COST- BENEFIT ANALYSIS OF WIND TURBINES INSTALLATION AND USE IN DODOMA MUNICIPALITY

By

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A dissertation submitted in partial fulfillment of the requirements for the Masters of Science in Natural Resource Management of the University of Dodoma

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CERTIFICATION

The Undersigned certifies that she has read and hereby recommends for acceptance by the University of Dodoma a dissertation entitled **“Cost-Benefit Analysis of Wind Turbines Installation and Use in Dodoma Municipality”** in partial fulfilment of the requirements for the degree of Master of Science in Natural Resource Management of the University of Dodoma.

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(SUPERVISOR)

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I **, Oyari Aloyce**, declare that this dissertation is my own original work and that it will not be presented to any other University for a similar or any other degree award.

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DEDICATION

This study is dedicated to Aloyce Nyebhusa Kabati,my lovely wife Iswasha Laurensia and my lovely daughter Alice Aloyce Kabati.

ABSTRACT

Generation of power using hydropower-plants suffers from water resources fluctuation in power generating reservoir, considerably during extended dry periods. This, impacts negatively on power supply stability as a result of constant power disruptions due to ever increasing demand for electricity. The use of wind turbines as alternative source for power generation is in worldwide demand. A sit is a green grows and economically attractive option, it harvests reliable, clean and efficiently energy from wind. Analysis of costs and benefits of wind turbines installation and use was done for different hub positions (25, 45, and 65m).The study employed different methods such as: documentary review, cost-benefit analysis, residual mass curve, statistical parameters and linear regression. Wind speed data were collected from TMA weather station (Dodoma airport) located in Dodoma Municipality for long-term period of observations (1986-2015).Costs of wind turbine installation were consulted at Singida wind farm project. Current power tariffs in Dodoma were received from TANESCO. Collected raw data were processed to useful information and analyzed to derive accurate and precise results.

The study found that, long-term annual mean wind speed at 10 m equal to 5.1 m/s is higher than the minimal average wind speed potential for power generation (5.0 m/s). Extrapolation of wind speed by power law, to other heights (25, 45and 65 m) showed significant increment of wind speed. At 25 m above ground wind speed was 10% more than at anemometer position. While such wind speed at 45 m and 65 m was 16% and 20%higher. As well, the period for power generation increased. At height 25 m period for power generation was one month longer than at 10 m height. Whereas, at 45 m and 65 m it was2 months and 2.5 months longer. Application of cost-benefit analysis showed that, in 20 years period, costs would be outweighed by benefits. Lastly, evaluation of planned wind farm project with different hub positions was based on BCR criterion. Particularly, the benefits for hub position at 25 m were found 2 times greater than investment costs and O &M costs together. Hence, the installation of wind farm with hub position25 m will be more profitable.

Key words: cost-benefit analysis, long-term wind speed analysis, wind power generation, green energy, Dodoma Municipality.

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LIST OF ACRONYMS AND ABBREVIATIONS

AC	Air Conditioner
AFREPREN	Energy Environment and Development Network for Africa
BCR	Benefit-Cost Ratio
BoT	Bank of Tanzania
CanWEA	Canada Wind Energy Association
CBA	Cost-Benefit Analysis
CDIG	China Dalian International Economic and Technical Cooperation Group
CRDB	Cooperative Rural Development Bank
DANIDA	The Danish International Development Agency
DPT	Dines Pressure Tube
EEA	European Environment Agency
EUR	Euro
EWEA	European Wind Energy Agency
GoT	Government of Tanzania
GTZ	Gesellschaft für Technische Zusammenarbeit
GW	Gigawatt
GWEC	Global Wind Energy Council
IEA	International Energy Agency
IEC	International Electric Technical Commission
IPP	Independent Power Producer
IRENA	International Renewable Energy Agency
ISA	International Standard Atmosphere

ITCZ	Inter-tropical convergence zone
Kg	Kilogramme
KW	Kilowatt
M	Metre
MW	Megawatt
NB	Net Benefit
NGO	Non- Governmental Organization
NPV	Net Present Value
O &M	Operation and Maintenance
OIES	Oxford Institute for Energy Studies
PV	Present Value
TANESCO	Tanzania Electricity Supply Company
TMA	Tanzania Meteorological Agency
TSh	Tanzania Shilling
TVs	Televisions
UK	United Kingdom
URT	United Republic of Tanzania
USD	United States Dollar
W	Watt
WEC	World Energy Council
WMO	World Meteorological Organization
WTGS	Wind Turbine Generator System
WWEA	World Wind Energy Association

LIST OF POWER CONVERSION UNITS

1,000 W =1 kW

1,000 kW =1 MW

1,000 MW =1 GW

1,000 Wh =1 kWh

1,000 kWh =1 MWh

1,000 MWh =1 GWh

LIST OF PARAMETERS

B_1	Socio-economic benefit
B_2	Economic benefit
B_3	Environmental benefit
C	Wind farm project annual capacity
C_1	Investment cost
C_2	Operational and maintenance cost
C_3	Environmental and social cost
CO_2	Carbondioxide
DOC	Discounted overall cost
E	Annual energy production
OC	Overall cost
P	Power
T	Hours for power generation in a year
V	Wind speed
$\overline{V}$	Long-term average wind speed
V_i	Long-term mean wind speed in each year
Z	Reference height
Z_0	Height above the earth's surface

CHAPTER ONE

INTRODUCTION

1.0 Introduction

This chapter focuses on the background of the problem, the statement of the research problem. It portrays the general objective, specific objectives, research questions and ends with the significance of the study.

1.1 Background

Green energy is environmentally friendly source that replenished at a sustainable rate by natural processes. These energy sources include wind, solar, geothermal, water, and biomass. Due to their sustainability, these resources contribute to less negative air, water and natural resource impacts. Greening energy is one of the earliest drivers of greener growth (International Energy Agency, 2010).Green energy sources have become useful worldwide. Global Trends in Renewable Energy Investment (2014) indicates that renewable, not including hydropower, accounted for 43.6 percent of total global new electric generating capacity in 2013, thus preventing an estimated 1.2 gigatons of carbon dioxide emissions from being released into the atmosphere. Moreover, the share of total global electricity production generated by green energy resources is escalating mainly because these energy systems are becoming less expensive and cost effective to environment (Bloomberg New Energy Finance,2011).Wind resource has become a green economically attractive option for commercial electricity generation since the dawn of the 21st century.

Africa has wind resource potential that matches elsewhere in the world. Its wind resource is best around the coasts and in the eastern highlands. But less wind turbines installation capacity has been done in Africa- over 90 percent of that installation capacity is widely distributed in North and East Africa. According to Global Wind Energy Council (GWEC, 2014), at the end of 2014, over 99% of the municipality's total wind installations were spread across ten countries – Morocco (0.79 GW), Egypt (0.61 GW), South Africa (0.57 GW), Tunisia (0.25 GW), Ethiopia (0.17 GW), Cape Verde (0.024 GW), Kenya (0.019 GW), and Algeria (0.010 GW). However, current figures indicate that, the installed capacity of 1 GW in Africa constitutes less than 1 percent of global capacity (ibid).With this trend, wind resource potentiality in Africa needs to be harvested to ensure reliable, clean and efficient electricity generation, that would meet immediate electricity demand for population growth and a robust economic growth rate.

In this regard, the cost-benefit analysis of wind turbines installation and use is significant in harnessing power from wind. According to Kaldellisand Kavadias (2007) wind turbine installation and use involve analysis of costs, and benefits. Accordingly, the influence of the governing parameter-wind potential is used to estimate the optimum corresponding electricity production. Denny (2007) studied cost-benefit analysis of wind power and noted that, wind generation requires complex forecasting techniques which account for wind speed, wind direction, hub height, geographical surroundings, wind farm size and turbine dispersion. Thus, cost-benefit analysis (CBA) is required in identifying and quantifying the costs and benefits associated with increased wind penetration for wind turbine installation and use (Denny, 2007).The idea of CBA also remains significant when installing a wind turbine. Nicholas and Barry (2010) studied on Wind Turbine installation at Principia College in USA, where the CBA theory was used to calculate the costs and benefits of the proposed turbine to determine the discounted net present value (NPV). The amount of wind energy that a wind turbine would generate is calculated using measured onsite wind speed in conjunction with power curves provided by turbine manufacturers. In addition, because of the positive economic impact it would have in increasing energy security, not only is the NPV positive, but the sensitivity analysis also remains positive under a wide variety of conditions including varying the discount rate, costs, and quantity of electricity generated (ibid).On the other hand, CBA is not only useful in evaluating the profitability of the project, but also requires analysis of uncertainty associated with wind turbine installation and use.

1.2 Statement of the Problem

Power generation is increasingly becoming a challenge for many developing countries. Asthe economies of these countries grow, often times they find their investment into power supply is not linked to the growth of their respective economies. As a result, these countries’ economies suffer tremendous power outage. Tanzania like other developing countries generates its power using hydropower-plants located in Mtera, Kidatu, Kihansi, Pangani, Hale, Nyumba ya Mungu; Ubungo and Kinyerezi gas plants, with gas produced from SongoSongo. According to Weischer (2012), the current capacity of producing by power generation plants amounts 500 MW in contrast to the demand of about 833 MW. It is further claimed that, power supply in the country is not stable due to constant power disruptions caused by the ever increasing demand for electricity as a result of expanding economy of Tanzania. Tanzania’s economy has been growing steadily at 6%

annually for last twelve years (Weischer, 2012). However, this growth has been challenged by climate change impacting on water resources which fluctuates considerably during extended dry periods. In past decade, the hydropower-plants of Tanzania reservoirs had experienced low water stage due to shortage of rainfall (Yawson *et al*., 2005). Weischer (2012) reports that, frequent power outages especially during dry seasons, which cripple the hydroelectric power in most of Municipalities of the country. Dodoma depends on Mtera hydro-power plant generation which is stable, but also depends much on availability of water in Mtera reservoir. In turn, the Municipality experiences frequent short cuts of power especially in dry seasons – when water stage is low in power generating reservoirs. At the same time Dodoma Municipality is one of the areas predominantly attractive with the wind resource potentiality. Mmasi *et al*., (2001) reports that based on wind resources in Tanzania, Dodoma is one of the suitable areas for generation of electricity using wind as the source of energy. Despite this wind potentiality, the analysis of costs and benefits for wind turbine installation and use has not been applied in ensuring the reliability of power supply in the Municipality, as well as the long-term variability and long-term trend has not yet been well studied. Therefore, this study was undertaken to determine the cost-benefit analysis of wind turbines installation and use in Dodoma Municipality.

1.3 Research Objectives

1.3.1General Objective

The overall objective of the study was undertaken to determine the cost-benefit analysis of wind turbines installation and use in Dodoma Municipality.

1.3.2 Specific Objectives

Specifically the study intended:

1. To perform long-term analysis of wind speed and detect its trend.
2. To analyze the costs of wind turbines installation and use.
3. To estimate the benefits of wind turbines use.

1.4 Research Questions

The following were the research questions:

1. What is the long-term mean wind speed and its trend?
2. What are the costs of wind turbines installation and use?
3. What are the benefits of wind turbines use?

1.5 Significance of the Study

The study seeks to undertake the cost-benefit analysis of wind turbine installation and use. It is expected that the study findings will be useful to the Government of Tanzania (GoT) and governmental and non-governmental institutions in explaining the cost effective and harnessing environmental friendly energy. Additionally, the study will provide policy makers with practical information of wind resource potentiality for solving power shortage in Dodoma Municipality. Furthermore, the study findings will be the initial milestone to other researchers interested in similar areas of research. Finally, the study will provide local community with a solution to reduce portion of the costs for power supply and utility that is likely to result from hydro-power. In addition, reliable power supply will attract new investors in manufacturing industry and thereby generating additional benefits for improving the local community livelihood.

CHAPTER TWO:

LITERATURE REVIEW

2.0 Introduction

This chapter deals with literature from studies done by other researchers on wind turbines use, wind resource in leading wind-generating countries and cost-benefit analysis of wind turbine installation and use. Different books, journals, dissertations and thesis and articles have been used for the purpose of enriching this part. Sub-sections in this chapter include: definition of the key terms, theoretical review, and empirical support. Finally, the chapter identifies research gap of the study and conceptual framework.

2.1 Definition of the Key Terms

This sub-section provides understanding and definitions of the key terms found in this work. Important terms in this study are: cost, benefit, cost-benefit analysis, wind turbine, wind turbine installation, weather station, wind speed and wind direction:

Cost

Cost concept means that the amount where any asset is bought is written in the financial statement. It is the exact amount in which the investment is limited to the actual costs-capital, operating, associated with implementing the project (David *et al*., 2013). For the sake of this study, costs refer to the amount of money spent for construction, operating and maintaining running of the project.

Benefit

Benefit is the return expected from a project articulated in terms of improvements or cost savings. They can be quantifiable (tangible) and non-quantifiable (intangible) achievements (Boardman *et al*., 2006).

Cost-Benefit Analysis

Cost-benefit analysis (CBA) is the method used to guide decisions about the relative ranking, or prioritization, of numerous investment options or can be used to determine the economic usefulness of making any given investments in the first place (Pearce *et al*., 2006). In this setting, cost-benefit analysis is the appropriate analytical framework for determining viability ofa project and its practical implementation for the well-being of the community (Pearce *et al*., 2006).

Wind Turbine

According to Trent (2014) a wind turbine is a machine that harnesses wind energy for a purpose like grinding grain, pumping water, or generating electricity. It is a structure or machine that converts wind into usable energy through the rotation of a wheel made up of adjustable blades to generate electricity. The electric wind turbine comes in two different types-smaller electric wind turbine which is used to generate power for a single building, usually a private residence and the larger electric wind turbine used on a commercial scale to produce vast amounts of electricity (Trent, 2014).

Weather Station

Weather station is a facility on land or sea with instruments and equipment for measuring atmospheric conditions to provide information for weather forecasts and to study the weather and climate. According to World Meteorological Organization (WMO, 2010),the meteorological station is where atmospheric conditions are measured and make necessary weather data available for various uses. The main variables of the meteorological measurements are: air temperature, soil temperature, relative humidity, atmospheric pressure at station level, solar radiation/sun duration, precipitation, snow depth, visibility, sky cover, wind speed and wind direction.

Wind Speed

Wind speed, or wind flow velocity, is a fundamental atmospheric rate caused by air moving from high pressure to low pressure, usually due to changes in temperature (Hogan, 2010). Wurman (2007) asserts that it is the rate of the movement of wind in distance per unit of time that is reported in a couple of ways: nautical miles per hour, or metre per second.

Wind Direction

Wind direction describes the direction on a compass from which the wind emanates. According to Jet (2008), itis the direction from which the wind originates and usually reported in cardinal directions or in azimuth degrees.

2.2 Theoretical Review

2.2.1 Cost-Benefit Analysis Theory

Cost-benefit analysis (CBA) theory estimates the benefits and costs of an investment for two reasons: to determine the project’s viability and to compare one project investment with other competing projects, to determine the more feasible one (Boardman*et al*., 2006). During analysis of CBA, it could be recognized that perfect appraisal of all present and future costs and benefits are difficult. Marsh *et al*., (2008) portray that; CBA can offer a well-educated estimate of the best costs and benefits, perfection in terms of economic efficiency. Thus, it tries to answer the question about the magnitude of the benefits associated with an action minus the costs of taking that action to arrive at the worth of the project. Additionally, Galion and Eisner (2004) add that, for determining the rationality of investment in any project whether commercial or a project undertaken for social uplift as a whole, cost benefit analysis is a necessary working technique of economic or commercial evaluation of a project. However, the application of the theory is linked to expensive and cumbersome undertaking depending on the range of input data used to determine a project's costs and benefits. Chuan-Zhong and Karl-Gustaf (2010) recommend that, CBA is useful in projects where the potential costs of the project(s) are significant enough to justify the allocation of resources to forecast measure and evaluate anticipated benefits, costs and impacts. On the other hand, Pearce *et al*. (2006), view CBA as common methodology used for determining costs and benefits of a project with the goal usually being to determine a discounted net present value or the total worth of the project. The argument in favour of this relies on being able to evaluate net present value (NPV) by applying discount rate, including four components: a benefit sum in operating years, a construction cost sum in construction years, an operating cost sum in operating years and an external cost sum (Harris& Roach, 2013).

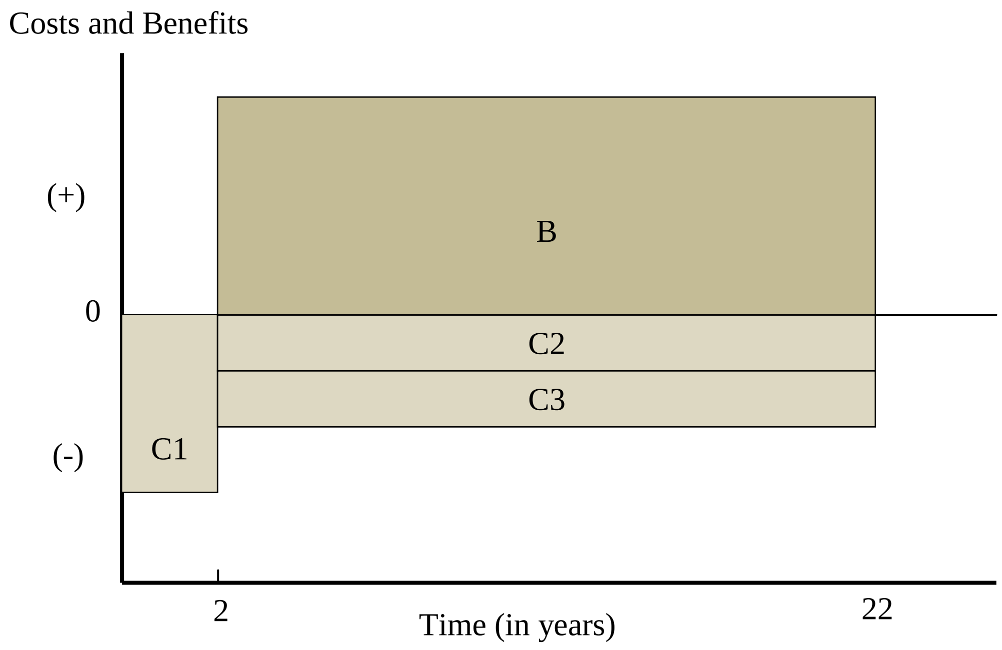


Figure 1: Costs and Benefits of a Project over Time

Where: C_1– Construction Costs;C_2– Operating Costs;C_3– Environmental and Social Costs; B– Benefits.

Source: adopted from Harris and Roach (2013).

The formula for calculating costs and benefits over time is shown below:

$$NPV = \sum_{i=2}^{22} B/(1+r)^i - \sum_{i=1}^{2} C1i/(1+r)^i - \sum_{i=2}^{22} C2i/(1+r)^i - \sum_{i=2}^{22} C3i\,/(1+r)^i \quad (1)$$

Where: C_1– Construction Costs;C_2– Operating Costs;C_3–Environmental and Social Costs; B– Benefits; and r–discount rate.

A similar argument that can be given in evaluating projects involves the choice of a discount rate. According to Harris and Roach (2013),the theory behind discounting is that a dollar today is worth more than a dollar tomorrow – even correcting for inflation. It is the annual rate at which dollar values are considered to increase over time. International agencies such as the World Bank, often uses 10 percent for project evaluation. As indicated above a rate of 7 percent to 10 percent will have a substantial effect in discounting long-term costs or benefits (Harris & Roach, 2013). Likewise Denny (2007) reports that, when the net benefits of wind generation are being calculated, each of the costs and benefits are accrues annually for a certain number of years and these are then discounted by the planned interest rate. According to Denny (2007) it would be expected that, a lower discount rate increases the net benefits of wind generation and a higher discount rate reduces them. In Tanzania, data about long-term discount rate was not present. However, those about inflation rate for years 2010-2015 were only available in statistics.

It is worth to note that, CBA theory is linked to evaluation of a project under the ground of criteria for project evaluation to justify the project's viability and profitability. Boadway (2006)points out three of them: first, the present value (PV) criterion. It aggregates the discounted net benefits and costs of the project without regard to whom they accrue for.The present value of a project could be calculated as:

$$\mathrm{PV} = \sum_{i=1}^{n} \frac{B_i - C_i}{(1+r)^i} \qquad (2)$$

Where: Bi– the project's discounted benefit in year i, where i– 1 to n years; Ci– the project's discounted costs in year i, where i– 1 to n years ;n– the total number of years for the project duration/ life span; r – the discount rate.

With regard to this study, the wind turbine installation and use project will be viable and profitable, if the calculated PV will be found positive.

Second, Net Present Value(NPV) criterion, considers the difference between the total discounted benefits minus the total discounted costs, which gives the Net Present Value of a project. Compared with another project with a lower NPV, that is measured to be less lucrative. In other words, the higher the NPV, the greater the calculated benefits of the project. In regard to this study, the wind turbine installation and use will be viable if it found with positive net benefits and a higher NPV.

$$\text{NPV} = [\textstyle\sum_{i=1}^{n} Bi/(1+r)^{i}]\text{-}\sum_{i=1}^{n} Ci/(1+r)^{i}] \quad (3)$$

Where: *Bi*– the project's benefit in year *i*, where *i*– 1 to *n* years; *Ci*– the project's costs in year *i*, where *i*– 1 to n years; *n*– the total number of years for the project duration/ life span; *r* – the discount rate.

Third, Benefit-Cost Ratio (BCR). It is the ratio of project benefits versus project costs. It involves summing the total discounted benefits for a project over its entire duration/life span and dividing it over the total discounted costs of the project. It is the ratio of the PV of benefits to the PV of costs. The criterion used prefers smaller projects that may offer less benefit, but their costs, including environmental costs, are significantly lower.

$$BCR = \frac{[\sum_{i=1}^{n} Bi/(1+r)^{i}]}{[\sum_{i=1}^{n} Ci/(1+r)^{i}]} \quad (4)$$

Where: *Bi*– the project's benefit in year *i*, where *i*– 1 to *n* years; *Ci*– the project's costs in year *i*, where *i*– 1 to n years; *n*– the total number of years for the project duration/ life span; *r* – the discount rate.

With regard to this study, the wind turbine installation and use will be worth undertaking or viable if the project offers less benefits as well as its costs are significantly lower. In other words, if the benefits exceed the costs, the project will be viable. Generally, CBA theory will help to justify the viability of the wind turbine installation and use in Dodoma Municipality.

2.2.2 Theory of Wind Energy Calculation

Theoretically, energy possessed in wind is basically the kinetic energy of large masses of air moving over the earth’s surface. Wind energy is harnessed by a wind turbine for a purpose like generating electricity (Trent, 2014). The annual energy production from a wind turbine in given climate is in relation to power generated from wind and period for that power generation. Thus, calculation of the wind energy is given by the following equation:

$$E = P \times t \tag{5}$$

Where: E–annual energy production in kilowatthour(kWh); P– is power in watts (W); t– is time for power generation in a year in hours (h).

The theory further describes that the physical amount of the power would be harvested from wind in formula (5) that, the power in the wind is proportional to: the area of wind turbine being swept by the wind, the cube of the wind speed and the air density - which varies with altitude (Smail,2003).In addition, Dunnett (2000) adds that, any wind turbine can only possibly extract a maximum of 59.3% of the kinetic energy of the wind into mechanical energy turning a rotor. The theoretical maximum power efficiency of any design of wind turbine is 0.59.This is called the *Power coefficient* with values of 0.35-0.45 (Dunnett, 2000).Thus, the extractable power from the wind is given by:

$$P = \frac{1}{2}\rho \times A \times V^3 \times C_p \tag{6}$$

Where: *P*– is power in watts (W), *ρ*–is the air density in kilogramme per cubic metre (kg/m^3); *A*–is the swept rotor area in square metres (m^2); *V*–is the wind speed in metres per second (m/s) and Cp –is Power Coefficient.

Technically, air density is refers to the mass per unit volume of earth's atmosphere. Density describes how tightly packed something is. For example, an object with a lot of material in a small space is denser than an object that has lots of air space included. Generally, in the atmosphere, gas that is less dense has a lower concentration of molecules per volume than a denser gas and will tend to rise compared to the air around it (Thogersen, 2005). Gipe (2004) explained that, the air density varies with altitude and temperature. It decreases with increasing temperature that is air is less dense in summer than winter, varying 10-15 percent from one season to another. Despite the changes in temperature, it has a modest influence on the power in the wind. For wind turbines, the air density is a key parameter when estimating the wind power output energy as shown in (5). Linking the swept area of the turbine in (6) can be calculated from the length of the turbine blades using the equation for the area of a circle (Bird, 2007).

$$A = \pi r^2 \tag{7}$$

Where: *A*–the swept area, *r*–is the radius which is equal to the blade length in meter, and π – is 3.14.

The theory works hand in hand with wind turbine installation as it allows that the calculation of wind power would be generated by a variable greater wind speed at higher altitudes based on the wind turbine system (Munteanu *et al*., 2006). The kinetic energy in the wind can be converted into useful energy- electricity which is absolutely clean source of energy, since there are no emissions or direct influences on the environment (Hakansson & Nilsson, 2008). Wind power can be unreliable, as the wind cannot be controlled thus subjected to factors that can reduce its speed and cause it to change direction. Zhang (2004) clarifies that, a suitable geographic location with high altitude and wind consistency in certain season of the year increases wind speed that in turn generates more electricity from wind power. However, it is significant to note winds with an average wind speed potential for power generation. In general, with regard to wind potentiality for power generation, average wind speed above 5m/s is strong enough to ensure economically sound operations. For example at this speed, 5 kW can be produced with a rotor diameter of 5m per annum. Smail *et al*., (2003) report that, significant areas of the world have mean annual wind speed of above 4-5 m/s which is potential for electricity generation for small-scale wind turbine. European Environment Agency-EEA (2009) also reports an assessment carried out by the World Energy Council in 1994 which showed that, the areas with an average wind speeds higher than 5.1 m/s at 10 m height is suitable for wind power generation. In addition, the argument of wind speed is that its changes with the changes of height linked to the strength and stability of the wind power. The reduction in wind velocity near the surface is a function of surface roughness, so wind velocity profiles are quite different for different terrains, irregular ground, and man-made obstructions on the ground can reduce the geostrophic wind speed by 40% to 50% (Wizelius, 2007). These effects are taken into account when siting wind turbines. The magnitude of the wind whose speed is largely influenced by the height of the convective boundary layer is also related to structure of currents or winds near a horizontal boundary in which the flow direction rotates as one moves away from the boundary (Ghosal, 2005). Generally, the theory of power in wind could be applied in this study because it helps to analyze the benefits based on wind potentiality and its estimation of the power output generation.

2.2.3 Power Law

A power law is a functional relationship between two quantities, where a relative change in one quantity results in a proportional relative change in the other quantity, independent of the initial size of those quantities: one quantity varies as a power of another (Yaneer, 2015). According to Emeis (2013) the power law is derived from physical and dimensional arguments. Empirically, it is linked to the description of the variation of wind speed with height above the ground level- wind shear. The wind speed at the ground is zero due to the friction between the ground surface and air. The variation of wind speed with elevation at a given site is usually characterized by applying power law. Grigsby (2012) noted that, a change in wind speed with height and the wind speed at different higher heights can be calculated from a known wind speed which helps to estimate the wind power output. On the other hand, Kothari *et al.*, (2011) point out that, wind measurements area carried out at an elevation of 10 m. The effect of height is mainly due to roughness on the earth's surface which can be estimated by the power law equation that is related to wind speed at two different heights. The International Electro Technical Commission (IEC) recommends using power law when measurements at one height (usually called the reference height) are available. The power law equation is given by:

$$V_z = V_{zo}\left(\frac{z}{Z_0}\right)\alpha \tag{8}$$

Where: Z–is the height above the earth's surface; Z_0–is the reference height for which, wind speed$-V_{zo}$ is known;V_z–is the wind speed at height Z; and α–is the power law exponent–the wind shear coefficient. Empirical results indicate that wind shear coefficient normally is between 0.1 and 0.2 (Berg *et al*., 2013). According to the IEC standard; the wind shear exponent cannot exceed 0.2 and has to be positive. The standard sets these requirements to avoid enhanced fatigue damage and the risk of blade-tower interaction, which can occur with negative shear (Berg *et al*., 2013). Kreith (2014) stated that, modern wind turbines as a rule are installed at different positions than 10 m above ground surface. Each turbine ranges from 25 m and above .Sometimes it can reach 120 m above the ground surface. Those wind turbines capture more wind energy and lower cost per power output. With regard to this study, power law was used to extrapolate the wind data at 25, 45 and 65 m height to yield an annual mean wind speed in relation to a hub height.

2.2.4 Residual Mass Curve Theory

The theory is based on the fact that a graph of the cumulative departures from a given reference such as the arithmetic average as a function of time or date (Redyy, 2005). Oltman and Tracy (2010) relate it to studies of trends or possible changes in cumulative values over a long –time period. In this regard, the residual-mass curve is characterized by changes in the relation between two variables (Reddy, 2005). This method is applied best in long –term analysis of trend that accentuates more clearly the rise and fall of the cumulative flow records (Bharali,2015).Additionally, it is a convenient way to check the consistency of a record in the analysis of a long record, except when the scarcity of other old records makes it infeasible (Bharali, 2015). Raghunath (2006) urges that, the process of long-term analysis has to be done for consecutive years and the highest peak suggests the sum of the positive quantities (ΣSurplus), thus ensuring the potentiality of the cumulative values and the succeeding lowest trough gives the negative quantities (ΣDeficit) of the required wind potential to meet the specified demand. In relation to wind resources, the method is suitable for a long-term analysis of wind speed. Isemr (2000) reports that, wind speed analysis is usually performed from measured wind data records at surface meteorological stations over periods of time. The residual mass curve shows the cumulative departures from a given reference such as the arithmetic average as ordinate, plotted against time. Similarly, wind speed changes over time -the cumulative deviations from some average value indicate a significant change of surface wind speed. Schwarb (2011) adds that, the cumulative deviations have the advantage that changes in the mean amount of wind speed and therefore, are recognised easily. Residual mass curve method, proposed by Sudler in 1927 shows the formula of the method's application as presented below:

$$\sum(V_i - 1) \qquad (9)$$

Where: ∑–is the sum; *V*–is the value of wind speed observed in period and *i* given time (years). However, to calculate arithmetic mean wind speeds–V_i;

$$V_i = \frac{\mathrm{Vi}}{\overline{V}} \qquad (10)$$

Where: V_i− is the arithmetic mean wind speeds;V_i– is wind speed in each year;$\overline{V}$–is an average wind speed and i –is period in years.

Then drawn residual mass curve is obtained by subtracting one (9) value from the arithmetic mean obtained from (10) above against the given time in years. With regard to this study, a residual mass curve theory was used for long-term analysis of the wind speed. It helped to detect cycles of wind speed, which in future could be used for prediction of wind speed.

2.2.5 Linear Regression Model

Linear regression is a statistical procedure for predicting the value of a dependent variable from an independent variable when the relationship between the variables is described with a linear model (Zhang, 2015). Wolverton (2009) defines it as a model that shows relationship between two variables and how each can impact the other. In essence, it involves showing how the variation in the dependent variable can be captured by change in the independent variable. It is linked to three major applications: used to identify the strength of the effect that the independent variable(s) have on a dependent variable. Secondly, it is applied to forecast effects or impacts of changes, understand how much will the dependent variable change, when changing one or more independent variables. Thirdly, it is used to predict trends and future values, to get point estimates (Ibid). In relation to wind resource, it is critical to understand the long-term trend of wind resource for development, investment and operation of wind power plant. Zhang (2015) argues that, it is credible to apply a reliable technique to predict wind speed trend and variation in order to estimate the magnitude of wind resource. In this regard, linear regression approach is suitable to detect trends and predict future values of wind speeds. Jonsson (2010) concurs with Zhang that, it is possible to predict and estimate the magnitude of wind using the linear trend as detected from wind speed data analysis. In addition, prediction can be made once the regression equation is determined. The prediction within the range of values used for model- fitting a regression is officially known as an interpolation and extrapolation and it involves prediction outside the range of values fitting a regression (Hanslian *et al*., 2011).While linear regression has limited applicability in some situations because it can work only when the dependent variable is of continuous nature, it is still a very well-known technique in the situations it can be used (Wolverton, 2009). It assumes a linear relation between the independent and dependent variables, but it must be noted that sometimes, transformations can also be applied to nonlinear relationships to make them applicable in a linear regression model (Wolverton, 2009). Rongers *et al*.,(2005) have pointed that, the method results into a better prediction of wind speed trend and its stability for estimating the wind size of the target site. However, it may encounter consistently under predicts the wind speed as-the lengths of the consistent periods become insufficient for valuable linear regression application. Similarly, wind data from surface meteorological stations greatly suffer from issues of inconsistency.

Linear regression studies the linear relationship between the dependent variable Y and a single independent variable X (Wolverton, 2009). The linear regression model describes the dependent variable with a straight line that is defined by the equation:

$$y = aX + b \tag{11}$$

Where: a– is a slope (regression coefficient);b–is the y–intersect of the line. The parameters a and b of the regression line are estimated from the values of the dependent variable Y and the independent variable X with the aid of statistical methods. The regression line enables one to predict the value of the dependent variable Y from that of the independent variable X. The size and sign of a-coefficient in linear equation affect its graph: Scatter plot with regression line. A positive relationship is represented by a rising regression line ($a > 0$) in formula (11) above. A negative relationship is represented by a falling regression line ($a < 0$) and its equation is as follows:

$$y = -aX + b \tag{12}$$

With regard to this study, a linear regression model of the wind speed was used to detect significance of the trend and then estimate its magnitude. When the slope a is positive, it means that the wind speed has an upward trend; if a is negative, it shows a downward trend.WMO (2011) has established that a coefficient with value greater than ±0.3 is significant in climatology because implies that, the site has a significant increment or reduction of study parameter (wind speed).

2.3 Empirical Review

According to Willis *et al.*, (2003) the study on wind turbine installation system, adapted to extract energy from natural wind currents is disclosed wherein a plurality of individual wind wheel modules are stacked vertically in a tower-like structure and are interconnected with one another to operate in a unitary manner. Additionally, Ingram *et al.*, (2003) report that, a rotatable windshield is provided about the rotor assembly for improving output efficiency of the wind wheel and protecting the rotor assembly from damage in the event of excessively high wind speed. The angular position of the windshield is determined by an automatic control system responsive to wind speed and direction (Ingram *et al*., 2003). The wind turbine use in the most promising sites with wind potential is useful for capturing amount of energy for each site. Ahmed and Abouzeid (2001) argue that, sites with wind potential offer sufficient wind energy for economic utilization and represent a good example for utilizing wind energy to supply a part of the energy requirements to those communities for improving their livelihood. On the other hand, Ezechukwu (2013) views the wind turbine use as an option to harness the power in the wind into electrical energy from many wind catchment sites at various locations in the country, to meet the demands of aggressive consumers searching alternative energy supply. Additionally, wind turbine use creates job opportunities and market such as construction, maintenance and repair which take place. Again, several companies continue the manufacture of wind turbines for imports and selling of mills (Ezechukwu, 2013).

2.3.1 Overview of Wind Turbines Use Worldwide

Globally, the amount of operating wind energy capacity has increased more between 2000 and 2012. According to the World Wind Energy organisation (WWEA, 2012), wind turbines with a total energy potential of 45 gigawatts (GW) were installed internationally. That brings global wind power capacity to 282 GW, which covers 3 percent of global electricity demand. This indicates that many countries around the world are using wind turbines for power generation. According to the WWEA statistics released (2013), 100 countries worldwide now produce electricity with wind power. In 2014, about 51 GW-worth of wind capacity was installed around the global, which amounts to a 44 percent increase over the previous year’s totals (Payne, 2015).

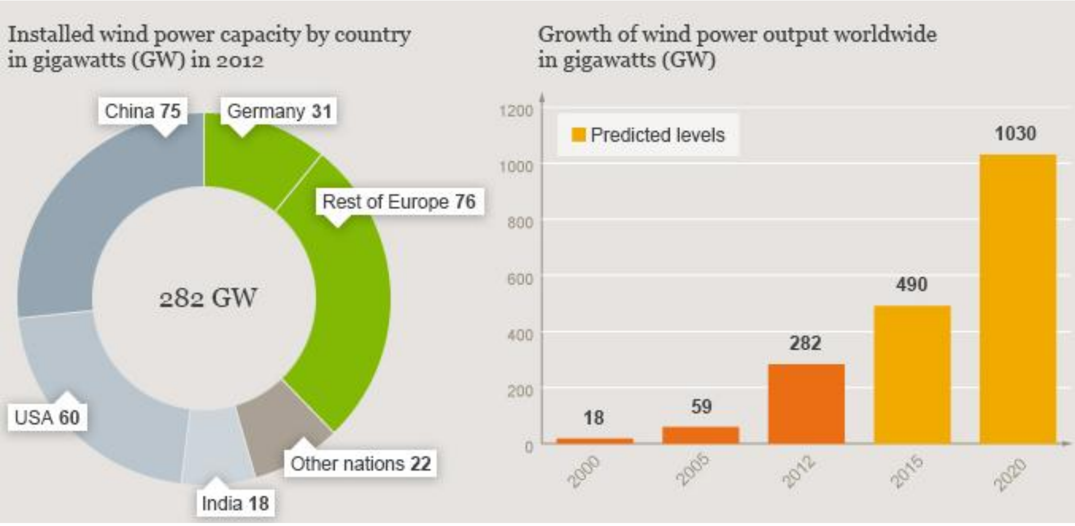


Figure 2: The Global Wind Power Usage and Growth of Wind Power Output

Source: WWEA (2012).

WWEA's World Wind Energy Report (2012) highlights China as a leading country which has installed wind power capacity amounting to 75 GW of the world 282 GW followed by SA 60 GW, Germany 31 GW, rest of European countries 76 GW, India constitutes 18 GW and other nations in the world 22 GW (Figure 2).

The wind turbine use in Tanzania is still at low capacity despite its potential winds in coastal and inland areas. According to Mark and Hankins (2009), a number of coastal and inland areas were studied more carefully and results are promising a number of sites have average speeds exceeding 8 m/s in certain locations were seen to offer potential use of wind resource.

Despite this potential of wind resource distribution in Tanzania, the findings reflect less harnessing energy from wind resource (Ahlborg & Hammar, 2011). Nzali (2006) describes the places with wind turbines use in Tanzania to be: Dodoma, Arusha, Iringa, Kagera, Mara, Mtwara, Rukwa, Shinyanga, Singida, Tanga, Tabora, Kilimanjaro, Mbeya and Dar es Salaam. These regions were categorized by Nzali (2006) into the five zones for easy assessment: Zone I (Iringa, Mbeya and Rukwa), Zone II (Dodoma, Singida and Tabora), Zone III (Shinyanga, Musoma and Kagera), Zone IV (Tanga, Kilimanjaro and Arusha) and Zone V (Lindi and Mtwara).In all studied zones, there were detected 106 installed wind turbines of which 47 were working and 59 wind turbines were not working. Further, 75% of these were owned by community based units, 9.5% by Missionary organizations, 8.5% by Government and 7% by private individuals and all of these wind turbines were installed for water pumping (Nzali, 2006). Mashauri (2011) also indicates that, wind turbines in the country have been used mainly for water pumping. Nzali (2006) asserts that, few attempts have been made to install wind turbines for electricity generation in Tanzania which mainly have been for charging batteries. The first two systems were installed at Sikonge Moravian Mission and the Kili wind project at Bukene, both in Tabora region. The other projects were installed at St. Gasper Hospital of Itigi in Manyoni district. In Karatu (Arusha) at Mang`ola, one Non- Governmental Organization (NGO) has installed a wind turbine of 400W for electricity generation for battery charging, power lighting and powering of computers and for communication purposes (Nzali, 2006).

According to Global Wind Energy Council (2014) report up to date there is no any grid connected wind farms in Tanzania, but the first phase of the 50 MW Singida Wind Farm is currently under construction and is expected to come online in 2016. The second phase in 2018 of the project will add a further 100 MW to the wind farm (Global Wind Energy Council report, 2014).

2.3.2 Wind Resource

2.3.2.1 Wind Resource in Leading Wind-Generating Countries

In China, wind resource offers an important alternative source of energy for generation of electricity in a country. According to the Oxford Institute for Energy Studies-OIES (2015), a survey by the China Meteorological Administration showed that exploitable onshore wind energy (at the height of 50 m) amounts to 2,380 GW. McElroy *et al*., (2009) report that, in 2005, meteorological data were used to assess area for the potential for wind generated electricity in the country. A study made use of assimilation data for the 5-years interval 2004-2008 and results indicated an annual average wind speed of 6 m/s at a height of 50 metres. In USA, an estimate of the electricity that could be generated from wind potential on a monthly basis is illustrated for both onshore and offshore environments where the wind power potential for both environments is greatest in winter, peaking in January, lowest in summer, with a minimum in August. According to Lu *et al*., (2009) an average wind speeds derived for the 4-year period 2004-2007, indicated wind resources which annually averaged wind speed of 6.9 m/s at a height of 80 metres. Embarking in Germany, a study on an analysis of potential wind resources across the country primarily based on wind speed data. The potentiality was subsequently determined with the aid of the reference from the meteorological data and results showed that the nationwide wind harnessing capacity and output for the development of potential sites relied on annual mean wind speed of 7.5 m/s at a height of 140 m (Lütkehus, 2010).

Draxl *et al*., (2014) consider that the wind resource potential in India usually has seasonal cycle; that is the wind speed is highest in the summer from May to August, with maximum average wind speed exceeding 10 m/s, especially along the coasts. The wind speed is lowest in October and November with average wind speeds not exceeding 7 m/s at coastal sites. However, specific sites on the mainland experience are abundant with wind resources. According to Lakshmanan *et al*., (2009) annual mean wind speed for India is 6 m/s. Canada is a world leader in the production and use of renewable energy, its huge land mass gives it some of the best wind resources on the planet. However the wind resource potential in the country is seasonal where winter and spring season experience high winds almost the whole of Canada (McIntyre *et al*., 2008). According to Canada Wind Energy Association (CanWEA, 2009) the long-term mean wind speed in Canada is 5.8 m/s. In addition, wind energy can potentially support 20% of Canada's electricity demands (55,000 MW) by 2025 (CanWEA, 2009).As well Australia has significant wind resources. It has some of the world's best wind resources along its south-western, southern and south eastern margins. More isolated areas of the eastern margin also have excellent wind resources. The share of wind energy in total electricity generation in the country is projected to increase from 1.5 per cent in 2007–08 to 12.1 per cent in 2029–30 (Coppin *et al*., 2003). World Energy Council (WEC, 2007) reported that, Australia is among the locations with the highest wind energy potential including the westerly wind belts between latitudes 35° and 50°, whose annual average wind speed is of 6 m/s.

The Middle East countries also have significant wind potential. Several countries such as Qatar, Oman, Kuwait and Saudi Arabia have wind speed potential for wind electricity generation. Alam *et al*., (2011) show that, various wind speed and wind power characteristics have been potentially reported around the Middle East countries. For example, offshore and onshore wind power project development in Qatar; wind resource assessment of the south western municipality of Jordan. Al-Nassar *et al.,* (2005) point out that, the annual mean wind speed in Kuwait ranges from 3.7 to 5.5 m/s.In Saudi Arabia, wind resource assessment has been carried in the country in recent years (Alam *et al*., 2011). According to Al-Abbadi (2005) an assessment of wind energy production for five different locations in Saudi Arabia yield an average wind speed of 5.7 m/s. Similarly, Al-Tajer and Poullikkas (2015) confirm that, the availability of the annual mean wind speed in the country builds up confidence on the amount of energy that could be generated to provide for future demands.

2.3.2.2 Wind Resource in Tanzania

Tanzania is considered by the global wind power community to be an area with wind potential. In 2003, a number of inland areas were studied more carefully and results promised where a number of sites were found with average speed exceeding 8 m/s at the height of 10 m. Certain locations were seen to offer potential use wind resource. In the coastal areas prevailing South-Eastern (S.E. Trades) and North-Eastern (N.E. Monsoon) winds offered marginal potential as wind farm sites (DANIDA/Risø/TANESCO, 2003). Additionally, DANIDA/Risø/ TANESCO also used satellite data to evaluate off-shore coastal wind speeds and found that: the average of annual wind speed was over 6 m/s along the coast. It is reported that there is no significant variation between the North and the South coast of Tanzania and there is a significant seasonal difference in wind speed (speed range between less than 5 m/s in November/December and over 8 m/s in July

(DANIDA/Risø/TANESCO, 2003). Specific locations for which there is detailed information are described in Table 1 below.

However, Hankins (2009) comments that, apart from this number of areas being considered with wind potential for wind farm, yet a country has an estimated multi-GW wind potential that has not been quantified. Dodoma is also one of the inland areas considered for wind resources potentiality. According to Mayaya *et al.*, (2015) meteorological data for the period from 1980 to 2011 obtained at TMA wind speed for Dodoma Municipality were also analyzed using time series analysis wind speed showed an increasing trends, because of the sensitivity of the potential wind speed value, the determination of specific sites for wind energy projects depends on accurate meteorological measurements, and sites measurements.

Table 1: Annual Average Wind Speed (m/s) at Different Positions above the Ground Surface in Tanzania

Site	10 m above (m/s)	30 m above (m/s)
Singida	8.2	9.4
Makambako	7.6	8.7
Karatu (Arusha)	4.9	5.5
Mkumbara (Tanga)	4.1	4.9
Gomvu (Kigamboni)	3.6	4.3
Litembe (Mtwara)	3.2	4.5

Source: DANIDA/Risø/ TANESCO (2003).

Masamba (2013), determined annual wind speed and the wind speed distribution in years 2007-2012. Then the wind data from height 10 m (position of anemometer) was extrapolated to 50 metre height by using Power Law. The wind speed at 50 metre yielded an annual mean wind speed of 5.5 m/s. Mashauri (2011) infers that, estimates of the wind resources in Tanzania are expressed in wind power representing a range of mean wind power density or equivalent mean speed at specified heights above the ground.

2.3.3 Costs of Wind Turbine Installation

The birth of modern wind-driven electricity generation has improved dramatically up to the present wind turbine installations costs (Hau & Renouard, 2006). The analysis of costs can be very detailed as shown below:

$$C = C_1 + C_2 + C_3 \tag{13}$$

Where: C–is the total installed costsC_1– is investment costs,C_2–isoperation and maintenance (O&M) costs and C_3– is environmental and social costs. However, the costs of wind turbine installation in regard to this study included construction, operational and maintenance costs.

Investment Costs

The costs base on wind turbine design and composed components for general system operation. The construction costs involve purchasing suitable materials (example, type of the turbine and its size) and mechanical components and paying wind turbine designers (set up of location) as well as installation technicians (Santjer *et al.*, 2001).Dunnett (2000) contends that, construction costs always depend on the wind turbine system, wind speed and the amount of power output. All construction costs in the study are crucial to assure incorporation of all components correctly and confirming their suitability for proper installation in the required technical standards, to avoid the technical failures in setting up the turbines properly. For sake of this study, investment cost composed capital plus interest of loan.

Operation and Maintenance Costs

According to Dunnett (2000) operating costs are often low and so accessing to initial capital cost is an advantage when considering wind-electric system. The realistic estimates for supporting the ongoing of the project performance within the planned time bound. The operation and maintenance in regard to this study are costs applied in running, maintaining and managing business and to ensure production of estimated net revenue of the project.

Environmental and Social Costs

Environmental and social costs are the costs of the resources used as a result of environmental and social consequences following the implementation of the project (Turnley, 2002). These would include: relocation, clearance of flora, increase of noise and social disruption.

First, wind turbine installation and use project involves relocation of big numbers of people due to leasing large tracts of land for a lay-down area and environmental pollution from noise. Thus, resettlement costs would be incurred even if the project's economics will appear favourable, yet these people's rights to remain in their homes may be given a greater social priority (Turnley, 2002).

Second, site preparation will involve land clearance (flora) for access roads, a lay-down area, construction offices, the substation, and the generator tower footings (Smail *et al.*, 2003). Likewise, the wind turbine use commonly has impacts on avifauna –birds' mortality from collisions with rotor blade, hence ecological costs. Smallwood *et al*.,(2009) report that, impacts on avifauna -bird mortality from collisions with rotor blade especially bat mortality is common in wind farms.

Third, most of the concerns that have been raised in countries using wind energy relate to noise levels. Smail *et al*., (2003) point out that, wind rotors, gearboxes and generators create vibration, acoustic noise when functioning and wind turbine use leads to electromagnetic interference where some television frequency bands are susceptible to interference from wind generators.

Fourth, social disruption, when the wind is not blowing wind turbine does not generate power. In turn, it leads to electricity demand and cos**ts** of electricity storage from other energy sources**.** Sometimes, when a wind farm is proposed, communities are split into supporters and opponents. Occasionally, bad feeling arises more often due to people spreading misinformation about wind farms than being due to the wind farms themselves (Rosenbloom, 2006).

2.3.4 Benefits of Wind Turbine Use

According to AFREPREN (2012), the wind turbine use results in a number of broader benefits including: economic, social as well as environmental. On the other hand, Tan *et al*., (2013) suggest that, benefits of wind turbine use rely on electricity generation, manufacturing, sales, marketing and investment platform. Generally, the benefits of wind turbine use may be grouped into economic, socio-economic and environmental as follows:

$$B = B_1 + B_2 + B_3 \tag{14}$$

Where: B – Benefits of wind turbine use; B_1–is economic benefit; B_2– is socio-economic benefit; B_3– is environmental benefit.

Economic Benefit

Electricity generation from wind turbine, supplies the surrounding area with clear, sustainable, renewable electricity thus a solution to power shortage in the local community (Donnelly, 2012).Wind turbine energy is also a great way to defray a portion of the costs of power supply and utility. This in turn cuts dependency on the utility and results in lower power bills each month (Donnelly, 2012). Further, Cost of production to the local industries reduces due to abundant availability of power and at affordable rates. In addition, the project provides relief to the economy by reducing the use of heavy fossil fuels based power generation (Tan *et al.*, 2013). Wiser and Bolinger (2007) acknowledge once established, wind turbines require very little regular maintenance, needing only to be oiled once a year.

Socio-economic Benefit

Use of wind power in industries as a cheap energy enhances the growth of industries and in turn attracts investments in industrial sector that would result in enhancement of employment opportunities. Wind energy projects create new short and long term jobs. Related employment ranges from meteorologists and surveyors to structural engineers, assembly workers, lawyers, bankers, and technicians (Edmonds *et al.*, 2007). Additionally, launching of investments and job creation contribute significantly to local economic development and sustainable livelihoods programme.

Further, reliable power supply benefits local communities to identify and prioritize the most productive and beneficial projects to engage in (AFREPREN, 2012).

Environmental Benefit

Wind turbine electricity generation does not create environmental pollution through production of harmful particulate emissions, rather it substantially reduces air pollution, water pollution, and global climate change associated with traditional generation technologies which involve burning of fossil fuels (AFREPREN, 2012).The area surrounding the project is an area not only of scenic beauty but also one of enormous potential for those concerned with preserving the natural environment and helping to build a more sustainable environment. In addition, Wiser and Bolinger (2007) argue that, wind turbine use conserves water resources. For example, producing the same amount of electricity can take about 600 times more water with nuclear power than wind, and about 500 times more water with coal than wind.

2.4 Research Gap

The gained knowledge identified from the literature review indicates that wind turbines studies have been done by several researchers (Kasasi & Kainkwa, 2002; Kainkwa, 2007). Again, Mashauri (2011) studied the attractive wind resource potentiality as justification for the potentiality of wind resource for power generation. DANIDA/Risø/TANESCO(2003) evaluated also onshore average annual potential wind speed for power generation. Nzali (2006) reports that, the wind resource potential in the area are used with wind turbine mainly for water pumping and non-wind turbine use for electricity generation. Masamba (2013), determined annual wind speed in Dodoma at the height of 50 m equal to 5.5m/s. Similarly, Mmasi *et al*., (2001) cites Dodoma as among the suitable areas for generation of electricity using wind based on wind resources-a review on the renewable energy resources for rural application in Tanzania. Therefore, the analysis of costs and benefits of wind turbine installation as well as wind long-term trends in Dodoma Municipality and its use has less documented, hence the focus of this study.

2.5 Conceptual Framework

A conceptual framework is a visual or written product used to explain the concepts, or variables to be studied and presumed relationships among them (Ravitch &Riggan, 2012). It entails a network, or a plane of interlinked concepts that together provide a comprehensive understanding of a phenomenon (Brains *et al*., 2011). Generally, the following is the way ideas are organized to achieve a research project's purpose.

Tanzania's development has experienced high economic growth, averaging between 5 to 7 percent over the past decade, as well population growth of 47.78 million populations as per 2012 census. Owing to economic liberalization and population growth in the country, there has been an increased demand for stable power for industries and residents; wide coverage by TANESCO grid power as well as promoting of green sources of energy use. Additionally, a more recent use of electronic devices such as air conditioner (AC), mobile phones; computers; fridges and televisions (TVs) also added high demand for power has led to the current demand of 833 MW while the supply situation in the country is only500 MW something that result to frequent power shortage which in turn impacts on income losses; devices' damage as well as leading to shifting of Investors' investments. The severity of the crisis is based on reliance of hydropower generation that suffers from shortage of rainfall during dry seasons, hence insufficient water levels in the main hydropower stations. Hence, Wind resources potential entirely becomes an alternative for power generation, due to its high potentiality, friendly source (green) of energy-preventing an estimated 1.2 gigatons of carbon dioxide emissions from being released into the atmosphere globally and it is renewable source of energy that is, replenished at a sustainable rate by natural processes. Moreover, to ensure wind power generation, analysis of long-term wind trends is a cornerstone. Residual mass curve and linear regression methods suit the purpose – long-term analysis of wind speed and its trend is then performed discover facts about its trend, variation and finally estimation of wind size. Having detected wind potential is not enough to guarantee wind power generation but also quantifying costs-construction, operation and environmental and social as well as benefits is significant. With this regard, cost-benefit analysis is used to estimate the benefits and costs as well as determine the project's viability using project evaluation criteria. Therefore, the detection of reliable wind speed and quantification of costs and benefits as well as evaluated project's viability using project evaluation criteria-present value, net benefits and net present value, give the opportunity for wind turbine installation. Finally, the improved power supply overcomes the problem of frequent power shortages through availability of reliable electricity supply; creating investments platform an employment opportunities as well as conserving environment through a reduction of greenhouse gases emission. Below is the conceptual framework of this study.

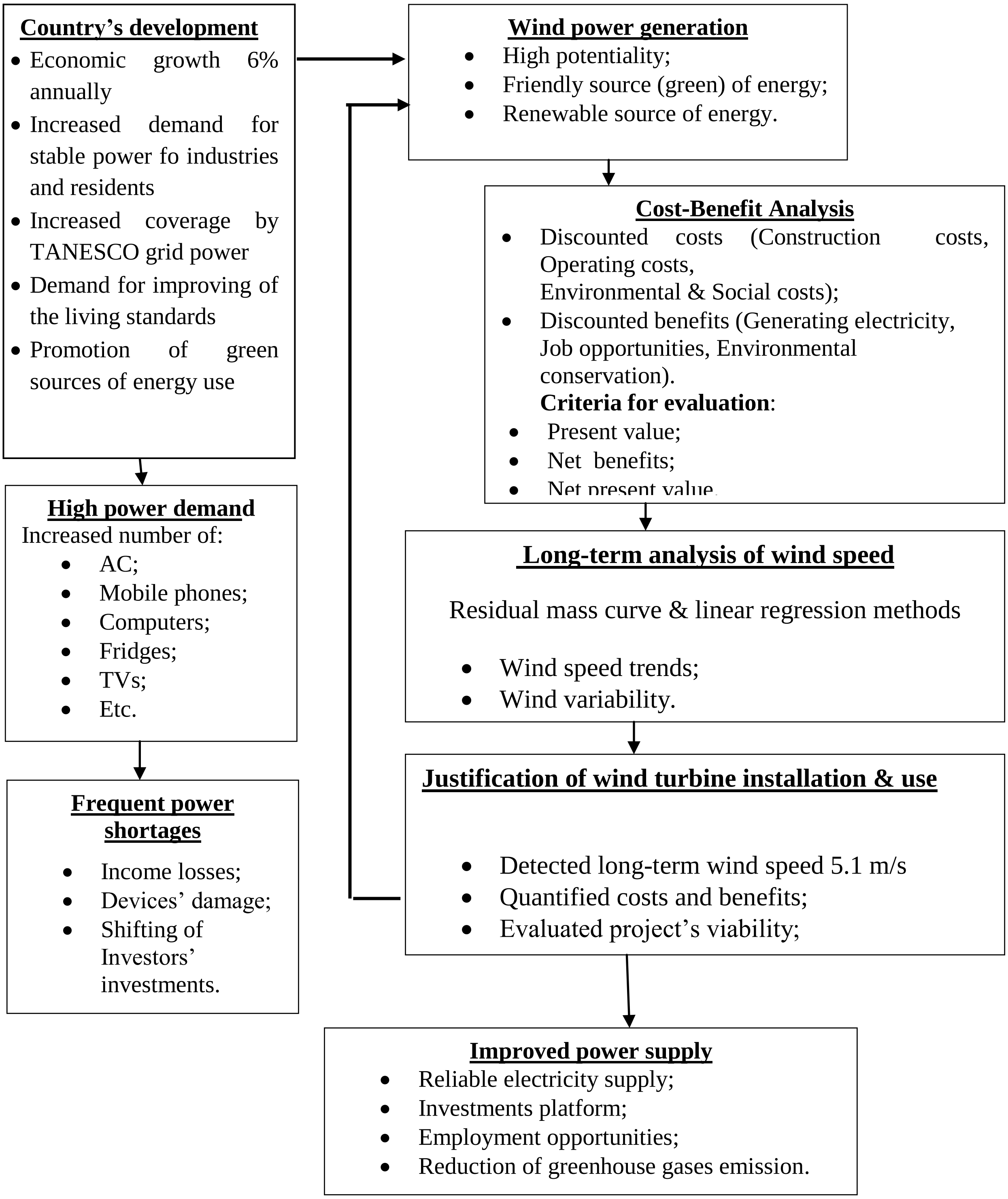


Figure 3: Conceptual Framework.

Source: by author (2016)

CHAPTER THREE

RESEARCH METHODOLOGY

3.0Introduction

This Chapter deals with the description of the methods applied in carrying out this study. It is organized under the following sub-topics: study area selection and criteria, research design, methods of data collection, data analysis, data validity and reliability.

Research methodology is the way that is used to systematically solve the problem. It simply shows how the research is done scientifically and reasons as to why a researcher adopts any method in the research. Cresswel (2003) defines it as a systematic, theoretical analysis of the methods applied in the field of research study. Kitchin and Tate (2000) support that; it is the coherent set of rules and procedures which can be used to investigate a phenomenon or situation within the framework dictated by epistemological and ontological ideas.

3.1 Research Design

Research design is the overall plan for connecting the conceptual research problems to the pertinent (and achievable) empirical research. It articulates the required data, what methods are going to be used to collect and analyse these data, and how all of this is going to answer your research question (Babbie, 1998).According to Bhattacherjee (2012), the research design can be a case study, experimental, cross-sectional, survey or longitudinal design. The choice of research designs depends on nature of the study (Louis *et al*., 1998).

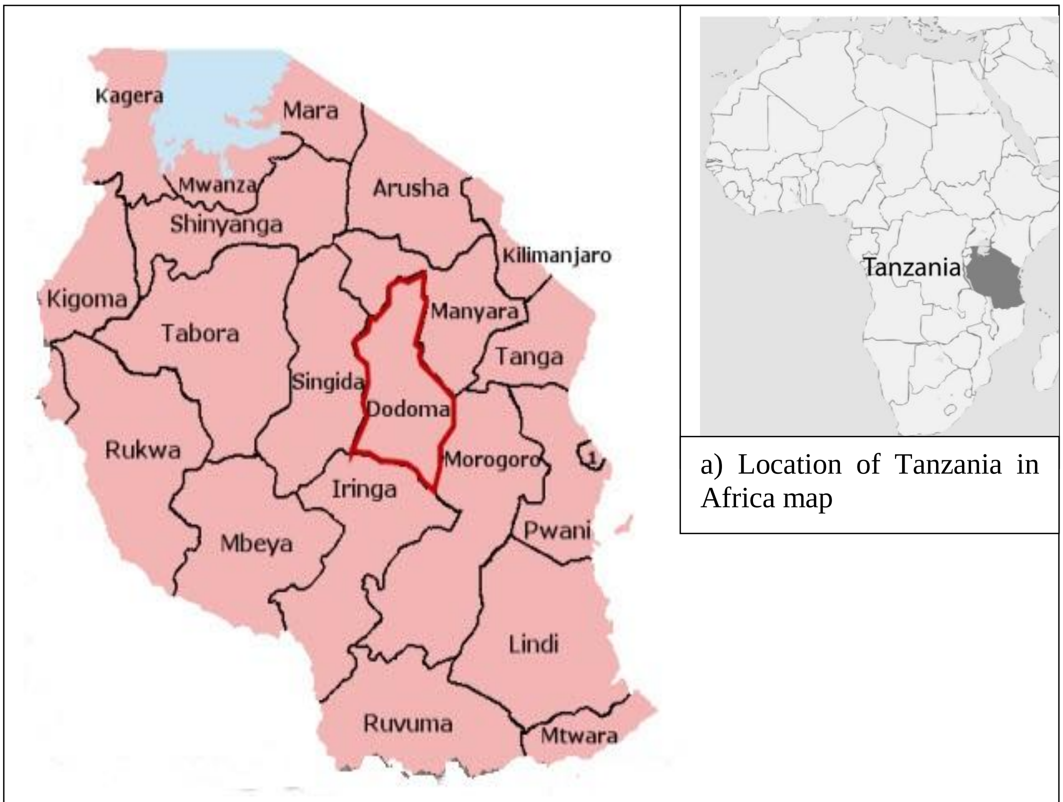
This study employed quantitative research approach because it attempted to investigate wind resource potentiality in Dodoma Municipality as well cost – benefit analysis used for estimation of costs and benefits of wind turbines installation and use. erring (2007) supports that, a case study research design attempts to elucidate certain features of a spatially delimited phenomenon observed at a single point in time or over some period of time and explain an inference.

3.2 Selection of the Study Area and Geographical Description

3.2.1 Selection of the Study Area

The study was carried out in Dodoma municipality (Figure 4). The area was selected basing on the reasons that; firstly, the wind resource potentiality in Dodoma municipality is among the highest in Tanzania. Particularly, Mmasi *et al*., (2001) report that, based on wind resources in Tanzania; Dodoma is among the suitable areas for generation of electricity using wind a

s the source of energy. Secondly the Municipality experiences frequent short cuts of power especially in dry seasons – when water stage in power generating reservoirs is low. Masamba (2013) reports that, Dodoma’s windy climate is characterized by low wind speed during summer (wet periods) and strong winds during winter (dry periods) and mostly from East and North-East. Dry periods are a windy season where the distribution of wind is strong and potential for power generation which can be used to supplement the shortfall in hydro-electricity generation.



a) Location of Tanzania in Africa map

b) Location of Dodoma municipality in Tanzania

Figure: The Location of Tanzania in Africa (a) and Location of Dodoma Municipality in Tanzania.

Source: (a) www.mermaidray.com.au; (b) commons.wikimedia.org (assessed on 11.02.2016).

3.2.2 Geographical Description

3.2.2.1 Location

Dodoma municipality is ranked 12th largest among the municipalities in Tanzania Mainland and covers an area of 41,311 square kilometres which is equivalent to about 5% of the total area (URT, 2007). It lies in the heart of Tanzania (Figure 4) in the eastern-central part of the country, the main city being about 480 km from the coast with an estimate terrain elevation of 1043m above sea level. It is located at6°00'00" South of Equator and 36°00'00" East of Greenwich Meridian. Dodoma Municipality is characterized by plateau rising from some 830 metres in Bahi swamps to 2,000 metres above sea level in the highlands North of Kondoa. The Dodoma Municipality is bordered by Manyara region in the north, Singida region in the west, Iringa region in the south, and Morogoro region in the southeast (URT, 2014).

3.2.3 Climate

Dodoma Municipality has a dry savannah type of climate, with a long dry season lasting between late April to early December and a short single wet season during the remaining months. The municipality lies in a rain shadow behind the mountains area of Dodoma in the eastern side (URT, 2002).The climate is largely controlled by the movement of air masses associated with the inter-tropical convergence zone (ITCZ) that influences changing of the seasons in a year. For example the rainfall pattern is irregular with significant variation from one year to the next and often several concurrent years with below average rainfall (McCartney, 2007).

Air Temperature

Air temperature varies according to altitude but generally the average maximum and minimum is 31° C and 18° C respectively for October to December. The figures for the cool dry season of June to August are 27°C to 28°C and 10°C to 11°C (URT, 2002).

Rainfall

The average rainfall for Dodoma semi-arid area is 570mm per annum about 85% of this falls in four months between December and March. Rainfall is higher in Mpwapwa and Kondoa districts, thus the zone receives the unimodal rainfall.The rainfall in Dodoma is not only low but also unpredictable in frequency and amount, particularly in the month of January in which most crops are generally grown (URT, 2002).

Wind

The wind distribution in Dodoma is usually seasonal. The wind speed is high during the dry seasons-the windy seasons. Masamba (2013) asserts that, the windy season, which is from March to November, coincides with the dry season that exacerbates the potential wind speed distribution in the Municipality.

3.3 Sources of Data

The study encompassed only secondary sources of data. The secondary data are the second information which skimmed from various readings like books, journals, articles, newspapers and research reports. These data are available at the level of analysis suitable for answering the researcher's questions (Bhattacherjee, 2012). For the sake of this study, data were collected from Tanzania Metrological Agency (TMA) weather station, Singida wind farm project and Tanzania Electricity Supply Company (TANESCO).

Data about daily wind speed for 5 years (2011-2015) and monthly mean wind speed for 30 years (1986-2015) were collected from one weather station located in Dodoma Municipality for long-term period of observations as shown in Table 2.

Table 2: TMA Weather Station in Dodoma Municipality

No	WMO number	Name	Latitude	Longitude	Altitude, m	Wind speed with period of observations	
1	9635001	Dodoma airport	6.170	35.770	1120	Daily	2011-2015
						Monthly mean	1986-2015

Source:TMA (2016).

An official document about Singida wind-farm planning and construction (CDIG, 2014) was consulted to get experience about capital costs of construction and interest of loan. Data about current TANESCO tariffs in 2016 were collected from TANESCO Dodoma region head quarters' office (Table 3).

Table 3: TANESCO Tariffs in 2016

Tariff category*	Power consumer(Kwh/month)*	Annual Power consumption (kWh)*	Price (TSh/kWh)*	Power Distribution (%)**
D1	Consumers of less or equal 75 units	8,003,075.00	122	7.1
T1	Consumers of more than 75 units	69,597,104.80	356.24	61.1
T2	Consumers of more than 7,500 units	17,672,275.00	195	15.5
T3	Consumers connected to medium voltage	18,125,116.00	157	15.9
T4	Public lighting	-	-	-
T5	Zanzibar	-	-	-
T6	TANESCO	422,496.00	-	0.4
T7	Kahama	-	-	-
Total		**113,820,066.80**		**100**

Source: * TANESCO Dodoma Region Head quarters' (2016).

** Author(2016).

3.4 Methods of Data Collection

The methods are the techniques or processes used in gathering information for research study (Dawson, 2002).

3.4.1 Documentary Review

Documentation in this context embodies a large body of data, which are related to the study and have already been collected by other researchers. According to Bailey (1999) the method gives a room to research to review a variety of existing sources (documents, reports, data files, and other written artefacts).

In application for this research, documentary review method provided a systematic procedure for identifying, analysing, and deriving useful information from existing documents. With regard to this study, data were collected from archived weather records, articles, documents and periodicals related to wind data in the area of study and worldwide. Also under this method, the data related to cost of wind installation and use were collected from official documents about Singida wind-farm construction.

3.5 Methods of Data Processing and Analysis

These are techniques for designing data processing and analytical systems. The processing of data/information is an essential dimension of stream lining the raw data collected to useful information (Ranjit, 2011). Microsoft Excel software version: 14.0.4734.1000 part of Microsoft Office Professional Plus 2010 was used for processing of the collected data. In addition, various statistical techniques were used for analysis to derive accurate and precise results: residual mass curve, statistical parameters, linear regression and cost-benefit analysis. Finally, results were presented in form of residual mass curve, histogram, line graph and linear regression.

3.5.1 Residual Mass Curve Method

The residual mass curve method is a valuable instrument for data analysis. This method of plotting saves the additional space needed for plotting a continuously rising mass curve and to accentuate more clearly the crests and troughs of the cumulative flow records (Reddy, 2005).Shaw *et al*., (2011) points that, the use of the technique makes it easier to determine the occurrence and frequencies of periods of critical potential wind speed, when there is a sufficient long-term representative series of wind data records for analysis. Additionally, the method helps to determine the sequences of periods from historical records having lowest flow of wind speed that are abstracted and for each sequence the cumulative amounts plotted against time. Subramanya (2008) urges that, the method is widely used for analysis of long-term records of events, however, it assumes definite sequence of events and this is its drawback. This study used the residual mass curves method for long-term analysis of wind speed in the area of study to discover facts about its cyclicity. Specifically, data about wind speed in each month and years were calculated for detection of long-term average wind speed for 30 years period (1986-2015). Then the residual mass curve formulas (9) and (10) (See paragraph 2.2.4) respectively was used for calculating a sum of cumulative arithmetic average $\sum(V_i - 1)$, where an observed wind speed in each year-$V_i$divided by an average wind speed-$\overline{V}$ will result to arithmetic mean wind speeds-V_i. Lastly a calculated a sum of cumulative arithmetic average was used to plot a graph against time in years.

3.5.2 Statistical Parameters

These are numerical quantities that characterize given information or some aspect of it. This means that they tell information about particular collected data. Parameter in statistics is an important component for any statistical analysis (Siddharth, 2011). The most common statistical parameter- *mean* was used in this study to tell how the wind data behave on an average basis. Particularly daily wind data were used for calculation of monthly mean wind speed and monthly wind data were used for calculating annual mean wind speed and detection of months with maximum and minimum wind potentiality for wind power generation.

3.5.3 Linear Regression Method

Zhang (2015) defines linear regression as a statistical technique for analysis predicting the value of a dependent variable from an independent variable when the relationship between the variables can be described with a linear model. Thus, it is a common statistical data analysis technique used to determine the extent to which there is a linear relationship between a dependent variable and one or more independent variables. With regard to this study, linear regression method was used for analysing the trend of wind speed in the area of study to discover facts about significance of the trend and then estimate its magnitudes. In application, the calculated long-term average wind speed over thirty years was linked to the equations (11) and (12) respectively. Where the variables y - wind speed (in m/s) and, X- the time in years was substituted in the equations above to calculate the value of wind speed; a-the slope of the trend (in m/s per year) indicating the detected change. If coefficient a is more ±0.3, it indicates the more obvious variation of trend and small value compared to its coefficient shows the slight variation trend over a given period of time. Likewise a positive slope-*a*, means that the wind speed has an upward trend and when negative, it has a downward trend (WMO, 2011).

3.5.4 Cost-Benefit Analysis Method

A cost benefit analysis is the monetary or safety valuation of the risk of performing a task (or performing a task in a certain way) vs. benefit of performing the task (or performing the task in a certain way). Ray *et al*., (2009) argue that, it is a technique used to justify the project's viability through estimating the total costs of a programme or project with its benefits, using a common monetary unit. This study adopted cost–benefit analysis approach to analyse the costs associated with wind mills installation and use and benefits which could be achieved during power generation.

In particular, costs data were collected from Singida wind-farm to generate total installation costs for one wind turbine as expressed in the formula (13). The lifetime of wind turbine was limited by the 20years due to necessity to re-update wind turbine mechanisms. Nicholas and Barry (2010) report the normal operational lifespan of a typical wind turbine is approximately 20-30 years. After the approximated operational time ends a wind turbine can be re-updated to extend its lifespan by an additional 15 years or more, making the expected operating life of a wind turbine comparable to the 30 to 50 years (Wilburn, 2011). Since the lifetime of the planned wind farm was set to 20 years, construction costs were quantified within year 1-2 (2years of construction), operational and maintenance costs were calculated from year 3-22 (20 years lifetime). A 5percent to 6.5 percent discount rate was applied to construction and installation costs to evaluate the future costs and benefits of the wind turbine installation and use basing on the Tanzania average inflation rate

(5.5%) trend from the year 2010-2015. The Bank of Tanzania (2015) reports that, the inflation rate has been fluctuating year to year, it ranges between 4.8 percent and 6.4 percent consecutively in five years. Benefits were based on wind potentiality and its prediction in power output generation. The wind potentiality was linked to power law which was used to extrapolate the wind data at 25, 45, and 65 m height to yield an annual mean wind speed in relation to a hub height for power generation (formula 8). The estimated power output was calculated using a formula 6 of the power in the wind. Basing on the power production of one wind turbine used as reference and helped to propose number of wind turbines needed to cover the needs of the Municipality. Benefits like costs were discounted using the same discount rate to present in order to harmonize them in future.

All costs and benefits were defined for different hub positions (25 m, 45 m and 65 m) in order to identify the best relationship between cost and benefit. According to Lee *et al*., (2014), wind energy captured on typical wind farms varies due to wind speed, location and hub height. In the same way, energy production costs vary as the function of hub positions. Finally, calculations of NPV and BCR, were used as criteria for project evaluation and in helping to justify the project's viability and profitability. Positive NPV shows that the project is profitable, while highest BCR will indicate the best project, hence benefits in several times will overcome the costs.

CHAPTER FOUR

RESULTS AND DISCUSSIONS

4.0 Introduction

This chapter presents the results of the study on cost-benefit analysis of wind turbine installation and use in Dodoma Municipality. The chapter is guided by the research objectives found in chapter one of this study. The first part of the chapter presents a long-term analysis of wind speed and detection of its cycle and trend. Then the next part is about the costs of wind turbine installation and use. The last part presents the benefits of wind turbine use and project evaluation.

4.1 Wind Resource Assessment

The amount of energy that can be harvested at a given location depends on the local wind climate. The local wind resource is by far the most important determinant of the profitability of wind energy investments. The quality of wind resource assessments is often the most important economic element in the development of wind power projects. Financiers of large wind farms will often require a due diligence reanalysis of the resource assessment, usually in the form of a second opinion on the conclusions to be drawn from the available data (EWEA, 2009). Wind resource assessment in this study focused on wind speed and not wind direction due to the fact that, wind direction in the area of study was stable. On this particular aspect, Masamba (2013) reports that, Dodoma’s wind direction is characterized by being stable and most of the time the wind direction is East to North-East.

4.1.1 Wind Regime in Dodoma Municipality

Wind regime always remains an important characteristic for estimating the wind energy potential of a site, long-term wind data from the meteorological stations near the site can be carefully extrapolated to represent the wind profile at the potential site (Erich & Von, 2005*)*. In studying the wind resource potentiality in the area of study, the wind data were collected from Dodoma Airport meteorological station for long-term time series (1986-2015). In particular, monthly mean wind speed was calculated from daily average wind speed at height of 10 metres (location of anemometer). On a base of monthly mean wind speeds, long-term monthly mean wind speed for 30 years period (1986-2015) was calculated as shown in Table 4.

Table 4: Long-term (1986-2015) Monthly Mean Wind Speeds (V, m/s) at Dodoma Weather Station

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Average
Average	3.3	3.1	3.6	4.7	5.4	5.4	5.7	6.2	6.6	6.8	5.9	4.3	5.1

Source: Author (2016).

The long-term monthly mean wind speeds are shown in Figure 5, months from December to March experience low wind speed ranging from 3 m/s to 4 m/s whereas from April to middle of December wind speed is higher than other months, ranging from 5 m/s to more than 6 m/s. In addition, annual long-term mean average wind speed was calculated and resulted to 5.1 m/s (Table 4). This result shows the availability of wind potentiality in study area for power generation. As EEA (2009) reports, the areas with an average wind speeds higher than 5.0 m/s at 10 m height is suitable for wind power generation. Due to that, Dodoma Municipality is the area which could be suitable for wind turbine installation and wind power generation.

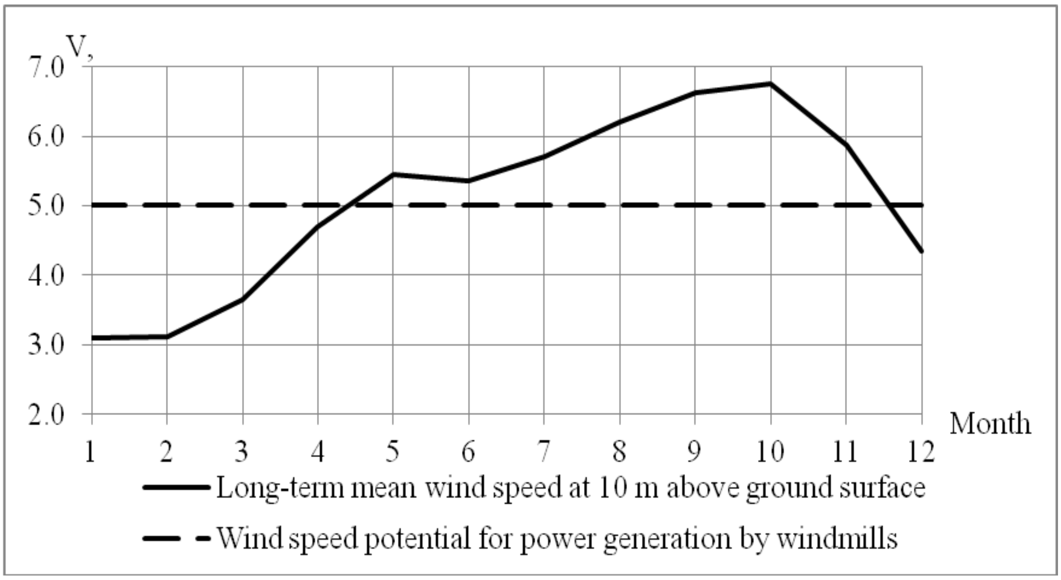


Figure 5: Long-term (1986-2015) Monthly Mean Wind Speeds for Dodoma Weather Station at 10 Meters above Ground Surface

Source: Author (2016).

Analysis of observed results (Figure 5) shows that high wind speed which could be potential for power generation was observed for 7 months (May-November). On this particular aspect, Masamba (2013) also asserts that, these months are the windy season in Dodoma Municipality and potential wind speed distribution is promising for wind power generation. Such results are valid for hub position at 10 metres above ground surface. Modern hubs could be located at different heights (25 m, 45 m, 65 m and above) and wind potentiality need to be studied at these positions. Unfortunately, weather stations perform observations of wind speed at standard position 10 m above ground surface (position of an anemometer). For recalculation of long-term wind speed for needed hubs locations the Power law can be applied because it allows calculation of the wind speed at any heights form known base wind speed.

4.1.2 Application of Power Law

According to Power law (Yaneer, 2015), wind speed increases with increased height above ground. Change in wind speed with height and the wind speed at different higher heights can be calculated from a known wind speed which helps to estimate different wind power outputs (Grigsby, 2012). This is more appreciable on wind turbine operation in capturing wind energy, as height increases wind speed as well containing much more energy than low height with low wind speed (Bianchi *et al*., 2007). Due to this annual long-term mean wind speed at the height 10 m above ground, was used as a base for extrapolation to other heights (Table 4). Particularly for 25, 45 and 65 m above ground with use of formula 7 (See paragraph 2.2.3). Initial data which were used in formula 7 were the reference height for which, wind speed is known $(V_{zo},$m/s), the wind speed at the needed height (Z, m/s) and the power law exponent which was represented by the wind shear coefficient (α). Wind shear exponent was adapted from Singida wind farm project because both Singida and Dodoma have the similar climatic condition that is characterized by similar rainfall in short season, variation in temperature due to altitude and season. Likewise wind is largely controlled by air mass patterns, altogether form semi -arid central zone of Tanzania (URT, 2007). Wind shear exponent of 0.094 was developed from synchronous observations at 10 m (position of the anemometer) and at 30m above ground surface at Singida wind farm (CDIG, 2014).Small size of the wind shear exponent (0.094) indicated slight increase of wind speed with height, while on average, wind shear exponent could vary in between 0.1-0.2, and has to be positive not negative in order to avoid enhanced fatigue damage and risk of blade tower interaction (Berg *et al*., 2013).

Table 5: Long-term Monthly Mean and Average Wind Speeds at Different Heights

Month	Wind speed,m/s			
	10 m*	25m**	45m**	65m**
January	3.3	3.6	3.8	3.9
February	3.1	3.4	3.6	3.7
March	3.6	4.0	4.2	4.3
April	4.7	**5.1**	**5.4**	**5.6**
May	**5.4**	**5.9**	**6.3**	**6.5**
June	**5.4**	**5.8**	**6.2**	**6.4**
July	**5.7**	**6.2**	**6.6**	**6.8**
August	**6.2**	**6.8**	**7.1**	**7.4**
September	**6.6**	**7.2**	**7.6**	**7.9**
October	**6.8**	**7.4**	**7.8**	**8.1**
November	**5.9**	**6.4**	**6.8**	**7.0**
December	4.3	4.7	**5.0**	**5.2**
Average	5.1	5.4	5.8	6.1
Increment in wind speed from 10 meters (%)	-	10%	16%	20%

* - Wind speed at 10 m above ground at Dodoma weather station.

** - Calculated wind speeds.

Source: Author (2016).

Calculation of the results of annual long-term wind speed for different heights shows that from the base location (10 metres above ground – location of anemometer) to height of 25 metres wind speed will be 10% more. While at 45 and 65 metres, it will be 16% and 20% higher. Particularly, projection of wind speed to hub location of 65 metres gives better increment in wind speed from 10 metres. At that position annual mean wind speed will increase to 6.1 m/s (Table 5), and this will increase annual energy production. Additionally, Figure 6 shows that during this period wind speed increased more than 5 m/s for all calculated heights.

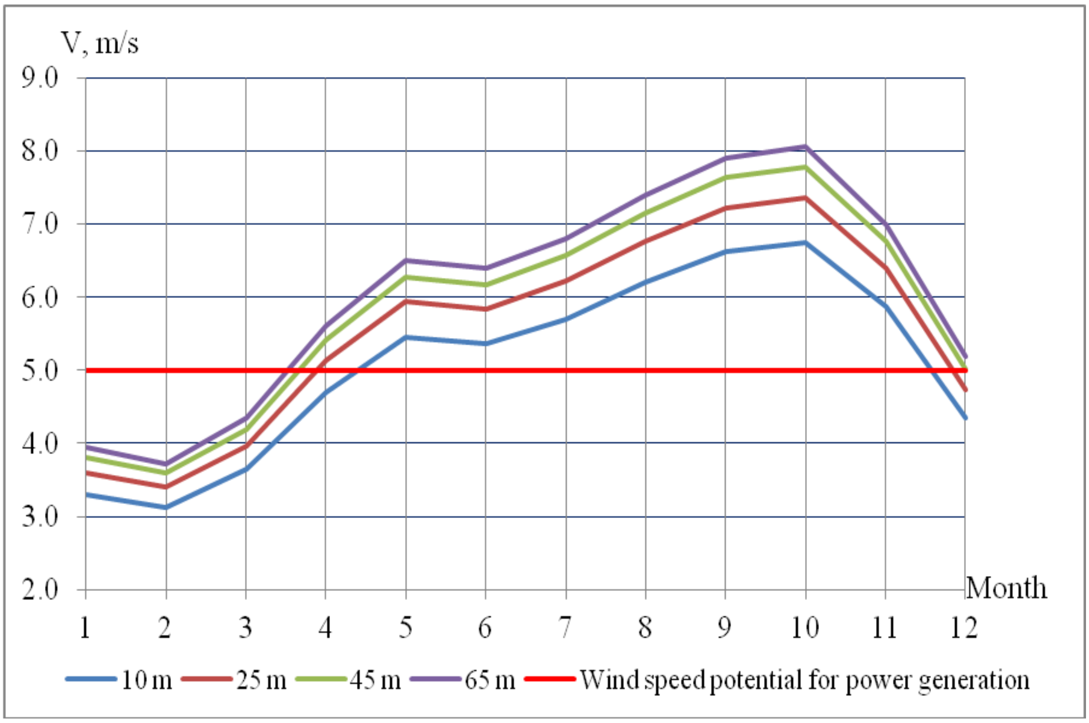


Figure 6: Calculated Monthly Mean Wind Speeds (m/s) at Different Heights

Source: Author (2016).

As indicated in Figure 6, periods with mean wind speeds above 5 m/s were increased for each height used for extrapolation of wind speeds. Particularly, at the height of 25 m period with potential winds became one month longer (total 8 months). At height of 45 m, it became two months longer (total 9 months) than similar period at location of anemometer (7 months).While at height of 65 m the period with wind potential for power generation became 2.5 months longer (total 9.5 months) compared to 10 m (location of anemometer).

Additionally, the height of 65m had higher monthly mean wind speed, due to high height of the hub than other hub positions. Based on the results, it implies that different hub locations have effects on their monthly wind speeds and annual energy production from the wind turbine due to the fact that the high height location usually has high monthly mean wind speed that impacts on power output. In the same vein, Grigsby (2012) reports that, wind speed increases with hub height something that helps to estimate the annual wind power output. As detected, period with wind potential for power generation increases with the increase of height. Due to that, the number of days potential for power generation was calculated for each hub position (Table 6).

Results revealed that, all days the between months April to November were effective for power generation for all hub positions. However, it was observed that, March and December had fewer potential days for power generation in relation to hub positions. Specifically, March had 4 days (25 m) 10 days (45 m) and 15 days (65 m). Likewise December had only 20 days at 25 m potential for power generation. Also the annual number of days potential for power generation for different hub positions was calculated. In particular, the results revealed 268 days (25 m); 285 days (45 m) and 290 days (65 m). Particularly, 65 m hub position had longer period for power generation (almost 1 month) more than 25 m hub position.

Table 6: Potential Days for Power Generation for Different Hub Positions

Month	Number of days with wind speed above 5.0 m/s			
	10 m	**25m**	**45m**	**65m**
Jan	-	-	-	-
Feb	-	-	-	-
Mar	-	4	10	15
Apr	17	30	30	30
May	31	31	31	31
Jun	30	30	30	30
Jul	31	31	31	31
Aug	31	31	31	31
Sep	30	30	30	30
Oct	31	31	31	31
Nov	30	30	30	30
Dec	15	20	31	31
Total days:	**246**	**268**	**285**	**290**

Source: Author (2016).

Generally, the results implied two observations. First, the height of hubs had effects on monthly wind speed. It is generally held that higher hubs will have greater wind speed always. Secondly, the height of the hub will impact on annual energy production. Higher hubs are likely to prolong period with wind speed potential for power generation and hence that will impact on increase in annual energy production.

4.1.3 Trend of Wind Speed in Dodoma Municipality

This part is detailed on analysing the trend of wind speed in the area of study. To enrich it, linear regression model and residual mass curve were applied as shown below:

Linear Regression

Linear regression method was applied for detection of wind speed trend and its magnitude. Initial data about long-term mean wind speed for period 1986-2015 at 10 m (position of anemometer) was used. According to WMO (2011), two parameters describe the trend of wind speed: sign of the slope coefficient and value of the slope coefficient.

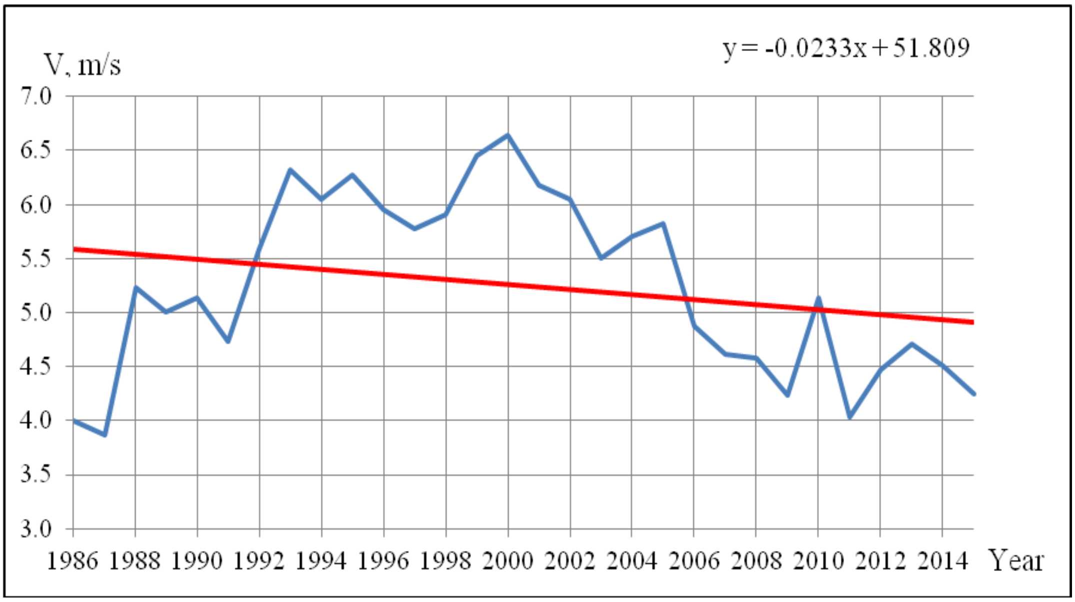


Figure 7:Long-term (1986-2015) Mean Wind Speed Distribution with Trend Line at Dodoma Weather Station

Source: Author (2016).

Analysis of result in Figure 7 showed that wind speed could vary from year to year. Additionally, based on the trend line equation y= -0.0233x+51.809, the value of the slope is *a*=-0.0233.In long-term perspective for the period 1986-2015, it was revealed to have downward trend, because the slope coefficient (*a)* is negative (*a*=-0.0233). According to Thomas (2009), the slope of the wind speed trend (in m/s per year) indicates the detected change, as well as a positive slope which indicates the wind speed with an upward trend and a negative one that portrays a downward trend.

Evaluation of the magnitude and its change shows that, the slope coefficient was less than ±0.3, value recommended by WMO (2011) for evaluation of trend significance. If the value of the slope coefficient is less than recommended, it means that the trend of any phenomenon is not significant, and this could be due to slight variations of wind speed from year to year. Likewise, variation in wind speed could be linked to both atmospheric circulation changes and ground surface variations that have effect on wind speed stability. On this particular aspect, Amadi and Udo (2015), found that, aerosol emissions, greenhouse gas concentrations and surface temperatures could affect the atmospheric circulation and stability hence impact on wind speed.

These results contrast to the study findings by Mayaya *et al*(2015) where the analysis of meteorological data for Dodoma Municipality in the past years 1980-2009 (19 years) was done. Mayaya *et al* (2015) results showed an upward trend of wind speed in Dodoma whereas the trends detected in the current study show an opposite downward trend (a=-0.0233).Such opposite results can be due to the use of different periods for trend detection. On this aspect, Mayaya *et al*., (2015) used only 19 years whereas the current study used longer period that is 30 years. Ideally, for long-term trend detection, it is advised for the researchers to use data for the whole period of observation at weather station in order to avoid to generate biased results. Additionally, for detection of cycles in wind speed, the residual mass curve method was used.

Residual Mass Curve

According to Isemer (2000), long-term wind speed analysis also could be performed using residual mass curve in which the cumulative departures from a given reference such as the arithmetic average as ordinate, is plotted against time. Wind speed changes over time, in particular the cumulative deviations from some average value will indicate a significant change of surface wind speed (ibid). Initial data about long-term mean wind speed for period 1986-2015 was used for the residual mass curve construction (Figure 8).

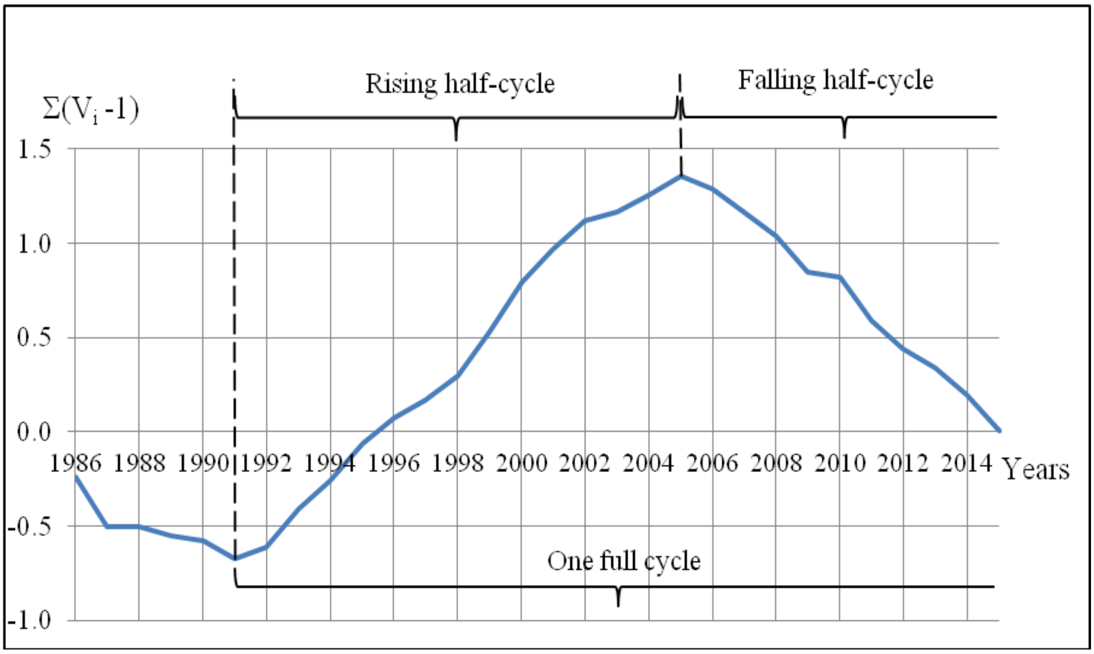


Figure 8: Residual Mass Curve of the Long-term (1986-2015) Mean Wind Speed at Dodoma Weather Station

Source: Author (2016).

According to Oltman and Tracy (2010), residual mass curve analyses trends or possible changes in cumulative values over a long –time period. Again, continuously mass curve accentuates more clearly the crests and troughs of the cumulative flow records (Reddy, 2005). Bharali (2015) noted that mass curve plotting accentuates more clearly the rising and falling of the cumulative flow records. Due to that, long-term monthly mean wind speed (1986-2015) was used to calculate a sum of cumulative arithmetic average for plotting in mass curve for detection of wind cycles. Particularly, the formulas 9 and 10 (See paragraph 2.2.4) respectively, were used for calculation of a sum of cumulative arithmetic average. Initial data which were used in formulas were: long-term mean wind speed in each year(V_i, m/s) and average wind speed for the period from 1986-2015 ($\overline{V}$,m/s).

The analysis of residual mass curve (Figure 8) shows that, due to the limited period of observed data accessed in TMA, it is not possible to detect the whole cycle of wind speed in Dodoma Municipality. But a half of a cycle was detected. So, increment of the wind speed was detected during 1991-2005 (14 years). While falling of the wind speed was detected in years 1986-1991 and 2006-2015, those half-cycles did not end due to limited data. During rising half-cycle the wind speed tends to increase from year to year and will be highest during that period. While during falling half-cycle wind speeds tend to decrease and will be usually minimal. According to Schlesinger (1990) wind cycles and half-cycles are inherent phenomena responsible for a good deal of long term predictability of wind speed. Due to atmospheric variability, wind speed significantly induces changes (increases and decreases. To assume for example, that an average size of half-cycle for Dodoma Municipality is 14 years the end of falling half-cycle which started in year 2005could be predicted. This cycle will end in year 2019. After 2019 wind speed shall start increasing and will rise till 2033. Unfortunately, those predictions are approximated due to limited initial data (just 30 years) and could be improved in future if the period with observation of wind speed data will be 100years and more.

4.2 Costs of Wind Turbine Installation and Use

Like other renewable energy technologies, wind is capital intensive, but has no fuel costs (IRENA, 2012). The key parameters governing wind power installations are the:

- Cost of capital.
- Investment costs.
- Operation and maintenance costs.
- Capacity factor.
- Economic lifetime.

Costs included into capital cost were calculated for Dodoma Municipality on a base of Singida wind farm project costs (CIDG, 2014). That project was created for 33 wind turbines with hub position at 65 m above ground. Costs for Dodoma wind farm project were recalculated with use of proportion method for 15 wind turbines.

4.2.1 Wind Turbine Description and Model Selection

In the current study, the same wind turbine generator systems(WTGSs) were used as for Singida wind farm project. According to China Dalian International Economic and Technical Cooperation Group Co., Ltd-CDIG (2014), model selection of WTGSs was based on factors of fully maximizing investment benefits, models of low price, high energy production, safe reliable operation and erection condition. Table 6 below presents the description of the WTGS and its main parameters. Fifteen WTGS with a capacity of 1,500 kW each (total capacity 22,500 kW), was evaluated in terms of costs for future installation in Dodoma Municipality.

Table 7: Main Parameters of Wind Turbine Generator Systems

Item		Parameter
WGTS	Model	DFIG
	Single capacity (KW)	1,500
	Number of WTGS	15
	Total installed capacity (MW)	22.5
	Power Coefficient	0.42
Rotor	Diameter (m)	77
	Swept area (m^2)	4396
	Power control	variable speed ,variable pitch
	In-wind speed (m/s)	3
	Rated speed (m/s)	12
	Safe wind speed (m/s)	22
Blade	Length (m)	37.3
Brake system	Emergency braking	3-blade independent variable pitch brake
Tower	Model	Cone-shaped steel drum
	Height (m)	65
Weight	Rotor (t)	30.4
	Cabin (t)	55.4
	Tower (t)	105.8

Source: CDIG (2014).

There exists a wide range of manufacturers in the world market of wind turbines namely Gold wind (China); General Electric (USA); Gamesa (Spain) and Vestas (Denmark).All of these offer installation of hubs at the different height above ground surface (Avis & Maegaard, 2008). Particularly the China Dalian International Group (CDIG) manufacturer, which was used for the study, offers installation of wind turbines at 25 m, 45 m and 65 m above ground surface. Due to this, all costs and benefits will be defined for three and hub positions (25 m, 45 m and 65 m). Those data were then used in NPV and BCR criteria for justification of viability and profitability of wind-farm projects with different hub positions.

4.2.2 Capital Costs

The capital costs of a wind power project can be broken down into the following major categories:

- The turbine cost;
- Civil works;
- Grid connection cost;
- Other capital costs.

The analysis of the results indicated that the capital costs included: Turbines cost 56,201,641,336TSh; Civil works 24,581,055,878TSh, Grid connection 2,989,442,617TSh and other capital costs 12,093,553,353TSh, amounted to a total cost of 95,865,693,184 Tanzanian Shillings (Table 8). Their percentages weights were 58.6%, 25.3%, 3.1% and 12.6% respectively (Table 8).

It is vivid that the cost for turbines weighed more compared to cost of civil works, grid connection as well as other capital costs. This weight of each cost (Table 8, column 6) could be associated with the reality which exists in the country, maturity of the wind industry in the country, presence of qualified staff and project specifics. For example, IRENA (2012) noted that, presence of the local manufacturers, the degree of competition in a wind market, the bargaining power of market actors, would impact on the costs of wind turbines and their installation.

Table 8: Capital Cost for 15 Wind Turbines with Hub Position at 65 m in TShs

№	Name of works/costs	Cost for equipment Procurement, TSh	Cost for Construction and Installation, TSh	Total, TSh	Propor-tion %
1	2	3	3	4	5
1	Turbine cost	56,201,641,336		56,201,641,336	58.6
2	Civil works				
	• Auxiliary works for construction		2,252,668,688	2,252,668,688	2.3
	• Wind turbine installation		8,942,143,725	8,942,143,725	9.3
	• Construction works		13,386,243,465	13,386,243,465	14.0
3	Grid connection costs	535,696,809	2,453,745,807	2,989,442,617	3.1
4	Other capital costs		12,093,553,353	12,093,553,353	12.6
Total:				**95,865,693,184**	**100.0**

Source: Author (2016).

Turbine Cost

This item involved cost of equipment purchased for the wind farm project. That is the costs associated with blades, towers and transformers. Also, the following installations needed to be carried out; the WTGSs and box transformers, fabrication, concrete batching plant, the electrical equipment and monitoring system in the step-up substations and set-up transformation equipment and installation. In addition, turbine cost included shipping cost, other transportation to Dodoma wind farm site and Insurance cost. The purchase and shipping of lifting equipment, wind turbines, heavy and over-sized transportation equipment was done from China to Dar es Salaam port (CDIG, 2014). Other transportation of purchased materials and heavy and over-sized equipment needed to be transported by road from Dar es Salaam Port to Dodoma wind farm site. Cost of equipment was adopted from Singida wind farm project created for one hub position 65 m and for 33 wind turbines (CDIG, 2014) and was recalculated for three hub positions (25 m, 45 m and 65 m) and for 15 wind turbines. The costs expressed in Dollars were converted into Tanzania shillings through the exchange rates of the CRDB Bank which were calculated by means of average between buying (USD 1 = 2,111.71 Tsh) and selling (USD 1 = 2,241.71 TSh) the rates were as follows: USD 1 = 2176.71 TSh. Exchange rates were consulted online on the CRDB website (accessed 14.06.2016 on web-site: http://crdbbank.com/tz/treasury-services/exchange-rates.html). Calculated cost of wind turbines was 56,201,641,336 TSh, weighing 58.6% of the project costs (Table 8).

Civil Works:

This part is termed the main construction works of the wind farm project, including site preparation and foundations for towers. The civil work quantities of this part mainly included: Auxiliary works for construction, wind turbine installation and construction works (CDIG, 2014).

Auxiliary Works for Construction; these were subsidiary kind of works that gave help or assistance for construction. These included: roads in the site, ground levelling of material warehouse, ground levelling of site office and disposal areas. Based on the results of civil work costs break down (Table 8), cost for auxiliary works for construction amounted to 2,252,668,688TSh with a share of 2.3% of the civil work costs.

Wind Turbine Installations, these included the WTGSs installation platform and box transformers, fabrication and installation of concrete batching plant, the electrical equipment and monitoring system in the step-up substations and set-up transformation equipment and installation. Likewise, the cost of wind turbine installation was quantified to 8,942,143,725TSh with proportion of 9.3% of the capital costs (Table 8).

Construction Works

These included excavation of the ground and levelling of the wind generator platforms, construction such as step-up substation and complex building, and ground levelling of concrete batching plant (CDIG, 2014).These construction works covered 13,386,243.465TSh which gives 14% in the cost break down of the civil works (Table 8).

Grid Connection Costs:

These included costs for the electrical work, electricity lines and the connection point together (bear to) transformers and step-up substations, as well as the connection to the local distribution or transmission network. Transformers and substations involved power transmission line from step-up substation in the wind farm site to sub-station in the area of study. Transmission network associated power evacuation works in which wind farm was connected to electricity grids followed by lying of the power transmission cables, lines connection to the local distribution (IRENA, 2012). According to the capital cost distribution (Table 8), the grid connection costs constituted 2,989,442,617TSh that covered 3.1 % of the capital costs.

Other Capital Costs:

Also there were additional expenses that were incurred in relation to the direct costs of wind farm project. Other capital costs included the construction of buildings, control systems, project consultancy, preparation, investigation and design. Costs also involved, salaries of the employees, basic consulting service charge, investigation and design cost at pre-feasibility study stage, supervision cost, techno-economic assessment and review cost, personnel training and advance mobilization cost (CDIG, 2014). These other capital costs amounted to 12,093,553,353TSh and covered a share of 12.6% (Table 8).

Unfortunately, the distribution of costs in capital cost for developing countries are not available. Due to that, costs for Dodoma wind farm project were compared with costs for developed countries. As indicated in Table 9, the capital cost for typical onshore wind power systems in developed countries were broken into: cost shared by percentages in wind turbine (65-84%), grid connection (9-14%), construction (4-16%) and other capital cost (4-10%). The calculated results for Dodoma wind farm project (Table 8) and cost for typical onshore wind power systems in developed countries (Table 9) showed similar figures. Particularly, wind turbine cost for Dodoma was 67.9% that is similar 6% to the minimal cost in developed countries.

According to IRENA report (2012) the capital cost of a wind power project is dominated by the cost for the wind turbines (this does not only include towers but also installation) and this can be as much as 84% of the capital cost (Table 8). Similarly, for other renewable technologies, the high upfront costs of wind power can be a barrier to their uptake, despite the fact there is no fuel price risk once the wind farm is built (ibid).

Table 9: Capital Cost Breakdown for Onshore Wind Power Systems in Developed Countries and in Tanzania

Type of costs	In developed countries*	In Tanzania for Dodoma**
Wind turbine and installation costs (%)	65-84	67.9 (58.6+9.3)
Grid connection cost (%)	9-14	3.1
Construction cost (%)(without installation costs)	4-16	16.3
Other capital cost (%)	4-10	12.6

Source: * IRENA (2012).
** Author (2016).

Construction cost for planned wind farm is 16.3% and it's close to the maximum values in developed countries (Table 9). That comparability with maximum values is because of the immaturity of the wind market in Tanzania and due to that, absence of skilled personnel. Again, grid connection cost accounted for 3.1% compared to the same costs in the developed countries that vary 9-14%. Other capital cost in the developed countries varies in percentages 4-10% compared to related cost in the planned wind farm 12.6% that is, 9% above that in the developed countries. This is due to costs of components included in the other capital costs which vary depending on turbine size, as well as the country of installation, land ownership structure and the nature of the soil.

In addition to this capital costs for two more hub positions 25 m and 45mwere calculated. This could help to justify choice of the best hub position for a planned project. The increment of costs for different hub positions, were calculated from the capital costs for 65m above ground surface using the proportional method. The costs of wind turbines and their installations for hub position 65 m were used as 100% of costs and were recalculated for other hub positions (25 m and 45 m) (Table 10). Greatest cost belongs to project with hub position 65m and for other hub positions cost tends to decrease. This implied that, different hub heights of the wind turbine would attribute different costs depending on its height of it. Higher hubs would attribute to higher costs and lower hubs would be always cheaper. This is in line with Lee *et al*., (2014) who assert that, prices of wind turbine continue to vary significantly with hub heights within the markets because the height of the hub has effect not only on wind speed but also on annual energy production, and any change of one hub height to another for highly wind speed and maximum energy production increases financial terms as well (Lee *et al*., 2014).

Table 10: Capital Costs of Projects with Different Hub Positions in TSh

Costs	Hub position (m)		
	25m	45m	65m
Percent of capital (%)	51*	83*	100*
Capital cost (TShs)	63,945,238,503**	84,791,249,723**	95,865,693,184**

Source: * accessed 25.05.2016 on web-site: http://potential168.en.made-in-china.com/product-group/moeEprqdvQWt/Construction-Hoist-catalog-1.html.
** Author (2016).

4.2.3 Investment Costs

Investment costs usually account for those costs associated with project financing (EWEA, 2009).Investment costs are for only the upfront cash flow as a utility to get the power plant. Sometimes, these are referred to as overnight costs; since it is what one would have to pay if the power plant could be built one night (Benth *et al.*, 2014). Also EWEA (2009) concurs that, total costs are required in investing in wind energy project, as wind power is becoming economically competitive and considered to be fully commercial. Generally, investment cost for planned project will be equal to capital costs plus interest of loan.

Due to the size of a planned project for Dodoma Municipality, there a need for loan as adopted for Singida wind farm project (CDIG, 2014). An annual interest rate for the whole project could be as 2.0% with possible credit period of 20 years and the loan could be repaid by means of average capital twice a year. Similar strategy for loan payments was adopted for Singida wind farm project (CDIG, 2014). Based on the interest rate of 2% and loan duration of 20 years was calculated on interest of loan in Tanzanian Shillings (Table 11).

Table 11: Interest of Loan for Project with Different Hub Positions in TSh

Parameter	**Costs, TSh**	**%**
25m		
Capital cost (TSh)	63,945,238,503	71
Interest of loan (TSh)	25,578,095,401	29
Total cost of a project (TSh)	**89,523,333,904**	**100**
45m		
Capital cost (TSh)	84,791,249,723	71
Interest of loan (TSh)	33,916,499,889	29
Total cost of a project (TSh)	**118,707,749,612**	**100**
65m		
Capital cost (TSh)	95,865,693,184	71
Interest of loan (TSh)	38,346,277,274	29
Total cost of a project (TSh)	**134,211,970,458**	**100**

Source: Author (2016).

As indicated in Table 11, the capital cost of a project at different hub positions (65, 45 and 25 m) covered 71% of the total cost of the project while interest of loan (with interest-rate 2% and 20 years period) covered 29% of the total cost of a project. Compared to other related studies (EWEA, 2009; IRENA, 2012) the interest of loan could cover even up to 40% of the total cost. In Tanzania for instance, after the investment pays off, the cost of producing electricity from wind energy would be lower than any other fuel based technology and hence, would be generally lower than the electricity price. Again, the longer the wind turbine runs after the pay-back time, the more profitable the investment (EWEA, 2009).

Capital investment cost is associated with static cost per power supplied to the user. It is usually affected by the capacity of the wind turbine, the low capacity increases the capital investment costs while the higher one decreases them (Gupta, 2012). Generally, capital investment cost is the ratio of the total costs of the project to the theoretical wind turbine capacity. The capital investment costs (USD/kW) could be calculated by formula 15.

$$\text{Capital investment cost} = \frac{\text{total cost of the project (USD)}}{\text{theoretical wind turbines capacity (kW)}} \tag{15}$$

The capital investment costs of Dodoma Municipality wind farm was calculated in USD/kW in order to compare it with the capital investment cost in developed countries which is expressed in USD/kW. For that purpose, the total cost of the projects with three hub positions was recalculated from TSh/kW to USD/kW (Table 12).

The results shows that the project with hub position at 25 m has minimal capital investment costs due to the lowest investment into wind turbines and its installations, while the wind turbines capacity remains the same as for other hub positions (22,500 kW). The highest hub position has the maximal capital investment costs due to intensive capital investment.

Table 12: Capital Investment Costs

Hub position	Total cost of a project		Theoretical wind turbines capacity, kW (See paragraph 4.2.1)	Capital investment cost, USD/kW
	TSh	USD		
25 m	89,523,333,904	41,127,818	22,500	1,828
45 m	118,707,749,612	54,535,399	22,500	2,424
65 m	134,211,970,458	61,658,177	22,500	2,740

Source: Author (2016).

The capacity of the wind turbines used for calculation of the capital investment cost was theoretical. While in reality of power generation with wind turbines is annual energy production will depend on the wind speed at the height of the hub. The higher hubs will have stronger winds with longest periods in a year.

According to other studies (Blanco, 2009; EWEA, 2009; Douglas-Westwood, 2010; Make Consulting, 2011), the capital investment cost of wind farm projects in developed countries range 1,700-2,450 USD/kW. In this concept, the additional increment of the capital investment cost for Dodoma project would be USD 128-290 per kW more than in developed countries. This could be due to immaturity of wind industry in Tanzania, absence of skilled staff, the local manufacturers and competition in wind market.

4.2.4 Operation and Maintenance Costs

Wind turbines like other industrial equipment, require operational and maintenance service. This leads to longer run of the wind turbines for more profitable investment. In this sense, O&M costs are expenses which constitute a sizeable share of the total annual costs of a wind turbine to keep it running (EWEA, 2009).O&M costs are related to a limited number of cost components, and include: insurance, regular maintenance, repair and spare parts. The cost of O&M components tend to increase as the turbine gets older because costs for repair and spare parts are particularly influenced by turbine age. EWEA (2009) pointed out that, during the first two years (year 1-2) of wind turbine life time there is no O&M costs because a turbine is usually covered by the manufacturer’s warranty. O&M costs could be calculated as:

$$O\&M = CXO\&M_i,\text{TSh} \tag{16}$$

Where O&M – total operational and maintenance cost, TSh; C – wind farm project annual capacity, kWh; $O\&M_i$ – operation and maintenance cost in each year (3-20) of wind turbine use, TSh/kWh. Both parameters are studied below:

4.2.4.1 Annual Capacities of Projects

The annual energy yield of a wind turbine is of fundamental importance in the evaluation of any project. The power is combined with the maximum period for power generation to give the projection of the energy that could be generated throughout the year, as the formula shows below:

$$E = P \times T \qquad \text{(Formula 5, see paragraph 2.2.2)}$$

Where E- annual energy generated (kWh); P - is power in watts (kW); T - is time for power generation in a year in hours (h).

The power (P, kW) could be calculated using the formula 6 (See paragraph 2.2.2).

$$P = \frac{1}{2}\rho \times A \times V^3 \times C_p$$

Where: P - is power in watts (W); ρ - is the air density in kilogram per cubic metre (kg/m^3); A - is the swept rotor area in square metre (m^2); V - is the wind speed in meters per second (m/s); Cp-is Power Coefficient, energy in watt per hour (Wh) and time in hours (h).

Air density is the mass per unit volume of earth's atmosphere that varies with altitude and temperature. In addition, within an atmospheric layer, the temperature variation is a function of the location altitude that attributes also to variation in air density of local sites, since moist air is less dense than dry (Gipe, 2004). As a key parameter when estimating the wind power output energy, air density 1.06 kg/m^3 from Singida wind farm site was used in this study because of climatic consideration. Both Singida and Dodoma are located in semi-arid areas that would experience the similar climates (regime of air temperature, humidity, wind speed and precipitations) and similar air density.

The swept area is the area in which the power in the wind passes through with a particular speed. It is often measured or calculated by the manufacturer from the specified radius of the blade. In this study, the swept area of the turbine was calculated from the length of the turbine blades which is equal to radius of the blades specified in the main parameters of the selected wind turbine used in this study in Table 7 (CDIG, 2014). The equation for the area of a circle in formula (7) was calculated by using swept area for one wind turbine (4396 m^2).

Power coefficient is a measure of wind turbine efficiency. It is given as the ratio of actual electric power produced by a wind turbine divided by the total wind power flowing into the turbine blades at specified wind speed (Watson, 2015). In this study, power coefficient of 0.42 was used as specified in the main parameters of the wind turbine (Table 7). This aligns with Bird (2007) who supports that, the power coefficient value is unique to each turbine type and is a function of wind speed that the turbine is operating in and often measured or calculated by the manufacturer.

The monthly mean wind speed data from Dodoma weather station were used to calculate the wind speed. Long term (1986-2015) monthly mean wind speed at a height of 10 metre above ground was used to calculate long-term annual mean wind speed (5.1 m/s). Then power law was applied and wind speed for different hub positions were calculated (See Table 5). For hub position 65 m above ground, the annual mean wind speed was 6.1 m/s (Table 5) and it was used for calculation of power (Table 13). Similarly, power for other positions was calculated. The time for power generations in hours needed to be known for annual energy generation in the study area. In Table 5 (See paragraph 4.1.2), basing on power law days for potential power generation are given with wind speed above 5.1 m/s. For example, for hub position 65 m above the ground, it is equal to 290 days or 6,960 hours in a year. After that, the annual energy generation (E, kWh) was calculated as power times number of hours potential for power generation to yield an annual energy in kWh. The calculated annual energy 1,545,900 kWh yield was a projection of how much energy would be produced by a single wind turbine annually based on its specifications and calculated annual mean wind speed at 65 m height location. Erich and Von (2005) concur that, the calculation of the annual energy yield of a wind turbine is related to the specification of wind turbine and wind speed at hub height. In particular, analysis of results of annual energy production at different hub positions show that maximum energy could be generated at highest hub, while minimum energy will be generated at lowest hub as per wind speed distribution and period for power generation. Generally, the wind farm including 15 wind turbines with 65 m hub position would generate 23,188,510kWh annually according to annual energy production (Table 13, column 7).

Table 13: Calculated Annual Energy Production for Different Hub Positions

Hub position, (m)	V, (m/s)	Power		Time, (hr)	Annual energy, (kWh)	
		W	kW		1 wind turbine	15 wind turbines
1	2	3	4	5	6	7
25	5.6	171,849	171.849	6,432	1,105,333	16,579,995
45	5.9	200,974	200.974	6,840	1,374,659	20,619,885
65	6.1	222,112	222.112	6,960	1,545,901	23,188,515

Source: Author (2016).

4.2.4.2 Operational and Maintenance Cost in each Year of Wind Turbine Use

Data about O&M costs change with the wind turbine use has been extracted from the graph of the O&M costs reported for selected sizes and types of wind turbines in Jensen *et al* (2002). The used graph shows changes of O&M cost during wind turbine exploitation. Particularly, the values of O&M cost for 3 different types of wind turbines were detected in 11 years. After that data were averaged and O&M costs calculated in each year of turbine exploitation. Basing on the graph (Figure 9) of O&M cost change within 11 years period, trend line was derived and corresponding equation shows increment of O&M cost from year to year of wind turbine use. Equation was used for calculation of O&M cost in relation to the year of its use.

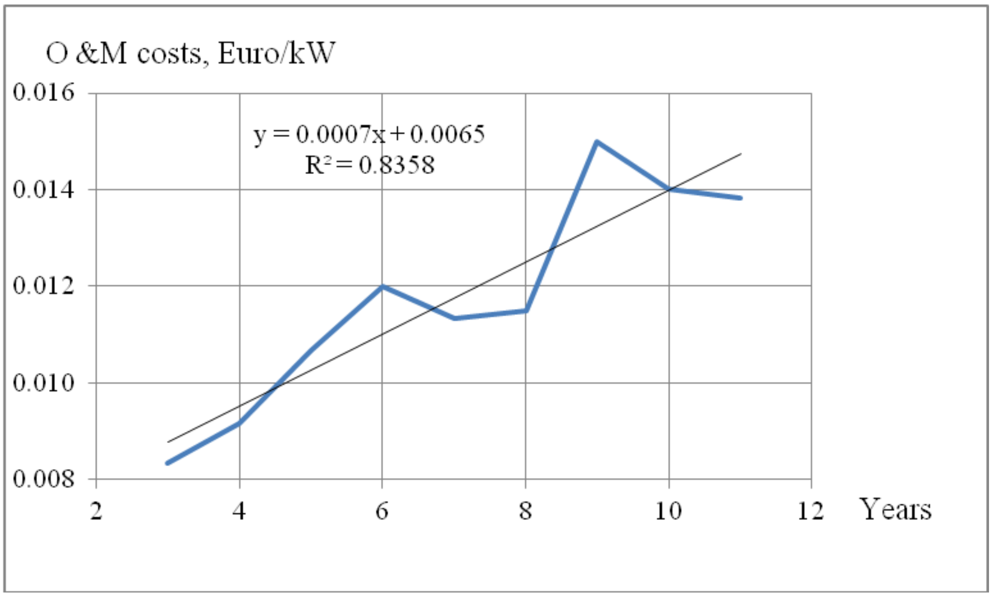


Figure 9: Operational and Maintenance Cost (O&M, Euro/kW) per Kilowatt of Generated Energy in Exploitation Period

Source: Author (2016) based on data from EWEA (2009).

Costs were calculated in EURO/kW for years 3-22 (20 years period), because years 1-2 would allocated for construction of the wind farm and in those years it would not operate. Additionally, EURO was converted into Tanzania Shillings through the exchange rates of the CRDB Bank which was calculated by means of average between buying (EURO 1 = 2,382.00 TSh) and selling (EURO 1 = 2,522.00 TSh) rates as follows: EURO 1 = 2,452.00 TSh (Table 14, column 2). Exchange rates were consulted online on the CRDB website (accessed 14.06.2016 on web-site: http://crdbbank.com/tz/treasury-services/exchange-rates.html).Annual capacities of wind farm projects were estimated in paragraph 4.2.4.1 for projects with different hub positions (Table 13, column 6). The total operational and maintenance costs were calculated for all hub positions on a base of formula 16. The results for years 3-22are presented in Table 14.

Table 14: Operational and Maintenance Cost for Project with 65 m Hub for 20 years

Year	O&M cost, TSh/kWh	O&M cost in exploitation period, TSh		
		25 m	45 m	65 m
1	2	3	4	5
3	0*	0*	0*	0*
4	0*	0*	0*	0*
5	21	23,308,378	28, 987, 709	32, 598, 724
6	23	25, 205, 572	31, 347, 174	35, 252, 108
7	25	27, 102, 765	33, 706, 639	37, 905, 493
8	26	28, 999, 959	36, 066, 103	40, 558, 877
9	28	30, 897, 152	38, 425, 568	43, 212, 261
10	30	32, 794, 346	40, 785, 033	45, 865, 646
11	31	34, 691, 539	43, 144, 498	48, 519, 030
12	33	36, 588, 733	45, 503, 962	51, 172, 415
13	35	38, 485, 927	47, 863, 427	53, 825, 799
14	37	40, 383, 120	50, 222, 892	56, 479, 184
15	38	42, 280, 314	52, 582, 356	59, 132, 568
16	40	44, 177, 507	54, 941, 821	61, 785, 953
17	42	46, 074, 701	57, 301, 286	64, 439, 337
18	43	47, 971, 894	59, 660, 750	67, 092, 722
19	45	49, 869, 088	62, 020, 215	69, 746, 106
20	47	51, 766, 281	64, 379, 680	72, 399, 491
21	49	53, 663, 475	66, 739, 145	75, 052, 875
22	50	55, 560, 669	69, 098, 609	77, 706, 260

* During first two years of wind turbine life time O&M cost covered by manufacturer's warranty (EWEA, 2009).

Source: Author (2016).

Analysis of the O&M costs show that costs rise with time and in year 18 it would be almost 2 times greater than in year 5 (Table 13). This increase of O&M costs with the time could be linked particularly to costs for repair and spare parts which are particularly influenced by turbine age, starting low and increasing over time. Chang (2011) portrays that, the trend to minimize cost of energy and increase efficiency of wind turbine however, increases operational and maintenance costs year to year.

Wind industry worldwide is still young and developing in terms of new technology and design used. That, unfortunately, does not favour to estimate future O&M cost of the wind turbines after 20 years of their use. According to US Energy Department (2013) the technological development and materials in use result into O& M cost stabilization due to the turbine reliability that improve and the scale wind turbine which increases. Particularly, the variable O&M expenses tied to labour rates, royalties and other cost decline something which makes O&M cost stabilise as they are affected by technology improvement. However, projections that have to do with growing O&M costs would include insurance, property taxes, site maintenance and legal fees because these are not affected by technology improvement (ibid). In support of this, Padraze (2015) reports that, O&M cost stabilization is expected due to wind market stabilization with a gradually increasing share of investments in onshore wind farms which in turn affects operational and maintenance costs. Later these costs could be used for calculation of the Net Present Value (NPV), which would help to evaluate projects.

4.2.5 Economic Lifetime

The economic lifetime of a project depends on the lifetime of the wind turbines. The basic generation costs of a wind power plant, includes the lifetime of the turbine as one of the key elements that determine the basic costs of wind energy. Wind turbines from the international wind turbine manufacturers are usually type-certified to withstand particularly the total cost of producing wind energy throughout the lifetime of production capacity. An average life-time of a wind turbine is 20-30 years, after that it needs to be re-updated (EWEA, 2009). The economic life time of the wind turbine is the whole given period of wind power production within the entire life-time of the capacity. A concern of the economic life time of particular wind turbines for Dodoma wind farm project were planned for 20 years. Thereafter, wind turbines would be re-updated and used in next 20 years life-time period. Due to that cost calculations were done for 20 years period.

Another fact related to economic lifetime is about how low turbulence could increase turbine life time. According to Jha (2011) wind velocity varies over time and space. The particular variation is the result of changes in friction at the surface which is linked to turbulence. Also, terrain features create turbulence that in turn may inflict destruction of wind turbine. In this regard, wind yield in consistent with turbulent environment reduces wind turbine lifetime (ibid). In addition, Rivkin *et al*., (2013) adds that, the result of increased turbulence is material fatigue which reduces life time of the turbines. In turn, it decreases energy production as well as efficiency of the entire system.

On the other hand, wind turbines are usually type-certified to safe by with stand particular local climate class for 20 years, although they survive longer, particularly in low turbulence climates (EWEA, 2009). Rashid (2011) low turbulence gives lower fatigue loads on wind turbine, Due to this fact; they would have an increase of longer life expectancy around 25-30 years.

4.3 The Benefits of Wind Turbine Use

The estimation of benefits of the wind turbines use could be achieved based on the analyzed wind potentiality (See paragraph 4.1). In order to calculate those benefits calculation of power selling benefits as well as estimation of other associated benefits were done.

4.3.1 Economic Benefits

The use of wind turbine supplies the surrounding area with clear, sustainable, renewable electricity that provides a solution to power shortage in the local community (Donnelly, 2012). In particular it defrays a portion of the costs of power supply and utility. This in turn cuts dependency on the utility and results in lower power bills each month. On this particular aspect, Tan *et al*., (2013) concur that, wind turbine use provides abundant power and at affordable rates as compared to costs of power generation based on heavy fossil fuels that would increase high costs of power supply and utility.

The power selling benefit was calculated in monetary terms based on tariffs data and annual capacity of power generation. Data about current tariffs in 2016 was obtained from TANESCO (See paragraph 3.3). Data about annual capacity of power generation was calculated as expressed in section 4.2.4.1 (Table 12). The benefit was accrued in accordance to the tariff category proportionality in percentages and price per tariff. Particularly, the annual amount of the power which could be generated at the wind farm by 15 wind turbines was distributed proportionally to the annual energy consumption of each tariff. Summation of the benefit values for each tariff category gives the total selling benefit in TSh (Table 15).

Table 15: Power Selling Benefit for Project with Hub Positions at 25, 45 and 65 m

Tariff Category	Annual energy (kWh)	Power consumed per tariff category		Price, (TSh)	Benefit, (TSh)
		%	Power, (kWh)		
25 m					
DI	23,188,510	7.1	1,177,179.65	122	143,615,917
T1		61.1	10,130,376.95	356.24	3,608,845,483
T2		15.5	2,569,899.23	195	501,130,349
T3		15.9	2,636,219.21	157	413,886,415
T6		0.4	66,319.98	-	
Total		**100**	**16,579,995**		**4,667,478,164**
45 m					
DI	20,619,885	7.1	1,464,011.84	122	178,609,444
T1		61.1	12,598,749.74	356.24	4,488,178,606
T2		15.5	3,196,082.18	195	623,236,024
T3		15.9	3,278,561.72	157	514,734,189
T6		0.4	82,479.54	-	
Total		**100**	**20,619,885**		**5,804,758,263**
65 m					
DI	16,579,995	7.1	1,646,384	122	200,858,875
T1		61.1	14,168,180	356.24	5,047,272,350
T2		15.5	3,594,219	195	700,872,721
T3		15.9	3,686,973	157	578,854,780
T6		0.4	92,754	-	
Total		**100**	**23,188,510**		**6,527,858,727**

Source: Author (2016)

Analysis of power selling benefit calculations for planned project with different hub positions indicate that, selling power benefit of 6,527,858,727 TSh could be accrued with hub position 65 m ; 5,804,758,263TSh at 45 m and 4,667,478,164 TSh at 25 m. Based on the results, it was observed that, power selling benefit rises with the increase of hub height. The planned project with high hub position will generate more power compared to lower hub position. Due to power law (Yaneer, 2015) wind speed increases with increase of height. Particularly, mean wind speed at 65 m by 13% than wind speed at 25 m. Zayas *et al.*, (2015) concur that, an increase of annual energy production at higher hub height is due to high wind speed and increased period with wind speed potential for power generation.

4.3.2 Other Associated Benefits

4.3.2.1 Socio-Economic Benefit

Wind turbine use would help in launching of investments as well creation of employment opportunities not only to the local community surrounding the area of study but also to people across Tanzania. This would involve Particularly, launching of investments and job creation that would contribute significantly to local economic development and sustainable livelihood programme. As noted by Edmonds *et al.*, (2007), wind energy projects create new short and long term jobs related employment ranging from meteorologists and surveyors to structural engineers, assembly workers, lawyers, bankers, and technicians. The construction and maintenance of infrastructures such as roads to service wind farm project site, would improve access to local residents and other outdoor related activities. For example, the local community would identify and prioritize the most productive and beneficial activities to engage in.

4.3.2.2 Environmental Benefit

The environmental benefit could be achieved through the use of wind turbines. It was observed that, the use of wind turbine for power generation is environmentally friendly because green energy is produced. Global Trends in Renewable Energy Investment (2014) reports that, an estimation of 1.2 gigatons of carbon dioxide emissions have been reduced from being globally released into the atmosphere up to early 2013 due to the use of clean energy harnessed from wind resource. According to Jacobson (2008),tons of carbon dioxide can be emitted through different generation technologies (such as gas, coal, peat). The US Department of Energy report (Spath & Mann, 2000) estimates the greenhouse gas emissions for typical gas fired from power plants based on international emission. The net greenhouse gas, emission is given as carbon dioxide emitted per GW of generated power. As Jacobson (2008) asserts, natural gas fired from power plant technology at generation 1 GW of power emits 484tons of carbon dioxide.

Taking an example of the Kinyerezi-240 Mw gas-fired from power plant now it will over time inevitably contribute to the amount of carbon dioxide emission into the atmosphere at its operation while, use of wind turbines generation will help to decrease amount of gases produced at Kinyerezi gas power plant. This is because part of power demand will be covered by wind turbines use. In particular a generation capacity of 23,188,510kWh (23,188.51 GWh) for planned wind farm project with hub position (See paragraph 4.2.4.1), was calculated into related amount carbon dioxide of emissions (tones/GWh). The carbon dioxide emissions in tones could be calculated using formula 17:

$$CO_2 = \mathrm{C} \times \mathrm{t} \tag{17}$$

Where: CO_2– carbondioxide, tons; C –planned wind farm project capacity, GWh ; t – coefficient of CO_2emission per GWh,tons/GWh.

Table 16: Amount of Carbon Dioxide which could be Prevented for Emission by use of the Wind Turbines

Hub position	Annual energy for 15 wind turbines		Prevented amount of carbon dioxide emission, (tons/year)
	kWh	GWh	
25 m	16,579,995	16.6	8,025
45 m	20,619,885	20.6	9,980
65 m	23,188,515	23.2	11,223

Source: Author (2016).

The greatest reduction of the carbon dioxide emission will be with use of wind turbines with hub at 65 m (11,223 tons/year). With this, more power could be generated by green sources of energy with wind turbines than greater amount of carbon dioxide gas that will be prevented for emission into the atmosphere.

4.3.3 Project Evaluation

In determining the project’s viability or comparing one project among others, the application of the CBA is important. As Boardman *et al.*, (2006) argue that, CBA theory estimates the benefits and costs of projects for two reasons: to determine the project’s viability and to compare one project investment with other competing projects, to determine which is more feasible. Owing to that knowledge, costs and benefits of Dodoma wind farm projects with different hub positions (25,45 and 65 m) were calculated then evaluation of the project was done based on the project evaluation criteria (See paragraph 2.2.1).

4.3.3.1 Discounting of Costs

The overall costs calculations involved cost of project and O&M cost for three different hub positions (25, 45, and 65 m) as it is in formula (18).

$$OC = \sum_{1}^{2} C_1 + \sum_{22}^{5} C_2 \tag{18}$$

Where: OC – overall cost;C_1 – investment costs ; C_2 – operating and maintenance costs.

Investment cost of project was calculated as capital cost of a project and interest of loan (Table 11). O&M cost was calculated in paragraph 4.2.4.2 (Table 13). The discount rate was applied for harmonization of current costs and future benefits (formula 19). Harris and Roach (2013) noted that, discount rate is a helpful mechanism that equates today's money with its value in the future. Its application plays a crucial role in the relative weighting of costs and benefits.

$$DOC = \sum_{1}^{2} C_{1i}/(1+r)^{i} + \sum_{22}^{5} C_{2i}/(1+r)^{i} \tag{19}$$

Where: DOC – discounted overall cost; C_1 – investment costs; C_2 – operating and maintenance costs; and r - discount rate.

The average discount rate for Tanzania in last 5 years (2010-2015) was 5.5%. The Bank of Tanzania (2015) reports that, the inflation rate has been fluctuating year to year and it ranges between 4.8% and 6.4% consecutively in five years (2010-2015). Due to that, it was decided that discount rates at 5% and 6.5% be used. Those two discount rates will help to evaluate projects at different scenarios in the country's economy. Low discount rate will correspond to low inflation, while high discount rate will be showing scenario with high inflation. High discount rate decreases the present value, whereas low discount rate increases present value of the project's economic benefits relative to overall costs.

All costs (investment cost and O&M cost) were discounted with two discount rates and were presented in Appendices2-4 (columns 2, 3, 4, 6).

4.3.3.2 Discounting of Benefits

The project overall benefit was estimated as sum of the power selling benefit, socio-economic benefit and environmental benefit. However, socio-economic and environmental benefits were not quantified into monetary terms due to the fact that methods of their conversion were not available, and valuing environmental benefits into monetary terms is challenging. Harris and Roach (2013) note that, valuing the environment benefits (preventing and absorbing potential pollution) is necessarily a troublesome endeavour, because what nature gives us is priceless and rejects reducing these services to mere monetary values. Due to that, only calculated power selling benefits for different hub positions were discounted at rates of 5% and 6.5% (Appendix 2, 3, 4; columns 8, 10).

4.3.3.3 Net Present Value Criterion

According to Boadway (2006), the Net Present Value (NPV) criterion is the difference between the cumulative sum of the total discounted benefits and the total discounted costs.NPV criterion was applied to evaluate the planned wind farm project for different hub positions (25, 45, and 65) in order to determine the project with which hub position would be profitable (Table 16). Kendrick (2006) argues that, after the NPV has been calculated for all of projects, the entrepreneur compares the particular NPVs then applies the NPV decision rule: accept the project with the highest NPV.

Table 17: NPV for Different Hub Positions, TSh

Year	NPV, TSh					
	25 m		45 m		65 m	
	5%*	6.5%*	5%*	6.5%*	5%*	6.5%*
Year 3	-73,301,678,644	-70,247,843,109	-97,529,848,913	-93,466,638,849	-110,298,336,448	-105,703,175,934
Year 4	-65,779,179,389	-62,096,448,505	-87,871,201,955	-82,956,638,349	-99,407,024,906	-93,847,726,470
Year 5	-58,633,157,110	-54,459,569,197	-78,695,203,194	-73,109,250,852	-89,059,889,200	-82,739,642,223
Year 6	-51,828,837,320	-47,290,090,716	-69,957,917,425	-63,864,494,636	-79,207,454,239	-72,311,334,624
Year 7	-45,349,881,058	-40,559,406,895	-61,638,369,710	-55,185,490,699	-69,826,068,557	-62,521,203,973
Year 8	-39,180,730,619	-34,240,662,326	-53,716,587,912	-47,037,616,889	-60,893,211,442	-53,330,196,290
Year 9	-33,306,572,196	-28,308,645,213	-46,173,554,751	-39,388,369,802	-52,387,438,871	-44,701,647,534
Year 10	-27,713,300,314	-22,739,686,778	-38,991,162,153	-32,207,235,119	-44,288,332,037	-36,601,137,346
Year 11	-22,387,483,963	-17,511,566,824	-32,152,167,779	-25,465,565,885	-36,576,448,336	-28,996,351,750
Year 12	-17,316,334,342	-12,603,425,082	-25,640,153,642	-19,136,468,232	-29,233,274,695	-21,856,954,246
Year 13	-12,487,674,159	-7,995,677,982	-19,439,486,692	-13,194,694,097	-22,241,183,137	-15,154,464,805
Year 14	-7,889,908,387	-3,669,940,511	-13,535,281,286	-7,616,540,509	-15,583,388,458	-8,862,146,257
Year 15	-3,511,996,425	+391,047,135	-7,913,363,461	-2,379,755,032	-9,243,907,945	-2,954,897,637
Year 16	+656,574,413	+4,203,488,418	-2,560,236,907	+2,536,553,000	-3,207,523,003	+2,590,845,945
Year 17	+4,625,814,138	+7,782,595,110	+2,536,949,433	+71,51,995,820	+2,540,257,375	+77,97,207,300
Year 18	+8,405,254,125	+11,142,647,983	+7,390,432,207	+11,484,985,459	+8,013,231,389	+12,684,955,414
Year 19	+12,003,969,995	+14,297,053,791	+12,011,863,033	+15,552,807,198	+13,224,537,559	+17,273,588,294
Year 20	+15,430,603,411	+17,258,398,762	+16,412,336,467	+19,371,688,517	+18,186,686,259	+21,581,410,746
Year 21	+18,693,382,824	+20,038,498,811	+20,602,416,636	+22,956,863,832	+22,911,589,753	+25,625,607,393
Year 22	+21,800,143,233	+22,648,446,691	+24,592,162,594	+26,322,635,263	+27,410,590,783	+29,422,311,228

* -discount rates; “-“– costs more than benefits; “+” – benefits more than costs.

Source: Author (2016).

Additionally, for calculation of the NPV the discounted data were used. All expected future benefits over the life time of the project deliverable need to be discounted to the present value, and from these all discounted project costs are deducted to give a single monetary measure. The higher the NPV calculated, the greater will be benefits of the project. The NPV for planned wind farm project over time could be calculated by combining the discounted benefits (at 5% and 6.5%) minus overall costs (at 5% and 6.5%) respectively for years 3-22 (Table 16).

Analysis of the NPV calculations shows that projects with different hub positions are viable because the benefits overcome the costs. But different years for its achieving are needed. Particularly, the benefits for hub position at 25 m will cover costs in the year 16 at 5% discount rates and one year before at 6.5% discount rate. Wind turbines with hub positions at 45 m and 65 m will cover the costs in the same years. For 6.5% discount rate the positive NPV and hence benefits cover the costs are detected in year 16. For 5% discount rate the benefit will cover costs in year 17.

Based on the results; it is implied that, the payback period of planned wind farm project for hub position 25 m would be only one year shorter than similar period for 45 m and65 m hub positions. Such difference in periods between hub positions for receiving positive NPV (benefit cover costs) is not significant, hence the evaluation between projects need to be used as additional criterion.

4.3.3.4Benefit-Cost Ratio Criterion

Benefit-cost ratio (BCR), is the ratio of project benefits versus project costs. It involves summing the total discounted benefits for a project over its entire duration/life span and dividing it over the total discounted costs of the project (Harris & Roach, 2013). Gopalakrishnan *et al*., (2014) also noted that calculated BCR value can be used as a measure of cost-effectiveness to determine the economic viability of a project. The BCR may give a good sense of the desirability of a single project among others based on the project benefit-cost ratios (Harris & Roach, 2013). In this respect, it can be used to select the best project among others. BCR criterion was applied to evaluate projects with different hub positions (25, 45, and 65) in order to determine more cost-effective and profitable (Figure10). BCR criterion also uses discounted data (benefits and costs).

Table 18: Benefit-Cost Ratios (BCR) for Projects with Different Hub Positions

Hub position in m above ground	Discount rate	BCR_{20}*	BCR_{30}**
1	2	3	4
25 m	5%	1.70	3.37
	6.5%	2.00	4.35
45 m	5%	1.60	3.17
	6.5%	1.88	4.09
65 m	5%	1.59	3.15
	6.5%	1.87	4.07

* Benefit-cost ratio for 20 years.
** Benefit-cost ratio for 30 years.

Source: Author (2016).

The analysis of the results above shows that, BCR for projects with all hub positions (25, 45, 65 m) is positive. The best BCR was detected for hub position 25 m, while it was lower at hub position 65 m (Table 18). The project with hub position 25 m has higher BCR. This demonstrates that, there low costs in comparison to the benefits. Benefits are in 2 times greater than costs after 20 years of the turbine use (BCR=2.0). Despite the highest benefits from power selling, the projects with highest hub positions (45 m and 65m) will be less effective due to more high capital cost and hence increased interest of loan. BCR for that hub position, has almost similar values at 5% (BCR_{45}=1.6; BCR_{65}=1.59) and 6.5% discount rates (BCR_{45}=1.88; BCR_{65}=1.87) in 20 years (Table 18).

Additionally, BCR was calculated after 30 years of wind farm use (Table 18, column 4). It was done because the power selling benefits for higher hubs was greater than benefits for lower hub position. Hence, after 30 years of wind farm use, the benefit could significantly overcome the overall costs. However, the analysis of the results proved that the project with hub at 25 m remained more cost effective (BCR25=4.35).Therefore, the project with hub position at 25 m is recommended for development and implementation.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATIONS

5.0 Introduction

The study sought to undertake the cost-benefit analysis of wind turbine installation and use in Dodoma municipality. Specifically, the objectives were to perform long-term analysis of wind speed and detect its trend, analyze the costs of wind turbine installation and use and finally, estimate the benefits of wind turbine use. The chapter starts with the presentation of the summary of the results, conclusion, recommendations, and ends up with suggested areas for further studies.

5.1 Summary of the Results

5.1.1 Wind Resource Assessment

In performing the long-term analysis of wind speed, the wind data of daily average wind speed at height of 10 metres (location of anemometer) were collected from Dodoma Airport meteorological station for long-term time series (1986-2015). Analysis of the results indicated that, long-term annual mean wind speed was at 10 m equal to 5.1 m/s. This is higher than the minimal average wind speed potential for power generation (5.0 m/s). However, the extrapolation of the wind speed (5.1 m/s) by power law to other heights (25, 45 and 65 m) helps to prove that wind speed increases with height. At the height of 25 metres, wind speed was 10% more, while at 45 and 65 metres it was 16% and 20% higher. Likewise, the period with the days potential for power generation increased. At the height of 25 m period for power generation was one month longer than at 10 m height, whereas at 45 m and 65 m were 2 months and 2.5 months longer. Also, analysis of the wind speed trend showed insignificant (*a*= -0.02) downward trend. Additionally, the residual mass curve showed un-ended half-cycles due to the limited data. Particularly, the rising of the wind speed was detected during 1991-2005 (rising half-cycle). While falling of the wind speed was detected in years 1986-1991 and 2006-2015 (falling half-cycles). After 2019 wind speed could start rising till 2033. Generally, based on the analysis of wind speed data, there was detected seasonal potential wind resource in the study area.

5.1.2 Costs of Wind Turbine Installation and Use

The analysis of costs of wind turbine installation and use were involved, as well as investment costs and operational and maintenance costs. Generally, the results indicated that, a breakdown of investment costs by percentages included capital cost (71%) and interest of loan (29%). Also the study found that operational and maintenance depended on annual energy production. This was minimal in the first years and rose according with its use. Finally, the investment cost and O&M costs were discounted at 5% and 6.5% rates for 25, 45 and 65 m hub positions. Generally, costs of wind turbine installation and use were found higher at high hub position (65 m) compared to lower hub positions (45 and 25 m).

5.1.3 Benefits of Wind Turbine Use

Estimated benefits of wind turbine use included economic, socio-economic, and environmental benefits. Under socio-economic benefits there were found improved employment opportunities, infrastructures such as roads and etc. Likewise, reduction of annual emission of carbon dioxide, supply of renewable power could be detected as environmental benefit. Power selling benefit was evaluated under the economic benefit. In particular, power selling benefit was calculated into monetary term based on tariffs data for different hub positions. The results revealed that hub position 65 m could offer higher power selling benefit compared to other hub positions (45 m and 25 m).

5.1.4 Project Evaluation

In determining the project's viability or comparing it among others, NPV and BCR criteria were used. Analysis of the NPV results showed that projects with all hub positions (25, 45 and 65 m) are viable, this is because the benefits cover the costs in different years for its achievement. Such difference in periods between hub positions for receiving positive NPV (benefit cover costs) was not significant. Additionally, analysis results with BCR criterion showed that all projects could be profitable. The best BCR was detected for hub position 25 m, where benefits would be 2 times greater than costs after 20 years of its use (BCR=2.0). Similarly, after 30 years of wind farm use, the benefits could significantly overcome the overall costs (BCR=4.35) compared to other hub positions (45 and 65 m).

5.2 Conclusion

This study undertook Cost-Benefit Analysis of wind turbine installation and use, the methodology used to determine the viability and profitability of the project. In addition, a number of applications were conducted and the study came up with various results from which the conclusion is drawn.

The results revealed that long-term monthly mean wind speed for 30 years period (1986-2015) at the height 10 m above ground was potential for power generation in the area of study. With the extrapolation by power law to other heights, wind speed was found to be higher. Thus, the seasonal potential of the wind resource was detected in the study area. Additionally, the results revealed a variability trend of wind spend over 30 years period that influenced by atmospheric circulation changes that in turn had an effect on wind speed.

It was found that costs of wind turbine installation and use were increased with the increase of hub position of the wind turbine, which additionally impacted the level of benefits. Also, it was found that the estimated benefits of wind turbine use ranged from electric power supply, selling of generated power into monetary, employment opportunities and improved infrastructures (roads) that linked outdoor activities. With environmental conservation, it was found that wind power generation resulted in reduction of annual carbon dioxide emissions. In particular, the emission reduction depended on the capacity of the wind turbine and annual generated power output. Generally, it was revealed that the planned wind farm project with hub position 25 m would be more viable and profitable based on the BCR criterion.

5.3 Recommendations

The recommendations for this study are based on the results of the study:

The results demonstrated that potential wind distribution for wind power generation was seasonal in the area of study. Therefore, it is recommended that wind power could be used as an option for power generation during the months with wind speed potential for power generation to supplement other sources.

Also it was demonstrated by results that wind power is clean and environmentally sustainable as it reduces the amount of emitted greenhouse gases in the atmosphere. Hence it is recommended that areas with detected wind resource potential in the country should be used for wind power generation to support reduction of the carbon dioxide emission.

Application of the cost-benefit analysis showed that all projects were profitable, but only one with hub position 25 m offered benefits 2 times more than costs. Therefore, it is recommended that there should development and establishment of wind turbines with hub position 25 m in Dodoma Municipality.

This study presented a comprehensive knowledge on costs analysis of wind turbine installation and use. Thus, it is recommended to government and non-governmental institutions, investors to share information for better practice in wind farm projects.

5.4 Areas for Further Research

Various studies related to this study were conducted and were of enormous significance. As a quiet scientific involvement, the researcher acknowledges that there is a lot which need to be revisited despite the fact that this study focused on cost-benefit analysis of wind turbine installation and use. The following are suggested areas for further research:

The results showed variation of the half cycle trend of wind speed in the area of study due to the limited period of the observed data (30 years) as accessed in TMA. Therefore, it is suggested that in further studies related to wind resource, maximal period of observed data should be used for detection of the whole cycles of wind speed.

This study concentrated on the costs and benefits of wind turbine installation and use; however the methodology could easily be adapted to incorporate the costs and benefits for other forms of renewable energy generation (solar and tides) for example. A broad comparative study on renewable energy generation would provide useful results as it would indicate source of energy with more potentiality.

The O&M costs calculated in this study were based on annual output capacity of the planned wind farm and standard economic life of the wind turbine (20 years) onshore increased over time. This has to do especially with climatic conditions of the area where wind turbine installed are impacting on its life time. Analysis of O&M costs in respect of economic life time of the wind turbine would provide an interesting area for future research. Again, the study about O&M cost change would be more useful if it would use more years.

This study did not take into account the factors of the wind growing technology. An interesting area for future research would be to analyze different factors affecting wind growing technology and therefore determining their impacts on costs and benefits of wind power generation.

REFERENCES

Ahlborg, H.and Hammar, L. (2011), *Drivers and Barriers to Rural Electrification in Tanzania and Mozambique – Grid extention, Off-grid and Renewable Energy Sources*. World Renewable Energy Congress. Policy Issues, Linköping.

Ahmed, H.and Abouzeid, M. (2001), Utilization of Wind Energy in Egypt at Remote Areas. *Journal of Renewable Energy*, Volume 23.Pages 595-604.

Al-Abbadi, N. (2005).Wind energy resource assessment for five locations in Saudi Arabia. *Journal of Renewable Energy* .Volume 1489–1499.

Alam, M. Shafiqur, R. Josua, M. and Luai, M. A. (2011), *Wind Speed and Power Characteristics at Different Heights for a Wind Data Collection Tower in Saudi Arabia*. World Renewable Energy Congress, Linkopimg ,Sweden.

Al-Tajer, Y, and Poullikkas, A. (2015), Parametric Analysis for the Implementation of Wind power in United Arab Emirates. *Journal of Renewable and Sustainable Energy Reviews,* Volume 52 .Pages 635–644.

Amadi, S. O. and Udo, S. (2015), Analysis of Trends and Variations of Monthly Mean Wind Speed Data in Nigeria.*IOSR Journal of Applied Physics (IOSR-JAP) e-ISSN: 2278-4861.Volume 7, Issue 4 Ver. I , PP 31-41.*

American Wind Energy Association (2014), *Windpower Inaugurates Vision of a Far Larger Industry,* American Wind Energy Association news release on 6/5/.2014.

Archer, C. L., and Jacobson M. Z. (2005), Evaluation of global wind power, *Journal of Geophysics. Resources* 110, D12110, doi:10.1029/2004JD00546.

Avis,M. and Maegaard, P. (2008), Worldwide Wind Turbine Market and Manufacturing Trends. XMIRE Danish Windmill Pioneers. [http://en.wikipedia.org/wiki/List_of_wind_turbine_manufacturers], web site accessed on 15/6/2016.

Babbie, E. (1998), *The Practice of Social Sciences Research, 9th education,* Wadsworth: USA.

Bailey, K. (I999), *Methods of Social Research*, Macmillan Publishing Co: UK

Bank of Tanzania (2015), *Monthly Economic Review*. [http://www.bot.go.tz/Publications/MonthlyEconomicReviews/MER%20APRIL%202015.pdf] website accessed 7/03/2016.

Benth, F.E; Kholodnyi, V.A; Laurence, P (2004), *Quantitative Energy Finance – Modelling , Pricing Hedging in Energy and Commodity Markets* .Springer Science +Business Media: NewYork.

Berg, J.; Mann, J and Nielsen, M. (2013), *Introduction to Micro Meteorology for Wind Energy,* Technical University of Denmark (DTU): Lyngby, Dermark.

Bharali, B. (2015), Estimation of Reservoir Storage Capacity by using Residual Mass Curve. *Journal of Civil Engineering and Environmental Technology* Volume 2.

Bhattacherjee, A. (2012), Social Science Research: Principles, Methods, and Practices- Textbooks Collection. Book 3[*.http://scholarcommons.usf.edu/oa_textbooks/3],*web site accessed on 11/7/2015.

Bianchi,F.D., De Battista,H., Mantz, R.J. (2007), Wind Turbine Control Systems Principles, Modelling and Gain Scheduling Design. [*http://www.springer.com/978-1-84628-492-2],*web site accessed on 10/5/2016].

Bird, J. (2007), *Engineering Mathematics, 5th Edition*. Elsevier Ltd: UK.

Bloomberg New Energy Finance (2011), *Catalyzing Investment in Low-Carbon, Climate Resilient Growth*, presentation to OECD Workshop, Paris.

Boadway, R. (2006), *Principles of Cost-Benefit Analysis*, Queen's University, Public Policy Review, Kingston, Canada Vol.2, No.1

Boardman, A. E., Greenberg, D. H., Vining, A. R. and Weimer, D. L. (2006), *Cost-benefit Analysis: Concepts and Practice 3rd edition*, Prentice Hall: New York.

Brains, C., Willnat, L., Manheim, J. and Rich, R. (2011), *Empirical Political Analysis: Quantitative and Qualitative Research Methods*, Longman: New York.

Canada Wind Energy Association (2009), WindVision 2025 Powering Canada's future: Backgrounders on Wind Energy. Ottawa, Canada: Canada Wind Energy Association. [*http//:www.canwea.ca/images/uploads/File/Windvision_backgrounder_e.pdf.]*, web site accessed on 8/2/2016.

Chang, F (2011), *Structural Health Monitoring: Condition Based on Maintenance and Intelligent StructuresProceedings of the 8th International Workshop on Structural Heath Monitoring,* Stanford University: USA.

China Dalian International Economic and Technical Cooperation Group (2014), *Revised Feasibility Study Report on Development ofSingida Wind Farm Project*, *Unpublished report*, China Dalian International Economic &Technical Cooperation Group Co., Ltd.

Chuan-Zhong, L. and Karl-Gustaf, L. (2010), *Dynamic cost-benefit analysis of large projects: The role of capital cost*. Working paper ISSN 1653-6975.

Coppin, A.P. Ayotte ,K, and Steggel, N. (2003), *Wind Resources Assessment in Australia –A planners' Guide* . Wind Energy Research Unit CSIRO Land and Water version 1.1 October 2015.

Cooperative Rural Development Bank Exchange rates [http://crdbbank.com/tz/treasury-services/exchange-rates.html], website accessed 14/06/2016.

Creswell, J.(2003), *Research Design: Qualitative, Quantitative and Mixed MethodsApproach.Thousand Oaks*, Sage Publications: California.

David, R., Ngulube, P., and Dube, A. (2013), A cost-benefit analysis of document management strategies used at a financial institution in Zimbabwe, *Journal of Information Management* Volume 15.

Dawson, C. (2002), *Practical Research Methods*. UBS Publishers' Distributors: New Delhi.

Denny, E. (2007), *A Cost Benefit Analysis of Wind Power, Thesis Report*. National University of Ireland, Ireland.

Donald, M. (2012), *MetroWind-Metrowind Van Saddens Wind Farm. PrEng, PrCPM Feasibility at Selected Sites in Tanzania*, Draft Final Report, May 2003.

Donnelly, T. (2012), *African Clean Energy Developments- Cookhouse Wind Farm*,NERSA Presentation March 2012.

Draxl, C., Purkayastha A. and Parker, Z. (2014), *Wind Resource Assessment of Gujarat*, Technical Report .India.

Dunnett, S. (2000), *Small Wind Energy Systems for Battery Charging*, Practical Action Technical Information Leaflet.

Edmonds, J.A., M.A. Wise, J.J. Dooley, S.H. Kim, S.J. Smith, P.J. Runci, L.E. Clarke, E.L. Malone, and G.M. Stokes. (2007), *Global Energy Technology Strategy: Addressing Climate Change*. Richland, WA: Global Energy Strategy Technology Project.

Emeis, S. (2013), *Wind energy Meteorology –Atmospheric Physics for Wind Power Generation*.Spinger: Heidelberg.

Energy Environment and Development Network for Africa (2012), Clean Energy and Water: An Assessment for Services for Adaptation to Climate Change. Final assessment report: [*http:// www.afrepren.org*], web site accessed 20/2/ 2016.

Erich, H. and Von, R. (2005*), Wind Turbines: Fundamentals, Technologies, Application, and Economics*, *2ndEdition*: Springer, Germany.

European Environment Agency (2009), *Europe's onshore and offshore wind energy potential: An assessment of environmental and economic constraints*. Office for Official Publications of the European Communities: Luxembourg.

European Wind Energy Agency (2009), *Wind Energy –Fact: A Guide to the Technology*, *Economics and Future of Wind Power*. Earth San Publisher: UK

Ezechukwu, O. (2013), The Wind Powered Generator. IOSR *Journal of Electrical and Electronics Engineering,*Volume 7, Issue 5 PP 25-29.

Gallion, B. and Eisner, S. (2004), *The Urban Pattern City Planning and Design*. CBS publishers & Distributors: New Delhi.

Gerring, J. (2007), *Case Study Research: Principles and Practices*. Cambridge University Press: New York.

Gesellschaft für Technische Zusammenarbeit (2009), *Business Guide Tanzania: World Energy Outlook*, International Energy Agency -OECD Publishing: Eschborn.

Ghosal, M. (2005), *Vertical Wind Speed Gradient - Renewable Energy Resources*. Alpha Science International Ltd: London.

Gipe, J. (2004), *Wind Power: Renewable Energy for Home, Farm and Business*. Chelsea Green Publishing Company: UK.

Global Trends in Renewable Energy Investment (2014), Global Trends Report, Germany [*http://fs-unep-centre.org/publications/gtr-2014*], web site accessed 13/5/2015

Global Wind Energy Council (2014), *Global Wind Report Annual Market Update*, Germany.

Gopalakrishnan, K., Steyn, W and Harvey, J. (2014), *Climate Change, Energy, Sustainability and Pavements*. Springer: Heidelberg, Berlin.

Grigsby, L. (2012*), Electric Power Generation, Transmission and Distribution 3rd Edition*. CRC Press, Taylor &Francis Group: USA.

Gupta, M.K. (2012), *Power Plant engineering* .PHI Learning Private Limited: New Delhi.

Håkansson, A. and Nilsson, P. (2008), *Windpower Africa - Manual*. Unpublished work, Halmstad University.

Hammar, L. (2011), *Distribution of Wind and Solar Energy Resources in Tanzania and Mozambique*. Chalmers University of Technology: Gothenburg, Sweden.

Hankins, M. (2009), Tanzania's Wind Energy Market- Target Market Analysis. Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ). GmbH Potsdamer Platz : Berlin, Germany.

Hanslian, D., Hosek, J. (2011*), The Use of Measures –Correlate –Predict Methods in Wind Wind Energy Applications.* Annual Meeting Abstract, 8, Ems 2011-739.

Harris, J. M. and Roach, B. (2013), *Environmental and Natural Resource Economics: A Contemporary Approach Third Edition*. M.E. Sharpe: London, England.

Hau, E. and Renouard, V. (2006), *Wind Turbines-Wind Turbine Costs: Springer-Verlag Berlin Heidelberg.* Springer Berlin Heidelberg; Berlin.

Hogan, M. (2010), *Abiotic factor. Encyclopedia of Earth. eds Emily Monosson and C. Cleveland*. National Council for Science and the Environment, Washington DC.

Ingram J, S Willis and McIntyre S. (2003), *Method and Crane for Installing, Maintaining and Decommissioning Wind Turbines*, US Patent, Wind Rose Data. Natural Resources Conservation Service.

International Renewable Energy Agency (2010), *Renewable energy technologies: cost analysis series*. June 2010. Wind Power. Issue 5/5.

Isemer, H.J. (2000), *Trends in Marine Surface Wind Speed: Ocean Weather Stations versus Voluntary Observing Ships*. GKSS - Research Centre Institute for Atmospheric Physics. Geesthacht, Germany.

Jet, S. (2008), *How to Read Weather Maps: National Weather Service*. Retrieved 2015-12-16.

Jha , A.R (2011), Wind Turbine Technology . Tylor & Francis Group, LLC: New York.

Jonsson, C. (2010), *Statistical Analysis of Wind Data Regarding Long-Term Correction*. Uppsala University, Sweden.

Kaldellis, J.K.and Kavadias, K.A. (2007), *Cost–benefit analysis of remote hybrid wind–diesel power stations: Case study Aegean Sea islands*. Energy Policy, Volume 35, Issue 3, Pages 1525–1538.

Kasasi, A. and Kainkwa, R. (2002), Assessment of Wind Energy Potential for Electricity Generation in Setchet, Hanang, Tanzania, *Journal of Science*: Dar es Salaam.

Kendrick,T. (2006), *Results Without Authority: Controlling a Project When the Team Doesn’t Report to You*. AMACOM, American Management Association: New York.

Kimambo, C. (2002*), Appropriate Technologies for Renewable Energy Development in Tanzania*. Rathaus Hamburg: Altoona.

Kothari, C. (2005), *Research Methodology, Methods and Techniques,* Wishwa: New Delhi.

Kothari, D.P., Singal, K.C. and Ranjan, B. (2011*), Renewable Energy Sources and Emerging Technologies 2^{nd} Edition* . PHI Learning Private Limited: New Delhi.

Kreith, F.(2014), *Principles of Sustainable Energy Systems 2^{nd} Edition*. CRC Press, Taylor &Francis Group: USA.

Lakshmanan, N., Gomathinayagam, S., Harikrishna, P. Abraham, A. and Chitra S. G. (2008), *Basic wind speed map of India with long-term hourly wind data Structural Engineering Research Centre*, CSIR Taramani: India.

Louis, C., Lawrence, M. and Keith, M. (2007), *Research Methods in Education Sixth edition*.Routledge 270 Madison Avenue: New York.

Lu, Xi., Michael, B. and Juha, K. (2009), *Global Potential for Wind-generated Electricity*. Proceedings of the National Academy of Sciences of the United States of America 106(27): 10933-10938.

Lütkehus, H.S. (2010), Onshore Wind Energy Potential in Germany. Umweltbundesamt, Germany.[*http://www.umweltbundesamt.de/uba-info-medien/3997.htm]*, website accessed on 12/3/2016.

Marsh, K., Chalfin, A. and Roman, J.K. (2008), What Does Cost-Benefit Analysis Add to Decision-Making? Evidence from the criminal justice system literature. *Journal of Experimental Criminology*,Volume 4.

Masamba, M. (2013), *Assessing the Potential of Wind Energy for Electrical Power Generation in Dodoma Region*, Master's dissertation Report .University of Nairobi: Nairobi.

Mashauri, A. (2011), *A Review on the Renewable Energy Resources for Rural Application inTanzania*, Renewable Energy - Trends and Applications, InTech ISBN: 978-953-307-939-4.

Mayaya, H.K., Opata, G. and Kipkorir, E.C. (2015), Understanding Climate Change and Manifestation of Its Driven Impacts in the Semi -Arid Areas of

DodomaRegion, Tanzania. *Ethiopian Journal of Environmental Studies and Management* Volume 8, 364-376.

McCartney, M. (2007), Technical Note: Hydrology of the Bahi Wetland, Tanzania. *Journal of International Development, 26:1, p23-45*

McElroy, M.B., Xi Lu, Chris P. N. and Yuxuan, W. (2009), Potential for Wind-generated Electricity in China. *Journal of Science* Volume 325(5946): 1378-1380.

McIntyre, J.H, Lubitz, W.D, and Stiver, W.H. (2008), *Wind Energy Resource Assessment Using Wind Atlas and Meteorological Data for the City of Guelph, Canada*. Presented at 7th World Energy Conference, Canada.

Mmasi, R.C., Lujara, N.K., and Mfinanga, J.S. (2001), *Wind Energy Potential in Tanzania, International Conference on Electrical Engineering and Technology*, The University of Dar es Salaam, Pp.EP6-EP11.

Munteanu, I.; Guiraud, J.; Roye, D.; Bacha, S.; Bratcu, A.I. (2006), *Sliding Mode Energy-Reliability Optimization of a Variable Speed Wind Power System*, Variable Structure Systems VSS'06. International Workshop on, On page(s): 92 - 97

Nicholas, H. J, and Barry, D. (2010), A Net-Present Value Analysis for a Wind Turbine Purchase at a Small US College:[*http:// www.mdpi.com/journal/energies ISSN 1996-1073*.], web site accessed on 21/11/2015.

Nzali, A. (2006), *Wind Energy Utilization in Tanzania*, PREA Workshop, Dar es Salaam.

OIE S (2015), *Decarbonizing China’s power system with wind power: The past and the future*. The University of OXFORD: UK.

Oltiman, R.R and Tracy, H.J. (2010), *Trends in Climate and In Precipitation –Runoff Relation Missouri River Basin*.The University of California: US.

Payne, C. (2015*), Inhabitat - Sustainable Design Innovation, Eco Architecture, Green Building. Green design & eco innovation for a better world*. Prackakashan, New Delhi.

Pearce, D.; Atkinson, G.; Mourato, S. (2006), *Cost-Benefit Analysis and the Environment: Recent Development s First Edition*, OECD Publishing: Paris, France.

Pedraza, J.M. (2015), *Electrical Energy Generating in Europe: The Current Situation and Perspectives in the Use of Renewable Energy Sources and Nuclear Power for Regional Electricity Generation*. Springer International Publisher: London.

Raghunatha, H.M. (2006*), Hydrology: Principles,Analysis and Design Revised* 2^{nd} *Edition*.New Age International (P) Limited: New Delhi.

Ranjit, K. (2011), *Research Methodology: A Step-by-Step Guide for Beginners Third Edition*, SAGE Publications Ltd: London.

Rashid, M.H. (2011), *Power Electronics Handbook Devices, Circuits and Applications* 3^{rd} *Edition* . Elsevier Inc :UK

Ravitch, and Riggan. (2012), *Reason and Rigor: How Conceptual Frameworks Guide Research*. Thousand Oaks CA,Sage Publisher: California.

Ray, S., Josh, B. and Kitsap (2009), *Cost Benefit- Analysis: General Methods and Approach*. Puget Sound Municipal Council Information Centre 1011 Western Avenue Seattle, Washington 98104.

Reddy,P.J. (2005), *A Textbook of Hydrology*. Laxmi Publication (P) LTD:US.

Risø National Laboratory/Danida (2003), *Wind Measurements and Wind Power*, Rue d 'Arlon: Brussels, Belgium.

Rivkin, D.A., Anderson, L.D; and Silk, L. (2013), *Wind Turbines Operations, Maintenance, Diagnosis and Repair*. Jones & Bartllet Learning: Burlington.

Santjer, F., Sobeck, L. and Gerdes, G. (2001),*Influence of the Electrical Design of Offshore Wind farms and of Transmission Lines on Efficiency*, Second International Workshop on Transmission Networks for Offshore Wind Farms, Stockholm, Sweden 30-31.

Schlesinger, M. (1990), *Climate –Ocean Interaction*. Kluwer Academic Publisher: Netherlands

Schwarb M., Acu˜na, D., Konzelmann, Th., Rohrer, M., Salzmann, N., Lopez, B. and Silvestre, E. (2011), *A Data Portal for Municipalityal Climatic Trend Analysis In A Peruvian High Andes Municipality*. Advances in Science & Research Open Access Proceedings. University of Zurich, Switzerland.

Shaw, M.E., Beven, K.J.,Chappell, N.A and Lamb, R. (2011), *Hydrology in Practice Fourth Edition* .Spon Press: US.

Siddharth, K. (2011), Parameters and Statistics.[*http://explorable.com/parameters-and-statistics],*web site accessed on 29/6/2015.

Smail, K., Simon, D. and Hugh, P. (2003), *Small Wind Systems for Rural*, Energy Services ITDG Publishing, ISBN 1 85339 555 2.

Smallwood, S.., Rugge, L.; Morrison, M. (2009), Influence of Behaviour on Bird Mortality in Wind Energy Developments. *Journal of Wildlife Management*,Volume 73, 1082–1098.

Subramanya,K. (2008), *Engineering Hydrology Third Edition*.Tata McGraw Hill Publishing Company Limited; New Delhi.

Tan, X., Zhao, Y., Polycarp, C. and Bai,J. (2013), China’s Overseas Investments in the Wind and Solar Industries: Trends and Drivers. Working Paper. Washington, DC: World Resources Institute. [*http://www.wri.org/publication/china-overseas-investmentsin-wind-and-solar-trends-and-drivers],* web site accessed on 10/1/2016.

TANESCO (2010), *Report on the Long-run Marginal Cost of Services Tariff Study*. Done by Rober Verstom– Consulting Economist.

The Price of Wind turbine Generator System [http://potential168.en.made-in-china.com/product-group/moeEprqdvQWt/Construction-Hoist-catalog-1.html],website accessed 25/05/2016.

Thogersen, M.L. (2005), *WindPRO –Energy: Modelling of the Variation of Air Density with Altitude through Pressure, Humidity and Temperature*.EMD International A/S: Denmark.

Thomas, D.C. (2009), *Statistical Methods in Environmental Epidemiology* .Oxford University Press inc: New York.

Trent, H. (2014), The Cost and Benefits of Installing a Wind Turbine [*http://www.thesimpledollar.com/looking-at-the-costs-and-benefits-of-installing-a-wind turbine-wind-turbine/*], web site accessed on 4/5/2015

Turnley, J.G. (2002), *Social, Cultural, Economic Impact Assessments: A Literature Review*. Galisteo Consulting Group, In: USA.

U.S. Energy Department (2013), *Power in America's Future: 20 % Wind Energy By 2030*. Dover Publications, Inc: New York.

United Republic of Tanzania (2007), National Adaptation Programme of Action (NAPA).Vice President's Office, Division of Environment.Dar es Salaam, Tanzania.

United Republic of Tanzania. (2002), National Sample Census of Agriculture. Volume VIII-a: MunicipalityReportDodoma.[*http://www.nbs.go.tz/takwimu/Agriculture/Dodoma%municipality%report.pdf]*, web site accessed on 17/7/2015.

United Republic of Tanzania. (2014), *Location and Climate of Dodoma. Capital Development Authority*Report, Dodoma Municipality.

Watson, D.E.(2015), FT Exploring Science and Technology. *.[http://www.ftexploring.com/wind-energy/wind-power-coefficient.htm],web site accessed* 5/6/2015

Webb, D. F (2001*), Coronal Mass Ejections: The Key to Major Interplanetary and Geomagnetic Disturbances*.Nature Publishing Group: UK

Weischer, L. (2012), *Achieving Development Goals with Renewable Energy: The Case of Tanzania. Inside stories on climate compatible development*. World Resources Institute: Washington, DC.

Weischer, L. (2012), *Climate and Development Knowledge Network (CDKN)-Inside Stories on Climate Compatible Development*. World Resources Institute: UK.

Wilburn, D.R. (2011), *Wind Energy in the United States and Materials Required for the Land-Based Wind Turbine Industry From 2010 Through 2030*: U.S. Geological Survey Scientific Investigations Report 2011–5036.

Willis, J., Blair, E., Anthony, J.and Hansen, E. (2003), *Method and Means for Mounting a wind Turbine on a Tower*, Valmont Industries' Inc, United States Patents: USA.

Wiser, R. and Bolinger, M. (2007), Annual Report on U.S. Wind Power Installation, Cost, and Performance Trends. DOE/GO - 102007-2433. Golden, CO: NREL. [*http://www.osti.gov/bridge/product.biblio.jsp?query_id=0&page=0&osti_id =908214]*, web site accessed on 26/5/2016.

Witkin, B. and Altschuld, J (1995), *Planning and Conducting Needs Assessments: A Practical Guide*. Sage Publications, Inc: California.

Wizelius, T. (2007), *Developing Wind Power Projects*. Earth scans Publications Ltd: London.

WMO (2010), *Guide to the Global Observing System*. Updated in 2012 , (WMO¬-No. 488), Geneva.

WMO (2011), *Guide to Climatological Practice*s, *2011 Edition*.(WMO-No. 100), Geneva.

Wolverton, M.L.(2009), *An Introduction to Statistics for Appraisers* .Appraisal Institute: Chicago.

World Energy Council (2007), Survey of Energy Resources, London.[*http://www.worldenergy.org/]*, web site accessed on 3/7/2015.

Wurman, J. (2007). *Doppler On Wheels*:Center for Severe Weather Research.

Yaneer, B.*(2015)*, Concepts – Power law. New England Complex Systems Institute. *[http:www.necsi.edu/guide/concepts/powerlaw.html.]*, web site accessed on 16/2/2016.

Yawson D. K., Kongo V. M. and Kachroo,R. K. (2005), Application of Linear and Nonlinear Techniques in River Flow Forecasting in the Kilombero River Basin, Tanzania*: Hydrological Sciences Journal. 2005. 50:5, -796, DOI:10.1623/ hysj.2005.50.5.783.*

Yousef, S. and Ali, G.(2010), *Reduced Solar Wind Speed During the Period 2006–2010.*International Association of Geomagnetism and Aeronomy (IAGA) 2nd Symposium: Solar Wind – Space Environment Interaction,Cairo, Egypt.

Zayas, J., Derby, M., Gilman, P., Ananthan, S. , Lantz, E., Cotrell, J., Beck ,F. and Tusing, R. (2015), *Enabling Wind Power Nationwide*: U.S. Department of Energy, USA.

Zhang, M.H. (2015), *Wind Resource Assessment and Micro-Siting Science and Engineering First Edition*, John Wiley& Sons Singapore Pte Ltd: Singapore.

Zhang, X; Da-ping X. and Yi-bing, L. (2004), *Adaptive Optimal Fuzzy Control for Variable Speed Fixed Pitch Wind Turbines*, Intelligent Control and Automation, Fifth World Congress, Volume: 3, 15-19.

APPENDICES

Appendix 1: Mean monthly wind speed (m/s) for 30 years (1986-2015)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1986	2.5	2.0	2.0	4.5	4.5	3.5	4.0	5.0	6.5	5.0	5.0	2.0
1987	2.0	1.5	2.0	2.5	3.5	3.0	4.5	6.0	5.0	6.0	5.5	3.0
1988	2.5	2.0	3.5	4.5	5.0	5.5	5.0	6.5	6.5	7.5	6.0	5.5
1989	3.0	3.5	3.5	4.5	5.0	5.5	5.0	7.0	5.5	6.5	6.5	2.5
1990	3.0	4.0	3.0	4.0	4.5	4.5	5.5	5.5	6.5	7.0	6.5	5.5
1991	4.0	2.0	3.0	4.0	5.5	3.5	5.5	5.5	6.0	6.0	6.5	4.5
1992	4.0	3.0	4.0	5.0	6.0	6.0	5.5	5.5	7.5	6.5	6.5	6.0
1993	4.5	4.5	4.0	6.5	6.5	4.5	6.5	6.5	8.0	8.0	7.5	7.0
1994	4.0	2.5	4.5	7.0	6.5	6.0	7.0	6.5	7.5	7.0	6.5	5.5
1995	4.0	2.5	4.5	6.5	6.0	7.0	7.0	7.0	7.5	8.0	7.5	5.5
1996	4.0	3.0	4.5	5.5	6.5	6.0	6.5	6.5	6.5	8.0	7.5	5.0
1997	4.5	3.0	4.5	5.5	6.0	7.0	6.5	7.5	7.0	8.0	5.0	3.5
1998	4.5	3.0	5.5	4.5	5.0	5.5	5.5	7.0	7.5	7.0	7.0	7.5
1999	4.5	5.5	3.5	5.5	7.0	7.0	6.5	7.5	8.0	7.0	7.5	6.0
2000	4.5	3.5	4.0	6.0	9.5	7.5	8.0	7.0	8.5	8.5	6.5	4.0
2001	7.0	4.5	5.5	5.5	3.5	6.5	6.0	7.5	7.5	8.0	7.5	6.0
2002	2.0	4.5	4.0	6.0	6.0	6.5	6.5	7.0	8.0	7.0	7.0	4.0
2003	2.5	4.0	5.0	5.5	5.5	6.5	6.0	6.5	7.5	*	4.0	4.5
2004	3.5	3.5	4.5	5.0	7.0	6.5	6.5	6.0	7.0	7.0	*	4.0
2005	4.0	4.5	3.0	5.5	5.5	6.5	7.0	6.5	6.0	7.0	6.0	6.5
2006	4.7	*	2.6	4.1	4.7	5.2	5.8	5.6	6.7	6.6	5.1	2.5
2007	1.8	1.6	2.4	4.7	5.2	4.2	5.0	5.7	6.2	6.4	5.9	3.5
2008	3.0	2.3	3.1	4.5	5.0	4.8	5.2	5.8	5.2	5.7	4.8	4.0
2009	3.1	3.3	3.6	3.3	4.5	4.4	4.7	5.4	5.8	5.3	2.9	3.4
2010	3.2	3.1	3.6	4.6	5.3	5.2	5.5	6.0	6.4	6.5	5.8	4.3
2011	2.3	2.2	2.4	3.1	4.2	3.8	4.3	5.5	6.4	6.0	4.4	2.2
2012	1.2	3.4	2.4	3.0	4.8	4.6	4.9	5.2	6.3	6.4	5.2	2.9
2013	1.8	2.5	3.9	3.7	5.2	4.5	5.1	5.6	5.5	6.3	5.9	3.8
2014	1.8	2.2	2.8	3.8	5.2	5.5	5.1	5.6	4.2	5.7	5.8	3.5
2015	1.8	3.2	4.5	2.9	4.7	4.2	5.0	5.6	6.2	5.9	2.2	2.2

* N.d. – no data

Appendix 2: NPV of Dodoma wind farm project at hub position 25 m

Years	Investment cost		Operational Cost				Benefit				NPV	
	5%	6.5%	5%	Summ 5%	6.5%	Summ 6.5%	5%	Summ 5%	6.5%	Summ 6.5%	5%	6.5%
1	2	3	4	5	6	7	8	9	10	11	12	13
Year 1	85260318004	84059468455										
Year 2	81200302861	78929078361										
Year 3	77333621772	74111810668					4445217299	4445217299	4173912957	4173912957	-72888404473	-69937897711
Year 4	73651068355	69588554618					4031943128	8477160427	3679969104	7853882061	-65173907927	-61734672557
Year 5	70143874624	65341365838	28043537	28043537	26875210	26875210	3657091273	12134251700	3244478921	11098360981	-57981579386	-54216129647
Year 6	66803690118	61353395153	29251762	57295300	27638267	54513477	3317089590	15451341290	2860524958	13958885940	-51295053528	-47339995737
Year 7	63622562017	57608821740	30281328	87576627	28208070	82721546	3008698041	18460039331	2522008383	16480894323	-45074946058	-41045205871
Year 8	60592916207	54092790366	29992934	117569561	27545908	110267455	2728977815	21189017146	2223552102	18704446425	-39286329499	-35278076487
Year 9	57707539244	50791352457	30761984	148331545	27854295	138121750	2475263324	23664280470	1960415352	20664861776	-33894927230	-29988368930
Year 10	54959561185	47691410757	31389779	179721324	28022430	166144180	2245136802	25909417272	1728418393	22393280169	-28870422589	-25131986409
Year 11	52342439224	44780667378	30891529	210612852	27189212	193333392	2036405262	27945822534	1523876121	23917156290	-24186003837	-20670177696
Year 12	49849942118	42047575003	31318600	241931453	27176859	220510251	1847079603	29792902137	1343539527	25260695817	-19815108528	-16566368935
Year 13	47476135350	39481291082	31634950	273566403	27064734	247574984	1675355649	31468257786	1184544096	26445239913	-15734311161	-12788476185
Year 14	45215367000	37071634819	31850154	305416557	26865061	274440045	1519596961	32987854747	1044364298	27489604211	-11922095697	-9307590563
Year 15	43062254286	34809046779	31153303	336569860	25907177	300347222	1378319239	34366173986	920773478	28410377690	-8359510440	-6098321867
Year 16	41011670749	32684550966	31231382	367801242	25606303	325953525	1250176180	35616350166	811808484	29222186174	-5027519341	-3136411267
Year 17	39058734046	30689719217	31231382	399032624	25245651	351199176	1133946649	36750296815	715738486	29937924660	-1909404608	-400595381
Year 18	37198794330	28816637762	30452368	429484992	24269237	375468413	1028523037	37778819852	631037480	30568962140	+1009510514*	+2127792791*
Year 19	35427423171	27057875833	30351197	459836189	23847924	399316337	932900714	38711720566	556360052	31125322192	+3744133584	+4466762696
Year 20	33740403020	25406456181	30190609	490026798	23387635	422703973	846168448	39557889014	490520005	31615842197	+6307512792	+6632089988

Year 21	32133717162	23855827400	29976491	520003289	22894699	445598671	767499726	40325388741	432471515	32048313712	+8711674867	+8638084983
Year 22	30603540154	22399837934	29131673	549134962	21936091	467534762	696144876	41021533617	381292526	32429606238	+10967128424	+10497303066

* year then benefits cover the costs.

Appendix 3: NPV of Dodoma wind farm project at hub position 45 m

Years	Investment cost		Operational Cost				Benefit				NPV	
	5%	6.5%	5%	Summ 5%	6.5%	Summ 6.5%	5%	Summ 5%	6.5%	Summ 6.5%	5%	6.5%
1	2	3	4	5	6	7	8	9	10	11	12	13
Year 1	113054999630	111462675692										
Year 2	107671428219	104659789382										
Year 3	102544217352	98272102706					5528341203	5528341203	5190930707	5190930707	-97015876149	-93081171999
Year 4	97661159383	92274274841					5014368438	10542709641	4576632244	9767562951	-87118449742	-82506711890
Year 5	93010627983	86642511588	28043537	28043537	26875210	26875210	4548179989	15090889630	4035030302	13802593253	-77891694816	-72813043125
Year 6	88581550460	81354470975	29251762	57295300	27638267	54513477	4125333323	19216222953	3557521922	17360115174	-69308032207	-63939842324
Year 7	84363381391	76389174624	30281328	87576627	28208070	82721546	3741798933	22958021886	3136522226	20496637400	-61317782877	-55809815677
Year 8	80346077515	71726924530	29992934	117569561	27545908	110267455	3393921935	26351943821	2765343936	23261981336	-53876564133	-48354675738
Year 9	76520073824	67349224911	30761984	148331545	27854295	138121750	3078387242	29430331063	2438091151	25700072488	-46941411216	-41511030673
Year 10	72876260785	63238708836	31389779	179721324	28022430	166144180	2792187975	32222519038	2149565696	27849638184	-40474020423	-35222926473
Year 11	69405962652	59379069330	30891529	210612852	27189212	193333392	2532596803	34755115840	1895184550	29744822733	-34440233959	-29440913205
Year 12	66100916811	55754994676	31318600	241931453	27176859	220510251	2297139957	37052255797	1670907051	31415729784	-28806729561	-24118754641
Year 13	62953254106	52352107677	31634950	273566403	27064734	247574984	2083573657	39135829454	1473170712	32888900496	-23543858249	-19215632197
Year 14	59955480101	49156908617	31850154	305416557	26865061	274440045	1889862728	41025692182	1298834633	34187735129	-18624371363	-14694733442
Year 15	57100457239	46156721706	31153303	336569860	25907177	300347222	1714161204	42739853386	1145129611	35332864741	-14024033993	-10523509743
Year 16	54381387847	43339644794	31231382	367801242	25606303	325953525	1554794743	44294648129	1009614152	36342478892	-9718938476	-6671212377
Year 17	51791797949	40694502154	31231382	399032624	25245651	351199176	1410244665	45704892794	890135689	37232614581	-5687872532	-3110688397
Year 18	49325521856	38210800145	30452368	429484992	24269237	375468413	1279133483	46984026276	784796393	38017410974	-1912010588	+182079243*
Year 19	46976687482	35878685582	30351197	459836189	23847924	399316337	1160211776	48144238052	691923025	38709333999	+1627386759*	+3229964754
Year 20	44739702364	33688906650	30190609	490026798	23387635	422703973	1052346282	49196584334	610040358	39319374357	+4946908768	+6053171680

Year 21	42609240347	31632776197	29976491	520003289	22894699	445598671	954509099	50151093433	537847744	39857222102	+8061856376	+8670044576
Year 22	40580228902	29702137274	29131673	549134962	21936091	467534762	865767890	51016861324	474198457	40331420558	+10985767384	+11096818047

* year then benefits cover the costs.

Appendix 4: NPV of Dodoma wind farm project at hub position 65 m

Years	**Investment cost**		**Operational Cost**				**Benefit**				**NPV**	
	5%	**6.5%**	**5%**	**Summ 5%**	**6.5%**	**Summ 6.5%**	**5%**	**Summ 5%**	**6.5%**	**Summ 6.5%**	**5%**	**6.5%**
1	2	3	4	5	6	7	8	9	10	11	12	13
Year 1	127830448055	126030019209										
Year 2	121743283862	118338046206										
Year 3	115945984631	111115536344					6217008311	6217008311	5837566489	5837566489	-109728976319	-105277969854
Year 4	110424747267	104333836942					5920960296	12137968608	5481283089	11318849578	-98286778660	-93014987364
Year 5	105166425969	97966044077	28043537	28043537	26875210	26875210	5639009806	17776978414	5146744684	16465594262	-87361404018	-81473574605
Year 6	100158500923	91986895847	29251762	57295300	27638267	54513477	5370485530	23147463943	4832624117	21298218379	-76953741680	-70634163992
Year 7	95389048498	86372672157	30281328	87576627	28208070	82721546	5114748123	28262212067	4537675227	25835893606	-67039259804	-60454057005
Year 8	90846712855	81101100617	29992934	117569561	27545908	110267455	4871188689	33133400756	4260727913	30096621518	-57595742538	-50894211644
Year 9	86520678910	76151268185	30761984	148331545	27854295	138121750	4639227323	37772628078	4000683486	34097305004	-48599719286	-41915841431
Year 10	82400646581	71503538202	31389779	179721324	28022430	166144180	4418311736	42190939814	3756510315	37853815319	-40029985442	-33483578703
Year 11	78476806267	67139472490	30891529	210612852	27189212	193333392	4207915939	46398855753	3527239733	41381055052	-31867337661	-25565084046
Year 12	74739815493	63041758207	31318600	241931453	27176859	220510251	4007538990	50406394743	3311962190	44693017243	-24091489297	-18128230713
Year 13	71180776660	59194139161	31634950	273566403	27064734	247574984	3816703800	54223098543	3109823653	47802840896	-16684111714	-11143723281
Year 14	67791215866	55581351325	31850154	305416557	26865061	274440045	3634956000	57858054542	2920022209	50722863105	-9627744767	-4584048175
Year 15	64563062730	52189062277	31153303	336569860	25907177	300347222	3461862857	61319917399	2741804891	53464667996	-2906575471	+1575952941*
Year 16	61488631171	49003814345	31231382	367801242	25606303	325953525	3297012245	64616929644	2574464687	56039132683	+3496099714*	+7361271864
Year 17	58560601115	46012971216	31231382	399032624	25245651	351199176	3140011661	67756941305	2417337734	58456470417	+9595372814	+12794698377
Year 18	55772001062	43204667808	30452368	429484992	24269237	375468413	2990487297	70747428602	2269800689	60726271106	+15404912531	+17897071712
Year 19	53116191488	40567763200	30351197	459836189	23847924	399316337	2848083140	73595511741	2131268253	62857539359	+20939156443	+22689092496
Year 20	50586849036	38091796432	30190609	490026798	23387635	422703973	2712460133	76307971874	2001190848	64858730207	+26211149636	+27189637748
Year 21	48177951463	35766945007	29976491	520003289	22894699	445598671	2583295365	78891267239	1879052439	66737782646	+31233319065	+31416436311

Year 22	45883763298	33583985922	29131673	549134962	21936091	467534762	2460281300	81351548539	1764368487	68502151134	+36016920203	+35385699974

* year then benefits cover the costs