ROOFTOP-BUILDING RENEWABLE POWER SYSTEM AT THREE REGIONS IN NORTHERN CYPRUS

A THESIS SUBMITTED TO THE GRADUATE SCHOOL OF APPLIED SCIENCES OF NEAR EAST UNIVERSITY

By

Raafat AL ZOUBI

In Partial Fulfillment of the Requirements for the Degree of Master of Science in Civil Engineering

NICOSIA, 2019

RAAFAT AL ZOUBI

ROOFTOP-BUILDING RENEWABLE POWER SYSTEM AT THREE REGIONS IN NORTHERN CYPRUS

NEU 2019

ROOFTOP-BUILDING RENEWABLE POWER SYSTEM AT THREE REGIONS IN NORTHERN CYPRUS

A THESIS SUBMITTED TO THE GRADUATE

SCHOOL OF APPLIED SCIENCE

OF

NEAR EAST UNIVERSITY

By

Raafat AL ZOUBI

In Partial Fulfillment of the Requirements for
the Degree of Master of Science
in
Civil Engineering

NICOSIA, 2019

Raafat AL ZOUBI: ROOFTOP-BUILDING RENEWABLE POWER SYSTEM AT THREE REGIONS IN NORTHERN CYPRUS

Approval of Director of Graduate School of

Applied Sciences

Prof. Dr. Nadire ÇAVUŞ

We certify this thesis is satisfactory for the award of the degree of Master of Science in Civil Engineering

Examining Committee in Charge:

Prof. Dr. Hüseyin Gökçekuş	Committee Chairman, Supervisor, Civil Engineering, NEU,
Assist. Prof. Dr. Belal Shneikat	Economic and administrative sciences, Kyrenia University
Assist. Prof. Dr. Beste Çubukçuoğlu	Civil Engineering Department, NEU
Dr. Fidan Aslanova	Civil Engineering Department, NEU
Assist. Prof. Dr. Youssef KASSEM	Co-Supervisor Mechanical Engineering Department, NEU

I hereby declare that, all the information in this document has been obtained and presented in accordance with academic rules and ethical conduct. I also declare that, as required by these rules and conduct, I have fully cited and referenced all material and results that are not original to this work.

Name, Last Name:

Signature:

Date:

ACKNOWLEDGEMENTS

I would like to express my sincere gratitude and thanks to my supervisors Prof. Dr. Hüseyin GÖKÇEKUŞ and Assist. Prof. Dr. Youssef KASSEM for their guidance, suggestions and much good advice and his patience during the correction of the thesis. They have been my mentor and my support at all the times. I am very thankful to them for giving me an opportunity to work on interesting projects I am immensely grateful for your kindness, patience, time and professional contributions to the success of my study. Thanks for always pushing me for more.

I would also like to thank Assist. Prof. Dr. Belal SHNEIKAT for giving me the opportunity to further my knowledge in the management area. Without him, I would not have the opportunity to carry out such interesting research.

This research was generously supported by the Department of Civil Engineering of Near East University. I am also grateful to all supporters.

I would also like to express heartiest thanks to my parents, my wife and my family members for their patience, ever constant encouragement and love during my studies.

To my parents ...

ABSTRACT

The increased energy demand and related environmental problems caused by burning fossil fuels have raised interest in alternative energy sources. This research explores student's opinions regarding renewable energy, technologies, and benefits in Northern Cyprus. In order to investigate the opinions and the level of awareness of the post-graduate students, a multiple choice questionnaire was designed. The results show that the majority of students have heard about renewable energy technologies in terms of wind and solar and are concerned about using it to generate electricity in Northern Cyprus. Moreover, this study investigates the wind characteristics and available wind energy for three urban regions in Northern Cyprus using Weibull distribution function. The results illustrate that Gazimağusa is the most applicable location for harvesting the kinetic energy of the wind compared to Lefkoşa and Girne. Furthermore, Logistic distribution function is used for analyzing the global solar radiation based on various periods. Moreover, this work presents an economic evaluation of three regions with promising solar/wind potential. Therefore, a small-scale (10kW) grid-connected solar /wind system that is able to generate electricity with an excellent percentage of clean energy was proposed and developed. The analysis indicates that the proposed PV projects were very promised in the all studied regions. In addition, the proposed PV systems are the most economical option for generating electricity compared to wind system due to low electricity prices and recovery of initial investment. Consequently, the simulation results expect to help in demonstrating the advantages and challenges of installing a grid-connected PV system for residential in Northern Cyprus in order to reduce the electricity consumption produced by fossil fuel.

Keyword: Economic analysis; grid-connected; Northern Cyprus; renewable projects; urban regions; public opinion

ÖZET

Artan enerji talebi ve fosil yakıtların yanmasından kaynaklanan çevresel problemler alternatif enerji kaynaklarına ilgi artmıştır. Bu makale, öğrencinin Kuzey Kıbrıs'taki yenilenebilir enerji, teknolojiler ve faydalar hakkındaki görüşlerini incelemektedir. Mezuniyet sonrası öğrencilerin görüş ve farkındalık seviyelerini araştırmak için çoktan seçmeli bir anket tasarlanmıştır. Sonuçlar, öğrencilerin çoğunluğunun rüzgar ve güneş açısından yenilenebilir enerji teknolojilerini duyduğunu ve Kuzey Kıbrıs'ta elektrik üretmek için kullanmaktan endişe duyduklarını göstermektedir. Öğrencinin görüşlerine dayanarak, bu çalışma Weibull dağılım işlevini kullanarak Kuzey Kıbrıs'taki üç kentsel bölge için rüzgar özelliklerini ve mevcut rüzgar enerjisini incelemektedir. Sonuçlar, Gazimağusa'nın, rüzgarın kinetik enerjisini Lefkoşa ve Girne'ye kıyasla hasat için en uygun yer olduğunu göstermektedir. Ayrıca, küresel güneş ışınımını çeşitli dönemlere göre analiz etmek için Lojistik dağıtım fonksiyonu kullanılmaktadır. Dahası, bu çalışma ümit vaat eden güneş / rüzgar potansiyeli ile üç bölgenin ekonomik bir değerlendirmesini sunuyor. Bu nedenle, mükemmel oranda temiz enerjiyle elektrik üretebilen küçük ölçekli (10 kW) bir şebekeye bağlı güneş / rüzgar sistemi önerildi ve geliştirildi. Analiz, önerilen PV projelerinin tüm çalışılan bölgelerde çok vaat edildiğini göstermektedir. Ayrıca, önerilen PV sistemleri, düşük elektrik fiyatları ve ilk yatırımın geri kazanılması nedeniyle rüzgar sistemine kıyasla elektrik üretmek için en ekonomik seçenektir. Sonuç olarak, simülasyon sonuçları, fosil yakıtın ürettiği elektrik tüketimini azaltmak için Kuzey Kıbrıs'ta konutlar için şebekeye bağlı bir PV sistemi kurmanın avantajlarını ve zorluklarını göstermeye yardımcı olmayı beklemektedir.

Kelimeler: Ekonomik analiz; çevre analizi; şebekeye bağlı yenilenebilir projeler; Kuzey Kıbrıs

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOLS

$\boldsymbol{A}$	Swept area in m^2
$\boldsymbol{B}$	The total benefit of the project
$\boldsymbol{C}$	Total initial cost of the project
$\boldsymbol{C_G}$	GHG reduction income
$\boldsymbol{C_c}$	The annual capacity savings or income
$\boldsymbol{C_e}$	The annual energy savings or income
$\boldsymbol{C_f}$	The annual cost of fuel
$\boldsymbol{C_n}$	The after-tax cash flow in year *n*
$\boldsymbol{C_{O\&M}}$	The yearly operation and maintenance costs incurred by the clean energy project
$\boldsymbol{C_R}$	The annual renewable energy (RE) production credit income
$\boldsymbol{r}$	Discount rate
$\boldsymbol{, f_d}$	The debt ratio
$\boldsymbol{f(v)}$	Probability density function (PDF)
$\boldsymbol{P}$	Wind power in W
$\boldsymbol{\bar{P}}$	Mean wind power in W
$\boldsymbol{v_1}$	Wind speed at the original height z_1
$\boldsymbol{\bar{v}}$	Mean wind speed in m/s
$\boldsymbol{N}$	Project life in years
Δ_G	The annual GHG emission reduction.
$\boldsymbol{\rho}$	Air density
$\boldsymbol{\alpha}$	The surface roughness coefficient

YAKIN DOĞU ÜNİVERSİTESİ

BİLİMSEL ARAŞTIRMALAR ETİK KURULU

11.12.2018

Dear Raafat Al Zoubi

Your application titled **“Renewable Energy Technologies in Northern Cyprus: A Survey of University Students”** with the application number YDÜ/FB/2018/45 has been evaluated by the Scientific Research Ethics Committee and granted approval. You can start your research on the condition that you will abide by the information provided in your application form.

Assoc. Prof. Dr. Direnç Kanol

Rapporteur of the Scientific Research Ethics Committee

Direnc Kanol

Note: If you need to provide an official letter to an institution with the signature of the Head of NEU Scientific Research Ethics Committee, please apply to the secretariat of the ethics committee by showing this documen

CHAPTER 1
INTRODUCTION

1.1 Background

Renewable energy technologies areconsidered as important sources in Twenty one century, which can be replaced the use of fossil fuel and reduced the global warming. Internationally, the tendency in power consumption level is growing owing to industrialization and quick vary in the set of living of the people in excess of the previous few decades(Bano and Rao 2016; Padmavathi and Daniel 2013; Sharma and Chandel 2013; Shiva Kumar and Sudhakar 2015; Khanna et al., 2017). Optional source such as solar power and bio-mass power are wanted to decrease the GHG (Kumar et al., 2017).Renewable energy sources are ideal candidate for global energy transition that must occur over the century (REN21 et al., 2012; De et al., 2011; De et al., 2014; Pakistan Energy Yearbook 2001 et al., 2002; Muhammad et al., 2017).One of the most important renewable energy resources are wind and solar energy. Wind and Solar energiesare environmentally friendly and economically perfect sustainable electric power production. Wind energy and solar energy is converted to electric power using wind turbine and solar PV technologies, respectively. Wind and solar energy is the world's fastest-growing energy source and it can power industry, businesses, and homes with clean, renewable electricity for many years to come (Razmjoo et al., 2017; Spellman &Stoudt, 2013). Wind speed and Sunlight can be converted directly into electricity using wind turbines (Al Zohbi et al., 2015) and solar photovoltaic (PV) (Shiva Kumar &Sudhakar, 2015), respectively. They are a considerable power source for meeting electricity demand in many countries (Cantarello& Newton, 2014).

In Northern Cyprus, the electricity is currently produced using diesel generators power stations and PV power plant, which installed in Serhatköy with the capacity of 212MW and 1.27MW, respectively (Yenen&Fahrioglu, 2013; Kassem et al., 2018). Moreover, increasing population, rising life standards, and rapidly growing tourism and industry sectors have led to an increase in the demand for fossil fuels. Increasing demand in conventional sources has encouraged the authors to investigate in the field of renewable energy sources especially wind and solar energy for electricity generating in Northern Part of Cyprus.

1.2 Objectives of the Research

The first objective of this study is to provide a better understanding of the relationship between renewable technologies (wind turbines and PV) and the cheapest energy cost at three major cities located in the Northern part of Cyprus. In addition, this work aims to analyze the level of awarenessof energy efficiency in terms of renewable energy sources,technologies, and benefits in Northern Cyprus. Furthermore, this study also addressed how the thinkingand acceptance rate of renewable energy technologies varyespecially for the respondents' own. Moreover, the second objective of this study is to evaluate the economic and environmental effects of wind and solar rooftop-building system that influence electricity cost and CO_2 emission in most of the cities, in particular, the case study of Lefkoşa, Girne, and Gazimağusa.

The study focused on finding the best renewable technologies can be used to generate electricity in Northern Cyprus.

1.3 Thesis Outlines

Chapter 1 is provided a short description of renewable energy in terms of wind and solar energy and the objective of this work. In chapter 2 is explained the fundamental concept of renewable energy and wind turbine. Chapter 3 is describedthe methods used to analyze the climate data including wind, solar radiation and sunshine duration. In addition, simulation tools that used to study the economic evolution of renewable rooftop system are explained. The electricity cost generated by renewable system and environmental effect is discussed in chapter 4. The final conclusion on the current study is described in chapter 5.

CHAPTER 2
RENEWABLE ENERGY

2.1 Renewable energy

Renewable sources of energy are independent, naturally and not artificially existingand they are already being economically exploited or will become so in the nearfuture as shown in Figure 2.1.

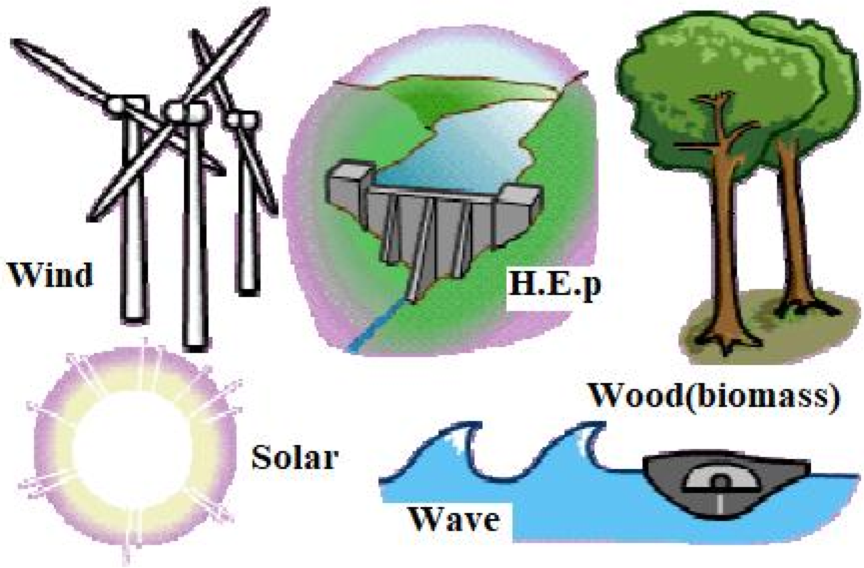


Figure 2.1: Renewable energy sources

Renewable energy sources have as their basic origin the sun. The radiation from thesun that reaches the Earth’s ground, apart from the vital contribution in the creation,growth and maintenance of life of our planet, provides our planet with energy invarious forms. Moreover solar radiation heats directly and evaporates large quantitiesof marine water and it maintains the natural cycle of the water, creating lakes andrivers that constitute an additional source of energy (Hydroelectric energy). Solarradiation puts in movement the air masses of the atmosphere (Wind energy) and itcreates waves (Wave energy). Finally is absorbed from combined materials andproduces electricity (Photovoltaic effect) and it contributes in the growth of flora viathe photosynthesis phenomenon and with the combustion of plants produces energy(Biomass).

Renewable sources are safe and unlimited in the sense that there is no possibility ofreserves being run down. With some exceptions, proposed renewable energy sourcesare local and so cannot be exploited by a foreign power as has happened with oil overmany years. Furthermore renewable sources can add diversity to energy supply andalmost none of them releases gaseous or liquid pollutants during the operation.

Of course renewable sources, with the current economic and technological facts, arenot able, at least for the moment, to give a clear and a radical solution to the energyproblems of humanity. However if their use is combined with an effort to save largeamounts from existing conventional energy resources, it is possible that a progressiveremoval of humanity's nightmare, a befalling energy winter, may be accomplished.

2.2 Solar Energy

The sun is the largest energy source of life while at the same time it is the ultimate source of most of our renewable energy supplies.

The sun is a typical star with the following characteristics: mass 2×1030 kg, beam length 700.000 km, age 5×10^9 years and it is calculated that it still has roughly 5 billion more years of life. Its surface temperature is about 5800 K while the internal temperature is approximately 15.000.000 K. This temperature derives from reactions which were based on the transformation of hydrogen in helium.

Energy, is the result of the high temperature of the sun and the continuous emission of large amounts of energy. It is calculated that for each gram of hydrogen, that is converted to He, sun radiates energy equal with U= 1.67×105 kWh. The solar energy is emitted to the universe mainly by electromagnetic radiation.

The earth spins in an elliptic orbit around the sun while the distance from the sun is estimated to be 150.000.000 km. The light in order to cover this distance, having thespeed of 300.000 km/sec, requires approximately 8.5 min. The emitted radiation is removed actinic by the aster to the space and the intensity of the radiation J, is calculated according to the equation below:

$$J = \frac{P}{4\pi d^2} \quad (2.1)$$

Where P is the power of electromagnetic radiation and d is the distance from the sun.Approximately one-third of this radiation is reflected back. The rest is absorbed andretransmitted to the space while the earth reradiates just as energy as it receives andcreates a stable energy balance at a temperature suitable for life.

Solar energy can be used to generate electricity in a direct way with the use ofphotovoltaic panels.

2.3 Wind Energy

Wind energy is a free, clean, and inexhaustible energy source. Ithas served mankind for many centuries by propelling ships anddriving wind turbines to grind grains and pump water. Windpower and other forms of solar power are being strongly encouraged.Wind power may become a major source of energy in spiteof slightly higher costs than other traditional sources of energygeneration. Considerable progress is being made in making windpower less expensive. But even without a clear cost advantage,wind power will become important in the world energy sources.Wind energy is the world’s fastest-growing energy source and itcan power industry, businesses and homes with clean, renewableelectricity for many years to come. Wind turbines do not consumefuel due to its operation. It does not produce emissions such as carbondioxide, sulphur dioxide, mercury, particulates, or any othertype of air pollution.

2.4 Review study

Several researchers have studied wind and solar potential of various locations in world and Northern Cyprus.

For instant, Al Zohbi et al. (2015) investigated the wind characteristics using actual wind data for five sites in Lebanon. They concluded that the wind power could reduce the electricity crisis in Lebanon.

Bilir et al. (2015) analyzed the wind speed characteristics at Incek region of Ankara in Turkey using actual wind data measured at various height (20 and 30m). It is found that wind energy source in this region is classified to be poor and small-wind turbine capacity can be used to produce electricity.

Ammari et al. (2015) evaluated the wind power at five different locations in Jordan and examined the feasibility of using different wind turbines with the different power rated capacity to be employed in the wind farm. The results showed that Aqaba Airport and Ras-Muneef have a good wind speed for generating electricity, while the desert locations of Safawi and Azraq South have moderate wind energy generation potential and Queen Alia Airport has a poor in wind energy potential.

More recently, Alayatet al. (2018) studied techno-economic assessment of the wind power potential for eight locations, namely, Lefkoşa, Ercan, Girne, Güzelyurt, Gazimağusa, Dipkarpaz, YeniBoğaziçi, and Salamis, distributed over the Northern part of Cyprus. The results showed that small-scale wind turbine use could be suitable for generating electricity in the studied locations.

Kassem et al. (2018) are evaluated the economic feasibility of 12MW grid-connected wind farms and PV plants for producing electricity at Girne and Lefkoşa in Northern Cyprus.The authors concluded that PV plants are the most economical option compared to wind farms for generating electricity in the selected studied.

Kassem et al. (2018) are analyzed the wind power potential at Salamis region in Northern Cyprus. They found that high capacity wind turbine (MW) could not be suitable for electricity production in the region based on the value of wind power density.

Solyali et al. (2016) studied wind power potential for Selvili-Tepelocation in Northern Cyprus. The authors found that wind energy sources in this site are classified to be marginal (wind power class is 2).

Kassem&Gökçekuş (2018) evaluated and analyzed the techno-economic of proposing a 1MW grid-connected PV power plant in Lefke town. The analyzing result showed that PV plant could be used as a viable alternative to reduce the GHG emissions in Northern Cyprus and generating electricity from environmentally friendly scours.

Mohammadi et al. (2018) evaluated the potential of developing 5 MW gird-connected PV power plants in eight selected cities in the southern coast of Iran from technical, financial and environmental viewpoints. The results showed that southern coast of Iran has a huge potential and actual market opportunities for investors to develop grid-connected PV projects.

Elhodeiby et al. (2011) presented a performance analysis of 3.6 kW Rooftop grid connected solar photovoltaic (PV) system in Egypt. The system was monitored for one year and all the electricity generated was fed into the 220 V, 50 Hz low voltage grid to the consumer.

CHAPTER 3
MATERIAL AND METHOD

3.1 MeasurementData

Cyprus is the third biggest island in the Mediterranean Sea and the climate of Cyprus is a typical Mediterranean climate (Mehmet &Bicak, 2002). Climate conditions on the island vary by geographical factors. Cyprus was divided into two sides in 1974 after the war (Mehmet &Bicak, 2002). It has a total surface area of 9.250 km^2 and north of Island is 3.355 km^2. Cyprus has blocked further EU negotiations with Turkey over the issue of Turkey's support for the break-away Northern Cyprus region (Hobbs, 2016). The major's cities in Northern Cyprus are Lefkoşa, Girne, and Gazimağusa. The total population in these cities is estimated to be 94824 people for Lefkoşa, 69163 for Girne and 69741 for Gazimağusa in 2011 (Statistics and research department, 2017). Furthermore, the total urban building at Lefkoşa, Girne, and Gazimağusa for 2016 was 353, 111, and 145 building, respectively (Statistics and research department, 2017). Climate data for various periods (wind speed, solar radiation, and sunshine duration) collected from the Meteorology Department located in Lefkoşa were analyzed. The data used for this work are monthly data using a simple statistical method to calculate the average monthly climate data. The meteorological station's information, which was considered for the calculation, analysis and prediction purposes, is listed in Table 3.1. The locations of these meteorological stations are given in Figure 3.1.

Table 3.1: Details of each region used in this study

Location	Coordinates		Area	Altitude	Period data	
	Latitude [°N]	Longitude [°E]	[m^2]	[m]	Wind speed at a 10m height	Solar radiation at 2m height
Lefkoşa	35° 10’12.9”	33° 21’31.32”	502	146	2008-2016	2008-2016
Girne	35° 20’0.6”	33° 18’51.156”	690	7	2000-2016	2000-2016
Gazimağusa	35° 7’15.9924”	33° 56’15.1116”	997	7	2009-2016	2009-2016

Figure 3.1: The geographic location of the study area

3.2 Wind Power Density

Wind power density (WPD) value can be regarded as a representative value for the wind energy potential of a region. The model of wind power density describes the distributions of wind energy at various wind speed values. The WPD value in W/m^2 depends only on the air density and the wind speed as given by (Ayodele et al. 2013)

$$W = \frac{P}{A} = \frac{1}{2}\rho v^3 \quad (3.1)$$

where Pis the wind power in W, A is a swept area in m^2, ρ is the air density ($\rho = 1.225\ \mathrm{kg/m^3}$) and v is wind speed in m/s.

Moreover, for a period measurement, the mean wind power density ($\overline{\mathrm{WPD}}$) in W/m^2 can be calculated using Eq. (2) (Irwanto et al. 2014).

$$\overline{W} = \frac{\bar{P}}{A} = \frac{1}{2}\rho \bar{v}^3 \quad (3.2)$$

where $\overline{P}$ is the mean wind power in W and $\overline{v}$ is the mean wind speed in m/s.

If the distribution of wind speed is taken into account, then Eq. (1) can be written as (Ayodele et al. 2013)

$$\frac{P}{A} = \frac{1}{2}\rho\int_0^\infty v^3 f(v)d \quad (3.3)$$

where $f(v)$ is the probability density function (PDF).

Furthermore, the wind power density distribution for a specified distribution function *f(v)* can be computed as (Mohammadi et al. 2017):

$$\frac{P}{A} = \frac{1}{2}\rho v^3 f(v)(3.4)$$

For wind energy assessments, the simple power law model is usually adopted to convert the wind speeds to various heights. It is expressed as (Irwanto et al. 2014)

$$\frac{v}{v_1} = \left(\frac{z}{z_1}\right)^\alpha (3.5)$$

where v is the wind speed at the wind turbine hub height z, v_1 is the wind speed at the original height z_1 , and α is the surface roughness coefficient, which depends on the characteristics of the region [13]. In this study, the wind speed data was measured at the height of 10 m above ground level; therefore, the value of α can be obtained from the following expression(Masseran, 2015;Irwanto et al. 2014).

$$\alpha = \frac{0.37 - 0.088 ln\,(v_1\ )}{1 - 0.088 ln\,(z_1\ /10)} (3.6)$$

3.3 Details of Proposed Rooftop Grid Connected Renewable System

3.3.110kW Grid-Connected Wind System

The terms "wind energy" or "wind power" describe the process by which the wind is used to generate mechanical power or electricity. Wind turbines convert the kinetic energy in the wind into mechanical power as presented in the previous section. This mechanical power can be used for specific tasks (such as grinding grain or pumping water) or a generator can convert this mechanical power into electricity to power homes, businesses, schools, and other facilities. In this section we will discuss the basic design of wind electric turbines.

The basic components of a wind electric system analyzed herein are shown in Figure 3.2. A step-up gearbox and a suitable coupling connect the wind turbine to the Permanent Magnet Synchronous Generator (PMSG). The generated power of continuously varying frequency is fed to local load through suitable power converters, to ensure constant voltage and constant frequency. Since the wind power fluctuates with wind velocity, the generator output voltage and frequency vary continuously. The varying AC voltage is rectified into DC in a diode bridge. The DC voltage is inverted to get the desired AC voltage and frequency employing a PWM inverter. The PWM inverter can be connected directly with a local grid such that it exchanges continuously the power between the DC side and the grid.

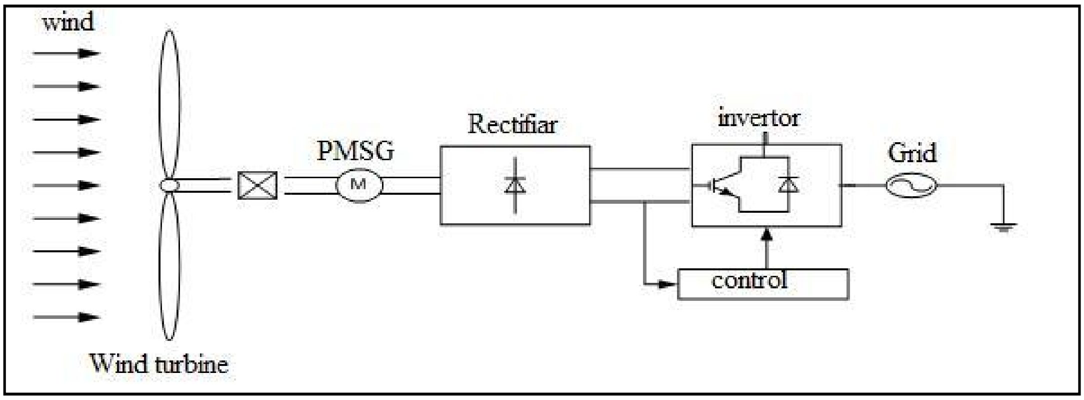


Figure 3.2: Block diagram of Wind Electric Generator system

3.3.2 10kW Grid-Connected Solar PV System

Installation of PV power plants in studied locations is quite convenient, reduces the amount of operations and the maintenance to be carried out, There is no disturbance while operating the power plants. Energy conversion is environment friendly and does not generate any carbon emissions. While manufacturing the solar power plant components some carbon emission is possible. Bearing in mind all the possibilities, 10kW solar PV plant is suggested for these selected locations to reduce the fossil fuels consumption. The grid-connected solar PV plant consists of the following components (Shukla et al., 2016):

- Solar module: The current solar module manufacturing industry develops a variety of solar panel-based solar panels. However, in large scale PVC plant installations, Crystalline solar module is widely used.
- Inverters: inverters are chosen based on the rating of the solar power plant, for a size of 10kW PV plant, one inverter whose rating is 12kW can be used.
- Mountings: include structures on which PV panels, inverters, and other items are placed. Mounting of PV panels is a major one to be considered here, make sure that they are mounted in optimal angles as per the location conditions.
- Grid connection: Sub-station and its components such as transformers, pure measuring systems, protection systems are the most important components for grid connection.
- DC/AC cables: cables are required for connecting panels, inverter and to the grid.

Figure 3.3 shows all the components of the solar PV plant with their respective specification. In the suggested 10kW solar PV plant, if any excess power is generated it can supplied to the grid. If there is any shortage the electricity provided to the grid can be utilized. The phenomenon is generally referred as ‘net metering’.

Figure 3.3: Block diagram showing the components of solar PV plant.

3.3.2.1 PV Plant Layout

There is a need of 65m^2, usually to install 10kW solar PV plant. The solar panel is rated 300W by the Canadian Solar maker. 34 PV panels are used to generate 10kW power. An inverter with capacity of 12kW is used.

3.3.2.2 Tilt Angle

The tilt angle proposed for the solar PV plant is almost very close to the latitude of the location, as it is best for the maximum absorption of the solar radiation. However, Pakistan is almost very close to equatorial regions and experience huge potentials of solar radiations. The tilt angle for this proposed plant is considered as the optimized value from the simulation study carried out in PVGIS software tool.

3.3.2.3 Solar Panel

For these PV plant is crystalline one which is the proposed solar panel used. For this study, Canadian Solar CS6X-300M (300 W) was selected. The solar panel rating is 300 W in each, to achieve voltage and current rating according to the requirement of the inverter; the panels are arranged in the wire.

3.3.2.4 Inverter

The proposed inverters with capacity of 10kW used are manufactured products by tHeiA inverters. The inner rate of the selected THEIA series inverter is 10kWp. The internal operating characteristics (input voltage) of the inverter DC voltage is 450–820 V DC and the output of the proposed inverters voltage is 220 V AC with 50 Hz frequency. The selected inverters performance is greater than 98%.

3.4 Simulation Software

3.4.1 Photovoltaic Geographical Information System (PVGIS) Simulation Tool

In this study, the solar resource potentials at the selected location are taken from the radiation databases available from the PVGIS. During the PV plant modeling in PVGIS simulation tool, solar radiation considered is from the PVGIS-CMSAF (Satellite Application Facility on Climate Monitoring) database.

To simulate using PVGIS, few assumptions and inputs were used. The Latitude and Longitude for the selected regions are given in Table3.1. Figure 3.4 shows the framework of the simulation study using PVGIS carried out on the 45kW solar PV plant. PVGIS allows the user to input the parameters required for RETScreen software such as slope or tilt angle and azimuth angle of the PV module.

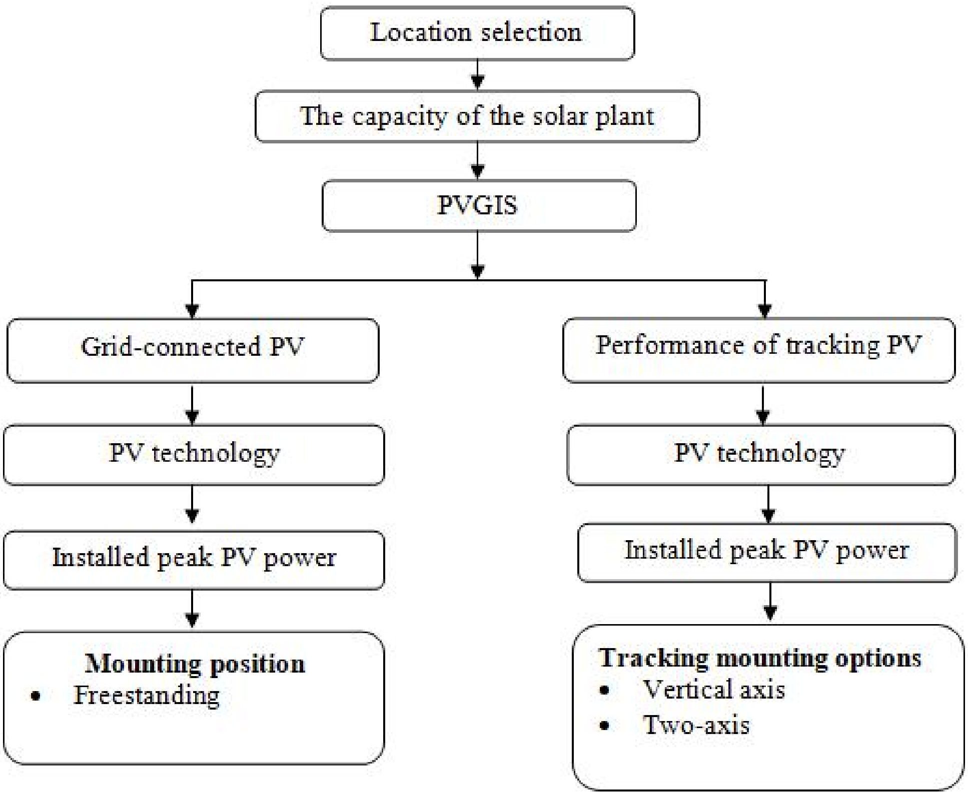


Figure 3.4: The framework of the simulation study using PVGIS

3.4.2 Clean Energy Management Software (RETScreen)

RETScreen is clean energy management software for energy efficiency, renewable energy and cogeneration project feasibility analysis as well as ongoing energy performance analysis.

In order to evaluate the technical, economic, and environmental effect of renewable energy projects, RETScreen software was used in this study. RETScreen software is a useful tool for analyzing and evaluating the feasibility of grid-connected renewable power system (Clean Energy Project Analysis, 2005). In this study, the important economic measures such as net present value (NPV), internal rate ofreturn (IRR), levelized cost of energy (LCOE), payback period (PB), annual life cycle savings(ALCS), and benefit-cost-ratio (B-C) were calculated using RETScreen software.

Net present value (NPV)

The model calculates the Net Present Value (NPV) of the project, which is the value of all future cash flows, discounted at the discount rate, in today's currency. NPV is related to the internal rate of return (IRR). NPV is thus calculated at a time 0 corresponding to the junction of the end of year 0 and the beginning of year 1. Under the NPV method, the present value of all cash inflows is compared against the present value of all cash outflows associated with an investment project. The difference between the present value of these cash flows, called the NPV, determines whether or not the project is generally a financially acceptable investment. Positive NPV values are an indicator of a potentially feasible project. In using the net present value method, it is necessary to choose a rate for discounting cash flows to present value. As a practical matter, organizations put much time and study into the choice of a discount rate. The model calculates the NPV using the cumulative after-tax cash flows. In cases where the user has selected not to conduct a tax analysis, the NPV calculated will be that of the pre-tax cash flows.

$$N \quad = \sum_{n=0}^{N} \frac{C_n}{(1+r)^n} \tag{3.7}$$

Levelized cost of energy (LCOE)

Levelized cost of energy is the ratio of discounted value of the total cost of the project during its lifetime including both capital costs and O&M cost to the electricity generated over the lifetime of the project. It is a robust measure to compare different electricity generation technologies.

$$L \quad = \frac{s\imath \quad o \;\; c \quad o \quad li_j}{s\,o \;\; e \qquad g \qquad o \quad li_j} \tag{3.8}$$

The internal rate of return (IRR)

Is a discount rate at which NPV (net present value) becomes zero.In other words, IRR is the opportunity cost at which the NPV becomes zero.

$$O = \sum_{n=0}^{N} \frac{C_n}{(1 + Il \quad)^n} \; (3.9)$$

Simple payback (SP)

The model calculates the simple payback (year), which represents the length of time that it takes for a proposed facility to recoup its own initial cost, out of the revenue or savings it generates. The basic premise of the simple payback method is that the more quickly the cost of an investment can be recovered, the more desirable is the investment. For example, in the case of the implementation of an energy project, a negative payback period would be an indication that the annual costs incurred are higher than the annual savings generated.

$$S \quad = \frac{C - I(}{(C_e \quad + C_c \quad + C_R \; + C_G \quad) - (C_{O\&M} + C_f \quad)} \; (3.10)$$

Equity payback (EP)

The model calculates the equity payback, which represents the length of time that it takes for the owner of a facility to recoup its own initial investment (equity) out of the project cash flows generated. The equity payback considers project cash flows from its inception as well as the leverage (level of debt) of the project, which makes it a better time indicator of the project merits than the simple payback. The model uses the year number and the cumulative after-tax cash flows in order to calculate this value

$$E \quad = \sum_{n=0}^{N} C_n \; (3.11)$$

Annual life cycle savings (ALCS)

The model calculates the annual life cycle savings which is the levelized nominal yearly savings having exactly the same life and net present value as the project. The annual life cycle savings are calculated using the net present value, the discount rate and the project life.

$$A \quad = \frac{N}{\frac{1}{r}\left(1 - \frac{1}{(1+r)^N}\right)} (3.12)$$

GHG emission reduction cost (GRC)

The GHG reduction cost is calculated by dividing the annual life cycle savings of the project by the net GHG reduction per year, averaged over the project life. For facilities with a net increase in GHG emission, the GHG reduction cost is irrelevant and hence not calculated. In order to calculate the true economic (not financial) cost of GHG reductions, a number of other parameters, such as the GHG credits transaction fee, GHG reduction credit rate, debt ratio, etc. should be set to 0. In addition "Income tax analysis" should not be selected and other taxes should also be set to 0.

$$G \quad = \frac{A}{\Delta_G} (3.13)$$

Benefit-Cost ratio (B-C)

The model calculates the net Benefit-Cost (B-C) ratio, which is the ratio of the net benefits to costs of the project. Net benefits represent the present value of annual revenue and savings less annual costs, while the cost is defined as the project equity.Ratios greater than 1 are indicative of profitable projects. The net benefit-cost ratio, similar to the profitability index, leads to the same conclusion as the net present value indicator.

$$B - C = \frac{N \quad + (1 - f_d)C}{(1 - f_d)C} (3.14)$$

where$N$ is the project life in years, C_n is the after-tax cash flow inyear n, and r is the discount rate, C is the total initial cost of the project, f_d is thedebt ratio, B is the total benefit of the project, $I($ is the incentivesand grants, C_e is the annual energy savings or income, C_c isthe annual capacity savings or income, C_R is the annual renewableenergy (RE) production credit income, C_G is the GHG reductionincome, $C_{O\&M}$ is the yearly operation and maintenance costsincurred by the clean energy project, C_f is the annual cost of fuel, which is zero for renewable projects, and Δ_G is the annual GHGemission reduction.

Relationship between IRR, Discount rate and NPV

- If IRR > Discount rate or opportunity cost of capital tis equal the NPV always positive
- If IRR <discount rate or opportunity cost of capital its equal the NPV is always negative
- If IRR = discount rate or opportunity cost of capital its equal the NPV is zero
    - As long as the NPV is positive, the project financially viable.
    - The moment that NPV become negative , the project is not financially viable

Figure 3.5 and Figure 3.6 shows the framework of the simulation study using RETScreen carried out on 45kW and 40kWrooftop grid connected solar PV plant and wind power turbine, respectively.

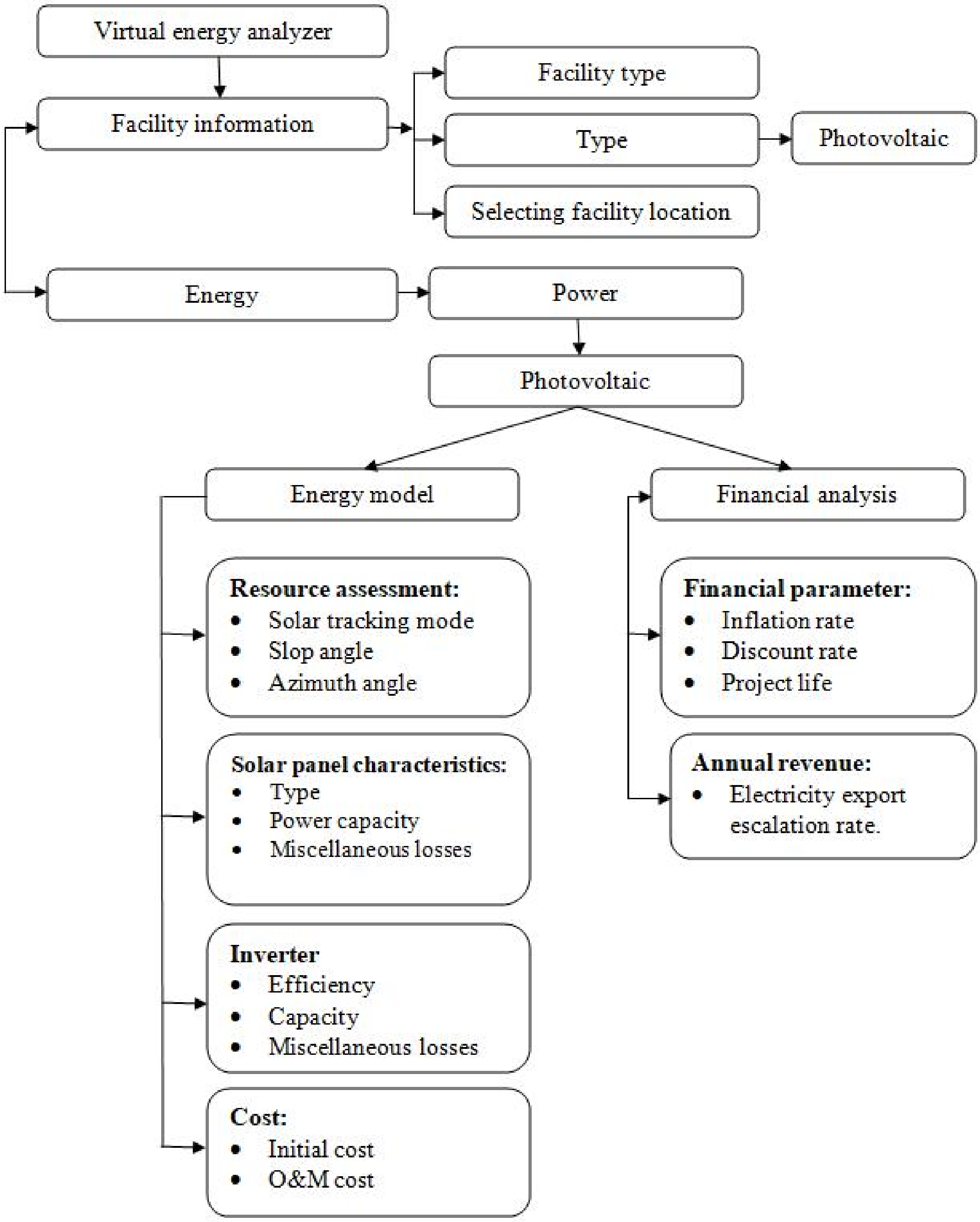


Figure 3.4: The framework of the simulation of 45kW solar PV using RETScreen

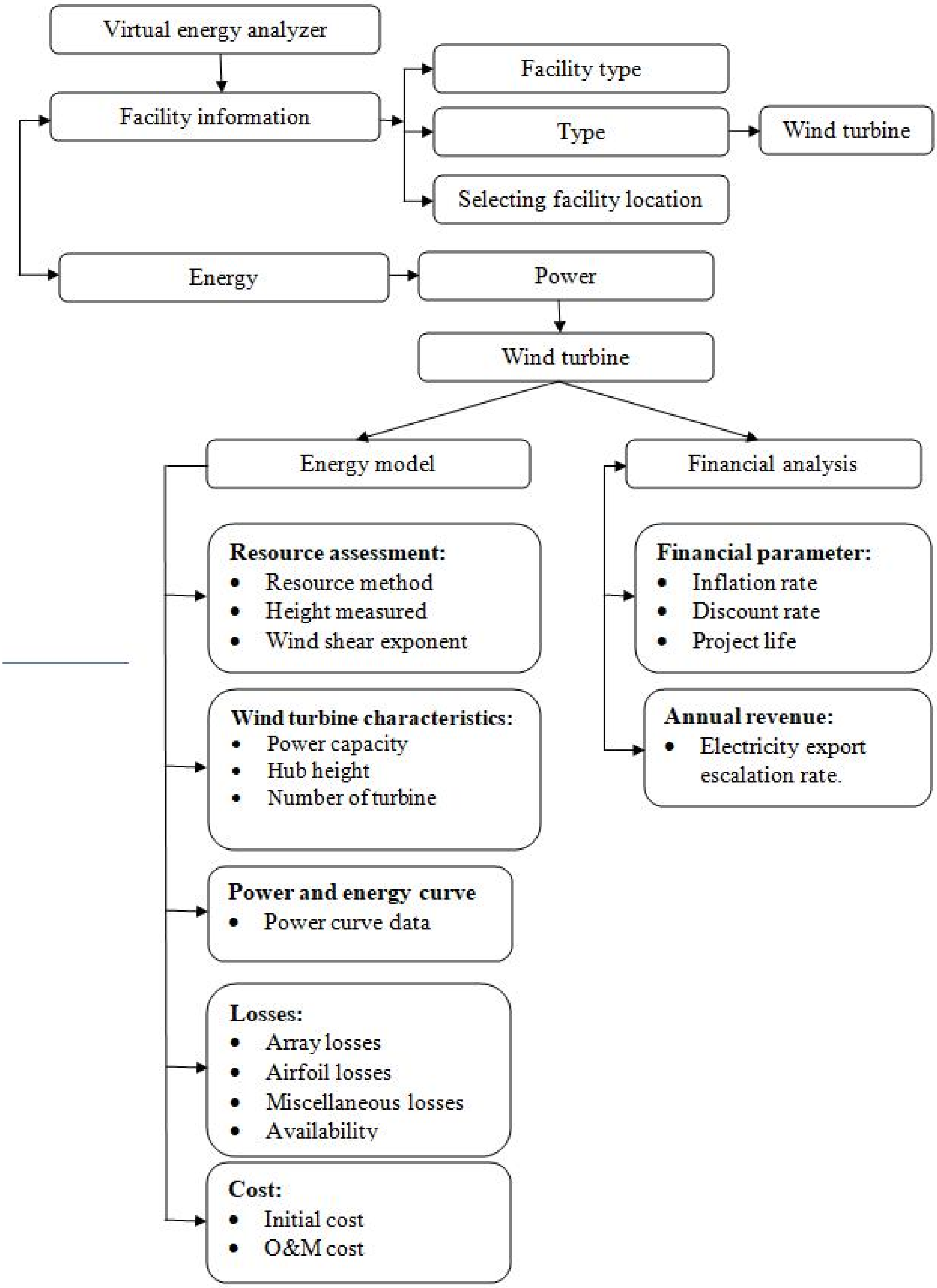


Figure 3.5: The framework of the simulation of 40kW wind system using RETScreen

3.5 Material Data

People usually receive weather information, water sources utilization, and its impact on the environment from conventional media (TV, Radio, and newspapers) and social media. Because of this continuous coverage of information, people are now better-informed and more interested in environmental issues such as water resources and climate change. Many studies have been conducted to gauge the opinions and awareness of people in different countries with respect to water resource; these studies have focused on freshwater resource and environment issues (Schumacher et al., 2019; Kardooni et al., 2018; Moula eta l., 2013; Ozil et al., 2008).

For this study, the survey questions consist of 14 multiple-choice questions, which covered various issues. The questionnaire designed for this study according to the previous scientific researches (Kardooni et al., 2018; Moula eta l., 2013; Ozil et al., 2008). The survey questions are divided into three parts: Part A: Background, Part B: General information about renewable energy and their benefits. Part A of the survey schedule elicits information relating to participants' background variables like participants' age, gender, etc. Part B is concerned about the renewable energy, renewable technology, and the renewable energy benefits. In addition, it is discussed the cost of the renewable energy technologies. The survey equations were collected from respondents aged 22 years and over with higher education qualifications by filling questionnaire data in tables. After that, the quantitative analysis is conducted by summarizing all the data and calculating the percentage of the choices for each question. Briefly, the survey equations were collected from post-graduate students (Master and PhD) and random sampling technique was used for collecting the data. The survey questionnaire is included in Appendix A. The sample was approximately 31% female and 69% male, defined by sampling method. Age ranged from 21 to 42 years old (below 25 years (50%), 25-30 (36%), 31-36 (11%) and 37-42 (1%)). For ethnic group, the questionnaires are collected from all universities located at three populated regions in Northern Cyprus (Lefkoşa, Girne, and Gazimağusa).

CHAPTER 4
RESULTS AND DISCUSSION

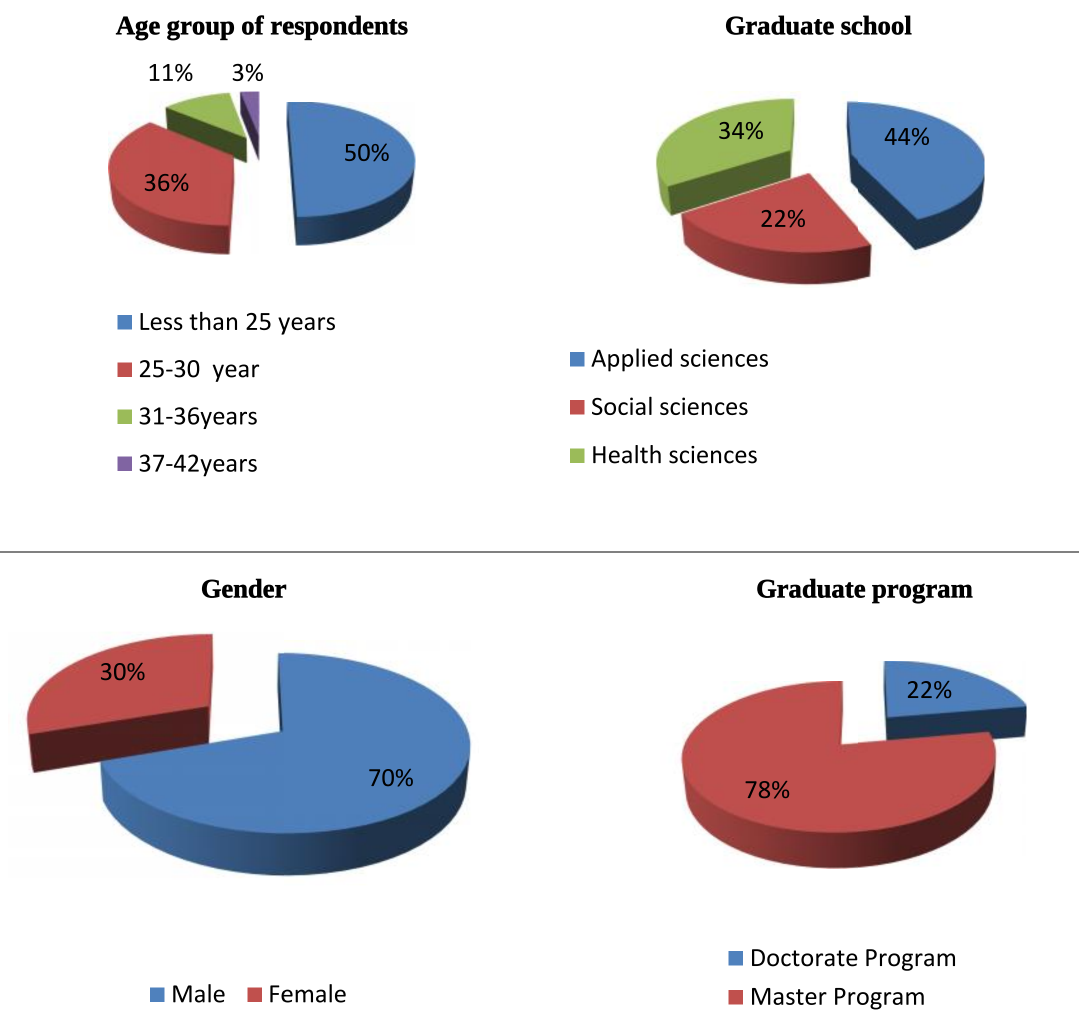
4.1. Postgraduate Students Opinion Analysis

As mentioned before, the survey equations were collected from respondents aged 20 years and over with higher education qualifications by filling questionnaire data in tables. The group age, gender, and level of the participants that have been chosen for this study in order to have an idea about the impact of the age, gender, and faculty of respondents on the results are shown in Table 4.1. It is noticed that most of the respondents come from the graduate school of applied science (44%) followed by a graduate school of health sciences (34%). Moreover, Table 4.1 shows that the data have been collected more from male respondent than female. As there is a higher male with a higher degree in most universities in Northern Cyprus, this might explain some of the differences in experiences and ideas about renewable energy and their technologies.

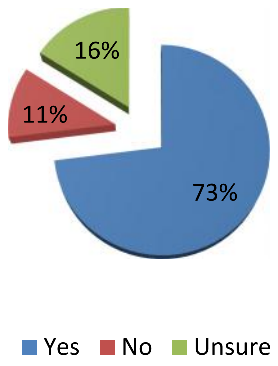
Moreover, the last question in Part A deals with the general question about the difference between renewable and non-renewable energy. As shown in Table 4.1. The majority of answering this question was Yes by 73% while 11% of respondents answered NO. However, 16% of respondents have not idea about renewable and non-renewable energy.

At the beginning of Part B, the students were asked to self-identify their level of knowledge and interest in renewable energy (Figure 4.1). It is found that 32% of the participants are familiar with renewable energy, their technologies, and benefits, while 41% of the participants indicated that they know very little about renewable energy technologies. In addition, only 27% of the participants are environmentally conscious and familiar with renewable energy, their technologies, and benefits. On the other hand, it can be seen that percentages of “very little” female and the students from the graduate school of health sciences was closed to each other, which about 23%. This result shows that more effort is required to widen the information base about renewable energy, their technologies, and benefits amongst female students and the students who are from the graduate school of health science.

Table 4.1: Results of survey questions of Part A



Difference between renewable and non-renewable energy



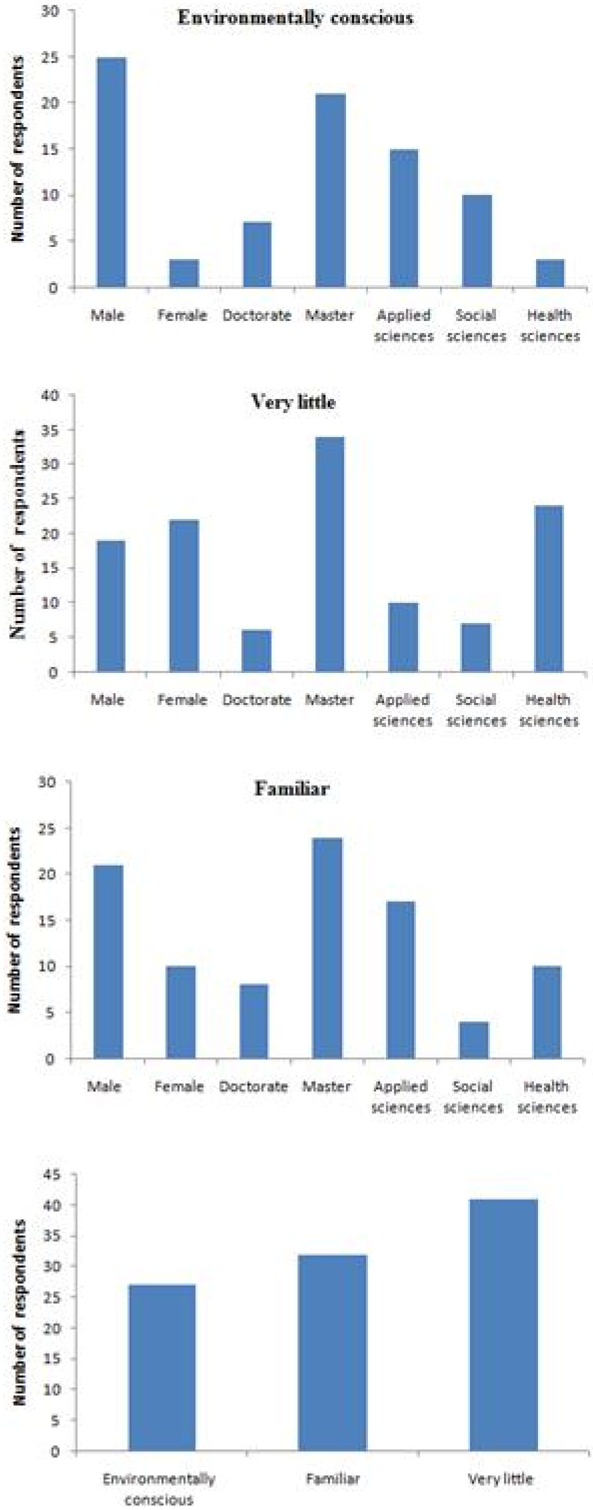
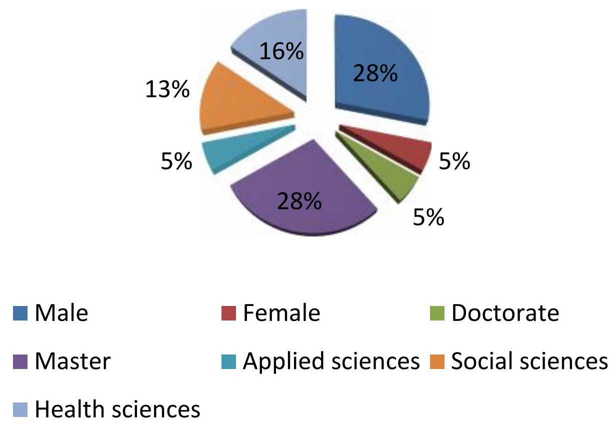


Figure 4.1: Level of interest in renewable energy

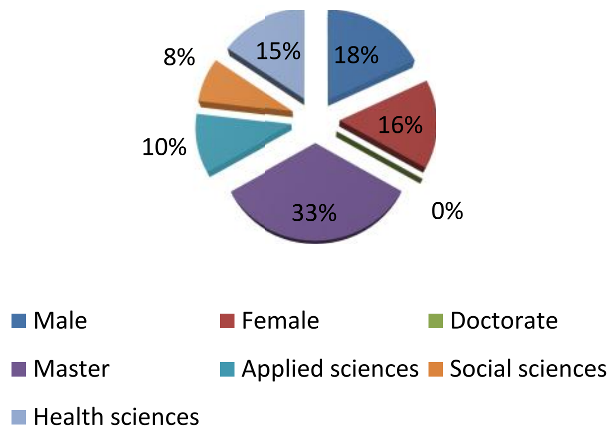
The second question in Part B deals with the level of concerning about renewable energy sources as shown in Table 4.2. The sum of responses in the “Neither concerned nor very concerned” and “Concerned” categories are close to each other about the renewable energy sources in Northern Cyprus, represent about 60% of the respondents. Significantly, Male students especially who are from the graduate school of applied or social science are more concerned about renewable energy sources and technologies and their benefits, probably because They know that Northern Cyprus has very high energy costs, both in urban centers and rural areas.

Table 4.2: Results of the second question in Part B

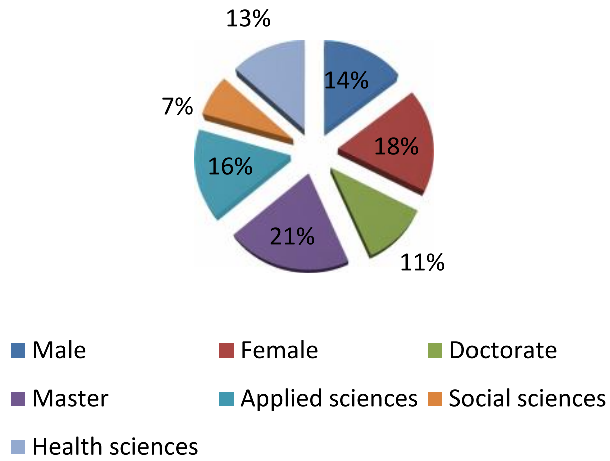
Very unconcerned



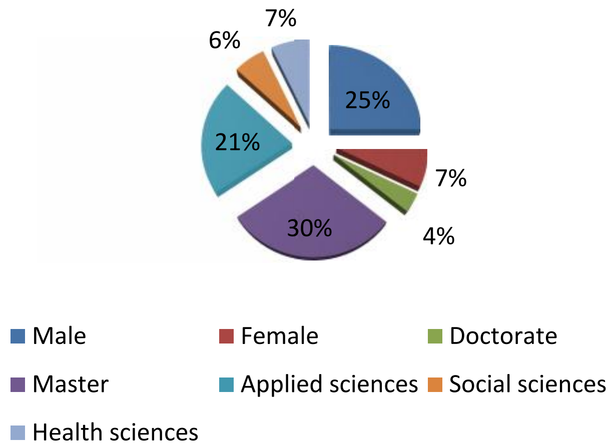
Less unconcerned

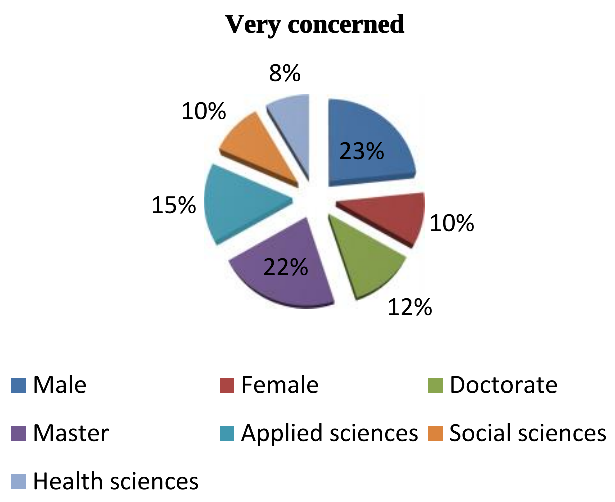


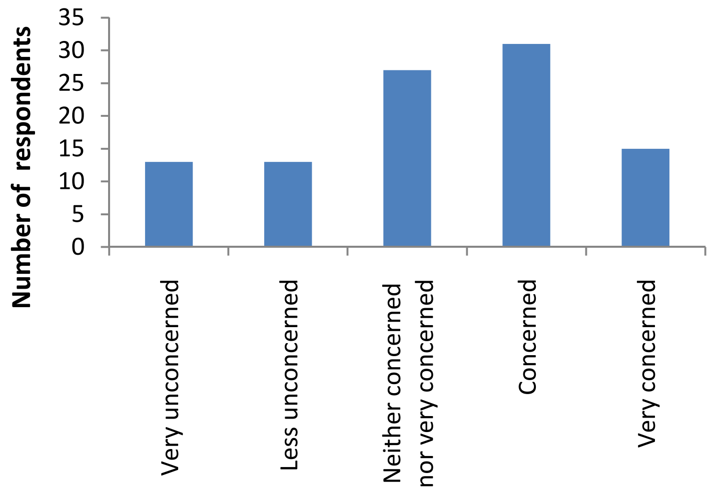
Neither concerned nor very concerned



Concerned







The third question in Part B (Figure 4.2) is focused on the disadvantage of renewable energy over tradition gas or electric energy. 27% of respondents were considered no disadvantage of using renewable energy and the insulation cost for this energy is high, while 10% of respondents do not have an idea about renewable energy technologies and how it works. Thus, it can be concluded that people have awarded about renewable energy, technologies, their benefits, and influence on the environment, human activities and health.

The fourth question tests the respondents' knowledge about the different kinds of renewable sources and technologies that can be used in Northern Cyprus. As it can be noted the question itself provided them with four different options, namely wind energy, solar energy, biomass, and biofuel. As shown in Figure 4.3, 58% of respondent were selected solar energy as a source for generating electricity in Northern Cyprus. However, 26% and 16% of respondent have chosen wind energy and other energies, respectively. This question was more of an informative type, which educated at least 70% of the people about the existing technologies while testing their knowledge. Notably, it was not very properly formulated to be able to extract awareness of particular renewable technology among participants.

In identifying the benefits of energy produced from renewable energy sources, the three groups of students performed similarly, as seen in Figure 4.4. It is curious that a higher percentage of graduate students agreed that renewable energy sources good for the environment (24%), reduce reliance on imported fuels (16%), reduce the energy bill (19%) and good for the economy (18%).

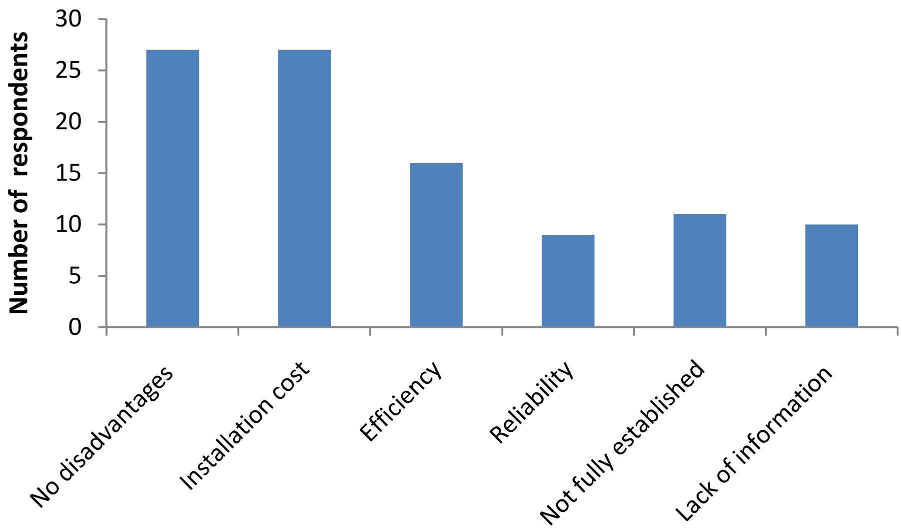


Figure 4.2: The disadvantage of using renewable energy over tradition gas or electricity energy

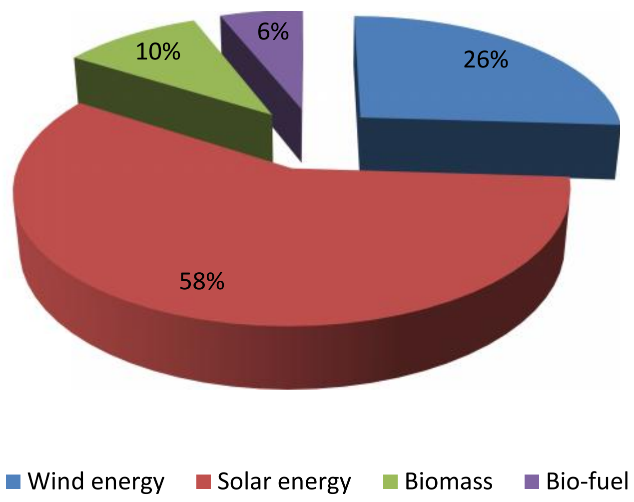


Figure 4.3: Type of renewable energy that can be used in Northern Cyprus

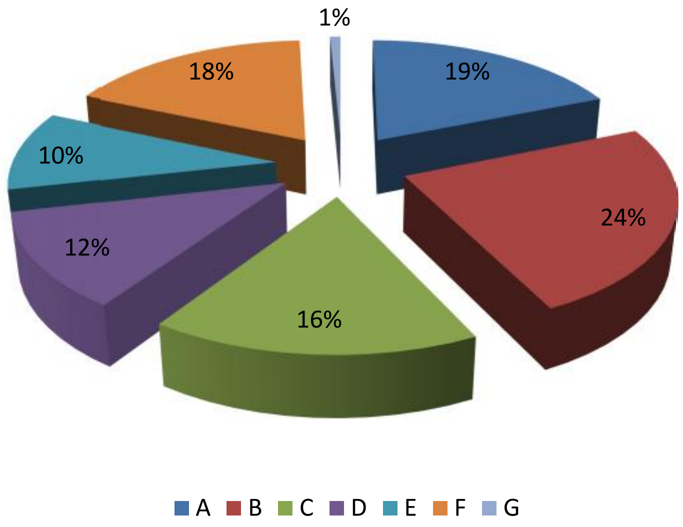


Figure 4.4: Benefits of generating electricity from renewable energy sources; A: Lower energy bills, B: Good for the environment, C: Less reliance onimported oil and natural gas, D: Less reliance on electric utility companies, E: There will not be a need for investment in nuclear power plants, F: Good for the economy, G: There will not be any benefit.

The fifth question is more focused on the difficulties of purchasing a renewable energy system at universities or cities in Northern Cyprus. Figure 4.5shows the factors that have an impact on the purchasing a renewable energy system at the region. It can be seen that respondents identified the choosing the correct technology, obtaining the correct and reliable information about renewable energy system have a significantly positive impact on the purchasing a renewable energy system at a specific region. This is because of respondents who are aware of the benefits of having a renewable energy system in the region.

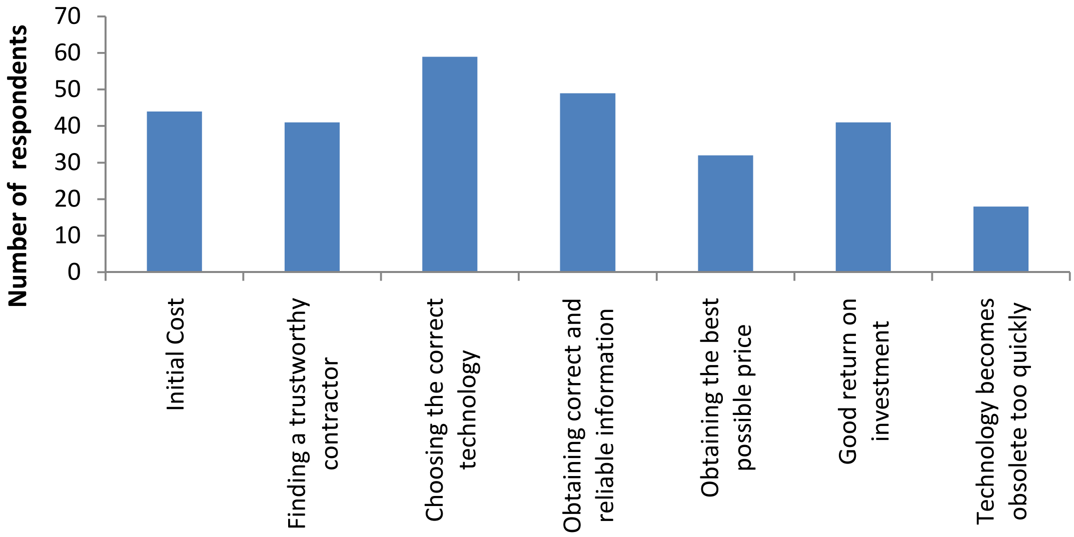


Figure 4.5: Purchasing a renewable energy system for universities or cities in Northern Cyprus

It can notice the difference of opinion where 65% of respondents suggest that solar/wind power plants are the best option for generating electricity in Northern Cyprus as shown in Figure 4.6. According to study results, respondents do care about the solar/wind energy system for producing electricity at any regions in Northern Cyprus since the results are exactly same as in the fourth question in Part B where only the suitable energy was asked without considering the generating electricity in Future.

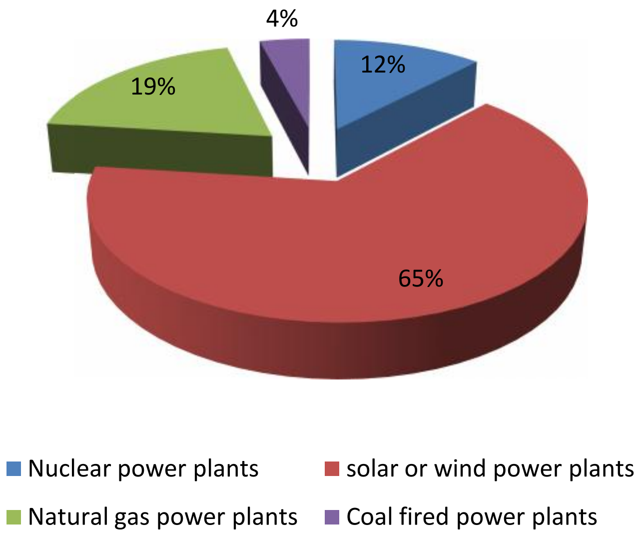


Figure 4.6: Future energy needs for the universities and cities

4.2. Wind Characteristics and Wind Energy Potential

4.2.1 Wind Speed Characteristics

Variations of the monthly mean wind speeds at each station for the years from 2010 to 2016 are illustrated in Figure 4.7. Moreover, the figure also shows the overall monthly mean wind speeds for the entire measurement period. The average monthly wind speeds at Gazimağusa vary from 3.7 m/s to 7.2 m/s and the general trend is that the mean wind speed decreases from March to August and then starts to increase afterwards for the rest of the year. In the graph plotted for Lefkoşa, the lowest wind speeds are around 1.5 m/s during November and highest values appear in June as 3.5 m/s. The average values for Girne illustrate that the minimum and maximum average wind speeds vary between approximately 1.5 m/s and 3.4 m/s for region.

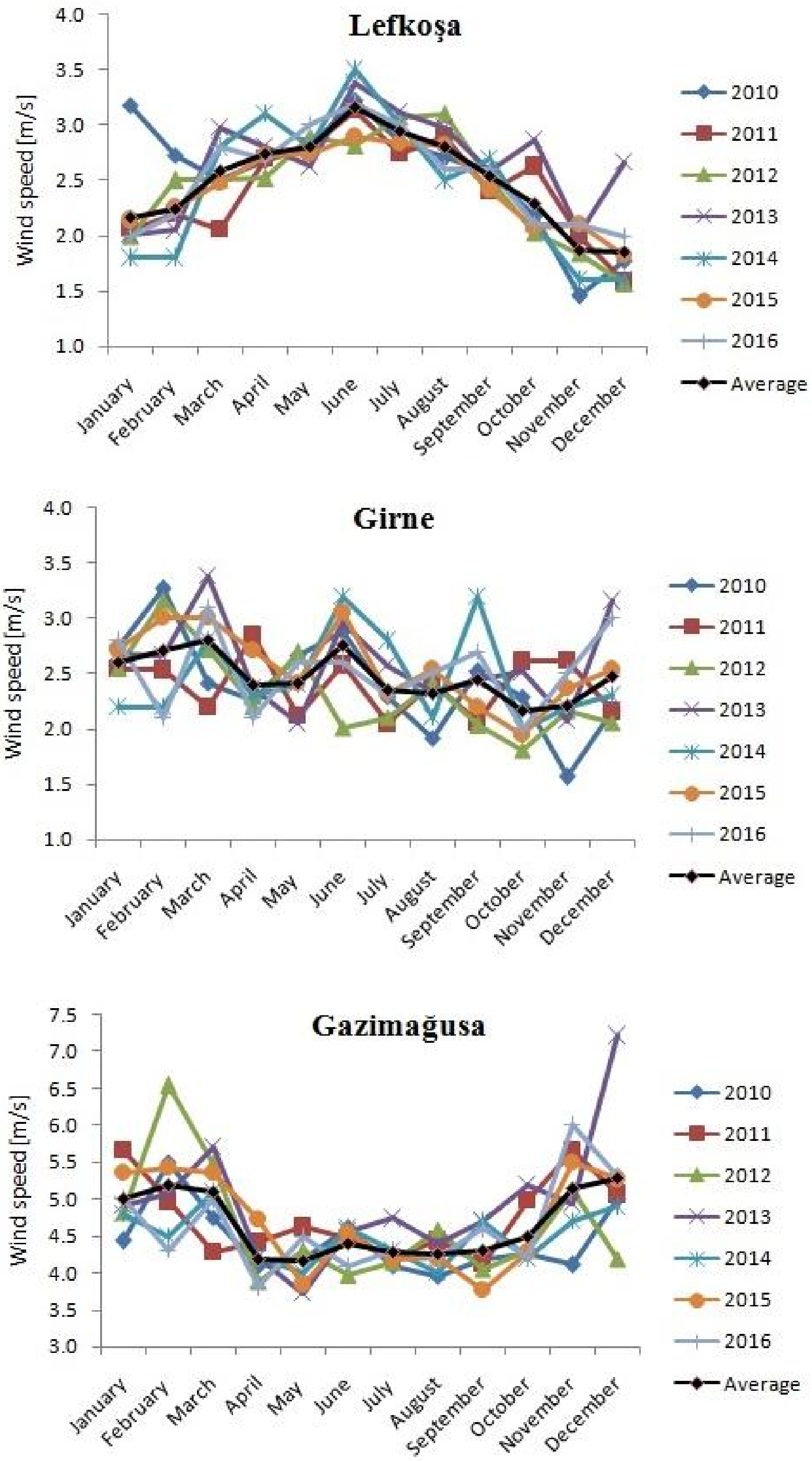


Figure 4.7: Monthly variation of the mean wind speed

The hourly variations of the mean wind speeds for each year from 2010 to 2016 have been presented in Figure 4.8. Furthermore, the overall average hourly wind speed variation for the entire measurement period from 2010 to 2016 has also been illustrated.

It is evident from the charts in Figure 4.8that similar patterns within the 24-h period are observed. The hourly average wind speeds slowly decrease early in the mornings and then start to increase until they reach a peak. After the highest values of the period, wind speeds are observed to decrease in Lefkoşa and Girne, except at Gazimağusa.

The average wind speed at the Gazimağusa region decreases from 1 a.m to 8 a.m and shows a sharp increase afterward, where it reaches its maximum value at around 1 p.m. The wind speeds decrease after 1 p.m in Famagusta until 8 p.m and the mean values show a marginal increase through the night. Overall, it can be determined from the data in Figure 4.8, that the coastal areas record maximum average wind speeds late in the afternoon and the minimum value occurs between 4 and 6 a.m. In contrast, the maximum wind speeds were observed at 2 p.m and the minimum speeds were between 3 a.m and 4 a.m. in Lefkoşa, which is the capital city of the country with the highest building density.

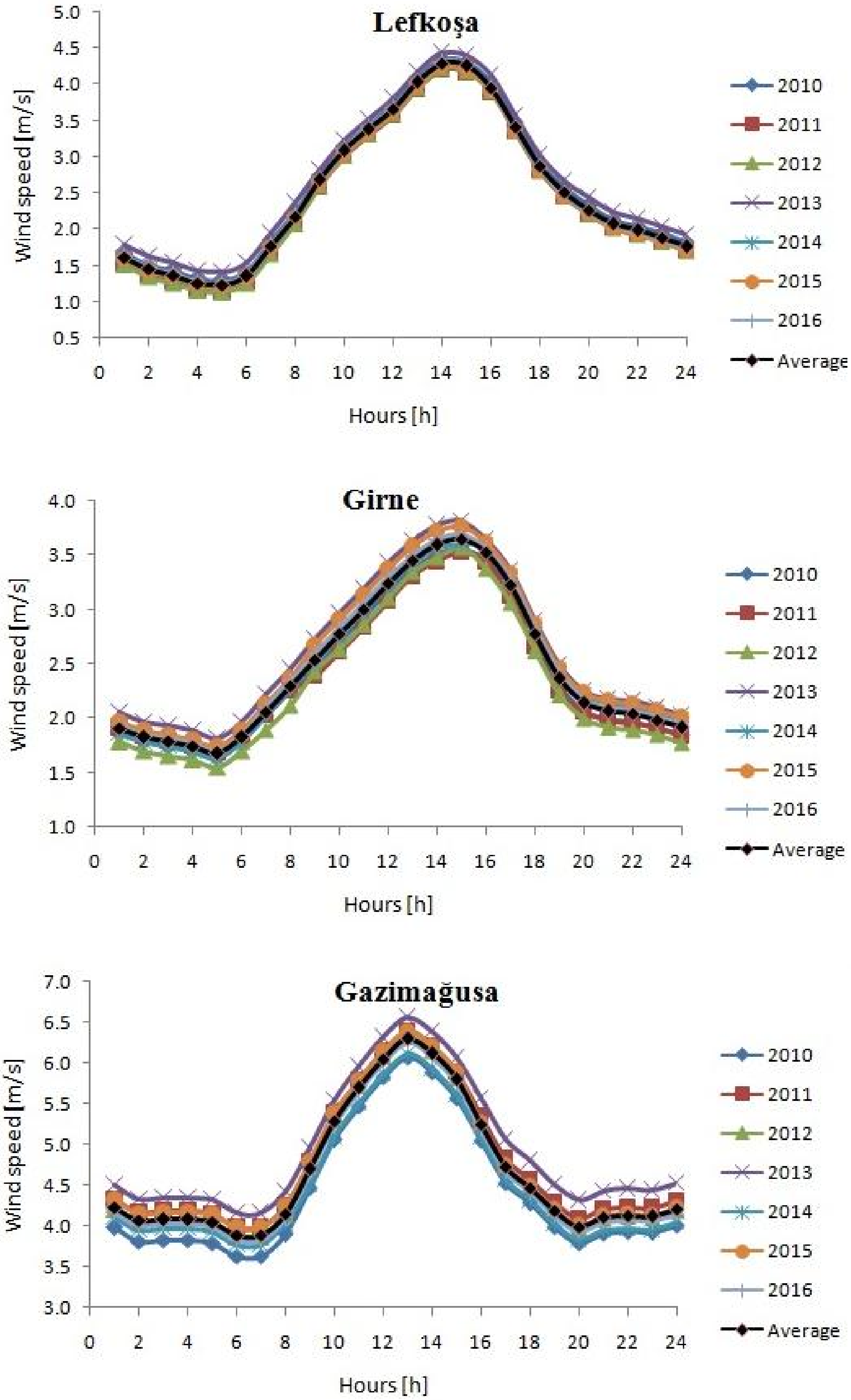


Figure 4.8: Hourly variation of the mean wind speed

4.2.2 Wind Speed Frequency Distribution at 10m Height

Table 4.3 illustrates the shape (k) and scale (c) values evaluated at each location for the entire wind data obtained for the six-year period between 2010 and 2016. Additionally, Figure 4.9 presents the yearly variations of the shape and scale parameters for the 7-year period in six different locations. It can be noted that the calculated yearly k parameter does not show significant differences throughout the years for all measurement locations. However, the c parameter shows profound changes during the measurement period. Moreover, the annual wind speed frequency distribution data from each region are presented in Figure 4.10 for the years from 2010 to 2016.

Table 4.3: Weibull parameters for each region (2010-2016) at a height of 10m

Region	Parameters		**Mean [m/s]**	**WPD [W/m^2]**	**Kolmogorov-Smirnov test**
	k	**c [m/s]**			
Lefkoşa	2.80	2.88	2.56	15.05	0.851
Girne	4.12	2.76	2.50	11.72	0.395
Gazimağusa	5.93	5.02	4.65	68.49	0.059

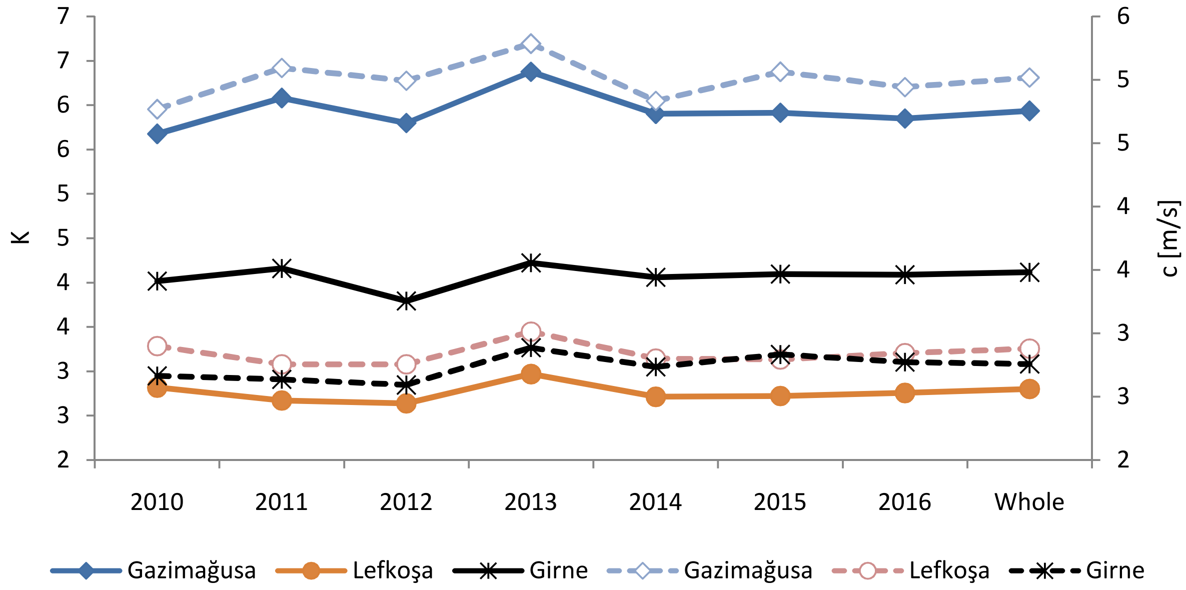


Figure 4.9: Yearly variation of shape and scale parameters for the areas at 10m Height

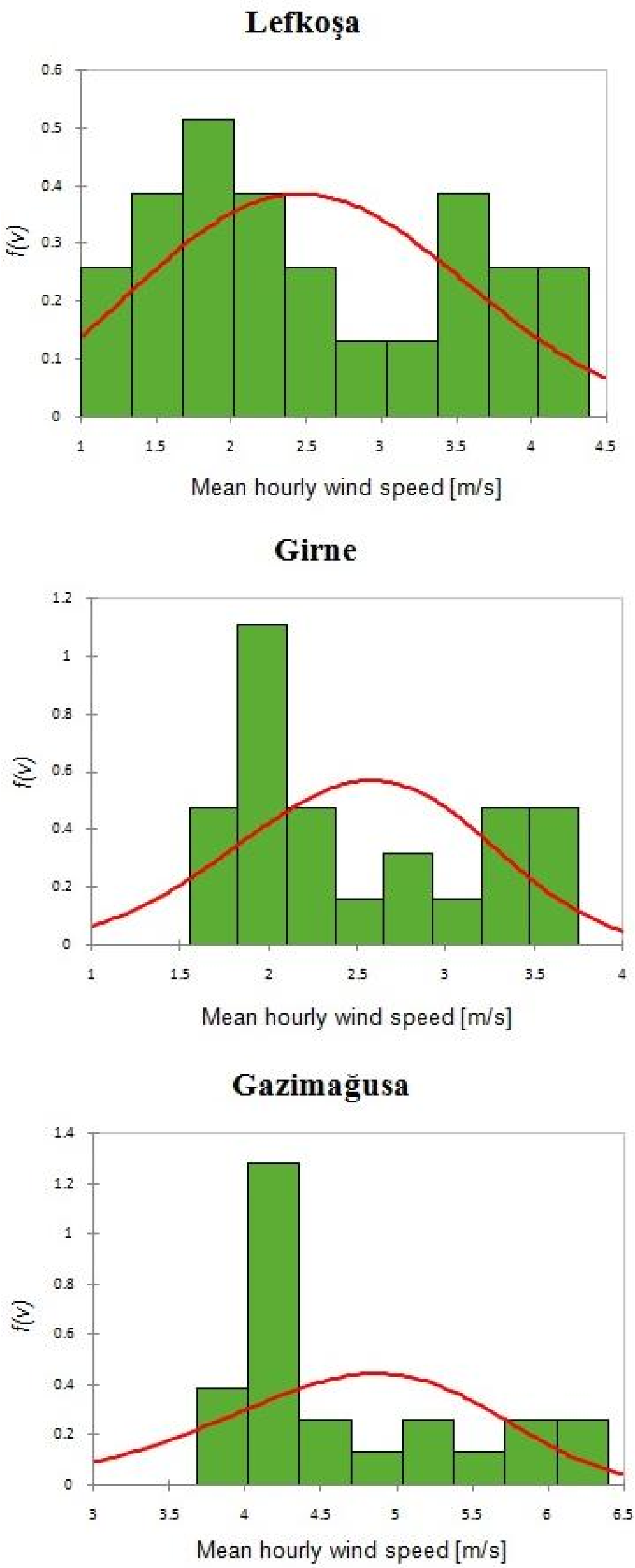


Figure 4.10: Wind speed probability frequency for the whole (2010-2016) at height 10m

4.2.3 Wind Speed and Wind Power Density at Various Heights

The optimum wind speed for a typical wind turbine should be equal to or higher than 6.7 m/s. At the same time, it is important to note that wind speeds higher than 11 m/s can be dangerous; therefore, it is not safe to invest in wind turbine in the regions that have a wind speed of more than 11 m/s wind speed during the year [40]. The roughness coefficient is expressed by the exponent α, which is associated with the characteristics of the land surface and its value varies between 0.05 and 0.5 [40]. The surface roughness values (α), determined by using Eq. (9) for different locations, is given in Table 4.4.

Table 4.4: Roughness values for different sites

Locations	Roughness value (α)
Gazimağusa	0.235
Lefkoşa	0.289
Girne	0.290

In this paper, annual mean wind speeds are estimated for different heights of 30, 50, 80, and 90m by using the roughness coefficients listed in Table 5. Wind speed increases as one moves higher above the ground and this variation is called the wind shear profile. Figure 13 presents the wind shear profiles at three different regions that are included in this study.

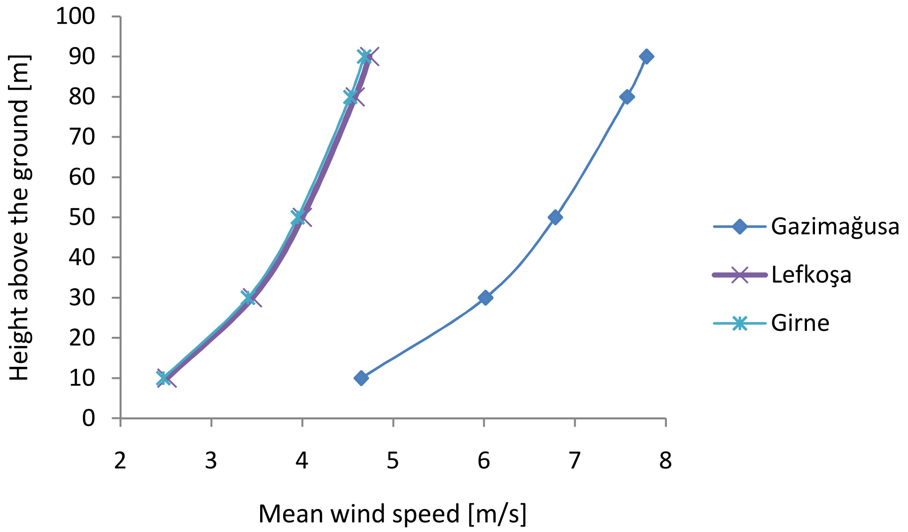


Figure 4.11: Vertical wind shear profile at six studied locations

For comparison purposes, the calculated annual WPD at various heights are presented in Table 4.5. The kinetic energy potential of the wind at each site is characterised by the mean power density ranges given in the literature [41]. Among the sites investigated in this study, the maximum estimated power density became prominent in the Gazimağusa region, where the highest density is 288.96 W/m^2 at a height of 90m (Table 4.5). According to the results of the current study and the mean power density ranges found in the literature, all of the locations chosen for investigation indicate poor wind energy potential. Therefore, high capacity wind turbines (MWs) are not feasible to be investigated in these areas. Nevertheless, small-scale wind turbines can be used to gather the wind energy potential in these regions.

Table 4.5: Annual wind power density at various heights

Height [m]	Region	Variable		
		Mean [m/s]	WPD [W/m^2]	Wind power class
30	**Gazimağusa**	6.02	133.50	poor
	Lefkoşa	3.45	25.20	
	Girne	3.40	24.17	
50	**Gazimağusa**	6.78	191.30	
	Lefkoşa	4.00	39.23	
	Girne	3.95	37.72	
80	**Gazimağusa**	7.58	266.37	
	Lefkoşa	4.58	58.95	
	Girne	4.53	56.79	
90	**Gazimağusa**	7.79	288.96	
	Lefkoşa	4.76	97.62	
	Girne	4.69	77.32	

4.2.4 Economic Analysis of Wind Potential

In the wind turbine industry, the wind turbine is classified into two categories, which are horizontal and vertical axis wind turbines (Paraschivoiu, 2009). Horizontal axis wind turbine is the most common turbine used today (Wang et al., 2017).

In this work, the capacity factor and generated electricity of different types wind turbine systems that could be placed over the roof of a reference building with different heights are studied. Based on the previous section, an Aircon10 (Horizontal axis wind turbine-10 kW) and Sunfurfs WT3 (Vertical axis wind turbine-30kW) were chosen, because start-up wind speed of these turbines are 2.5m/s and 1.8m/s, respectively and they are suitable for power generation in the low wind speed regions. The specification of the selected wind turbines is tabulated in Table 4.6. Furthermore, Table 4.7presents various assumptions that are used to examine the economics of wind energy system at three selected regions.

Table 4.6: Characteristics of the selected wind turbine

Technical data	Aircon10	Sunfurfs WT3
Rated output capacity [kW]	9.8≈10	10
Start-up wind speed [m/s]	-	1.8
Cut-in wind speed	2.5	Wind speed≥2.9m/s should continue to at least 30 minutes
Rated wind speed [m/s]	11	8
Cut-out wind speed [m/s]	32	-
Height [m]	12	12
Rotor diameter [m]		9
Cost [$]	22050*	29800

* The cost of wind turbine based on the rated power of the turbine (Gökçek&Genç, 2009)

Table 4.7: Values and assumptions for the economics of wind energy

Particular	Value
wind turbine capacity [kW]	10
Turbine hub height [m]	12
A lifetime of the project [year]	20
Inflation rate [%]	3
Discount rate [%]	12
Electricity export escalation rate [%]	5/15*
The initial cost of wind turbine [$/kW]	See Table 6
Wind Turbine Cost Share [%]	70
Grid connection Cost Share [%]	12
Civil work Cost Share [%]	9
Other Capital Cost Share [%]	8
O & M cost [%]	0

In order to a feasibility study for a wind rooftop system at Lefkoşa and Girne, electricity export escalation rate is assumed 15 %.

Table 4.8 presents the results of the capacity factor (CF) and annual generated electricity (GE) of the 10kW wind systems for all studied regions. It is observed that the values of CF of wind systems at Gazimağusa is the highest compared to other regions and are ranged from 20.5% to 31.6%, which deepens on the heights. The reason of these substantial increases is that cut-in wind speed, wind turbine start to rotate and generate power at wind speed is equal to cut-in speed, maximize the generation time, which leads to increase the capacity factor of the system. Additionally, it is noticed that the CF values at Lefkoşa and Girne are very low, which can be considered the wind rooftop systems at these two cities are not suitable for generating electricity.

Moreover, the cost of unit energy per kWh based on the PVC method for wind turbine systems at studied locations is presented in Table 4.8. It is noticed that the horizontal wind turbine has lower values of electricity cost compared to vertical axis wind turbine for all studied regions. In addition, it is observed that Gazimağusa has the lowest values of electricity cost compared to other regions. Furthermore, the wind system of Gazimağusa is a more economical option for generating electricity because of higher values of capacity factor as well as lower values of UCE values.

Table 4.8: Capacity factor and Generated electricity of wind turbine system

Region	Building floors	Height [m]	Aircon10			Sunfurfs WT3		
			CF [%]	GE [kWh/year]	E [$/kW]	CF [%]	GE [kWh/year]	E [$/kW]
Lefkoşa	3	22	6.4	5525	0.364	9.3	7495	0.411
	4	25	7.1	6069	0.332	10.1	8678	0.378
	5	28	8.9	7657	0.318	12.7	10924	0.331
	6	31	10	8734	0.278	14.5	12463	0.302
Girne	3	22	6.4	5499	0.368	10.2	8922	0.442
	4	25	7.1	6070	0.338	11.1	9723	0.401
	5	28	9.6	8226	0.249	15.1	13192	0.296
	6	31	10.1	8668	0.223	17.2	14755	0.261
Gazimağusa	3	22	20.5	17626	0.138	27.3	23459	0.141
	4	25	22	18862	0.129	28.9	24800	0.133
	5	28	23.3	19993	0.122	30.12	25120	0.127
	6	31	24.5	21033	0.116	31.6	27120	0.121

3.3. Solar Radiation Characteristics and Solar Energy Potential

3.3.1 Global Solar Radiation Characteristics

Figure 4.12shows the mean monthly global solar radiation and sunshine duration variations throughout the years at Girne and Lefkoşa. In addition, the mean monthly global solar radiation variations for all years at three selected regions in Northern Cyprus is shown in Figure 4.12. It is observed from Figure 11 that the monthly average solar radiation values range from 228.584 to 676.789 Cla/cm^2-day for Lefkoşa, 178.930 to 630.224 Cla/cm^2-day for Girne and 205.718 to 672.183 Cla/cm^2-day Gazimağusa. During the period of measurement, the highest mean monthly global solar radiation occurred in summer (June, July, and August) at all selected cities, while the minimum occurred in winter (December, January, and February).

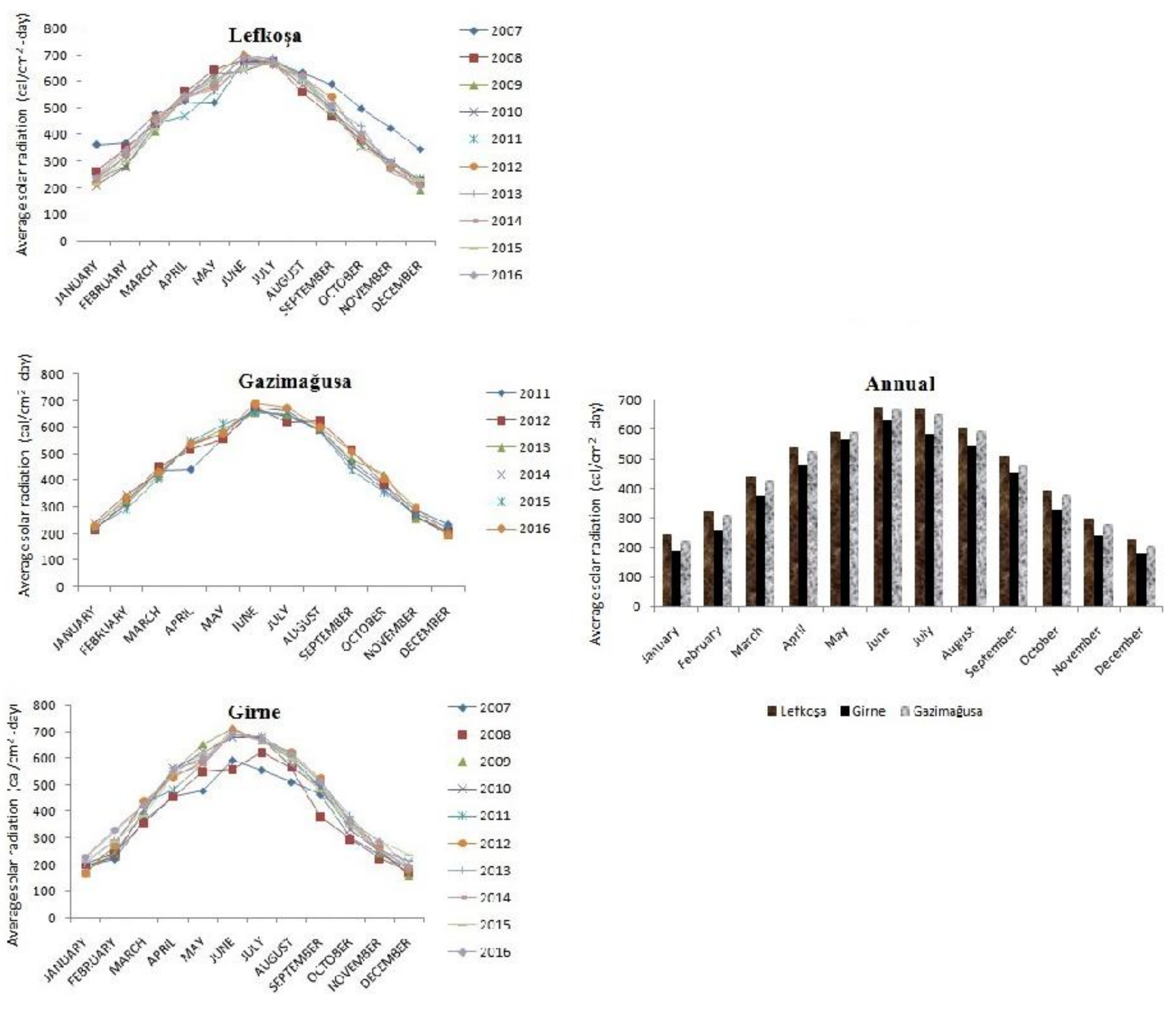


Figure 4.12: Average global solar radiation during the investigated period

Based on Figure 4.13, it is observed that Lefkoşa has a higher annual global solar radiation followed by Gazimağusa. The mean monthly sunshine duration varies from 5.263 to 11.429 h/day for Lefkoşa, 4.158 to 11.599 h/day for Girne and 4.475-11.168 h/day Gazimağusa as shown in Figure 4.13. Additionally, it is found that the mean monthly sunshine duration for all cities is approximately 8h/day. Moreover, it can be seen that the annual sunshine duration for the studied regions ranged between 7.914 h/day and 11. h/day for all regions (Figure 4.13).

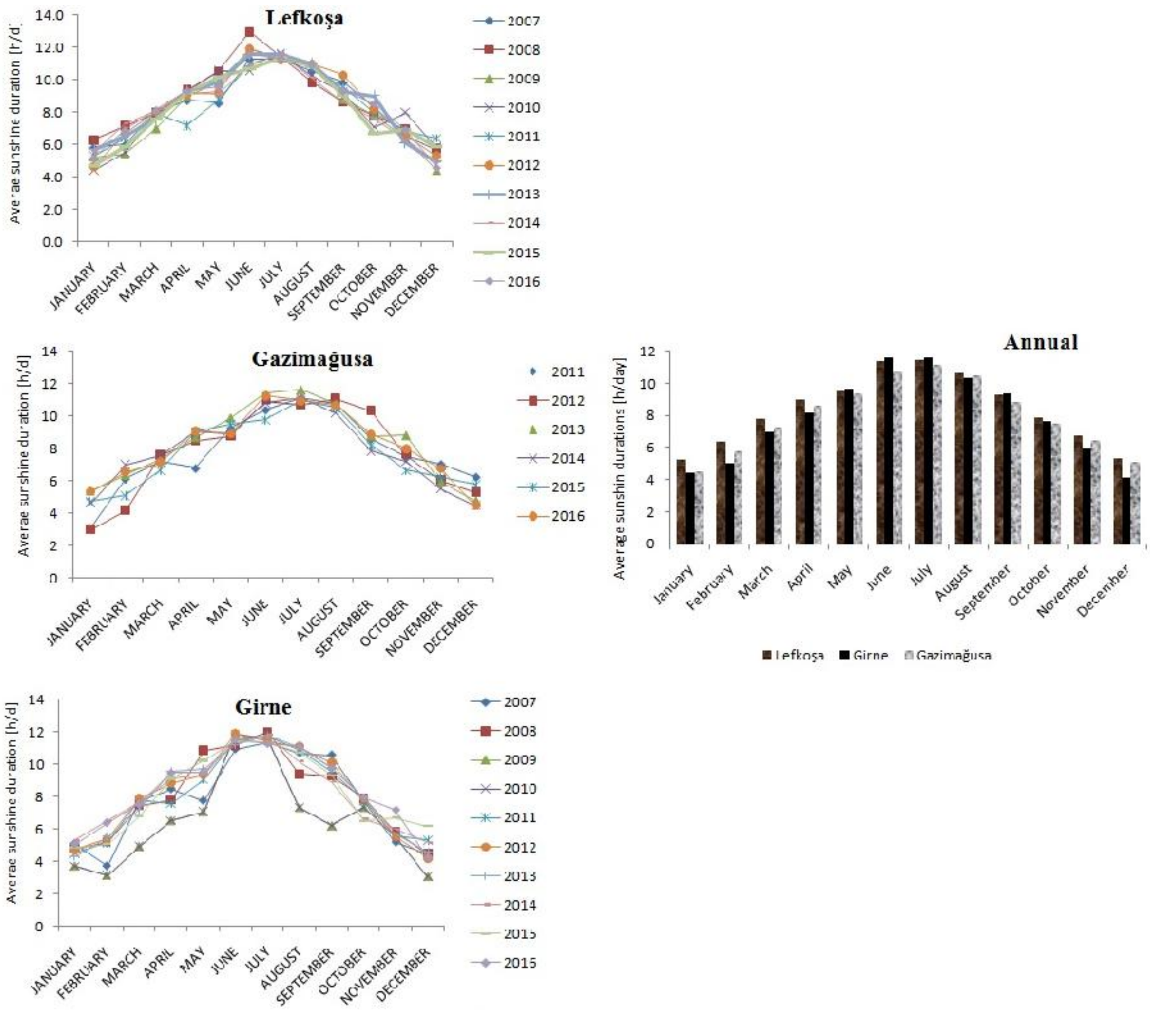


Figure 4.13: Average sunshine duration during the investigated period

4.3.2 Global Solar Radiation Distributions

The scientific researchers were investigated the use of probability density function in modeling monthly average global solar radiation. For instant, Kassem et al. (2018) foundthat Logistic distribution function was the best distribution for analyzing the global solar radiation of Girne and Lefkoşa. More recent, AyodeleandOgunjuyigbe(2015) proposed a probability distribution of clearness index for predicting the global solar. They found that logistic distribution provided the best fit for clearness index and the proposed method is effective in predicting the monthly average global solar radiation. Logistic distribution has the shape of normal distribution but with a heavier tail i.e. higher kurtosis. The $f(G)$and the $F(G)$ of this distribution can be expressed as Eq.s (23) and (24) respectively.

$$f(G) = \frac{e \quad \left(\frac{G-L}{s}\right)}{s\left(1 + e. \quad \left(-\frac{G-L}{s}\right)\right)^2} - \infty < G < \infty (4.1)$$

$$F(G) = \frac{1}{1 + e. \quad \left(-\frac{G-L}{s}\right)} - \infty < G < \infty (4.2)$$

where L and S are location parameter and the scale parameter, respectively.

Therefore, logistic distribution function was used to analysis the global solar radiation data of three selected regions. The $f(G)$ curves of global solar radiation for various periods are shown in Figure4.14.

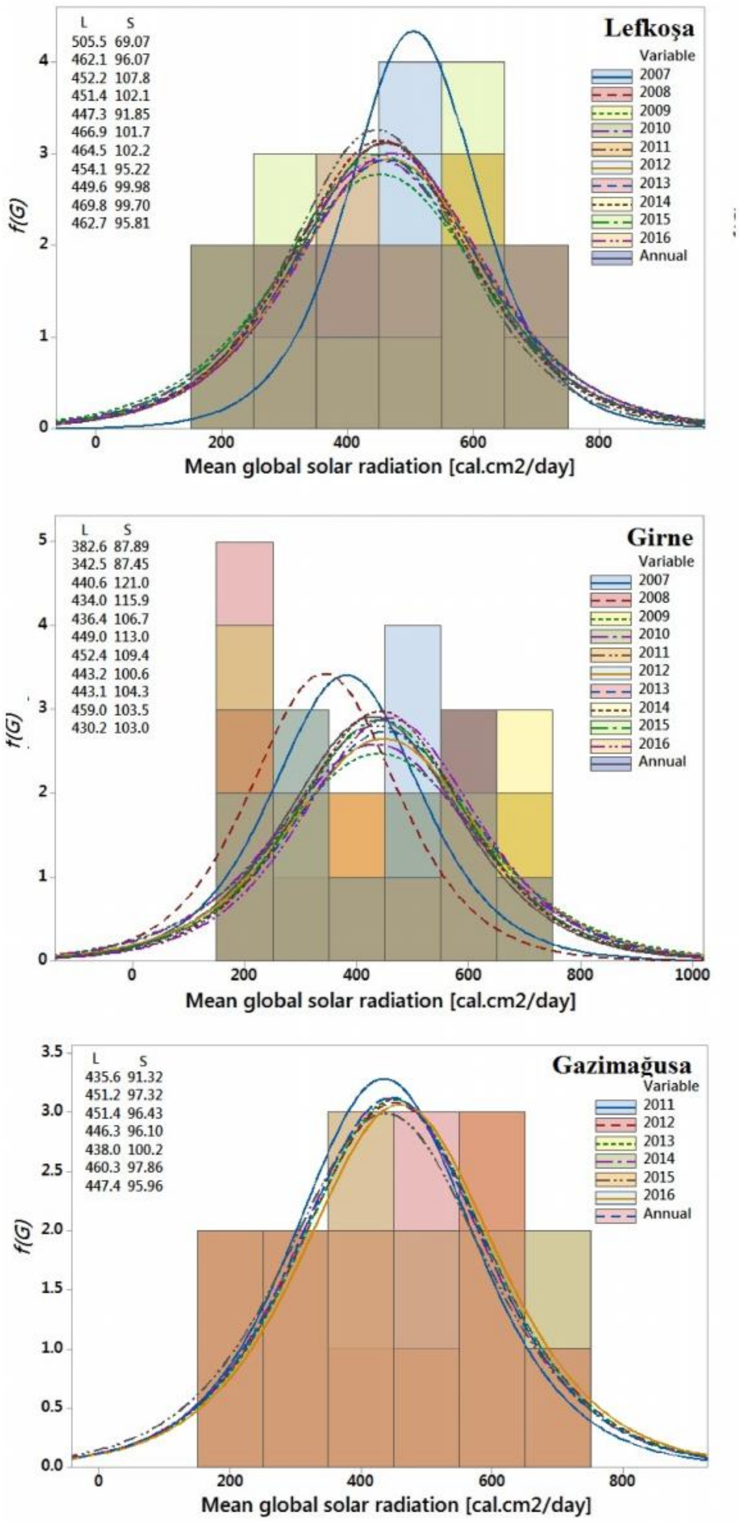


Figure 4.14: Fitting *f(G)* to the global solar radiation data of studied regions

4.3.3 Solar Resource Potential At Three Selected Regions in Northern Cyprus Using PVGIS Tool

In this study, the solar resource potentials at the selected location are taken from the radiation databases available from the PVGIS. During the PV plant modeling in PVGIS simulation tool, solar radiation considered is from the PVGIS-CMSAF database.

To simulate using PVGIS, few assumptions and inputs were used. Figure 4.16 shows the framework of the simulation study using PVGIS carried out on the 45kW solar PV plant. Table 4.8 is summarized the input and output results of PVGIS software. PVGIS allows the user to input the parameters required for RETScreen software such as slope or tilt angle and azimuth angle of the PV module. As shown in Table 4.8, the use of the two-axis-tracking system has maximum annual solar irradiation and energy production compared to fixed tilt and 1-axis-tracking systems.

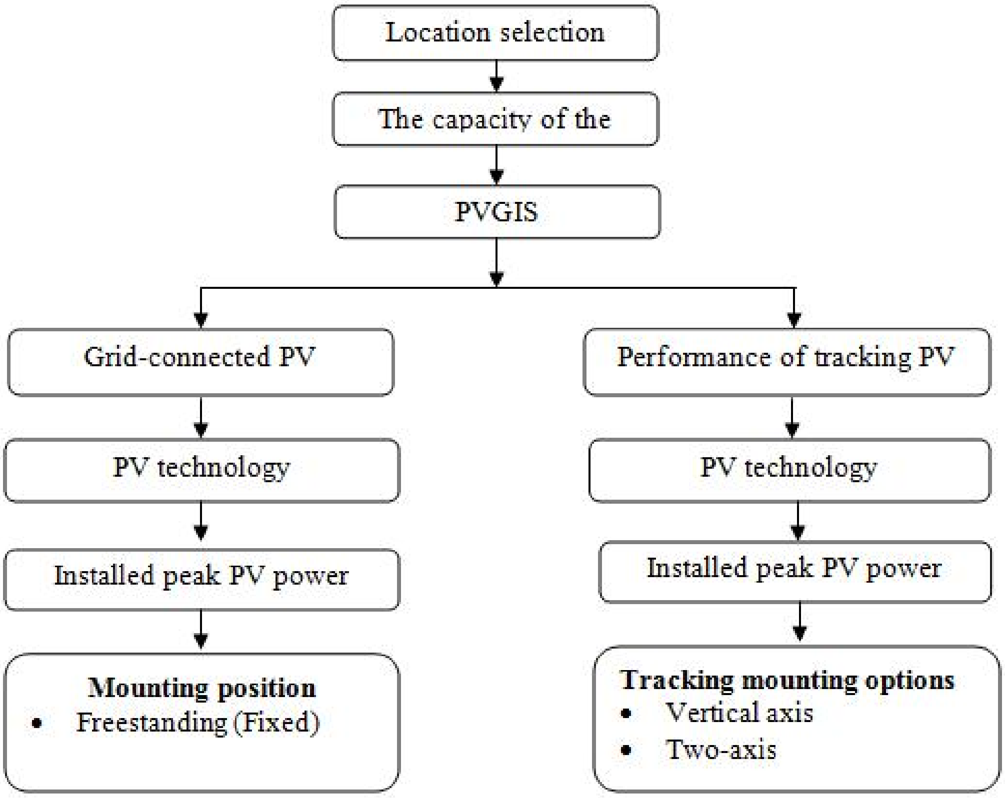


Figure 4.15: The framework of the simulation study using PVGIS

Considering the PVGIS Simulation, for Freestanding system, maximum solar radiation potential at selected regions is achieved in July followed by August (Figure 4.16). The minimum potential is observed in January for Lefkoşa and in December for Girne and Gazimağusa (Figure 4.16). Moreover, it is found that for 1-axis and 2-axis tracking system, the maximum radiation is observed in the month of July for all studied regions, while the minimum one is recorded in January for Lefkoşa and Gazimağusa and in December for Girne .It is found that Gazimağusa has the maximum annual solar radiation potential compared to other regions. In addition, the energy generations on a monthly and annually basis based on PVGIS are shown in Figure 4.16. It is found that 2-axis tracking mode has the maximum energy production compared to Freestanding and 1-axis tracking mode.

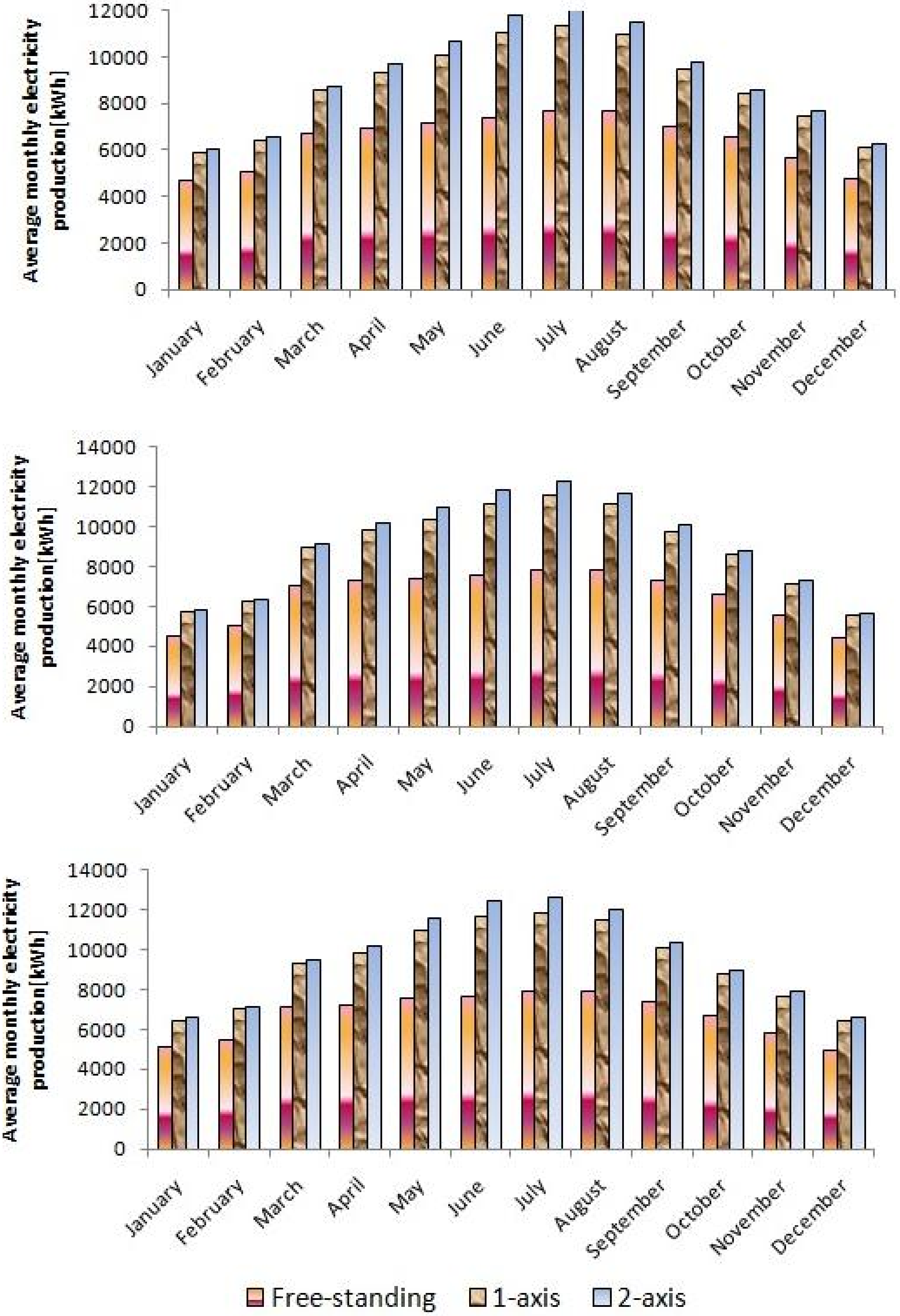


Figure 4.16: Average monthly electricity production and in-plane irradiation for studied regions using PVGIS simulation tool

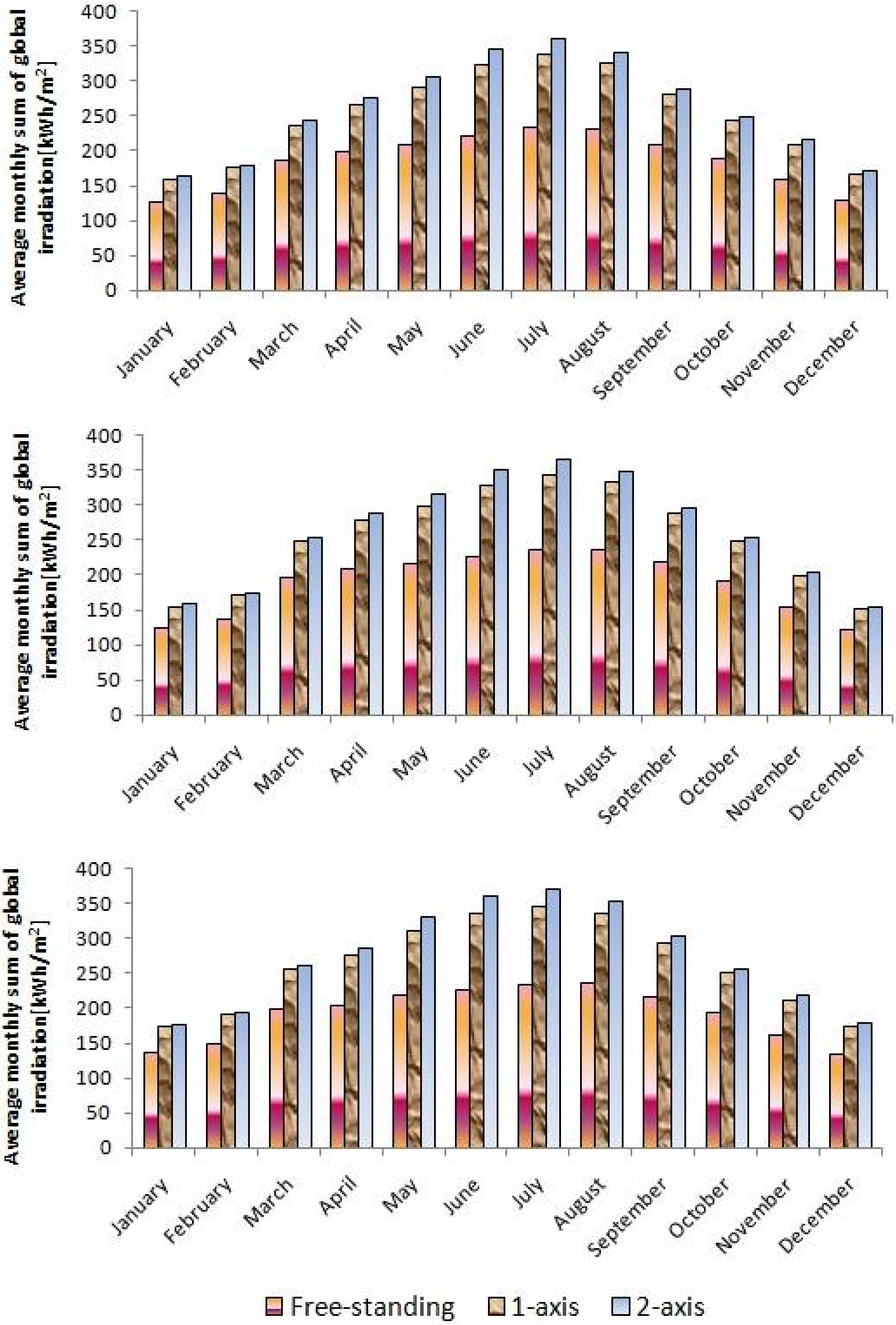


Figure 4.16: Continued

4.3.4 Economic Analysis of Solar Energy Potential

The economic analysis describes the cash flow return on investment during the utilization of the PV plant. The economic parameters used for the study is assumed based on previous scientific research. Thus, the economic parameters that used for economic studies of PV plants are presented in Table 4.9.

The annual produced electricity exported to grid and CF values of 45MW PV plants for three different tracking modes are shown in Table 4.10. In general, the generated electricity and CF values of use tracking system are higher than fixed-tilt option (Mohammadi et al., 2018). Because trackers minimize the angle of incidence between the incoming solar radiation and the surface of PV panels and therefore maximize the amount of solar radiation absorbed by PV panels (Mohammadi et al., 2018). Therefore, it is observed that the highest generated electricity and CF is obtained from the two-axis tracking system, while, the lowest one obtained from Fixed-axis system as shown in Table 4.10.

The results of economic performance of small-scale plants for various tracking-mounting options are tabulated in Table4.10. The results indicated that economic feasibility of PV plants for electricity power generation provided an estimated cost ranging from 0.035 to 0.053$/kWh of energy produced under different tracking-mounting options for all studied regions. In addition, it is can be seen that 2-axis tracking is more economical option for generating electricity in Northern Cyprus because of higher values of NPV, BCR, ALCS, and IRR as well as lower values of EB, SB and LCOE values.

Table 4.8: Summary of grid-connected performance of 10-kW PV plant using PVGIS

Tracking System		Parameters	Lefkoşa	Girne	Gazimağusa
Tracking System	Input	**Location [Lat/Lon]**	35.164/33.315	35.340/ 33.319	35.117/33.950
		Database used	PVGIS-CMSAF	PVGIS-CMSAF	PVGIS-CMSAF
		PV technology	Crystalline silicon	Crystalline silicon	Crystalline silicon
		System loss [%]	14%	14%	14%
Freestanding (Fixed)	**Output**	**Slope angle [°]**	31	31	32
		Azimuth angle [°]	-8	-5	-4
		Yearly PV energy production [kWh]	17300	17500	18100
		Yearly in-plane irradiation [kWh/m²]	2240	2280	2270
1-axis	**Output**	**Slope angle [°]**	53	53	54
		Azimuth angle [°]	0	0	0
		Yearly PV energy production [kWh]	23500	23700	24900
		Yearly in-plane irradiation [kWh/m²]	3010	3050	3090
2-axis	**Output**	**Slope angle [°]**	-	-	-
		Azimuth angle [°]	-	-	-
		Yearly PV energy production [kWh]	24400	24600	25900
		Yearly in-plane irradiation [kWh/m²]	3140	3170	3230

Table 4.9: Economic parameters used for economic analysis of grid-connected 10kW PV plant

Parameters	**Value**
Technical data	
Plant capacity	10kW
PV module type	mono-Si - CS6X-300M
Losses	15%
Number of PV module	34
Solar collector area	65 m^2
Capital Cost	
CS6X-300M	250-300$
Inverter (12kW)	1500-3000$
Total capital cost	12000$
O&M cost	
Fixed tiled system	1.5 c$/kWh
1-axis tracking system	1.8 c$/kWh
2-axis tracking system	1.8 c$/kWh
Other parameters	
Inflation rate	7.2%
Discount rate	3%
Project life	25 year
Electricity export escalation rate	5%

Table 4.10: Performance of 10kW PV power plants

City	Tracking mode	CF [%]	Generated electricity [kWh/year]	Electricity export revenue [$]
Lefkoşa	Fixed	17.8	15873	1587
	One-axis	22.9	20450	2045
	Two-axis	24.2	21651	2165

City	Economic performance							
	Tracking mode	NPV [$]	EPB [year]	SPB [year]	LCOE [$/kWh]	BCR	ALCS [$/year]	IRR [%]
Lefkoşa	Fixed	36834	4.1	7.6	0.053	11.2	2115	30.1
	One-axis	51670	2.7	5.9	0.041	15.4	2967	42.2
	Two-axis	55562	2.5	5.5	0.039	16.4	3191	45.4

City	Tracking mode	CF [%]	Generated electricity [kWh/year]	Electricity export revenue [$]
Girne	Fixed	17.8	15918	1592
	One-axis	22.9	20497	2050
	Two-axis	24.2	21691	2169

City	Economic performance							
	Tracking mode	NPV [$]	EPB [year]	SPB [year]	LCOE [$/kWh]	BCR	ALCS [$/year]	IRR [%]
Girne	Fixed	36981	4.1	7.5	0.053	11.3	2124	30.2
	One-axis	51820	2.7	5.9	0.041	15.4	2976	42.3
	Two-axis	55693	2.5	5.5	0.039	16.5	3198	45.5

City	Tracking mode	CF [%]	Generated electricity [kWh/year]	Electricity export revenue [$]
Gazimağusa	Fixed	19.2	17173	1717
	One-axis	25.1	22451	2245
	Two-axis	26.6	23760	2376

City	Economic performance							
	Tracking mode	NPV [$]	EPB [year]	SPB [year]	LCOE [$/kWh]	BCR	ALCS [$/year]	IRR [%]
Gazimağusa	Fixed	41047	3.6	7	0.049	12.4	2357	33.5
	One-axis	58153	2.4	5.3	0.037	17.2	3340	47.6
	Two-axis	62396	2.2	5.1	0.035	18.3	3583	51.2

4.4 Discussion

This particular paper aimed to depict the attitudes of people on a series of issues related to electricity production, renewable energy and explore the impact of the public's knowledge about renewable energy technologies. The current study found that the cost of renewable energy has a direct impact on public intention to use renewable energy technologies. It means that public perception about the cost of renewable energy is one of the key elements to encourage or discourage them from using renewable energy technologies. In terms of cost, another finding was that most of the respondents believed that the price of renewable energy products is expensive. In addition, based on public opinion, it is found that approximately 95% of respondent were selected solar energy as the best sources for generating electricity in Northern Cyprus. This agreement may be due to the awareness of widely used solar heating systems in Northern Cyprus. The respondents who are aware of district heating benefits have surely responded positively, as it is the cheapest and most energy efficient way of producing heat and hot water.

In Northern Cyprus, the electricity energy generated by diesel generators (212MW) and PV power plant (1.27MW) installed in Serhatköy. In the last decade, there has been a sharp increase in the population of Northern Cyprus, mainly due to the international tourism and higher education sectors. Consequently, the growth of the population has led to an increase in energy demand (Figure 4.17), where nearly all of the energy production is currently dependent on fossil fuels. The increased energy demand and related environmental problems caused by burning fossil fuels has raised interest in alternative energy sources. According to KibrisTürkElektrikKurumu (2018), the diesel electricity cost is about 0.15$/kWh (0-250kWh) and 0.17$/kWh (250-500 kWh). Based on the public opinion section (3.1), the authors assessed economic evaluations of developing 10kWgird-connected solar/wind power systems. Thus, the results of the collected data and analysis show that the proposed 10kW PV projects are very promising in the selected regions due to the obtained results of economic performance. The recovery of the initial investment of PV power generation can be achieved in 2.2 to 4.1 years, which depends on the location of the studied region in Northern Cyprus. Moreover, with regard to the wind potential in Northern Cyprus, the wind systems is not willing to invest in this type of technology due to high electricity prices and recovery of initial investment. In addition, this type of technology is not suitable to use in Lefkoşa and Girne due to low capacity factor. Moreover, it is noticed that these systems are the most economical option for generating electricity than the producing electricity by diesel generating because of lower value of LCOE. In addition, Figure 4.18(a) shows the total annual electricity generated by solar/wind systems at selected regions in Northern Cyprus. Figure 4.18 (b)-(d) is also showed the comparison between the electricity cost generated by solar/wind systems with diesel. For example, the electricity cost of the same total annual electricity generated by PV/wind systems and diesel is compared and illustrated in Figure 4.18(b)-(d). The results show that using solar system for producing electricity in Northern Cyprus could be reduced the electricity cost with average of 70% comparing to diesel electricity cost. Moreover, the net fuel savings by the overall electricity-generation system with solar systems are nearly three times greater than those obtained with wind systems.

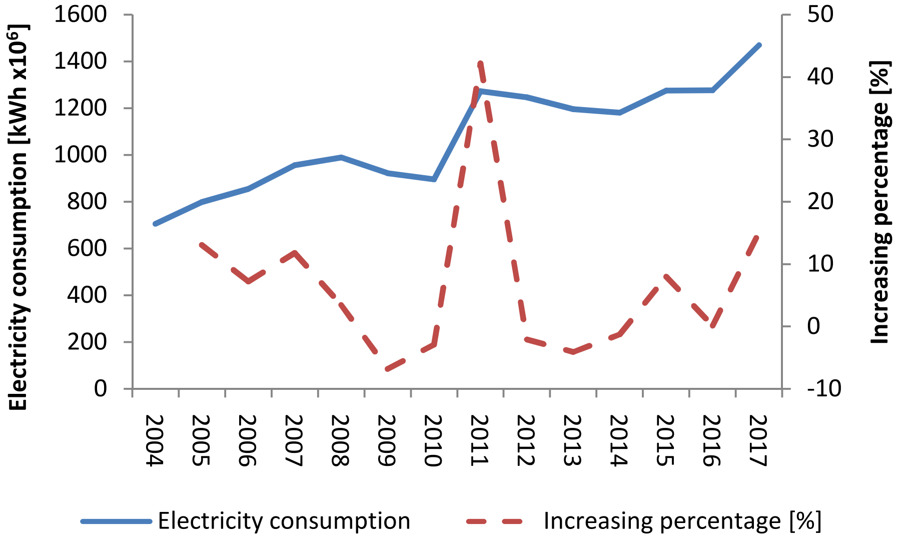


Figure 4.17: Electricity demand in Northern Cyprus (2004-2017) (KibrisTürkElektrikKurumu, 2018)

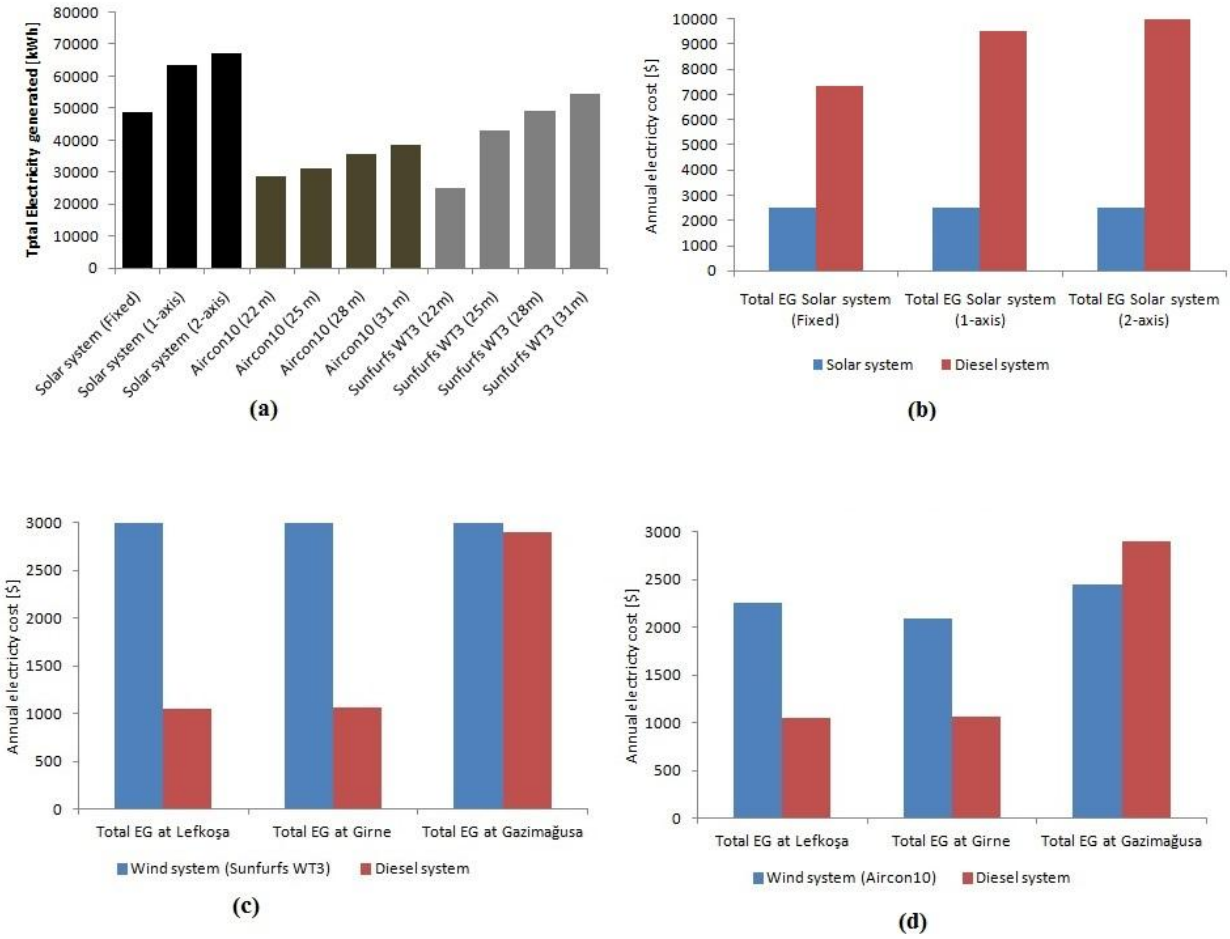


Figure 4.18: Total Electricity generated (EG) and solar/wind vs diesel electricity cost; (a) electricity generated by PV systems and wind systems, (b) comparison between PV systems electricity cost vs. diesel electricity, (c) comparison between wind system (Aircon10) electricity cost vs.diesel electricity and (d) comparison between wind system(Sunfurfs WT3) electricity cost vs. diesel electricity

CHAPTER 5
CONCLUSIONS AND FUTURE WORKS

5.1 Conclusions

This study set out to explore public opinion about renewable energy, technologies, as well as benefits in Northern Cyprus. Data were collected from all over Northern Cyprus especially from the three major cities, namely; Lefkoşa, Girne, and Gazimağusa. The results of this survey are identified opinion on renewable energy with focused on environmental condition and generating during a period of significant interest in electrical issues in Northern Cyprus. This study has the potential to improve the information and knowledge base to effectively support decision makers aiming at sustainable renewable resource management and planning.

Moreover, the present paper is aimed to give a conscious analysis of the performance of a 10kW grid-connected solar/wind power system for the most populated regions in Northern Cyprus. In comparison with solar and wind systems, the 2-axis tracking systems are the best optional for producing electricity in the studied regions. Generally, it concluded that PV system project is the most economical option for generating electricity in studied regions location than the wind system due to low electricity prices and recovery of initial investment. Moreover, the net fuel savings by the overall electricity-generation system with solar systems are nearly three times greater than those obtained with wind systems.

5.2. Limitation of the research

Limitations are potential weaknesses in our study and are out of our control. The study limitations are

1. Due to the nature of the research questions, this research was based on qualitative research methods. The survey conducted in the research did not, for the most part, yield statistically significant results.
2. Some respondents have difficulty in understanding the questionnaires.
3. Most of respondents were not English first-language speakers, and they may have misunderstood the questionnaires.

5.3 Future Work

In this study, Weibull distribution was used to study the wind speed characteristics. In addition, PVGIS and RETScreen were used to analyze the performance of solar system in three selected regions. As future work, different distribution such as Normal and Logistic, Log-Logistic, Lognormal functions will be used to analyze the wind speed distribution at three regions. Additionally, PV*SOL and PVWATT'S simulation tool will be used and compared with PVGIS and RETScreen tool.

REFERENCES

Al Zohbi, G., Hendrick, P., &Bouillard, P. (2015). Wind characteristics and wind energy potential analysis in five sites in Lebanon. *International Journal of Hydrogen Energy*, *40*(44), 15311-15319.

Alayat, M., Kassem, Y., &Çamur, H. (2018). Assessment of Wind Energy Potential as a Power Generation Source: A Case Study of Eight Selected Locations in Northern Cyprus. *Energies*, 11(10), 2697

Ayodele, T., &Ogunjuyigbe, A. (2015). Prediction of monthly average global solar radiation based on statistical distribution of clearness index. Energy, 90, 1733-1742

Baranes, E., Jacqmin, J., &Poudou, J. (2015). Non-Renewable and Intermittent Renewable Energy Sources: Friends and Foes? *SSRN Electronic Journal*.

Benedek, J., Sebestyén, T., &Bartók, B. (2018). Evaluation of renewable energy sources in peripheral areas and renewable energy-based rural development. *Renewable and Sustainable Energy Reviews*, *90*, 516-535.

Biswas, P. P., Suganthan, P., &Amaratunga, G. A. (2017).Optimal power flow solutions incorporating stochastic wind and solar power. *Energy Conversion and Management*, *148*, 1194-1207.

Cantarello, E., & Newton, A. C. (2014). *An Introduction to the Green Economy: Science, Systems and Sustainability*. New York

Evrendilek, F., &Ertekin, C. (2003).Assessing the potential of renewable energy sources in Turkey. *Renewable Energy*, *28*(15), 2303-2315.

Gao, X. S., Yang, H., & Lu, L. (2014). Study on offshore wind power potential and wind farm optimization in Hong Kong. *Applied Energy*, *130*, 519-531.

Giannakopoulos, C., Psiloglou, B., Lemesios, G., Xevgenos, D., Papadaskalopoulou, C., Karali, A., …Loizidou, M. (2015). Climate change impacts, vulnerability and adaptive capacity of the electrical energy sector in Cyprus. *Regional Environmental Change*, *16*(7), 1891-1904.

Gökçek, M., &Genç, M. S. (2009). Evaluation of electricity generation and energy cost of wind energy conversion systems (WECSs) in Central Turkey. *Applied Energy*, 86(12), 2731-2739

Gökgöz, F., &Güvercin, M. T. (2018).Energy security and renewable energy efficiency in EU. *Renewable and Sustainable Energy Reviews*, *96*, 226-239.

Gómez-Navarro, T., &Ribó-Pérez, D. (2018).Assessing the obstacles to the participation of renewable energy sources in the electricity market of Colombia. *Renewable and Sustainable Energy Reviews*, *90*, 131-141.

Hache, E. (2018). Do renewable energies improve energy security in the long run? *International Economics*, *156*, 127-135.

Hobbs. (2016). *Fundamentals of World Regional Geography*.Cengage Learning

Irwanto, M., Gomesh, N., Mamat, M., &Yusoff, Y. (2014).Assessment of wind power generation potential in Perlis, Malaysia. *Renewable and Sustainable Energy Reviews*, *38*, 296-308.

Jadhav, H., & Roy, R. (2015).Stochastic optimal power flow incorporating offshore wind farm and electric vehicles. *International Journal of Electrical Power & Energy Systems*, *69*, 173-187.

Kabir, E., Kumar, P., Kumar, S., Adelodun, A., & Kim, K. (2018). Solar energy: Potential and future prospects. *Renewable and Sustainable Energy Reviews*, *82*, 894-900.

Kardooni, R., Yusoff, S. B., Kari, F. B., &Moeenizadeh, L. (2018).Public opinion on renewable energy technologies and climate change in Peninsular Malaysia. Renewable Energy, 116, 659-668.

Kassem, Y. Gökçekuş, H. &Çamur, H. (2018). Economic assessment of renewable power generation based on wind speed and solar radiation in urban regions. *Global J. Environ. Sci. Manage*., 4(4),465-482

Kassem, Y., &Gökçekuş, H. (2018). GHG emissions and energy performance of 1MWp grid-connected solar PV plant at Lefke in Northern Cyprus: a Case study. *Disaster Science and Engineering*. In press

Kassem, Y., Çamur, H., &Gökçekuş, H. (2018). Economic assessment of renewable power generation based on wind speed and solar radiation in urban regions. *Global J. Environ. Sci. Manage*, *4*(4), 465-482.

Kassem, Y., Gökçekuş, H., &Çamur, H. (2018).Effects of Climate Characteristics on Wind Power Potential and Economic Evaluation in Salamis Region, Northern Cyprus. *International Journal of Applied Environmental Sciences*, (13), 3, 287-307.

Khan, M. A., Rehman, S., & Al-Sulaiman, F. A. (2018). A hybrid renewable energy system as a potential energy source for water desalination using reverse osmosis: A review. *Renewable and Sustainable Energy Reviews, 97*, 456-477.

Khanna, V., Shekher, A., Singh, A., &Budhraja, V. (2017). Performance of grid connected photovoltaic system in North of India. *2017 IEEE 44th Photovoltaic Specialist Conference (PVSC).*

Khanna, V., Shekher, A., Singh, A., &Budhraja, V. (2017). Performance of grid connected photovoltaic system in North of India. *2017 IEEE 44th Photovoltaic Specialist Conference (PVSC).*

KibrisTürkElektrikKurumu. (2018). Retrieved October 5, 2018, from https://www.kibtek.com/tarifeler/

Kousksou, T., Allouhi, A., Belattar, M., Jamil, A., El Rhafiki, T., Arid, A., &Zeraouli, Y. (2015).Renewable energy potential and national policy directions for sustainable development in Morocco. *Renewable and Sustainable Energy Reviews*, *47*, 46-57.

Kumar, N. M., Kumar, M. R., Rejoice, P. R., & Mathew, M. (2017). Performance analysis of 100 kWp grid connected Si-poly photovoltaic system using PVsyst simulation tool. *Energy Procedia*, *117*, 180-189.

Li, C., Liu, Y., Li, G., Li, J., Zhu, D., Jia, W., …Zhai, X. (2016). Evaluation of wind energy resource and wind turbine characteristics at two locations in China. *Technology in Society*, *47*, 121-128.

Lin, B., & Chen, Y. (2018). Does electricity price matter for innovation in renewable energy technologies in China? *Energy Economics*, *1*.

Manoj Kumar, N., Sudhakar, K., &Samykano, M. (2017). Techno-economic analysis of 1 MWp grid connected solar PV plant in Malaysia. *International Journal of Ambient Energy*, 1-10.

Mehmet, O., &Bicak, H. (2002).Modern and traditional irrigation technologies in the Eastern Mediterranean.*Ottawa: IDRC International Development Research Centre*.

Mohammadi, K., Naderi, M., &Saghafifar, M. (2018).Economic feasibility of developing grid-connected photovoltaic plants in the southern coast of Iran. *Energy*, *156*, 17-31.

Moula, M. E., Maula, J., Hamdy, M., Fang, T., Jung, N., &Lahdelma, R. (2013).Researching social acceptability of renewable energy technologies in Finland. International Journal of Sustainable Built Environment, 2(1), 89-98.

Owusu, P. A., &Asumadu-Sarkodie, S. (2016). A review of renewable energy sources, sustainability issues and climate change mitigation. *Cogent Engineering*, *3*(1).

Ozil, E., Ugursal, V. I., Akbulut, U., &Ozpinar, A. (2008). Renewable Energy and Environmental Awareness and Opinions: A Survey of University Students in Canada, Romania, and Turkey. International Journal of Green Energy, 5(3), 174-188.

Paraschivoiu, I. (2009). *Wind turbine design: With emphasis on Darrieus concept. Montréal*: Presses internationals Polytechniques

Paska, J., &Surma, T. (2014). Electricity generation from renewable energy sources in Poland. *Renewable Energy*, *71*, 286-294.

Prasad, A. A., Taylor, R. A., & Kay, M. (2017). Assessment of solar and wind resource synergy in Australia. *Applied Energy*, *190*, 354-367.

Razmjoo, A., Qolipour, M., Shirmohammadi, R., Heibati, S. M., &Faraji, I. (2017). Techno-economic evaluation of standalone hybrid solar-wind systems for small residential districts in the central desert of Iran

Schumacher, K., Krones, F., McKenna, R., &Schultmann, F. (2019). Public acceptance of renewable energies and energy autonomy: A comparative study in the French, German and Swiss Upper Rhine region. Energy Policy, 126, 315-332.

Shiva Kumar, B., &Sudhakar, K. (2015). Performance evaluation of 10 MW grid connected solar photovoltaic power plant in India. *Energy Reports*, *1*, 184-192.

Shoaib, M., Siddiqui, I., Amir, Y. M., &Rehman, S. U. (2017). Evaluation of wind power potential in Baburband (Pakistan) using Weibull distribution function. *Renewable and Sustainable Energy Reviews*, *70*, 1343-1351.

Solyali, D., Altunç, M., Tolun, S., &Aslan, Z. (2016). Wind resource assessment of Northern Cyprus. *Renewable and Sustainable Energy Reviews*, *55*, 180-187.

Taliotis, C., Taibi, E., Howells, M., Rogner, H., Bazilian, M., &Welsch, M. (2017). Renewable energy technology integration for the island of Cyprus: A cost-optimization approach. *Energy*, *137*, 31-41.

Vogiatzis, N., Kotti, K., Spanomitsios, S., &Stoukides, M. (2004). 04/02445 Analysis of wind potential and characteristics in North Aegean, Greece. *Fuel and Energy Abstracts*, *45*(5), 342-343.

Wang, B., Cot, L., Adolphe, L., &Geoffroy, S. (2017). Estimation of wind energy of a building with canopy roof.*Sustainable Cities and Society*, 35, 402-416

Woldeyohannes, A. D., Woldemichael, D. E., &Baheta, A. T. (2016).Sustainable renewable energy resources utilization in rural areas. *Renewable and Sustainable Energy Reviews*, *66*, 1-9.

Yenen, M.;Fahrioglu, M., (2013). Wind and solar energy assessment of Northern Cyprus. 2013 12th International Conference on Environment and Electrical Engineering

Zerrahn, A., Schill, W., &Kemfert, C. (2018).On the economics of electrical storage for variable renewable energy sources. *European Economic Review*, *108*, 259-279.

APPENIDIX

APPENDIX 1

A QUESTIONNAIRE ABOUT RENEWABLE ENERGY TECHNOLOGY

Dear students:

Hello! We are researchers from Near East University. We are conducting a survey on International postgraduate students' opinions about renewable energy technologies that can be used for generating electricity at the universities in Northern Cyprus. We would like toinvite you to answer the questions in our questionnaire. Your decision as to whether or not to take part in this study is completely voluntary (of your free will). You are not asked to mention your name or any other information that may lead to identify you. Yourcooperation with our research is highly appreciated and we assure that all data wecollect will be used for research purposes only.

1. Do you know the difference between renewable and non-renewable energy?

- ☐ Yes
- ☐ No
- ☐ Unsure

2. Which of the following statement(s) best represent your level of interest in renewableenergy?

- ☐ I am environmentally conscious and familiar with renewable energy technologiesand their benefits.
- ☐ I am familiar with renewable energy technologies and their benefits
- ☐ I know very little about renewable energy technologies and their benefits

3. How much you are concerned about renewable energy source?

- ☐ Very unconcerned
- ☐ Less unconcerned
- ☐ Neither concerned nor very concerned
- ☐ Concerned
- ☐ Very concerned

4. In your opinion, What are the disadvantages of using renewable energy over tradition gas or electricity energy?

- ☐ I don't see any disadvantages of using renewable energy
- ☐ Installation cost
- ☐ Efficiency
- ☐ Reliability
- ☐ I feel it is not fully established
- ☐ Lack of information on how it works
- ☐ Other,

5. To what extent do you think renewable energy can solve the electricity problem at the university?

- [ ] To a very small scale
- [ ] To a small extent
- [ ] To a moderate extent
- [ ] To a large extent
- [ ] To a very large extent

6. Which renewable energy do you think has the most extensive scope to be successfully implemented across the universities by 2030?

- [ ] Wind energy
- [ ] Solar energy
- [ ] Biomass
- [ ] Bio-fuel

7. What are the benefits of using electricity and/or thermal energy produced from renewableenergy sources? (Mark all that apply))

- [ ] Lower energy bills.
- [ ] Good for the environment.
- [ ] Less reliance on imported oil and natural gas
- [ ] Less reliance on electric utility companies.
- [ ] There will not be a need for investment in nuclear power plants.
- [ ] Good for the economy
- [ ] There will not be any benefit.

8. If we were to consider purchasing a renewable energy system for Near East University, which are the TOP THREE difficulties you would likely experience? (Rank the top three, 1 most important, 3 least important)

- [ ] Initial Cost
- [ ] Finding a trustworthy contractor
- [ ] Choosing the correct technology
- [ ] Obtaining correct and reliable information
- [ ] Obtaining the best possible price
- [ ] Good return on investment
- [ ] Technology becomes obsolete too quickly

9. To satisfy the future energy needs of our university, what options should be given priorityto (Mark all that apply)

- ☐ Nuclear power plants
- ☐ Power plants that rely on renewable energy resources such as solar or wind
- ☐ Natural gas power plants
- ☐ Coal fired power plants

10. Would you consider buying your electrical energy from a renewable source even if it isslightly more expensive?

- ☐ Yes
- ☐ No
- ☐ I don’t know

11. Gender

- ☐ Male
- ☐ Female

12. Age

- ☐ Less than 25 years
- ☐ 25-30 year
- ☐ 31-36years
- ☐ 37-42years
- ☐ Over 42 years

13. Faculty

- ☐ Applied sciences
- ☐ Social sciences
- ☐ Health sciences