An-Najah National University

Faculty of Graduate Studies

ASSESSMENT OF WIND ENERGY POTENTIAL IN PALESTINIAN TERRITORIES

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This Thesis was Defended Successfully on 24/06/2024 and approved by

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Dedication

يشرّفني أن أهدي هذا الانجاز العلمي لمن بلّغنا الرسالة وحثّنا على طلب العلم ..... إلى خير البريّة وسيّد ولد آدم؛ سيّدنا محمّد عليه الصلاة والسلام.

الى امهاتنا وأباؤنا ..... الى من زرعَ بداخلي طلب العلم ..... الى من تطلّع لنجاحي بنظرات الأمل والتفاؤل الى من كان دعاؤها سرّ نجاحي ..... الى أمّي العزيزة.

الى من قاسمتني الحياة ..... الى من بيني وبينها المودة والرحمة ..... الى زوجتي العزيزة.

إلى معلمينا الأحباب، وخاصة أولئك الذين كان لهم الأثر الكبير فينا.

إلى رفاق الدّرب، إلى إخوتي وأصدقائي وأحبائي.

الى أرواح شهدائنا ..... الى الاسرى ..... الى وطننا العزيز

إلى الأهل والأحباب في غزة هاشم.

أهدي هذه الأطروحة إليكم جميعا، والله من وراء القصد.

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Declaration

I, the undersigned, declare that I submitted the thesis entitled:

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I declare that the work provided in this thesis, unless otherwise referenced, is the researcher’s own work, and has not been submitted elsewhere for any other degree or qualification.

Student's Name: **Motasem Qasem Solaiman**

Signature: 

Date: **24/06/2024**

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ASSESSMENT OF WIND ENERGY POTENTIAL IN PALESTINIAN TERRITORIES

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Abstract

The Occupied Palestinian Territories (OPT) face significant challenges due to a high dependency on imported conventional energy sources, including petroleum and approximately 90% of its electrical energy needs from Israeli companies. This dependency results in elevated energy costs and susceptibility to price fluctuations. Amidst these challenges, the energy dilemma has a vital solution in renewable energy. with wind energy representing an underutilized yet promising resource within the OPT. Despite its global significance, wind energy's potential remains largely untapped in the OPT due to a limited number of studies, professional capacity constraints, and geopolitical barriers, alongside the high costs associated with wind energy technologies. These factors have led to a palpable sense of frustration and the perception of wind energy projects as impractical within the region.

This study uses exacting scientific procedures to thoroughly examine and assess the OPT's potential for wind energy. Employing the Weibull distribution method, The goal of the study is to present a thorough summary of the state of wind resource evaluations as of right now., explore existing wind energy conversion technologies suitable for the OPT, and present detailed wind characteristics for specific regions under study. Additionally, it aims to identify the most viable locations for wind turbine installations and determine the most appropriate turbine types for these areas. Through this approach, the research endeavors to offer substantive insights and recommendations to overcome the challenges facing wind energy implementation in the OPT.

Keywords: Wind Energy, Renewable Energy, Wind Turbine, Assessment, Wind Power in Palestine.

Chapter One

Introduction and theoretical background

1.1 Introduction

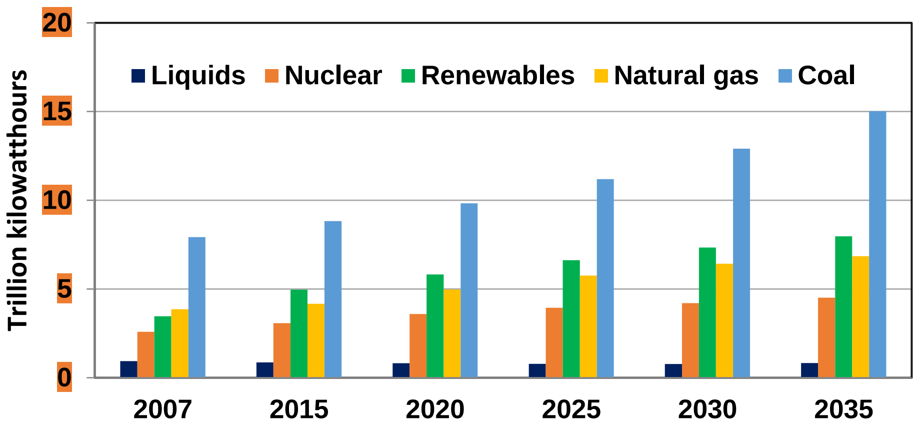
The world has advanced quickly in the last several decades in every sphere of existence. Consequently, there is unquestionably a significant rise in the need for energy. In fact, in 2018, global energy consumption increased by 2.3%, more than double the average pace of growth since 2010. As a result of increased energy use, Global CO2 emissions connected to energy grew by around 1.7% in 2018, peaking at 33.1 Gt CO2 (1).

Furthermore, global electricity demand increased by 4% in 2018 to more than 23,000 terawatt-hours (TWh) (1,2) and in recent years, Palestine has seen a significant increase in energy demand as a result of the country's high population growth, rising living standards, and rapid expansion of the industrial sector.

Palestine is a non-oil-producing country, and renewable energy plays an important part in its energy policies. Conventional energy supplies will be depleted sooner or later, and the age of petroleum is drawing to an end, making the future dangerously susceptible. The over use of traditional energy sources has had a negative impact on the environment. This is regarded as a challenge to the whole global as shown in figure1.1. depicts how the mix of main fuels used for electricity generation has changed during the last four decades.

Figure 1.1

The mix of primary fuels for electricity generation has been changed during the past four decades



The Occupied Palestinian territories (OPT) grapple with a significant energy demand shortfall alongside volatile energy pricing. Compounded by the lack of border control by the Palestinian Authority, energy procurement is entirely reliant on Israeli suppliers. Locally, only a minor portion of the electricity demand is met through the Gaza power plant, with approximately 37 MW imported from neighboring Jordan and Egypt.

Despite having the lowest overall the region's energy usage, the Palestinian Territories bear the burden of the highest energy expenses compared to any other location in the Middle East. In 2017, per capita energy consumption in Palestine stood at 1138.3 kWh, reflecting both the challenges of access and the economic strain associated with energy expenditure (1). In fact, Palestinian households spend about 10% of their income on energy (2) Remarkably, Israel has been collecting approximately 12 million shekels monthly from Palestinian electricity consumers to fund its own renewable energy initiatives. This revenue stream, however, could have been redirected to invest in the energy sector within the Palestinian territories, fostering local development and sustainability (3).

Electricity access remains unreliable for many Palestinians, particularly in the Gaza Strip. Thus, prioritizing renewable energy and implementing energy-efficient measures emerges as the most effective solution to Palestine's energy security challenges. By reducing reliance on conventional energy sources, such initiatives not only enhance resilience but also contribute to the amelioration of living standards and economic conditions (4, 5). This will diminish the need for imported electricity, fostering greater energy sustainability at a reduced cost. Additionally, it will play a pivotal role in curbing CO_2 emissions, thereby contributing to environmental preservation and long-term ecological health (6, 7) as in 2016, carbon emissions reached 4,645.5 tons, as reported by PCBS (1).

Renewable energy (RE) emerges as the paramount solution to meet the exponentially growing energy demands. RE harnesses energy from naturally replenished resources such as solar, wind, geothermal, hydropower, tidal energy, and biofuels, thus contributing to environmental preservation. In 2018, CO_2 emissions surged by over 4%, highlighting the urgency of transitioning to RE to mitigate climate impacts; this transition has the potential to avert 215 Mt of emissions. Notably, electricity generated from RE sources witnessed a commendable increase of over 7% in 2018. Presently, RE accounts for approximately 45% of the global growth in electricity generation and encompasses over 25% of the world's power output. Embracing Renewable Energy Sources (RES) alongside energy efficiency measures stands as the foremost strategy to diminish reliance on conventional energy sources. For Palestinians, this approach signifies a pivotal step towards energy independence and sustainability(8, 9).

The core focus of the Palestinian Energy National Resources Authority (PENRA) lies in leveraging renewable energy for electricity generation. PENRA's strategy aimed to generate 240 GWh of electricity from Renewable Energy Sources (RES) by 2020, constituting approximately 10% of the total electrical energy demand (10).

In the Palestinian territories, three primary renewable energy resources stand out: solar, wind, and biomass. Despite this abundance, numerous studies highlight the untapped potential of wind power in Palestine. Presently, there are no projects specifically geared towards harnessing wind energy, indicating a significant opportunity awaiting exploration and development.

Aside from this, the amount of electricity generated from wind and solar PV increased by roughly 12% and 31%, respectively, in 2018With around 3000 hours of sunshine annually and solar radiation (kWh/m2/day) readings for 2013 of 8.27 in Ramallah, 7.51 in Hebron, 6.86 in Salfit, and 6.15 in Tubas, respectively, Palestine has a substantial potential for solar energy.

The primary objectives of this research are to delve deeper into the analysis, assessment, and research of the Occupied Palestinian Territories' (OPT) wind energy potential using exacting scientific methods. This endeavor holds significant importance, particularly considering the inclusion of wind energy in the Renewable Energy (RE) strategy implemented by the Palestinian Energy National Resources Authority (PENRA) (11) RE strategy suggests utilizing about 4MW from small scales wind turbines and 40MW from large scale wind turbines as shown in table1.1.

Table 1.1
Strategy for RE ad EE in OPT for 2020 (12)

Technology	2020 (MW)
PV system –Grid connected	25
Roof tops PV system (Palestinian Solar Initiative)	20
CSP	20
Bio gas from landfills	18
Biogas from manures	3
Small scale wind turbines	4
Large scale wind turbines	40
Total	130

1.2 Overview

The process by which wind turbines transform wind energy into a form that can be used is known as wind power, such as mechanical energy. This mechanical energy can fulfill certain objectives, like grinding grain or pumping water, or it can be converted by a generator into electricity to supply households, businesses, schools, and other facilities. Wind turbines typically feature two or three elongated blades designed to capture wind energy and transform it into electricity. As the blades rotate in response to the wind, the kinetic energy of the wind is transformed into electricity, powering a generator.

To generate sufficient electricity for urban areas, multiple wind turbine towers must be grouped together to form what is known as a 'wind farm.' While smaller turbines may be installed to supply electricity to isolated areas, these massive wind farms are usually linked to the nearby power grid. Wind farms situated on agricultural or grazing land typically have minimal environmental impact compared to other energy sources. Additionally, residential wind energy systems are becoming available and can potentially power individual appliances or entire homes, depending on their size and capacity.

The emissions linked to generating electricity from wind technology are virtually non-existent since no fuels are burned in the process. Consequently, wind energy stands as a clean and environmentally friendly source of electricity. Wind farms don't emit any greenhouse gasses or air pollution like conventional power plants do. Moreover, wind energy is both clean and reliable, offering a cost-effective solution for generating electricity. Wind-generated electricity does not contribute to global warming or the formation of acid rain. Furthermore, unlike nuclear power plants, wind power poses no risk of radioactive exposure. In regions with low rainfall, wind turbines could need a modest amount of water. Water is utilized to remove dirt and insects off the turbine's blades in order to maintain optimal efficiency if rainfall is insufficient to keep them clean. On the other hand, wind turbines operate without generating any wastewater during the electricity generation process. Additionally, wind technology produces minimal amounts of solid waste.

While wind turbines typically occupy land, they can also be situated offshore. The land surrounding wind turbines remains available for alternative uses such as cattle grazing or agriculture. Upon removal, wind turbines leave behind no solid waste or fuel residues. However, the aesthetic impact of large wind farms is a concern, and improperly installed turbines may contribute to soil erosion. Noise can also be a factor, although advancements in blade design aim to reduce its impact. Bird and bat mortality has been observed at some wind farms, but improvements in turbine technology and siting have helped alleviate this issue.

The use of wind energy to generate electricity has garnered significant attention globally in recent times. We give an overview of wind energy systems in this chapter.

Currently, numerous university wind energy research initiatives are underway in a wide range of nations, including the United States, Germany, Spain, Denmark, Japan, South Korea, Canada, Australia, and India. The American Wind Energy Association (AWEA), the National Renewable Energy Laboratory (NREL), and the Global Wind Energy Council (GWEC) are notable institutions devoted to wind energy research. According to a GWEC analysis, wind energy might provide about 12% of global electricity demand by 2020, highlighting the importance of wind energy research in the debate today.

Within the scope of this study, a concise review is conducted on the prevailing advancements within the domain of global wind energy, with particular emphasis on key facets including market dynamics, technological advancements, economic considerations, environmental impacts, wind energy prospects, and ongoing research and development initiatives. Each of these domains is scrutinized to provide insights and highlights pertinent to the current discourse. In particular, an analysis of the global wind power capacity and energy generation's temporal evolution is included in the section on global market dynamics, alongside an exploration of leading market trends and key statistics shaping the contemporary landscape of wind power worldwide. Subsequently, the technology issues section delves into discussions encompassing the upscaling of wind turbine machinery, elucidating the principal technological attributes characterizing modern wind turbines, and addressing pertinent issues such as grid integration, machine efficiency, and the burgeoning small-scale wind turbine industry.

A thorough analysis covering the evolution of investment costs over time as mentioned in 5.3, the comparative costs of onshore and offshore applications, the impact of financial support mechanisms, the new job opportunities resulting from the growth of the wind energy sector, and a comparative evaluation with other power generation technologies is provided in the economics section.

The environmental performance section then provides information about the effects of wind energy by emphasizing the reduced externalities and degrees of social acceptance of wind power. Finally, the research and development (R&D) and wind energy prospects section offers a succinct summary of future goals on the technological and market fronts.

1.3 Main Social Impact of Wind and Means of Mitigating

1.3.1 Cost Issues

Compared to traditional fossil fuel generators, wind power still requires a comparatively high initial investment, despite a dramatic decrease in cost over the past ten years. Roughly eighty percent of this expenditure is related to the machinery itself (13), with the remaining portion going toward site setup and installation. When wind-producing systems are compared to alternative generating technologies, wind costs become significantly more competitive when considering a "life-cycle" cost base that accounts for fuel and operating expenses over the course of the generator's lifespan. This is chiefly due to the absence of ongoing fuel procurement expenses and minimal operating costs associated with wind power.

1.3.2 Environmental Concerns

While wind power plants exert a comparatively lesser environmental footprint in contrast to fossil fuel counterparts, certain concerns persist regarding the noise generated by rotor blades, typically restricted to 35 to 45 decibels at a distance of 300 meters(14). Additionally, aesthetic considerations and the risk of bird and bat fatalities resulting from collisions with rotor blades remain pertinent issues. However, many of these challenges have been effectively mitigated or significantly reduced through technological advancements and meticulous siting practices. Notably, wind turbine manufacturers have made significant strides in refining designs and aerodynamics to minimize noise levels and minimize wildlife impact.

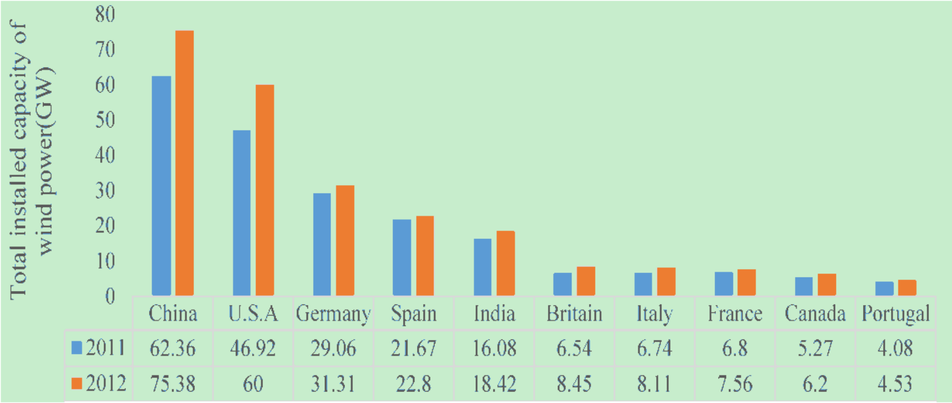
1.3.3 Worldwide Status of Wind Energy

By fully using the continual cost decrease of wind generator technology during periods when the cost of conventional fuels instead rises, wind energy is a clean energy source that helps to lessen dependency on fossil fuels (15). Today, wind energy holds significant promise as a key player in the global shift towards clean energy solutions, with numerous countries actively investing in its development and deployment as show in figure 1.2. Its relevance in the shift to a cleaner and more sustainable energy future is further highlighted by the fact that it is an environmentally benign and sustainable energy source.

Wind energy is poised to remain a primary contributor to energy consumption in key regions such as the USA, Europe, and China for generations to come. Even if the worldwide wind sector saw a record-breaking year in 2020—93 GW of new capacity installed—a remarkable 53 percent increase from the year before—this growth is insufficient to help the world reach net zero emissions by 2050. As a result, a substantial shift towards renewable energies is imperative, with a target of at least 80% of electricity derived from renewable sources. To effectively mitigate the impacts of climate change and adhere to a net zero pathway, the installation rate of wind power needs to triple over the next decade, thereby accelerating the transition towards a sustainable energy future.

Figure 1.2

The top 10 countries with the most wind power



	China	U.S.A	Germany	Spain	India	Britain	Italy	France	Canada	Portugal
2011	62.36	46.92	29.06	21.67	16.08	6.54	6.74	6.8	5.27	4.08
2012	75.38	60	31.31	22.8	18.42	8.45	8.11	7.56	6.2	4.53

The global wind power market has grown by about four times in the last ten years because to economies of scale and technological developments, securing its place as one of the most reliable and competitive energy sources in the world. The COVID-19 epidemic caused interruptions to the worldwide supply chain, project development, and the economy overall, but the wind industry showed incredible resiliency in 2020. achieving record-breaking growth. The two biggest wind power markets in the world, China and the US, saw a significant increase in installations, which was the main cause of this spike. These nations combined constitute more than half of the global wind power capacity and accounted for about 75% of the new installations in 2020.

With 242 GW of wind generating capacity today, approximately 1.1 billion tons of CO2 are avoided globally (16)—an amount equal to South America's yearly carbon emissions. For instance, the states of the United States that border the Rocky Mountains and the Great Plains have enough wind resources to provide 10% to 25% of their total electricity needs (17). Across the Atlantic, wind energy will assist the European Union (EU) in achieving its objectives for the production of electricity using wind power.

1.4 Motivation

The Palestinian territories face chronic electricity shortages largely due to their heavy reliance on the Israeli electrical grid. It is imperative to explore alternative power sources to address this issue. Wind energy emerges as a prominent candidate, offering significant potential as a clean and reliable power source.

Unlike solar panels, which primarily generate electricity during daylight hours, wind turbines can produce power consistently throughout the day. However, to optimize their efficiency, careful consideration must be given to their placement based on comprehensive studies of wind speed data. Therefore, this study aims to identify suitable locations and provide relevant data to guide future endeavors in wind turbine placement, thereby facilitating the effective utilization of wind energy resources.

1.5 Objectives

The primary goals of this study are outlined as follows:

1. to provide information about the Occupied Palestinian Territories' (OPT) wind energy potential.
2. to look into the opportunities and problems that wind energy has in the OPT.
3. To contribute to public awareness regarding the environmental impacts of renewable energy sources compared to traditional energy sources.
4. to give a summary of the state of wind resource assessment research as of right now.
5. Presenting the existing wind energy conversion technologies used to harness the available wind in OPT.
6. To conduct a detailed analysis on the economic aspects associated with deploying wind energy conversion technologies.
7. To characterize wind patterns in the studied regions of the OPT.
8. To choose the best method of deployment and the most practical locations for the installation of wind turbines.
9. Providing inputs to decision makers about the suitable regions for wind energy utilization.
10. To create a long-term plan for technology transfer, knowledge sharing, and capacity building that includes instruction and training on the creation, application, and upkeep of renewable energy technologies, especially wind energy.

1.6 Hypotheses

The main hypotheses of this study are as follows:

- There exist numerous elevated areas within the Palestinian territories that harbor significant wind potential suitable for wind turbine deployment.
- The capacity of wind turbines and productivity to meet satisfying points of electrical energy generation in terms of daily, monthly and annual production.

- Economic feasibility of investing in wind, especially as it contributes to reducing electricity shortages and increasing energy independence in the Palestinian territories.

1.7 Literature Review

The wind energy has experienced rapid growth globally, expanding from 23 GW in 2001 to over 650 GW by 2019, with a reserve capacity exceeding 400 million MW. With the growing demand for power, the effective utilization of wind energy can significantly contribute to meeting this demand. Assessing wind energy potential involves employing innovative methods following thorough studies of wind characteristics, including speed and density, utilizing reliable databases for accurate analysis.

Maher M. Al-Maghalseh (18) discusses how renewable energy distributed generation units are increasingly significant components within systems due to their numerous advantages. However, they also pose certain drawbacks, such as bidirectional power flow and adverse effects on protection systems. Determining the appropriate size of distributed generation units integrated into the grid involves employing specialized techniques and methods like Newton-Raphson algorithms. This enables the optimization of grid utilization.

S.S. Chandel (19) emphasizes the significance of comprehending wind behaviour to mitigate adverse impacts on the power system, including transient voltages, currents, power fluctuations, and quality issues resulting from the stochastic nature of wind. India has prioritized this endeavor, establishing a dedicated ministry to spearhead studies and develop methodologies and software tools for analyzing wind behavior, conducting technical assessments, and assessing economic viability.

The importance of precise wind potential estimation prior to harnessing wind energy was underscored by Muhammad Sumair (20). Various methods exist for estimating Weibull parameters, with some deemed more accurate than others. These include the Maximum Likelihood Method (MLM), Least Square Method (LSM), Energy Pattern Factor Method (EPFM), and Modified Method of Moment (MMOM). Among these, the Modified Method of Moment (MMOM) stands out as the most accurate method based on findings from relevant studies and experiments.

Arian Bahrami (21) highlights Turkmenistan's significant natural gas reserves, ranking it as the world's fourth-largest gas reserve. With a projected 60% increase in global demand by 2030, Diversifying energy sources is important in order to fulfil this need. Reducing greenhouse gas emissions is one of the main goals for protecting the environment, which emphasizes the value of renewable energy (RE) sources, especially wind turbines.

Turkmenistan aims to harness wind energy to address this challenge. Two scenarios have been proposed to achieve this goal: firstly, direct gas sales to Europe via pipelines, which encountered political and technical obstacles and proved unfeasible. The alternative approach involves utilizing gas for electricity generation and exporting it to neighboring countries to finance wind farm projects.

Turkey's energy consumption is experiencing rapid growth, driven by industrial and population expansion as it was noted by B. Yaniktepe (22). This surge has prompted the country to seek sustainable alternatives to conventional resources. Wind energy stands out as particularly promising due to Turkey's geographical attributes. Assessing wind energy potential for specific sites entails acquiring comprehensive insights into wind characteristics, including speed, direction, continuity, and availability. To study the wind potential and characteristics in Osmaniye, A distinct model was used the Weibull model.

Electricity generation in Nigeria heavily relies on conventional resources such as gas and fossil fuels as highlighted by T.R. Ayodele (23). However, the country's limited conventional resources coupled with its large population have led to an energy deficit and widespread poverty. Consequently, there is a pressing need to conduct studies assessing wind potential across Nigeria's six geological zones. Fifteen locations have been scrutinized to evaluate their economic feasibility and identify the most suitable types of wind turbines.

Arian Bahrami (24) underscores the significant hurdles Uzbekistan encounters in harnessing renewable energy sources (RES), particularly wind energy. These challenges stem from the exceptionally low electricity prices and the abundant use of natural gas for electricity production. Additionally, Uzbekistan faces relatively low average wind speeds. After thorough evaluation, it was determined that GOLDWIND 140/3 wind turbines are best suited for the country's wind speed characteristics. Implementing such initiatives would be facilitated by government support, especially considering RES as long-term investments.Tariq Abu Hamed (25) highlights the significant impact of energy poverty on both global and local scales, which has garnered increasing attention on the international stage in recent decades. Lack of access to sufficient, dependable, affordable, and clean energy sources is known as energy poverty.

Access to sufficient and sustainable power sources is crucial, serving as a cornerstone for prosperity and economic development, particularly in Palestine where reliance on insufficient Israeli power sources is prevalent. Renewably produced energy (RE) sources have been linked to reducing energy poverty and slowing down global warming, according to a number of studies.

Wael A. Salah (26) also highlighted that in Palestine, the high average radiation and daily sunshine rate of solar energy make it a dependable energy source. The transition from fossil fuel resources to renewable alternatives is deemed a strategic solution, offering positive implications for the economy and environment. Moreover, it facilitates electrification in rural and remote areas and crucially reduces dependence on Israeli power resources.

90% of Palestinian power demand is reliant on imports from neighboring countries, underscoring the imperative for pursuing power independence as mentioned in A. De Meij et al. (27) Studies suggest that up to 25% of power demand can potentially be met through locally sourced renewable energy (RE) forms, notably solar, wind, and biomass.

Regarding wind energy, specific areas in Hebron, Northern Ramallah, and the Gaza Strip exhibit promising potential for feasible benefits. This underscores the necessity for conducting studies and developing methodologies, particularly given the antiquated nature of the available database, which is based on measurements recorded in the Beaufort Force scale from 1940 to 1947.

To address this, automated meteorological stations are utilized for measuring wind speed and behaviors. Additionally, systems such as the Weather Research and Forecasting (WRF) simulation system are employed to augment data collection and analysis efforts.

Shabbaneh and Hasan (28) carried out an analysis using data from automated weather sensors and data from the past. They examined measurements spanning from 1940 to 1983 to assess wind potential across the Occupied Palestinian Territories (OPT). Specifically, the data, initially the information used as the foundation for their analysis was first documented in the Beaufort Force scale between 1940 and 1947. For Palestine's West Bank, the researchers computed the Weibull density distribution function's form and scale parameters. Their findings revealed that the areas with the highest wind potential were primarily situated in the West Bank, notably in the Hebron area and the northern region of Ramallah.

M.S. Ismail (29) highlighted that Palestine is situated within an area characterized by abundant solar radiation, averaging about 6 kWh/m2/day. This solar resource encourages the utilization of solar energy, particularly in remote areas. To enhance the reliability of power systems and mitigate vulnerability associated with single-source power systems, hybrid systems are favored. Integrating wind turbines with photovoltaic (PV) systems, for instance, offers increased reliability and reduced electricity costs.

Rushdi Kitaneh (30) observes that the mean wind speeds in Hebron and Nablus are greater, exceeding 3.5 m/s. As a result, July had the highest and average yearly wind power density measurements, both of which reached 37.85 W/m^2. While wind speed measurements in Jenin, Jericho, and Nablus were taken at approximately 6 meters above ground level, in Hebron, they were recorded at a height of 10 meters. This discrepancy suggests that power production significantly increases at higher elevations.
The diverse array of methodologies employed in appraising wind energy were highlighted by M.J. Shawon (31), encompassing established methods like the Present Value Cost (PVC) and Levelized Cost of Electricity (LCOE) approaches, while also proposing simpler and more efficient alternatives. One such method involves computing the cost per kWh, which relies on core factors such as turbine expenditure, wind speed, and financial considerations.

Antonis Tsikalakis et al. (32) accentuates the significant solar radiation potential present in the MENA (Middle East and North Africa) region, which ranks among the highest worldwide. Nevertheless, this potential remains largely untapped. Leveraging distributed generation (DG) systems centered on solar energy, particularly photovoltaics (PVs), holds promise for substantially elevating electrification rates at competitive price points. Furthermore, such initiatives have the potential to yield societal benefits by effectively meeting local energy demands at affordable rates.

augmenting electrification rates at competitive cost levels. Furthermore, such initiatives are poised to engender societal benefits by satisfactorily addressing local energy demands while ensuring economic viability.

Despite the scarcity of literature addressing the wind energy potential in Palestine the study examined this crucial factor in order to provide insight into the potential and viability of wind energy use in the area.

Chapter Two

Research Methodology and Wind Energy Conversion System

2.1 Research Methodology

As stated, before this study aims to identify suitable locations and provide relevant data to guide future endeavors in wind turbine placement, thereby facilitating the effective utilization of wind energy resources.

Using a mixed-methods approach, this study combines qualitative case studies with quantitative analysis. Economic variables including GDP growth, employment rates, and investment levels will be compared with policies pertaining to renewable energy through quantitative analysis using econometric models. Qualitative case studies will provide insights into the contextual factors shaping the implementation and outcomes of renewable energy policies in selected countries.

In order to investigate the most significant and recent research on wind energy in the Occupied Palestinian Territories (OPT), a thorough assessment of the literature was conducted. This review encompassed research focusing on the region's specific challenges, opportunities, and advancements in wind energy utilization. Additionally, the methodology for evaluating and assessing wind energy potential and feasibility in the OPT was thoroughly examined. The wind data served as the cornerstone of this research. The most reliable source of wind data was determined to be long-term data collected from meteorological stations. The site's one-year dataset was enough to show long-term fluctuations in the wind profile at a ten percent accuracy level. Wind flowers were produced for each site as they would be shown later.

The gathered wind data from the area required to be appropriately processed and analyzed to ascertain the site's potential for wind energy. Weibull It is the statistical model used for wind data analysis. The probability density function and the cumulative distribution function were used to quantify the fluctuations in wind velocity in the Weibull distribution. The assessment of Wind Energy Conversion Systems (WECS) proposed at a site was a complex process as it depended on various factors simultaneously. The strength of the site's predominant wind spectrum and its accessibility to the turbine were among these factors, as was the rotor's aerodynamic efficiency in converting wind power into mechanical shaft power and its ability to manipulate, transmit, and transform this power into the desired form.

The study examined wind profiles from 2000 to 2011 and found that the year 2003 had the highest annual average wind speeds, while the year 2008 had the lowest annual average wind speeds. Peak wind speeds were usually recorded in the winter months in the West Bank regions, with a predominance of westerly winds.

The analysis of wind power density and yearly energy production from a 100-kW wind turbine reveals a modest potential for wind energy in Palestine, despite generally stable wind power density throughout the 12-year period (2000–2011) in Gaza and the West Bank, indicating a consistent wind resource.

Upon comprehensive examination of the results obtained for various Palestinian cities, it was determined that Hebron emerges as the most promising city for wind energy exploitation, followed closely by Ramallah. Conversely, Jericho exhibits the lowest wind energy potential. Notably, the city of Hebron showcased the highest average wind speed at 5.06 m/s, succeeded by Ramallah at 4.56 m/s. Based on these findings, it is recommended that priority be given to the exploitation of wind energy resources in these cities.

The ethical standards for performing research with human beings will be followed in this study. Every participant will be asked for their informed consent before any data is collected or analysed, and confidentiality will always be upheld. Any potential conflicts of interest will be disclosed and addressed transparently.

2.2 Wind Energy Conversion System

2.2.1 Introduction

Since wind energy generation is one of the most economical and ecologically good ways to produce power from renewable sources, it has been observed that it is the renewable energy source with the fastest pace of technological advancement. Wind energy conversion systems transform wind energy from kinetic energy into electrical power or other energy types. Over the last ten years, wind power generation has grown significantly and gained recognition as an economically viable and ecologically sustainable method of producing electricity. This chapter covers the basic concept of a wind energy conversion system, its components, system modeling, and the different types of wind turbines. (33).

One clean, sustainable energy source is wind. It is a gas flow that is brought about by changes in atmospheric pressure. Air moves from areas of higher pressure to those of lower pressure when there is a difference in atmospheric pressure. However, as the sun heats the wind differently around the planet and stores between 1% and 2% of the solar energy that reaches the planet in the wind, all of these are a result of solar influences.

The human attempted to use and benefit from the wind in his life. In addition, the wind is utilized in a variety of ways, such as propelling sailing boats, turning windmills to extract subterranean water, etc.

In general, there are two sorts of wind: global and local. The global wind refers to the huge motions throughout the globe, whilst the local wind refers to the wind movements in a single region of the planet. The wind can be characterized by its speed and direction, and is governed by a combination of three forces (34):

- Pressure-gradient force (PGF).
- force of Coriolis.
- Friction

The earth's surface exerts a significant influence on wind characteristics, affecting factors such as friction and pressure. As a result, wind can vary in temperature, with warm winds being less dense than cold ones. Land and ocean surfaces contribute differently to wind patterns due to variations in surface smoothness. These differences in surface characteristics lead to distinct air pressure fluctuations, contributing to the formation of ocean and land breezes, which in turn result in disparate temperature conditions. During the day, the seas are heated more than the land, causing the air above the land to rise and the wind speed to increase from the ocean to the land, and vice versa at night.

Each the system of wind energy harnesses the kinetic energy of the wind, converting it into either mechanical or electrical energy. While wind turbines vary greatly in size, they all operate on the same fundamental principles. Each system typically comprises a rotor, it is made up of blades that transform wind energy into shaft rotational energy. This rotational energy is then transmitted to a drive train housed within a nacelle, which contains various components such as gears and shafts. Finally, the mechanical energy is converted into electrical energy by a generator located within the nacelle. This electricity can be stored in batteries or transmitted directly to home power grids or utility companies for widespread use.

This chapter provides an overview of the wind energy conversion system, delving into its fundamental principles, the essential components comprising such a system, and the modelling techniques employed. Additionally, it explores the various types of wind turbines utilized in wind energy generation.

2.2.2 Historical

Humans first endeavoured to harness the power of wind for energy during the era of sail-propelled ships and boats, a concept that originated with the movement of boats along the Nile River around 5000 B.C. Subsequently, wind power found utility in tasks such as powering grain grinding mills and water pumps. The earliest known use of rudimentary windmills occurred in China around 200 B.C., primarily for water pumping purposes, while Persia and the Middle East adopted vertical-axis windmills with woven reed sails for grain grinding. These developments marked significant milestones in the utilization of wind energy. Over time, wind energy technology underwent a series of advancements, evolving from rudimentary and cumbersome devices to the sophisticated and efficient equipment seen today.

Centuries ago, the foundation of wind energy technology was laid, with early ancient wind instruments dating back thousands of years. One of the first notable developments was the introduction of vertical-axis windmills approximately 200 BC, close to the borders between Persia and Afghanistan. Afterward, horizontal-axis windmills emerged in regions like the Netherlands and the Mediterranean between 1300 and 1875 AD (35, 36). The refinement and advancement of these systems continued into the 19th century, notably in the United States There, between 1850 and 1970, more than 6 million tiny wind devices were used to pump water. Specifically, in 1888, the installation of the first large-scale wind turbine designed for electricity generation occurred in Cleveland, Ohio. Additionally, Denmark achieved a milestone in 1890 with the construction of the world's inaugural modern wind turbine, specifically engineered to produce power for outlying districts. This marked the initial foray into electricity generation through wind energy. In Denmark, 25 kW machines were widely used in the latter stages of World War I.

During this period, there was a notable shift towards more systematic and organized procedures in the engineering design of turbines. These advancements contributed to the potential for exceptional performance in the field, attributed to the adoption of low-solidity rotors and aerodynamically optimized blades. Furthermore, the evolution of wind generators in the USA was influenced by the design principles of airplane propellers and monoplane wings. Between 1935 and 1970, substantial advancements were made in Denmark, France, Germany, and the UK, proving the feasibility of installing wind turbines on a wide scale. European nations kept pursuing advancements in wind energy after World War II. For instance, Denmark's Gedser mill, featuring a 200 kW three-bladed upwind rotor, operated successfully until the early 1960s (37).

Where in 1968, for instance, Germany was the country that pioneered the development of light-weight constant-speed rotors. They featured basic hollow towers that were supported by man ropes, and connected to those towers were blades made of fiberglass. This breed's most potent example has a diameter of 15 meters and a rated output of 100 kW. and a number of sophisticated horizontal-axis designs were created, with both of the aforementioned concepts dictating the future horizontal-axis design approaches later emerging in the 1970s, when Denmark and California were the first to use wind to generate electricity on a commercial scale. In the period spanning from 1973 to 1986, the commercial market for wind turbines underwent a significant evolution. Initially focused on domestic and agricultural applications with power ratings ranging from 1 to 25 kW, the market gradually transitioned towards utility-scale wind farms with capacities ranging from 50 to 600 kW. During this period, California experienced the first notable surge in large-scale wind energy integration (38), where over 16,000 machines, ranging from 20 to 350 kW (a total of 1.7 GW), were installed between 1981 and 1990, as a result of the incentives (such as the federal investment and energy credits) given by the USA government. In northern Europe on the other hand, wind farm installations increased steadily through the 80s and the 90s, with the higher cost of electricity and the excellent wind resources leading to the creation of a small but stable market. After 1990 most market activity shifted to Europe (39) where in 1990, more than 10,000 megawatts of wind power capacity were utilized across the world., with the last twenty years bringing wind energy to the front line of the global scene with major players from all world regions.

Over the past few centuries, there have been numerous ups and downs in the global wind energy business. But the most significant periods for the wind energy industry turned out to be the 20th and 21st century. During these two centuries, a number of noteworthy and inventive technologies were developed.

Nuclear and hydropower combined accounted for about 65 terawatt hours of Sweden's 2003 energy production, which totaled 143 terawatt hours. Steam energy is used to produce 11 terawatt hours. Wind energy has been the fastest-growing exporter of renewable energy worldwide over the past several years, and its capacity is also expanding in Sweden. As of the end of 2003, there was approximately 400MW of installed wind power.

Sweden's wind energy output increased dramatically between 2000 and 2011, rising from 0.5 terawatt hours to 7.1 terawatt hours. There were about 2000 working wind turbines in the nation by 2011. In the upcoming years, it is anticipated that the pace of research and development in the wind energy industry would quicken. A number of novel ideas were developed at this time, such as the Musgrove rotor, the vortex turbine, and diffuser-enhanced design. These turbines' prototypes were built and tested, but only the horizontal axis propeller design seems likely to be successfully applied in the marketplace.

In recent decades, significant advancements in wind power technology have been observed globally, with European and developed nations leading the way. However, progress in developing countries has been comparatively slower. Palestine, classified as a developing nation with limited resources, has faced additional challenges due to decades of conflict and territorial division between Israeli and Palestinian territories. This division has created stark economic disparities within the region, with Israeli territories enjoying a level of development on par with European standards, while Palestinian territories lag behind. Addressing this gap necessitates distinct development policies and planning strategies tailored to the unique circumstances and available resources of each region.

2.2.3 Background of Wind Resource Assessment (WRA) in Occupied Palestinian Territories

The investigation into wind potential in Occupied Palestinian Territories began in the early 1980s with a study conducted by Manes et al. In their research they determined the mean wind speeds, both seasonal and annual, for different stations. across Occupied

Palestinian Territories. Additionally, they analysed the wind frequency roses for these stations (40).

In 1986, surveys were undertaken by Druyan to encompass an area of 10,000 square kilometers in the Negev desert (41) These field surveys involved direct measurements at selected sites using handheld anemometers. Subsequently, automatic measurement stations were established at some of these sites for further observation and comparison. The study, which utilized data from meteorological stations in the Negev (41), is regarded as a significant advancement in wind resource assessment in Palestine/Israel, as it took topology and roughness into consideration.

Ten possible locations in the Negev region were identified by the study for more research. However, logistical challenges were highlighted, such as limited access due to mountainous terrain, military zones, or protected natural reserves (41). Consequently, the decision to proceed with further investigation on the Israeli side lies within the deliberations of the Occupied Palestinian Territories intra-governmental authorities.

In 1997, Shabbaneh and Hasan proposed further study based on data collected from 49 stations across Occupied Palestinian Territories (28). The data from Occupied Palestinian Territories meteorological stations covered the period from 1972 to 1983, while additional data from Palestinian territories, including the Gaza Strip, spanned from 1940 to 1947.

The study not only mapped out the boundaries of the wind potential in the Palestinian territories, but it also carried out a feasibility analysis, taking payback periods into account, to determine whether investing in wind power for electricity generation was a viable alternative to diesel stand-alone generators. The investigation of alternate energy options for Palestinians is greatly aided by this study. But since the data were gathered during two distinct time periods, it's probable that various standards were used at each interval, which could have an effect on the data's accuracy. In addition, new methods for evaluating wind resources have been established to improve the accuracy of wind power estimation; these developments have occurred since the study was carried out in 1997 (28).

In 2003, Furspane et al. proposed another study focusing on the wind power potential in the southern region of Israel, specifically "the Negev". The study included precise topographic maps that provided complete information about roughness length and surrounding impediments, in addition to utilizing data collected from 24 sites (42).

Mean wind power and velocity were mapped at 50-meter altitudes in the Negev region. Because this study uses more sophisticated models for assessing wind resources, it is significant. It was still somewhat limited, though.

Additionally, the study suggested building more stations in the Negev's suggested regions, which include the high Negev Mountains, the Judea Mountains in the southeast, the Eilat Mountains, and the Eilat Bay, all of which show a high potential for wind energy. It strongly suggests that these recommended stations measure wind speed at consistent heights and use uniform types of anemometers (42).

In the realm of wind power projects in Israel/Palestine, a notable project was initiated in the Golan Heights near the border with Syria in 1993. Ten turbines were installed, boasting a cumulative rated capacity of 6 MW (27). Recent developments suggest that permissions have been granted for the repowering of this project by a Korean company (41). Moving to the northern region of the West Bank, near a settlement called Jalboun and in proximity to the Palestinian-Israeli border, a single wind turbine was erected for testing purposes. However, there have been reports indicating plans for a wind farm in the area, although these plans were reportedly halted by an environmentalist group (43). In the southern region of the West Bank, near the Jerusalem area, a location known as Susya saw the establishment of small-scale wind projects aimed at supporting the Bedouin community and their way of life, facilitated by the Comet-MT organization (43).

2.3 Wind Energy in the OPT

Renewable energy sources, particularly wind energy, have not been efficiently utilized in the Occupied Palestinian Territories (OPT). Despite the abundance of sunshine, with no fewer than 320 sunny days annually, only small-scale projects have emerged in the past decade. The utilization of wind energy remains significantly limited in the OPT due to various factors, including the scarcity of suitable land for installing wind energy systems, financial constraints, insufficient professional expertise, and the constraints imposed by Israeli occupation authorities. The wind energy potential in the OPT is assessed to be small to moderate and remains largely untapped, resulting in the limited scope of wind energy projects. Based on available data and the topographical characteristics of the occupied West Bank, the potential for wind energy appears to be primarily concentrated in mountainous areas with elevations ranging from approximately 700 to 1,000 meters above mean sea level (MSL).

As a result, certain regions in the West Bank are suitable for producing wind energy. These regions include the areas of Nablus, Ramallah, Bethlehem, and Hebron, which are located from the north to the south of the West Bank. These regions are mostly defined by [26]:

1. more than 700 meters above mean sea level.
2. Average wind speed of no less than 5 m/s.
3. As was previously mentioned, wind energy has a practically good potential for energy generation when compared to neighboring countries. Notwithstanding these OPT characteristics, a small number of wind-powered projects for domestic use and a few medium-sized projects for commercial have been assessed for possible wind energy generation.

2.3.1 Prospects for Wind Energy in Palestine in the Future Strengths

a. Some West Bank highlands have good average wind speeds of up to 6.2 m/s (26).
b. Since wind turbines (WT) take up less space, they are the ideal option.
c. Since small wind turbines may be produced entirely locally, their cost can be reduced.
d. knowledge about the Palestinian Authority's position on renewable energy sources.
e. The Palestinian government is working to create a wind map and advance the renewable energy law.
f. Make up for the yearly 6% increase in the demand for electricity.

2.3.2 Palestine's Prospects for Wind Power in the Future Cons

a. the majority of Palestinian areas' modest wind speed.
b. There's nothing new to report on wind energy. Every prior study was based on information gathered between 1991 and 2013. and Lack of research on wind projects.
c. Lack of technical and human capabilities, and the absence of professional training on the modern applications and designs
d. high project expenses in relation to the majority of Palestinian families' income.
e. The Palestinian National Authority (PNA) offers no financial incentives or support to promote the implementation of wind energy projects.

f. Poor infrastructure in the Palestinian Territories and electricity networks to transmit wind energy to them.
g. Foreign investment is hindered by the Israeli occupation and the political climate in Palestine.
h. The Palestinian administration lacks strategies to address the growing demand for power and lacks answers to the issues related to shortcuts.

2.4 Wind Energy Technology

The power generated from wind turbine that attached to the rotor is delivered to generator via a gearbox. The gearbox and generator included in a housing called a nacelle. Some turbine designs eliminate a gearbox using direct driving. The electric power is transferred from the tower to a transformer and eventually to the grid network. Wind turbines are capable of producing power in a broad range of wind speeds, from 3 to 4 m/s to roughly 25 m/s, or 90 km/h (56 mph), which is comparable to gale force 9 or 10. Most modern turbine models take full use of the wind's continual variations by varying their working speeds and pitch control, which involves rotating or yawing the entire rotor in response to changes in wind direction. The turbine's ability to adjust to different wind speeds and work in tandem with the electrical grid is enhanced when it operates at a variable speed. It is possible to adjust the turbine's performance and electricity output thanks to sophisticated control systems. Modern wind technology can function well in a variety of environments, including deserts, frigid arctic regions, and locations with both low and high wind speeds. Wind farms are composed of clusters of turbines that are highly available, generally well-integrated with the environment, and well-liked by the general people. Modern turbine designs are streamlined, attractive, and sleek since they are made of lightweight materials. Reliability, grid compatibility, acoustic performance (noise reduction), maximum efficiency and aerodynamic performance, high productivity at low wind speeds, and offshore growth are the primary design drivers for current wind technology.

The size and height of wind turbines have also increased. The largest turbines built today have generators 100 times larger than those built in 1980. Their rotor diameters have grown eight times throughout that time. The Enercon E126, which has a rotor diameter of 126 meters and a power capacity of 6 MW, is currently the largest turbine in operation. In 2007, the average capacity of turbines installed worldwide was 1,492 kW. The offshore industry, where installing turbines on the seabed necessitates making the best use of each foundation, has been the primary impetus for greater capacity machines. The costs of offshore construction are higher than those of onshore development since they include establishing enormous foundations in the seabed, gathering electricity, and sending it to the shore. While the offshore wind farms that have been put into place thus far have utilized turbines with a maximum capacity of 3.6 MW, a variety of designs with a capacity of 5 MW and more are now being used, and these are anticipated to become the norm in the years to come.

However, in the last several years, the 1.5 to 3 MW range of turbine size has become more uniform for land-based turbines. This has made it possible to produce thousands more turbines of the same design in series, which has increased reliability and allowed teething issues to be worked out. Variations in the drive train system to lower loads and increase reliability, enhanced control systems, partially to ensure better compatibility with the grid network, and the use of various combinations of composite materials to manufacture blades—especially to ensure that their weight is kept to a minimum—are examples of ongoing innovations in turbine design (33).

2.4.1 Technology of wind energy conversion

A wind energy conversion technology is a sophisticated network of interconnected components designed to harness the kinetic energy captured by the turbine blades and convert it first into mechanical energy and then into electrical energy with the assistance of generators. Scientifically, winds originate from the differential heating of the Earth's surface, leading to variations in pressure and temperature that drive air movement. These disparities are particularly evident in proximity to bodies of water such as lakes and oceans. As a result, air movement persists both day and night, rendering coastal and offshore region’s ideal locations for the establishment of WECS.

Wind energy conversion systems (WECS) are frequently utilized in off-grid hybrid renewable energy systems (HRES). Particularly in developing nations lacking a centralized utility grid or with inadequate transmission infrastructure, wind energy plays a pivotal role. In such contexts, WECS, either independently or in combination with other renewable energy systems, can effectively power various applications including residential buildings, commercial establishments, agricultural operations, and other facilities. This integration ensures a consistent and dependable energy supply for endusers. The efficiency of the rotor's interaction with the wind flow profoundly influences the conversion rate of wind energy into usable forms of energy. This chapter will delve into key concepts integral to the conversion process of wind energy.

2.5 The parts Components of Wind Turbine System

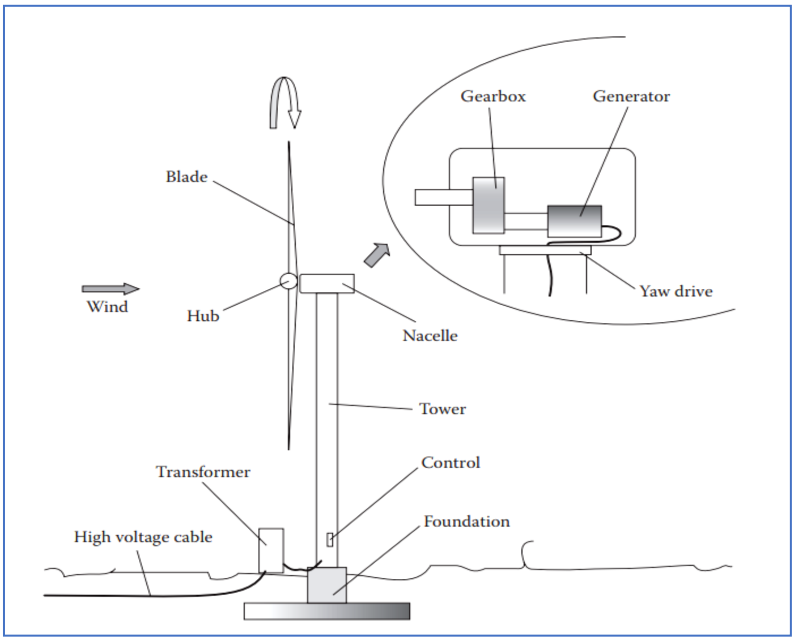
A set of rotor blades—typically three—rotate around a hub in a typical wind turbine. The gearbox and generator, which are housed inside the nacelle along with the electrical components, are connected to the hub. Figure 4.1 illustrates and summarizes the fundamental parts of a wind turbine system, which are further discussed below.

The nacelle: contains the electrical components, including the generator, yaw mechanism, wind speed and director monitor, brake, and gearbox, and it is positioned above the tower.

Rotor blades: One of the most important factors affecting turbine power is blade diameter; the longer of the blades, the larger the output. However, important components are also their design and the materials they use. Fiberglass bonded with polyester or wood epoxy is commonly used to make blades. A new material associated with a technique introduced by producers such as Suzlon is vacuum resin infusion. Blades usually rotate at a constant speed (the more conventional option) or at a variable speed, between 10 and 30 rotations per minute.

Figure 2.1

Major turbine components



Gearboxes and direct drives: The majority of wind turbines have gearboxes, which raise the rotating speed that the generators need. In order to eliminate the costly gears, some new technologies are investigating direct drives generators.

Brake: a disk that is utilized in emergency conditions to halt the rotor blades and to guarantee the turbine's safety in the event of extremely strong winds or other unusual circumstances.

Controller: a group of electrical parts that regulate the speed, start, and stop of the turbine rotor blades. Generally, in the model with constant wind speed, the controller initiates the turbine at 8 to 14 miles per hour and shuts it off at 55 miles per hour (to prevent damage from strong, turbulent winds).

Generator: the apparatus that generates energy with a 50-cycle alternating current (AC).

The yaw mechanism of wind power generators: The yaw mechanism of more conventional wind turbines is linked to sensors (such as anemometers) that track the direction of the wind, rotating the tower head and aligning the blades with the wind.

Tower: sustains the rotor and nacelle. The generator's electricity travels down wires inside the tower, through a transformer, and onto the electrical grid.

Base: Big turbines are constructed on a foundation made of concrete. It is an easy task to cover or dig these out when a wind turbine stops producing, leaving minimal evidence behind.

2.5.1 Recognizing Wind at the Spot

In essence, locating on-site wind resources before the project's building phase is critical for the wind energy sector. A few necessary elements for determining the wind resources at a site include wind direction and speed. Because wind has a notable effect on the formation of ecological and biological indicators, such as sand dunes and trees, it is easiest to measure wind intensity at a place using biological indicators. Unfortunately, because this method is too rough to utilize for precise wind speed readings, it cannot be used. As a result, devices including cups, pressure tubes, pressure plates, and sonic anemometers were created to measure wind speed and direction with greater accuracy.

Examination of Wind Information The fundamental information needed to identify wind resources at a place is typically wind speed and direction; however, for a deeper understanding of wind features, this data must be properly examined. We can aggregate and average wind data over time intervals over which we are interested in determining the wind profile. For instance, the wind profile is projected hourly by the diurnal wind profile.

Accurate methods for measuring wind direction and speed have been developed, including pressure plates, cups, tubes, and sound anemometers.

2.5.2 Evaluation of Wind Potential

An assessment of a wind energy site's potential for wind turbine use is conducted. The goals of the wind energy program define the best course of action when evaluating the wind resource in a given area. There are several approaches to this process.

On the process of evaluating wind energy sites, there is, nevertheless, general consensus. The wind resource of a region can be evaluated in a number of ways. Aspects of evaluating wind resources using simply measurements are covered in this article. Many regions all around the world have effectively used this strategy.

One of the most important steps in determining the wind power potential is measuring the wind velocities in a particular location. The distribution of wind speed is given, which facilitates the power potential calculation. On the other hand, the obtained wind data have a wide range and diverse observation techniques, requiring the inclusion of additional parameters to explain the behavior of the collected data. One of the most useful and efficient methods is to use a distribution function (44). The Weibull distribution was a very useful method with a number of benefits (45). The two-parameter Weibull distribution accurately describes the power density and speed frequencies.

2.6 Weibull Distribution

A continuous probability distribution known as the Weibull distribution is described here. In the field of reliability engineering, it is one of the lifespan distributions that is employed the most frequently and has applications. The value of the shape parameter determines the characteristics that are exhibited by this adaptable distribution. Depending on the value of the shape parameter, this distribution can take on the characteristics of other types of distributions. It is utilized for the purpose of analyzing the life data and contributes to the determination of the reliability of the items. In this article, we will discuss in depth what the Weibull distribution is, what the Weibull distribution formula is, the properties of the Weibull distribution, the reliability of the Weibull distribution, some examples of the Weibull distribution, a Weibull distribution with two parameters, and an inverse Weibull distribution. This is to help you understand the Weibull distribution better (46).

2.6.1 The Definition of the Weibull Distribution

The Weibull distribution is a sort of continuous probability distribution that is utilized in the process of assessing product reliability, as well as the analysis of life data and the times at which models fail. In addition to this, it is able to incorporate a vast amount of data from a variety of other subjects, such as hydrology, economics, biology, and a good number of engineering sciences. It results in an extremely high value of the probability distribution, which is frequently utilized to simulate dependability, wind speeds, survivability, and a variety of other types of data. The versatility of the Weibull distribution, which allows it to replicate a variety of different distributions such as the exponential and the normal distributions, is the primary reason for its widespread application. With the assistance of two factors, one is able to evaluate the Weibull distribution's dependability. The two-parameter probability density function (pdf) and the three-parameter pdf versions of the Weibull probability density function are the most popular implementations of this statistical tool. The Weibull distribution pdf is another name for this function.

Formula for the Weibull Distribution the Weibull formula is next on our agenda, so let's have a look at it. The three-parameter formulation of the Weibull distribution, which may be regarded as the generic expression of the Weibull pdf, is provided by the equation (1).

Weibull probability distribution function & cumulative distribution function.

Weibull probability distribution function (abbreviated pdf) is desirable to depict the fluctuation in WS during any time interval using two parameters and it is given by equation (1) below.

$$F(v) = \frac{k}{c}\left(\frac{v}{c}\right)^{k-1} \exp\left(-\left(\frac{v}{c}\right)^{k}\right), k > 0, v > 0, c > 1 \qquad \ldots (1)$$

Where;

c represents the scale parameter (m/s)

k represents the shape parameter.

One could acquire a reliable approximation of the Weibull distribution parameters by utilizing a straightforward curve fitting process. The integration of the Weibull pdf is the cumulative distribution function. It is the total of every speed interval's relative frequency. Equation (2) provides the corresponding cumulative probability function of the Weibull distribution.

$$F(v) = \int_0^v f(v)\, dv \ = 1 - exp - \left(\frac{v}{c}\right)^k \qquad \ldots (2)$$

The shape parameter describes the behavior of the wind based on its value; a little k value indicates very little wind speed variations. Conversely, a high value of (k) means that there are an equal number of high and low wind speeds experienced by the site. The wind distribution at most places is usually at k = 2.

2.6.2 Weibull distribution of wind speed

When the wind speed frequency (distribution) is unknown, the Weibull distribution can be used to estimate the wind speed distribution for a site by putting in the shape parameter(k) and the scale parameter(c).

For wind speed is a stochastic quantity, the most common density function used to represent wind speed is the Weibull distribution, whose probability density function f(υ) is given by equation (1)

Equation (1) may be used to calculate the probability of occurrence of wind speed between certain intervals, where V is the wind speed, k is the shape factor, and c is the scale factor.

There are several methods by Weibull shape factor “k” and Weibull scale of the factor of “c” can be determined. it is possible to calculate the parameter k using the average wind speed by applying the formulae in table 2.1.

Table 2.1

The k factor calculation

Variance	Velocity	K
Low	V = 4 m/s	1,05√ Ṽ
Medium	V> 4 m/s	0,94√ Ṽ
High	V< 4 m/s	0,93 √ Ṽ

Since the wind speed in the proposed wind farm is greater than 4 [m/s], the k factor is calculated with k= 0, 94√Ṽ as following:

k = 0,94√5.06=2, 11

Where the 5.06 m/s is the best wind speed in OPT.

The Weibull scale of factor c is a characteristic speed related to the average wind speed at the site calculated by:

$$c = (\tilde{V}/ \Gamma\ (1 + 1/ k)) \qquad \ldots (3)$$

Equation (3) may be used to calculate the Weibull scale factor, where Γ is the gamma function, Ṽ is the Average wind speed, and k is the Weibull shape factor. Applying the Equation (3) the scale factor is calculated as follows:

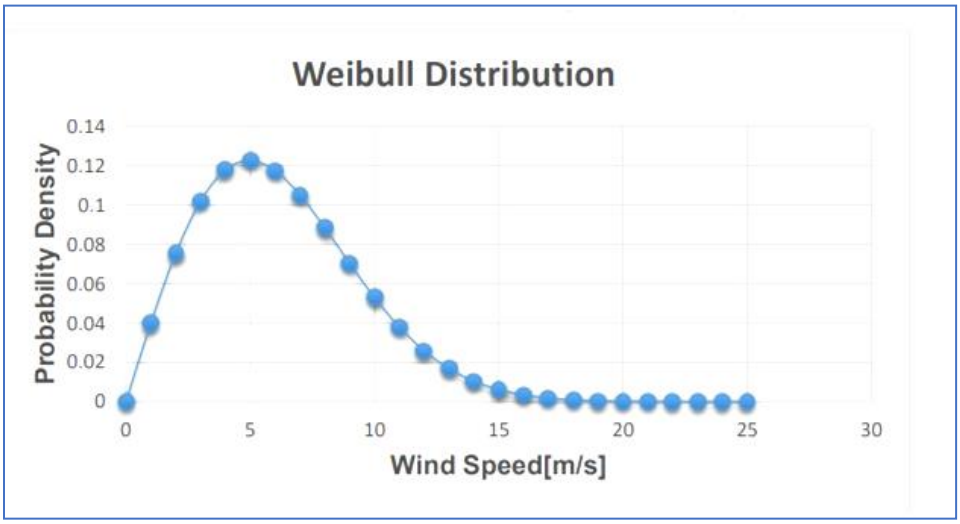
c = (Ṽ/ Γ (1 + 1/ k)) = 8,72/ Γ (1 + 1 k) = 8,72/ Γ (1,361) = 8,72/ 0,9354 = 9,31 [m/s]

Applying the Equation (3), the probability density function is calculated, and the results are shown in figure 2.2 below

f(v) = (2,11/ 9,31). (V/ 9,31) ^ (2,77−1) exp [− (V/ 9,31) ^ (2,11)]

Figure 2.2

Weibull distribution of wind speed at selected site, author's diagram



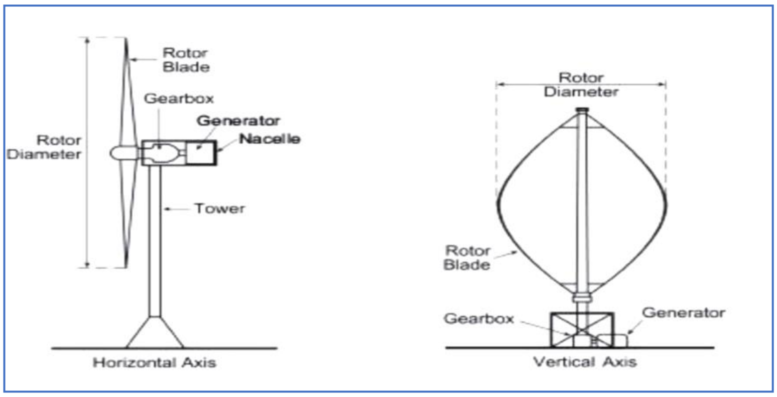
2.7 Types of Wind Turbine

- Wind Turbine Variations Based on the axis around which the wind turbine revolves, there are two types of wind turbines.
- Horizontal-axis wind turbines (HAWT) are more prevalent than vertical-axis turbines. The type of turbine that revolves around a vertical axis (VAWT).

Both kinds use a spinning motion to generate energy as shown in figure 2.3.

Figure 2.3

Displays wind turbine kinds



2.7.1 Vertical-Axis Wind Turbines (VAWT)

There are two primary types of Vertical-Axis Wind Turbines (VAWT):

The Savonius and the Darrieus. The Darrieus employs blades like to those seen on HAWTS, whilst the Savonius functions like a water wheel employing drag forces.

The blades revolve around a vertical axis, and the turbine is positioned optimally to use the wind. One of the VAWT's blades is functioning nicely with the wind, while the other blades are effectively pushing in the other direction.

However, VAWT tend to be larger than HAWT, and it might be difficult to place them on a tower tall enough to take advantage of stronger and cleaner wind. One of the benefits of VAWT is that it does not require a yaw mechanism because it can capture wind from any direction.

2.7.2 Horizontal-Axis Wind Turbines (HAWT)

The electrical generator and the primary rotor shaft are often positioned atop a HAWT's tower. This technique, known as yawing, is necessary by the HAWT's design to gain maximum power by facing into the wind.

In most cases, the turbine is connected to the generator's shaft through a gearbox, which converts the slow revolution of the blades into a rapid rotation that is more suited for driving an electrical generator.

The HAWT is composed of many mechanical components. Some of the components create electricity, while others serve to safeguard the turbine.

Chapter Three

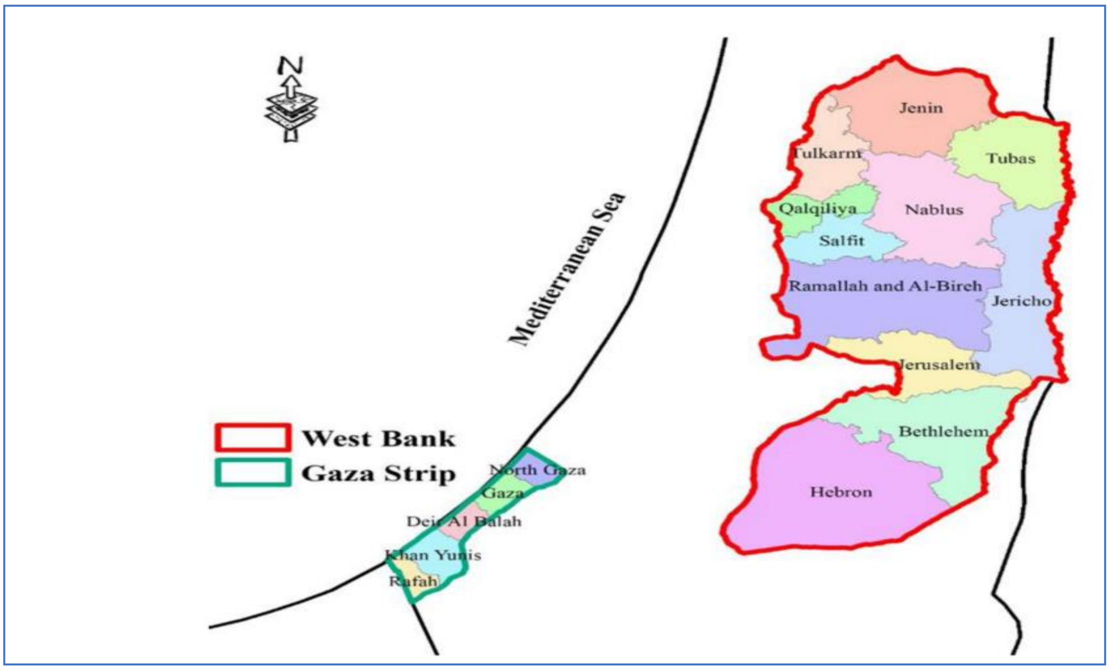
Wind regime Analysis in Main Palestinians Cities

3.1 Introduction

Palestine is located between 34°20' - 35°30'E and 31°10' - 32°30N, on the western tip of the Asian continent and the easternmost point of the Mediterranean Sea. Palestine's elevation varies from 300 meters below sea level in the Jordan Valley to sea level at the Gaza Strip's shoreline, and in some places in the West Bank, it reaches 1000 meters above sea level. As indicated in figure 5.1 Palestine is separated into two disconnected parts: The West Bank (WB) and the Gaza Strip (GS). Palestine is located in a subtropical environment and is heavily influenced by the Mediterranean climate (17, 47). Palestine's climate is typically hot and dry in the summer and cold and rainy in the winter. October to early May is when it rains, while December through February is when it rains the most heavily. Climate differences including changes in average rainfall and wind speed are caused by altitude changes in WB. In WB, rainfall ranges from 15 to 600 mm on average. Of course, this has an impact on Palestine's range of agricultural practices. In WB, the daily average temperature ranges from 8 to 23 ◦C, with a relative humidity of 51 to 83% (10).

Figure 3.1

Palestine (West bank and Gaza Strip)



The total population is about 4.4 million. of which over 1.7 million reside in the Gaza Strip and 2.47 million in the West Bank. The average household size is roughly 5.6 people, and the population growth rate is approximately 3.0%. and in 2023 The total population increased to about 5.48 million (48).

In this study, we report the power density and yearly energy production for the West Bank along with the wind atlas for the Eastern Mediterranean with an emphasis on the Palestine region. For this investigation, the Weather Research Forecasting model is employed. The World Bank's Best Practice Guidelines for Mesoscale Wind Mapping Projects served as the foundation for this study's methodology and result analysis. the World Bank's Energy Sector Management Assistance Program (49). That report provides a draft set of best practice guidelines to assess the quality in mesoscale meteorological modelling. Acknowledging the need for high-quality, national resource mapping and geospatial planning, ESMAP has launched a new program to support RE resource mapping operations in developing nations.

This study presents the analysis of the climatology of the wind profile over the State of Palestine, together with the selection of the typical meteorological year, the wind power density and the annual energy production. Furthermore, the project's importance stems from the fact that it is being constructed using updated data that was gathered between 2000 and 2011 (12 years) using the numerical weather prediction model WRF. Our analysis of the wind profiles showed that the highest yearly average wind speeds are calculated for 2003, while the lowest yearly average wind speeds are calculated for 2008. For Gaza and West Bank region the highest wind speeds are observed during the winter period and the prevailing wind direction is westerly for both Gaza and West Bank.

Based on a statistical study of wind climatology data, 2011 can be regarded as a normal meteorological year. The strongest wind speeds are estimated over the elevated terrain in the West Bank region's center. One of the requirements for high-quality modeling findings is that the connection $RMSEmod < STDEVobs$ hold true for 16 out of 20 stations, according to the examination of the comparison between the calculated wind speeds and the observations. In Gaza and the West Bank, there have been relatively little changes in wind power density and AEP over a 12-year period (2000–2011). The best area in the West Bank is east of Hebron, according to the AEP at 80 meters. so, this project's goal is to investigate Palestine's wind energy resources. (West Bank)

In this chapter, various analyses are employed to delve deeper into the nature of wind speed distribution at each location. Among these analyses, the probability density function (PDF) stands out as a crucial tool for gaining insights into the characteristics of wind distribution.

PDF of wind speed for a location is a mathematical model that describes the likelihood of different wind speeds occurring at that particular location. The PDF is an essential tool in understanding the behavior of wind speed, which is a critical parameter in various fields such as renewable energy, environmental studies, and transportation planning.

The PDF of wind speed is a continuous function that represents the distribution of wind speeds over a particular time period, such as an hour, a day, or a year. The PDF function considers the frequency and intensity of wind speed occurrences and provides valuable information for predicting and analyzing the wind resource at a specific location. The shape of the PDF curve indicates the most probable wind speeds, the occurrence of extreme events, and the frequency of calm conditions.

Wind speed PDFs are typically derived from observational data collected from weather stations or numerical modeling simulations. They can vary significantly between locations and can change over time due to changes in climate, land use, and other factors. Accurate characterization of wind speed PDFs is crucial for developing efficient and reliable wind energy systems, assessing wind-related risks, and designing structures that can withstand wind loads (50).

As introduced in the previous chapters The Weibull distribution is a common statistical distribution used to model wind speed PDFs, which takes into account both the mean wind speed and the variability of wind speed. The Weibull distribution is characterized by two parameters: the shape parameter (k) and the scale parameter (c).

The shape parameter of the Weibull distribution determines the shape of the PDF curve and reflects the variability of wind speeds at the location. A higher value of the shape parameter indicates a narrower PDF curve, meaning that the wind speeds at the location are less variable and closer to the mean wind speed. Conversely, a lower value of the shape parameter indicates a wider PDF curve, meaning that the wind speeds are more variable and farther from the mean wind speed. The shape parameter is typically estimated using statistical methods, such as maximum likelihood estimation (51).

The scale parameter of the Weibull distribution represents the wind speed at which the PDF curve starts to rise from zero, and is related to the mean wind speed at the location. A higher value of the scale parameter indicates a higher mean wind speed, and vice versa.

3.2 Wind Regime Analysis

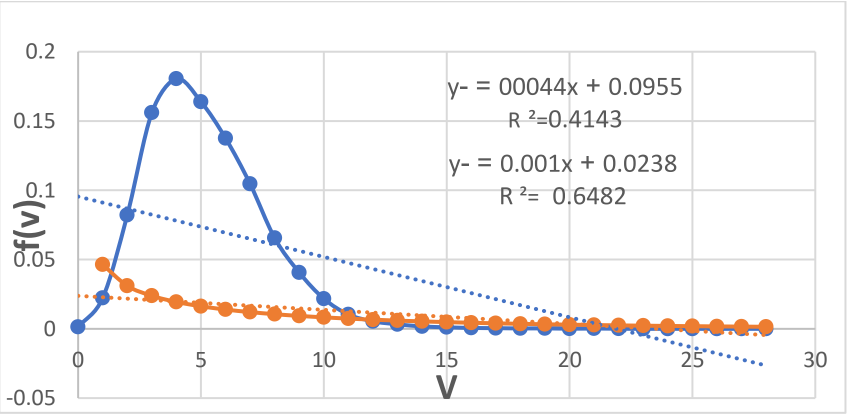
3.2.1 Hebron City

The city of Hebron is located in southern Palestine, 36 km from the city of Jerusalem. It is located at latitude 31:31 north and longitude 8:35 east, 36 km south of Jerusalem. The population of Hebron Governorate is about 729,193 people in 2016, according to the Central Bureau of Statistics. Palestinian. Its area is 11,400 square meters, and its area is about 18% of the area of the West Bank Hebron has a mountainous character, as it rises 1,032 meters above sea level, and the Hebron Mountain range is considered the largest mountain in Palestine.

Hebron has a moderate Mediterranean climate, with an average temperature in the summer of twenty-one degrees Celsius, and an average temperature in the winter of approximately fourteen degrees Celsius. Below, the wind speed in Hebron will be presented and the extent of its benefit will be analyzed. The PDF for Hebron location is shown in figure 3.2.

Figure 3.2

probability density function (PDF) of Hebron Location

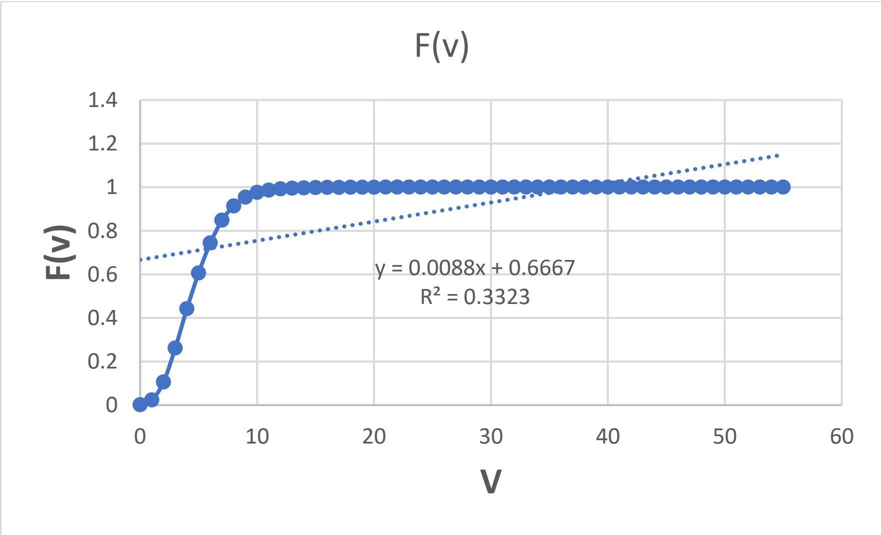


The Mean wind speed of Hebron location as can be extracted from figure 5.2 is 5.06m/s.

The PDF curve starts at zero wind speed. The most frequent wind speed is near 5 m/s; velocity above 10 m/s is rare. The PDF curve would be relatively wide and it indicates that wind speeds at this location are variable and ranges from zero to 10 m/s. There are some extreme values exceeds 10 m/s. In order to find parameters of Weibull distribution, firstly the cumulative distribution function F(V) of Hebron is evaluated then the scale parameter is typically estimated using regression analysis in this thesis as shown in figure 3.3 below.

Figure 3.3

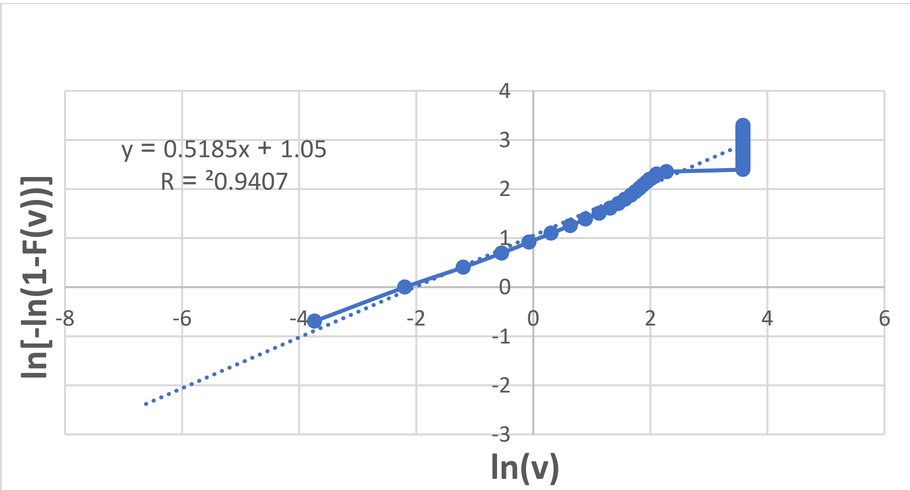
Cumulative Distribution Function of Hebron Location



The value of scale factor c and shape factor k can be extracted once draw the relation between ln(v) and ln(-ln(1-F(v)) as shown in figure 3.4.

Figure 3.4

Regression analysis to find shape and scale parameters of Weibull Distribution



By analogy the value of the scale factor c is 7.576 m/s and the shape factor is k is 0.5185. Based on those values the PDF would have the following characteristics:

The first side of the equation is equal to the second side

$$Ln\left[-Ln\left(1-F(v)\right)\right] = k * Ln(v) - k * ln(c)$$

Assume that $y = Ln\left[-Ln\left(1-F(v)\right)\right]$

$$y = k * Ln(v) - k * ln(c)$$

$$y = ax + b$$

a=k, b=k*ln(c)

From the slope equation, k was found

$$y = 0.5185\, x + 1.05$$

⊳ $a = k$ = 0.5185

⊳ $b = k * \ln{(c)}$

∴ $1.05 = 0.5185 * lnc$

$lnc = \frac{1.05}{0.5185}$

lnc =2.02

$e^{lnc} = e^{2.02}$

$c = 7.576$

It can be seen from the previous graphics that the scale parameter value is 7.5 and the shape scale value is 0.5. The most frequent wind velocity

$$V_{FMAX} = \text{C} \left(\frac{K-1}{K}\right)^{1/K}$$

$$= 7.5 \left(\frac{0.5-1}{0.5}\right)^{1/0.5}$$

=7.5 m/s

Velocity contributing the maximum energy

$$V_{EMAX} = \frac{C\ (K+2)^{1/K}}{K^{1/K}}$$

$$= \frac{7.5(0.5+2)^{1/0.5}}{0.5^{1/0.5}}$$

=187.48 m/s

Energy density

$$E_D = \frac{p_a\ c^3}{2} \frac{3}{k}\ \Gamma(\frac{3}{k})$$

$$= \frac{1.1\ (7.5)^3}{2} \frac{3}{0.5}\ \Gamma(\frac{3}{0.5})$$

= 167.062 kWh/m2

To analyze the results of Weibull distribution, estimate the followings:

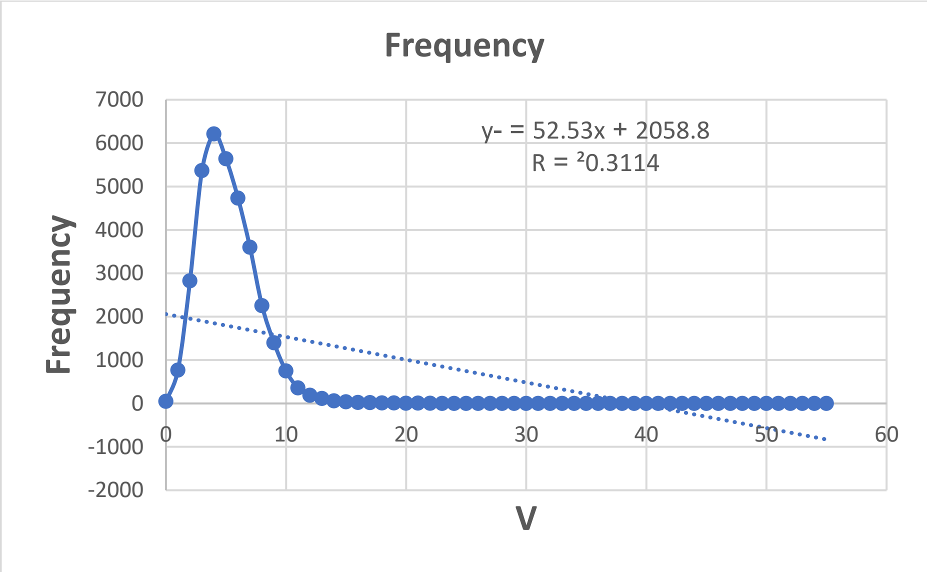
$$\text{Annual energy intensity} = E_D \times 8760$$

=1463463.12 kWh/m2.

As shown in figure 3.5, the relationship between the number of times the wind speed is repeated and the wind speed is as shown. In the city of Hebron, the speed of 4 m/s was repeated 6209 times (This number indicates the frequency of the aforementioned wind speeds during the entire year) .

Figure 3.5

The relationship between the number of times the wind speed is repeated and the wind



3.2.2 Nablus City

Nablus is one of the most populous Palestinian cities and its most important location. The city of Nablus is located in the north of the West Bank. It is located at longitude 35.16 and latitude 32.13. The population of Nablus Governorate was about 388,321 people in the year (2017), according to the Palestinian Central Bureau of Statistics.

The northwesterly winds are the prevailing wind directions in the Nablus area, and the general annual average wind speed is (10) km/hour. As for the relative humidity in Nablus Governorate, the general annual average reaches (61%). It rises 550 meters above sea level, while its edges reach a height of up to 800 meters

Its average temperature in the summer is estimated at 28.9 °C, and its average temperature in the winter is approximately 3.9 °C. Below will be shown the wind speed in Nablus and an analysis of the extent to which it can be used.

The PDF for Nablus location is shown in A.1. The Mean wind speed of Nablus location as can be extracted from A.1 is 3.119 m/s. The PDF curve starts at zero wind speed. The most frequent wind speed is near 5 m/s; velocity above 10 m/s is rare.

The PDF curve would be relatively wide and it indicates that wind speeds at this location are variable and ranges from zero to 10 m/s. There are some extreme values exceeds 10 m/s.

In order to find parameters of Weibull distribution, firstly the cumulative distribution function F(V) of Nablus is evaluated as shown in figure A.2.

The value of scale factor c and shape factor k can be extracted once draw the relation between ln(v) and ln(-ln(1-F(v)) as shown in figure A.3.

By analogy, the value of the scale factor c is 2.988 m/s and the shape factor is k is 1.2876. Based on those values the PDF would have the following characteristics:

The first side of the equation is equal to the second side

$Ln\left[-Ln\left(1-F(v)\right)\right] = k * Ln(v) - k * ln(c)$

Assume that $y = Ln\left[-Ln\left(1-F(v)\right)\right]$

$y = k * Ln(v) - k * ln(c)$

$y = ax + b$

a=k, b=k*ln(c)

From the slope equation, k was found

$y = 1.2876\, x + 1.4097$

⊳ $a = k$ = 1.2876

⊳ $b = k * lnc$

∴ $1.4097 = 1.28 * lnc$

$lnc = \frac{1.4097}{1.2876}$

$lnc = 1.094$

$e^{lnc} = e^{1.094}$

$c = 2.988$

It can be seen from the previous graphics that the scale parameter value is 2.9 and the shape scale value is 1.28

The most frequent wind velocity

$V_{FMAX} = \text{ C } \left(\frac{K-1}{K}\right)^{1/K}$

$= 2.98 \left(\frac{1.28-1}{1.28}\right)^{1/1.28}$

=0.9 m/s

Velocity contributing the maximum energy

$V_{EMAX} = \frac{C\ (K+2)^{\frac{1}{K}}}{K^{\frac{1}{K}}}$

$= \frac{2.98\ (1.28+2)^{1/1.28}}{1.28^{1/1.28}}$

=6.22 m/s

Energy density

$E_D = \frac{p_a\ c^3}{2}\frac{3}{k}\ \Gamma(\frac{3}{k})$

$= \frac{1.1\ (2.98)^3}{2}\frac{3}{1.28}\ \Gamma(\frac{3}{1.28})$

=0.0392 kWh/m2

To analyze the results of Weibull distribution, estimate the followings:

Annual energy intensity= E_D*8760

=3416.4 kWh/m2.

As shown in A.4, the relationship between the number of times the wind speed is repeated and the wind speed is as shown. In the city of Nablus, the speed of 4 m/s was repeated 6602 times(This number indicates the frequency of the aforementioned wind speeds during the entire year) .

3.2.3 Jenin city

The city of Jenin is located in the north of the West Bank, at latitude 32.28 north and longitude 35.18 east of Greenwich. The area of Jenin Governorate is 583 square kilometers, or 9.7% of the total area of the West Bank, with a population of about 356. ,000 people. Year (2017) According to the Palestinian Central Bureau of Statistics, the city rises above sea level at a rate of 175 meters.

The climate of the Jenin region differs from the general climate of Palestine, due to its topographical situation. The city is located at an altitude ranging between 125 and 225 meters, and is surrounded by a number of highlands. From the east, it is surrounded by the Jalboun Mountains, and from the south, west, and northwest, it is surrounded by the Nablus Mountains and its extension into Mount Carmel. Although it opens to Marj Ibn Amer, it is closed by the Galilee Mountains at a distance not exceeding 20 meters. how much. This situation reduced the city's benefit from the rainy, temperature-modifying westerly and southwesterly winds, and also distanced Jenin's climate from the Mediterranean climate. As for the relative humidity in the city of Jenin, the general annual average reaches.(%69)

Below will be shown the wind speed in the city of Jenin and an analysis of the extent to which it can be used. The PDF for Jenin location is shown in figure A.5. The Mean wind speed of Jenin location as can be extracted from A.5 is 3.668 m/s.

The PDF curve starts at zero wind speed. The most frequent wind speed is near 5 m/s. speeds higher than 10 m/s is rare. The PDF curve would be relatively wide and it indicates that wind speeds at this location are variable and ranges from zero to 10 m/s. There are some extreme values exceeds 10 m/s.

In order to find parameters of Weibull distribution, firstly the cumulative distribution function F(V) of Jenin is evaluated as shown in figure A.6. The value of scale factor c and shape factor k can be extracted once draw the relation between ln(v) and ln(-ln(1-F(v)) as shown in figure A.7.

By analogy the value of the scale factor c is 3.395 m/s and the shape factor is k is 0.6. Based on those values the PDF would have the following characteristics:

$$Ln\left[-Ln\left(1-F(v)\right)\right] = k * Ln(v) - k * ln(c)$$

$y = Ln[-Ln(1 - F(v))]$

$y = k * Ln(v) - k * ln(c)$

$y = ax + b$

$y = 0.6001x + 0.7336$

⊳ $a = k$ = 0.6

⊳ $b = k * lnc$

∴ $0.7336 = 0.6001 * lnc$

$lnc = \frac{0.7336}{0.6001}$

$lnc = 1.222$

$e^{lnc} = e^{1.222}$

$c = 3.395$

It can be seen from the previous graphics that the scale parameter value is 3.395 and the shape scale value is 0.6

The most frequent wind velocity

$V_{FMAX} =$ C $\left(\frac{K-1}{K}\right)^{1/K}$

$= 3.395 \left(\frac{0.6-1}{0.6}\right)^{1/0.6}$

= - 1.7 m/s

Velocity contributing the maximum energy

$V_{EMAX} = \frac{C\,(K+2)^{1/K}}{K^{1/K}}$

$= \frac{3.39(0.6+2)^{1/0.6}}{0.6^{1/0.6}}$

=38.64 m/s

Energy density

$E_D = \frac{p_a \; c^3}{2} \frac{3}{k} \; \Gamma(\frac{3}{k})$

$= \frac{1.1 \; (3.39)^3}{2} \frac{3}{0.6} \; \Gamma(\frac{3}{0.6})$

=0.2571 kW/m2

To analyze the results of Weibull distribution, estimate the followings:

Annual energy intensity= E_D*8760

=2252 kWh/m2.

As shown in figure A.8, the relationship between the number of times the wind speed is repeated and the wind speed is as shown. In the city of Jenin, the speed of 3 m/s was repeated 6616 times (This number indicates the frequency of the aforementioned wind speeds during the entire year) .

3.2.4 Bethlehem city

Bethlehem is located in the south of the West Bank, 31°43′0″N 35°12′0″E and at an altitude of about 775 meters above sea level, 30 meters higher than Jerusalem. Bethlehem is located in the southern part of the Hebron Mountains. The area of the city of Bethlehem is 575 square kilometers, and its population is 217,400 people, according to the 2017 population census of the Palestinian Central Bureau of Statistics.

Below will be shown the wind speed in the city of Jenin and an analysis of the extent to which it can be used. The PDF for Bethlehem location is shown in figure A.9.

The PDF curve starts at zero wind speed. The most frequent wind speed is near 5 m/s. speeds higher than 10 m/s is rare. The PDF curve would be relatively wide and it indicates that wind speeds at this location are variable and ranges from zero to 10 m/s. There are some extreme values exceeds 10 m/s.

In order to find parameters of Weibull distribution, firstly the cumulative distribution function F(V) of Bethlehem is evaluated as shown in figure A.10. The value of scale factor c and shape factor k can be extracted once draw the relation between ln(v) and ln(-ln(1-F(v)) as shown in figure A.11.

By analogy the value of the scale factor c is 2.3199 m/s and the shape factor is k is 0.763. Based on those values the PDF would have the following:

$$Ln\left[-Ln\left(1 - F(v)\right)\right] = k * Ln(v) - k * \ln(c)$$

$$y = Ln\left[-Ln\left(1 - F(v)\right)\right]$$

$$y = k * Ln(v) - k * ln(c)$$

$$y = ax + b$$

$$y = 0.763\, x + 0.6421$$

⊳ $a = k$ = 0.763

⊳ $b = k * lnc$

∴ $0.6421 = 0.763 * lnc$

$$lnc = \frac{0.6421}{0.763}$$

$$lnc = 0.8415$$

$$e^{lnc} = e^{0.8415}$$

$$c = 2.3199$$

It can be seen from the previous graphics that the scale parameter value is 2.3 and the shape scale value is 0.7

The most frequent wind velocity:

$$V_{FMAX} = C \left(\frac{K-1}{K}\right)^{1/K}$$

$= \ 2.3\left(\frac{0.7-1}{0.7}\right)^{1/0.7}$

= - 0.68m/s

Velocity contributing the maximum energy:

$$V_{EMAX} \ = \frac{C\ (K+2)^{1/K}}{K^{1/K}}$$

$$= \frac{2.3\ (0.7+2)^{1/0.7}}{0.7^{1/0.7}}$$

=15.8 m/s

Energy density:

$$E_D = \frac{p_a\ c^3}{2}\frac{3}{k}\ \Gamma(\frac{3}{k})$$

$$= \frac{1.1\ \ (2.23)^3}{2}\frac{3}{0.7}\ \Gamma(\frac{3}{0.7})$$

= 0.228 kW/m2

To analyze the results of Weibull distribution, estimate the followings:

Annual energy intensity= E_D*8760

=1997kWh/m2

As shown in figure A.12, the relationship between the number of times the wind speed is repeated and the wind speed is as shown. In the city of Bethlehem, the speed of 3 m/s was repeated 7918 times (This number indicates the frequency of the aforementioned wind speeds during the entire year) .

3.2.5 Duma

The village of Duma is located in central Palestine, in the northeastern part of the West Bank, about 25 km south of Nablus city center, 32.0556544°N 35.3760928°E. Its area is approximately 17,351 dunams, and the population of Duma is currently about 2,674 people, according to the 2017 general population census conducted by the Palestinian Central Bureau of Statistics. It is at an altitude of about 617 meters above sea level, and the average temperature reaches 20. Degrees Celsius and the average relative humidity is about 66%.

The PDF for Duma location is shown in figure A.13. The Mean wind speed of Duma location as can be extracted from figure A.13 is 3.69 m/s.

The PDF curve starts at zero wind speed. The most frequent wind speed is near 5 m/s; velocity above 10 m/s is rare. The PDF curve would be relatively wide and it indicates that wind speeds at this location are variable and ranges from zero to 10 m/s. There are some extreme values exceeds 10 m/s.

In order to find parameters of Weibull distribution, firstly the cumulative distribution function F(V) of Duma is evaluated as shown in figure A.14. The value of scale factor c and shape factor k can be extracted once draw the relation between ln(v) and ln(-ln(1-F(v)) as shown in figure A.15.

$$Ln\left[-Ln\left(1-F(v)\right)\right] = k * Ln(v) - k * ln(c)$$

$$y = Ln\left[-Ln\left(1-F(v)\right)\right]$$

$$y = k * Ln(v) - k * ln(c)$$

$$y = ax + b$$

$$y = 0.7051\,x + 0.8547$$

⊳ $a = k = 0.7051$

⊳ $b = k * lnc$

∴ $0.8547 = 0.7051 * lnc$

$$lnc = \frac{0.8547}{0.7051}$$

$$lnc = 1.212$$

$$e^{lnc} = e^{1.212}$$

$$c = 3.360$$

It can be seen from the previous graphics that the scale parameter value is 3.36 and the shape scale value is 0.7

The most frequent wind velocity

$$V_{FMAX} = \text{C} \left(\frac{K-1}{K}\right)^{1/K}$$

$$= 3.36 \left(\frac{0.7-1}{0.7}\right)^{1/0.7}$$

= - 1 m/s

Velocity contributing the maximum energy

$$V_{EMAX} = \frac{C\ (K+2)^{1/K}}{K^{1/K}}$$

$$= \frac{3.36\ (0.7+2)^{1/0.7}}{0.7^{1/0.7}}$$

=23.11 m/s

Energy density

$$E_D = \frac{p_a\ c^3}{2} \frac{3}{k}\ \Gamma(\frac{3}{k})$$

$$= \frac{1.1(\ 3.36)^3}{2} \frac{3}{0.7}\ \Gamma(\frac{3}{0.7})$$

=0.7928 kWh/m2

To analyze the results of Weibull distribution, estimate the followings:

Annual energy intensity = E_D*8760

=6944.9 kWh/m2.

As shown in figure A.16, the relationship between the number of times the wind speed is repeated and the wind speed is as shown. In the city of Duma, the speed of 3 m/s was repeated 1647 times (This number indicates the frequency of the aforementioned wind speeds during the entire year) .

3.2.6 Ramallah City

The city of Ramallah is located in the West Bank, approximately 15 km north of Jerusalem, 31°53′49″N 35°12′06″E. It is 880 meters above sea level. Its area is 16.5 km^2. Its population is approximately 38,998 people**.**

Ramallah is a mountainous city, built on mountains overlooking the Palestinian coast to the west, while to the east and south it is surrounded by mountains. The city is about 45 kilometers away from the Mediterranean Sea, which can be seen from its hills. Due to the sea's proximity to it, the air that blows on it from the west carries with it Some humidity, as the general average annual humidity reaches (68%), the average annual temperature ranges between 5-25 degrees Celsius, and the winds are northeasterly, dry, and relatively cold**.**

Below will be shown the wind speed in the city of Ramallah and an analysis of the extent of its benefit**.** The PDF for Ramallah location is shown in figure A.17.

The Mean wind speed of Ramallah location as can be extracted from figure A.17 is 4.56 m/s. The PDF curve starts at zero wind speed. The most frequent wind speed is near 5 m/s; velocity above 10 m/s is rare.

The PDF curve would be relatively wide and it indicates that wind speeds at this location are variable and ranges from zero to 10 m/s. There are some extreme values exceeds 10 m/s. In order to find parameters of Weibull distribution, firstly the cumulative distribution function F(V) of Ramallah is evaluated as shown in figure A.18.

The value of scale factor c and shape factor k can be extracted once draw the relation between ln(v) and ln(-ln(1-F(v)) as shown in figure A.19.

$$Ln\left[-Ln\left(1-F(v)\right)\right] = k * Ln(v) - k * ln(c)$$

$$y = Ln\left[-Ln\left(1-F(v)\right)\right]$$

$$y = k * Ln(v) - k * ln(c)$$

$$y = ax + b$$

$$y = 0.6987\,x + 1.1754$$

➢ $a = k$ = 0.6987

➢ $b = k * lnc$

∴ $1.1754 = 0.6987 * lnc$

$lnc = \frac{1.1754}{0.6987}$

$lnc = 1.682$

$e^{lnc} = e^{1.682}$

$c = 5.377$

It can be seen from the previous graphics that the scale parameter value is 5.3 and the shape scale value is 0.69

The most frequent wind velocity

$V_{FMAX} = \text{C} \left(\frac{K-1}{K}\right)^{1/K}$

$= 5.3 \left(\frac{0.69-1}{0.69}\right)^{1/0.69}$

=- 1.6m/s

Velocity contributing the maximum energy

$$V_{EMAX} = \frac{C\ (K+2)^{1/K}}{K^{1/K}}$$

$$= \frac{5.3(0.69+2)^{1/0.69}}{0.69^{1/0.69}}$$

=36.46 m/s

Energy density

$E_D = \frac{p_a\ c^3}{2} \frac{3}{k}\ \Gamma(\frac{3}{k})$

$= \frac{1.1\ (5.3)^3}{2} \frac{3}{0.69}\ \Gamma(\frac{3}{0.69})$

=0.3111kWh/m2

To analyze the results of Weibull distribution, estimate the followings:

Annual energy intensity= E_D*8760

=2725.2 kWh.

As shown in figure A.20, the relationship between the number of times the wind speed is repeated and the wind speed is as shown. In the city of Ramallah, the speed of 6 m/s was repeated 4322 times (This number indicates the frequency of the aforementioned wind speeds during the entire year) .

3.2.7 Jericho City

Jericho is located in the West Bank near the Jordan River, 16 km north of the Dead Sea, 31.8606225°N 35.4469982°E, 250 meters below sea level, and 30 km east of Jerusalem. The city of Jericho is considered the lowest area in the world. Its area is 45 km², representing 9.9% of the total area of the West Bank (Palestinian Central Bureau of Statistics 2021). Its population density reached 393.5 people/km2

Jericho's climate is characterized by a tropical desert, with summer temperatures reaching more than 40 degrees Celsius, while winter temperatures are more moderate and range between 15-25 degrees Celsius. Jericho is a very dry area, receiving very little rainfall, and the city has a very high incidence of strong winds. While the average relative humidity for 2021 at Jericho station was 42%.

The PDF for Jericho location is shown in figure A.21. The Mean wind speed of Jericho location as can be extracted from figure A.21 is 2.689 m/s.

The PDF curve starts at zero wind speed. The most frequent wind speed is near 5 m/s; velocity above 10 m/s is rare. The PDF curve would be relatively wide and it indicates that wind speeds at this location are variable and ranges from zero to 10 m/s. There are some extreme values exceeds 10 m/s. In order to find parameters of Weibull distribution, firstly the cumulative distribution function F(V) of Jericho is evaluated as shown in figure A.22. The value of scale factor c and shape factor k can be extracted once draw the relation between ln(v) and ln(-ln(1-F(v)) as shown in figure A.23.

$$Ln[-Ln(1-F(v))] = k * Ln(v) - k * ln(c)$$

$$y = Ln[-Ln(1-F(v))]$$

$$y = k * Ln(v) - k * ln(c)$$

$$y = ax + b$$

$$y = 0.9454\, x + 0.4152$$

⊳ $a = k$ = 0.9454

⊳ $b = k * lnc$

∴ $0.4152 = 0.9454 * lnc$

$$lnc = \frac{0.4152}{0.9454}$$

$$lnc = 0.4391$$

$$e^{lnc} = e^{0.4391}$$

$$c = 1.551$$

It can be seen from the previous graphics that the scale parameter value is 1.5 and the shape scale value is 0.9

The most frequent wind velocity

$$V_{FMAX} = C \left(\frac{K-1}{K}\right)^{1/K}$$

$$= 1.5 \left(\frac{0.9-1}{0.9}\right)^{1/0.9}$$

= -0.13 m/s

Velocity contributing the maximum energy

$$V_{EMAX} = \frac{C\,(K+2)^{1/K}}{K^{1/K}}$$

$$= \frac{1.55\ (0.9+2)^{1/0.9}}{0.9^{1/0.9}}$$

=5.6 m/s

Energy density

$$E_D = \frac{p_a\ c^3}{2} \frac{3}{k}\ \Gamma(\frac{3}{k})$$

$$= \frac{1.1\ (1.55)^3}{2} \frac{3}{0.9}\ \Gamma(\frac{3}{0.9})$$

=0.018433 kWh/m2

To analyze the results of Weibull distribution, estimate the followings:

Annual energy intensity= E_D*8760

=161.18 kWh/m2.

As shown in figure A.24, the relationship between the number of times the wind speed is repeated and the wind speed is as shown. In the city of Jericho, the speed of 2 m/s was repeated 9000 times(This number indicates the frequency of the aforementioned wind speeds during the entire year) .

3.2.8 Tulkarm City

Tulkarm is located in the northwest of the West Bank, 32°18'40"N, 35°1'51"E. It is about 15 km from the Mediterranean Sea, and about 90 km from the city of Jerusalem. The city is surrounded to the west by its occupied towns, coastal strip, and the Mediterranean Sea, with an area of 268 square kilometers. The Palestinian Central Bureau of Statistics estimated the governorate's population for the year 2020 at approximately 195 thousand people, which represents 3.8% of the total population of Palestine.

The city of Tulkarm and its countryside rise above sea level from 65 meters in the west to 600 meters in the east, where Mount Rashin is the highest peak in the city.

The city of Tulkarm is distinguished by its unique topography. Where the nature is mountainous to the east of the city and plain to the west. The mountainous lands constitute 70% of the city's total land - while the plane lands constitute 30%. Tulkarm enjoys a

Mediterranean climate (warm rain in the winter, hot and dry in the summer). Humidity reaches nearly high levels with an annual average of 69.6%. In winter. The summer months are humid, with an average humidity of 70.3%.

The PDF for Tulkarm location is shown in figure A.25, The Mean wind speed of Tulkarm location as can be extracted from figure A.25 is 3.167 m/s.

The PDF curve starts at zero wind speed. The most frequent wind speed is near 5 m/s; velocity above 10 m/s is rare. The PDF curve would be relatively wide and it indicates that wind speeds at this location are variable and ranges from zero to 10 m/s. There are some extreme values exceeds 10 m/s. In order to find parameters of Weibull distribution, firstly the cumulative distribution function F(V) of Tulkarm is evaluated as shown in figure A.26.

The value of scale factor c and shape factor k can be extracted once draw the relation between ln(v) and ln(-ln(1-F(v)) as shown in figure A.27.

$$Ln\left[-Ln\left(1-F(v)\right)\right] = k * Ln(v) - k * ln(c)$$

$$y = Ln\left[-Ln\left(1-F(v)\right)\right]$$

$$y = k * Ln(v) - k * ln(c)$$

$$y = ax + b$$

$$y = 0.7013\,x + 0.5397$$

⊳ $a = k = 0.7013$

⊳ $b = k * lnc$

∴ $0.5397 = 0.7013 * lnc$

$$lnc = \frac{0.5397}{0.7013}$$

$$lnc = 0.7695$$

$$e^{lnc} = e^{0.7695}$$

$$c = 2.158$$

It can be seen from the previous graphics that the scale parameter value is 2.15 and the shape scale value is 0.7

The most frequent wind velocity

$$V_{FMAX} = \text{C} \left(\frac{K-1}{K}\right)^{1/K}$$

$$= 2.15 \left(\frac{0.7-1}{0.7}\right)^{1/0.7}$$

$$= 0.645 \text{ m/s}$$

Velocity contributing the maximum energy

$$V_{EMAX} = \frac{C\ (K+2)^{1/K}}{K^{1/K}}$$

$$= \frac{2.15\ (0.7+2)^{1/0.7}}{0.7^{1/0.7}}$$

$$=14.8 \text{ m/s}$$

Energy density

$$E_D = \frac{p_a\ c^3}{2} \frac{3}{k}\ \Gamma(\frac{3}{k})$$

$$= \frac{1.1(\ 2.15)^3}{2} \frac{3}{0.7}\ \Gamma(\frac{3}{0.7})$$

=0.209 kWh/m2

To analyze the results of Weibull distribution, estimate the followings:

Annual energy intensity= E_D*8760

=1830.8 kWh/m2.

As shown in figure A.28 the relationship between the number of times the wind speed is repeated and the wind speed is as shown. In the city of Tulkarm, the speed of 3 m/s was repeated 7466 times) This number indicates the frequency of the aforementioned wind speeds during the entire year) .

Table 3.1 below shows the c and k values for each city in Palestine.

Table 3.1
The values of C and K for Palestine cities

city	c	k
Hebron	7.576	0.5185
Nablus	2.988	1.2876
Jenin	3.395	0.6001
Bethlehem	2.3199	0.763
Duma	3.360	0.7051
Ramallah	5.377	0.6987
Jericho	1.551	0.9454
Tulkarm	2.158	0.7013

After analyzing the data collected from the aforementioned cities, Hebron emerged as the most favorable location for wind energy exploitation, indicated by the highest constant C value of 7.5 compared to other cities studied.

Furthermore, the wind speed readings revealed that Hebron and Ramallah exhibited the highest average wind speeds, with Hebron recording an average wind speed of 5.06 m/s, followed by Ramallah with 4.56 m/s. Based on these findings, it is recommended to prioritize these cities for wind energy utilization.

3.3 Economic study for the Hebron city

After calculate C&K for above the cities will make economic study for the Hebron city, The Weibull distribution for Hebron City is shown table 3.2:

Table 3.2
The Weibull distribution for Hebron City

Range	Duration (hours)	% of fw	P	P*fw	Fp	Class (m/s) Vc	Weibull values
0-1	292.584	3.34	0.11	0.004	0	1	0.0334
1-2	556.26	6.35	2.05	0.13	0	2	0.0635
2-3	766.5	8.75	9.531	0.83	0	3	0.0875
3-4	907.536	10.36	26.15	2.71	0.01	4	0.1036
4-5	973.24	11.11	55.58	6.175	0.02	5	0.1111
5-6	968.856	11.06	101.49	11.22	0.04	6	0.1106
6-7	906.66	10.35	167.52	17.34	0.05	7	0.1035
7-8	802.416	9.16	257.34	23.57	0.07	8	0.0916
8-9	676.272	7.72	374.61	28.92	0.09	9	0.0772
9-10	543.996	6.21	523	32.48	0.10	10	0.0621
10-11	418.73	4.78	706.5	33.75	0.11	11	0.0478
11-12	309.23	3.53	927.73	32.74	0.11	12	0.0353
12-13	219	2.5	1191.41	29.78	0.10	13	0.025
13-14	148.92	1.7	1500.82	25.51	0.08	14	0.017
14-15	96.36	1.1	1859.66	20.45	0.06	15	0.011
15-16	61.4	0.70	2271.56	15.90	0.05	16	0.007
16-17	36.792	0.42	2740.2	11.50	0.04	17	0.0042
17-18	21.024	0.24	3269.22	7.846	0.02	18	0.0024
18-19	12.264	0.14	3862.3	5.40	0.02	19	0.0014
19-20	6.132	0.07	4523.07	3.16	0.01	20	0
20-21	3.5	0.04	5255.2	2.10	0	21	0
21-22	1.752	0.02	6062.4	1.21	0	22	0
22-23	0	00.00	6948.3	0	0	23	0
Total	8760			312.75 W	1.00		1.00

σ=Sqrt (Pi)/2, Pi = 3.14.

(C/Vav) =2/ (Sqrt (Pi)), C=1.128 * Vav, C=7.6704 m/s.

Fp = P*fw / Pt.

Pt = 312.75 w/m^2

Weibull shape factor (K) = 0.5185

Weibull scale factor (C) = 7.576 m/s

Mean wind speed = 5.06 m/s.

Available power in the wind (Pt) = 312.75 w/m^2 = flux.

The ratio between the flux and the Weibull scale factor (R) = flux / (0.5*C^3* ρ) , ρ=1.22

The maximum energy available at a wind speed Ume(max) according to Weibull given by:

Ume (max) = C * ((k+2)/K) ^(1/K)

In this study

Ume(max) = 10 m/s and this value is the rated wind speed

Because the small average wind speed in our site we will consider the results from Weibull distribution and the rated wind speed = 10 m/s and will design the wind turbine according to it.

In our project, we depend on the result that we found by Weibull distributions.

Selecting the appropriate wind turbine type and number of blades

According to the figures from literature on page N. (169 &174) we get the following table 3.3:

Table 3.3
Types of wind turbine

Type		eff.	Tip speed ratio (T.S.R)	Appropriate mean wind speed (m/s)
Left type (horizontal axis wind turbines)	Double bladed	0.4 – 0.47	3.5 – 7	8.5 – 15
	Three bladed	0.39 -0.43	3 – 6	7 – 10
	Multi blade	Up to 0.31	Up to 1.8	3.5 – 6.8
Left type (vertical axis wind turbines)	Darrieus (egg beater)	0.23 – 0.35	4.5 – 7	High rated power & high Vav.
Drag type (horizontal axis wind turbine)	Cross wind Savonius	Up to 0.2	Up to 1.4	
Drag type (vertical axis wind turbine)	Savonius & multi-bladed Savonius	Up to 0.2	Up to 1.4	

In our study I will choose left type (horizontal) three blade wind turbine with T.S.R = 6 or more.

Eff. = 0.4 = Cp.

According to Weibull distribution:

We get that the rated wind speed (Vr) is 10 m/s.

Output power (Pout) = Cp* 0.5*A* ρ * Vr^3

Pout = 75 Kw, Cp = 0.4.

So, A = 307.37 m^2

Then length of the blade needed = 9.8 m = r.

Now T.S.R =(2*Pi*r*N)/Vr

N = 0.98 r.p.s → n = 60 * N → n(turbine) = 58.8 r.p.m

(r.p.s): revolution per second.

(r.p.m): rotation per minute.

Selecting height of tower

$(Vw/V0) = (H/H0)^n$, n: roughness coefficient (0.1 – 0.4)

V0 = 6.8 m/s @ H0 = 3 m

Suppose Vw = 10 m/s, Roughness coefficient = 0.16 (land planted with short trees)

we need to find H

$(10/6.8) = (H/3)^{0.16}$

Log 1.47 = 0.16 * log(H/3)

Then, H = 33 m (Height of tower needed)

So, the wind turbine that I need has these properties:

rated power = 75 Kw, number of blades = 3

T.S.R = 6 or more, n(turbine) = 58.8 r.p.m

Length of blade = (9-12) m, Cp=0.4, H= 33 m

And when I looking for wind turbines, the appropriate one that I found as follow:

THUNYA-75kW Wind Turbine has the following characteristics:

Rated power 75 Kw, rated wind speed = 10.5 m/s, tip speed ratio = 7, length of the blade = 9.75 m

Swept area = 298.5 m², cut-in wind speed = 2.5 m/s = 5.6 m.p.h.

N = 1.1 r.p.s , n(turbine) = 68.6 r.p.m , Cp = 0.35 .

Rated power 75 Kw, rated wind speed = 10.5 m/s, tip speed ratio = 7 , length of the blade = 9.75 m

Swept area = 298.5 m², cut-in wind speed = 2.5 m/s = 5.6 m.p.h.

N = 1.1 r.p.s , n(turbine) = 68.6 r.p.m , Cp = 0.35 , H = 30 m

Selecting the generator type and its characteristics and determine the appropriate gear ratio and gear characteristics.

According to:

Danish wind industry association *Electrical Machines Drives and Power Systems* by Theodore Wildi I need asynchronous generator (induction generator).

Reasons for choosing this type of generator is that it is very reliable, tends to be comparatively inexpensive, high-energy density, small size per KW output power and synchronization to the supply line is not required.

The table 3.4 shows how the gear of generator changes relative to number of poles:

Table 3.4

The relation the gear of generator and to number of poles

Number of poles	Gear of generator (n)	Gear ratio
4 poles	1500 r.p.m	21.86
6 poles	1000 r.p.m	14.57
8 poles	750 r.p.m	10.93

n(generator) = 120*f / p

Gear ratio = n(generator)/n(turbine).

According to the previous table the gear ratio that I need should be the minimum and less than 20.

So, I need generator has 6 or 8 pole, rated power = (80-95) Kw, and when I searching about generators, I found this generator:

Product Name 50Hz brushless synchronous generator

Model No. ADG280S1-6

Rated power = 80 Kw

Pole count = 6 poles

Rated speed = 1000 r.p.m

Constructing of the wind duration curve for the given site

Wind duration curve help us to know the time duration in each wind speed and estimate the produced wind energy by the turbine.

Estimating the annual produced wind energy by the turbine (KWh/year) shown table 3.5

Table 3.5

The wind turbine energy produced

Number	V (M.P.H)	V(m/s)	T(hours)	Output power (KW)	Energy (KWH/YEAR)
1	40.27346	18	9.691562	75	726.8672
2	39.15475	17.5	12.74313	75	955.7346
3	38.03605	17	16.60008	75	1245.006
4	36.91734	16.5	21.42274	75	1606.706
5	35.79863	16	27.3872	75	2054.04
6	34.67993	15.5	34.68185	75	2601.139
7	33.56122	15	43.50222	75	3262.667
8	32.44251	14.5	54.0436	75	4053.27
9	31.3238	14	66.49164	75	4986.873
10	30.2051	13.5	81.01064	75	6075.798
11	29.08639	13	97.72991	75	7329.744
12	27.96768	12.5	116.7284	75	8754.632
13	26.84897	12	138.0184	75	10351.38
14	25.73027	11.5	161.5284	75	12114.63
15	24.61156	11	187.088	75	14031.6
16	23.49285	10.5	214.4131	75.03987	16089.53
17	22.37415	10	243.0957	64.82226	15758.01
18	21.25544	9.5	272.5981	55.57699	15150.18
19	20.13673	9	302.2526	47.25543	14283.08
20	19.01802	8.5	331.2696	39.80897	13187.5
21	17.89932	8	358.7519	33.189	11906.61
22	16.78061	7.5	383.7192	27.34689	10493.53
23	15.6619	7	405.14	22.23404	9007.896
24	14.54319	6.5	421.9701	17.80181	7511.833
25	13.42449	6	433.199	14.00161	6065.482
26	12.30578	5.5	437.8983	10.7848	4722.648
27	11.18707	5	435.2729	8.102783	3526.922
28	10.06837	4.5	424.7092	5.906928	2508.727
29	8.949658	4	405.8199	4.148625	1683.594
30	7.830951	3.5	378.4793	2.779254	1051.89
31	6.712244	3	342.8488	1.750201	600.0542
32	5.593536	2.5	299.3886	1.012848	303.235
Total					214000.8

So, the total energy extracted per year from wind distribution = 214000.8.

And we can know the total energy extracted per year by the turbine, by using other ways like the capacity factor or from the catalogue of wind turbine

Assume the price of kwh =0.4 nis and the cost of total generated energy per year = 0.4*214000.8=85600.32 nis

Estimating the total cost of the wind energy system and the cost of KWh produced.

The cost of installing a small wind turbine is vary, depending on the size of the system, the height of the tower, and the equipment you buy. In most cases, the larger and taller the wind turbine is, the more expensive it will be.

According to the American Wind Energy Association (AWEA), small wind turbines cost between $3,000 to $5,000 for every kilowatt of power capacity.

If we consider the cost of small wind turbine for Palestine =$ 4000

Then cost of our turbine = 75 Kw * 4000 = $300000.

In nis = 300000$*3.8=1050000 nis

Payback period=total cost (nis) /annual energy cost (nis)=1050000/85600=12.26 year

show below the specification of the chosen generator in the table 3.6

Table 3.6
the specification of the chosen generator

Product Name	50Hz brushless synchronous generator
Registered Brand:	IDEAL ELECTRIC
Model No:	ADG280-6
Rating Range:	100kVA – 312kVA
Rated Speed:	1000RPM
Pole Count:	6 poles

and in the table 3.7 below shown of the specification selected turbine will be attached to the model

Table 3.7

the specification selected turbine

Model No.	ADG280S1-6
Rated Power at Temp. Rise F (105ºC)	100kVA
Power Factor	0.8 (lag)
Rated Frequency	50Hz
Insulation	H
Protection	IP23
Rated Speed	1000RPM
Overspeed	1.25 times of rated speed
Pole Count	6 poles
Rated Voltage	3-phase 200/220/380/400/440V (line to line)
Rated Current (at 3p400V)	144.3A
Phase Connection	WYE with neutral
Stator Winding	6/12 leads
Coupling Structure	Single bearing with SAE flange & flexible plates, or double bearing with shaft extension
Overload Capacity	110% rated load for 1 hour continuously in every 6 hours
Short Circuit	300% rated current
Excitation Mode	Brushless excitation, with AVR voltage control & current compound excitation
Exciation at No Load	≤ 2.5A, 45VDC
Excitation at Full Load	≤5A, 90VDC
Harmonic Distortion	THD ≤2.5%, individual harmonic ≤2.0%
Steady Voltage Regulation	Within ±1.0%
Transient Voltage Regulation	Within ±12%
Voltage Recovery Time	< 0.1s
Rotor Balancing Quality	G1.0 grade as per ISO1940-1
Dielectric Strength	2000V/2mins for stator, 1500V/2mins for rotor & exciter
Ambient Conditions	Altitude 1000m, temperature 40ºC, related humidity 95%
Standard Compliance	IEC60034-1, NEMA MG1

Chapter Four
Conclusion and Recommendations

4.1 Conclusion

We examined the wind profile climatology, power density, and yearly energy production over the State of Palestine using WRF simulations from 2000 to 2011 (12 years) and presented our findings in this study. With the help of this climatology study, we were able to identify the usual climatic year and calculate the yearly energy production and wind power density.

The research of the wind profiles from 2000 to 2011 revealed that the year 2003 had the greatest annual average wind speeds, while the year 2008 had the lowest annual average wind speeds. the highest wind speeds are observed during the winter period and the prevailing wind direction is westerly for all the West Bank.

2011 is chosen as the example year for the meteorology. The predominant wind directions on the West Bank are north-westerly in the southern portion and south-westerly in the northern portion. The easterly winds of Hebron have been calculated to have the highest yearly average wind speeds, reaching up to around 5.3 m/s. The monthly average for Hebron in February is 5.06 ± 2.38 m/s.

During the winter period the dominant wind direction is south/south-westerly. During spring the dominant wind direction is north-westerly for westerly for the West Bank region with the lowest wind speeds in the northwestern part of the West Bank and the highest wind speeds over the central and to the southern part (Hebron area). June and July are the months with the greatest summertime wind speeds in the central West Bank. The dominant wind direction is mainly westerly all the West Bank with north-westerly winds for the southern part of the West Bank. The dominant wind direction during fall is mainly westerly for the West Bank region. On the other hand, November sees a westerly flow across the southern portion of the West Bank and a southerly/south-easterly wind direction over the northwestern portion of the territory. Over a 12-year span (2000 - 2011), the wind resource's minimal fluctuations provide high predictability. The examination of the annual energy production of a 100kW wind turbine and the wind power density, however, indicates that Palestine has little potential for wind energy. The area east of Hebron emerges as Class 3 and is the most suited place in the West Bank, according to the yearly energy production at 80 meters.

Despite the fact that Palestine is primarily located in regions with low wind speeds, wind power has undoubtedly bright future. Jericho has the lowest wind energy since the average wind speed there is less than 2.5 m/s. Additionally, Hebron has the most wind energy, especially at Al-Ahli Hospital, where the average monthly wind speed is 5.06 m/s, which can be utilized to offset an annual 6% rise in electricity demand. While there are many obstacles in the way of Palestine's development of wind power, most of them can be overcome by producing wind turbines locally. Using the hybrid PV/wind system can maximize efficiency while minimizing the cost of generated energy from using each system independently.

The evaluation of Palestine's wind resources and its strong wind potential are insufficient for the development of wind power plants. A survey has been used to inform the political situation assessment that has been carried out concurrently with the evaluation of wind resources.

Based on the results of the survey, it appears that the Israeli government will be somewhat against any project that benefits the Palestinian people. Additionally, it is highly likely that international non-governmental organizations will be successful in establishing wind power in Palestine, despite the additional challenges of managing permits and logistics between two governments instead of one.

Because wind energy is a free and renewable resource, its supply will not decrease despite current usage.

4.2 Recommendations

- creating a national fund and appropriate funding channels in coordination with the Palestinian government, business community, and outside financial institutions.
- Implementing policies and incentives to promote investment in renewable energy technologies and encourage their adoption.
- Prioritizing small-scale renewable energy projects and creating a comprehensive wind map to guide development efforts.
- drafting bilateral cooperation agreements with the goal of launching wind power projects.
- Conducting ongoing data collection on wind energy to ensure the reliability of studies and support the development of efficient projects.
- Additional site studies based on local wind data can improve the outcomes of upcoming development initiatives.
- It is strongly advised that more research be done to address the local acceptance of wind power on both sides.

List of Abbreviations

Abbreviation	Meaning
EPFM	Energy Pattern Factor Method
GS	Gaza Strip
GWEC	Global Wind Energy Council
HAWT	Horizontal-Axis Wind Turbines
HRES	hybrid renewable energy systems
LCOE	levelized cost of electricity
LSM	Least Square Method
MLM	Maximum Likelihood Method
NREL	National Renewable Energy Laboratory
OPT	Occupied Palestinian territory
PDF	Probability density function
PENRA	Palestinian Energy National Resources Authority
PGF	Pressure-gradient force
PNA	Palestinian National Authority
OPT	Occupied Palestinian Territories
PVC	Present value cost
RE	Renewable Energy
VAWT	Vertical-Axis Wind Turbines
WB	West Bank
WECS	Wind energy conversion system
WRA	Wind Resource Assessment
WT	Wind turbine
PSBS	Palestinian Central Bureau of Statistics
CSP	Concentrated solar power
GT	Giga ton
KM	Kilometer
TWh	terawatt-hours
AWEA	American Wind Energy Association

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Appendices

Appendix A

Figures of Study

Figure A.1

probability density function (PDF) of Nablus Location

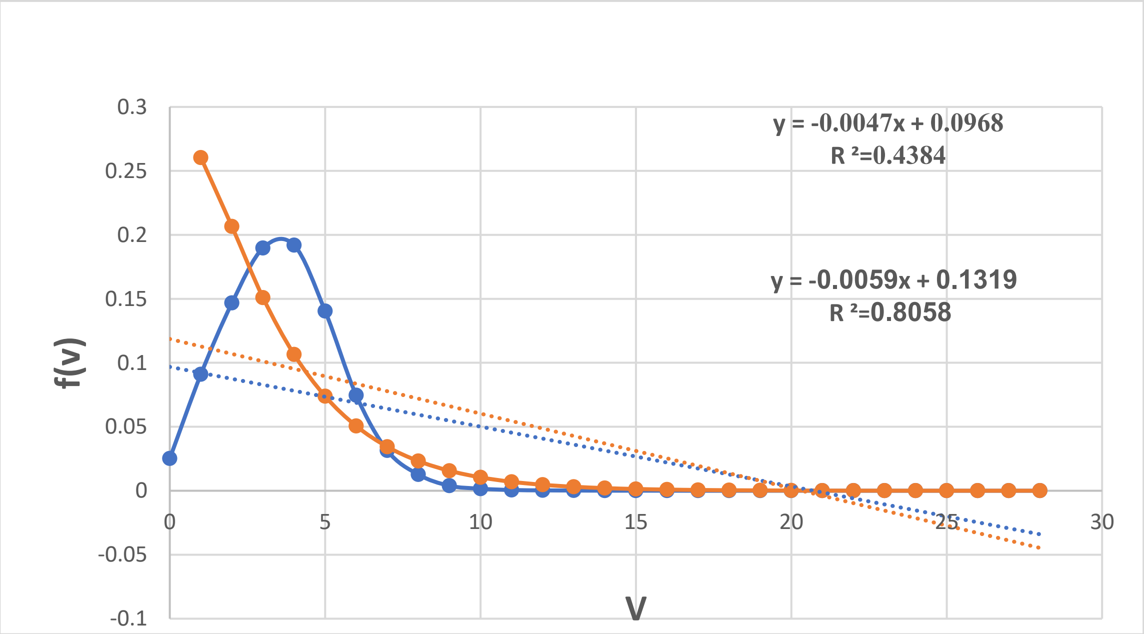


Figure A.2

Cumulative Distribution Function of Nablus Location

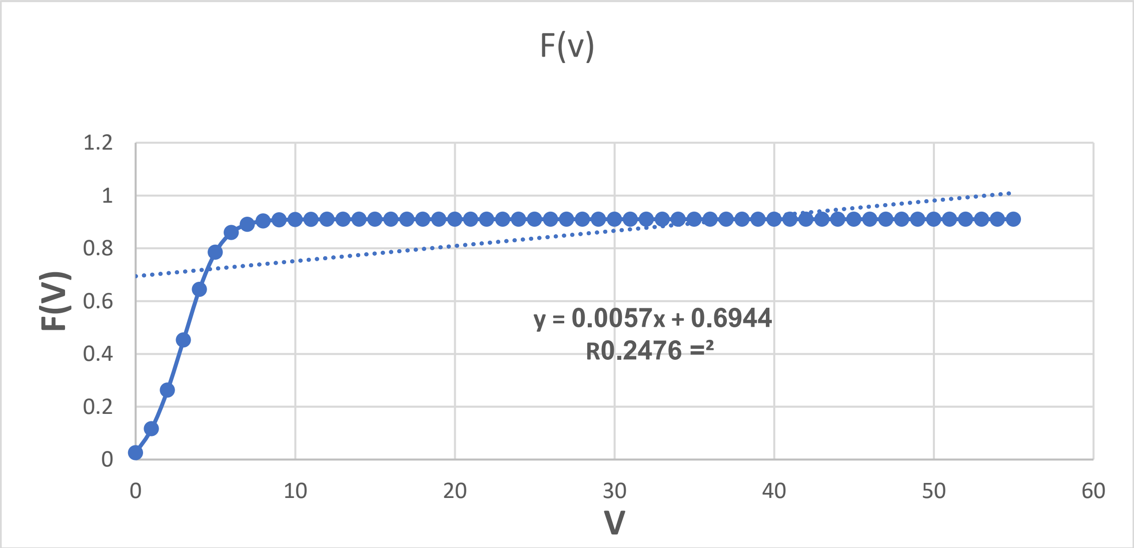


Figure A.3

Regression analysis to find shape and scale parameters of Weibull Distribution

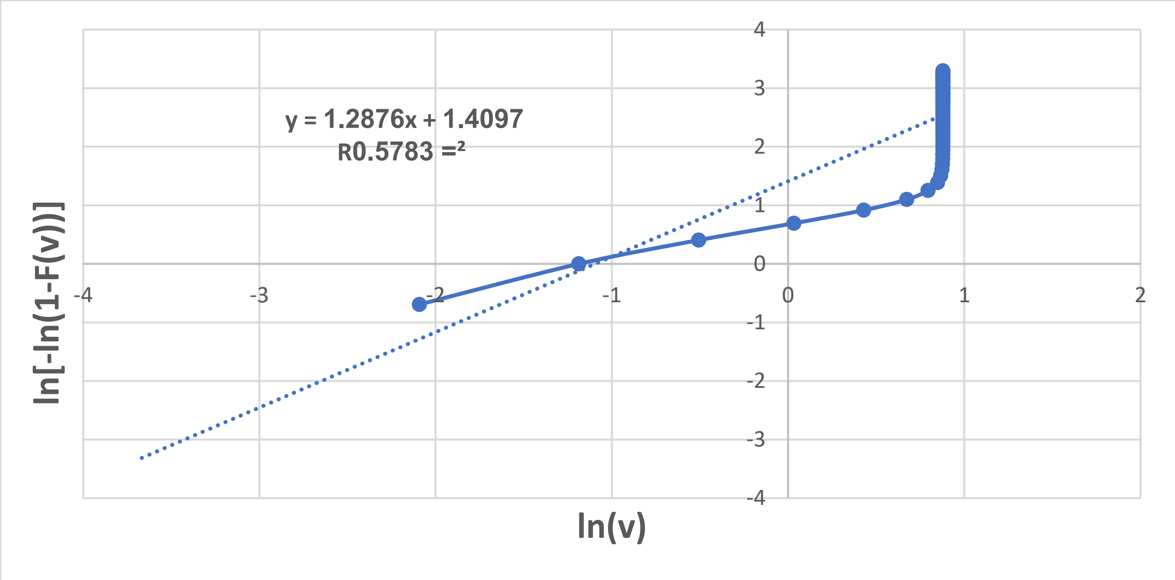


Figure A.4

The relationship between the number of times the wind speed is repeated and the wind speed

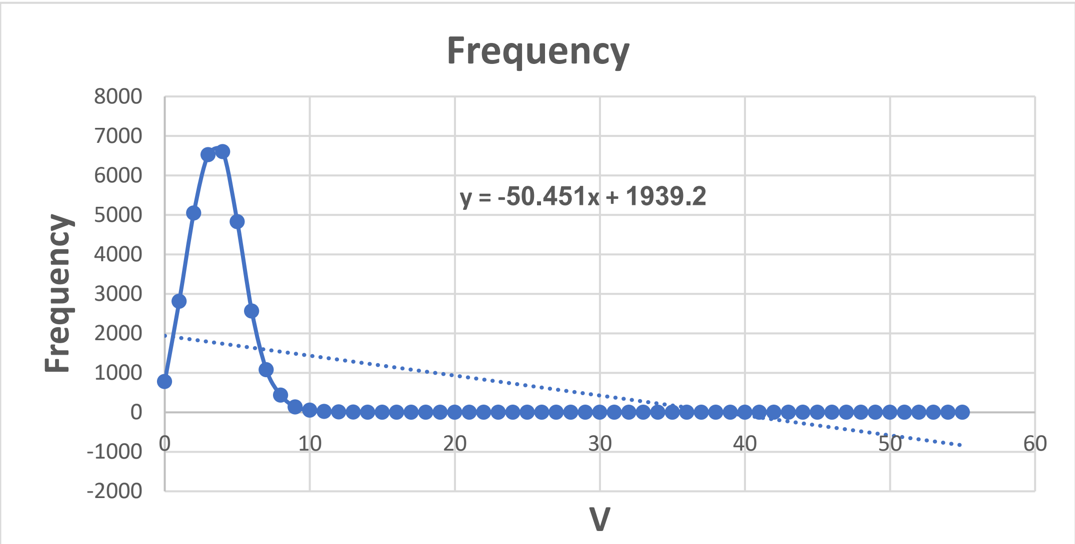


Figure A.5

probability density function (PDF) of Jenin Location

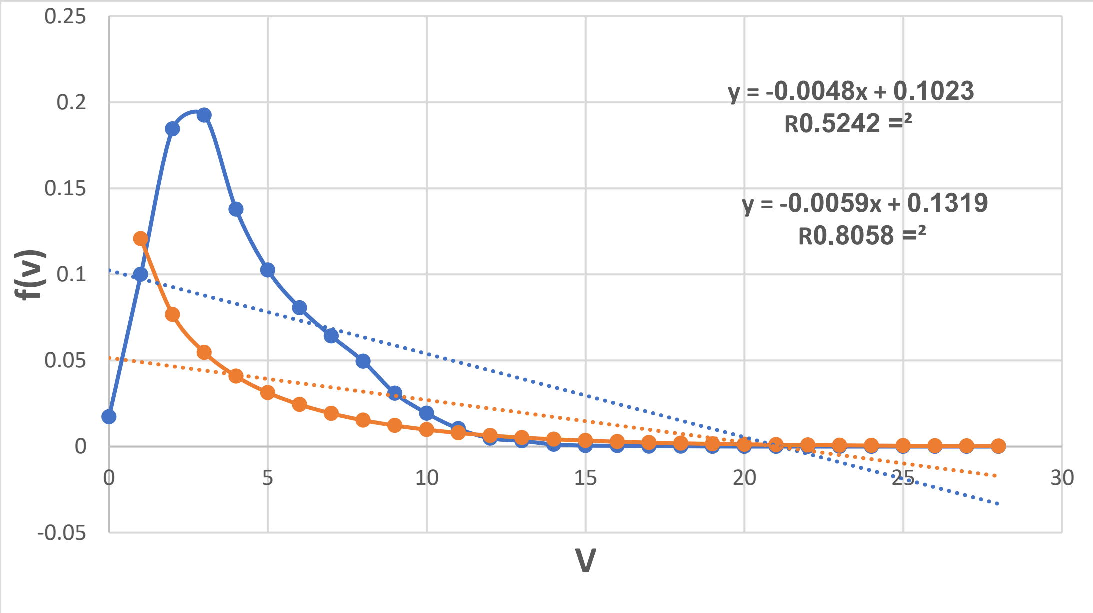


Figure A.6

Cumulative Distribution Function of Jenin Location

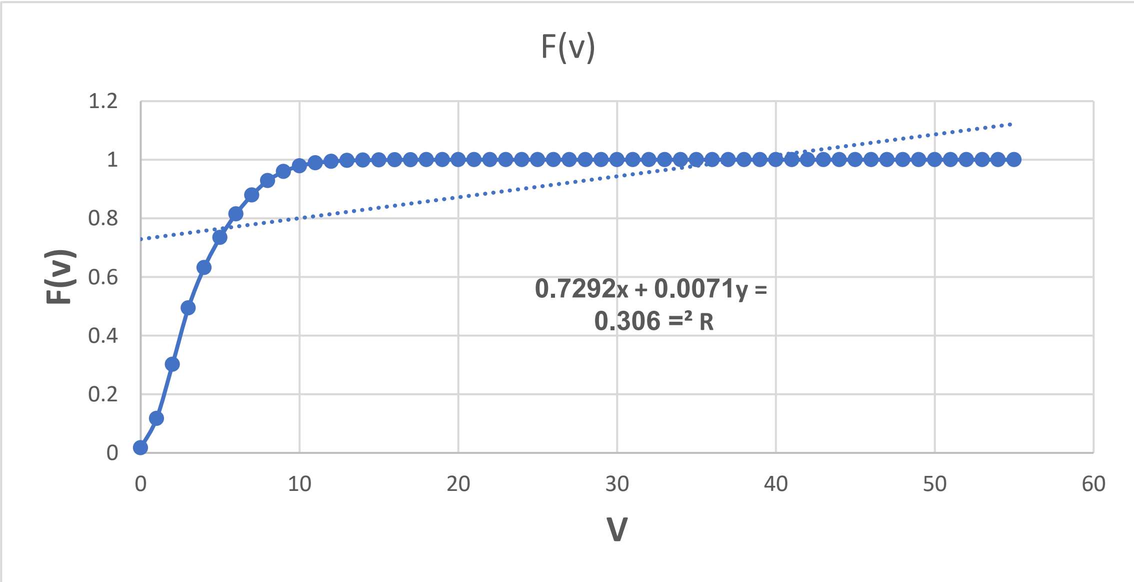


Figure A.7

Regression analysis to find shape and scale parameters of Weibull Distribution

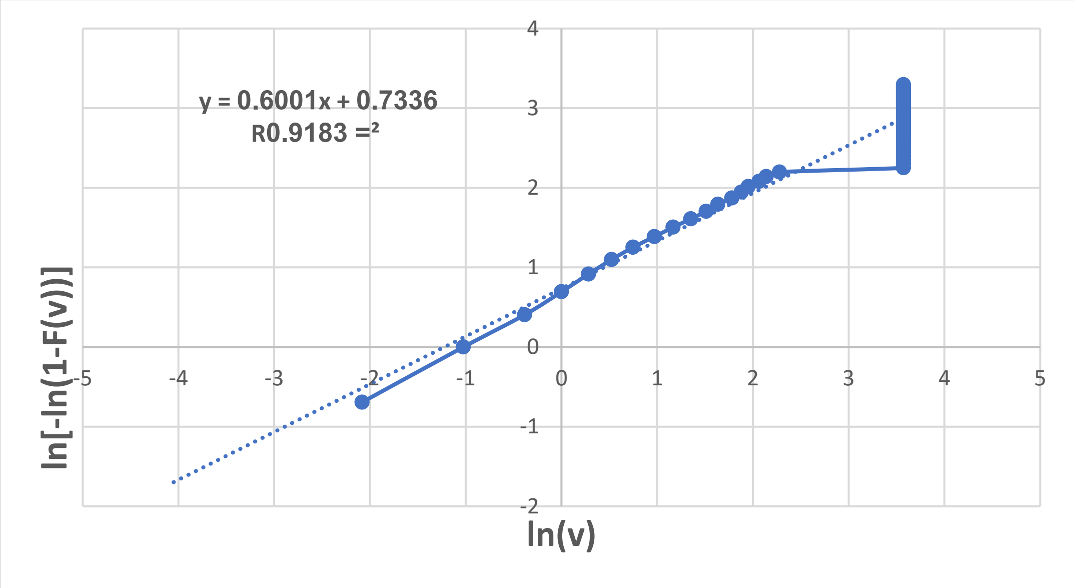


Figure A.8

The relationship between the number of times the wind speed is repeated **and**

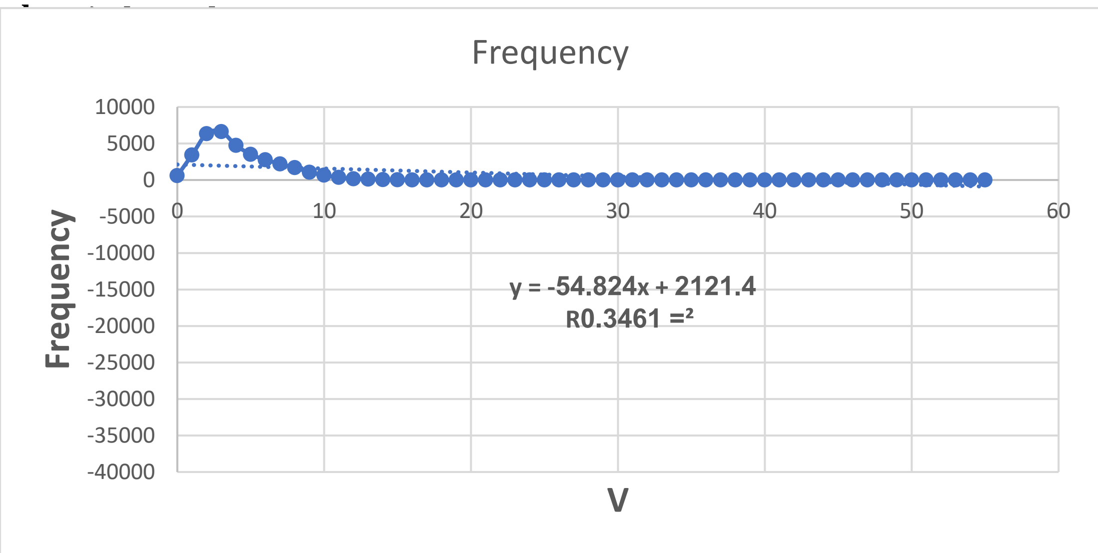


Figure A.9

Probability density function (PDF) of Jenin Location

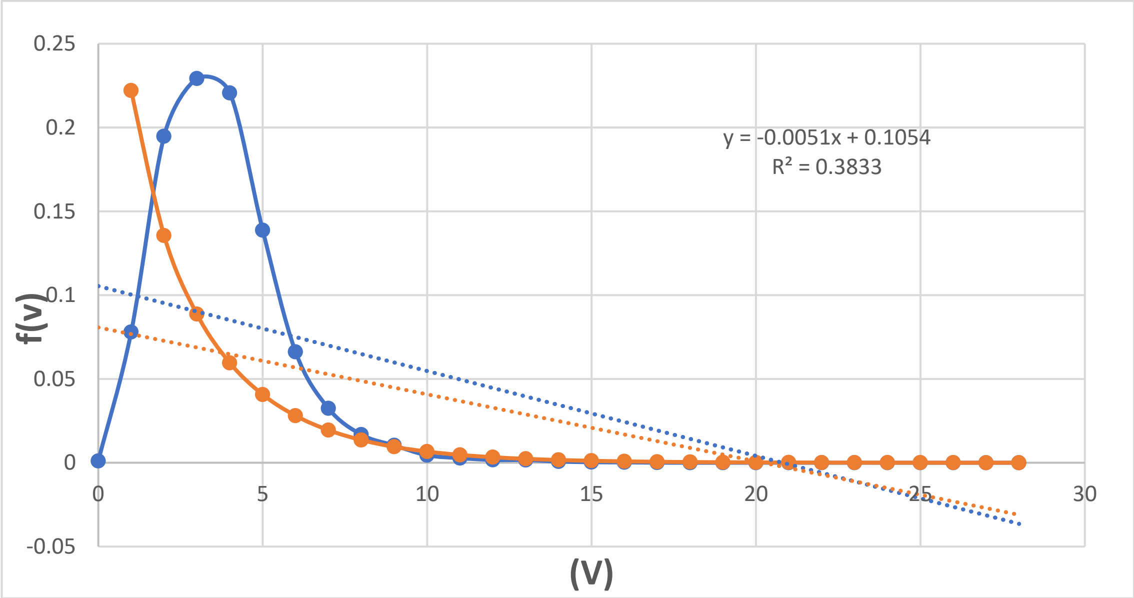


Figure A.10

Cumulative Distribution Function of Bethlehem Location.

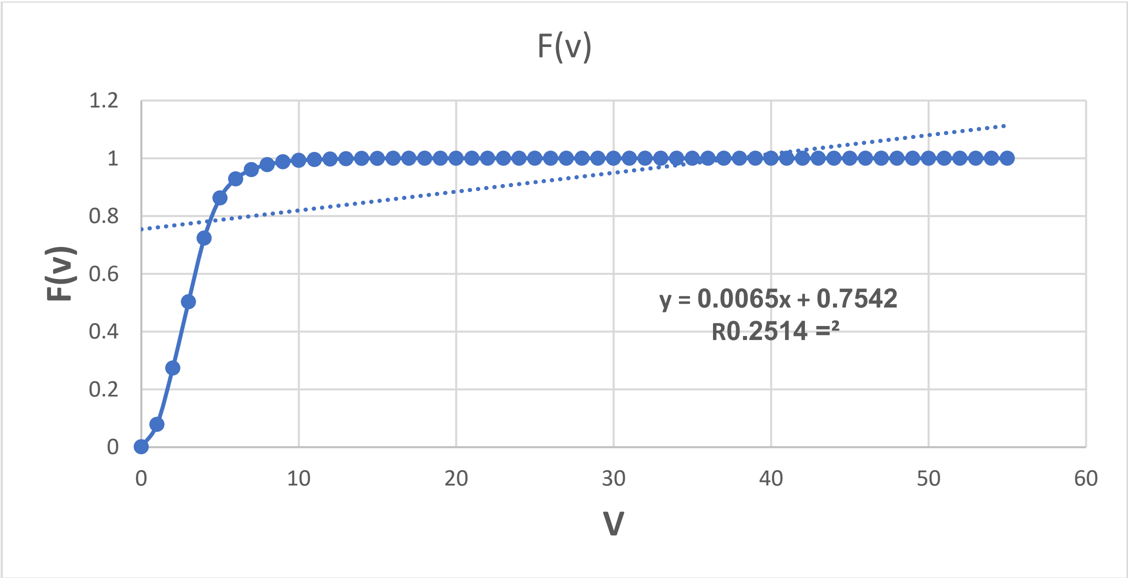


Figure A.11

Regression analysis to find shape and scale parameters of Weibull Distribution.

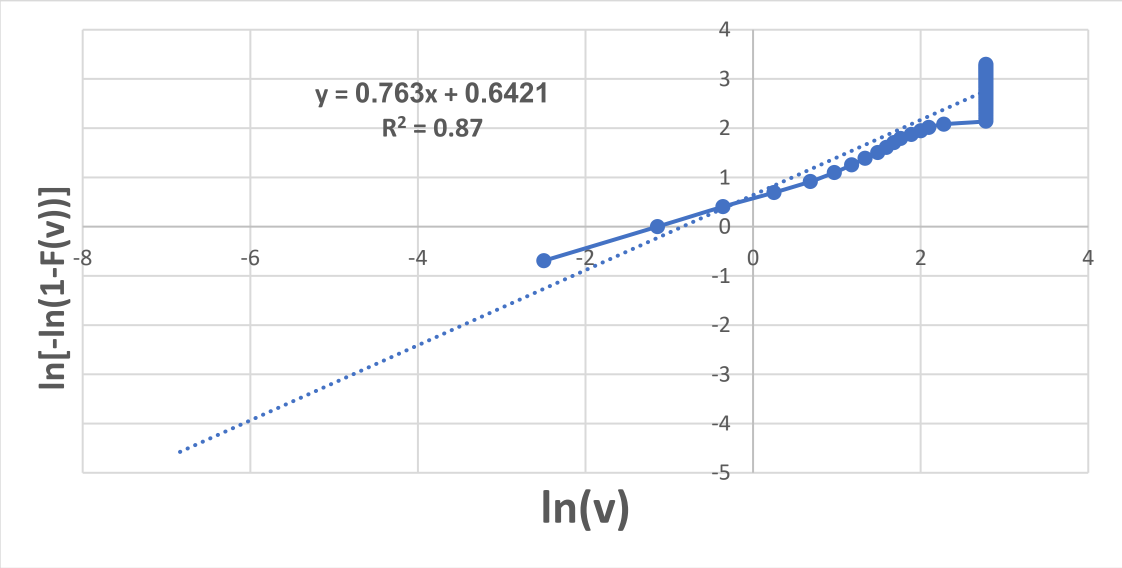


Figure A.12

The relationship between the number of times the wind speed is repeated and the wind speed

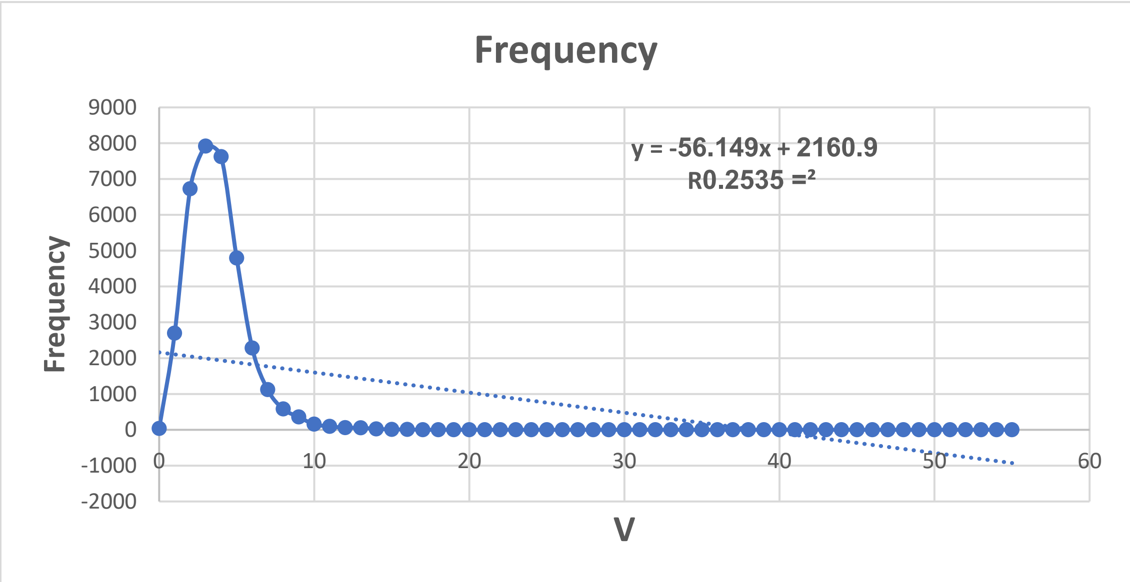


Figure A.13

probability density function (PDF) of Duma Location

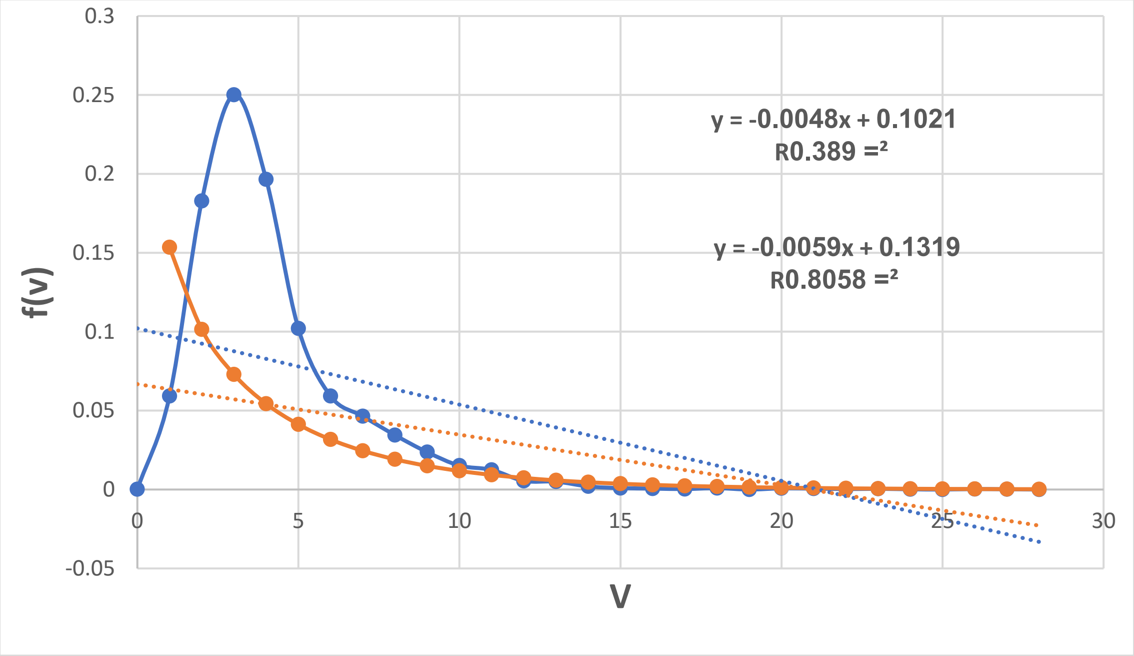


Figure A.14

Cumulative Distribution Function of Duma Location

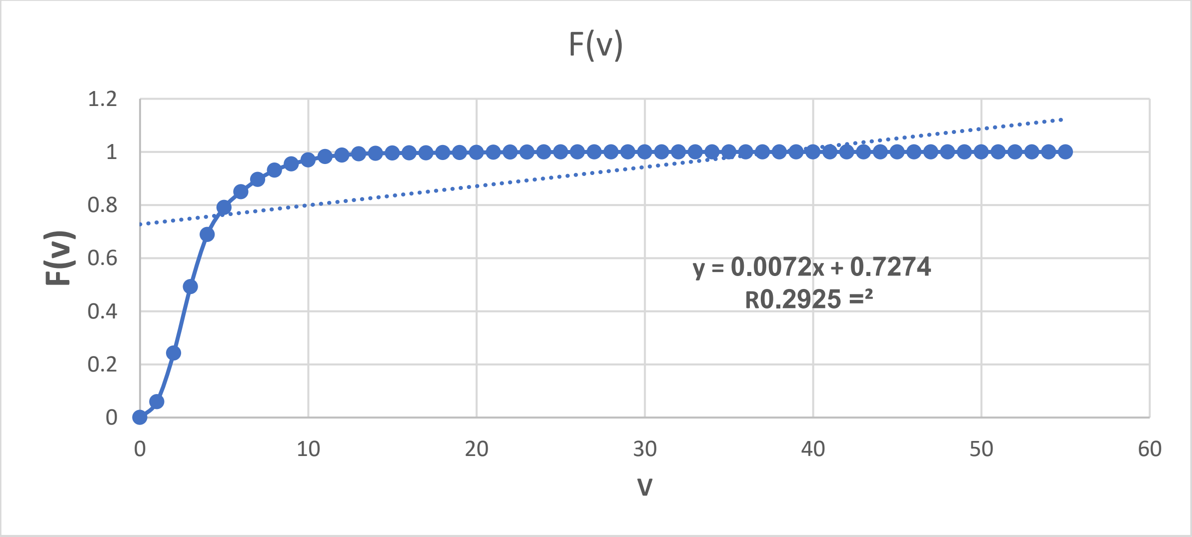


Figure A.15

Regression analysis to find shape and scale parameters of Weibull Distribution

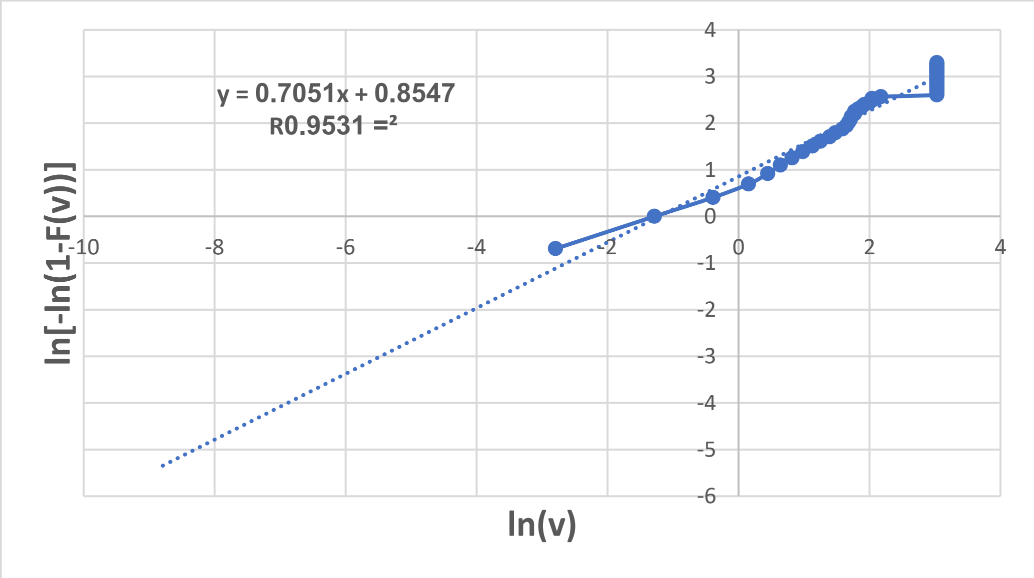


Figure A.16

The relationship between the number of times the wind speed is repeated and the wind speed

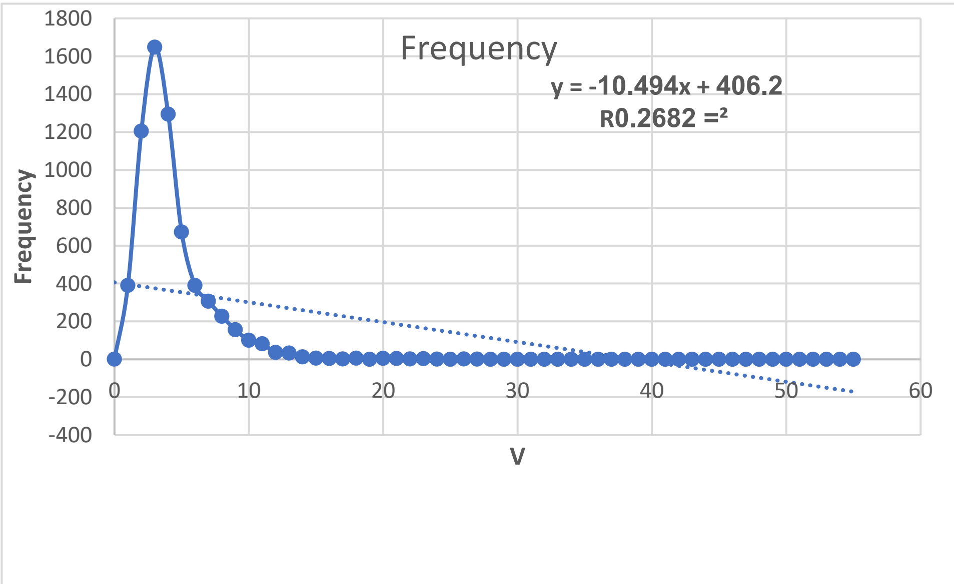


Figure A.17

probability density function (PDF) of Ramallah Location

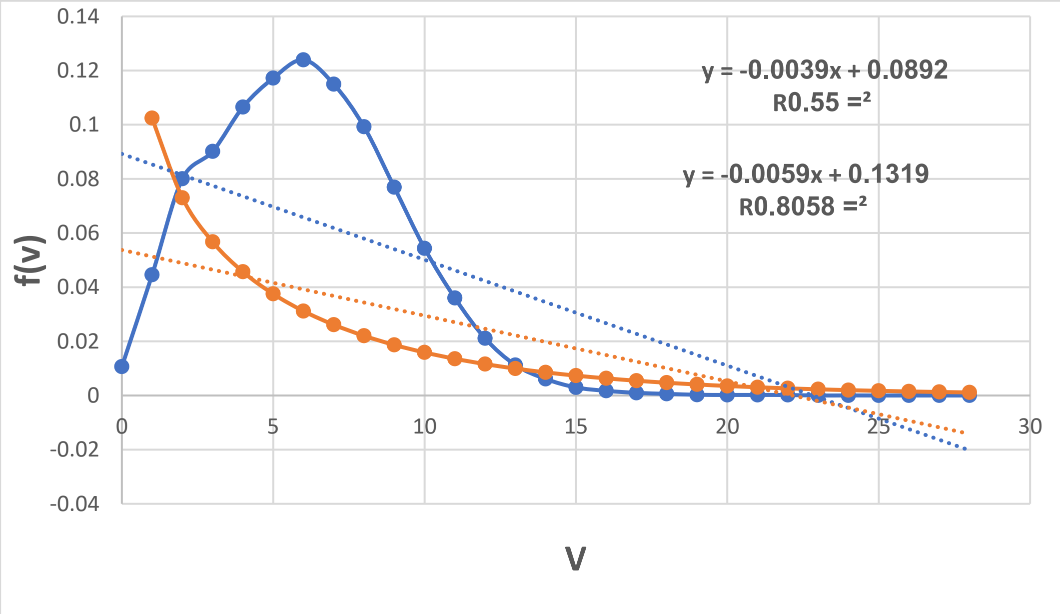


Figure A.18

Cumulative Distribution Function of Ramallah Location

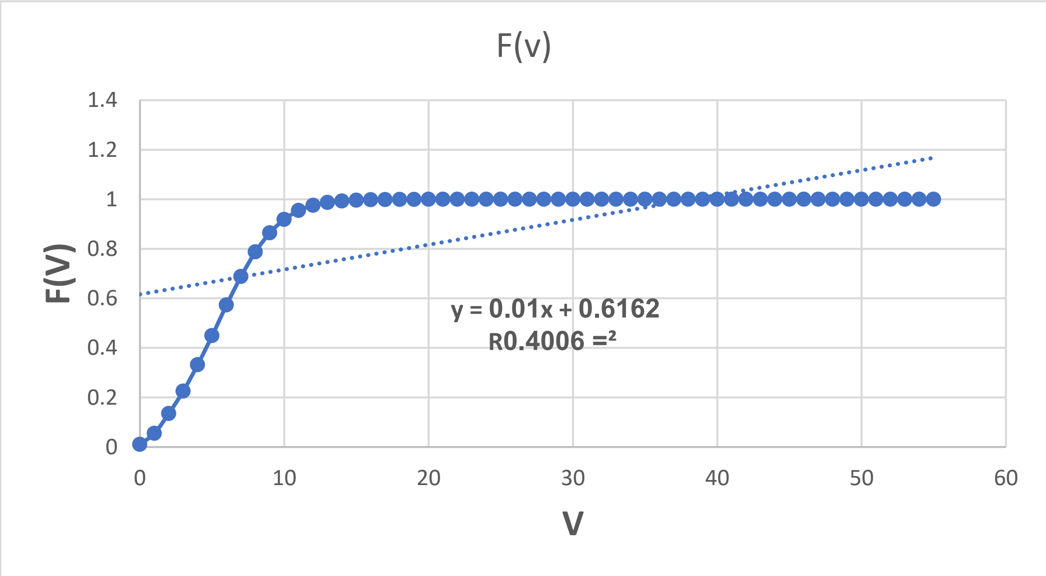


Figure A.19

Regression analysis to find shape and scale parameters of Weibull Distribute

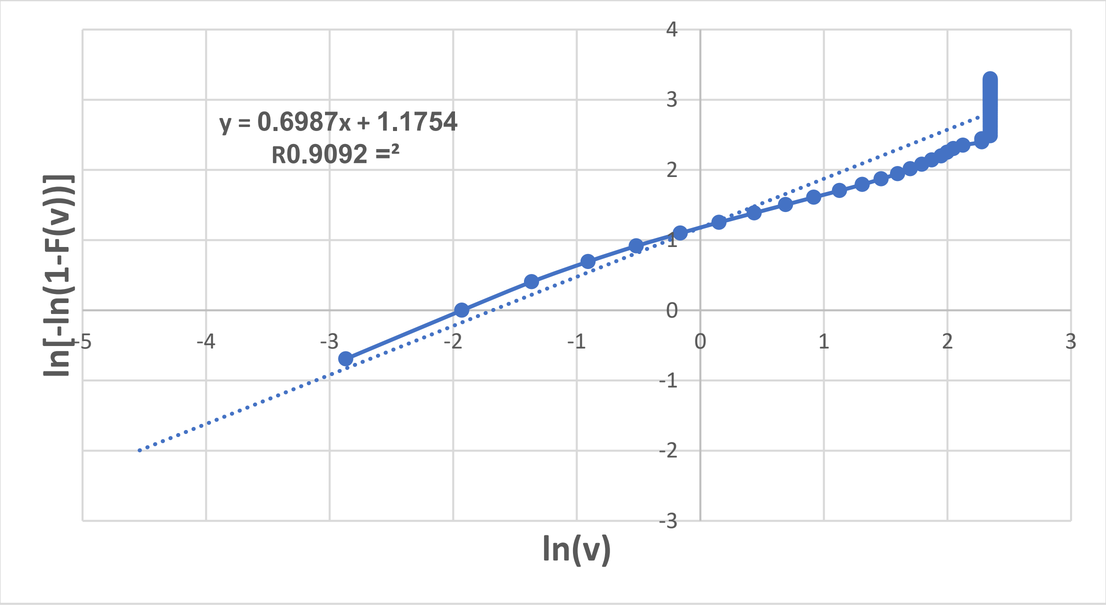


Figure A.20

the relationship between the number of times the wind speed is repeated and the wind speed

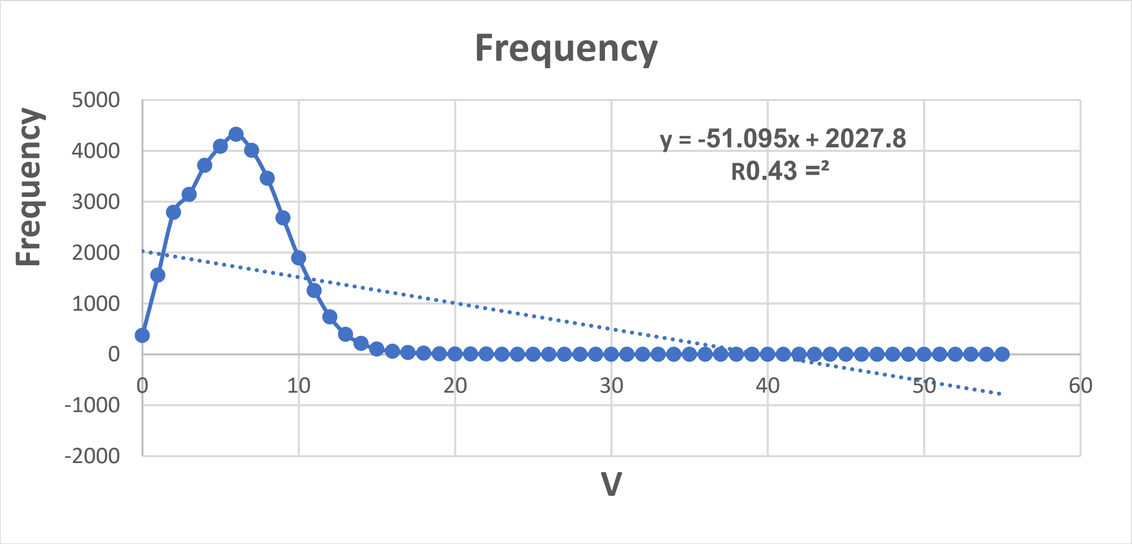


Figure A.21

probability density function (PDF) of Jericho Location

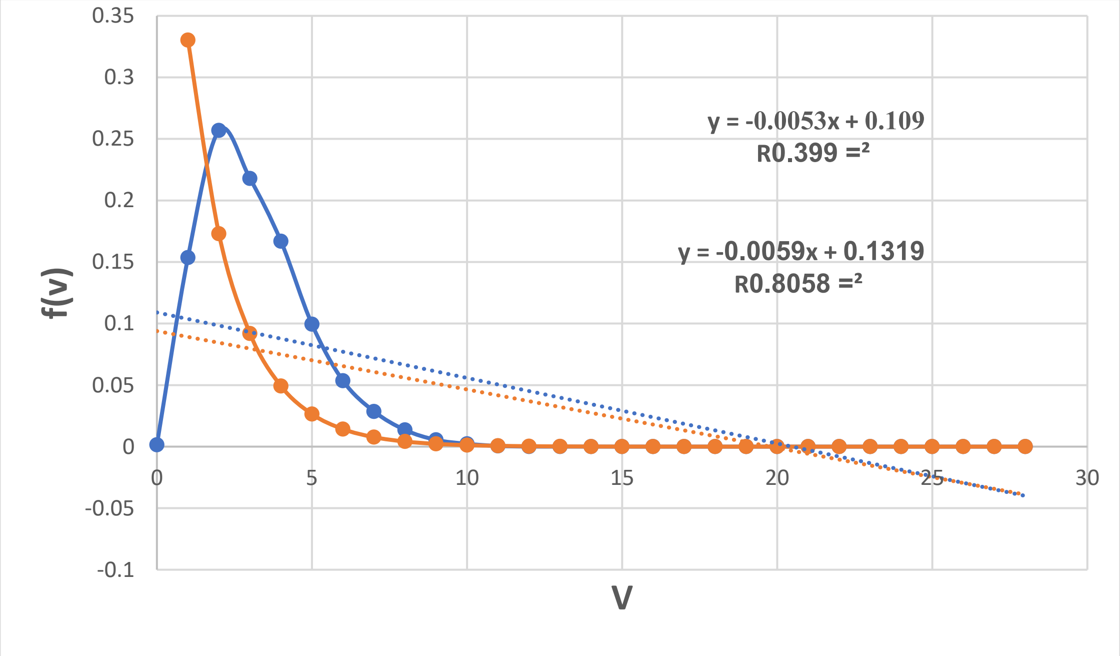


Figure A.22

Cumulative Distribution Function of Jericho Location.

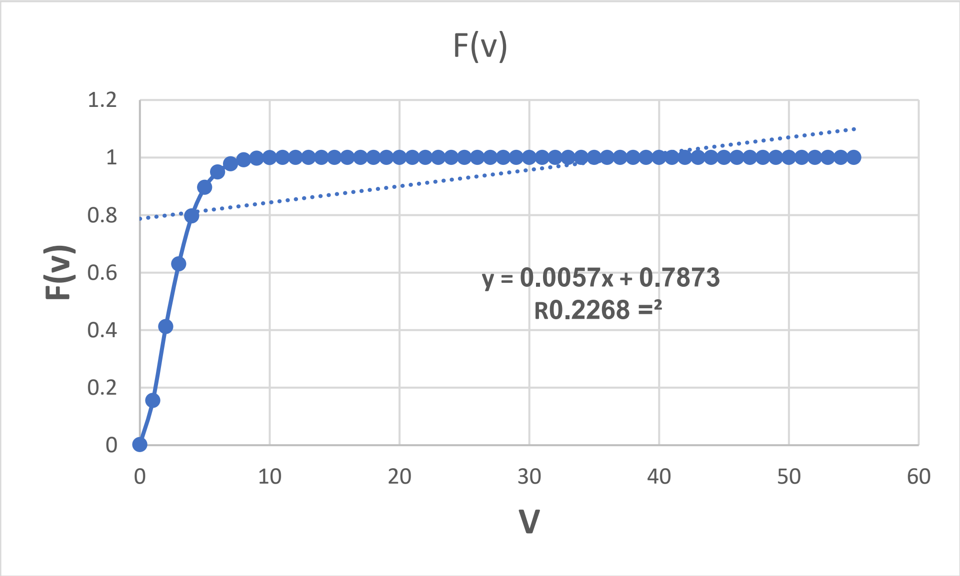


Figure A.23

Regression analysis to find shape and scale parameters of Weibull Distribute

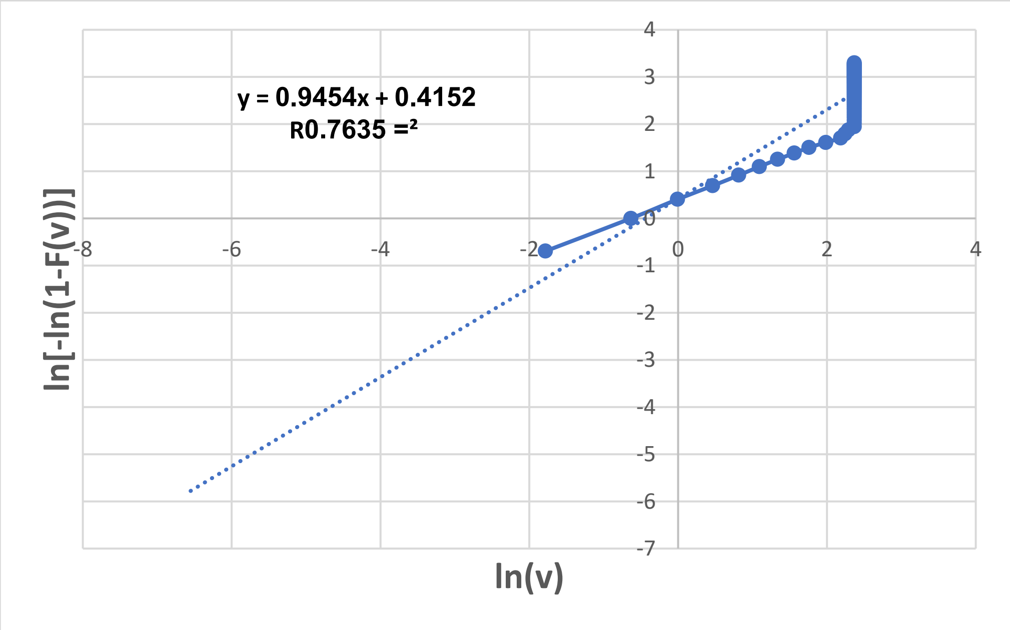


Figure A.24

The relationship between the number of times the wind speed is repeated and the wind speed

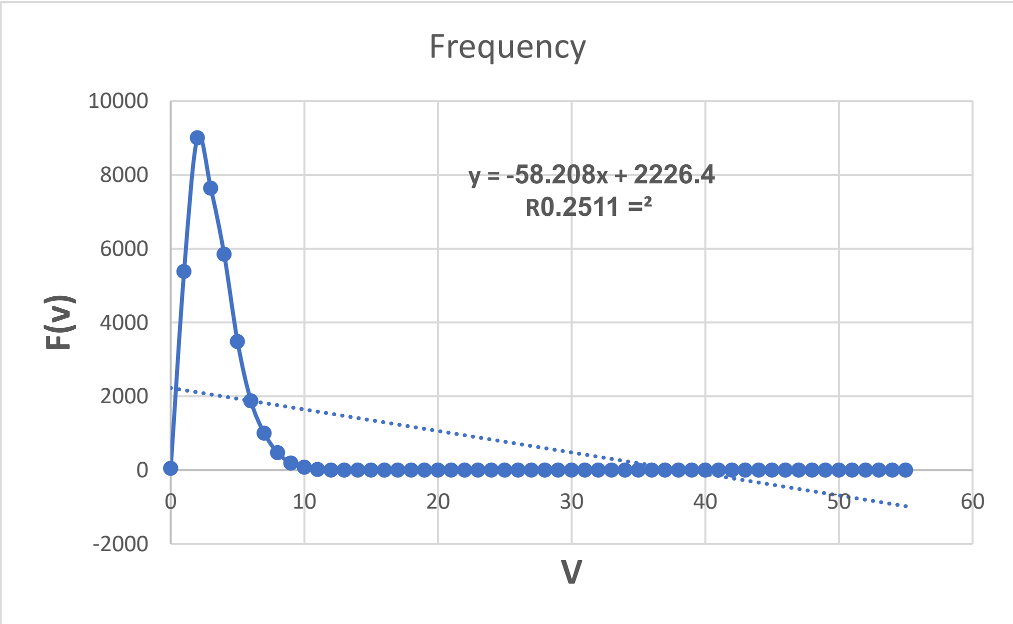


Figure A.25

probability density function (PDF) of Tulkarm Location

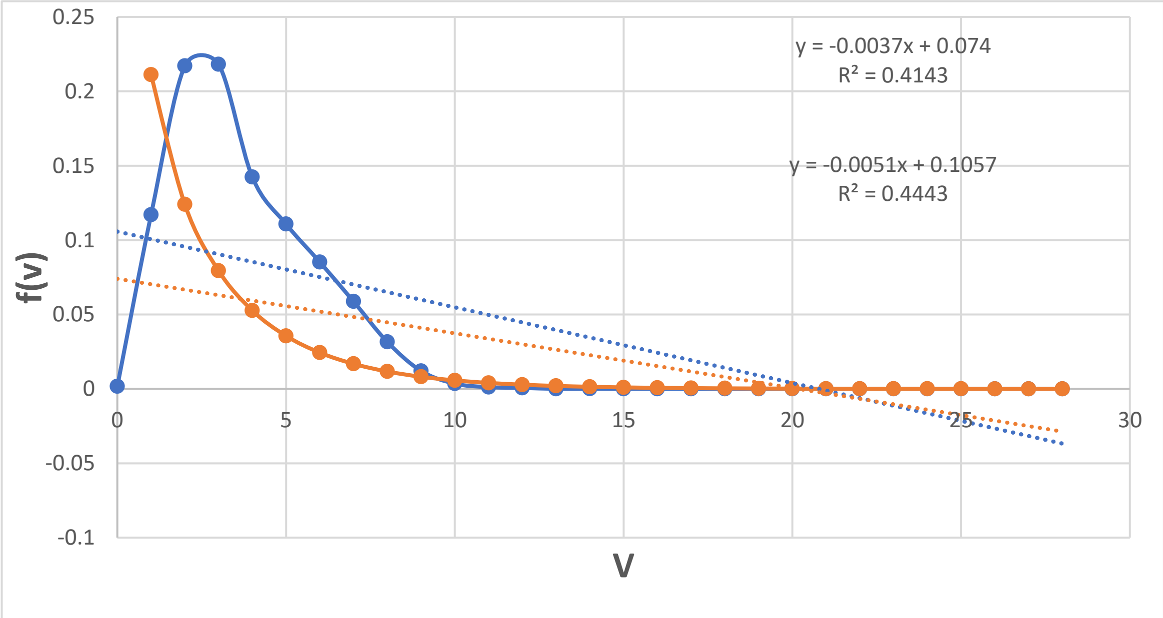


Figure A.26

Cumulative Distribution Function of Tulkarm Location

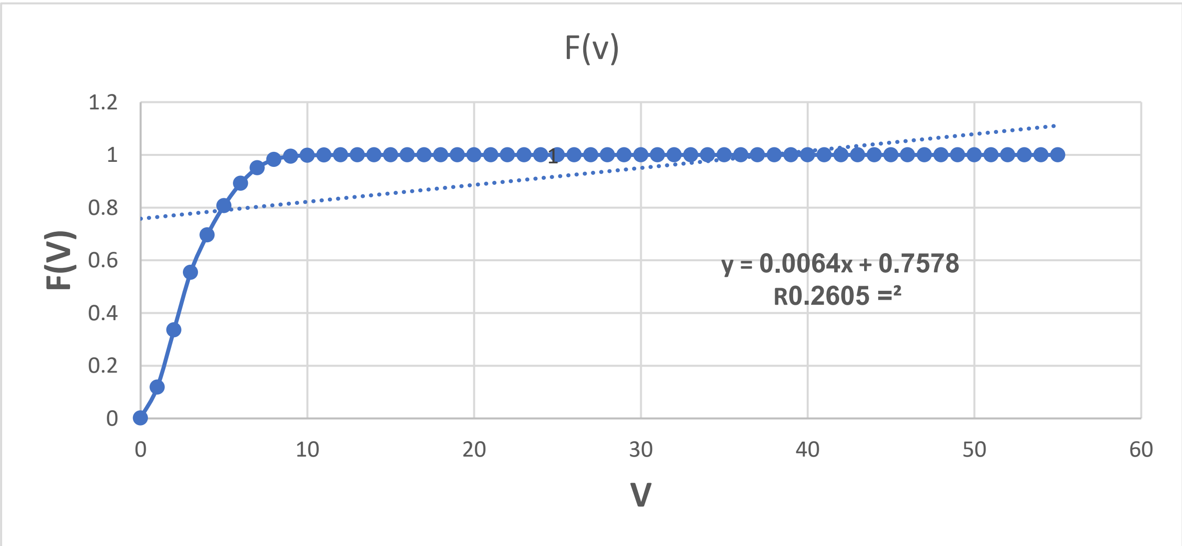


Figure A.27

Regression analysis to find shape and scale parameters of Weibull Distribute

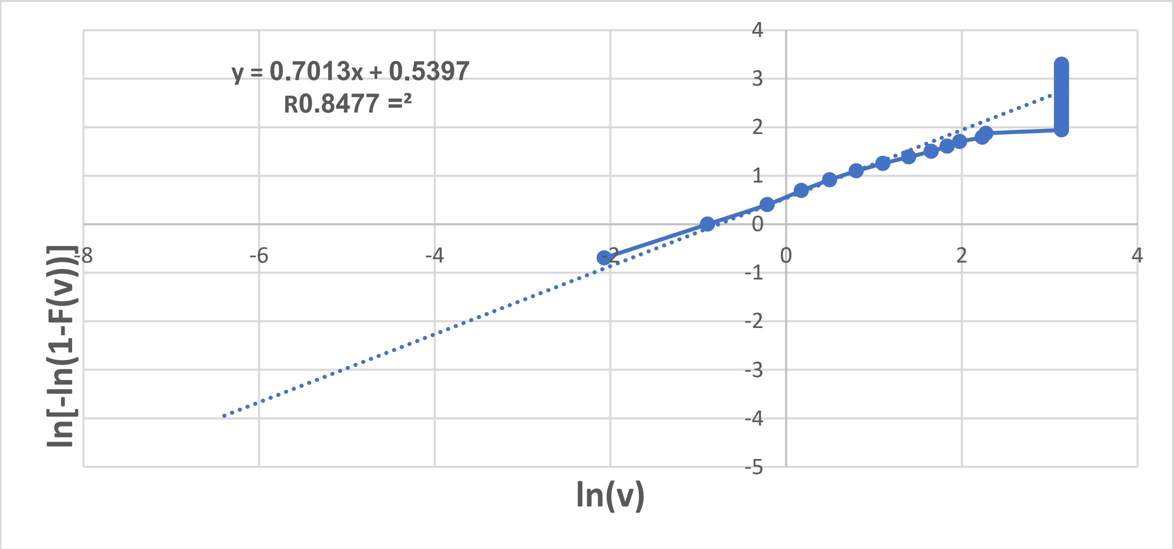
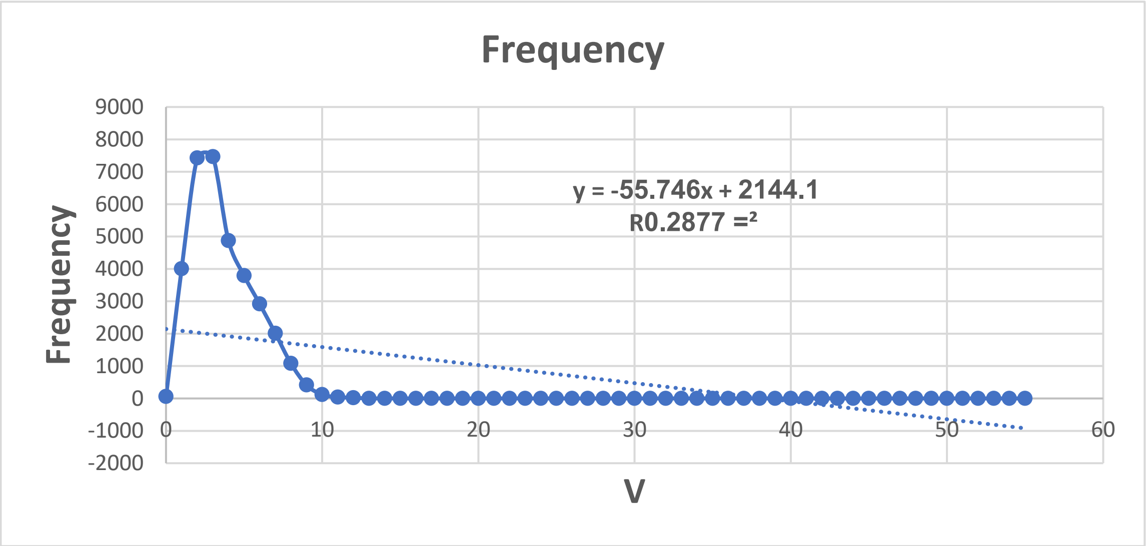


Figure A.28

The relationship between the number of times the wind speed is repeated and the wind speed



جــامعـــة النجاح الوطنية

كليـــة الدراســــات العليـــا

تقييم امكانيات طاقة الرياح في الاراضي الفلسطينية

إعداد

معتصم نواف قاسم سليمان

إشراف

أ.د. أيسر ياسين

قدمت هذه الرسالة استكمالا لمتطلبات الحصول على درجة الماجستير في هندسة القوى الكهربائية، من كلية الدراسات العليا، في جامعة النجاح الوطنية، نابلس– فلسطين.

2024

تقييم امكانيات طاقة الرياح في الاراضي الفلسطينية

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الملخص

تواجه الأراضي الفلسطينية تحديات كبيرة بسبب الاعتماد الكبير على مصادر الطاقة التقليدية المستوردة، بما في ذلك النفط وحوالي 90% من احتياجاتها من الطاقة الكهربائية من الشركات الإسرائيلية. ويؤدي هذا الاعتماد إلى ارتفاع تكاليف الطاقة والقابلية لتقلبات الأسعار. وفي خضم هذه التحديات، تظهر الطاقة المتجددة كحل حاسم لأزمة الطاقة، حيث تمثل طاقة الرياح موردًا غير مستغل ولكنه واعد في منطقة الأرض الفلسطينية المحتلة. على الرغم من أهميتها العالمية، تظل إمكانات طاقة الرياح غير مستغلة إلى حد كبير في الأراضي الفلسطينية بسبب العدد المحدود من الدراسات، والقيود على القدرات المهنية، والحواجز الجيوسياسية، إلى جانب التكاليف المرتفعة المرتبطة بتقنيات طاقة الرياح. وقد أدت هذه العوامل إلى شعور واضح بالإحباط والنظر إلى مشاريع طاقة الرياح على أنها غير عملية في المنطقة.

يهدف هذا البحث إلى إجراء تحليل وتقييم شامل لإمكانات طاقة الرياح في منطقة العمال من خلال أساليب علمية صارمة. باستخدام أسلوب التوزيع Weibull، تسعى الدراسة إلى تقديم نظرة عامة مفصلة عن الوضع الحالي لتقييم موارد الرياح، واستكشاف تقنيات تحويل طاقة الرياح الحالية المناسبة للأراضي الفلسطينية المحتلة، وتقديم خصائص الرياح التفصيلية لمناطق محددة قيد الدراسة. بالإضافة إلى ذلك، يهدف إلى تحديد المواقع الأكثر ملائمة لتركيب توربينات الرياح وتحديد أنواع التوربينات الأكثر ملاءمة لهذه المناطق. ومن خلال هذا النهج، يسعى البحث إلى تقديم رؤى وتوصيات موضوعية للتغلب على التحديات التي تواجه تنفيذ طاقة الرياح في منطقة المحيط الهادئ.

الكلمات المفتاحية: طاقة الرياح، الطاقة المتجددة، توربينات الرياح، تقييم، قدرة الرياح في فلسطين.