FEASIBILITY ANALYSIS FOR A WIND POWER PLANT IN LIBYA

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Approval of the Graduate School of Natural and Applied Sciences, Atılım University.

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This is to certify that we have read the thesis "FEASIBILITY ANALYSIS FOR A WIND POWER PLANT IN LIBYA" submitted by "Hasan Naji" and that in our opinion it is fully adequate, in scope and quality, as a thesis for the degree of Master of Science.

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ABSTRACT

FEASIBILITY ANALYSIS FOR A WIND POWER PLANT IN LIBYA

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July 2017, 58 pages

Like many countries of the world Libya is facing an increase in energy demand and is working to meet a part of this demand by the use of renewable energy sources.

In this study, a feasibility analysis has been made for the construction of a wind farm in Libya. A selection was made between two candidate areas in Tripoli Suburbs. In order to decide whether the wind speed is promising for the construction of a feasible wind energy facility, Weibull analysis has been conducted by calculating Weibull parameters (K, C). A suitable wind turbine has been chosen among two different types of 2.5 MW turbines, namely Liberty C99 and Siemens SWT, based on their energy output. It was found that the total power output of the wind farm for would be 100 MW. According to the calculations the investment would be paid back in 20 years with an internal rate of return (IRR) of 18%. This is substantial higher than the IRR value (10%) corresponding to projects considered to be feasible in the literature.

The results presented in this study are encouraging for investors and leading companies to develop large wind energy projects in Libya.

ÖZ

LİBYA'DAKİ BİR RÜZGAR ENERJİ SANTRALİ İÇİN FİZİBİLİTE ANALİZİ

Naji , Hasan

Yüksek Lisans, Elektrik ve Elektronik Mühendisliği Bölümü

Tez Yöneticisi: Yrd. Doç. Dr. Mehmet Efe Özbek

July 2017, 58. sayfa

Dünyadaki pek çok ülke gibi Libya da artan enerji talebi ile karşı karşıyadır ve bu talebin bir kısmını yenilenebilir enerji kaynakları ile karşılamaya çalışmaktadır.

Bu çalışmada Libya'da bir rüzgar santrali kurulması için fizibilite analizi gerçekleştirilmiştir. Tripoli'nin balniyölerinde bulunan iki aday arazi arasında tercih yapılmıştır. Rüzgar hızının fizibil bir rüzgar santrali kurulması için yeterli olup olmadığına karar vermek için Weibull analizi gerçekleştirilmiş, Weibull parametreleri (K,C) hesaplanmıştır. Liberty C99 ve Siemens SWT adlı 2.5 MW'lık iki farklı rüzgar turbini arasından, enerji çıktıları esas alınarak, bir seçim yapılmıştır. Rüzgar santralinin 100 MW çıkış gücüne ulaşacağı hesaplanmıştır. Hesaplamalar yapılan yatırımın, 20 yıl içersinde %18'lik bir iç getiri oranı (İGO) ile geri dönebileceğini göstermektedir. Bu oran literatürde fizibil kabul edilen projelere tekabül eden (%10) İGO'dan belirgin şekilde büyüktür.

Bu çalışmada sunulan sonuçlar, yatırımcıları ve önde gelen şirketleri Libya'da büyük rüzgar enerji projeleri gerçekleştirmek hususunda cesaretlendirecek niteliktedir.

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LIST OF ABBREVIATIONS

HAWT- Horizontal Axis Wind Turbine.

VAWT- Vertical Axis Wind Turbine.

GDP- Gross Domestic Product

REAOL- Renewable Energy Authority of Libya.

GECOL- General Electric Company of Libya.

LCOE - Levelized Cost of Energy.

(O & M)- Operating and Maintenance Costs.

C99- Clipper Turbine 2.5 MW, D99

SWT- Siemens Turbine 2.5 MW

IRR – Internal Rate Returns

CF – Cash Flow

NPV – Net Present Value

CHAPTER 1

INTRODUCTION

Since 1970, energy sources are considered to be under risk of getting exhausted. Energy demand is increasing gradually and the only way to meet these demands is the use of renewable energy sources. Furthermore, repairing infrastructure is considered necessary in energy sector. Therefore, all countries need alternative energy that cannot be consumed In addition, the gases that are produced by burning fossil fuels to produce energy, such as carbon dioxide, lead to global warming and raise earth's atmospheric temperature. In the end, this may even cause extinction of some animal and plant species, weather extremism and damaging of agricultural products. These important factors motivated many countries to use renewable sources for power generation [1].

Libya relies entirely on oil for electricity generation. Figure (1) shows the peak power demand of the general grid between 2002 and 2011 and the forecast for the subsequent years. The annual growth rate is around 10%. [2]

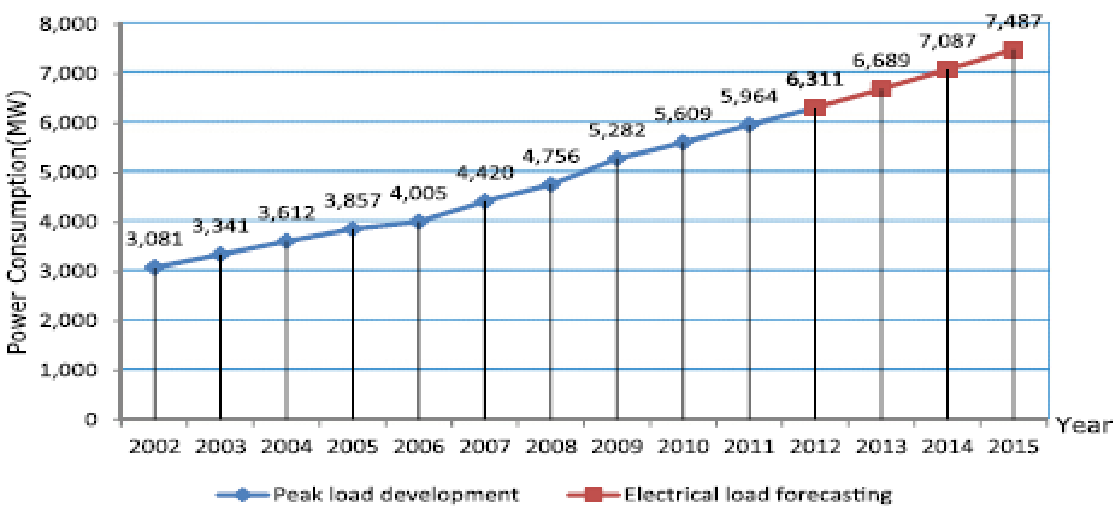

Figure 1: Peak demand during the period between 2002 and 2015

All of the above indicates the huge demand to find an alternative source to supply the energy needs in Libya. One of the most important renewable energy sources is wind energy [3]. Libya has the longest coast among the States bordering on the Mediterranean Sea with a length of approximately 1.955 kilometers. The best wind farms are on the coast because of the existence of appropriate wind year-round. In general, the wind speed in Libya reaches to 6 to 7.5 m/s at 40 m height. Figure (2) demonstrates the potential of wind energy in Libya [4].

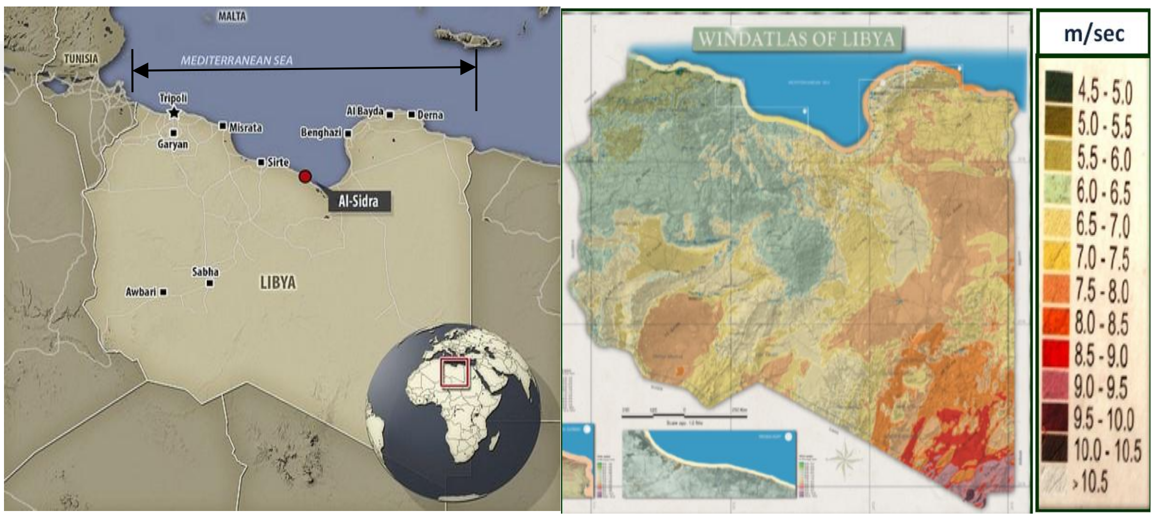

Figure 2: Map and wind speed distribution of Libya.

1.1 Research problem

Energy demand has increased in the world. Hence, many countries have worked to find a way to solve energy problems and their main concern, these countries have resorted to renewable energy as the best solution for these problems instead of other energy that dependent on high price sources, polluted the environment [5].

Due to the above, the problem of this study is that Libya is considered as one of the main countries that faces energy problems. The Libyan government aims to increase the production of energy using alternative energy to meet the energy demand in the future which is lowest cost, unpolluted and cannot be implemented. According to Libyan geographic site the Libyan government can use wind power as alternative energy [4] and use modern technology at lowest cost and high efficiency.

1.2 Research Question

This study basically aims to answer the following main question:

> What are the technical, geographical and economic feasibility for wind energy to supply the energy needs of Libya?

And from this question, several sub-questions were derived such as:

1. What is the appropriate type of turbines for wind energy generation in Libya?
2. What are the suitable sites for feasible wind energy generation in Libya?
3. How can we assess the feasibility of wind energy investment plans use technical, geography and economic data in Libya?
4. What are the essential recommendations that could be utilized to generate electrical power using wind energy in Libya?

1.3 Research Objectives

The current study aims to cover the following objectives:

1. To investigate the importance of wind energy in power generation compared to other power generation sources.
2. To determine the mechanism that could be used to generate electrical energy by wind energy.
3. To find advantages of use modern technology in wind farm such as: Siemens wind turbine and speed wind devices.
4. To use technical, geography and economic feasibility to choose the best wind energy system that could be utilized to generate power in Libya.

5. To produce several recommendations that could be utilized to generate electrical power using wind energy in Libya.

1.4 Research significance

Due to the huge increase of the electrical power demand in the world, particularly in Libya, and its importance in economic, social and educational section. Libya has worked to pay attention to energy and its sources and generation methods to meet the growing demand on this power source. Many countries relied on fossil fuels to generate power, but these sources unfortunately considered enforceable and pollute the environment when it's burned. Therefore, countries have resorted, including Libya, to solve the energy problem and its ability to meet the energy needs in light of industrial, economic, social and population growth developments, and meet the challenges that face Libya such as: lack of fossil fuel resources and increasing demand for electricity [6].

Hence, the significance of this study appears through facing the challenges that meet energy sources in Libya, by using alternative energy (wind energy) to generate power in it, and draw a clear picture of map about wind power in Libya represented the technical, economic and geographical feasibility, depend on modern technology to obtain a higher efficiency and low cost system. Also determine the appropriate location to install the wind farm according to wind speed and region geography in Libya. In addition to save fossil fuels and environment from pollution in Libya. This study could help Libyan government to select the suitable geography in Libya to establish wind farms at lowest cost and highest efficiency, and to cover the energy demand at the lowest cost in light of growing populations in Libya.

1.5 Study Limitations

There are a few studies that directly dealt with the use of renewable energy in Libya to cover the energy needs in this country. Therefore, this research focuses on the technical, geographical and economic feasibility for wind energy to supply the energy needs of Libya, and draw a clear picture of map about wind power in Libya which contains this feasibility, in addition to use a low cost and high efficient modern technology which are the Siemens wind turbine.

The beginning of this study will focus on selecting several area on the coast because of the presence of wind speed appropriate most days of the year, and calculate the wind speed at the appropriate height then calculate the output power that can be obtained at this height where the wind farm will be established in this region In addition to calculating the total cost of the project.

1.6 Scope and Outline of the Thesis

This study focuses on the economic, geographic and technical feasibility for wind farm in Libya, to cover the demand for electricity in the coming years. This study focuses on the installation of a wind farm at lowest cost and more efficient through use a modern technology such as Siemens wind turbine. In addition to choose an appropriate geographical location for install the wind farm in Libya. The second chapter is the literature review chapter that handled with several terms that are highly related to the study topic such as illustrating a background regarding wind energy history, wind speed and illustrating main wind turbines types, in addition to illustrate several previous related works on the study topic. Chapter three includes the tests and their results and the final chapter (chapter four) is the conclusions and recommendations of the study.

CHAPTER 2

BACKGROUND INFORMATION AND LITERATURE REVIEW

2.1 History of Wind energy

The history of wind power go back to the simple wind machines found on the Persian-Afghan border around 200 BC. Horizontal axis mills have been used in the Netherlands and the Mediterranean much later (1300e1875 m). Starting from the 12th century and going up to the early 20th century, water and wind energy were the best sources of mechanical energy in the West. Wind power systems were further developed in the United States during the 19th century, when more than 6 million small machines were used to pump water between 1850 and 1970 [7]. Also, Americans began using small windmills to generate electricity in remote rural areas, in 1920s. With the extension of the national grid in the 1930s, the use of local windmills has decreased dramatically. When the oil shortage in the seventies came, there has been a new interest in alternative energy sources, which has called for the return of the power mill. In the early 1980s, California's wind power started, mainly because of state policies that encouraged renewable energy sources. From that time on, support for wind development has spreader to other countries [8].

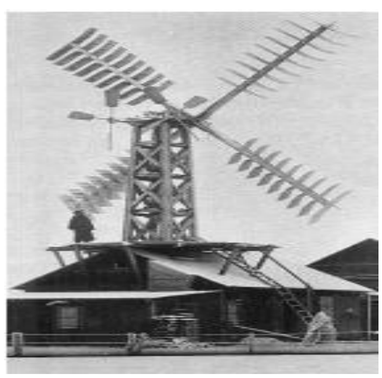

Figure 3: The first wind turbine for the production of direct current by Paul LaCour, Askov, Jütland,1891[9]

2.2 Type of Wind Turbines

Wind turbines are machines used to convert kinetic wind energy into mechanical energy. A wind turbine which converts mechanical energy into electricity is called a wind generator [10].

Wind turbines consist of a number of blades attached to the axis of the rotor in the middle, which together form the rotor. This rotor transforms the air flow and creates a force on the blades, which in turn produces a torque on the shaft. The shaft rotates around a horizontal axis and is essentially connected to the generator through a gearbox. These are inside the nacelle, which is located at the upper end of the tower, next to many other electrical parts. The generator generates electricity, which is transferred from the bottom of the tower to the adapter available; so that the output voltage (usually about 700V) can be converted to some voltage either on the country network (for example 33000V) or for any personal uses (about 240 volts).

There are generally two main types of wind turbines, namely horizontal wind turbines (HAWT) and vertical axis wind turbines (VAWT) [11].

2.2.1 Horizontal Axis Wind Turbine:

In horizontal wind turbines, the rotation axis of the rotor is parallel to the current of wind and earth. HAWT works when the wind passes over the entire airframe-shaped blade surfaces but passes more quickly in the upper side of the blade, thus, creating a low-pressure area above the flank. The difference in pressure at the top and bottom surfaces lead to aerobic lifting. Wind turbine blades are restricted to move in a plane with a center at its center, resulting in a lift force causing rotation around the axle [12].

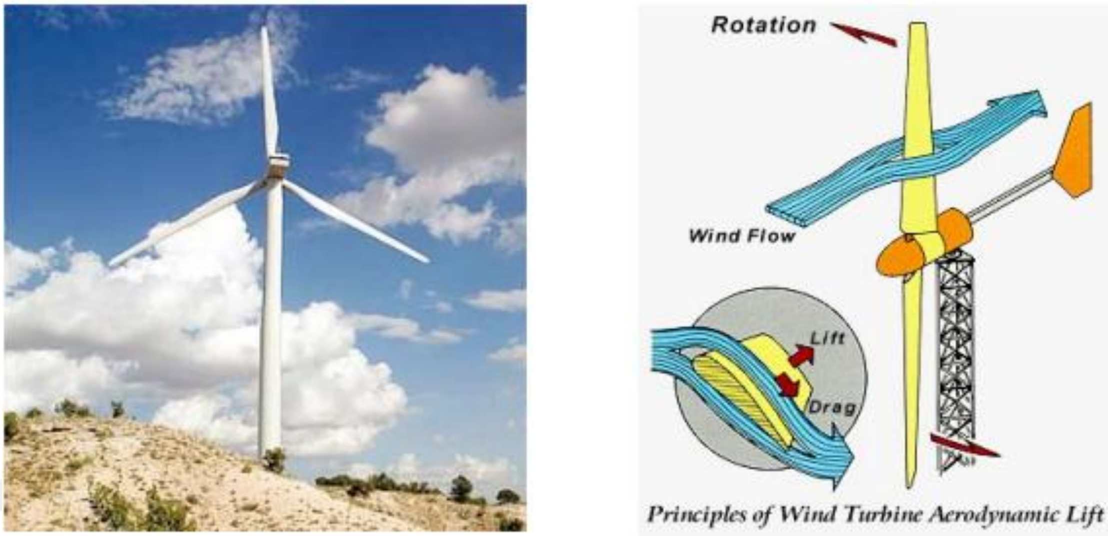

Figure 4: HAWT and the process of wind flow [12].

2.2.2 Vertical Axis Wind Turbine:

VAWT is a multi-directional wind turbine. Contrary to HAWT, a VAWT does not have to be directed so as to face the wind and can work with winds from any direction. The ability to place the gearbox and generator on ground level reduces the construction and maintenance costs. VAWT is silent and does not slow the wind as HAWT does. Therefore, VAWTs can be placed close together on the wind farm .These advantages make VAWT more suitable for domestic production of clean electric power in the industrial and residential area than HAWT and have led to increased interest in recent years [13]. The drawback of VWAT is that it is not self-starting [14].

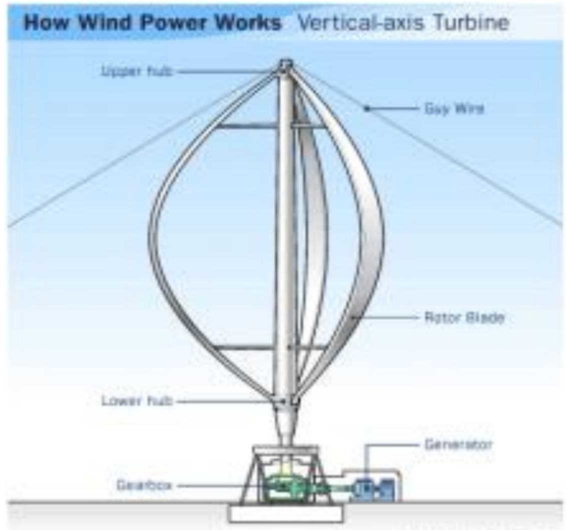

Figure 5: Vertical Axis Wind Turbine Components [14].

2.3 Related Work in the Literature

There are some research papers and studies for alternative energy sources and wind energy particularly in Libya, to provide relevant background information.

There is a high availability of wind energy in Libya. In [15], the authors have provided a comprehensive strategy for renewable energy in Libya, the most crucial sources, the ways of utilization and development of such resources in the future to be an effective substitute for fossil energy. This study aimed to draw up a clear picture of the data related to energy-sources for several different areas in Libya, based on some relevant figures provided by some government and international centers including field work. The results indicate that Libya is rich in renewable energy resources, and solar and wind energy is ultimately considered the main source of renewable energy.

In [16] , Elmabruk et.al. estimated the absorptive capacity of wind power in Libya and evaluated the wind resources. The work focused on the nature of wind resources in some Libyan areas and provided basic meteorological information about wind energy by analyzing the speed of winds in the selected areas. This study has clearly illustrated that considerable wind energy is available at some sites in Libya (the eastern city-Dernah has the maximum power, the annual energy and capacity factor).

In [17] authors proposed hydrogen storage technique as a balancing mechanism for renewable power. Hydrogen is shown to have a very big potential and financial benefit to enable the projected increase in renewable generation onto the electrical network. [18].

Another study [19] aimed to exhibit a new analytical method for the estimation of annual energy yield using the wind statistics for different sites in Libya. Results showed that the energy yield and capacity factor for the city of Darnah on the coast of the Mediterranean Sea was high and statistically acceptable.

Collins et.al. have suggested alternative methods to produce power forecasts from measured data and meteorological forecasts [20].

According to Thresher, Robinson and Veers [21], the development of wind energy technology and the adoption of robust standard design criteria helped to mitigate technology risks and attracted market capital for the development and deployment of large commercial wind plants. Offshore wind energy has great potential for electrical energy supply.

Mohammad, Das and Roy [22] provided a review of the advances in wind energy technology and energy conversion systems together with their technical features, converter topologies, their classifications, choice of generators and their social and environmental benefits.

Another work was done by Jonasson et. al. [23], which aimed to assess the economic feasibility of utilising wind energy in Iceland. Using the meteorological data obtained from the Icelandic wind atlas, three best sites to establish a wind farm were determined. Furthermore, the data was used to estimate the annual power production of the wind farm which consists of 10 turbines, each with 2 MW rating, having a capacity factor of 46%. The study discusses the challenges that face wind energy systems, such as: the lack of laws and legislation pertinent to wind energy, technical problems such as the special tools that must be installed in the wind farm, and the issue of connecting the system to the grid.

They have tried to assess whether the turbine they selected is compatible with the geographical conditions - high wind speeds and occasional ice storms - in Iceland by collecting information from the manufacturer, energy companies and governmental organizations. The economic analysis included consideration of the costs (investment, O & M), electricity price, variation of the Icelandic electricity market, and other market variables. PV, IRR ratio have calculated starting from price, discount rate, investment cost, number of turbines and exchange rate. They report that most of the costs emerge at the beginning, before the wind farm starts its energy production. It is estimated that the turbine alone stands for 80% of this capital cost. The estimation of the costs associated with the O/M was particularly difficult and analyses were done using only approximate values. A discount rate of 5% to 10% was used and the average price of electricity was estimated to be 1.2 c€/kWh over the life time of the turbine. The cost for leasing land, is estimated to lie between 1.5 to 10% of the revenue. It was stresses that the assumptions used in the calculations may change depending on various factors and this may significantly affect the analysis results, such as the size and number of turbines.

In the mentioned study, economic feasibility of using wind power to generate electricity was assessed through determination of the return internal rate, present value, percentage of benefits and cost and pay-back period. This study revealed that the cost of the wind farm in Iceland at the moment is still low, and considering the future challenges, such as increase in the electricity prices, using wind power can be feasible from an economic perspective.

In [24], the aim was to find the effect of the export of electric power generated from the desert, using wind and PV energy to Europe and the Middle East countries. This study included 44 countries and impact of this power generation on economic (GDP) and social (job, public and network infrastructure), environmental (CO_2 emission) and political (wars and conflicts) parameters through the years 2012, 2020, 2050, were assessed. Results showed that this project can cover a large amount of energy needs in the region, and can export 15% of the total Europe’s demand in 2050. The project can generate a great job opportunity for the participating countries in 2020-2050, reduce CO_2 emissions, and solve many political problems.

In [25] wind power potential in Ghana has been investigated. Suitable locations have been identified, environmental impacts have been assessed and technological issues have been considered. The study showed that it is possible to generate a total wing power of 5.64GW in Ghana and the investment can payback in about 5.5 years.

Al-Yousef [26] has studied the feasibility of wind farms in Saudi Arabia from the geographic, economic and technical viewpoints. According to this paper, Saudi Arabia's electricity demand will double in the next 15 years, dramatically increasing liquid fuel consumption. The author has followed analytical approach, has described fully the data, calculations, results and provided substantial discussions. In this study, the wind speed data has been taken from the Presidency of Meteorology and Environment, for two sites ' Dhahran and Jouf '.

This study revealed that Saudi Arabia is a good source for wind comparing with other countries which use wind energy technique to generate electricity, wind energy is competitive on the demand for energy and represent a chance for decrease fuel consumption.

Through what has been introduced in previous studies, one may note that they share many of the important aspects of the feasibility problem of wind power in Libya (wind speed estimation, identification of areas for the establishment of farms, estimation of energy production). However, comprehensive data on the use of wind power in Libya is still missing. In an attempt to fill this gap, in this study, we will focus on the technical, geographical, and economic feasibility of wind energy to supply the energy needs of Tripoli.

2.4 Renewable Energy Strategy in Libya

Libya is an important country in the Middle East and North Africa because of its strategic geographical location in North Africa. It is located in a place that connects southern Europe with the rest of Africa and the East with the West Africa. Therefore, Libya's role in linking oil, gas and electricity to the international network is very fundamental and important. Although Libya is an oil-rich country, it is important to find and use alternative sources of energy since it is not reasonable to rely on one type of energy resource and the oil reserves is not unlimited. Besides the concern of securing oil resources for future generations, there is a strong motivation for conservation of the environment and reducing pollution [27].

Energy plays an essential role in the economic, social and economic development of any country. Several studies have shown that there is a strong relationship between electricity consumption and economic growth. One of the priorities of Libya's development plans is the process of connecting power lines to all regions. [28].

Available data indicates that Libya is rich in solar and wind energy resources. Libya is located in the center of North Africa, covering a huge area of 1,760,000 square kilometers. It is located on a long coast of 1,955 km on the Mediterranean Sea, and a large portion of its land area is desert. This confirms the high potential of the region to produce Solar and wind energy that can be used to generate electricity.

Although renewable energy such as solar energy and wind as discussed above are widely available in Libya, it is very difficult to break the dependence on oil and natural gas because it is a major and almost total adoption, not only for energy supply but also as a revenue for financial development [29].

2.5 Energy Demand Scenarios for Libya

Although Libya has significant potential for solar and wind power, the role of these resources in actual energy projects is negligible. In the past, several steps have been taken to start developing the renewable energy sector in all regions of Libya.

As illustrated in figure (6), a goal has been set by The Renewable Energy Authority of Libya (REAOL) for obtaining 10% of countries energy demand from renewable energy sources by 2020 [30].

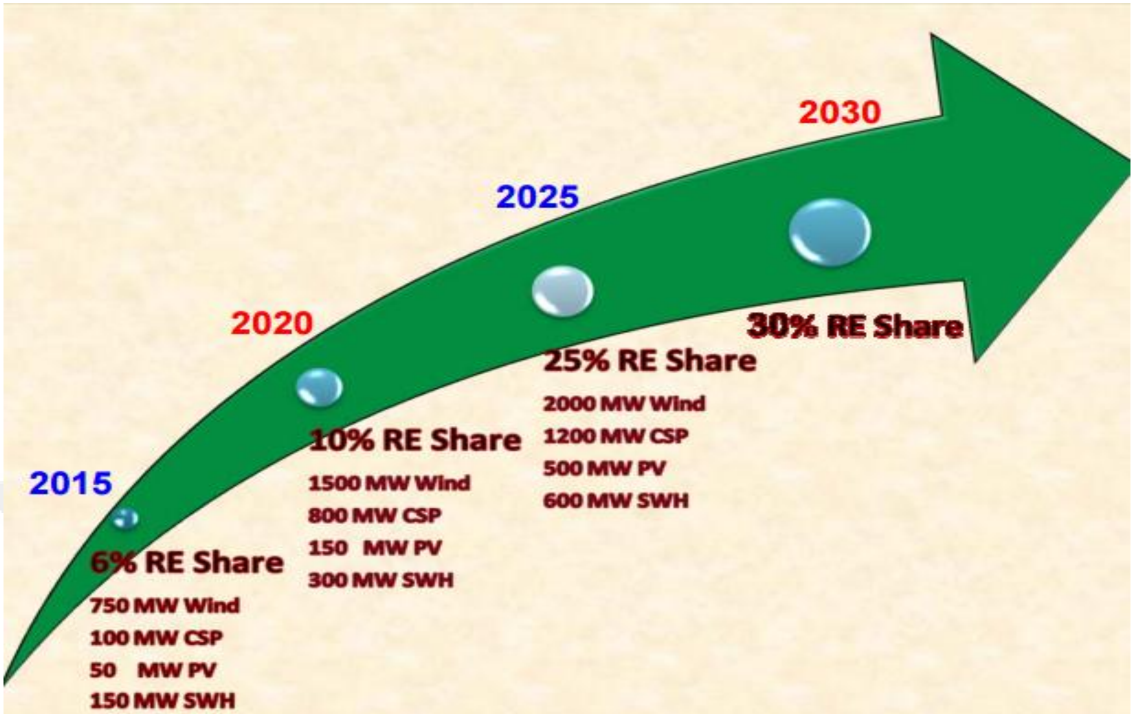

Figure 6: The Renewable Energy Projection of Libya [30].

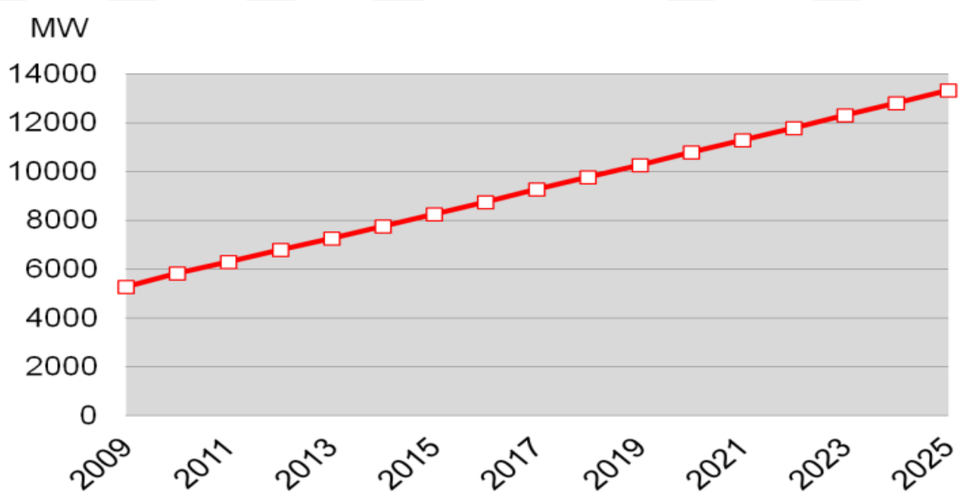

Figure 7: Forecasted Peak Load During 2009- 2025

Figure (7) shows that the energy demand in Libya over the years between 2009 and 2025 is expected to increase significantly. This is why the resources of energy production should be diversified and alternatives to the energy produced from Fossil fuels should be put into service.

There are many factors that affect the energy demand in Libya, including per capita income, population and economic growth, and environmental factors. Even, government’s laws and regulations have an impact on the demand for electricity and the general lifestyle of society.

2.5.1 The role of income on demand for electricity

Income is has a strong impact on the standard of living and it is the real per capita income which determines the purchasing power of individuals. A high level of income stimulates the individual to buy electricity-utilising equipment, which leads to increased demand. Libya is a middle-income country and one of the most industrialized countries in Africa. Its economy is highly dependent on energy, especially oil [31].

2.5.2 Population growth as a determinant of electricity demand

A high rate of population growth pushes official policies to promote rapid growth so as to meet the needs of the population. Population growth has a significant impact on the increase in energy demand in Libya. Libya's population growth has exceeded 2% per year for several years [32] and this trend may be expected to continue. These statistics stimulate development in key economic areas such as electricity supply. Libyan government has been in a position to meet the needs of electricity, using its wealth in oil resources. [33]

2.5.3 Industrial sector

Libya's industrial sector affects economic growth and demand for electricity. In 2003, the industrial sector requested 4 million tons of oil equivalent to produce energy. Energy demand is expected to rise to 11.2 million tons by 2030, forcing the government to take action to find alternative ways to generate electricity other than oil. Also, the promotion of manufacturing has led to increased demand for electricity in Libya [34].

Libya is one of the most famous countries in the iron and steel industries, also in the spread of aluminum factories. The abundance and diversity of these industries has led to increased demand for electricity to operate efficiently. In addition, electricity is used in industries processing the important foods such as tomato paste and tuna. Other manufacturing industries such as soft drinks, tobacco, clothing, footwear also require high energy [35].

2.5.4 Environmental factors affecting electricity demand

One of the main reasons for global heating is the use of fossil fuels in energy production. Because Libya relies heavily on fossil fuels, exploitation of renewable resources available in the region is crucial for contributing to the reduction of global warming [36]. In order to halt the further environmental degradation caused by the generation of electricity through the use of fossil fuels, as in Libya, countries must take responsible actions to solve this problem [37].

2.5.5 Lifestyle factors

The culture of the Libyan people affects the inherent demand for energy. Based on the country's industrial and social situation, the demand for electricity is on an upward curve. By reviewing the development trends of African countries in order to catch up with the rest of the world, one can infer that the demand for electricity will continue to increase [38]. The population in Libya is concentrated in the north of the country. This leads to the southern regions suffering from the lack of electrical connections [39].

As for the current application of alternative technologies and production of renewable energy, Libya is quite far away from meeting its the energy needs through cleaner energy. However, given the enormous potential for solar and wind power, Libya can achieve the green revolution and can meet the demand for electricity with renewable resources better than many countries of the world [40].

CHAPTER 3

Geographical and Economic Feasibility

3.1 Introduction:

In this section,

- A Brief History of Onshore & offshore wind farms.
- Choose the appropriate area for the wind farm in one of the areas located on the of Suburbs Tripoli.
- Find out the wind speed in this area depending on the Meteorological Center in Libya.
- Use Weibull parameter, these parameters were important to calculate available wind resource (P/A) in this area.
- Choose two different types of turbines and comparing them, then selected the most suitable turbine in terms of production and efficiency.
- Calculate the total cost of the wind farm.
- Apply the LOCE to know the price for per kilowatt.
- Determining the percentage of profits, the expected duration of the capital recovery.

3.2 Geographical Feasibility

3.2.1 Onshore & offshore wind farms

Before 2000, the major wind power generation was from wild wind farms. Onshore wind farms are more common since they are cheaper and require a simpler infrastructure and less advanced technology. The biggest limitation of optimization of onshore wind turbines is the diversity and variability of the wind speed above the ground. [41].

Figure 8: An Onshore Wind Turbine [42].

Offshore wind farms have a significant technical potential since there is a substantially high and almost constant wind speed on the sea throughout the year. Therefore, offshore wind farms are finding wide spread use in recent years. However, other possible uses of the sea area are limiting the development marine wind farms. The other uses marine areas include, for example, shipping routes, military use, oil and gas exploration, and even touristic use. [43].

Marine wind power did not become popular until early 2000 when the British government began to support offshore wind construction. Currently, the vast majority of offshore wind power off the UK coast. In general, offshore wind power is more expensive than onshore wind power [41].

Figure 9: An Offshore Wind Turbine. [44]

There is considerable difference between onshore wind power and offshore wind power, in terms of cost, maintenance process and availability of appropriate areas.

The initial investment required for offshore wind turbines is relatively higher compared to onshore wind turbines. Also, maintenance of offshore wind turbines is more expensive. The need for an analysis of the sea bed soil structure before the construction of turbine foundations further increases the costs. [45].

3.2.2 How to select wind farms location

There are many important factors and criteria to choose the best location for the wind farm, these factors are:

1. Wind speed. Wind speeds are different from region to region, so wind turbines need a certain speed to operate (3.5 to 4 m/s).
2. Proximity to the main network. To facilitate the process of connecting with the general electricity network
3. Closeness to the coast. Coastal areas have high wind speed over the year according to the Meteorological Center.

4. Area Size. The area size shall be sufficient and conform to the specifications used when installing turbines [46].
5. The wind farm must be far from the population to ensure that people are not disturbed with noise and sounds that produced turbine movement [47].
6. The area distance must be long to install a larger number of turbines that can generate more power.
7. The terrain must be a flat area, with no heights [48].

In this study based on the above considerations. Two areas were selected in Tripoli Suburbs for possible erection of wind turbines.

The areas were chosen near the city of Tripoli, because the most electricity consumption in Tripoli due to population density. As well as the provision of electricity distribution stations near the coast.

3.2.2.1 The first area:

"Janzur" where in the west of Tripoli near to Tripoli west steam station.

Figure 10: Map showing the location of first area

Figure 11: The first area where the wind farm is to be operated.

Janzur is a city in Libya. It lies about 12 kilometers from the west of the Libyan capital Tripoli. Its coast long about 15 km, it can be considered a major suburb of Tripoli and it have a biggest power plant in Libya," Tripoli west station."[48] [49]

After studying the location where could be install the wind farm, it is found to be too small, and it is concluded that this area is not suitable to install the wind farm to obtain the required energy. It is closeness to the neighboring buildings (shown in above Figure 11) is also another disadvantage. [48]

3.2.2.2 The Second Area:

The second area is "Qara Polly " which is in the east of Tripoli.

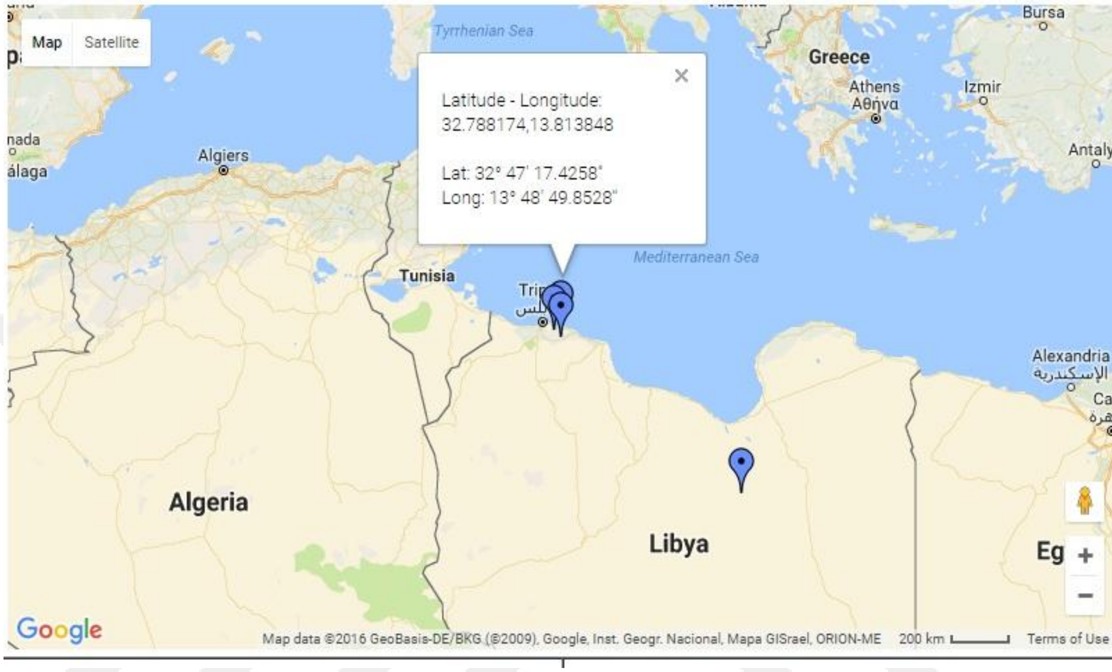

Figure 12: Map showing the location of second area.

Figure 13: The second area where the wind farm is to be operated.

Qara Polly is a coastal city, with a beach of length of about 18 km, and it is a rural area.

The Qara Polly is suitable for wind farm installation because it is located in the coast where the wind speed is high and almost constant for a long time. In addition, it is large enough to install a wind farm (13 kilometers square), far from population density, close to a electric power substation for grid connection and has a flat surface. Hence, it could be a good candidate for wind energy production.

Wind data are generally obtained from representative meteorological stations accredited to each country. In this study, we use monthly wind speed measurements taken by the meteorological center of Libya for a duration of four years at a height of 10 meters. Table1. [50].

Table 1: Mean monthly wind speed (m/s) for 4year in Qara Polly At a height of 10m:

	Year1	**Year2**	**Year3**	**Year4**
January	4.92	5.48	6.44	**6.5**
February	5.38	6.33	8.39	**6.22**
March	6.37	4.87	5.71	**7.26**
April	5.38	6.06	6.08	**6.5**
May	5.46	5.43	5.87	**6.26**
Jun	4.6	5.22	4.7	**6.52**
July	4.93	4.5	4.03	**6.36**
August	5.38	3.7	4	**6.57**
September	4.8	4.89	5.74	**6.68**
October	4.45	5.4	4.02	**6.73**
November	6.18	4.42	6.45	**6.9**
December	6.74	5.79	6.99	**7.49**

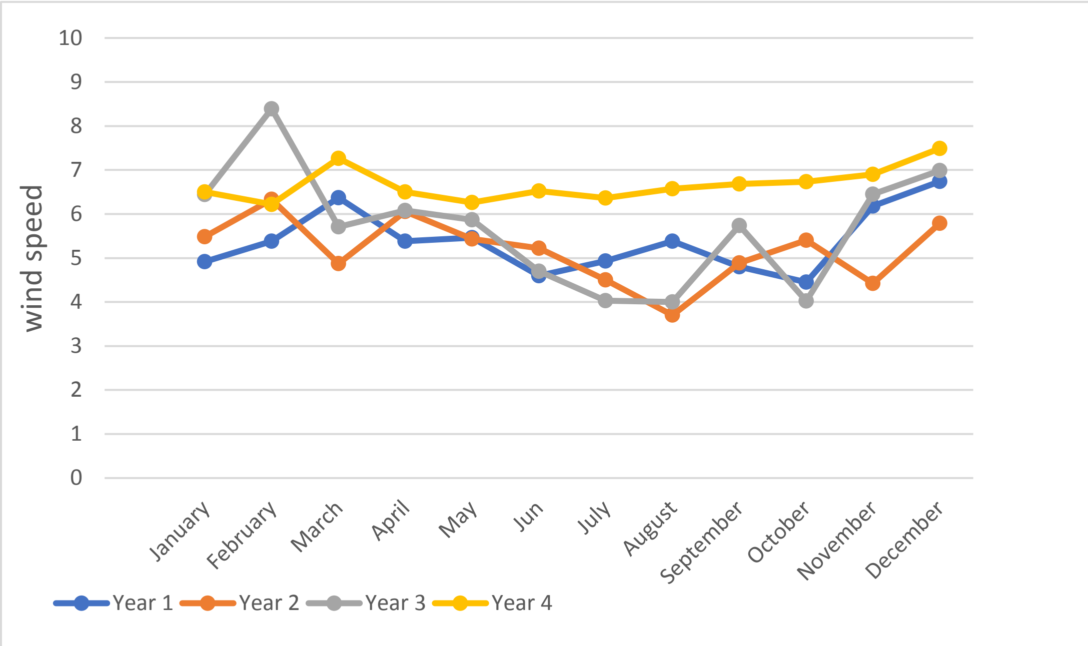

Figure 14: Average wind speed for each month for four years

We calculate V_{av}, the average wind speed, for each year using data in table1. V_{av} for one year is given by

$$Vav1 = \frac{1}{12}\sum_{i=1}^{12} v$$

V_{av} for 4 years can be calculated as

$$V_{av} = \frac{V_{av1} + V_{av2} + V_{av}3 + V_{av4}}{4}$$

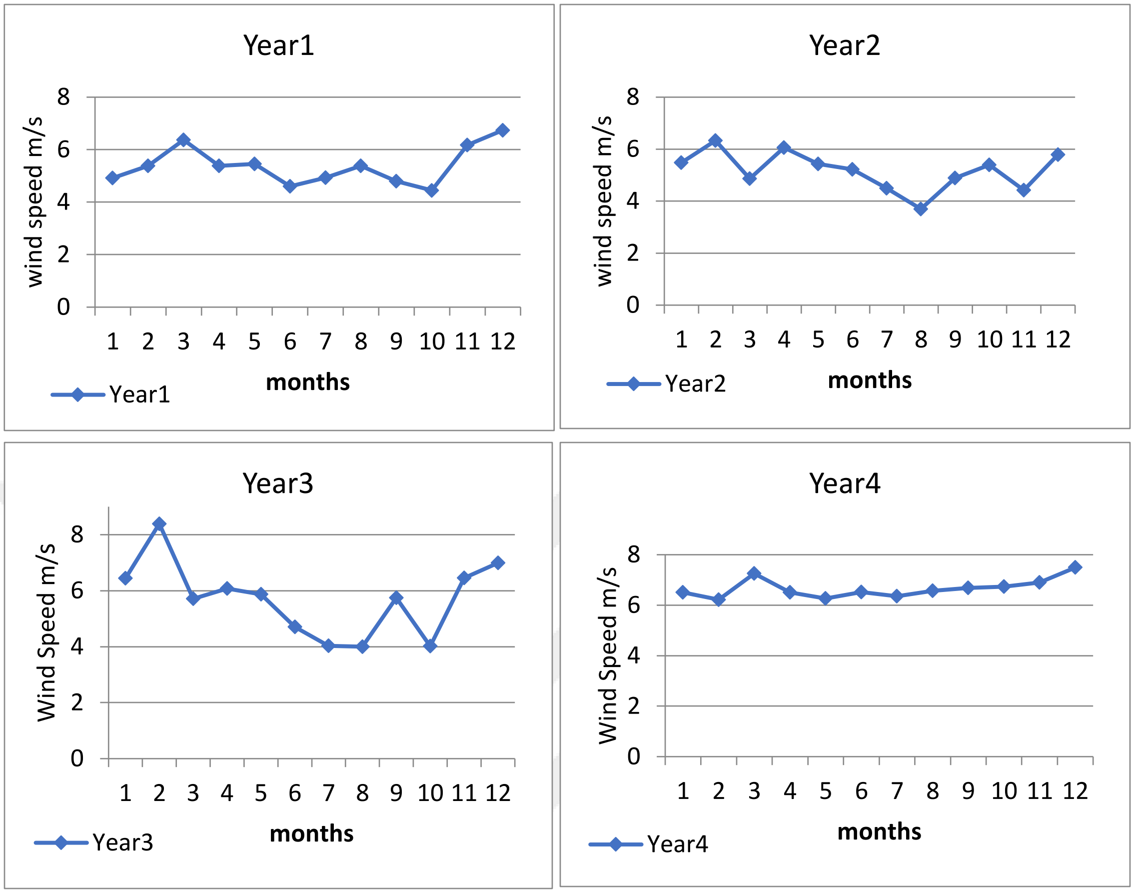

Table 2: Average wind speed at a high of 10 m for 4 years

Average Wind Speed m/s	**Years**			
	Year1	**Year2**	**Year3**	**Year4**
V_{av} (m/s)	5.38	5.17	5.7	6.68
V_{av} (m/s)	5.73			

The mean velocity values at a high of 10 m, for four consecutive years are shown in Table (2). Given at the speed required (3.5 to 8 m/s) to set up a wind farm, it is concluded that the wind speed is suitable for building the wind farm.

The analysis of the wind regime represents a fundamental step before developing any wind energy project as the cost of generating energy from wind in a specific site is heavily dependent on the wind resources. [51],[52].

During the last years, many distributions functions were suggested to describe the wind speed distribution and assess the wind energy potential. Among these are Pearson, Weibull, Rayleigh and Johnson functions. The Weibull distribution is the most commonly used in studying many natural phenomena as well as the wind speed. [53]

In order decide whether the wind speed calculated above is promising for the construction of a feasible wind energy facility, we conduct a Weibull analysis, calculate Weibull parameters (K,C) and find out the value of δ (variance of wind velocity), also K and (the dimensionless shape factor) and C (scale factor in m/s), figure (15) show the weibull distributions for measured wind speeds.

Weibull parameters (K,C), pertaining to the studied site, are calculated from [54] [55],

$$k = \left(\frac{\delta}{Vav}\right)^{-1.086}$$

$$C = \frac{Vav}{\Gamma(1+\frac{1}{k})}$$

$$\boldsymbol{\delta}^2 = \frac{1}{n-1}\sum_{1}^{n}(Vi - Vav)^2$$

Where δ is the standard deviation and Γ is the gamma function [55][56].

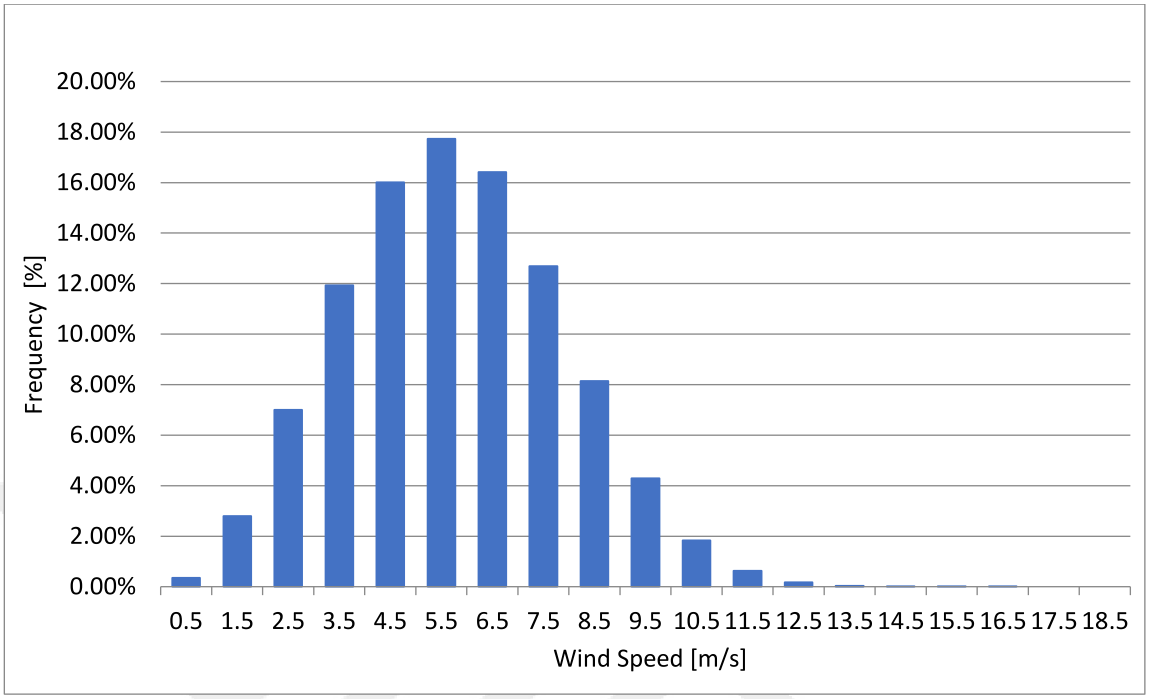

Figure 15: Weibull distributions for measured wind speeds

In order to evaluate the available wind resource, it is necessary to calculate the ratio P/A through the equation,

$$\frac{P}{A} = \frac{1}{2}\rho c^3 \Gamma\left(\frac{k+3}{k}\right) \text{ w/m}^2$$

where:

ρ , standard density which is equal to 1.225 kg/m^3

Table 3: Weibull parameters and value of (P/A)

Weibull parameters			
K	C m/s	*Γ*	P/A w/m^2
2.9	6.438	0.89	296.21

Using the values given the table (3), the value of (P/A) was calculated as 296.21 W/m^2. A classification based on the ratio (P/A) which can be used for a rough wind resource assessment is as follows: [57][58]

- Low ($\frac{P}{A} \leq 100 \ \mathrm{W/m^2}$)
- Rather fine ($100 \ \mathrm{W/m^2} \leq \frac{P}{A} \leq 300 \ \mathrm{W/m^2}$)
- Fine ($300 \ \mathrm{W/m^2} \leq \frac{P}{A} \leq 700 \ \mathrm{W/m^2}$)
- Excellent ($700 \ \mathrm{W/m^2} \leq \frac{P}{A}$)

This value calculated (P/A) value is in “Rather fine” category, but it is quite close to the “Fine” category as well. This approximate analysis shows that the wind resource in the selected area is promising for the construction of a feasible wind energy facility. Therefore, in the rest of this chapter we perform a more detailed feasibility analysis which also involves the selection of a suitable wind turbine.

3.3 Economic Feasibility

Wind energy projects can be of vital importance to Libyan economy under current conditions considering the destruction of several power plants during the war. Wind power may be one of the competing alternatives beside other conventional power generation methods. However, the feasibility of wind energy alternatives need to be studied including the selection of appropriate turbines in terms of cost, height and quantity of production, the total cost of the project.

3.3.1 Comparison between two different types of turbines

The feasibility study will be conducted using two different types of turbines having the same cost:

- Liberty C99 (Clipper) 2.5 MW
- Siemens SWT 2.5 MW

The characteristics and specifications of each turbine will now be given.

3.3.1.1 Liberty C99 (Clipper) 2.5 MW

The C99 Liberty wind turbines generate maximum wind power of 2500 kW in variable-wind speed. Since 2001, Liberty company has been involved in the construction and operation of several major wind power projects throughout the world. As the result their experience, a strong and light structure with increased efficiency and simpler design is obtained. [59] [60]

Table 4: Main data of Clipper Turbine.

	Main data	Rate
1	Rated power	2,500 k/w
2	Hup height	80 m
3	Rotor diameter	99 m
4	Rated wind speed	14 m/s
5	Cut-in wind speed	3.5 m/s
6	Cut-off wind speed	25 m/s

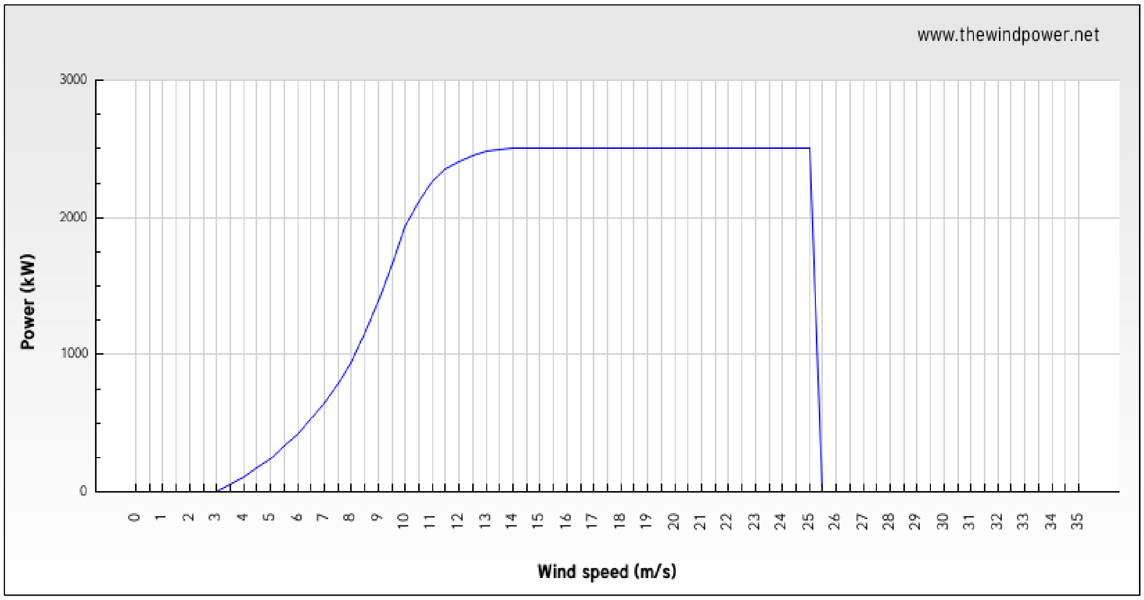

Figure 16: Power curve of C99 turbine [61].

3.3.1.2 SWT (Siemens) 2.5 MW

The SWT-2.5-120 is an important model among the terrestrial turbines. It is the result of the integration of extensive operational data and advanced design tools. With the experience gained from the SWT-2.3-120 model, the SWT-2.5-120 model has been devised which has increased power generation and improved efficiency [62].

Table 5: Main data of Siemens 2.5 MW.

	Main data	Rate
1	Rated power	2,500 kW
2	Rotor diameter	120 m
3	Hub height	85.1 m
4	Swept area	11,310 m2
5	Cut-in wind speed	2.5 m/s
6	Cut-off wind speed	22 m/s
7	Annual output at 8.5 m/s	9.5 GWh

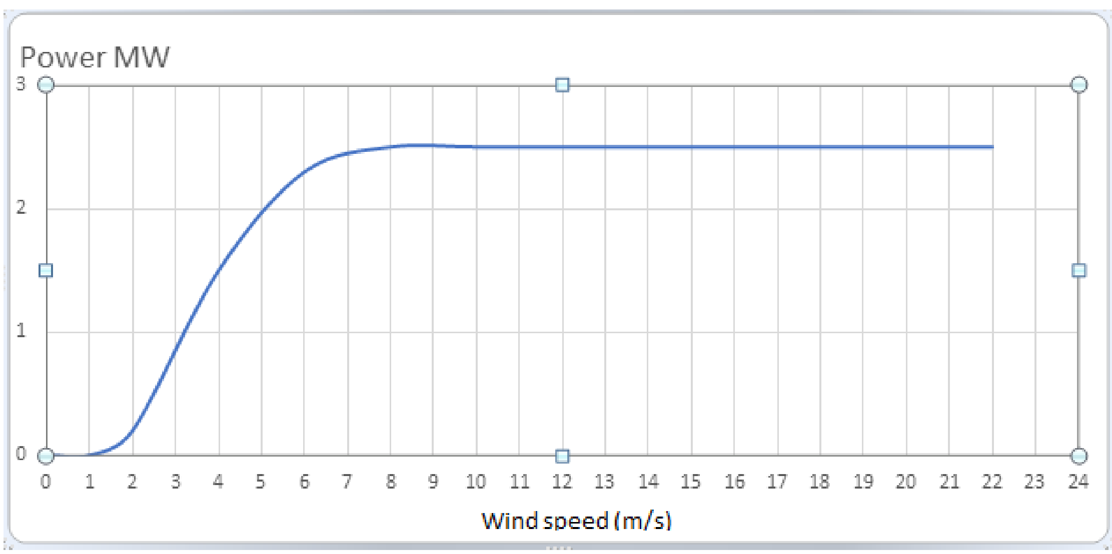

Figure 17: Power curve of Siemens turbine [63].

3.3.1.3 A comparison between two different types of turbines

In order to compare the suitability of the two turbines we calculate wind power for each turbine:

Wind power is given by

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

where:

ρ : is the standard density which is equal to 1.225 kg/m^3

A : is the distance between the fin rotation m^2

v : wind speed m/s

The wind speed is calculate at altitudes of 80 m, 85.1 m according to the specifications of the turbines. Velocity of the wind [m/s], at height of h is given by

$$Vi,h = Vref\ (\frac{h}{href})^{\alpha}$$

Where:

$Vref$:wind speed at reference altitude $href$

α : Hellmann exponent

The Hellmann exponent depends upon the type (coastal, mountain or water surface) of location, the shape of the terrain on the ground, and the stability of the air. Values of the Hellmann exponent for coastal locations are given in the table (6) below [64] [65]

Table 6: Hellmann constants for different wind farm locations.

Unstable air above open water surface	Unstable air above flat open coast	Neutral air above open water surface	Neutral air above flat open coast
0.06	0.11	0.10	0.16

In order calculate the number of turbines it is necessary to consider the area of the site. The site under our examination has a length of 8 km and a width of 1km.

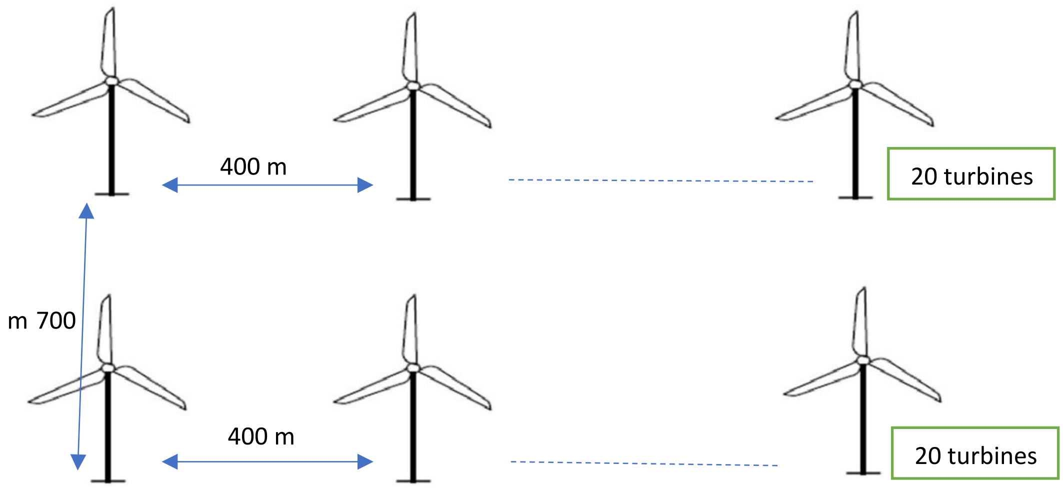

Figure 18: Placement of turbines in the selected area

In order to find the total power generation, we should first consider the placement of the turbines in the selected piece of land and calculate the total number of turbines. There are recommendations regarding the distances between the turbines. For turbines installed in a row,

Distance between the turbines should be 3D – 5D,

Distance between the rows should be 5D – 9D.

where (D) is the rotor diameter. [66] [67]

The possible placement of the turbines in the area of land in Qara Bully, for both turbine models, is illustrated in figure (18). It is possible to install 40 turbines in the region.

Table 7: Speed and Power for Year4

	Liberty C99 (Clipper) at 80 m	Siemens SWT at 85.1 m
Wind speed m/s	9.316	9.409
P (per turbine), MW	1.715	2.5
P (total), MW	68.6	100

Table 8: Speed and Power for each month, Liberty C99 (Clipper) & Siemens SWT

	Liberty C99 (Clipper)			Siemens SWT		
Months	Wind speed at (80m), m/s	P (per turbine), MW	P (total), MW	Wind speed at (85.1 m), m/s	P (per turbine), MW	P (total), MW
Jan	9.06	1.57	62.8	9.15	2.38	95.2
Feb	8.67	1.38	55.2	8.76	2.09	83.6
Mar	10.12	2.19	87.6	10.22	2.5	100
Apr	9.06	1.57	62.8	9.15	2.38	95.2
May	8.64	1.36	54.4	8.81	2.13	85.2
Jun	9.06	1.57	62.8	9.18	2.41	96.4
July	8.78	1.43	57.2	8.95	2.23	89.2
Aug	9.06	1.57	62.8	9.25	2.46	98.4
Sep	9.20	1.65	66	9.4	2.5	100
Oct	9.34	1.72	68.8	9.47	2.5	100
Nov	9.62	1.88	75.2	9.71	2.5	100
Dec	10.32	2.33	93.2	10.55	2.5	100

The monthly power generations as well as the total power generation has been calculated for both turbines and tabulated in tables (7) and (8). It is clear that Siemens (SWT 2.5-120) turbine can generate more power and we conclude that this model is preferable.

3.3.2 Cost Analysis

The analysis in this study focuses on estimating the costs of renewables (wind energy) from the perspective of a private investor, an independent power producer or an individual or community considering investment in renewables.

The most important parameter in the investment plan is the estimated cost of the wind facility. This includes the cost of turbines, land, construction, and the annual cost of operation and maintenance (O&M) and other costs (salaries, taxes, insurance) etc.

3.3.2.1 Cost Calculations

The calculation of the total cost of the project is shown in the following table (9) where, the initial investment or capital cost of project is found by summing the price of 40 turbines, the price of land, the annual cost of operation and maintenance, transport and electrical installation cost.

Table 9: Total cost structure for a wind turbine farm project.

Cost Item	**Cost ($)**
40 Turbines	170,000,000
Transport and installation	68,000,000
Operation and maintenance (O&M) + 2.5 % insurance	3,300,000 + 4,403,995
5 % taxes	8,500,000
Land price	5,281,000
Electricity towers	28,800
Transformer	850,000
TOTAL	260,363,795 $

The price of the Siemens SWT 2.5 MW turbine has been estimated using the data taken from [68]. The costs for transportation, installation and network integration is taken to be 40% of the price of wind turbines [69]. Operation and maintenance cost (O&M) for wind energy generation facilities is estimated by the National Renewable Energy Laboratory NREL as $33 per kilowatt per year, for 2016[70]. In addition, a 5% tax and 2.5% insurance should be added to the price of wind turbines [71]. The price of land in the Qara Polly coastal region as determined by the Libya government is 1.25 Libyan dinars per square meter (L.D.) which is equal to 0.880$/m2). [72]

In order to estimate the cost of power transmission line required, we consider that the distance between the two towers is supposed to be about 500 meters. It can be found that 6 towers will be required to cover the 3-km distance between the wind farm and power transformer station. Each tower weighs about 4 tons and the total cost of towers can be calculated using the estimate (1200 $) provided in [73] for the price of each ton of high voltage transmission towers. In addition to price of transformer. To raise the output voltage of the wind turbine to voltage of the General Electricity Company.

The calculation of the annual energy output is shown in table (10). Several factors affect the performance of turbines adversely resulting in a degradation in the annual output. These are:

- Significant impact on some sites "salinity of the sea"
- Insects "Algae"
- Dirty blades "The dust"

The annual decrease in power output of a turbine operating in in a coastal region can be estimated as 0.2 %. In table (7), power output of the wind farm for each year is calculated by considering this degradation factor. Figure 3. illustrates the degradation in the wind turbine output. [74] [75] [76]

Most wind turbines are expected to operate for about 20- 25 years with regular inspection and maintenance. We take the wind turbine life time to be 20 years as a conservative estimate [77].

Table 10: The annual energy output.

YEARS	POWER " OUTPUT" kwh/yr
Y1	376,680,000.00
Y2=y1(1-0.002)	375,926,640.00
Y3=y2(1-0.002)	375,174,786.72
Y4=y3(1-0.002)	374,424,437.15
Y5=y4(1-0.002)	373,675,588.27
Y6=y5(1-0.002)	372,928,237.10
Y7=y6(1-0.002)	372,182,380.62
Y8=y7(1-0.002)	371,438,015.86
Y9=y8(1-0.002)	370,695,139.83
Y10=y9(1-0.002)	369,953,749.55
Y11=y10(1-0.002)	369,213,842.05
Y12=y11(1-0.002)	368,475,414.37
Y13=y12(1-0.002)	367,738,463.54
Y14=y13(1-0.002)	367,002,986.61
Y15=y14(1-0.002)	366,268,980.64
Y16=y15(1-0.002)	365,536,442.68
Y17=y16(1-0.002)	364,805,369.79
Y18=y17(1-0.002)	364,075,759.05
Y19=y18(1-0.002)	363,347,607.53
Y20=y19(1-0.002)	362,620,912.32

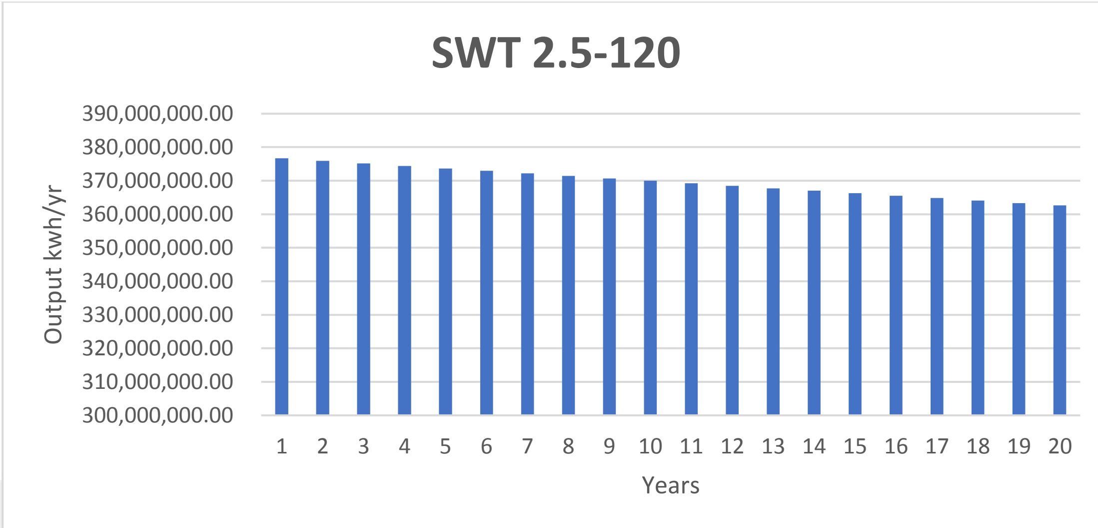

Figure 19: SWT 2.5-120 Output.

Table (10) and figure (19) show annual production value and loss rate, where the annual production is the total production of the plant multiplied by (365 * 24) and capacity factor [78]. The capacity factor is defined as the ratio of the total actual energy produced or supplied over a definite period of a power plant, to the energy that would have been produced if the plant (generating unit) had operated continuously at the maximum rating [79] [80] [81] [82].

By calculating the total cost of the project and the quantity of production for each year we can calculate the price for per kilowatt by use LCOE.

3.3.2.2 Calculation of the Price of electricity

The Levelized Cost of Energy (LCOE) is the minimum price of electricity required for the feasibility a project. An electricity price above this would yield a greater return on capital. The LCOE of renewable energy technologies varies by technology, country and project, based on the renewable energy resource, capital and operating costs, and the efficiency/performance of the technology. [83] [84] [85]

LCOE, is one of the most commonly used metrics for assessing the financial viability of energy projects, and comparing the lifetime costs of different technologies for electric power generation. The LCOE can, however, be applied to other energy projects as well (like oil and gas wells, or refineries).

The LCOE is the total cost of installing and operating a project expressed in dollars per kilowatt-hour of electricity generated by the system over its life. This description of the LCOE uses the vocabulary and equations described in the Manual for the Economic Evaluation of Energy Efficiency and Renewable Energy Technologies [86].

The formula used for calculating the LCOE of renewable energy technologies is:

$$LCOE = \frac{\sum_{t=1}^{n} \frac{I_t + M_t}{(1+r)^t}}{\sum_{t=1}^{n} \frac{E_t}{(1+r)^t}}$$

where,

I_t, Investment expenditures in year t.

M_t, Operations and maintenance expenditures in year t

E_t, Electricity generation in year t

r, Discount rate

n, Life of the system

Table 11 shows the price of electricity per kW calculated from the values provided in tables 9 and 10.

Table11: Result of the Levelized Cost of Energy (LCOE).

Parameter	**Description**	**Value**
I_t	Total Installed Cost.	260,363,795 $
M_t	Operation and maintenance (O&M) + 2.5 % insurance	3,300,000 + 4,403,995
E_t	The annual energy output.	For 20 Years 7,392,164,753.66 kwh/yr
R	Discount rate	10 %
N	Life of the system	20 Years
LCOE	The Levelized Cost Of Energy	5.896 cent per kwh/yr

Using the annual production E_t given in the table 11, the production cost, the recovery period, the profit rate, the internal rate of return (IRR) can be calculated as shown in Table 12.

The current selling price for electric energy in Libya is 17.5 cents per kWh [88]. However, production cost of electricity in Libya is much higher: 34 cents per kWh. Like in most Arab countries, the price of electricity is supported by the Libyan Government. In Tunisia electricity production cost 37.4 cents per kwh, whereas the selling price is 9.6 cents per kWh [89]. In Egypt, electricity production cost is 33.4 cents per kwh [90], and the selling price is 10.9 cents per kwh [91].

The LCOE value which we have calculated is significantly lower than the electricity production cost in Libya. This shows that the project under consideration is a feasible investment. The energy generated by the wind farm under consideration can be sold at a profitable price in Libya.

Table 12 and figure 20 shows the value of the cash flow for each year after the discount process of value (Maintenance and operation, Income tax and insurance).
In addition to the percentage of the return of the project Investment's internal rate of and the percentage of profits for the whole project period (IRR).

The feasibility of the project can be decided based on the IRR. The internal rate of return is the interest rate received for an investment consisting of payments (negative values) and income (positive values) that occur at regular periods. IRR is the interest rate at which sum of the present values of all incomes are equal to the sum of the present values of all payments through the course of the project. From a feasibility perspective, at an interest rate equal to IRR, the investment is paid back within the project period. An investor can assess the feasibility of a project by deciding whether the associated IRR is satisfactorily high. In literature, an interest rate in the interval of 5% to 10% is generally adopted for wind energy projects [86] [87]. The IRR value that we have calculated in this study, is significantly higher compared to these values, meaning that the project under consideration is feasible without doubt.

Net present value (NPV), also called net present worth, is an approach to evaluating investments that assesses the difference between all the revenue the investment can be expected to achieve over its whole life and all the costs involved.

NPV is calculated using the formula

$$NPV = \sum_{t=1}^{t} \left(\frac{C_t}{(1+r)^t} \right) - C_0$$

where, C_t is the net cash inflow during the period t. NPV is the difference between the sun of the present values of cash inflows and cash outflows. The cash outflows represent the operation and maintenance costs of the wind turbine, insurance and income tax. In this formula C_0 is the total initial investment cost, t is the number of time periods and r is the interest rate (discount rate).

The feasibility of a project can be assessed by selecting an acceptable interest rate and calculating the NPV using this rate. A positive NPV would indicate a feasible investment and a negative NPV would indicate an uneconomic investment. In wind energy projects the interest rate r is usually a number in the interval of 5% to 10% [86] [87]. In this study, we take r to be equal to 10%.

The NPV value calculated for the wind energy project under consideration is $76,543,638. In view of the positive value for NPV, this project is economically feasible for any investor. It can also be concluded that a wind energy project under the conditions in Libya is potentially a worthwhile investment.

Table 12: Annual production cost, Cash flow and Present value for Project

year	initial Investment $	Income from electric sale $	Maintenance (1000$)	Income tax	Insurance	Net income Cash flow
0	252,659,800	-	3,300	10 %	2.5 %	-252,659,800
1	-	65,919,000	3,300	10 %	2.5 %	47,484,005
2	-	65,787,162	3,300	10 %	2.5 %	47,373,629
3	-	65,655,587	3,300	10 %	2.5 %	47,263,473
4	-	65,524,276	3,300	10 %	2.5 %	47,153,538
5	-	65,393,227	3,300	10 %	2.5 %	47,043,823
6	-	65,262,441	3,300	10 %	2.5 %	46,934,328
7	-	65,131,916	3,300	10 %	2.5 %	46,825,051
8	-	65,001,652	3,300	10 %	2.5 %	46,715,993
9	-	64,871,649	3,300	10 %	2.5 %	46,607,153
10	-	64,741,906	3,300	10 %	2.5 %	46,498,531
11	-	64,612,422	3,300	10 %	2.5 %	46,390,126
12	-	64,483,197	3,300	10 %	2.5 %	46,281,937
13	-	64,354,231	3,300	10 %	2.5 %	46,173,965
14	-	64,225,522	3,300	10 %	2.5 %	46,066,210
15	-	64,097,071	3,300	10 %	2.5 %	45,958,669
16	-	63,968,877	3,300	10 %	2.5 %	45,851,344

17	-	63,840,939	3,300	10 %	2.5 %	45,744,233
18	-	63,713,257	3,300	10 %	2.5 %	45,637,337
19	-	63,585,831	3,300	10 %	2.5 %	45,530,654
20	-	63,458,659	3,300	10 %	2.5 %	45,424,185
IRR	18 %					
NPV	$76,543,638					

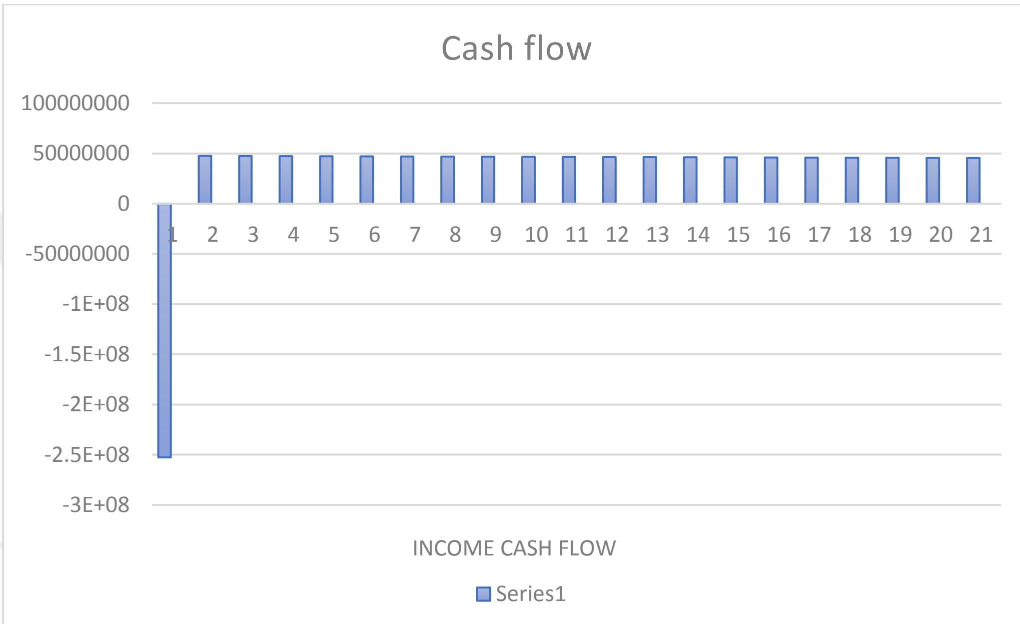

Figure 20: Cash flow for Project

CHAPTER 4

Conclusion and Recommendation

4.1 Conclusion

A review of the energy sector in Libya has revealed that there is a strong interest in renewable energy in order to meet the increasing energy demand.

Through the research about the usage of wind energy in Libya the following conclusions were made:

- The average wind speed for a selected region for four consecutive years is considered. The average wind speeds (5.73 m/s) is in the medium category meaning that turbines erected in the region can produce sufficient electrical energy.

- A preliminary feasibility study for the region and wind velocity was then carried out. Using shape factor & scale factor (K, C), P/A which represents the available wind resource, was calculated. A value of 296.21 W/m^2 was obtained which is close to “fine” category within the rough evaluation scale.

- The energy output was calculated so as to compare the two available turbines. Siemens SWT 2.5-120 with a total power output of 100 MW was found to superior to the clipper turbine with 68.6 MW output.

- The number of turbines suitable for the available region was decided. Considering the spacing between each turbine and the row and the distances between each row, we found that we needed 40 turbines at a cost of 170,000,000 $. The total initial cost of the project including the cost of the transformer and the land, was 260,363,795 $.

- The price of electricity for the project is determined by the use the LCOE to be 5.896 cent per kWh. Wind resource, capital and operating costs, the efficiency/performance of the technology and total energy output of wind farm has been considered in the calculation. The price is significantly higher compared to the current price in Libya (17.5 cent per kwh/yr) which proves the feasibility of the project from a different perspective.

- Calculating the NPV is a way investor determine how attractive a potential investment is. Since it essentially determines the present value of the gain or loss of an investment, it is easy to understand and is a great decision-making tool. In this study a positive NPV is obtained, which shows that the investment is worthwhile.
- The project under consideration additionally has benefits of preservation of the environment, reduction of carbon dioxide emissions, reduction of fossil fuel consumptions and availability of new job positions in energy sector.

4.2 Recommendations and proposed measures to enhance the production of electric power from wind farms in Libya:

Renewable energy is the next future and the best way to secure the growing demand for energy for future generations without harming the environment. Libya is a North African country rich in many renewable resources, the most important of which is wind energy, which is very suitable for generating electricity through turbines.

To promote the use and exploitation of wind energy, we will need more attention and capacity building from this system, while raising awareness through the various media to develop the concept of wind energy use and the importance of using it instead of using traditional resources that can be implemented at any time that harm the environment. Now will be reviewing a set of proposals for plans to accelerate the use of wind energy technologies, and these procedures can be acceptable or unacceptable in the opinion of some of the experts, and this discussion will be very useful to work to further develop and deploy the use of wind energy technologies.

- Encourage investors and leading companies to develop large wind energy projects to reduction of the initial cost, which leads to increased profitability and reduce the period of financial return of the project.
- Spread the idea of the importance of renewable energy rather than fossil energy, and also as a major importance in the preservation of the environment. This should be addressed by effective information campaigns that focus heavily on the benefits clean energy technology.

In order to reach this awareness, training courses, demonstration systems, manuals and workshops should be developed for the target users, and such programs should be developed on the basis of clear and understandable and studies.

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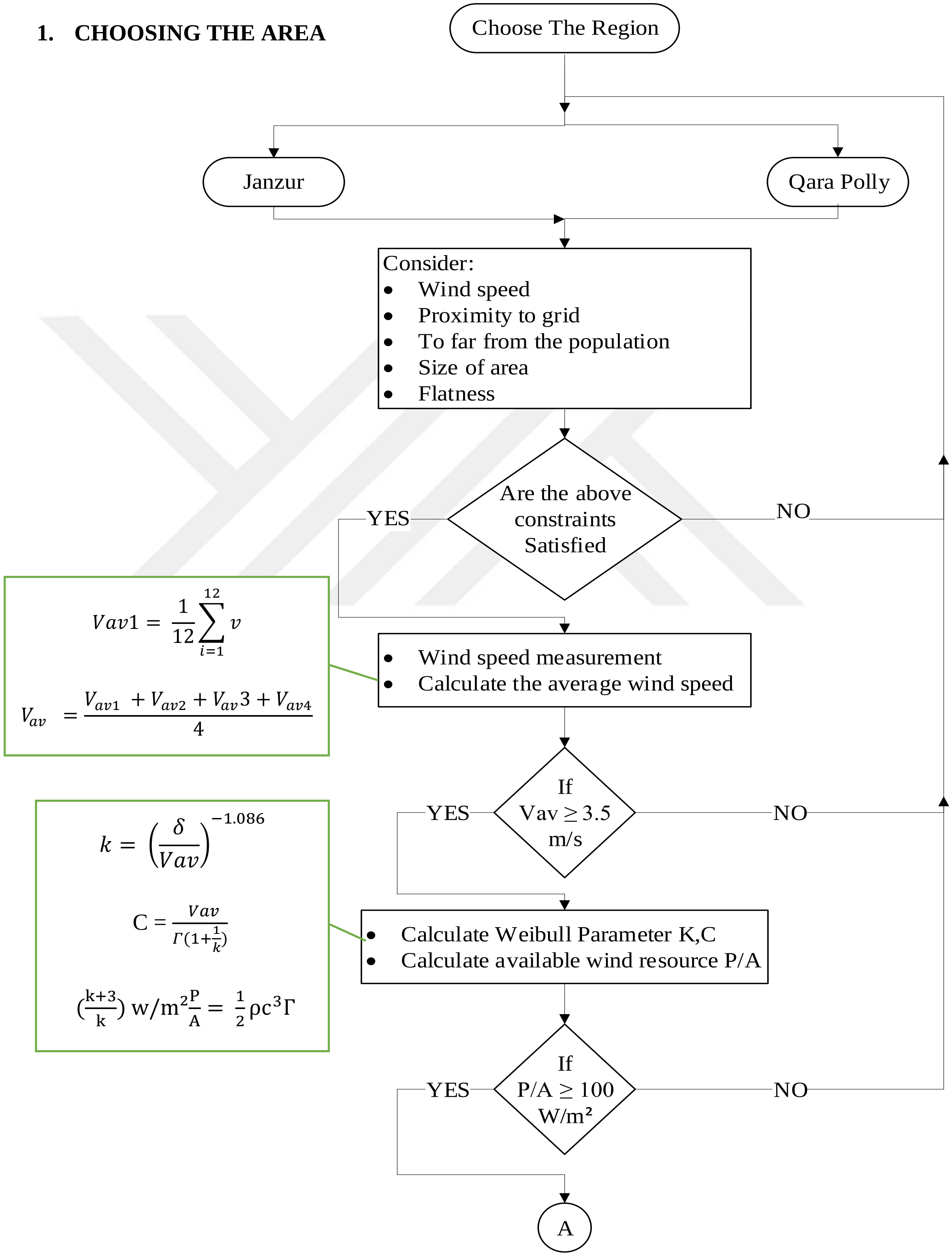
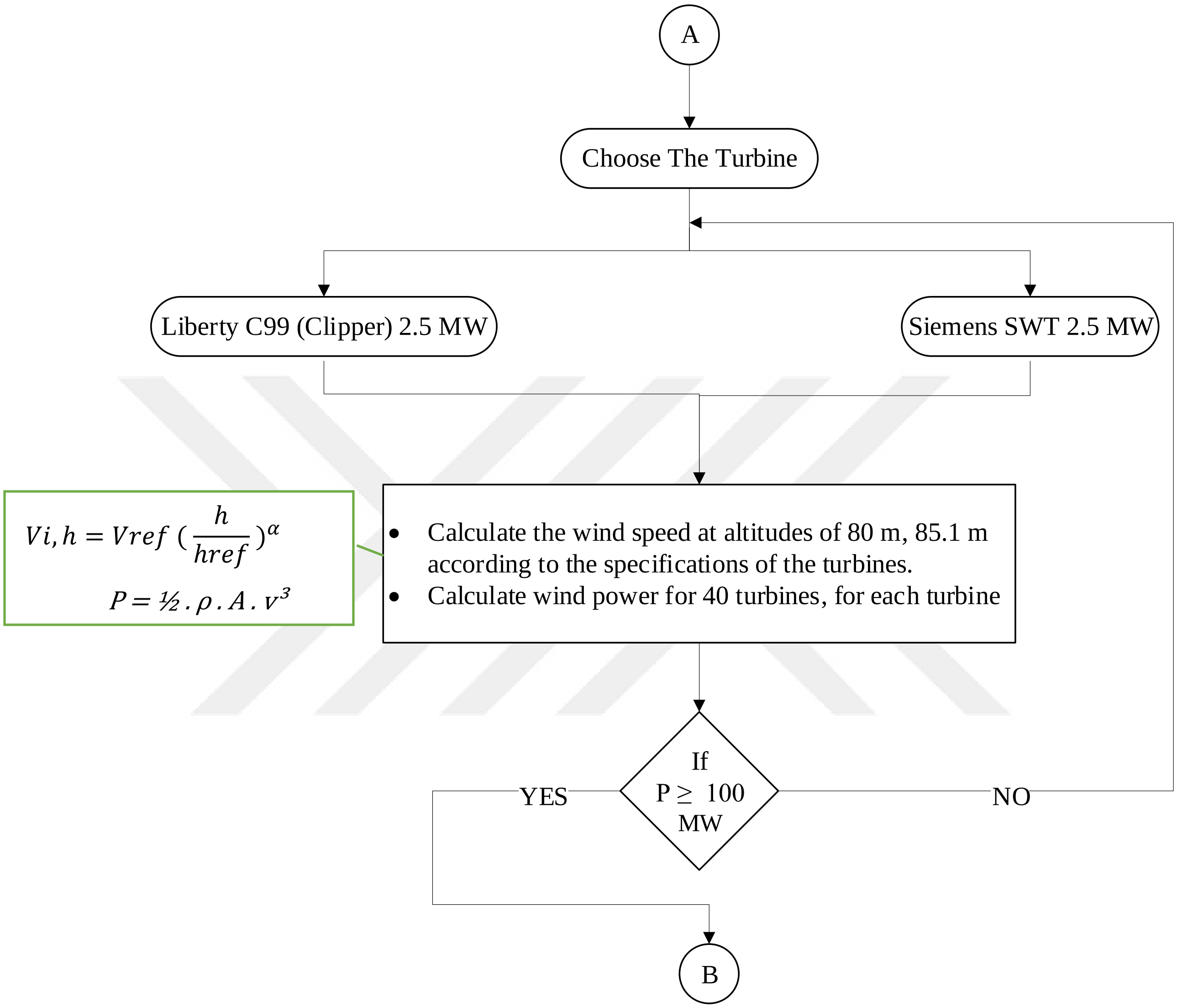
APPENDIX

1. CHOOSING THE AREA



2. CHOOSING THE TURBINE



3. COST ANALYSIS