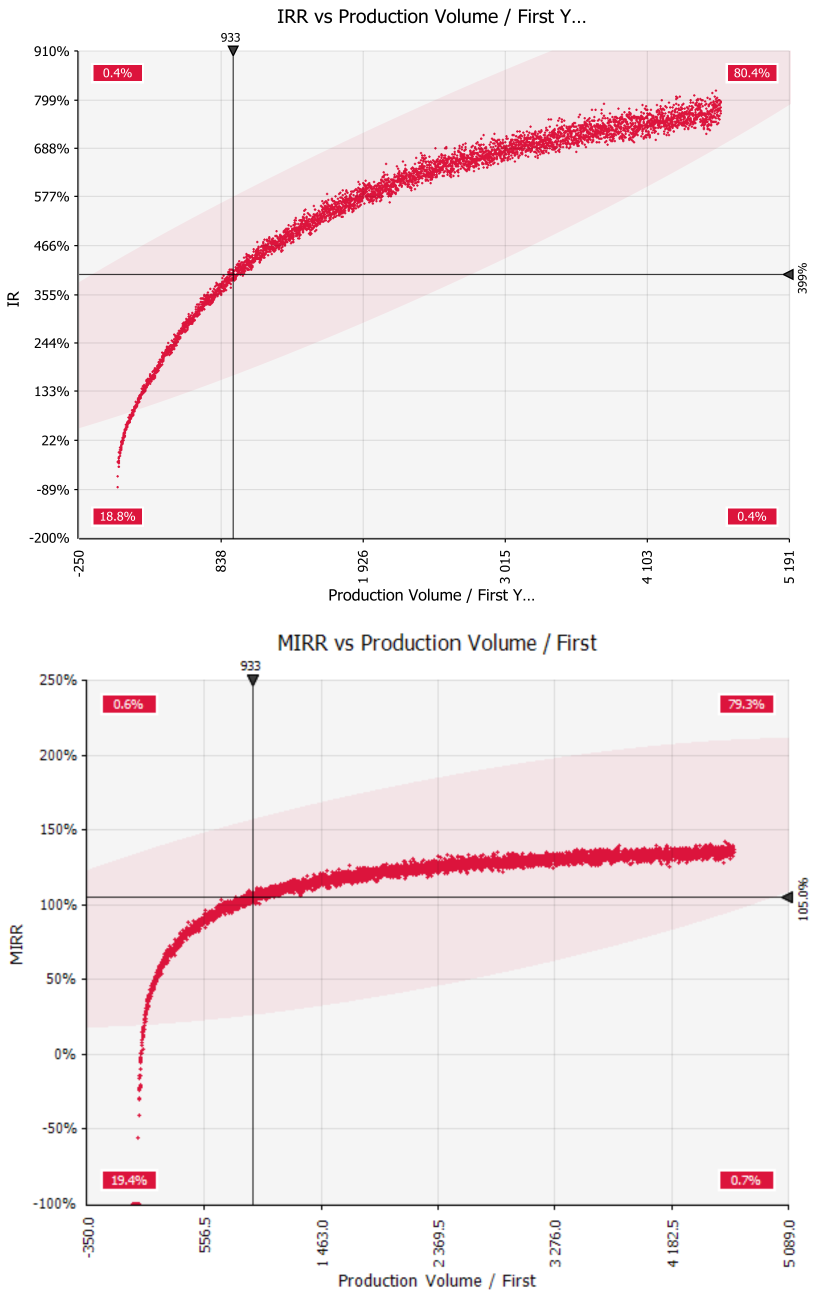


Figure 53: IRR vs MIRR over all the Production Range

It is evident that especially in the ranges defined for second and third scenarios the gradient declines rapidly. It is apparent that the graphs are almost flat in the section related to the third scenario. This behaviour can be interpreted as a lack of growth or a very slow growth in the long term by increasing the base production volume. In this case, the first and second scenarios seem more appealing from the metrics perspective. Although the first scenario has a better growth rate for those metrics, for the first section of the production range it does not reach the breakeven point and through the entire range most of the machines are underutilised due to low production volumes.

The comparison shows that out of the three scenarios, the second one has a better outcome, lower risk and positive perspective for the future. Therefore, the recommendation for this section is the second scenario. For choosing the best production volume out of the range defined in the second scenario the investors have to consider their financial conditions and by using the information mentioned in previous sections, decide on the amount of the investment and the possible range of NPV as the outcome over the course of five years.

Although based on these results the second scenario is recommended, even the results for the first scenario are unrealistically good. Usually in a small business an IRR of 20% translated to a profitable business where in the worst case scenario for this study, the IRR could reach up to 400%. In order to root out the causes of the unrealistic outcome of this simulation, the factors that have the most influence on the outcome of the simulation have to be identified. In the following graph, the factors that have the most effect on the IRR metric are identified.

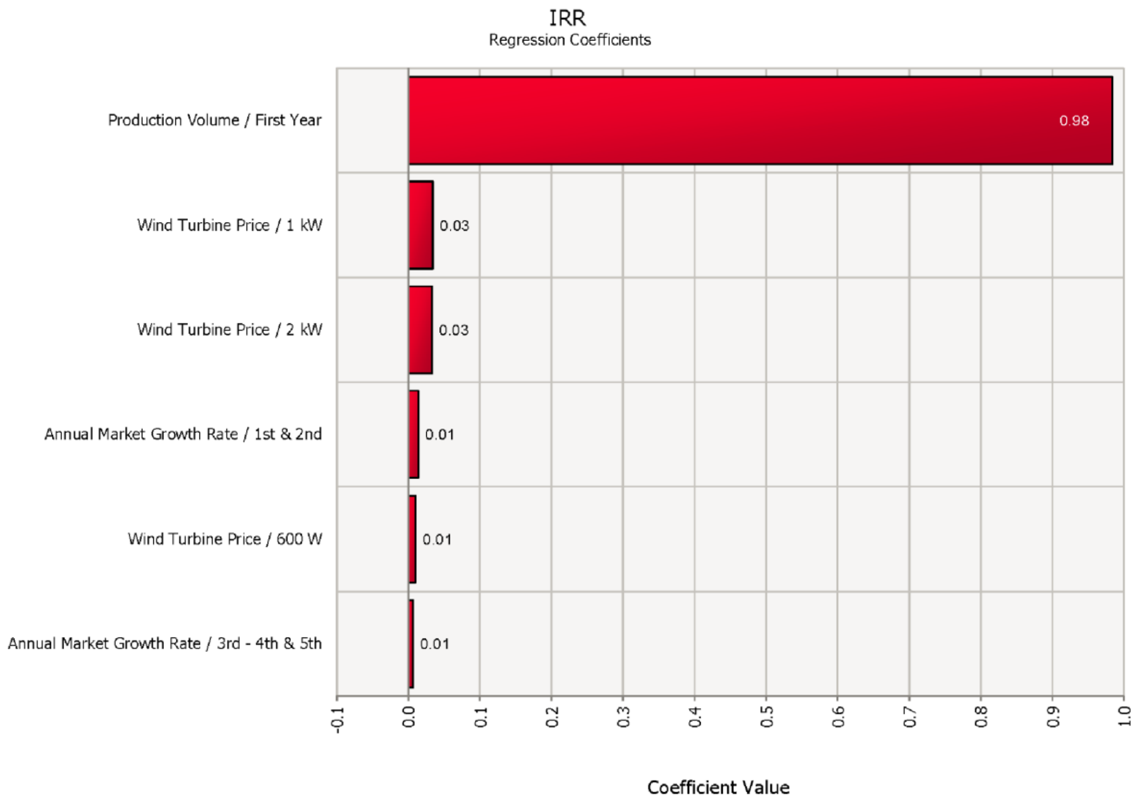


Figure 54: Regression Coefficients for IRR

As is evident from the above graph, the factor that affects IRR the most is the actual production volume. This factor was estimated based on the market study chapter. According to table 43 the factors that affect production volume are listed in the following table with their respective risks.

Table 46: Factors that Affect First Year Production Volume

No.	Risk	Risk Level
1	Governmental policies	High
2	Annual market growth	High
3	Electricity price	Medium
4	People awareness	Medium
5	Discount amount	Medium
6	Production volume limit for the first year	Medium

As was shown the government policy and annual market growth are the most influential factors on the first year production volume. The government can support the embedded electricity generation such as small-scale wind energy by facilitating the regulations and expedite the process involved. It should be noticed that this factor was also listed as one of the highest influential factors in table 44. Therefore, the designed scenarios are applicable as long as the market demands high production as it was stipulated previously.

The other factors that affect IRR are the products' prices as well as annual market growth which, as shown in the previous graph, all have a normal correlation with IRR.

In order to isolate the effect of the production volume on IRR, the investigation set out for pre-set IRR of 20% and 30%.which are considered a normal profit range for small business in the market. In the following graphs, the number of units which have to be produced to be able to achieve the 20% and 30% IRR is shown.

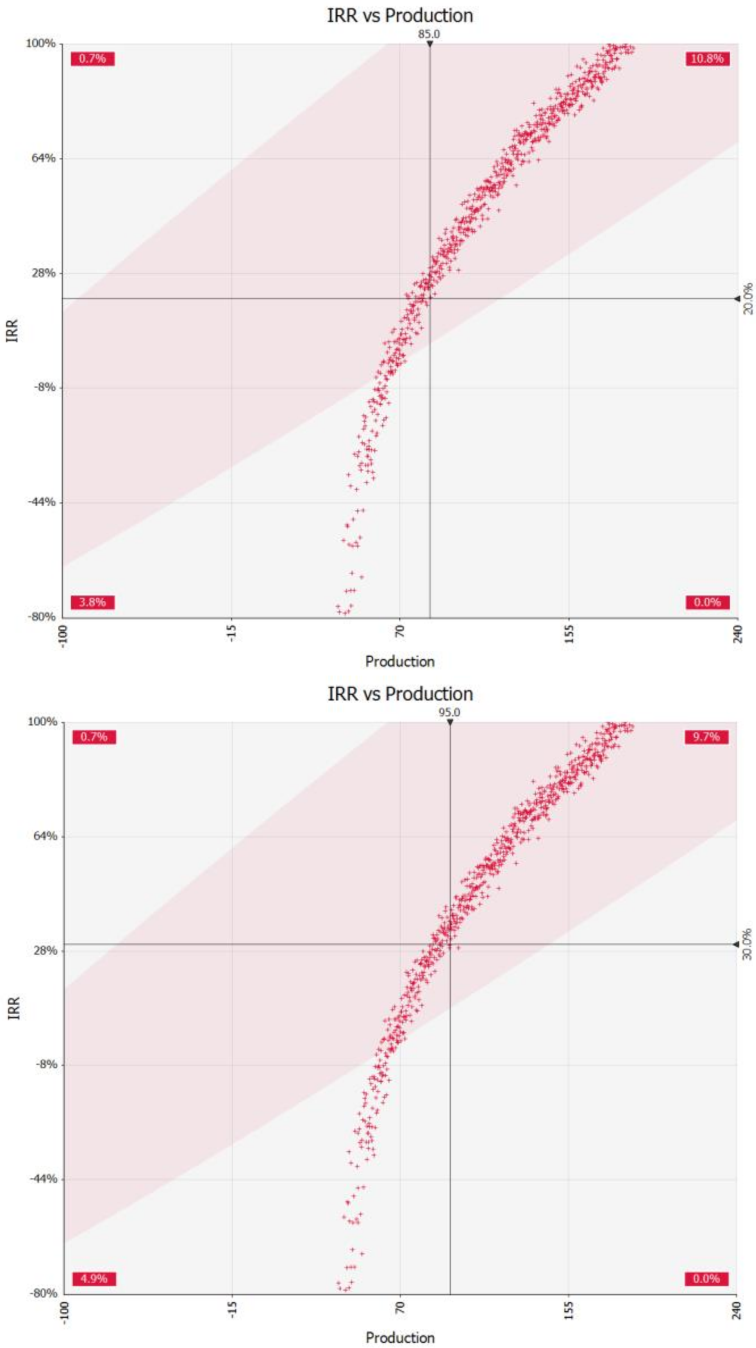


Figure 55: IRR 20% vs IRR 30%

As shown in the previous graph, in order to achieve IRR of 20%, between 75 and 85 units have to be sold. The same is true for IRR of 30% between 86 and 95 units. In a scenario where the market demand is lower than was assumed in the other scenarios, the Company can achieve relatively reasonable profit as shown above. In that case, some of the machines will become underutilised so that part of the product can be outsourced instead of produced and therefore, there won't be any need for those machines. That effect on the financial system can be investigated, but it is not in the scope of this study.

6.5.4.6 Fourth Scenario

As it said before the competitor product for small-scale wind turbines is the PV panel. Here a scenario is designed to simulate the situation where the small-scale wind turbine has to compete with PV panel on the price level. In order to simulate this scenario, the selling price of the wind turbines is set to that of the respective PV panel with the same power output. It has to be noted that the current PV panel's price is lower than the equal wind turbine.

Currently, the available price from the market is only for the PV panels and the mounting and stand's costs can be different due to the installing conditions and environmental factors. Since there is no estimation of the mounting equipment's price the same monopole tower price will be used for the purpose of this study. The other general assumptions will remain the same for this scenario except for the production range which covers the whole production range of the previous scenarios.

In the following graph, the new prices for wind turbines based on the PV panels' market price are shown.

Table 47: New Price for Wind Turbins

	600 W	1 kW	2 kW
Selling Price for the Whole Unit	33 280.00	36 780.00	49 780.00

For the purpose of this scenario the breakeven analysis was performed and the results are shown in the following graph.

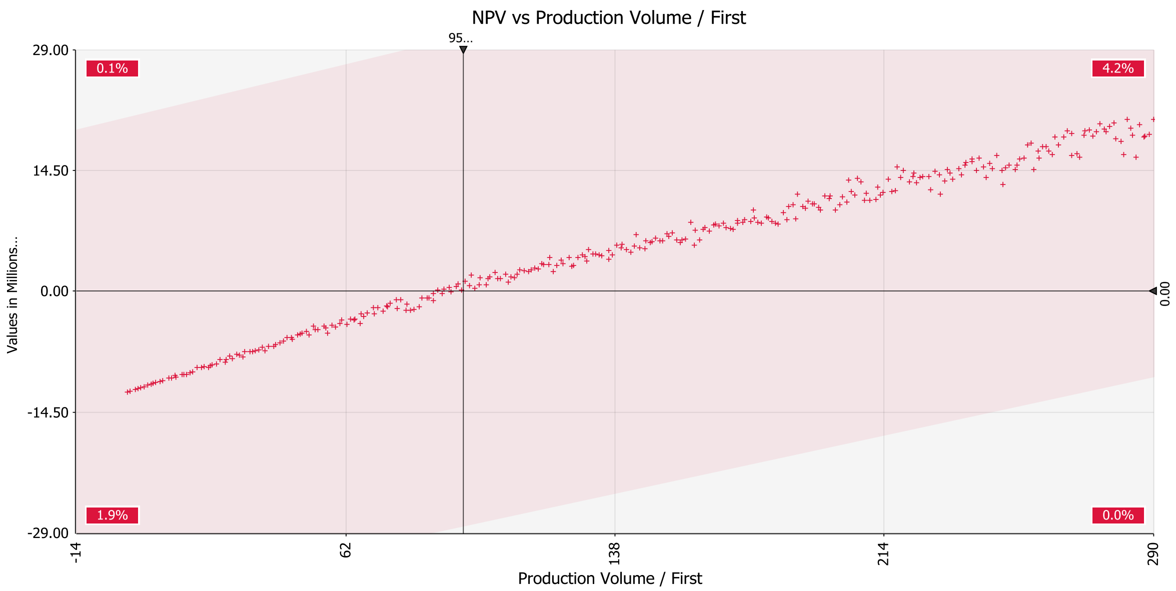


Figure 56: Breakeven Point When Competing with PV Price

The change in the selling price shifted the breakeven point towards higher production units as expected. The difference in production volume between this scenario and the previous once is around 27.5% more production in order to breakeven. It means that by producing 27.5% more units the Company can compete with the PV panel's on the same price level.

A quick comparison with the recommended scenario in the previous section shows that the MIRR rate with the same production volume for the first year as the second scenario can reach 121% where the same metric in the second scenario can go up to 130%. The difference mentioned here is also applicable to the other metrics, for instance, the NPV for the second scenario reaches 375 mR while for the fourth scenario at best it can go up to 293 mR, which shows around 22% decrease.

6.6 Recommendation

As was explained in section 6.5.4.5, the second scenario is the best of the first three scenarios. This is due to moderate initial production volume for the first year which is a rational decision for such a product that is very dependent on external factors and also because of the declining growth rate of MIRR and IRR which almost leads to a flat graph in the third scenario.

Also, as was mentioned in the same section, by isolating the initial production volume it is also possible to reach 20% and 30% IRR by producing less than 100 units. This also suggests that if the market demand is not as high as mentioned in the scenarios, the Company can still make a reasonable profit with low production.

From another point of view, the PV panels are well-known in the market and this might be a reason for the wind turbine to be rejected by some part of the target market. The same can happen due to the price difference. Since it might be a major problem for the Company, the fourth scenario was introduced for competing with PV panel's price level. The appraisal of this scenario shows that with less than 100 unit sales the Company can breakeven, which equates to around 27% more production volume than the second scenario to breakeven.

It has to be noted that all the 4 scenarios are valid as long as the assumptions mentioned in table 43 do not change. The slightest change in one or more of the factors can lead to a completely different outcome of the simulation.

To put it in a nutshell, the recommended scenario is the second scenario if the market demand and the factors mentioned in the risk register are as they were estimated in the market study; otherwise the Company can make a reasonable profit with low production level around 20% and 30% IRR. Also, in a case that the market resists accepting the price level in spite of an almost 10% difference in the Company's price level and the market price level for the same product, the fourth scenario could come into effect as plan B.

6.7 Chapter Summary

This chapter was started with the discussion of variable and fixed costs as well as all the calculations involved in those categories as the fundamental factors of the financial model. Then the pricing process and method for entering the market were discussed. Having the basis for the financial model, the factors that could affect the Company's financial state over the course of five years were discussed. Based on the information mentioned and the level of uncertainty for the product's demand in the market, three scenarios based on different production volumes were designed. Also, an additional scenario was introduced, considering the case in which the Company has to compete with the PV panel's price level in the market.

Having all of the information mentioned above, a comprehensive dynamic financial model was designed that covered all the relations and connections between different parts and sections of the Company. Using this model the simulations for the mentioned scenarios were performed, the results were discussed and based on these results a recommendation was made.

7 Conclusion

7.1 Summary

This thesis is opened with a brief discussion on the electricity conditions in South Africa. Chapter one delved into the problem statement, thesis configuration and arrangement of chapters. Following that a comprehensive literature review on the wind itself, how it is generated and wind usage in history was done in chapter two. Further in the chapter the electricity conversion from wind energy, wind turbine categories and a general introduction on the wind turbine's parts were discussed. At the end of the chapter the international view toward the small wind turbine was explained, followed by a review of the current small wind turbine manufacturers in the world.

In the third chapter, the focus was on the market for small wind turbines in South Africa. In this chapter the target markets were identified, the advantages and strengths corresponding to the target market were discussed. The factors that can influence the market, regarding the availability of the wind energy as well as the suitable conditions for harvesting it, were added to that section. Further in the chapter, the external factors that can affect the market such as increase in other energy carriers' prices, governmental policies toward renewable energy and the increase in community awareness were explored. As one of the key topics, identifying the competitors was included in the market study chapter. These included domestic and foreign competitors that have a presence in the defined target market. Having the details about the target market and the factors that affect it the most as well as the most common product ranges that cover the majority of the demand in the target market were chosen. Also, the potential target market share was estimated, by considering the competitors, their production ranges, presence in the markets and perceived service level. The factors that affect the growth in target market share were identified and 5-year forecast of the market, considering the growth expectation, was estimated.

In chapter four, detailed technical investigation was performed on the small wind turbine's components. In this chapter, the components that the Company could produce and those that have to be outsourced were identified. Following that, the work stations to produce the sub-products were designed, the time required for each sub-product to be produced estimated and equipment needed as well as human resources needed were calculated. Once manufacturing was sorted out, the administrative section was described complete with the organisational structure, office equipment needed and the capacity for the positions in that section were designed and discussed. Finally, the chapter closes with a detailed calculation of the capacity requirements for all the work stations in the production section, to determine exactly the equipment and human resources required based on the production volume.

In chapter five the financial aspects of the Company were discussed. The variable and fixed costs as well as detailed explanation of their components were introduced followed by the pricing section for the Company's products. Further in the chapter, the Company's financial state over the course of five years forecast was discussed, the factors affecting it were identified and explained and based on that a financial model was designed for the Company over the course of five years. Then four scenarios were introduced and implemented on the model, followed by their appraisals for each using metrics such as IRR, MIRR, NPV, cash flow as well as the breakeven point analysis, which were calculated for the scenarios. At the end of the chapter the results were compared and a recommendation made based on the scenarios' results.

7.2 Feasibility Study Conclusion

As the answer to the question in the problem statement section, the production of small-scale wind turbines in South Africa in the mentioned focus area was investigated. By modelling the technical and financial aspects of the production as close as possible to the real world conditions as well as considering a level of uncertainty for the contributing factors and using simulation methods to cover as many as possible outcomes for the financial model to form a population of the outcomes, the feasibility of the model was analysed. The results mentioned in the previous chapter indicate that it is financially feasible to produce small-scale wind turbines in the mentioned area in South Africa and as the metrics illustrated the Company can generate a high level of profit if the required sales are met.

7.3 Future Work

In this section, a few suggestions are made with respect to possible aspects to be added to the model to make it more realistic and more accurate.

- Based on the results of the simulation it is feasible to manufacture small-scale wind turbines in South Africa from the financial point of view, and based on the assumptions and the production methods assumed in this study. For producing the products, there are different methods of production as well as technologies involved which can be used. The question remains: *Will choosing a different method of production or another technology, make any changes to the feasibility status of the Company?* One possible approach to answering this question would be to investigate different methods and technologies involved in the production of small-scale wind turbines and perform the simulation for each of them and compare the results.
- Since the small-scale renewable energy generators are complementing each other, they are often seen as hybrid systems which consist of more than one type of renewable energy generators. For instance, there are hybrid systems of the wind and solar, or bio fuels and solar and wind. The PV panels are the most well-known renewable energy generators. The question here is: *Would it be feasible to produce the panels in South Africa as a division of the Company and switch from single type products to multi-type products?*

As was mentioned in the problem statement, the production and use of small-scale wind turbines in the African continent is way behind the international norms; another area of investigation would be to investigate *if it is possible to export the products to other countries and areas in the African continent that have ideal conditions for generating electricity?*

8 Appendices

8.1 Appendix A: Area Covered by WASA

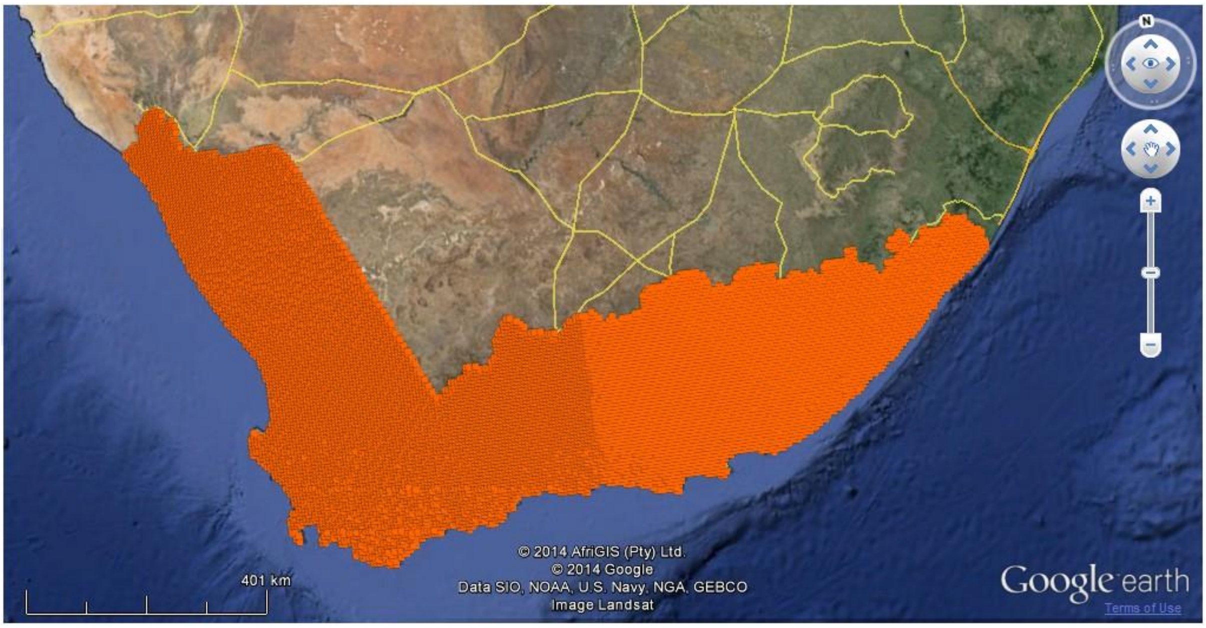


Figure 57: Area covered by WASA (WASA, 2014)

8.2 Appendix B: Wind Data for 10 Sites by WASA

The data was captured at standard heights above the ground level (10m, 20m, 40m, 62m and 100m) and different roughness classes: (R class 0 (0.000m) water areas; R class 1 (0.030m) farmland with open appearances, very few buildings, trees, airport area with some buildings and trees; R class 2 (0.100m) farmland with closed appearance; R class 3 (0.400m) low forest, suburbs, shelter belts, many trees and/or bushes and R class 4 (1.500m) tall forest (Department of Energy (DoE), 2014).

8.2.1 Wind Measurement Site (WM01)

Table 48: Wind Measurement Site (WM01) (DTU Wind Energy, 2014)

Height		R class 0	R class 1	R class 2	R class 3	R class 4
10m	U (m/s)	5.65	4.10	3.57	2.79	1.86
	P (W/m^2)	289	124	82	40	12
20m	U (m/s)	6.05	4.68	4.18	3.44	2.58
	P (W/m^2)	346	174	124	71	30
40m	U (m/s)	6.48	5.37	4.87	4.16	3.34
	P (W/m^2)	410	237	180	115	60
62m	U (m/s)	6.79	5.89	5.39	4.67	3.87
	P (W/m^2)	472	286	224	152	87
100m	U (m/s)	7.17	6.59	6.05	5.32	4.50
	P (W/m^2)	565	389	299	204	125

8.2.2 Wind Measurement Site (WM02)

Table 49: Wind Measurement Site (WM02) (DTU Wind Energy, 2014)

Height		R class 0	R class 1	R class 2	R class 3	R class 4
10m	U (m/s)	5.74	4.14	3.60	2.83	1.88
	P (W/m^2)	240	103	68	33	10
20m	U (m/s)	6.14	4.74	4.22	3.50	2.61
	P (W/m^2)	288	146	105	59	25
40m	U (m/s)	6.59	5.45	4.94	4.24	3.39
	P (W/m^2)	344	202	153	98	51
62m	U (m/s)	6.92	6.00	5.47	4.77	3.93
	P (W/m^2)	399	247	193	130	75
100m	U (m/s)	7.32	6.74	6.18	5.44	4.58
	P (W/m^2)	481	346	265	179	109

8.2.3 Wind Measurement Site (WM03)

Table 50: Wind Measurement Site (WM03) (DTU Wind Energy, 2014)

Height		R class 0	R class 1	R class 2	R class 3	R class 4
10m	U (m/s)	6.21	4.48	3.89	3.05	2.03
	P (W/m^2)	267	112	74	36	11
20m	U (m/s)	6.65	5.13	4.56	3.77	2.81
	P (W/m^2)	322	160	114	65	27
40m	U (m/s)	7.14	5.90	5.34	4.58	3.65
	P (W/m^2)	386	225	170	108	57
62m	U (m/s)	7.49	6.50	5.93	5.15	4.24
	P (W/m^2)	449	281	218	146	84
100m	U (m/s)	7.93	7.32	6.70	5.88	4.95
	P (W/m^2)	541	397	303	204	125

8.2.4 Wind Measurement Site (WM04)

Table 51: Wind Measurement Site (WM04) (DTU Wind Energy, 2014)

Height		R class 0	R class 1	R class 2	R class 3	R class 4
10m	U (m/s)	6.26	4.53	3.93	3.10	2.05
	P (W/m^2)	289	122	80	39	12
20m	U (m/s)	6.70	5.18	4.62	3.83	2.85
	P (W/m^2)	349	174	124	70	30
40m	U (m/s)	7.19	5.96	5.40	4.64	3.69
	P (W/m^2)	418	244	184	117	61
62m	U (m/s)	7.55	6.58	5.99	5.22	4.28
	P (W/m^2)	486	304	235	158	91
100m	U (m/s)	7.99	7.40	6.77	5.96	5.00
	P (W/m^2)	586	428	326	220	134

8.2.5 Wind Measurement Site (WM05)

Table 52: Wind Measurement Site (WM05) (DTU Wind Energy, 2014)

Height		R class 0	R class 1	R class 2	R class 3	R class 4
10m	U (m/s)	7.77	5.63	4.89	3.84	2.55
	P (W/m^2)	528	217	143	69	20
20m	U (m/s)	8.30	6.40	5.71	4.72	3.52
	P (W/m^2)	636	309	220	124	52
40m	U (m/s)	8.88	7.29	6.62	5.67	4.53
	P (W/m^2)	760	431	325	206	107
62m	U (m/s)	9.28	7.95	7.28	6.34	5.23
	P (W/m^2)	865	529	412	276	158
100m	U (m/s)	9.77	8.82	8.12	7.16	6.05
	P (W/m^2)	1019	700	544	376	232

8.2.6 Wind Measurement Site (WM06)

Table 53: Wind Measurement Site (WM06) (DTU Wind Energy, 2014)

Height		R class 0	R class 1	R class 2	R class 3	R class 4
10m	U (m/s)	6.54	4.74	4.11	3.23	2.15
	P (W/m^2)	365	156	103	49	15
20m	U (m/s)	6.99	5.41	4.81	3.98	2.98
	P (W/m^2)	440	220	157	89	37
40m	U (m/s)	7.49	6.18	5.60	4.80	3.85
	P (W/m^2)	523	302	229	146	75
62m	U (m/s)	7.84	6.78	6.19	5.38	4.45
	P (W/m^2)	598	369	288	194	110
100m	U (m/s)	8.28	7.56	6.94	6.11	5.18
	P (W/m^2)	714	492	381	261	161

8.2.7 Wind Measurement Site (WM07)

Table 54: Wind Measurement Site (WM07) (DTU Wind Energy, 2014)

Height		R class 0	R class 1	R class 2	R class 3	R class 4
10m	U (m/s)	6.56	4.71	4.10	3.22	2.14
	P (W/m^2)	320	136	89	43	13
20m	U (m/s)	7.02	5.39	4.81	3.98	2.96
	P (W/m^2)	385	193	137	78	33
40m	U (m/s)	7.53	6.19	5.63	4.82	3.84
	P (W/m^2)	460	268	203	129	67
62m	U (m/s)	7.90	6.82	6.23	5.42	4.46
	P (W/m^2)	533	332	257	173	99
100m	U (m/s)	8.35	7.67	7.04	6.18	5.20
	P (W/m^2)	642	464	355	240	146

8.2.8 Wind Measurement Site (WM08)

Table 55: Wind Measurement Site (WM08) (DTU Wind Energy, 2014)

Height		R class 0	R class 1	R class 2	R class 3	R class 4
10m	U (m/s)	6.93	5.02	4.36	3.42	2.27
	P (W/m^2)	408	172	113	54	16
20m	U (m/s)	7.42	5.72	5.10	4.22	3.14
	P (W/m^2)	492	243	173	98	41
40m	U (m/s)	7.94	6.55	5.94	5.09	4.06
	P (W/m^2)	585	337	254	162	84
62m	U (m/s)	8.31	7.17	6.55	5.71	4.69
	P (W/m^2)	670	412	321	216	124
100m	U (m/s)	8.77	8.00	7.35	6.48	5.45
	P (W/m^2)	794	553	428	294	181

8.2.9 Wind Measurement Site (WM09)

Table 56: Wind Measurement Site (WM09) (DTU Wind Energy, 2014)

Height		R class 0	R class 1	R class 2	R class 3	R class 4
10m	U (m/s)	6.67	4.83	4.20	3.29	2.20
	P (W/m^2)	341	143	94	46	14
20m	U (m/s)	7.14	5.51	4.93	4.07	3.04
	P (W/m^2)	411	204	146	83	35
40m	U (m/s)	7.66	6.33	5.75	4.92	3.94
	P (W/m^2)	492	285	216	138	71
62m	U (m/s)	8.02	6.96	6.36	5.53	4.56
	P (W/m^2)	567	353	274	185	106
100m	U (m/s)	8.48	7.80	7.16	6.29	5.31
	P (W/m^2)	678	486	374	255	156

8.2.10 Wind Measurement Site (WM10)

Table 57: Wind Measurement Site (WM10) (DTU Wind Energy, 2014)

Height		R class 0	R class 1	R class 2	R class 3	R class 4
10m	U (m/s)	5.68	4.11	3.58	2.81	1.87
	P (W/m^2)	253	111	73	35	10
20m	U (m/s)	6.08	4.70	4.19	3.47	2.58
	P (W/m^2)	303	155	111	63	27
40m	U (m/s)	6.52	5.39	4.89	4.19	3.35
	P (W/m^2)	358	212	161	103	54
62m	U (m/s)	6.84	5.93	5.42	4.71	3.88
	P (W/m^2)	414	256	201	136	78
100m	U (m/s)	7.23	6.65	6.10	5.37	4.53
	P (W/m^2)	499	350	269	183	113

8.3 Appendix C: Wind Rose and Weibull Distribution for 10 Sites

All the following information is captured at 20 m height and class 2 surface roughness.

8.3.1 Wind Measurement Site (WM01)

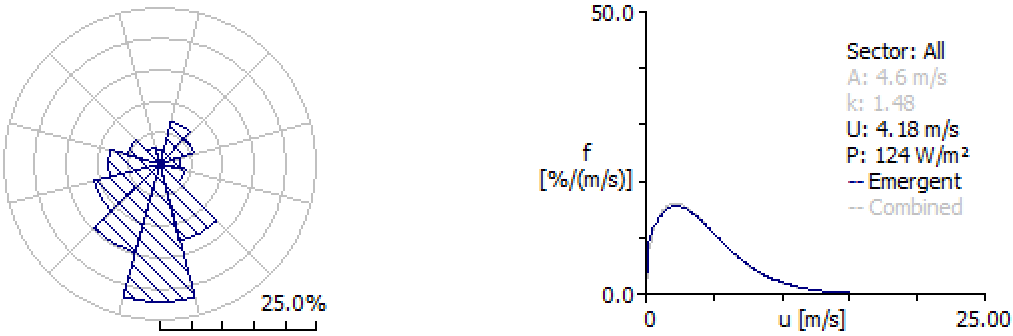


Figure 58: Wind Rose Graph, Weibull Distribution (DTU Wind Energy, 2014)

8.3.2 Wind Measurement Site (WM02)

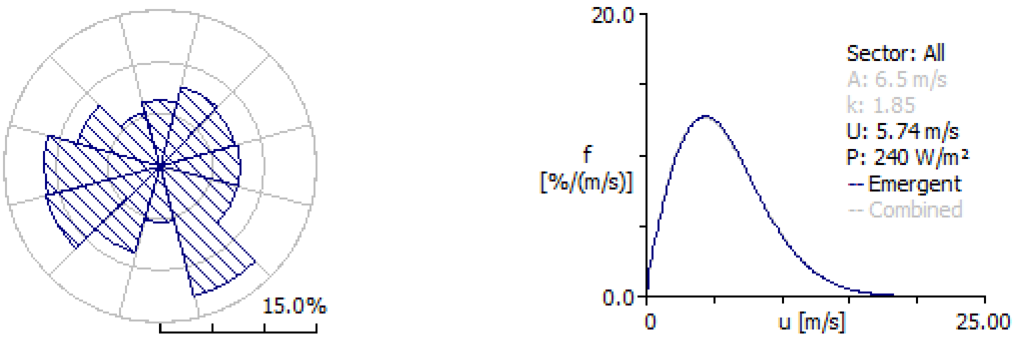


Figure 59: Wind Rose Graph, Weibull Distribution (DTU Wind Energy, 2014)

8.3.3 Wind Measurement Site (WM03)

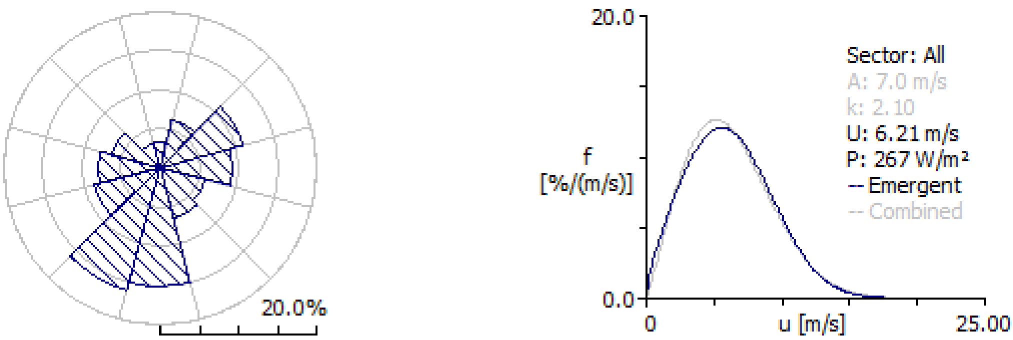


Figure 60: Wind Rose Graph, Weibull Distribution (DTU Wind Energy, 2014)

8.3.4 Wind Measurement Site (WM04)

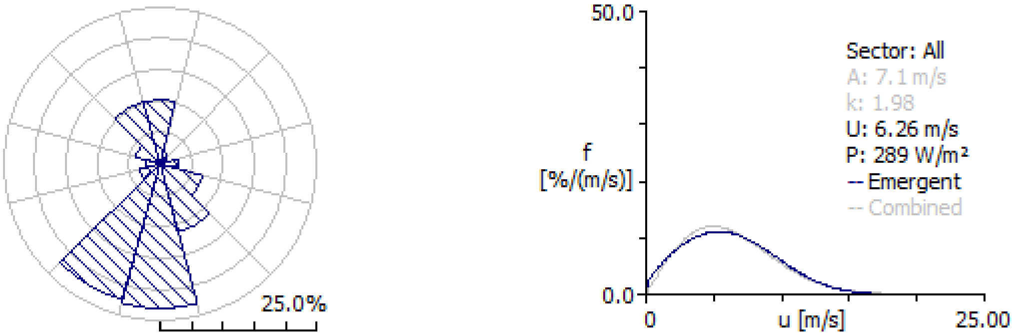


Figure 61: Wind Rose Graph, Weibull Distribution (DTU Wind Energy, 2014)

8.3.5 Wind Measurement Site (WM05)

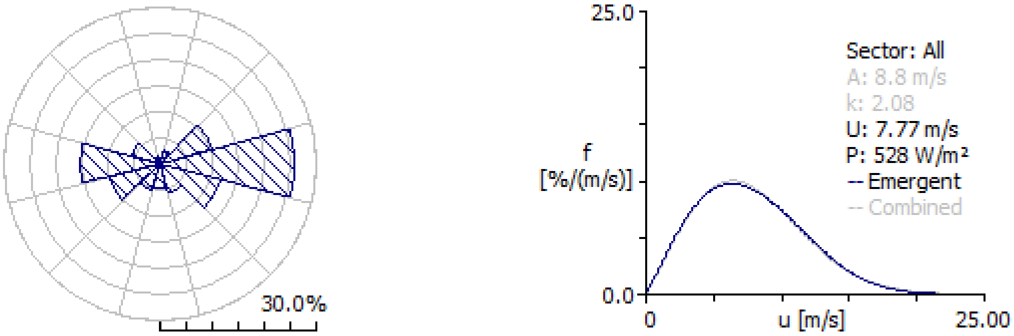


Figure 62: Wind Rose Graph, Weibull Distribution (DTU Wind Energy, 2014)

8.3.6 Wind Measurement Site (WM06)

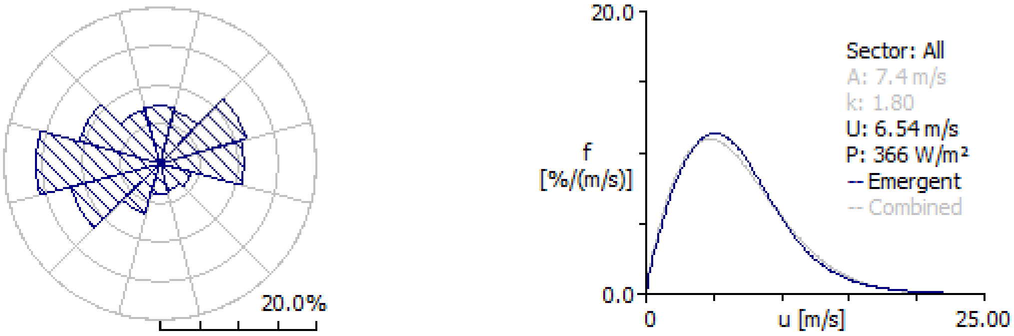


Figure 63: Wind Rose Graph, Weibull Distribution (DTU Wind Energy, 2014)

8.3.7 Wind Measurement Site (WM07)

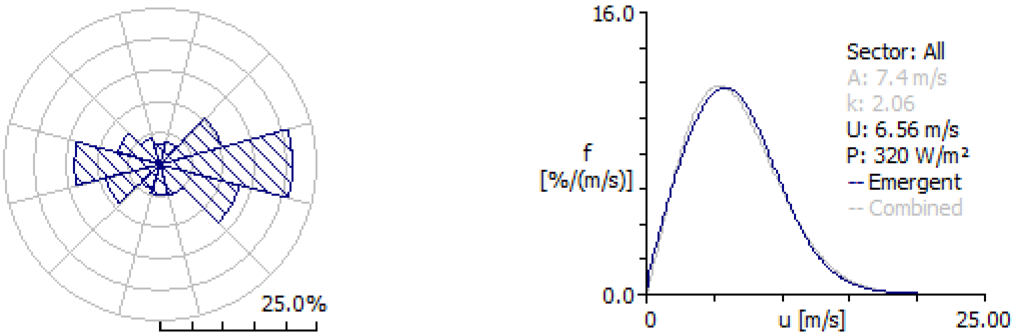


Figure 64: Wind Rose Graph, Weibull Distribution (DTU Wind Energy, 2014)

8.3.8 Wind Measurement Site (WM08)

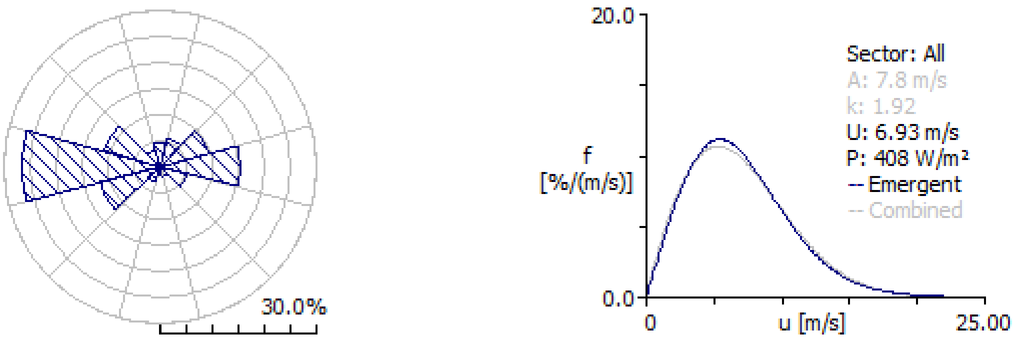


Figure 65: Wind Rose Graph, Weibull Distribution (DTU Wind Energy, 2014)

8.3.9 Wind Measurement Site (WM09)

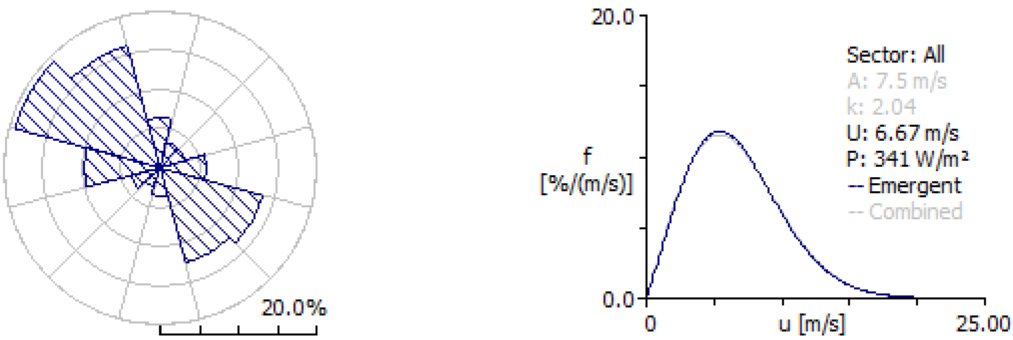


Figure 66: Wind Rose Graph, Weibull Distribution (DTU Wind Energy, 2014)

8.3.10 Wind Measurement Site (WM10)

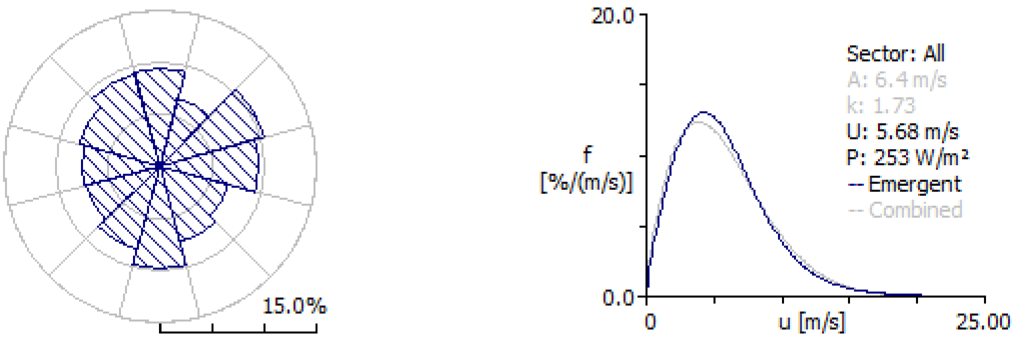


Figure 67: Wind Rose Graph, Weibull Distribution (DTU Wind Energy, 2014)

8.4 Appendix D: Households Statistic (Residential/Agricultural)

The following tables show households involved in agricultural and non-agricultural activities. The following statistics are only for the cities which covered by WASA.

Table 58: Western Cape Municipality Households Statistics (South Africa Government, 2015)

Local municipality	Household involved in agricultural activities	Household not involved in agricultural activities	Local municipality	Household involved in agricultural activities	Household not involved in agricultural activities
Beaufort West	1 593	11 497	Langeberg	2 979	22 145
Bergrivier	1 913	14 361	Matzikama	2 135	16 700
Bitou	1 605	15 040	Mossel Bay	2 013	26 012
Breede Valley	2 447	40 081	Oudtshoorn	2 235	19 675
Cape Agulhas	1 167	8 996	Overstrand	1 405	26 605
Cederberg	2 031	11 482	Prince Albert	590	2 989
City of Cape Town	34 383	1 034 190	Saldanha Bay	1 116	27 718
Drakenstein	3 645	56 130	Stellenbosch	2 805	40 615
George	4 074	49 477	Swartland	2 416	26 908
Hessequa	2 668	13 205	Swellendam	1 624	8 515
Kannaland	1 596	4 616	Theewaterskloof	2 459	26 425
Knysna	1 997	19 897	Witzenberg	3 189	24 229
Laingsburg	490	1 918	**Total**	**84 575**	**1 549 426**

Table 59: Northern Cape Municipality Households Statistics (South Africa Government, 2015)

Local municipality	Household involved in agricultural activities	Household not involved in agricultural activities	Local municipality	Household involved in agricultural activities	Household not involved in agricultural activities
Hantam	1 256	5 084	Richtersveld	460	3 083
Kamiesberg	913	2 230	**Total**	**4 535**	**21 684**
Nama Khoi	1 906	11 288			

Table 60: Eastern Cape Municipality Households Statistics (South Africa Government, 2015)

Local municipality	Household involved in agricultural activities	Household not involved in agricultural activities	Local municipality	Household involved in agricultural activities	Household not involved in agricultural activities
Amahlathi	15 581	18 578	Mbhashe	36 377	23 748
Baviaans	949	3 662	Mbizana	30 533	17 914
Blue Crane Route	1 733	8 027	Mhlontlo	25 591	17 823
Buffalo City	43 624	179 944	Mnquma	38 300	31 432
Camdeboo	1 733	10 667	Ndlambe	3 320	16 011
Elundini	19 436	18 418	Nelson Mandela Bay	14 165	310 127
Emalahleni-EC	16 335	15 347	Ngqushwa	12 178	9 206
Engcobo	22 187	15 027	Ngquza Hill	35 330	20 883
Gariep	2 599	7 171	Nkonkobe	13 984	21 371
Great Kei	3 559	6 751	Ntabankulu	15 679	8 717
Ikwezi	564	2 351	Nxuba	2 147	4 564
Inkwanca	1 899	4 329	Nyandeni	36 502	25 145
Intsika Yethu	23 639	16 809	Port St Johns	18 190	13 524
Inxuba Yethemba	3 342	15 122	Sakhisizwe	7 658	8 491
King Sabata Dalindyebo	48 405	56 835	Senqu	17 222	20 824
Kou-Kamma	1 983	9 049	Sundays River Valley	2 414	12 334
Kouga	2 002	27 445	Tsolwana	3 298	6 197
Lukanji	15 132	36 041	Umzimvubu	26 714	20 176
Makana	3 098	18 290	**Total**	**569 933**	**1 067 921**
Maletswai	2 533	9 571			

8.5 Appendix E: Available Target Market in 5-year Growth for each Market Segment

Table 61: Available Target Market in 5-year Growth

		Total available target Market for Households (non-farming)	Total available target Market for Households (farming)	Small businesses and manufacturing	Road signals	Telecoms	Villages without access to national grid	Marine Vessels
1st Year	Western Cape	193 678.00	80 346.00					
	Eastern Cape	144 169.00	512 939.00	14 810.00	500.00	100.00	50.00	500.00
	Northern Cape	3 469.00	3 628.00					
2nd Year	Western Cape	193 774.84	80 386.17					
	Eastern Cape	144 241.08	513 195.47	14 817.41	500.25	100.05	50.03	500.25
	Northern Cape	3 470.73	3 629.81					
3rd Year	Western Cape	193 871.73	80 426.37					
	Eastern Cape	144 313.21	513 452.07	14 824.81	500.50	100.10	50.05	500.50
	Northern Cape	3 472.47	3 631.63					
4th Year	Western Cape	193 968.66	80 466.58					
	Eastern Cape	144 385.36	513 708.79	14 832.23	500.75	100.15	50.08	500.75
	Northern Cape	3 474.21	3 633.44					
5th Year	Western Cape	194 065.65	80 506.81					
	Eastern Cape	144 457.55	513 965.65	14 839.64	501.00	100.20	50.10	501.00
	Northern Cape	3 475.94	3 635.26					

8.6 Appendix F: Off-grid and Grid-connected Systems

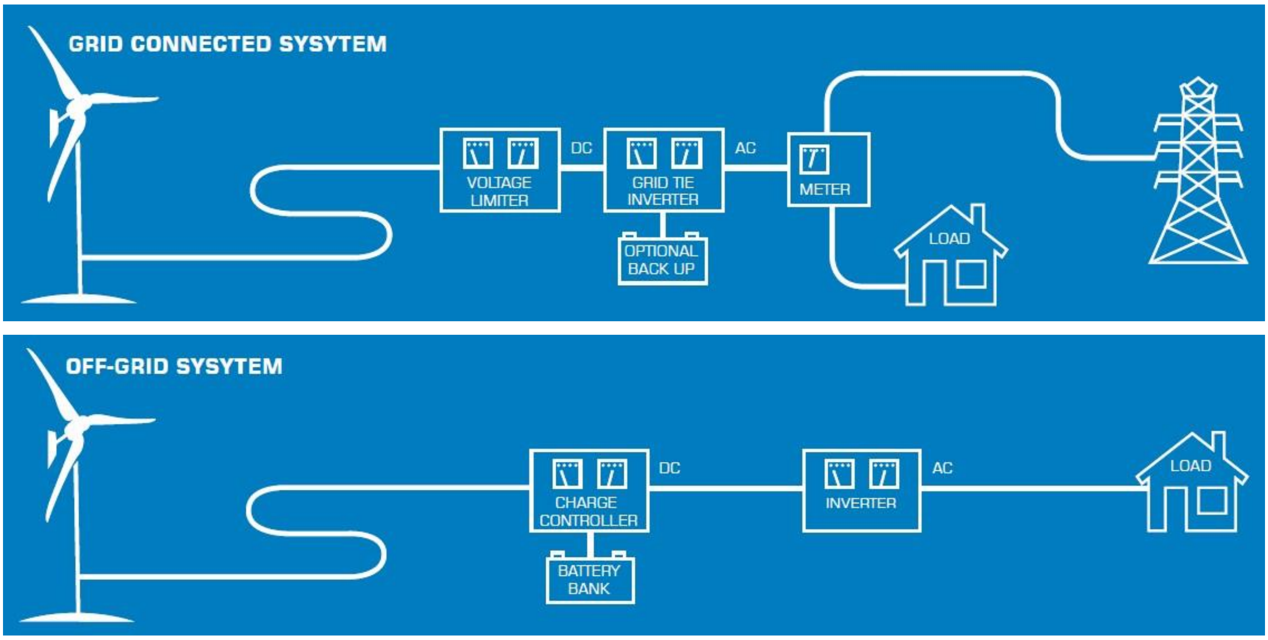


Figure 68: Off-grid and Grid-connected Systems (kestrel Wind Turbines, 2011b)(kestrel Wind Turbines, 2011c)

8.7 Appendix G: Component Status

Table 62: Components' Status

Item No.		Item Description	Manufactured	Purchased	Assembled
1		**Generator core**			•
	1-1	Shaft		•	
	1-2	Shaft's Nut		•	
	1-3	Spacer		•	
	1-4	Magnets		•	
	1-5	Magnets' Base		•	
2		**Generator Coil**			•
	2-1	Wires		•	
	2-2	Frame		•	
	2-3	Generator connector		•	
	2-4	Bolts and Nuts		•	
3		**Generator Case**			•
	3-1	Front Case		•	
	3-2	Back Case		•	
	3-3	Back Bearing		•	
	3-4	Front Bearing		•	
	3-5	Bolts and Nuts		•	
	3-6	Washers		•	
4		**Hub**		•	
5		**Blades**	•		
	5-1	Release Agent		•	
	5-2	Carbon Fibre Sheets		•	
	5-3	Epoxy Resin		•	
	5-4	Epoxy Hardener		•	
	5-5	Bolts and Nuts		•	
	5-6	Washers		•	
6		**Tail**			•
	6-1	Tail Boom		•	
	6-2	Tail fin		•	
	6-3	Bolts and Nuts		•	
	6-4	Washers		•	
7		**Interface**			•
	7-1	Master switch		•	
	7-2	Rectifier		•	
	7-3	Wires		•	
	7-4	Case		•	
	7-5	Bolts and Nuts		•	
	7-6	Washers		•	
	7-7	Terminals		•	
8		**Mounting Accessories**			•
	8-1	Metal parts		•	
	8-2	Flanges		•	
	8-3	Slip Ring		•	
	8-4	Bolts and Nuts		•	
	8-5	Washers		•	
	8-6	Pipes		•	
9		**Charge Controller**		•	
10		**Batteries**		•	
	10-1	Batteries		•	
	10-2	Cable terminals and bridges		•	
11		**Inverters**		•	

8.8 Appendix H: Operation Process Chart (OPC)

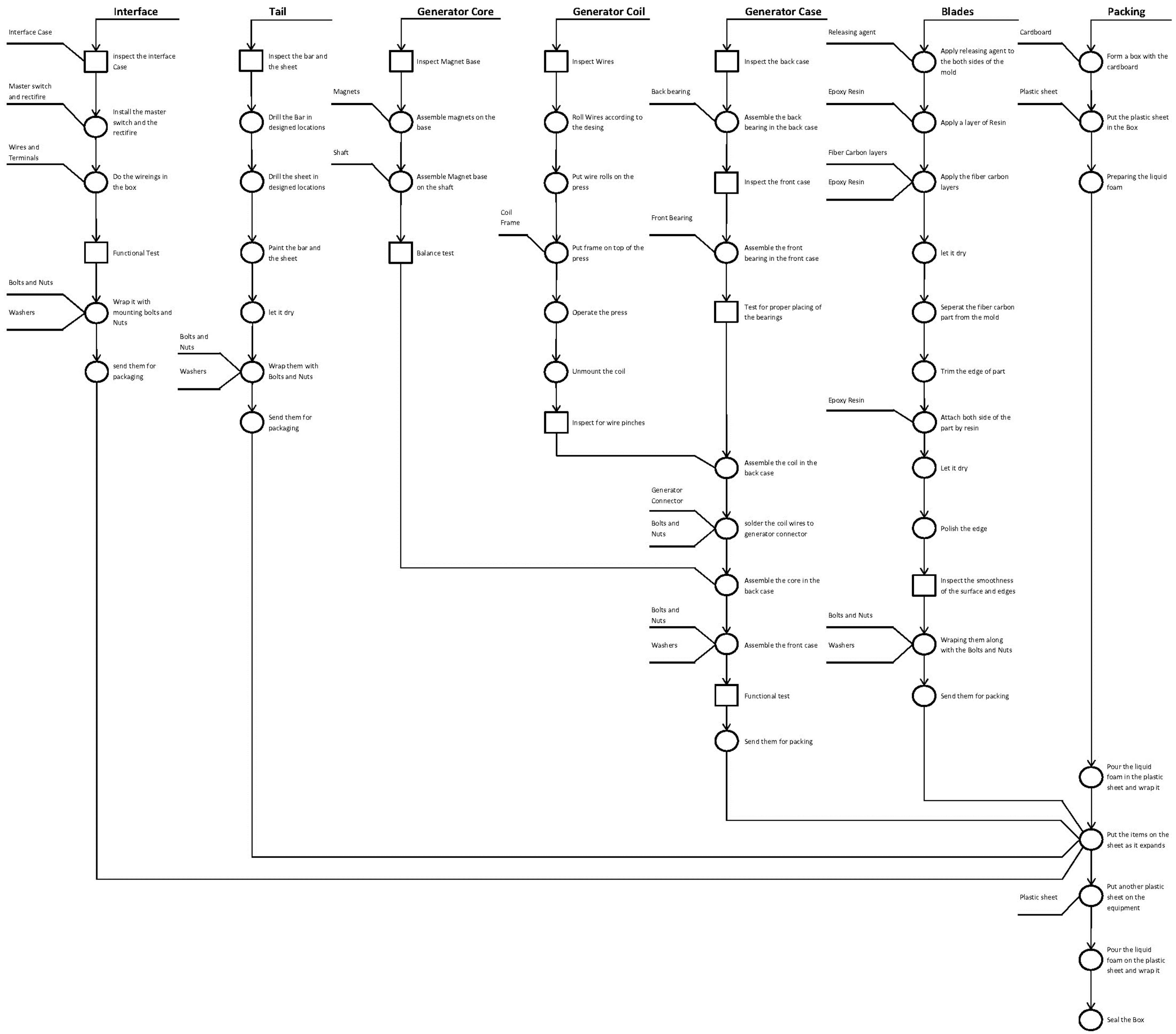


Figure 69: OPC

8.9 Appendix I: PERT Chart for Each Work Station

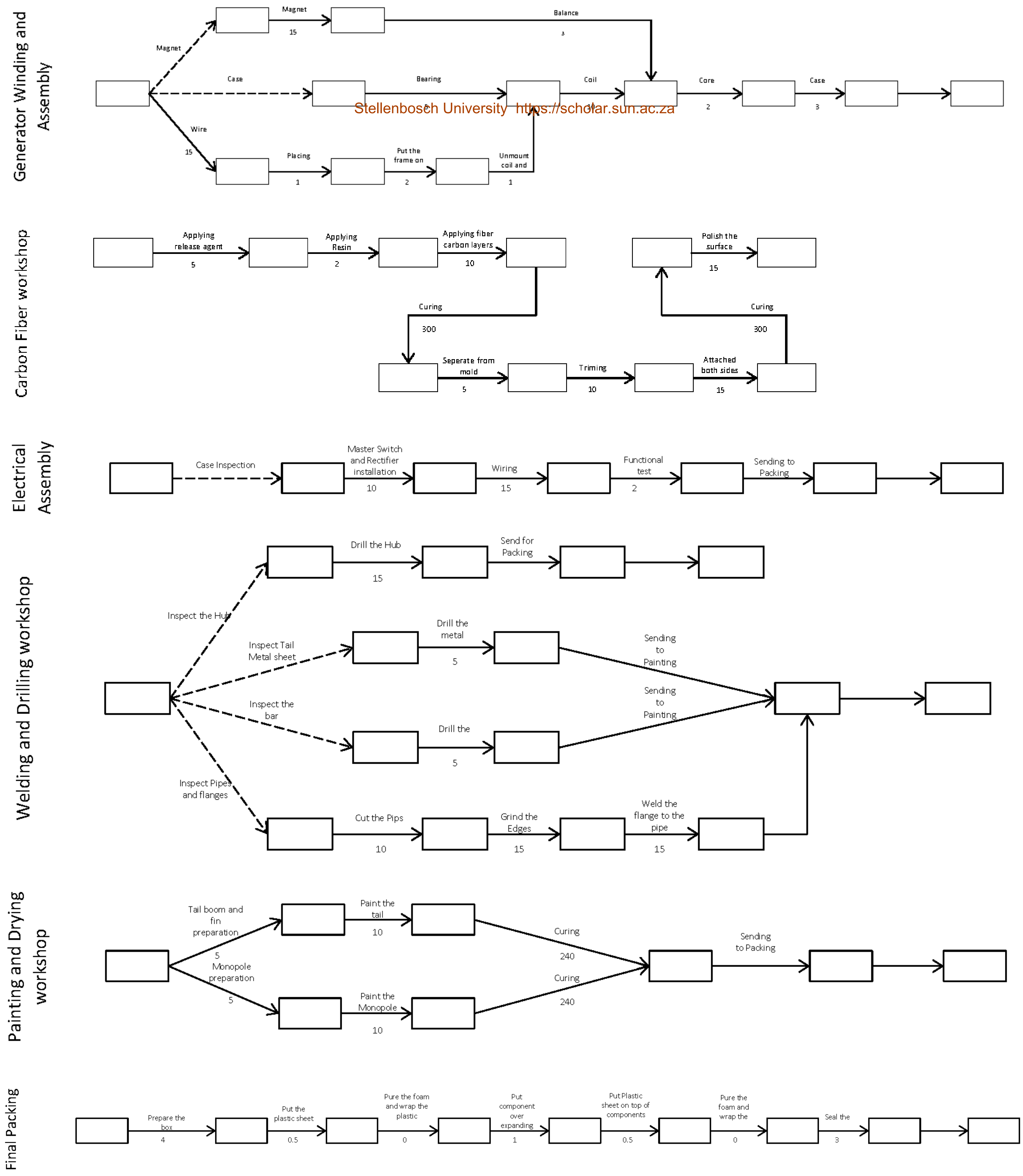


Figure 70: PERT Chart for Each Work Station

8.10 Appendix J: Overall PERT Chart and the Relation between WORK Stations

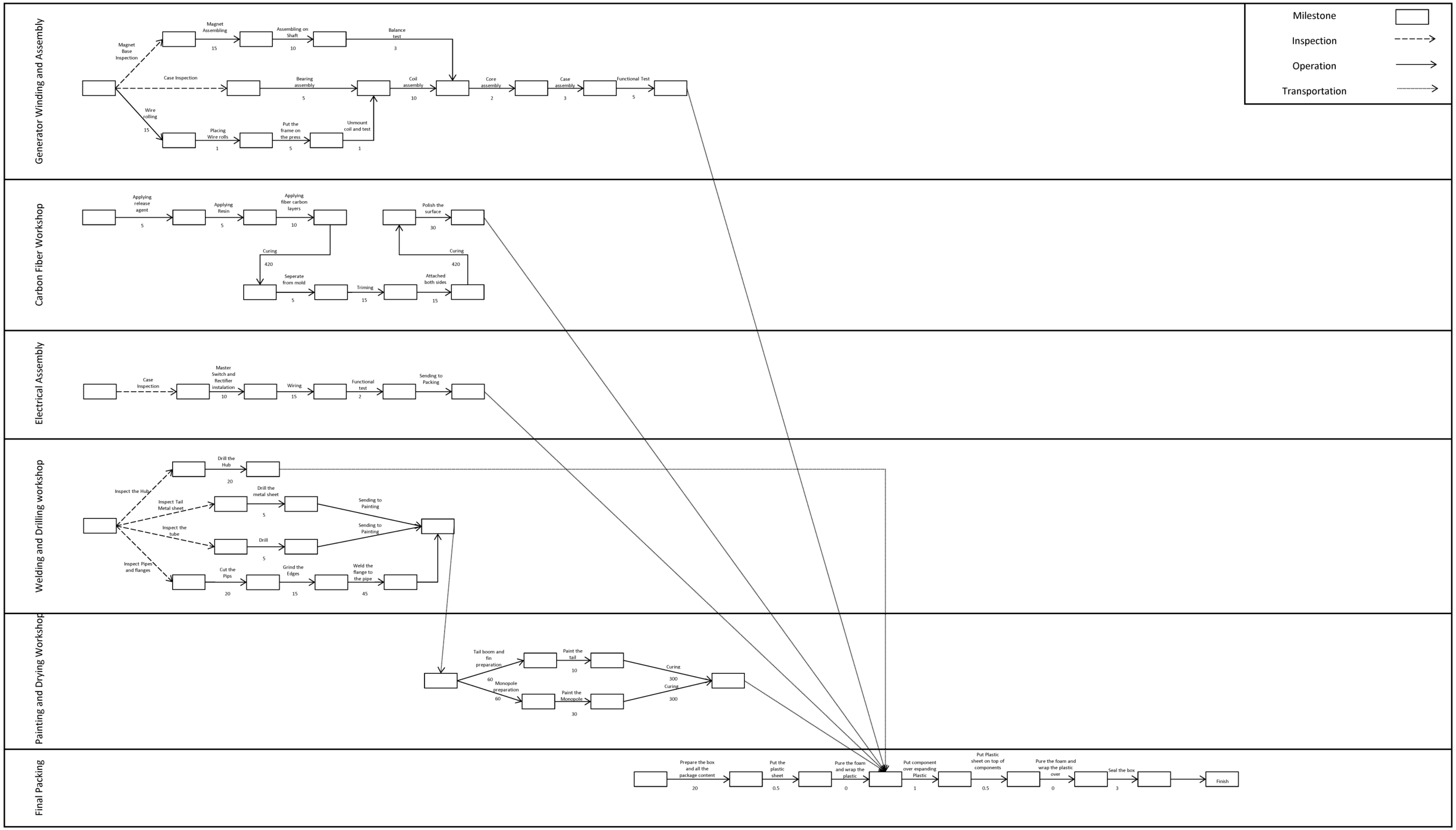


Figure 71: Overall PERT Chart and the Relation between Work Stations

8.11 Appendix K: Business Process for Sales Process

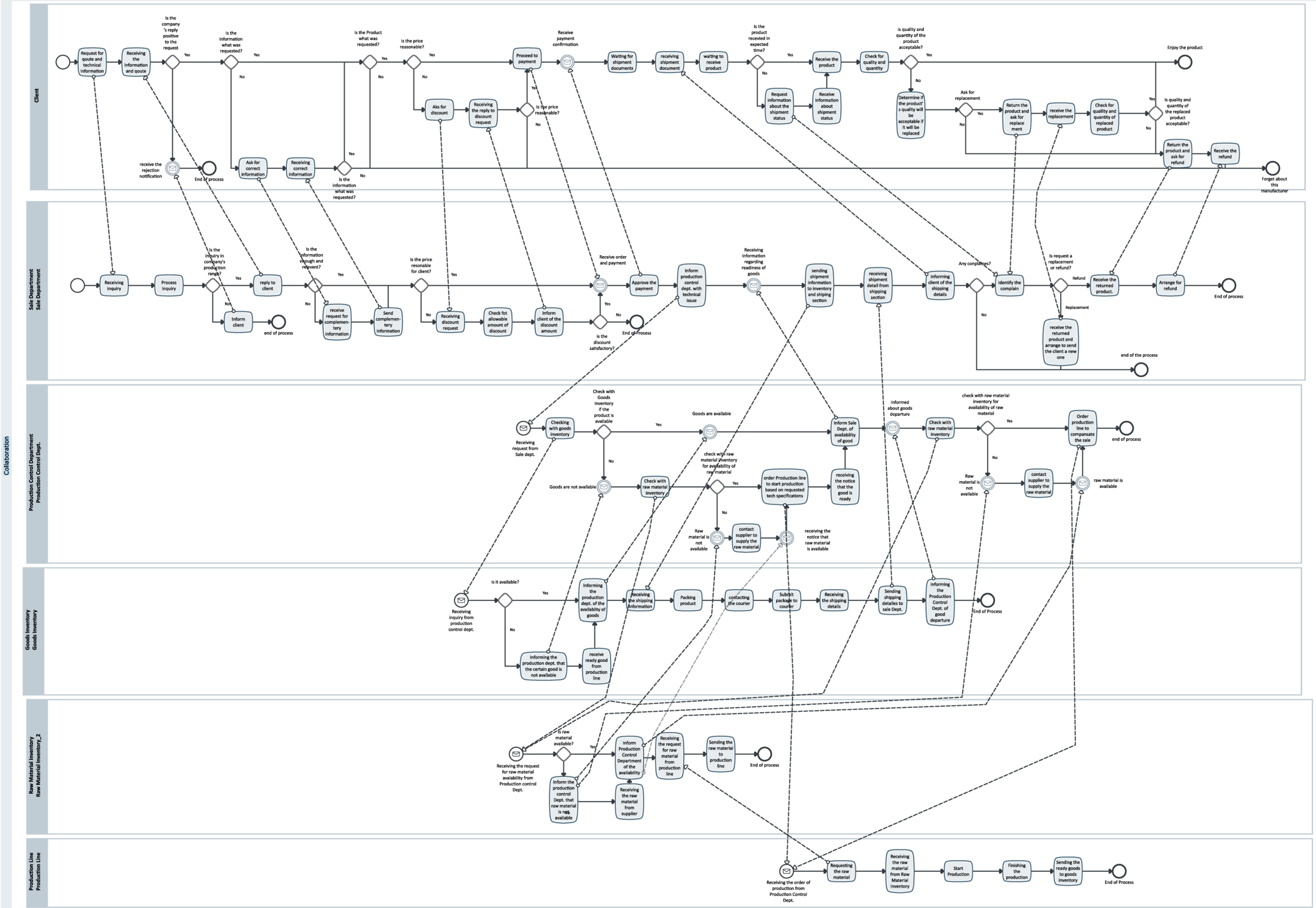


Figure 72: Sales Business Process

8.12 Appendix L: Financial Model Flowchart

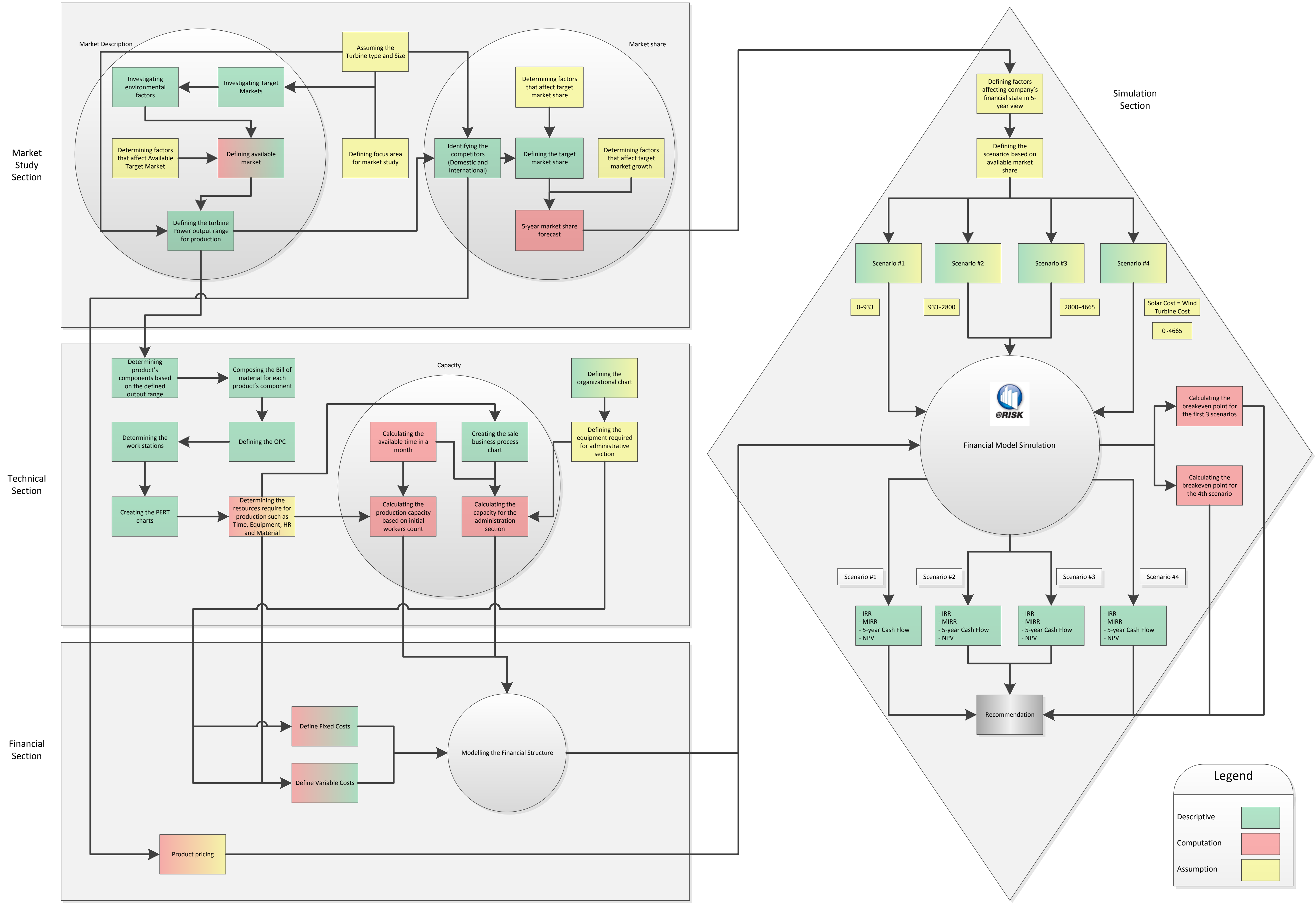


Figure 73: Financial Model Flowchart

8.13 Appendix O: Financial Model Excel Screenshot

8.13.1 Fixed Costs

Building and Land Rental

No.	Description	Per SQM	SQM	Price (Rand)
1	Rental	57.86	600	34716.00
	Total			34716.00

Staff's Health Insurance

No.	Description	Qty.	Amount	Price (Rand)
1	Contribution for Managerial Positions	2	800	19200.00
2	Contribution for below Managerial Positions	3	500	18000.00
	Total			37200.00

Administrative equipment

No.	Description	Qty.	Price (Rand)	Depreciation period	Cost price per Year
1	Aircon	1	9000.00	6	1500.00
2	Desk	5	1800.00	6	9000.00
3	Chair	5	700.00	6	3500.00
4	Bookcase	1	500.00	6	500.00
5	Computer	5	10500.00	3	17500.00
6	Printer	1	5500.00	5	5500.00
7	Fax	1	2100.00	3	2100.00
8	Phone	5	250.00	5	1250.00
9	Others	1	1000.00		1000.00
	Total		84350.00		41850.00

Miscellaneous

No.	Description	Qty.	Amount	Price (Rand)	Depreciation period	Cost price per Year
1	Pickup Car	1	156750	156750.00	4	39187.50
2	Fuel Consumption	100	13.66	16392.00		16392.00
	Total			173142.00		39187.50

Salaries (Administrative Section)(Annual)

No.	Description	Qty.	Current Employee	Price (Rand)
1	Managing Director	1	1	480000.00
2	Sale Manager	1	0	0.00
3	Production Manager	1	1	300000.00
4	Supply Chain Manager	1	0	0.00
5	Sale Specialist	2	1	180000.00
6	Production Specialist	1	1	180000.00
7	Supply Chain Specialist	1	0	0.00
8	Secretary	1	1	108000.00
	Total			1248000.00

Consumables (Administrative Section)(Annual)

No.	Description	Price (Rand)
1	Paper, Pen, ...	12360.00
2	Printer Cartridge	16000.00
3	Internet	9000.00
4	Telephone	9000.00
5	Office 365 (Software)	3200.00
	Total	49560.00

Machinery

No.	Description	Qty.	Price (Rand)	Depreciation period	Cost price per Year
1	Bench Vice	3	2649.36	5	7948.08
2	Electrical Spanner	2	3420.00	5	6840.00
3	Polisher	4	4570.26	5	18281.04
4	Drill Press Bench	2	4650.06	5	9300.12
5	Plasma Arc Cutter	2	8840.84	5	3536.34
6	Grinder	2	1340.64	5	2681.28
7	Welder Inverter	2	2324.46	5	4648.92
8	Tool Set	1	3587.58	5	3587.58
9	Coil Insertion	1	1092234.00	5	218446.80
10	Coil Insertion Tools*	3	410550.40	5	246330.24
11	Oven	3	1500.00	5	4500.00
12	Multimeter	2	581.40	5	1162.80
13	Soldering Iron	2	114.00	5	228.00
14	Tables and Chairs	12	1140.00	6	13680.00
	Total		2414424.70		541171.20

Utility

No.	Description	Price (Rand)
1	Water	6000.00
2	Electricity (Fixed Base)	15600.00
	Total	21600.00

Figure 74: Fixed Costs Screenshot

8.13.2 Variable Costs

Production Material Costs for 600W

No.	Description		Amount	Price (Rand)
	Generator x 1			**2173.76**
1		Shaft	1	51.30
2		Magnet base	25	125.00
3		Magnets	12	957.73
4		Wire		55.69
5		Coil Core		100.00
6		Cases		800.00
7		Bearings	2	70.00
8		Cables and connector		10.00
9		Bolts and Nuts	3 tall m6 m20 nut	4.04
	Blades x 3			**168.90**
10		Resin	128.5 g	14.08
11		Hardener	33.4 g	6.51
12		Carbon Fabric	4 layer	124.80
13		Mould Sealer	200 g for 10 times	11.06
14		Release agent	30 cc	10.04
15		Bolts and Nuts	3 m8	2.41
	Tail x1			**233.62**
16		Tail Fin		121.11
17		Tail Boom		85.58
18		Paint	100g	24.86
19		Bolts and Nuts	5 m6	2.07
	Hub x1			**97.61**
20		Round metal sheet		97.61
	Monopole x 1			**8125.83**
21		Flanges		1983.73
22		Pipes		6058.71
23		Paint	300g	74.58
24		Bolts and Nuts	11 m8	8.81
	Interface x 1			**387.75**
23		Case		130.00
24		Master Switch		150.00
25		Rectifier	1	82.75
26		Cables		25.00
	Total			**11525.2589**

Production Equipment (Once Off)

No.	Description	Amount	Price (Rand)	Depreciation period	Cost price per Year
1	Carbon Fiber Mould	43	75404.16	5	648475.78
2	Paint Compressor	4	15048.00	5	15048.00
	Total		**4519594.02**		**663523.78**

Production Consumables (Per Product)

No.	Description	Price (Rand)
1	Electrodes and Solder Wire	100.00
2	Sponge Pad	6.00
3	Brusher	24.00
4	Wooden Sticks	6.00
5	Sand Paper	10.00
6	Grinder Blades	3.50
7	Polisher head	10.00
8	Drill tool set	5.50
9	Tape Packaging	10.00
10	Carton Box	20.00
11	Foam for Packaging	55.00
	Total	**250.00**

Salaries (Production Section)(CTC)

No.	Description	No. of Employees	Price (Rand)Per Annual
1	Unskilled Worker	8	96000.00
2	Carbon Fiber Worker	6	132000.00
3	Welder	2	132000.00
4	Electrical Technician	1	132000.00
	Total		**1956000.00**

Insurance(Production Section)

No.	Description	No. of Employees	Price (Rand)Per Annual
1	500 R Contribution	17	6000.00
	Total		**102000.00**

Figure 75: Variable Costs Screenshot

8.13.3 Capacity

	Days	Hours	Efficiency	Maintanence	Total(hrs/month)
Available time	21	168	0.9	0.05	143.64

Annual Capacity Analysis											
Sub Products	Duration that an employee is working (min)	Duration that a machine or an equipment is working and employee is idle (min)	equipment needed	Equipment Qty.	Capacity per M	Annual Capacity	human resource	capacity Per M	Annual Capacity		Balanced Human Resource
Generator core	28						1	307.80	3693.60		
generator coil	22		Coil Insertion	1	1723.68	20684.16	1	391.75	4700.95	Unskilled Worker	2
generator case	25						1	344.74	4136.83		
Both blade sides	20	420	Mould(600)	3	42.35	508.21	2	67.60	811.14	Carbon Fiber Workshop	2
Final Blade	65	420	1kW	4	56.47	677.61					
			2kW	4	56.47	677.61					
Tailfin	5						1	287.28	3447.36	Welder	1
Tail boom	5										
Hub	20										
Monopole	80						1	107.73	1292.76	Electrical Technician	1
tail painting	70	300					1	53.87	646.38		
monopole painting	90	300									
interface	27						1	319.20	3830.40		
final packaging	25						1	344.74	4136.83		
						Total Position (Production Line)	10			Balanced Total Employee (Production Line)	6

Figure 76: Capacity Screenshot

8.13.4 Summary Sheet Screenshot

Items		Zero(investement)	First	Second	Third	Forth	Fifth	MIRR	IRR	PV	ADD
					Year						
Production Volume			314	401	491	601	735				
Annual Profit			3 569 754	4 969 823	6 260 716	8 188 343	10 797 972				
Variable Costs			5 975 739	7 973 826	10 357 428	12 648 848	16 303 549				
Fixed Costs			2 204 951	2 299 970	2 406 692	3 242 552	3 353 565				
Product Price											
	600		33 375	35 044	36 796	38 635	40 567				
	1k		37 103	38 959	40 907	42 952	45 099				
	2k		49 814	52 305	54 920	57 666	60 550				
VAT			1 054 434	1 406 533	1 798 758	2 373 636	3 029 111				
Income Tax			1 022 974	1 564 453	2 139 054	2 874 934	3 906 795				
Annual Revenue			12 888 603	17 267 661	22 200 356	28 532 657	36 639 065				
Cash Flow		-3 443 484	3 569 754	4 969 823	6 260 716	8 188 343	10 797 972	61%	131%	R 22 791 282.02	30 343 124

Annual Market Growth Rate	
second year	28%
from third year on	22%
Annual Inflation Rate	6.0%
Annual Product Price Increase	5%

the inputs are in the yellow cells, change then or define then as input in @ risk and re cal the whole spread sheet by pressing F9

Items	Discription		Cost (Rands)	Total Costs (Rands)	Note
Variable Costs				**5975738.88**	
	Raw Material Costs				
		600W	12131.85		
		1 kW	15771.41		
		2kW	20502.83		
	Production Equipment		**124408.66**		depreciation
	Production Consumables		**250.00**		
	Salaries (Production Line)		**492000.00**		
	Staff Health Insurance (Production Section)		**24000.00**		
	Electricity		**12.00**		
	Tax (VAT)		**1054434.18**		Excluded
	Income Tax		1022974.20		Excluded
Fixed Costs				**2204950.59**	
	Building and Land Rental		**17358.00**		per month
	Administrative Equipment		**41850.00**		
	Salaries (Administrative Section)		**1248000.00**		
	Administrative Section's Consumables		**49560.00**		
	Machinery		**505257.09**		
	Utility		**21600.00**		
	Staff Health Insurance (Administrative Section)		**37200.00**		
	Insurance		**4500.00**		Per month
	Miscellaneous		**39187.50**		

Production			
Range	600 W	1 kW	2 kW
Demand Percentage	0.227	0.399	0.374
Production Volume	**71**	**125**	**118**
Total Annual Production	**314**		

Price					
		Range			
Companies	Items	500 W	600 W	1 kW	2 kW
Kestrel					
	Wind Turbine	----	13167	28023.48	----
	Tower	----	25938	25938	----
Pegasus					
	Wind Turbine	----	14250	17670	32490
	Tower	----	28500	28500	28500
GW Store					
	Wind Turbine	10200	----	25624	22230
	Tower	----	----	----	----

Company's Products' Prices					
		Range			
Company	Items	500 W	600 W	1 kW	2 kW
The Company					
	Wind Turbine and Tower	----	33375	37103	49814

Company's Profit						
	Costs		Range			
			500 W	600 W	1 kW	2 kW
Annual Sale			----	2380950.993	4652569.122	5855082.8
Variable Costs	5975738.88					
Fixed Costs	2204950.59					
Total Costs	8180689.47	-				
Annual Total Revenue	12888602.95	+				
Annual total VAT	1054434.18	-				
Pre Tax Profit	3653479.30					
Income Tax	1022974.20					
Annual Net Profit	**3569754.34**					
Investment	**3443483.56**	-				

Figure 77: Summary Sheet Screenshot Screenshot

9 Bibliography

Ackermann, T., 2005. Wind Power in Power Systems Edited by. John Wiley & Sons, Ltd.

Albright, L.D., Vanek, F.M., 2008. Energy Systems Engineering Evaluation and Implementation. The McGraw-Hill Companies, Inc.

AMAZING MAGNETS, 2014. Magnet Grade Chart [WWW Document]. URL https://www.amazingmagnets.com/magnetgrades.aspx

Ashwill, T.D., 2003. Alternative Composite Materials for Megawatt-Scale Wind Turbine Blades: Design Considerations and Recommended Testing. J. Sol. Energy Eng. 125, 515.

Ayodele, T.R., Jimoh, a. a., Munda, J.., Agee, J.., M'boungui, G., 2013. Economic analysis of a small scale wind turbine for power generation in Johannesburg. 2013 IEEE Int. Conf. Ind. Technol. 1728–1732.

Bannon, N., Davis, J., Clement, E., 2013. Axial Flux Permanent Magnet Generator.

Bansal, R.., Bhatti, T.., Kothari, D.., 2002. On some of the design aspects of wind energy conversion systems. Energy Convers. Manag. 43, 2175–2187.

Blank, S.G., 2005. The Four Steps to the Epiphany: Successful Strategies for Products that Win. Cafepress.com (2005).

Branlard, E., 2008. Introduction to wind turbines aerodynamics: the actuator disk theory [WWW Document]. URL http://emmanuel.branlard.free.fr/work/papers/html/2008ecn/node58

Cape Business News, 2014. Cape Town to off-set small-scale electricity generation.

Carlin, P.W., Laxson, a. S., Muljadi, E.B., 2003. The History and State of the Art of Variable-Speed Wind Turbine Technology. Wind Energy 6, 129–159.

Chevrolet South Africa, 2014. Chevrolet Utility [WWW Document]. URL http://www.chevrolet.co.za/cars/utility/model-overview.html

City of Capetown Government, 2013. Save electricity [WWW Document].

Clear-Energy-Brands, 2015. Upwind and Down Wind [WWW Document]. URL http://www.cleanenergybrands.com/shoppingcart/knowledgemanager/questions/157/101+Small+Wind+Turbines

CSIR, 2010. Geospatial Analysis Platform [WWW Document].

Department Labour Republic of South Africa, 2012. Basic Guide to Working Hours [WWW Document]. URL http://www.labour.gov.za/DOL/legislation/acts/basic-guides/basic-guide-to-working-hours

Department of Energy, 2010. South african energy synopsis 2010.

Department of Energy (DoE), 2012. Clean Energy.

Department of Energy (DoE), R.D.E., 2014. SOUTH AFRICAN WIND ATLAS (WASA) GUIDE.

Department of Energy(DoE), 2011. INTEGRATED RESOURCE PLAN FOR ELECTRICITY 2010-2030.

Department of Labour Republic of South Africa, 2004. Unemployment Insurance Contributions Act, No. 4 of 2002.

DTU Wind Energy, 2014. WAsp version 11.1.

Duram-Smart Paint, 2011a. Datasheet-NS2 Galvanized Iron Cleaner.

Duram-Smart Paint, 2011b. Datasheet-NS6 Galvanized Iron Primer.

Duram-Smart Paint, 2011c. Datasheet-Rainkote.

Eriksson, S., Bernhoff, H., Leijon, M., 2008. Evaluation of different turbine concepts for wind power. Renew. Sustain. Energy Rev. 12, 1419–1434.

Eskom, 2011. Fact Sheet: Renewable energy: Hydroelectric power stations.

Fleck, B., Huot, M., 2009. Comparative life-cycle assessment of a small wind turbine for residential off-grid use. Renew. Energy 34, 2688–2696.

Free Energy Planet, 2015. Wind Turbine Design [WWW Document]. URL http://www.freeenergyplanet.biz/renewable-energy-systems/wind-turbine-design.html

G.Sullivan, W., M.Wicks, E., T.Luxhoj, J., 2003. Engineering Economy, 12th Editi. ed.

Global Wind Energy Council, 2012. Global Wind Report Annual Market update 2012.

Green Times, 2014. City to offset small-scale electricity generation.

Hatziargyriou, N., Member, S., Zervos, A., 2010. Wind Power Development in Europe. IEEE 89, 1765–1782.

Hau, E., 2006. Wind Turbines.

Heldman, K., 2007. Project Management Professional Exam Study Guide. Wiley Publishing, Inc.

Höök, M., Li, J., Johansson, K., Snowden, S., 2011. Growth Rates of Global Energy Systems and Future Outlooks. Nat. Resour. Res. 21, 23–41.

Huang, S.-C., Lo, S.-L., Lin, Y.-C., 2013. To Re-Explore the Causality between Barriers to Renewable Energy Development: A Case Study of Wind Energy. Energies 6, 4465–4488.

Intergovernmental Panel on Climate Change, 2012. Renewable Energy Sources and Climate Change Mitigation(Special Report of the Intergovernmental Panel on Climate Change).

Kang, H.-Y., Hung, M.-C., Pearn, W.L., Lee, A.H.I., Kang, M.-S., 2011. An Integrated Multi-Criteria Decision Making Model for Evaluating Wind Farm Performance. Energies 4, 2002–2026.

kestrel Wind, 2014. Kestrel Wind Installation [WWW Document]. URL http://www.kestrelwind.co.za/installations.asp

kestrel Wind Turbines, 2011a. Water Pumping Solutions.

kestrel Wind Turbines, 2011b. OFF-GRID SYSTEMS SOLUTIONS [WWW Document]. URL http://www.kestrelwind.co.za/assets/system brochures/off grid brochure.pdf

kestrel Wind Turbines, 2011c. GRID CONNECTED SYSYTEM BACK UP GRID CONNECTED SYSYTEM HYBRID SYSYTEM [WWW Document]. URL http://www.kestrelwind.co.za/assets/system brochures/kestrel-eveready_gridconnected_email.pdf

kestrel Wind Turbines, 2011d. Information Sheet-kestrel 600 800 1kw.

kestrel Wind Turbines, 2012. Installation and Maintenance Manual.

Kumar, A., Kumar, K., Kaushik, N., Sharma, S., Mishra, S., 2010. Renewable energy in India: Current status and future potentials. Renew. Sustain. Energy Rev. 14, 2434–2442.

L. Johnson, G., 2001. Wind Energy Systems.

Leading Edge, 2014. Small Wind Turbine Applications [WWW Document]. URL http://www.leturbines.com/applications/

Lun, I.Y.., Lam, J.C., 2000. A study of Weibull parameters using long-term wind observations. Renew. Energy 20, 145–153.

Lynn E. Newman, 2007. Pressure and Winds GPH 111 - Introduction to Physical Geography [WWW Document]. URL http://web.gccaz.edu/~lnewman/gph111/topic_units/Pressure_winds/pressure/pressure2.html

Mathew, S., 2006. Wind Energy Fundamentals, Resource Analysis and Economics. Springer-Verlag Berlin Heidelberg.

Mortensen, N.G., Hansen, J.C., Kelly, M.C., 2012. Wind Atlas for South Africa (WASA) Western Cape and parts of Northern and Eastern Cape Observational Wind Atlas for 10 Met . Masts in Northern , Western and Eastern Cape provinces.

Mostafaeipour, A., 2013. Economic evaluation of small wind turbine utilization in Kerman, Iran. Energy Convers. Manag. 73, 214–225.

National Energy Regulator of South Africa, 2012. NERSA Annual Report 2011-2012.

National Energy Regulator of South Africa, 2013. NERSA Annual report 2012/2013.

National Weather Service, 2008. JetStream - Online School for Weather [WWW Document]. URL http://oceanservice.noaa.gov/education/yos/resource/JetStream/ocean/sb_circ.htm

NERSA, 2014. ANNEXURE 1 MUNICIPAL TARIFF GUIDELINE , BENCHMARKS AND PROPOSED TIMELINES FOR MUNICIPAL TARIFF APPROVAL PROCESS FOR THE 2015/16 FINANCIAL YEAR.

Nordic Folkecenter for Renewable Energy, 2011. Small wind turbines on ships [WWW Document]. URL http://www.folkecenter.net/gb/news/world/windturbines_ships/

Omer, A.M., 2008. Energy, environment and sustainable development. Renew. Sustain. Energy Rev. 12, 2265–2300.

Ozgener, O., 2006. A small wind turbine system (SWTS) application and its performance analysis. Energy Convers. Manag. 47, 1326–1337.

R. Weart, S., 2008. The Discovery of Global Warming.

RSM Betty & Dickson, 2014. Detailed Tax Guide 2013/2014.

Sahin, a, 2004. Progress and recent trends in wind energy. Prog. Energy Combust. Sci. 30, 501–543.

SANEDI, 2014. Wind resource maps for WASA domain , South Africa Metadata and further information.

Shell South Africa, 2014. Petrol Price Update [WWW Document]. URL http://www.shell.com/zaf/products-services/on-the-road/fuels/petrolprice.html

Singh, R.K., Ahmed, M.R., 2013. Blade design and performance testing of a small wind turbine rotor for low wind speed applications. Renew. Energy 50, 812–819.

South Africa Government, 2015. Statistics South Africa [WWW Document]. URL http://beta2.statssa.gov.za/?page_id=964

SP-High Modulus, 2014. PRIME ™ 20LV Epoxy Infusion System 1–6.

Statistics South Africa, 2014. Survey of Employers and the Self-employed 2013.

Stefan Gsänger, 2014. SMALL WIND World Report.

Sthel, M.S., Tostes, J.G.R., Tavares, J.R., 2013. Current energy crisis and its economic and environmental consequences : Intense human cooperation 5, 244–252.

The Guardian, 2009. World carbon dioxide emissions data by country: China speeds ahead of the rest.

The World Wind Energy Association, 2013. Annual 2012 Report.

Tong, W., 2010. Wind Power Generation and Wind Turbine Design. WIT Press.

U.S. Department of Energy, 2003. Small Wind Electric Systems , A Massachusetts Consumer's Guide.

Valerie J.Faden, 2000. NET METERING OF RENEWABLE ENERGY: HOW TRADITIONAL ELECTRICITY SUPPLIERS FIGHT TO KEEP YOU IN THE DARK 1.

VERBON, G.P.J., 1999. Wind Power in the Netherlands , 1970-1 995. CENTAUR 41, 137–160.

WASA, 2014. TADPOLE [WWW Document].

Western Cape Government, 2002. Cost of Doing Business in South Africa [WWW Document]. URL http://www.westerncape.gov.za/general-publication/cost-doing-business-south-africa#cost

Western Cape Government, 2014. UTILITY SERVICES - ELECTRICITY SERVICES (CONSUMPTIVE) 40–42.

Wind-Turbine-Zone, 2010. Wind Turbine Sizes [WWW Document].

Worldometers, 2015. World Population [WWW Document]. URL http://www.worldometers.info/world-population/

Worldwide Inflation Data, 2013. average inflation South Africa (CPI) - by year [WWW Document]. URL http://www.inflation.eu/inflation-rates/south-africa/historic-inflation/cpi-inflation-south-africa.aspx