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**TITLE: ANALYSIS OF WIND ENERGY POTENTIAL AT A CATCHMENT  
AREA OF ZEBIDAR MOUNTAIN**

BY: BANTAMLAK LAKE

ADVISOR: Dr. SISAY SHEWAMARE (Ph.D.)

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**Wolkite University**  
**College Of Natural And Computational Sciences**  
**Department Of Physics**

The undersigned here by certify that they have read and recommend to the department of physics for acceptance a senior project entitled “*ANALYSIS OF WIND ENERGY POTENTIAL AT CATCHMENT AREA OF ZEBIDAR MOUNTAIN*” by **Bantamlak Lake** in partial fullment of the requirements for the degree of Bachelor of Science in Physics.

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**Approved by the Examination Committee:**

Dr. Sisay Shewamare, Adivisor: .....

Ms. Meron Bekabil, Examiner: .....

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# Abstract

In this project analysis of wind characteristics, monthly and annually average wind speed and wind energy potential at a catchment area of Zebidar Mountain were addressed. Annually and daily mean value of wind speed data is taken from metrology. The wind speed is always fluctuating, and thus the energy content of the wind is always changing. This variation of wind speed depends on the weather, local surface condition and obstacles. Thus the monthly mean wind speed ranges from 6 km/hr to 12 km/hr. The Power densities and the power at the area range from 11 W/m<sup>2</sup> to 87.3 W/m<sup>2</sup> and 3 Kw to 23 Kw respectively, depend on the value of mean wind speed distribution.

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## List of Symbols And Abbreviations

- A: Swept Area
- AEP: Annual Energy Production
- $P_{out}$ : Output Power
- $C_p$ : Power Coefficient
- $\rho$ : Denity of Air
- E: Energy of wind
- HAWT: Horizontal Axis Wind Turbine
- Kw: Killo watt
- M: Mass of air
- m: meter
- $P_{in}$ : Input Power
- $P_w$ : Power Density
- P: Wind Power
- t: Time
- U: Wind Speed
- WECS: Wind Energy Conservation System
- VAWT: Vertical Axis Wind Turbine

# Chapter 1

## Introduction

### 1.1 Background of study

Wind is simple air in motion. It is caused by the uneven heating of the earth's surface by the sun. Since the earth's surface is made of very different types of land and water, it absorbs the sun's heat at different rates. The kinetic energy of wind is harvested using wind turbines to generate electricity. Wind blows in every corner of the earth; however, it does not blow constantly. In addition, it must maintain a certain speed to be effective for running a wind turbine and generating electricity [1].

The term wind energy or wind power is referred to the process by which the wind is captured to generate electricity. Effective utilization of wind energy entails a detailed knowledge of the wind characteristics at the particular location. The distribution of wind speeds is important for the design of wind farms, power generators and agricultural applications like irrigation. The most important factors in wind energy production are the wind speed, the energy of the wind, the generator type and a feasibility study [2, 3].

Wind energy is among the potential alternatives of renewable clean energy to substitute for fossil fuel based energy sources, which contaminate the lower layers of the troposphere. Because of its cleanness, wind power is sought wherever possible for conversion to electricity with the hope that air pollution will be reduced as a result of less fossil fuel burning [4].

The project would have been analysis the potential of wind energy at the catchment area of Zebidar Mountain, which is a Mountain located in central Ethiopia. It is the

highest point in the Gurage Zone and the entire Southern Nations, Nationalities, and Peoples' Region. The mountain is located  $38^{\circ}23'E$  longitudinal,  $8^{\circ}17'N$  latitudinal and an elevation of 3719 meters above sea level [5].

## **1.2 Statement of problem**

This project work would have been expected to answer the following questions:

- What are the factors affecting wind power?
- How wind speed is impinge on wind power?
- What are wind turbines?
- What is the minimum wind speed to generate power at a catchment area of Zebidar Mountain?

## **1.3 Objective of the study**

### **1.3.1 General objective**

The general objective of this study is:

- To analysis wind energy potential at a catchment area of zebidar mountain.

### **1.3.2 Specific objectives**

The specific objectives of this study are:

- To illustrate wind speed and to calculate wind power at the catchment area of Zebidar Mountain.
- To settle on the wind power density for the area.
- To determine the minimum wind speed of the wind in which the turbine is required to generate power for the location.

## **1.4 Significance of the study**

This project was concerned about the analysis of wind energy. It would have expected to have the following significance:

- It raises public interest in the development of wind energy project.
- It contributes to acquire fundamental knowledge for better understanding of wind energy utilization.
- It would have been used as a document for the future researchers who study on this area.

## **1.5 Scope of the study**

The aim this study would have been to settle on the wind energy potential at the catchment area of Zebidar Mountain.

## **1.6 Limitation of the study**

Doing research is not such easy task rather there are a lot of up and down (challenges).

Some of the faced problems are:

- Less Internet access.
- There was no enough time to do the project, since we were trying to do the project with overlapping time constraints.
- Lack of materials, like anemometer to take primary data.
- No enough budgets to perform the project.

# Chapter 2

## Literature Review

### 2.1 Wind Energy Overview

Human efforts to harness wind energy dates back to the ancient times, when they used sails to propel ships and boats. Later, wind energy served the mankind by energizing grain grinding mills and water pumps. During its transformation from these crude and heavy devices to todays efficient and sophisticated machines, the technology went through various phases of development [6].

The primary causes of atmospheric air motion, or the wind, are uneven heating of the earth by solar radiation and the earths rotation. Differences in solar radiation absorption at the surface of the earth and transference back to the atmosphere create differences in atmospheric temperature, density, and pressure, which in turn create forces that move air from one place to another [6, 7].

The extraction of power from the wind with modern turbines and energy conversion systems is an established industry. Machines are manufactured with a capacity from tens of watts to several megawatts, and diameters of about 1meter to more than 100 meters. Traditional mechanical only machines have been further developed for water pumping, but the overriding commerce today is for electricity generation [9].

Wind is a form of solar energy. Wind flow patterns are modified by the earth's terrain, bodies of water, and vegetative cover. Wind varies with the geographical locations, time of day, season of the year, and height above the earths surface, weather and local landforms. Wind blows due to the uneven heating of the atmosphere by the sun, the

irregularities of the earth's surface, and rotation of the earth. Wind flow patterns depend on the earth's terrain, oceans, and vegetative coverage. Locally, buildings, plants and mountains control the wind pattern and also its speed. Understanding of the wind characteristics will help to optimize wind turbine design and select wind farm sites [10]. The wind flow or the kinetic energy in the wind is harvested by wind turbines to generate electricity. Wind turbines first convert the kinetic energy in the wind into the mechanical power, which then rotates a shaft to generate electricity [10, 11]. In addition to the growing economic attractiveness of wind energy, there are major essential arguments for its use throughout the world, such as:

1. Wind energy is one of the renewable energy systems with the lowest cost of electricity production and with the largest resource available.
2. Wind-power plants emit absolutely no carbon dioxide, the major pollutant when fuels are burned.
3. The operation of wind turbines leaves behind no dangerous residues as do nuclear plants.
4. Decommissioning costs of wind turbines are much smaller than those of many other types of power plants, especially compared with those of nuclear generators.
5. Land occupied by wind farms can find other immediate uses like agriculture [11].

The understanding of the wind characteristics will help to optimize wind turbine design, develop wind measuring techniques and select wind farm sites. The variation of the wind makes the measurement of the wind to be difficult and expensive equipment will be used; the two most important parameters regarding the measurement are the wind speed and the wind direction [11, 12].

### **2.1.1 Wind Speed**

Wind speed is one of the most critical characteristics in wind power generation. In fact, wind speed varies in both time and space, determined by many factors such

as geographic and weather conditions. Wind speed generally changes with height. Under normal conditions for flat terrain, a wind speed is lower at surfaces near the ground than higher distance above ground because the flow of air near the ground is retarded by frictional resistance by surface features of earth. Roughness of the ground by itself or due to vegetation, buildings and other structures present over the ground are the main causes for retardation of wind speed near the ground [13]. The wind speed can be grouping as:

- **Cut-in speed:** the minimum wind speed at which the machine will deliver useful power. 3.5 m/s is the typical cut-in speed, when a small turbine starts generating power.
- **Rated wind speed (10-15 m/s):** the wind speed at which the rated power (generally the maximum power output of the electrical generator) is reached.
- **Cut-out speed (25 m/s):** the maximum wind speed at which the turbine is allowed to deliver power (usually limited by engineering design and safety constraints) Power curves for existing machines can normally be obtained from the manufacturer. The curves are derived from field tests, using standardized testing methods and it is also possible to estimate the approximate shape of the power curve for a given machine. Such a process involves determination of the power characteristics of the wind turbine rotor and electrical generator, gearbox gear ratios, and component efficiencies [12, 13].

### 2.1.2 Wind Direction

Direction of wind is an important factor in the sitting of a wind energy conversion system. If the major share of energy available in the wind is received from a certain direction, it is important to avoid any obstructions to the wind flow from this side wind vanes were used to show the direction of wind in earlier days of wind distribution data collection. However, most of the anemometers used today have provisions to record the direction of wind along with its velocity. Information on the speed and direction of wind, in a combined form, can be presented in the Wind Roses. The Wind Rose is a chart which indicates the distribution of wind in different directions [14].

The wind speed can be measured accurately by installing the anemometer at a

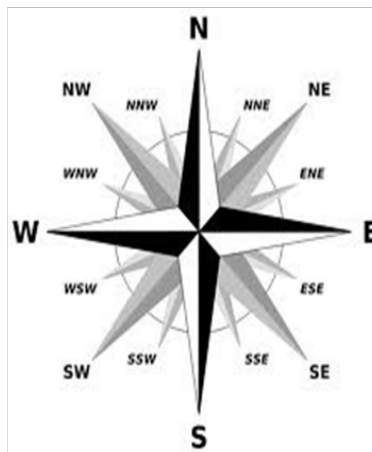


Figure 2.1: Wind Rose compass

prospective turbine site at the same height with the turbine hub height and also the wind direction can be measured with wind vanes associated with the anemometer. A Wind Rose is the term given to the way in which the joint wind speed and direction distribution is defined.

### 2.1.3 Wind Power Density

There are basic outputs and comparison parameters regarding the wind resource assessment that are average annual wind speed, annual wind direction, average power density, Annual Energy Production, wake losses and wind farm layout. These results are obtained using all the mandatory and available data. Out of these the power density is the basic parameter that determines the wind class of a wind farm. Along with the annual Energy Production(AEP) and mean wind speed the power density is a parameter which presents the general look and potential capacity of the wind farm. There are fundamental physical limits to how much energy we can extract from renewable resources. If we want to rigorously quantify this we calculate an energy source's power density in watts per square meter ( $w/m^2$ ). Power density in the wind is the amount of energy transported across a unit area in unit time and calculated as:

$$P_w = \frac{1}{2}\rho U^3 \quad (2.1)$$

Where;  $P_w$  - Power density,  $\rho$  - Density of air, U -Wind Speed the power density of the wind determines how much energy can be extracted by a wind turbine per unit area and is influenced by two factors: wind speed and air density. The power density is proportional to the cube of the wind speed. As air density decreases at higher altitudes and temperatures, the power density decreases proportionally.

## 2.2 Power From The Wind

The term wind power can be defined as the conversion of wind energy into useful forms of energy, such as using of wind turbines in order to generate electrical power, utilization of windmills for obtaining the so called mechanical power. Wind energy is the kinetic energy of air in motion. Total wind energy flowing through an imaginary area A during the time t is:

$$E = \frac{1}{2}MU^2 = \frac{1}{2}(Aut\rho)U^2 = \frac{1}{2}At\rho U^3 \quad (2.2)$$

Where:  $\rho$  = Density of air U = Mean Wind speed over time interval t (time averaged). Wind power in an open air stream is thus proportional to the third power of the wind speed; the available power increases eight fold when the wind speed doubles. Wind

turbines for grid electricity therefore need to be especially efficient at greater wind speeds. Power is energy per unit time, so the wind power incident on swept Area, A is:

$$P = \frac{1}{2} A \rho U^3 \quad (2.3)$$

## 2.3 Utilization of Wind Energy

Traditionally wind energy can be used for many purposes, such as for grinding grain, pumping water and long transportation. Nowadays the utilization of wind energy is become wide through technological developments. That is wind energy can be converted in to other form of energy like electricity. However, the conversion process is spade work (unchallengeable) and costly; It is too beneficial.

Wind energy can convert from one form to another through many processes. Wind is in fact a form of mechanical energy. It has to be harvested by appropriate engineered devices and converted into other useful energies such as electric energy. The major technical problem with a wind energy conversion system is the fluctuating and intermittent nature of wind. The harvesting system (typically a wind turbine) must react fast to the presence of wind or to a change in its direction and intensity [8].

It is important to be able to store the mechanical energy harvested from wind. Several wind energy storage methods are possible, where the mechanical energy resulting from wind is stored in various forms: kinetic (flywheels), electrochemical (batteries), chemical (hydrogen), and thermo mechanical (compressed air). Nevertheless, the most used systems are electrical generators actuated by wind energy and having local storage capacities in batteries and possibly being equipped with grid-connecting systems. Wind turbine efficiency reaches about 35% - 50% in the current technology [8, 9].

The harvested wind energy is normally converted in the shaft rotation of the wind turbine. The mechanical energy can then be used directly. For smooth generation, the mechanical energy can be stored in devices that are able to retrieve it in mechanical form, such as flywheels, hydro storage, or compressed air. A typical direct use of wind energy is water pumping; others may be grain milling and wood cutting. The shaft rotating mechanical energy can be converted by appropriate electric generators into electrical energy [9].

The extraction of power from the wind with modern wind turbines and energy conversion systems is an established industry. Machines are manufactured with a capacity from tens of watts to several megawatts, and diameters of about 1 m to more than 100 m. Traditional mechanical only machines have been further developed for water pumping, but the overriding commerce today is for electricity generation. Such wind turbine generators have become accepted as main stream generation for utility grid networks in many countries with wind power potential, e.g. in Europe, the USA and parts of India and China; other countries are steadily increasing their wind power capacity. Smaller wind turbine generators are common for isolated and autonomous power production.

## **2.4 Spatial and Temporal Variation of Wind Characteristics**

### **2.4.1 Variation With Height**

Wind speed varies with height above ground. This is referred to as wind shear. A machine with some hub height above the ground experience extreme stronger winds than a person at the ground level. Wind speed changes with height under normal conditions, a wind speed is greater at higher distance above ground. This is largely because the effect of surface features and turbulence diminishes as the height increases.

The variability depends on distance from the ground and roughness of the terrain. Within the height of local obstructions wind speed increases erratically, and violent directional fluctuations can occur in strong winds. Above this erratic region, the height, wind speed profile is given by expressions of the form.

### **2.4.2 Variations In Time**

Following conventional practice, variations in wind speed in time can be divided into the following categories:

- A) inter-annual;
- B) annual;

- C) diurnal(Time of day);
- D) Short term (gusts and turbulence).

### **Inter-annual**

Inter-annual variations in wind speed occur over time scales greater than one year. They can have a large effect on long-term wind turbine production. The ability to estimate the inter annual variability at a given site is almost as important as estimating the long-term mean wind at a site. Meteorologists generally conclude that it takes 30 years of data to determine long-term values of weather or climate and that it takes at least five years to arrive at a reliable average annual wind speed at a given location. nevertheless, shorter data records can be useful [16].

### **Annual**

Significant variations in seasonal or monthly averaged wind speeds are common over most of the world. For example, for the eastern one-third of the United States, maximum wind speeds occur during the winter and early spring. Spring maxima occur over the Great Plains, the North Central States, the Texas Coast, in the basins and valleys of the west, and the coastal areas of central and southern California. winter maxima occur over all US mountainous regions, except for some areas in the lower Southwest, where spring maxima occur. Spring and summer maxima occur in the wind corridors of Oregon, Washington, and California [16]

### **Diurnal (Time of day)**

In both tropical and temperate latitudes, large wind variations also can occur on a diurnal or daily time scale. This type of wind speed variation is due to differential heating of the earths surface during the daily radiation cycle. A typical diurnal variation is an increase in wind speed during the day with the wind speeds lowest during the hours from midnight to sun rise. Daily variations in solar radiation are responsible for diurnal wind variations in temperate latitude over relatively flat land areas.

The largest diurnal changes generally occur in spring and summer and the smallest in winter. Although gross features of the diurnal cycle can be established with a single year

of data, more detailed features such as the amplitude of the diurnal oscillation and the time of day that the maximum wind occur cannot be determined precisely [16].

### **Short-term**

Short-term wind speed variations of interest include turbulence and gusts. Short-term variations usually mean variations over time intervals of ten minutes or less. Ten-minute averages are typically determined using a sampling rate of about 1 second. It is generally accepted that variations in wind speed with periods from less than a second to ten minutes and that have a stochastic character are considered to represent turbulence. For wind energy applications, turbulent fluctuations in the flow need to be quantified. For example, turbine design considerations can include maximum load and fatigue prediction, structural excitations, control, system operation, and power quality [16].

## **2.5 Wind Turbines**

A wind turbine is an energy-converting machine to convert the kinetic energy of wind into mechanical energy and in turn into electrical energy. In the recent three decades, remarkable advances in wind turbine design have been achieved along with modern technological developments. It has been estimated that advances in aerodynamics, structural dynamics, and micrometeorology may contribute to 5% annual increase in the energy yield of wind turbines.

Various wind turbine concepts have been developed and built for maximizing the wind energy output, minimizing the turbine cost, and increasing the turbine efficiency and reliability. Wind turbines can be classified according to the turbine generator configuration, air flow path relative to the turbine rotor, turbine capacity, the generator-driving pattern, the power supply mode, and the location of turbine installation. Basically there are two categories of wind turbine design: horizontal axis wind turbines (HAWT) and vertical axis wind turbines (VAWT) [15].

### 2.5.1 Horizontal-Axis Wind Turbines (HAWT)

The horizontal axis wind turbines have emerged as the dominant technology. They place the rotor axis horizontal and in line with the wind direction. Wind farm modern wind turbine design. Today, the most common design of wind turbine is the (HAWT). That is, the axis of rotation is parallel to the ground.

HAWT rotors are usually classified according to the rotor orientation (upwind or downwind of the tower), hub design (rigid or teetering), rotor control (pitch vs. stall), number of blades (usually two or three blades), and how they are aligned with the wind (free yaw or active yaw). The principal subsystems of a typical (land-based) horizontal axis wind turbine include:

- The rotor, consisting of the blades and the supporting hub.
- The drive train, which includes the rotating parts of the wind turbine (exclusive of the rotor); It usually consists of shafts, gearbox, coupling, a mechanical brake, and the generator.
- The nacelle and main frame, including wind turbine housing, bedplate, and the yaw system; The tower and the foundation; The machine controls. The balance of the electrical system, including cables, switchgear, transformers, and possibly electronic power converters.

The main options in wind turbine design and construction include:

- Number of blades (commonly two or three); rotor orientation: downwind or upwind of tower; blade material, construction method, and profile;
- Hub design: rigid, teetering, or hinged; power control via aerodynamic control (stall control) or variable-pitch blades (pitch control); fixed or variable rotor speed; orientation by self-aligning action (free yaw), or direct control (active yaw);
- Synchronous or induction generator (squirrel cage or doubly fed); gearbox or direct drive generator.

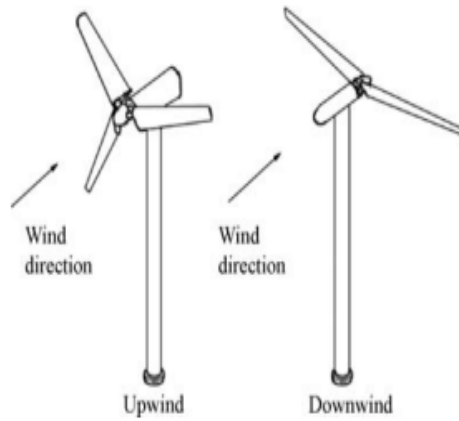


Figure 2.2: HAWT rotor configurations

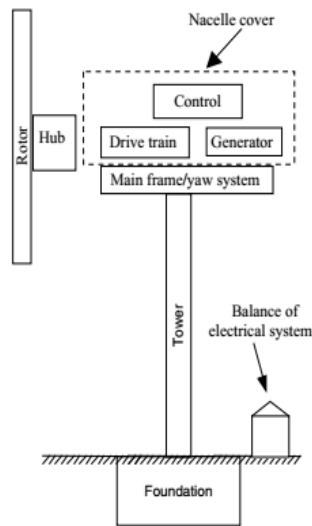


Figure 2.3: Major components of a horizontal axis wind turbine

### 2.5.2 Vertical Axis Wind Turbine (VAWT)

The VAWT operates well in fluctuating wind amplitudes provided that its direction remains quasi-constant. One important feature of the VAWT is that it does not need to be pointed in the direction of the wind. Thus VAWT installation is appropriate where the wind changes direction very frequently. Another feature of VAWT is that it allows placing the generator and gear box lower, close to the support system of the turbine. operation of some VAWT designs is based also on the aerodynamic lift principle, but there are designs that use form drag and aerodynamic friction to operate.

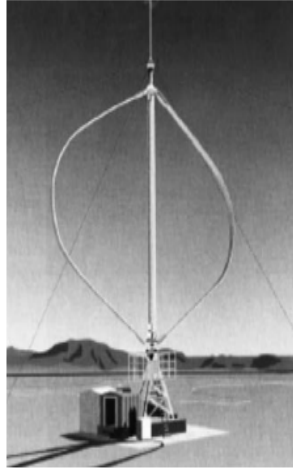


Figure 2.4: Sandia 17-meter Darrieus VAWT

### 2.5.3 Wind Power Coefficient ( $C_p$ )

Power Coefficient ( $C_p$ ) is a measure of wind turbine efficiency often used by the wind power industry.  $C_p$  is the ratio of actual electric power produced by a wind turbine divided by the total wind power flowing into the turbine blades at specific wind speed. When defined in this way, the power coefficient represents the combined efficiency of the various wind power system components which include the turbine blades, the shaft bearings and gear train, the generator and power.

$$C_p = \frac{P_{out}}{P_{in}} \quad (2.4)$$

Where:  $P_{out}$ ; is the actual electric power produced and  $p_{in}$ ; is Power entered into turbine here  $C_p$  is an efficiency factor called the power coefficient. Note that the power is Proportional to  $A$  and to the cube of wind speed  $V$ . Thus where as doubling may produce twice the power, a doubling of wind speed produces eight times the power potential.

The power coefficient  $C_p$  also varies with wind speed for individual machines. Since wind speed distribution is skewed, at any one time speeds less than average are more likely than speeds greater than average. Therefore the optimum design size of rotor and generator at a particular site depends on the power requirement, either to maximize generated energy per year or to provide frequent power. The structure comprising the

rotor, its matched electricity generator and other equipment is sometimes called a wind energy conversion system, WECS. However, it is increasingly common to use name wind turbine for the whole assembly.

The maximum rated power capacity of a wind turbine is given for a specified rated wind speed, commonly about 12m/s. At this speed, power production of about 0.3 Kw per meter square of cross-section would be expected with power coefficients  $C_p$  between 35 % and 45 %. The optimum rotation rate depends on the ratio of the blade tip speed to the wind speed, so small machines rotate rapidly and large machines slowly [14, 15].

## **2.6 Wind Potential Studies In Ethiopia**

Ethiopia, one of countries in the sub Sahara African region that relies on hydroelectric plants for the bulk of its power, is now turning to wind energy. It relies heavily on a limited set of renewable energy resources to meet its energy requirements: principally biomass for thermal energy in the residential and commercial sector and large hydro power for electricity. The Government of Ethiopia has planned to scale up and diversify the renewable energy mix, to minimize hydro power dependency; thus the focus has been shifted to renewable energy sources to fulfill the demand [12].

The Ashegoda wind farm, about 700 kms North of Addis Ababa has started generating 120 mega watt of electricity per year. It helps to start diversifying electricity generation. Its construction was funded from both domestic and international sources. The Adama wind farm, which is also now operational, is about 80 kms south of Addis Ababa. It produces 51 mega watt of electricity per year. Previous studies have shown that Ethiopia has sufficient wind speed to produce electricity from wind [13].

The Ethiopian government had prepared a master plan for wind and solar energy for investigating the available wind and solar energy resource, which recommends the major policy options to be developed for wind and solar energy expansion along with recommendation of 51 wind projects having a total planned capacity of 6,820 Mega watt [12].

# Chapter 3

## Methodology

### 3.1 Site Description And Methods

This project is designed both numerical and analytical view to describe and analysis wind characteristics and wind energy potential. The study was carried out in Wolkite University, main campus. Its found at a distance of 175 km from Addis Ababa and it is located in  $37^{\circ}47'E$  longitudinal,  $8.12^{\circ}17'N$  latitudinal and an elevation between 1910 and 1935 meters above sea level. To perform the study we need data from which we were draw conclusion for our study. So, we were used wind data collected from Zebidar mountain site. The Mountain has a latitude and longitude of  $8^{\circ}17'N$  and  $38^{\circ}23'E$  respectively with an elevation of 3719 meters above sea level.

### 3.2 Source of Data

The information for this study were gathered in different ways. The source of information is only secondary source of data, such as published articles, Internet, and text books. The wind speed data in annually time-series format over a period of 9 years (2010-2018) and also 15 days mean wind speed at the area were used and analyzed. The wind speed data were recorded at a height of 10 m, obtained from archive Satellites and meteorology. To achieve this goal, we had been surveyed an extensive literature survey.

### **3.3 Project Design**

To write this senior project, we used previous written source and gather extra information from Internet. This project working of the study by reviewing wind energy potential based on the published articles, the necessary information for the research work has been gathered starting from January to april 2019.

### **3.4 Methods of Data Analysis**

The wind speed and energy of a given wind speed data has been assessed and analyzed using secondary sources of information for the site i.e. the mean wind speed distribution was take from metrology. The wind speed and energy of a given wind speed data had been assessed and analyzed to determine the wind energy potential at a catchment area of Zebidar Mountain.

# Chapter 4

## Data Analysis

### 4.1 View Points of Zebidar Mountain

Zebidar Mountain is located in central Ethiopia. It is the highest point in the Gurage zone and the entire Southern Nations, Nationalities, and Peoples' Region. The mountain has latitude and longitude of and an elevation of 3719 meters above sea level [17]. Zebidar Mountain is described as part of an up warped massif, which overlooks the Rift Valley. This massif is composed of layers of silicic lavas and tuffs, except for the summit line which is hidden by the Rift Valley tuffs. It forms part of the divide separating the drainage basins of the Awash and Omo rivers.

The headwaters of the Omo lie in the central highlands between Gurage and the town of Nekemte. The Bilate River begins on the southern slope of the mountain, while the Gidabo River flows on the eastern slope. The Bilate River basin is volcanic, and contains several lake-filled maars and tuff rings dated to the Pleistocene and possibly Holocene periods. The Aleta people, believed to be descendants of the Maldea, live to the south of the Gidabo River. The area is part of the homeland of the Sidama people. It is the area in the region of the great rift valley [19, 20].

Around this mountain there is a well suggested climate in which is favorable to have enough access wind. The wind has variable speed and it has high contribution for generating power using materials such as wind turbine [17, 18].

## 4.2 Average wind speed distribution at catchment area of Zebidar Mountain

The wind speed distribution around Zebidar mountain varies in time and height due to uneven pour of wind at the area. Table 4.1 below shows the average wind speed recorded at 10 meter height in 15 days at catchment area of Zebidar mountain and respective wind power as well as power density for the area were premeditated using the wind speed data. The minimum mean wind speed is 6 km/hr and the maximum mean speed is 12 km/hr. However, the minimum wind speed (cut-in) speed to start the wind turbine which is known internationally is 7.5 km/hr.

Date	Vav(km/hr)	power (kw)	power density (w/m <sup>2</sup> )
Tuesday	9	9.57	36.81
Wednesday	6	2.84	10.92
Thursday	8	6.72	25.85
Friday	7	4.5	17.32
Saturday	7.5	5.54	21.31
Sunday	8	6.72	25.85
Monday	9	9.57	36.81
Tuesday	8.5	5.6	31.01
Wednesday	10	13.13	50.50
Thursday	11.5	19.97	76.81
Friday	10	13.13	50.50
Saturday	10.5	15.20	58.47
Sunday	12	22.69	87.28
Monday	11	17.47	67.20
Tuesday	10	13.13	50.50

Table 4.1: average wind speed, power and power density at the catchment area of Zebidar Mountain.

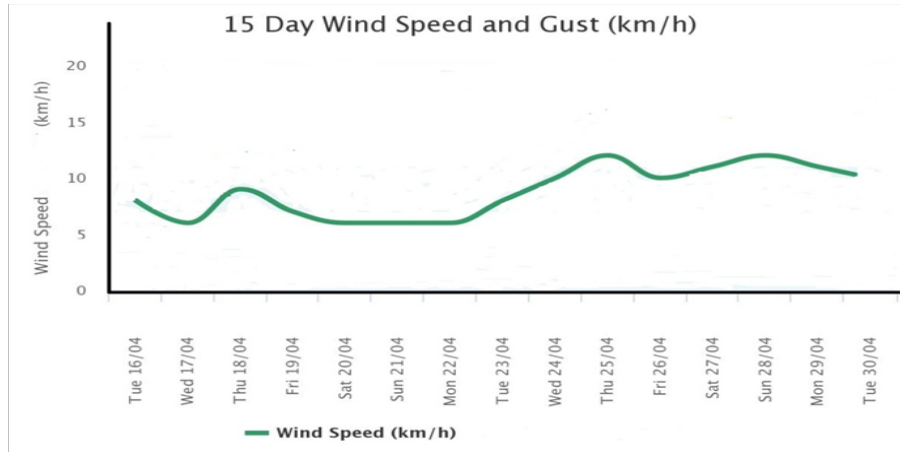


Figure 4.1: 15 day average wind speed at the catchment area of Zebidar Mountain.

Year	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Vav(km/hr)	9.5	7	6.5	8.5	8	7.5	7	7	6	9

Table 4.2 annual Average wind speed from the year 2009-2018

The average wind speed for the site varies from time to time daily and annually this accommodate effect on wind power production around the area. The maximum annual power density accomplish up to  $87.28 \text{ w/m}^2$ . For instance the wind speed distribution varies in time and this highly favors the fluctuation of wind power. In general wind speeds are as follows:

8 km/hr (2 m/s) is the minimum speed required to start rotating in most small wind turbines. 12 km/hr (3.5 m/s) is the typical cut-in speed, when a small turbine starts generating power. wind speed (30-50) km/hr or (10-15) m/s produce maximum generation power. At 25 m/s the turbine is stopped or beaked (cut-out speed).

From the data which recorded, the district at a catchment area of Zebidar mountain can generate an adequate amount of power whenever we use wind turbine with blade length of 35 meter. At 15 degree Celsius and air density of 1.225 kg per cubic meter we can get around 159 kw power from wind. When the wind speed increases at the area of Zebidar mountain the amount of wind power increases.

# Chapter 5

## Conclusion And Recommendation

### 5.1 Conclusion

Generally from wind speed data has been recorded at the catchment area of Zebidar mountain at a height of 10 meter above the ground and the yearly, mean wind speeds and wind power density availability for the location were settled on. Based on the analysis the following conclusions are made:

- The monthly maximum mean wind speed value of 12 km/hr shows that the area around Zebidar Mountain belongs to wind energy generative areas.
- The mean average wind power density at the catchment area of Zebidar Mountain is accomplish 42.77 w/m<sup>2</sup>
- The catchment area of Zebidar Mountain can spawn a maximum of 22.69 kilowatt power per small wind turbines from wind.
- The diurnal variations of the wind speed show a significant variation in wind characteristics among the seasons.

## 5.2 Recommendation

The need for renewable energy is felt increasingly in the world and wind energy can play an enormous role. A wind resource mapping project is in progress at the moment. Other issues are a possible lack of grid connection and flood risks. Finding suitable areas for wind farms is a point of attention because of the density of the population. If wind resources turn out to be sufficient and sufficient funding per kwh comes available and could be granted for a longer term, wind energy projects could be possible. Because of the lack of experience with wind energy in ethiopia. These opportunities lie in the field of providing services and knowledge as well as to export technology and materials to Ethiopia. It is important to push for further research concerning potential environmental research. Therefore,It is, advisable to first reconsider results of studies and environmental impact evaluation when thinking of studying of areas which are suitable to generate electric power from wind. Any interested scholars, can conduct an extensive research by taking long year data for more accurate estimation of the wind power engendering areas in order to facilitate the energy demands.

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