Economic Feasibility of 1kW Micro-Scale Wind Turbines for North Cyprus

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ABSTRACT

Electricity generation with fossil fuels is considered as one of the most significant means of carbon dioxide emission which has a major impact in the world climate changes. Nowadays, the renewable energy resources are desirable, since they are environmentally friendly and have low emissions in comparison to traditional resources of energy. In recent years, wind energy conversion units have been the fastest growing renewable energy technology all around the world.

The present work is concerned with the economic feasibility of micro-scale wind turbines. In this study life cycle cost analysis is applied for different 1- kW capacity models under different wind speeds in North Cyprus condition. Poor selection of turbine may lead to an economically suboptimal investment.

Six micro-scale wind turbines studied were Aeolos- H, Aeolos- V, Maglev CXF- V, Zonhan- H, Senwei- V and Airforce1- H. For feasibility it is required that the net present value should be positive or in other words the savings-to-investment ratio should be greater than 1. The results show that SW-1kW, ZH-1kW and Aeolos-H demonstrated feasibility at 5 m/s, 7 m/s and 9 m/s wind speeds respectively in scenario A which includes feed in tariff of 0.07 USD. In scenario B, which does not employ any feed in tariff, SW-1 kW and ZH-1 kW are found to be feasible at average wind speeds of 6 m/s and 8 m/s respectively.

Keywords: Wind energy**,** Renewable energy, Micro-scale wind turbine, Economic feasibility, Life cycle cost analysis, North Cyprus

ÖZ

Fosil yakıtlar ile yapılan elektrik üretimi, dünya iklim değişikliklerinde büyük katkısı olan karbondioksit emisyonunun en önemli kaynaklarından biri olarak kabul edilmektedir. Günümüzde, yenilenebilir enerji kaynakları, çevreye duyarlı olduklarından ve geleneksel enerji kaynaklarına kıyasla az emisyona sahip olduklarından daha çok Kabul görmektediler. Son yıllarda, rüzgar enerjisi çevrim üniteleri dünyada en hızlı yaygınlaşan yenilenebilir enerji teknologisi olmuştur.

Mevcut çalışma, mikro ölçekli rüzgar türbinlerinin ekonomik fizibilitesi ile ilgilidir. Bu çalışmada, Kuzey Kıbrıs'ta değişik rüzgar hızlarında 1 kW kapasiteli farklı modellerin kuzey kıbrıs şartlarında yaşam döngüsü maliyet analizini uygulanmıştır. Kötü türbin seçimi, ekonomik olarak optimal olmayan bir yatırıma neden olabilir.

İncelenen altı mikro ölçekli rüzgar türbinleri Aeolos-H, Aeolos-V, Maglev CXF-V, Zonhan-H, Senwei-V ve Airforce-H'dir. Fizibilite için net bugünkü değerin pozitif veya başka bir deyişle tasarrıfların yatırımlarla oranının 1’ den fazla olması gerekir. Sonuçlar, 0.07 USD satış tarifeli senaryoda, SW-1kW, ZH-1kW ve Aeolos-H'nin sırasıyla 5 m/s, 7 m/s ve 9 m/s rüzgar hızlarında fizibıl olduklarını göstermektedir. Sisteme satış yapılamıyan senaryoda SW-1 kW ve ZH-1 kW'nin fizibiliteleri sırasıyla 6 m/s ve 8 m/s rüzgar hızlarında mümkündür.

Anahtar Kelimeler: Rüzgar enerjisi, Yenilenebilir enerji kaynağı, Mikro ölçekli rüzgar türbini, Ekonomik fizibılitesi, Yaşam döngüsü maliyet analizini

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LIST OF ABBREVIATIONS

AEP	Annual Energy Production
AWEA	American Wind Energy Association
CERA	Cyprus Energy Regulatory Authority
CF	Capacity Factor
EAC	Electricity Authority of Cyprus
EEA	European Environment Agency
EU	European Union
EWEA	European Wind Energy Association
HAWT	Horizontal Axis Wind Turbine
IEC	International Energy Commission
IRES	International Renewable Energy System
IRR	Internal Rate Return
KIBTEK	Electricity Authority of Northern Cyprus
LCoE	Levelized Cost of Energy
NPV	Net Present Value
ROC	Republic of Cyprus
SIR	Savings to Investment Ratio
TRNC	Turkish Republic of Northern Cyprus
TSO	Cyprus Transmission System Operator
VAWT	Vertical Axis Wind Turbine

Chapter 1

INTRODUCTION

1.1 Background

Cyprus in the Mediterranean Sea is the third largest island. It is situated at the longitude and latitude of 33°00 E, 35°00 N and has 9,251 km^2 area. The island has been split into two de-facto states known as the South Cyprus and the Northern Cyprus Since 1983. The South Cyprus is governed under the Republic of Cyprus (ROC) by Greek Cypriots. This state includes 5,458 km^2 (59% of total) of land and according to the latest census done in October 2011 [1] it has the population of 862,000. The Northern Cyprus is governed under the Turkish Republic of Northern Cyprus (TRNC) by Turkish Cypriots. This part includes 3,355 km^2 (36% of total) of land [1] and according to the latest census done in December 2011 [1] it poses a population of 294,000. The remaining 438 km^2 (5% of total) area is governed as Sovereign Base Areas of the British Overseas Territory of areas called Akrotiri and Dhekelia.

Figure 1: The Island of Cyprus at the south of Turkey and North-West of Lebanon [2].

As a matter of fact the mentioned two parts have equal earth resources and are isolated from rest of the world in terms of electric supply. Regarding energy infrastructures, both parts can share electrical supply; however, they prefer not to unless there is a crucial event (for example, blackouts requiring re-energizing of the entire system or loss of major power stations). The consumption of the imported oil products provides total energy demands for both parts. Rapid rising of tourism and industry sectors, growth of population and life standards have resulted in growth of energy demands. Having a secluded energy system, which raises the demand, causes the country to be extremely dependent on imported oil in addition to causing a high burden on economy of the country. Depending on the limited oil storage capacity, the growing cost of energy supply, and the demand for environmental maintenance (that means a decrease in protection of the visual and natural beauty of the island and in emission of green house gases), Cyprus should utilize renewable resources.

Employing sustainable energy approaches in the island can be one of the ways to decrease the dependency to the imported fuels. By the year 2020 as per the European Climate Change Program, the target of gross electricity generation of 13% is held to be supplied by renewable energy sources in Southern Cyprus as a part of the EU, similarly the same targets are applied in the North [1].

Furthermore, any utility-scale renewable energy project would be as the first of its kind owing to the lack of experience in terms of financing, implementation, and operation of these systems in the island. Because of these perceived and associated risks, a barrier is created against incorporating renewable energy technologies in Cyprus [1].

1.2 Research Focus

The main focus of the current thesis would be exploring ways that experts select turbines from a variety of accessible ones, and determine the economic feasibility of micro scale wind turbines for urban utilization purpose in Northern Cyprus.

The cost-effectiveness of the investment is generally the initial basis of deciding to pick a wind turbine. In other words, a turbine which generates the uppermost net present value (NPV) would be selected via a qualified expert; though, there are usually several constraints for deciding on choosing the right turbines. These constraints might be as follows:

- Capital (constraints on the primary investment value);
- Spatial (narrow accessibility to wind or land resources);
- Accessibility (some specific models of wind turbine might not be accessible or possible to convey to the island).

- Capacity (constraints on the productivity of the turbine, due to technical or market matters).

According to the results of a talk with a famous energy infrastructure developer, the present way of choosing a turbine in this research will definitely cause several capacity and capital constraints. Afterward, to evaluate each turbine’s productivity and to confirm the required costs, the process of bidding with the producers of the most remarkable turbines would be the initial stage. It is noteworthy that this approach will be practical if we know that the commercially accessible turbines' subset, which should be evaluated, consist of the perfect turbines intended for the considered site. Possible results coming from this hypothesis, beside the way in which this hypothesis might be overlooked, will be the current thesis's general focus.

1.3 Aims and Objectives

This study intends to develop a method for selecting micro wind turbines and bearing 1-kW power capacity and which are available in market, to examine their economic feasibility. It is intended to determine the most suitable system for the households of North Cyprus.

a) Select wind turbine with 1 kW power rating from variety of accessible one
b) Determine the total investment cost of candidate wind turbines
c) Determine maintenance cost
d) Conduct life cycle analysis for candidate wind turbines
e) Select the economically feasible wind turbine system for 4m/s wind speed which is North Cyprus average wind speed

1.4 Motivation

It is predictable that a model utilizing cost-scaling approximations may efficiently evaluate the whole group of potential wind turbine designs (containing the turbines that have not been created so far). This prediction would be based upon the Levelized Cost of Energy (LCoE) or NPV without starting a bidding process with producers. This study will compare and contrast with the true data obtained from a considered turbine in a selected location in Cyprus. Then, this model is to be confirmed in the decision making stage via the comparison of its outcome. Based on this outcome, some suggests will be provided to energy infrastructure developers and experts for the sake of having a suitable and proper wind turbine selection. In addition, it might provide a new perspective into considering the features of a turbine to exploit the best of energy from definite wind sources in the site.

1.5 Outline of Thesis

Chapter 2 expands a presentation of the literature review some studies which has been done on economic feasibility of micro wind turbines in various locations for urban utilization purpose.

Chapter 3 introduces types of wind turbines and describes their technologies and how they work and compare them.

Chapter 4 explains current electricity demand and wind energy in North Cyprus.

Chapter 5 performs economic feasibility analysis for 1kW wind turbines for Northern Cyprus.

Chapter 6 presents a discussion on the obtained results and their inference. Also introduce the best option according to the purpose has been intended.

Chapter 7 presents a conclusion of the study results and recommendation for further research.

Chapter 2

LITERATURE REVIEW

The following chapter provides a summary of several researches done on economic practicability of micro wind turbines in various sites.

Recently, it has been approved that in remote rural areas, micro scale power generation have more suitability which is because of un-economical grid extension. A. Chauhan and R. P. Saini [3] have conducted a techno-economic practicability research about the growth of an Integrated Renewable Energy System($IRES$). The aim of their study was to solve the demands of cooking and electrical energy for a group of rural communities in Chamoli area in Uttarakhand state, India. They did a serious attempt to provide an appropriate micro wind turbine model for the chosen sites. For investigation, technical features of small-wind-turbine models were obtained from several companies. For wind-turbine models, moreover, the factor of capacity was predicted based upon the computations achieved from rated power output of wind turbines and annual energy generation. Based upon the capacity factor's maximum value, a micro model for wind turbines was presented.

Another study about the economic feasibility of an investment on micro wind turbines was done by Grieser et al. [4] in Germany. Based on their study, the place of micro wind turbines in urban districts has significant role on economic viability. The reason is about the considerably affected local wind speeds by urban structures and consequently of the potential energy given up from a turbine. Moreover they found out that micro wind turbines were the only beneficial models with favorable circumstances.

Z. Simic et al. [5] conducted a study about micro wind turbines bearing not more than 10 kW of installed power. In this study they did compare the power curves and examined numerous wind turbines. Additionally, they assessed the potential electricity generation for all of the examined turbines with their various power curves. They did this assessment with similar wind features and pole heights by means of a multi-annual data collection obtained from a site in Croatia. Effect of the power curve forms, as well as the turbine rated power in relation to its swept area, on the entire electricity generation and produced profit was discussed and considered. Their study's outcomes suggested more extensive range of both electricity costs and possible electricity generation than the expectation.

Furthermore, the economic viability of electricity production based upon wind turbines was studied by A. Mostafaeipour and K. M. Aligoodarz [6] located in the west of Iran. Their study aimed to assess the wind energy possibility and its features in terms of diurnal, yearly and monthly analysis via five-year-measured wind-speed data from 2005 to 2009 at $10m$ height. They also evaluated the economic viability of six various wind turbines with rated powers varying from 20 to $150kW$. In conclusion they found out that the E-3120 wind turbine among all turbines studied was the most striking alternative for installation.

Between two methods of power density method and the standard deviation method, A. Mostafaeipour and K. Mohammadi [7] put the focus of their research on finding the most suitable method for computing the wind power. On the other hand they did attempt to calculate the potential of wind energy in Zarrineh, Iran. Consequently, the data of wind speed collected in Zarrineh from 2004 to 2009 were chosen as sample data for assessing the performance. Power density was picked as a superior method for computation and estimation of wind energy potential according to hourly, monthly, seasonal and annual values. The outcomes suggested the lack of potentiality of Zarrineh for large scale turbines; though, it was obvious that the mentioned place might be a proper site for the production of electricity via micro wind turbines which is also economically practicable.

In another research A. Mostafaeipour et al. [8] studied the potential of wind energy in Zahedan, Iran. They analyzed wind data collected for 5 years in order to gain wind energy potential and wind power density. Weibull density function was utilized for obtaining the wind power density and energy of the mentioned city. The economic analysis and evaluation of four various wind turbines were studied. By using wind energy, they found out that installation of Proven $2.5kW$ model wind turbine in the mentioned city would be a proper recommendation due to its cost-efficiency.

Buenos Aires is another site which was research by Sibila et al. [9] based upon techno-economic performance of wind turbines as well as the evaluation of wind energy potential. The research was conducted in five different sites of Buenos Aires. They performed a techno-economic analysis in these sites on the basis of a group of commercial wind turbines. The results of their study suggested that the southwest of Buenos Aires could be a talented region for the wind energy extraction, and that region can be supported for the building of wind farms for electricity production.

E. S. Hrayshat and M. S. Al-Soud [10] paid close attention to study the viability of electrification of the wind energy in five chosen rural areas in Jordan (Fako'e South, Al-Risha al Sharkia, Fako'e North, Al-Risha al Garbia and Zabda). The results of this research which were obtained based upon viability analysis suggested that Zabda has enough features to be nominated as a site for exploiting wind energy; this is because of electrification utilizing micro turbines and possibility of this site in commercial scales in wind energy missions. In addition, Garbia and Sharkia were recognized as possible alternative for electrification based upon the systems of wind energy conversion. Based upon the viability of wind energy exploitation, Fako'e South and Fako'e North unlike Zabda were not successful in being selected as approving cases the.

An exergy and energy research about four various systems of wind power, containing vertical and also horizontal axis wind turbines conducted by G.F. Naterer, I. Dincer and K. Pope [11]. Throughout the selection of the required system for that research, important variability in operating parameters and turbine designs were noticed.

The industry of micro scale wind turbine has been developed in the UK with both private and governmental encouragements [12]. On the other hand, the governmental regulations in the UK also support the growth of various companies with an abundance design alternatives. Employment of micro wind turbines in urban communities has been supported by the UK through a funding plot in which a proportion of the preliminary investment costs is offered. These growth and encouragement are based upon the hypothesis that believes micro wind turbines are of possibility to decrease the built environment CO_2 emissions.

M. Bassyouni et al. [13] utilized the wind data collected in eleven years from 2002 to 2012 to verify the wind features of Jeddah in Saudi Arabia. These features consist of scale (c) parameters at $10m$ height, shape (k), wind possibility of density distribution and the daily, monthly and also annual wind speed. The results suggested that the wind possibility existing in the area could be utilized in micro scale off-grid wind appliances.

In addition, the wind energy features and also the wind power potential in Gharo Sindh in Pakistan were evaluated and studied by S. FarhanKhahro et al. [14]. The similarities and contracts of wind power densities were evaluated via calculated wind data and measured by means of Rayleigh and Weibull models. They conducted the evaluation of power production, from the wind data obtained from several wind turbine producers in Gharo. The economic and technical study of wind data obtained at Gharo suggested that this region might be suitable alternative with enough wind energy potential, therefore, might be a proper choice for expanding the wind power production missions.

15 various areas of six geographical zone in Nigeria were the other places to go under study by T.R. Ayodele, et al. [15] who analyzed the probability of using wind energy for electricity production. Their work intended to offer some new technical data which may result in best possible investment in wind technology for electricity production.

It is noteworthy that the employment of two−parameter Weibull distribution model will be an important effort in an area to evaluate the wind energy. L. Bilir et al. [16], were the researchers who worked on wind power density and the distribution of wind speed based on seasonal and yearly scales through Weibull distribution model.

As one of the most striking solutions, Darrieus vertical-axis wind turbines (VAWTs) have been nominated seriously which is because of their better reaction to a skewed and turbulent approaching flow, decreased acoustic emissions and low visual effect. F. Balduzzi et. al. [17] did an assessment on the energetic appropriateness of employment of a Darrieus VAWT in a construction's rooftop in a selected location in Europe. By the intention of offering a trustworthy evaluation of a turbine's real functioning in the selected area, a particular numerical model was used in order to report the impacts of a skewed flow on a Darrieus rotor's power performance. Finally, the outcome of the investigations were synthesized and added into the energy-familiarized research in order to assess the viability of a rooftop installation.

The assessment of energy production of small-scale wind power generators was shaped the research focus of Ali Naci Celik [18]. He evaluated the monthly wind energy generation of five various regions in the world throughout the Weibull wind data represented on behalf of an entire 96 months. The Weibull factors were verified throughout the gamma function on the basis of the statistics of wind distribution computed by the considered data. He then compared the monthly energy production computed from the Weibull representative data and the time-series. On the bases of his reports, it was found out that the Weibull-representative data are of high accuracy to approximate the wind energy production. In his study for the entire 96 months, the observed error in assessment of monthly energy production has been 2.79%.

In another study, Adamu Mengesha Yebi [19] aimed in his project to examine the techno-economically feasibility of wind energy system which provides heat and electricity for a specific living community in Ethiopia. To make his work clear in the optimization process, Adamu used HOMER software in order to verify the possible wind area and to maximize the cost-efficiency of wind energy systems.

The well-organized election of a wind turbine has currently been restricted to a developer's information of the accessibility of the goods on the market, and to their capability for comparing and examining of the accessible turbine designs ahead of investment. Poor selection of turbines may lead to an economically improper investment. Accordingly, Samuel Perkin employed Genetic Algorithms, models of cost-scaling, the theory of Blade Element Momentum in order to generate a new model in which the prediction of the best turbine design for a specific site could be possible [20].

E. Ugur et al. [21] studied the financial payback periods of small scale wind turbines for Istanbul conditions. They considered two 1-kW wind turbines; "Whisper 200" and "Zephir Airdolphin" and they found out that they have financial pay back periods of 25 and 63 years respectively. However, in their analysis they did not consider the time value of money and their results are not meaningful. Also maintenance is not included in this study.

Chapter 3

THE CLASSIFICATION AND COMPARISON OF WIND TURBINES

3.1 Background of Wind Turbines

As an environmental friendly energy resource, wind power has been recently considered seriously throughout the world. Each year, the installation of wind power systems increases comparing to the previous years; in addition, numerous countries pass different acts to allocate huge investments on planning this missions for their future.

If the machinery like grinding stones or pump directly utilizes mechanical energy, the machine would be generally named a windmill. However, it would be named a wind generator if the mechanical energy is transformed into electrical energy [19].

Decelerating the wind speed, a wind turbine catches the energy from the air in motion and then converts that energy into a spinning shaft that typically makes a generator to generate electricity. Several kinds of wind turbines are available in the market; however, they might be categorized into two classes based upon the rotation of their axis. These two categories are called vertical axis wind turbines ($VAWTs$) and horizontal axis wind turbines ($HAWTs$) [22].

3.1.1 Horizontal Axis Wind Turbine

The most frequently design for wind turbines is called a horizontal Axis Wind Turbine. Its blade rotation axis is actually parallel to the flow of wind as well as parallel to the ground [23]. The power coefficient Cp tells how efficiently a turbine converts the energy in the wind to electricity, having the highest hypothetical power coefficient Cp of nearly 0.45 is one of the significant features of the wind machines which are considered in this category [24]. The reason of its popularity by the wind machines is its strong coefficient compared to the alternative classes. A HAWT model has been shown in Fig.2.

Figure 2: Horizontal Axis Wind Turbine ($HAWT$) [25]

In the following there are some advantages and disadvantages of HAWT.

3.1.1.1 Advantages

a) Wind pitches variability to maximize the total wind attracted

b) Ability to enhance the tower height to control higher wind velocity at higher heights

c) Achieving the design popularity for the industrial generation of wind power

3.1.1.2 Disadvantages

a) Ineffectively near to ground level because of turbulence

b) Costly production due to having big scale

c) Consisting of powerful components (steel and carbon fiber) to encounter the winds in higher altitudes

d) Having quiet motion

e) Having slow start up speed

f) Having just one part in motion, lack of gearbox

g) Its design ability to cause a turbine be mounted closer to the ground

h) Inappropriateness for commercial roof installation

i) Lacking of simplicity for service and maintenance

j) Lacking better orientation with environment

k) Excluding enough Safety in speedy and powerful winds

l) Bearing smaller rotating diameter comparing to VAWT

m) Excluding safety for birds unlike the wildlife [22].

3.1.2 Vertical Axis Wind Turbine

Rotors of these wind machines move in columnar way in the course of wind. Generally VAWTs would be categorized in three important types and presented in Fig.3:

a) Darrieus rotor or D-rotor
b) Savonius rotor or S-rotor
c) H-Darrieus rotor

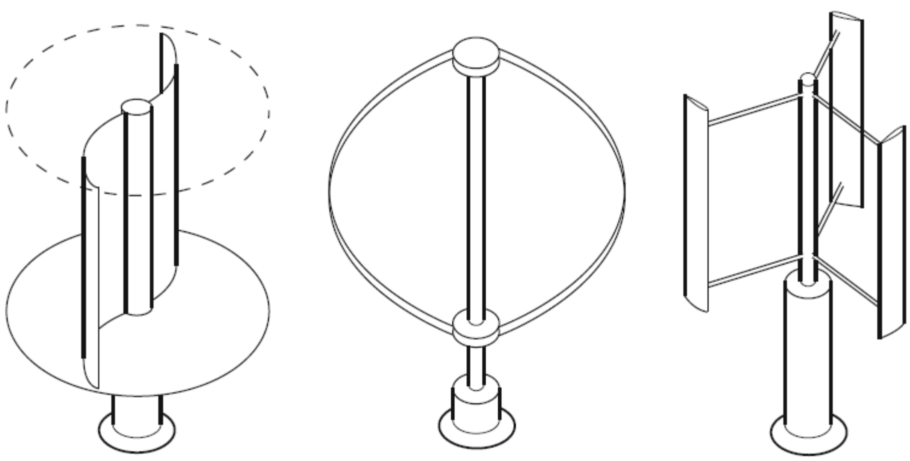


Figure 3: Different types of VAWT [22]

As it is seen in the figure above, Savonius turbines have S-shape form. These drag-type VAWTs rotate comparatively slow, though, give a high torque. They are helpful in pumping water, grinding grain and several other chores. However, they become inappropriate for producing electricity in big scale due to but their slow rotational speed.

Darrieus turbines are the most well-known vertical axis wind turbines. They are generally distinguished by their C-shape rotor blades which makes them have egg beater look. They are typically made of two or three blades. Darrieus turbines are not self operating. They must commence turbines prior to wind start rotating them. Figure 4 and 5 illustrate C-shape and Straight blade VAWTs.

Figure 4: C-shape VAWT [26]

Figure 5: Straight blade VAWTs [27]

Advantages and disadvantages of VAWTs are described in the following sub sections.

3.1.2.1 Advantages

a) Absorbing wind from all angles

b) Their pieces are of ability to be installed on ground level which cause lighter weight towers and easiness in servicing

c) Ability to absorb the same amount of wind with fewer materials

d) Being economical thanks to less height requirement for efficient function.

e) Not required a motor to spin rotor blades.

f) Trouble-free frequent maintenance because of their pieces placed below the vertical rotor shaft

g) Minute possibility of structural malfunction [26].

3.1.2.2 Disadvantages

a) Their rotors are characteristically close to ground level where wind is poor

b) Centrifugal force affects the blades

c) Weak self-running ability

d) They need support at top of turbine rotor

e) They need the whole rotor to be detached in order to change bearings

f) Generally weak reliability and function

g) Commercially unsuccessful

h) In comparison to HAWTs, they produce just half amount of energy.

i) Lack of ability to control winds at higher altitudes which is because of smaller height.

j) Absolute breakdown for maintenance [26].

Wind turbines components have been shown in Fig.6 and table 1 shows the comparison of wind turbines features.

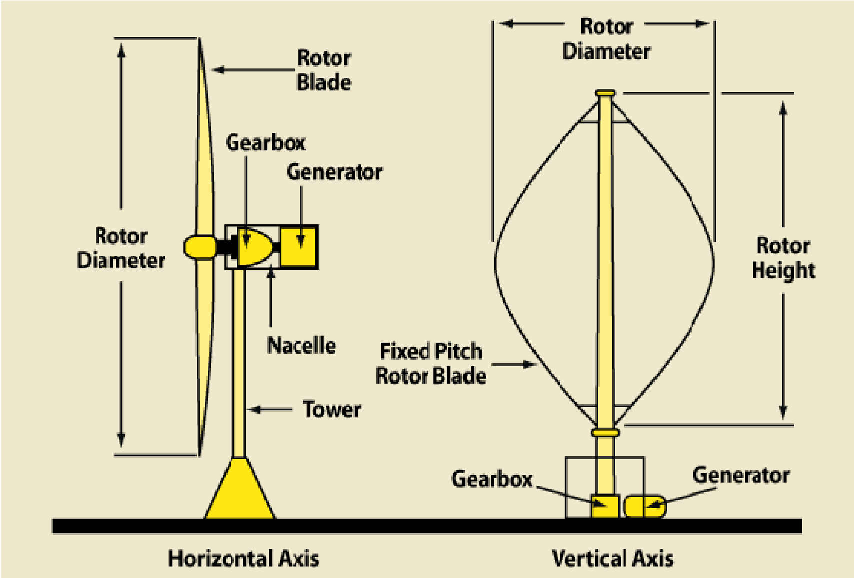


Figure 6: Key components of HAWT and VAWT [25]

Table 1: The Comparison of HAWT, H-rotor, Darrieus, Savonius wind turbines [25]

Features	H- rotor	Darrieus	Savonius	HAWT
Blade Profile	Moderate	Complicated	Simple	Complicated
Tower	Yes	No	No	Yes
Guy Wires	Optional	Yes	Yes	No
Noise	Low	Moderate	Moderate	High
Blade area	Moderate	Large	Large	Small
Blade load	Moderate	Low	Low	High
Generator position	On ground	On ground	On ground	Top of tower
Self starting	No	No	No	Yes
Tower interference	Small	Small	Small	Large
Foundation	Moderate	Simple	Simple	Extensive
Overall structure	Simple	Simple	Simple	Complicated
Yield/ size	<1kW	~kW	<1kW	1W to 8MW
Yaw mechanism needed	No	No	No	Yes

3.2 Wind Turbines Subsystems

The wind turbine subsystems are:

a) A nacelle includes the major pieces of a wind turbine, containing electrical generator and gearbox.

b) A wind turbine tower has the rotor and the nacelle. Normally, having a high tower is considered a benefit; because wind speeds enhance further away from the ground level.

c) The rotor blades absorb the energy of wind and then convey its power to the rotor hub.

d) The generator changes the mechanical energy obtaining from the rotating shaft into the electrical energy.

e) The gearbox enhances the rotational speed of the shaft in favor of the generator [25-28].

Figure 7 shows different pieces of a wind turbine.

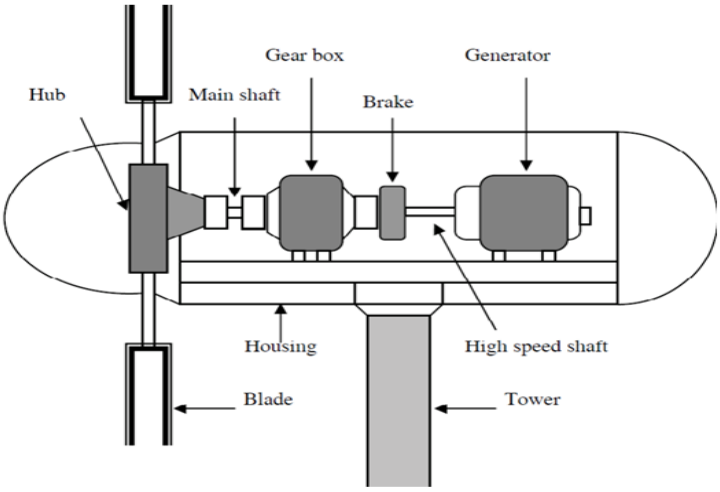


Figure 7: Basic wind Turbine Pieces [19].

3.3 Wind Turbines Categorization

3.3.1 Micro Scale Wind Turbines

Micro wind turbines have the suitability for the sites in which the electrical grid is not accessible. They may also be utilized in a per-structure basis, including water pumping, street lighting, and residents in isolated regions, predominantly in developing countries. They also have comparatively low cut-in speed in a start-up and works in normal wind speeds [25].

3.3.2 Small Scale Wind Turbines

IEC characterizes micro wind turbines as wind turbines having a rotor swept parts no larger than 200 m^2. These turbines are widely utilized on farms, residential buildings and other personal isolated purposes (in rural regions) like telecom sites, water pumping stations, etc. The Distribution of micro wind turbines could also enhance the electricity supply in the areas whilst avoids or postpones the demand to enhance the transmission lines capacity [29].

3.3.3 Medium Scale Wind Turbines

Medium wind turbines are the most widespread turbines. They could be utilized either off-grid or on-grid systems for wind power plants, hybrid systems distributed power, village power and etc [25-28].

3.3.4 Large Scale Wind Turbines

Recently, multi-megawatt wind turbines have turned out to be the summit of the international market of wind power systems. Majority of wind farms currently take advantage of megawatt wind turbines, particularly in off-shore wind farms [25-28].

3.3.5 Ultra-large Scale Wind Turbines

Ultra-large wind turbines are currently under research or initial phases of development [25-28].

3.4 Wind Turbine Comparison

VAWT and HAWT are two main types of turbines employed in power generation.

They have some advantages and disadvantages as following:

VAWT:

a) Low-cost

b) Simplicity in design

c) Easy to assemble or to install

d) Inefficient (10%)

e) Probable Safety Hazard

HAWT:

a) Safe

b) Efficient (35%)

c) Reliable

d) Complicated Installation

e) Expensive to attain optimal efficiency

f) More complicated design

McIntosh explains that the design of a wind turbine that works effectively in urban regains, causes a serious challenge; although, the wind in the environment is defined by several factors including quick shifts in speed and direction [30]. According to this wind circumstances, vertical-axis wind turbines could present numerous advantages comparing to horizontal-axis wind turbines. This occurs since vertical-axis turbines do not need a yaw control system, while, horizontal-axis wind turbines need to be rotated in order to track shifts in wind direction. Moreover, the gearbox and the generator of vertical-axis turbines could be placed on the bottom of turbines that results in decreasing the loads on the tower of turbines under uneven wind circumstances, and in easing the system maintenance. The major benefit of the characteristics of a vertical-axis configuration is enabling a fairly more compact design which reduces the pressure over the tower and the need for fewer mechanical pieces in comparison to a horizontal-axis turbine.

Chapter 4

CYPRUS AND WIND ENERGY

The employment of renewable energy solutions in Cyprus is considered as one of the possible ways to increase independency from the imported fuels. Similar to the Northern Cyprus, by the year 2020, the aim of 13% production of gross electricity has been fixed to be attained by renewable energy resources for every European climate change program, in the Southern Cyprus as a member of the EU [1].

Regarding the investment and employment of the renewable technologies, the lack of exact and trustworthy data about the performance and the cost details of the renewable power production technologies has been an important obstacle for the uptake of these technologies [1].

Far from any accessibility to trustworthy data about the related benefits and cost of renewable energy technologies, it would be quite demanding– if not unattainable– for financers, investors or government authorities to reach a precise evaluation of what shows that how renewable energy technologies are the most suitable ones based upon duration, operation, technical and finance issues [1].

4.1 Current Electricity Production and Corresponding CO_2 Emissions in Cyprus

The generation of electricity, in the Northern Cyprus is controlled and even owned by the government that is named "Electricity Authority of Northern Cyprus($KIBTEK$)." It bears the total capacity of $347.5MW$ generation of electricity [31].

Table 2 shows the breakdown of electricity generation in type and their capacity per station in Northern Cyprus. It should be noted that this table excludes any available renewable energy power generation stations as they are excluded from the capacity contributing the available generation capacity [1].

Table 2: Breakdown of electricity generation in type and capacity per station in Northern Cyprus [31].

	KIBTEK/ Teknecik	KIBTEK/ Dikmen	AKSA/ Kalecik	Total
Steam Turbine	120 MW			120 MW
Gas Turbine	50 MW			50 MW
Diesel Engine	70 MW	20 MW	87.5 MW	177.5 MW
Installed Capacity	240 MW	20 MW	87.5 MW	347.5 MW
Available Capacity	217MW	20 MW	87.5 MW	324.5 MW

"European Environment Agency" (EEA) presented data about CO_2 produced electricity per kilo-Watt hour in 2009 for every individual in the land, shows that Cyprus is Europe's one of the topmost emission generators with $0.67\ kg$ per kWh [36]. The two major reason for this issue are that the island's electricity production has been isolated and also it is completely dependent on imported oil [1].

4.2 Electricity Consumption of a Typical Household in Cyprus

The survey "Final Energy Consumption in Households" [1] was conducted in the South Cyprus by Statistical Service in 2009 for the first time. This survey did address the households in which inhabitants contained permanent of normal residency in the island far away their origin country or citizenship. The sample of the survey included 3300 households which were distributed in administrative areas and districts in both rural and urban regions. It was also representing the structure of population.

According to the results obtained and in terms of electricity and other energy resources, a usual household in the island used $6288\,kWh$ per year. In terms of electricity and other energy sources, the yearly usage of a typical household for home heating was moderately $642\,kWh$. The percentage of households utilizing air-conditioner throughout the warm months of a year was 80% which is very high. In average, during the warm months of the year, $50m^2$ out of $168m^2$ of houses could be kept cool, because the cooling systems of the 70% of these houses were installed during the last decade. In general, in order to cool down a space, the yearly energy usage of a normal household is $1.107kWh$, whereas the installed capacity of air conditioners for every household is averagely around $9.47\,kW$. Moreover, every typical household in average uses $382kWh$ of electricity as the major energy resource in addition to other energy sources. On the other hand the consumption of energy for cooking aims shoed to be mainly high for every household. The survey suggested that the cooking aims use $554kWh$ of electricity averagely, in addition to, other energy sources.

Based upon the electricity usage for the purpose of running lightning and electrical appliances, it is predicted that a usual household uses $3603kWh$ per year. All households are almost furnished with dish washers 93.7%, electronic iron 96.2%, freezer/refrigerator 99% and TV sets 99.1%. On the other hand, the usage of dishwashers 44.6%, cloth dryers 30.5% and satellite dished 29.9% are less widespread. Therefore, the electrical devices which have more frequent usages on the basis of a week period are washing machines 7 hours, computers 31 hours and TV sets 46 hours [5]. In table 3 it is shown the electricity usage of the final energy consumption in household in Cyprus in 2009.

Table 3: Breakdown of the electricity usage of the Final Energy consumption in Household in Cyprus in 2009 [1]

Energy Usage	Electricity (kWh)	Electricity (%)
Space Heating	642	10.21
Water Heating	382	6.08
Space Cooling	1107	17.60
Cooking	554	8.81
Electrical Application and Lighting	3603	57.30
Total	6288	100

4.3 Electricity Demand in Cyprus

The demand for domestic electricity is enhanced considerably in the period of summer. This is due to the enhanced usage of air-conditioners (AC) that dramatically alter the thermal comfort demands for the population of urban regions in developed countries [1].

Domestic demand is 36% of whole electricity usage [32] in the Southern Cyprus; while this percentage for the Northern Cyprus is 32% [31]. The electricity consumption for lightening of streets is 2% in both South and North Cyprus. In contrast, industry owns 18% in South Cyprus which is higher than that of North Cyprus with 8%. The percentage for agricultural affairs, on the other hand, is 6% in North Cyprus while it is 3% in South Cyprus. Distribution and transmission losses are the other major differences between two parts of the island. The claimed losses on North Cyprus reach to 15%, while this percentage for South Cyprus is 3% which is lower than the North part [1].

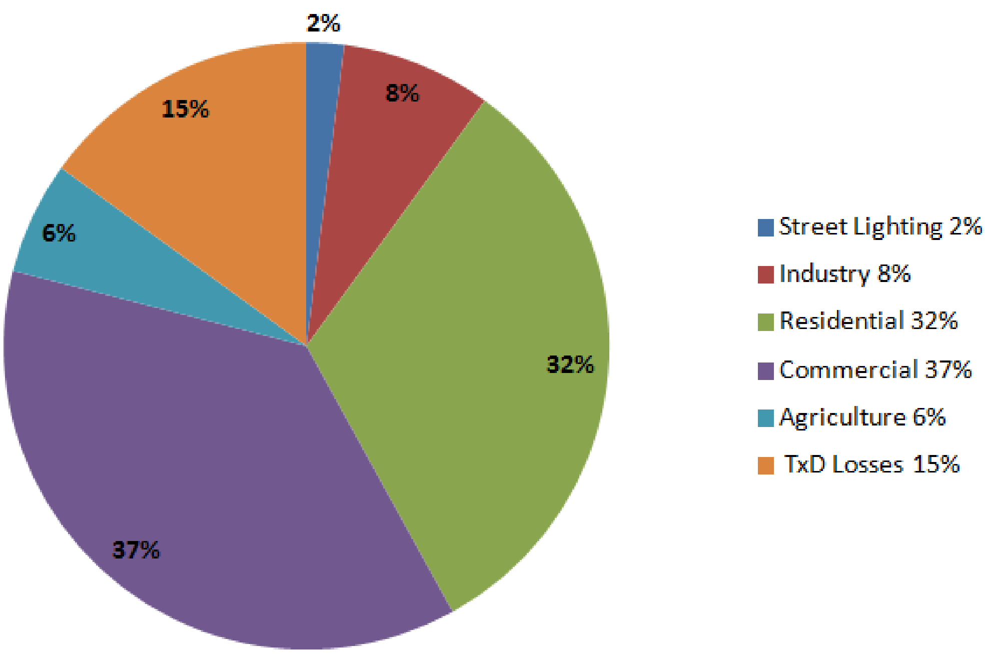


Figure 8: The breakdown of total electricity demand in terms of customer types of Northern Cyprus in 2010 [31].

In year 2010 the Electricity Authority of Northern Cyprus ($KIBTEK$) presented the data in which the energy demand for North Cyprus was $1243 GWh$. This number equals to 4.5% of the total demand. If there is no alternation in the mentioned amount of demand, by the year 2020 it would increase to 45% in electricity usage. Besides, M. Ilkan et al in their research reported that "The growth in annual electricity demand of the Turkish Republic of Northern Cyprus (TRNC) would be approximately 3.3% until 2020" [24]. Moreover, they concluded that the energy demand in the North Cyprus was $1243\ GWh$ and 3.3% which equals to nearly $41050\ MWh$ or $41\ GWh$. They showed that this enhance in demand by year 2020 is going to be26%. Table 4 is the summary of survey results of the Final Energy Consumption in Households of Cyprus conducted in 2009.

Table 4: Summary of survey results of the Final Energy Consumption in Households of Cyprus conducted in 2009 [1].

Energy Usage	**Electricity (kWh)**	**Electricity (%)**
Space Heating	642	10.21
Water Heating	382	6.08
Space Cooling	1107	17.60
Cooking	554	8.81
Electrical Appliances & Lighting	3603	57.30
TOTAL	6288	100

The indication from the various studies and the current trends of the increased electricity demand is that the electricity demand will be increased in the coming years if no changes are introduced. This rise can range from 33% to 46% for the Northern Cyprus and 36% to 53% for the South Cyprus until 2020 compared with the electricity demand of the year 2010 [1].

4.4 Wind Resource in Cyprus

Meteorological services have gathered a mean annual wind speed map related to Cyprus under the Ministry of Agriculture of South Cyprus. The gathered map is shaped through the mean annual wind speed (m/s) for the period from 1982 to 1992. This map shown at figure 9 suggests that plain areas of the island include mainly mean wind speed varying from 3 to 4 m/s and areas near the coast bays include mean speed range of 4 to 5 m/s [33].

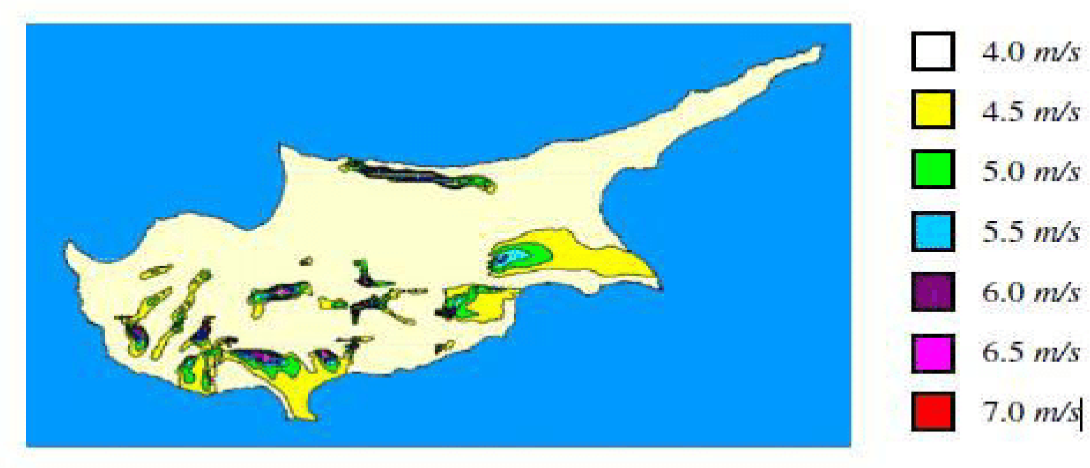


Figure 9: Cyprus mean annual wind speed (m/s) [33]

Figure 10, 11 and 12 shows the renewable energy capacity, consumption and technologies respectively in Cyprus.

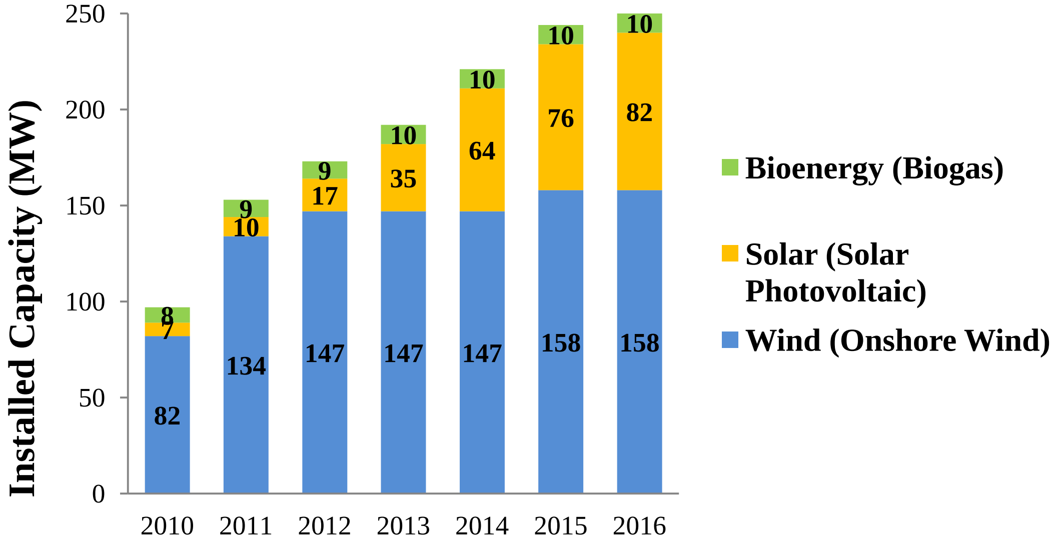


Figure 10: Installed renewable energy capacity in Cyprus between 2010 and 2016 [23]

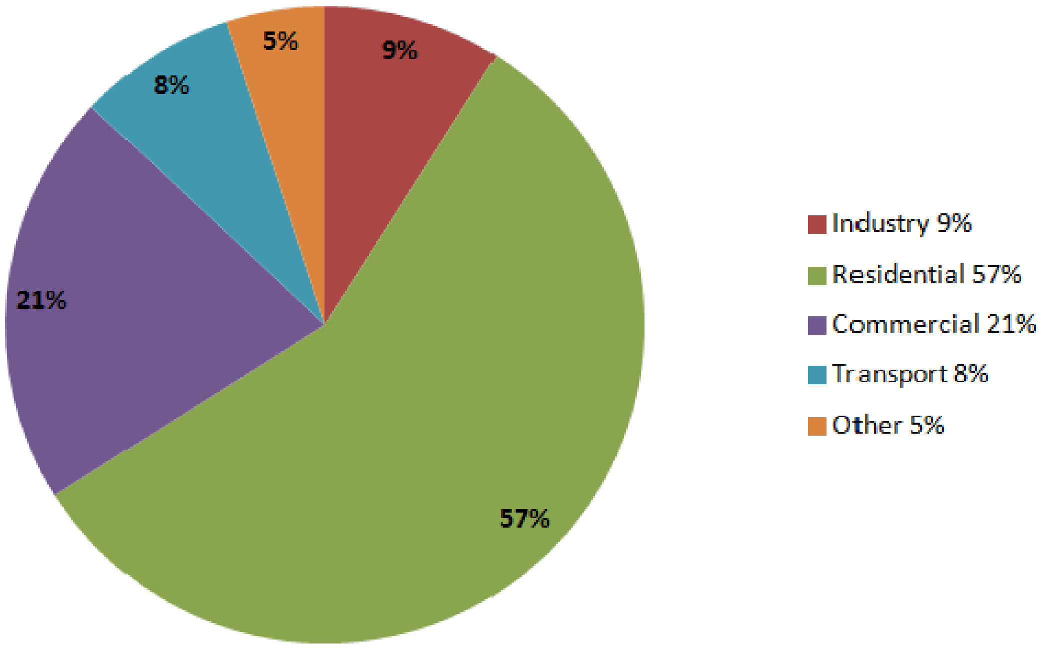


Figure 11: Renewable energy consumption in Cyprus in 2014 [23]

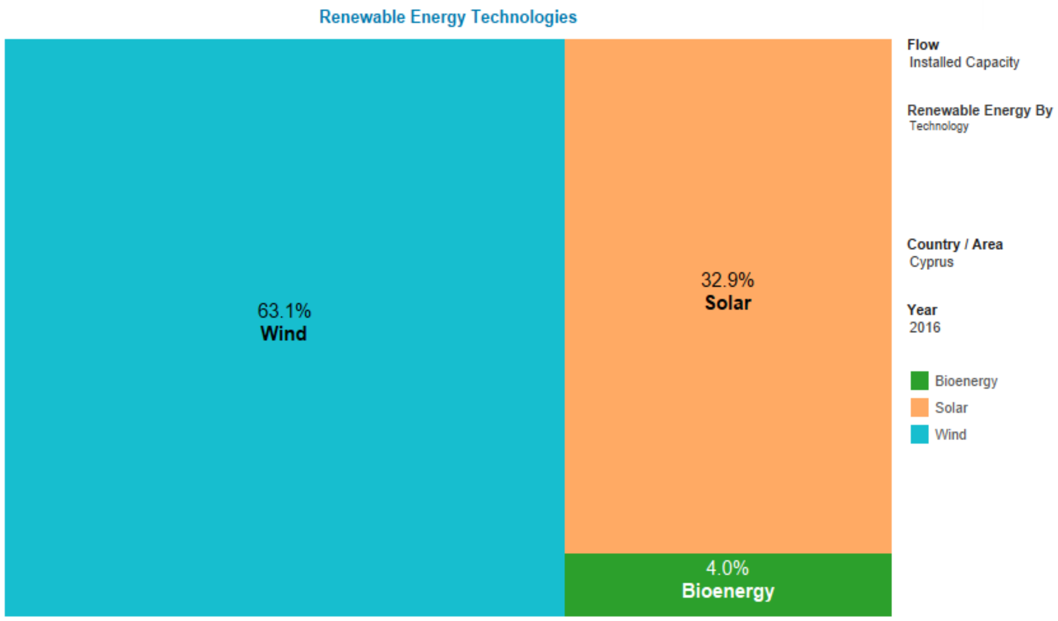


Figure 12: Renewable energy technologies in Cyprus in 2016 [23]

4.5 Wind Power Production in Cyprus

Since 2004 to present, Cyprus Energy Regulatory Authority $(CERA)$ has approved twenty five applications for wind parks with a total capacity of nearly $515\ MW$. On the other hand, because of the complexity of wind parks building, which is due to major barriers existing inside the wind energy incorporation in Cyprus energy system, up to present, there have been solely very few projects which have passed the connection agreement with TSO and solely there is one operational project while some other are under construction.

Up to date in Cyprus, wind farm projects are considered as one of those initial kinds. Although, projects are authorized by CERA, the ultimate law about city building/planning for wind farms has not yet passed and is only under guidance principles so far.

Moreover, present electricity generation is under operation by the electricity authorities in Cyprus. This makes the private systems for operation of big wind production to remain inexperienced and unknown in the industry of Cyprus power. According to wind form operators, the wind farms would be one of those initial commercially projects. Furthermore, staffing and knowledge infrastructures about maintenance, operation and construction need to commence from scratch that would be resulted in the training cost enhance.

Majority of these wind farms in South Cyprus, which bear connection agreement with TSO, are located in Larnaca. This is while, Nicosia bears solely one wind farm. Currently, in North Cyprus, no wind farms are under operation or under construction.

There has been no study or report to suggest the possibility of micro scale wind turbines in North Cyprus. Consequently, the core aim of this ongoing study has been to verify the techno-economic possibility of micro scale wind turbines for domestic usages. This study has been done in order to choose a cost-effective option of micro scale wind turbines.

Chapter 5

ECONOMIC ANALYSIS

5.1 Economic Feasibility Approach

In order to estimate the economic feasibility of micro wind turbines, it is essential to evaluate the annual energy generation and compare with the avoided electricity usage from the grid. For this reason life cycle cost analysis which is summarize is employed in this study [34].

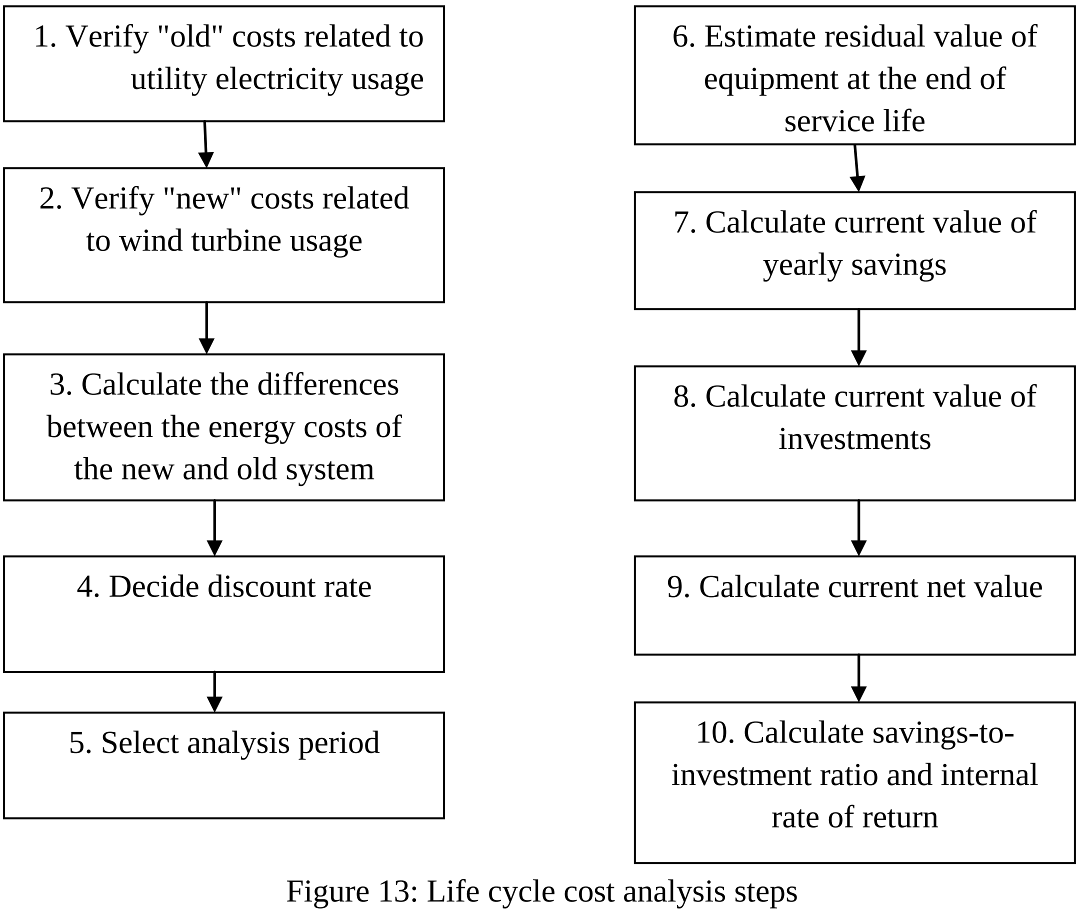


Figure 13: Life cycle cost analysis steps

5.2 Life Cycle Analysis (NPV, SIR, IRR and SP)

Based upon the price of wind turbines, it is estimated and settled a price for wind turbines in the next twenty years. Life cycle analysis is way to set all these inputs. Following the calculation stage, life cycle cost analysis comes up which comprises simple payback, Internal Rate Return (IRR) and Net Present Value (NPV) saving to investment ratio. The simple payback period (SP) is the length of time required to recover the cost of an investment. Internal rate return (IRR) is a discount_rate that makes the net present value (NPV) of all cash flows from a particular project equal to zero. Net present value of a project is the value of all payments, discounted back to the beginning of the investment [34].

$$NPV = \sum \text{PV Annual savings} - \sum \text{PV Life Cycle Investments} \quad (1)$$

$$SIR = \sum \text{PV Annual savings} / \sum \text{PV Life Cycle Investments} \quad (2)$$

$$IRR = Discount\ rate, where\ SIR = 1\ or\ NPV = 0 \quad (3)$$

$$SP = Initial\ investment\ /\ annual\ saving \quad (4)$$

5.3 Micro- Scale Wind Turbines under Study

Six micro scale wind turbines are compared, in this study, which are all accessible on the market: Senwei-V 1kw [35], Zonhan-H 1kW [36], Maglev CXF-V 1kW [37], Airforce1 [38], Aeolos-H 1kw and Aeolos-V 1kW [39].

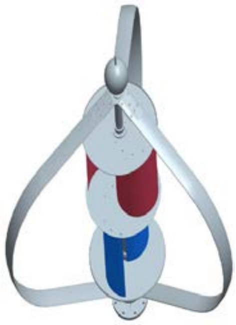
VAWT	 Aeolos-V 1kW [39]	 SW-1kW [35]	 Maglev CXF-1000 [38]
HAWT	 Aeolos-H 1kW [39]	 ZH-1kW [36]	 Airforce1-1kW [38]

Figure 14: Photos of candidate micro scale wind turbines

The major technical features of these six turbines have been recapitulated in table 5 and in table 6 the cost of candidate turbines and maintenance cost are illustrated. The specified cost of every turbine system has been obtained as a quotation from producer's representatives. Similar rated power as $1kW$ is applied for all of them.

Table 5: Technical specification of six candidate micro wind turbines [35-36-37-38-39]

Company Name	Yueqing Zonhan Wind Power Co., Ltd	Senwei Energy Technologies Co., Ltd	Aeolos Wind Turbine	Aeolos Wind Turbine	TYPMAR	Future Energy
Model Name	ZH-1kW	SW - 1kW	Aeolos - H 1kW	Aeolos- V 1kW	CXF-1000	Airforce 1
Turbine Type	HAWT	VAWT	HAWT	VAWT	VAWT	HAWT
Rated Power/Maximum Power	1000/1500 W	1000/1800 W	1000 W	1000/1500 W	1000W	1000W
Blade Material	Reinforced fiber glass	Glass fiber reinforced plastic	Glass fiber	Aluminum Alloy	Anodized Aluminum	Tough glass reinforced nylon
Number of Blades	3	3	3	3	3	3
Rotor Diameter (m)	2.8	3.2	3.2	2.8 (Height)-2 (Width)	2.5	1.8
Rated Wind Speed (m/s)	8	8	8	10	13	12.5
Startup Wind Speed (m/s)	2.5	2.5	2.5	2.5	1.5	3.5
Working Wind Speed (m/s)	3~25	3~20	3~25	3~25	3.5~15	3.5~15
Survived Wind Speed (m/s)	45	45	45	50	50	52
Generator Style	Three phase	Permanent-magnet 120v A.C	3 Phase permanent magnetic 48 VDC	3 Phase permanent magnet	3 phase AC	3 Phase Permanent Magnet
Weight	70kg	68kg	60kg	78kg	180kg	18kg (body)
Tower Height (m)	9	6	9	6	6	6
Life Time	15 years	20 years	25	20	20	20
Standards	EN 12100-1 :2003, EN 12100-2 :2003, EN 60204-1 :2006, EN 60034-1 :2004, BS EN 61400-2 :2006	IEC61400-2	CE	CE	CE,TUV, IEC	CE

Table 6: Cost of six candidate wind turbines [35-36-37-38-39]

Wind Turbine	ZH-1Kw	SW-1kW	Aeolos-H 1kW	Aeolos-V 1kW	CXF-1000	Airforce 1
Maintenance Cost	Every 5 years $100	Every 5 years $100	Every 5 years $100	Every 5 years $100	Every 5 years $100	Every 5 years $100
Turbine Body Price (Blades/Hub,Generator,Rotatory Body, Accessories)	$497	$390	$1586	$3100	$3017	$3648
Wind Turbine Tower Price	$230 (9m)	$157 (6m)	$1550 (9m)	$1120 (6m) +$ 560 (2m Roof Top Tower)	$1100 (6m)	$198 (6m)
Charge Controller Price	$196 (24V)	$354	$330	$560	$326	$221
Grid connected Inverter	$1133 (3kW option)	$520 (1.5kW option)	$2240	$2240	$500	$1000
Ex- Factory Price	$2056	$1421	$5706	$7580	$4943	$5067
Freight and Custom (%30 of Ex factory price)	$616.8	$426.3	$1711.8	$2274	$1482.9	$1520.1
Cost of Importing Wind Turbine	$2672.8	$1847.3	$7417.8	$9854	$6425.9	6587.1
Retail Price	$5345.6	$3694.6	$14835.6	$19708	12851.8	13174.2

Figure 14 shows the annual energy output of candidate turbines in different wind speeds. The information about the turbines was received from the related companies. The amount of annual energy output of candidate wind turbines was calculated by multiplying power of wind turbine in different wind speeds with $8760h$.

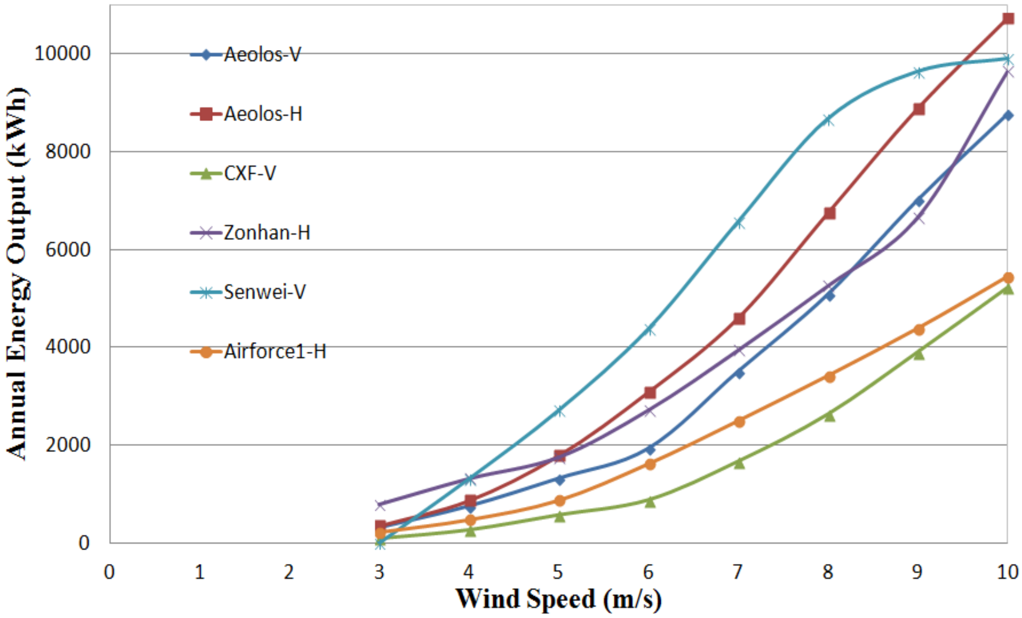


Figure 15: Total Annual Energy curve [35-36-37-38-39]

5.4 Wind Turbine Cost

The installed cost of a wind power project is dominated by the upfront capital cost for the wind turbines (including towers and installation) and this can be as much as 84% of the total installed cost. Similarly to other renewable technologies, the high upfront costs of wind power can be a barrier to their uptake, despite the fact there is no fuel price risk once the wind farm is built. The capital costs of a wind power project can be broken down into the following major categories:

a) The turbine cost: including blades, tower and transformer;
b) Civil works: including construction costs for site preparation and the foundations for the towers;
c) Grid connection costs: This can include transformers and substations, as well as the connection to the local distribution or transmission network; and
d) Other capital costs: these can include the construction of buildings, control systems, project consultancy costs, etc.

Capital cost estimates for distributed generation renewable energy technologies illustrates in fig.15.

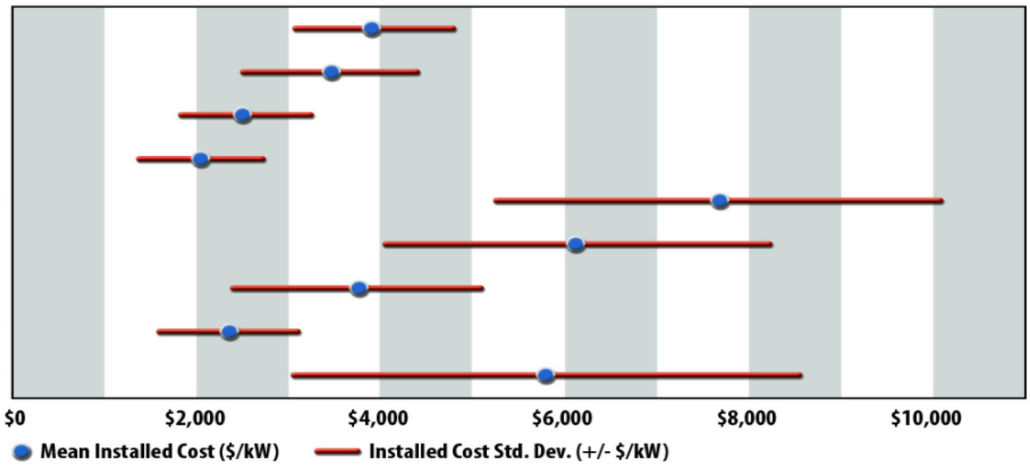


Figure 16: Indicates recent capital cost estimates for distributed generation renewable energy technologies [40].

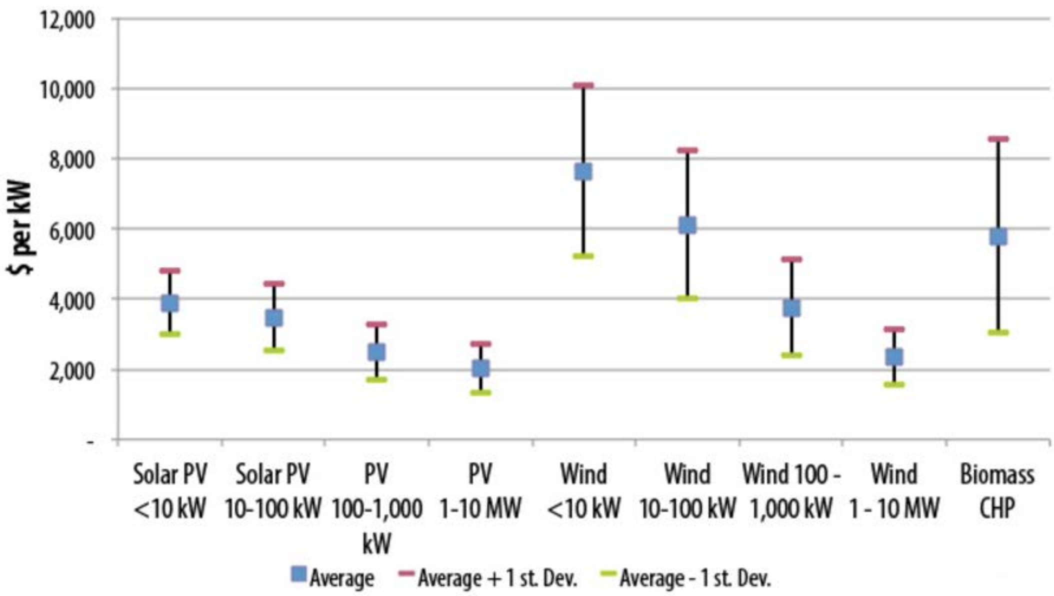


Figure 17**:** Installed Costs for Electric Generating Technologies [40]

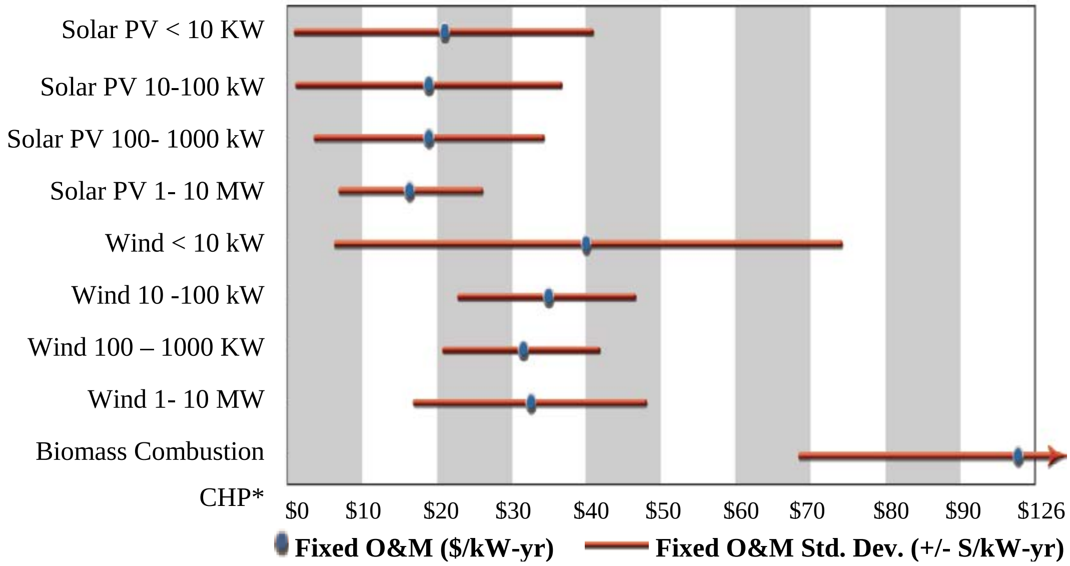


Figure 18: Shows recent operations and maintenance (O&M) cost estimates for distributed generation renewable energy technologies [40]

In this study the investment costs of the opted wind turbine are verified in steps one and two. The cost of wind turbines can be broken down into these components. These components are turbine price, installation cost, maintenance, tax and freight cost. Turbine initial cost includes turbine body, blades, inverter, tower and battery. For micro wind turbine the installation process it is too simple and the owner can install it easily according to installation manual which company provide it. In this thesis every 5 years, 100 USD considered as maintenance cost for micro wind turbines and for tax and freight cost 30% of turbine initial cost is considered. One of the computations for retail price is as follows:

Factory price of Aeolos-H= 5706 USD

Freight + Custom = 30% of factory price =5706 × 0.3= 1711.8

Retail Price= (5706+ 1711.8) × 2= 14835.6 USD

5.5 Annual Savings and Discount Rate

The annual savings are analyzed in the third step. Here, the mean wind speed in the island is verified as $4\ m/s$. The analysis has been done for 3m/s to 8 m/s to determine the most profitable turbine for different wind speeds. In addition, for this wind speed, the annual energy output (kWh) is verified for every wind turbine data attained from producer's depiction. It is calculate the annual savings by multiplying annual energy output in the cost of electricity (USD/kWh) in the island. Government has decided enter Feed-in tariff for renewable energy production in Cyprus, however the details of the tariff is not finished yet, but it is assumed 0.25 Turkish lira which is 0.07 USD in this project. The electricity price in Cyprus is 0.15 USD. So it is decided 0.07+ 0.15= 0.22 USD as electricity price for calculating the annual savings. The discount are based upon the conditions in Cyprus is verified in the following step. This discount is10%. A period of twenty years [40] is settled as the analysis period in this study.

$$\text{Annual Savings (USD)} = \text{Annual energy output} \times \text{Price of Electricity} \tag{5}$$

Chapter 6

RESULTS AND DISCUSSION

In the following chapter, the results of economic analysis, based upon the input factors explained in the previous chapter, are discussed. According to the objective of this study, the aim of this thesis is to verify the economic possibility of micro scale wind turbines for the North Cyprus at different wind speeds.

To advise an appropriate micro scale wind turbine, an analysis has been conducted. Technical features of micro wind turbines have been attained from several producers in order to investigate. The decided micro wind turbines have been compared according to the saving to investment ratio and the retail price. The analysis has been done for 3m/s to 10 m/s wind speed considering with Feed in tariff and without Feed in tariff.

Tables and figures below suggest a summary of the results attained from the calculations of NPV. Thus, the NPV is for the period of twenty years for various kinds of micro wind turbines.

6.1 Scenario A: Results with Considering Feed in Tariff

Table 7: NPVs, SIRs and SPs of Wind Turbines at 3m/s

Turbines	Aeolos – H	Aeolos – V	Maglev CXF - V	Zonhan - H	Snewei – V	Airforce1
Net Present Value (NPV)	-$14260	-$19208	-$12769	-$3948	-$3774	-$12828
Savings-to-Investment Ratio	0	0	0	0.3	0	0
Simple Payback (years)	192.7	289.8	676.4	30.8	-	263.5
Total Investment Cost (USD)	14835.5	19708	12851.8	5346	3694.3	13174.2

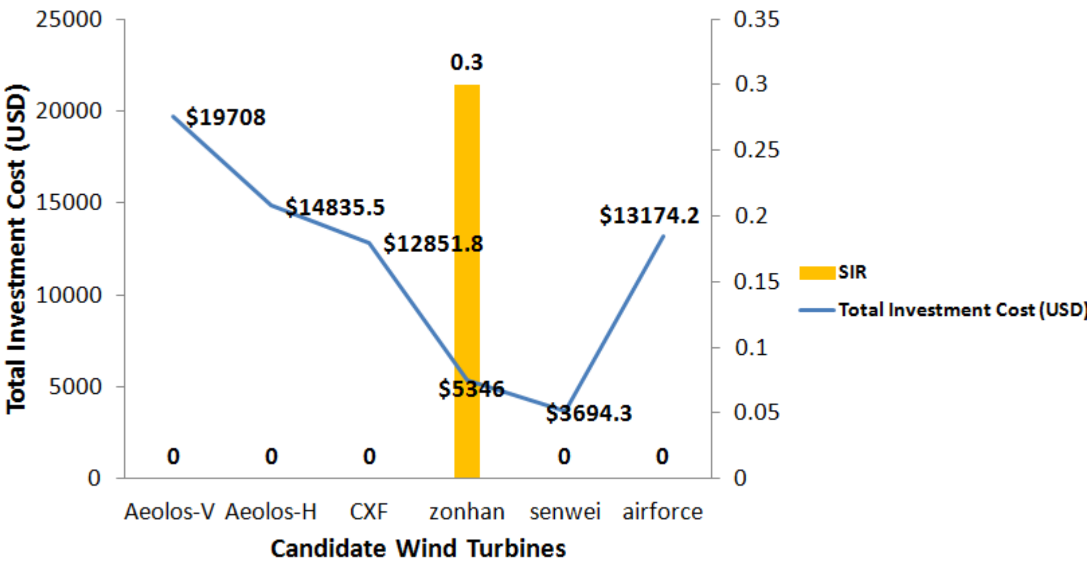


Figure 19: SIR vs total investment cost at 3m/s Wind Speed

Table 6 and Fig. 18 show the results of analysis at 3m/s wind speed. According to these results selected wind turbines in this range of price and power are not feasible for this wind speed because SIR is less than 1 and NPV for all the models in negative.

Table 8: NPVs, SIRs and SPs of Wind Turbines at 4m/s

Turbines	Aeolos – H	Aeolos – V	Maglev CXF - V	Zonhan - H	Snewei - V	Airforce1
Net Present Value (NPV)	-$13289	-$18382	-$12437	-$2964	-$1314	-$12351
Savings-to-Investment Ratio	0.1	0.1	0	0.5	0.7	0.1
Simple Payback (years)	77.7	119.4	221.6	18.5	12.8	124.3
Total Investment Cost (USD)	14835.5	19708	12851.8	5346	3694.3	13174.2

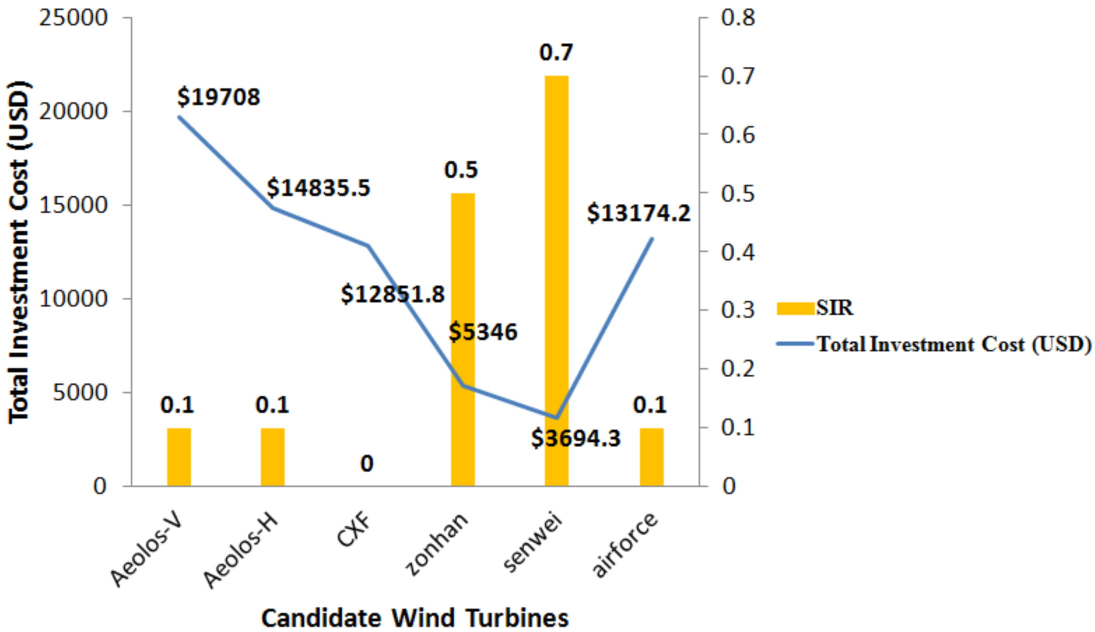


Figure 20: Savings to Investment Ratio vs Price at 4m/s Wind Speed

At 4 m/s wind speed which is mean wind speed of Cyprus still there is not any affordable model from candidate micro wind turbines with these prices.

Table 9: NPVs, SIRs and SPs of Wind Turbines at 5m/s

Turbines	Aeolos – H	Aeolos – V	Maglev CXF - V	Zonhan - H	Snewei – V	Airforce 1
Net Present Value (NPV)	-$11568	-$17327	-$11867	-$2144	$1309	-$11610
Savings-to-Investment Ratio	0.2	0.1	0.1	0.6	1.3	0.1
Simple Payback (years)	37.7	68.2	102.8	13.9	6.2	68.3
Total Investment Cost (USD)	14835.5	19708	12851.8	5346	3694.3	13174.2

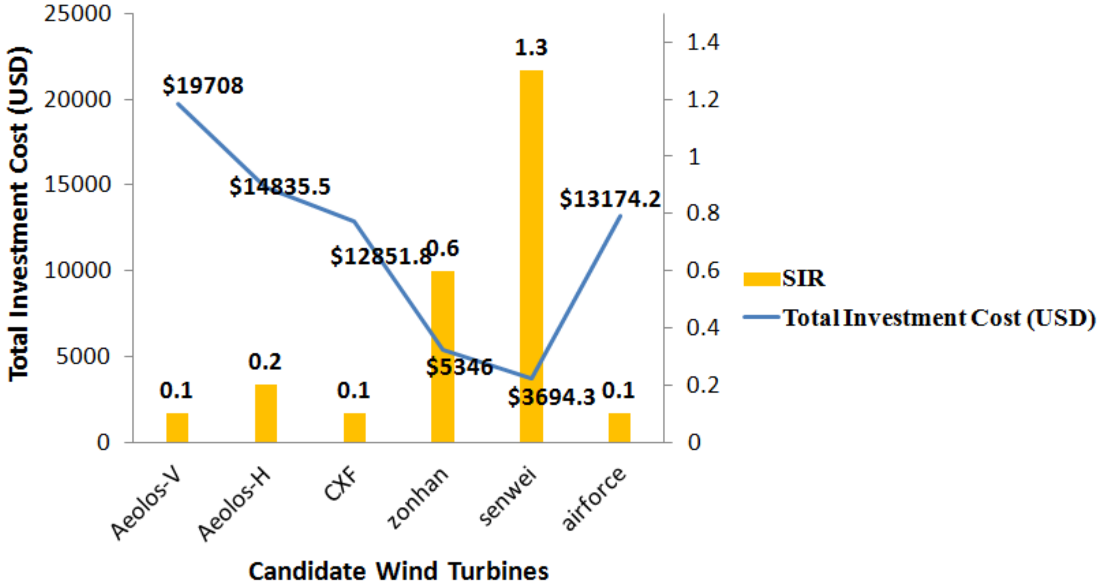


Figure 21: Savings to Investment Ratio vs Price at 5m/s Wind Speed

SW-1kW Vertical axis wind turbine with SIR= 1.3 at 5 m/s wind speed is economically feasible in Cyprus where the wind speed is 5 m/s.

Table 10: NPVs, SIRs and SPs of Wind Turbines at 6m/s

Turbines	Aeolos – H	Aeolos – V	Maglev CXF - V	Zonhan - H	Snewei - V	Airforce 1
Net Present Value (NPV)	-$9134	-$16177	-$11288	-$339	$4433	-$10214
Savings-to-Investment Ratio	0.4	0.2	0.1	0.9	2.2	0.2
Simple Payback (years)	21.8	46.5	66.6	8.9	3.8	36.9
Total Investment Cost (USD)	14835.5	19708	12851.5	5346	3694.3	13174.2

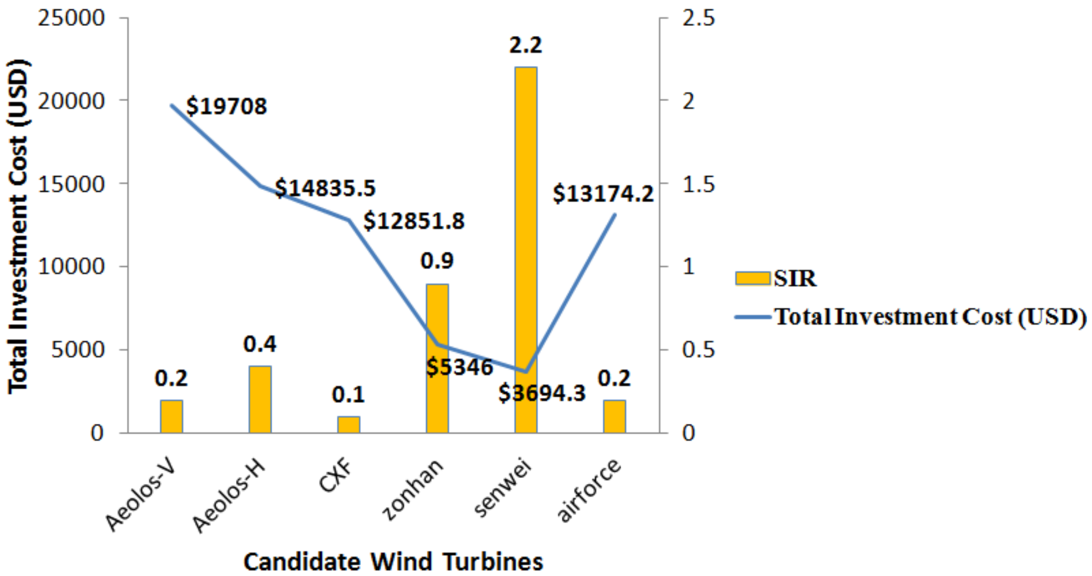


Figure 22: Savings to Investment Ratio vs Price at 6m/s Wind Speed

SW-1kW micro wind turbine is economically feasible for the sites with 6 m/s wind speed. According to results simple payback period and SIR for this turbine in this wind speed respectively are 3.8 and 2.2.

Table 11: NPVs, SIRs and SPs of Wind Turbines at 7m/s

Turbines	Aeolos – H	Aeolos – V	Maglev CXF – V	Zonhan - H	Snewei - V	Airforce1
Net Present Value (NPV)	-$6299	-$13223	-$9815	$1958	$8528	-$8579
Savings-to-Investment Ratio	0.6	0.3	0.2	1.4	3.3	0.4
Simple Payback (years)	14.7	25.6	35.1	6.2	2.6	24
Total Investment Cost (USD)	14835.5	19708	12851.8	5346	3694.3	13174.2

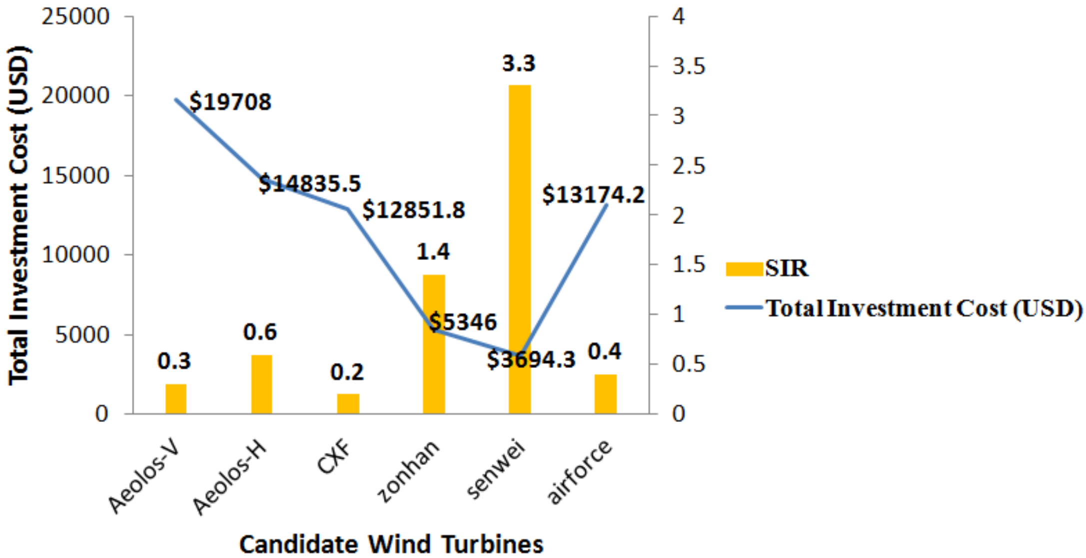


Figure 23: Savings to Investment Ratio vs Price at 7m/s Wind Speed

At 7 m/s wind speed two of the candidate models are become feasible, ZH-1kW horizontal axis wind turbine with SIR= 1.8 and SW-1kW vertical axis wind turbine with SIR= 4.3.

Table 12: NPVs, SIRs and SPs of Wind Turbines at 8m/s

Turbines	Aeolos – H	Aeolos – V	Maglev CXF – V	Zonhan - H	Snewei - V	Airforce1
Net Present Value (NPV)	-$2282	-$10272	-$8010	$4419	$12470	-$6851
Savings-to-Investment Ratio	0.8	0.5	0.4	1.8	4.3	0.5
Simple Payback (years)	10	17.6	22.2	4.6	1.9	17.5
Total Investment Cost (USD)	14835.5	19708	12851.8	5346	3694.3	13174.2

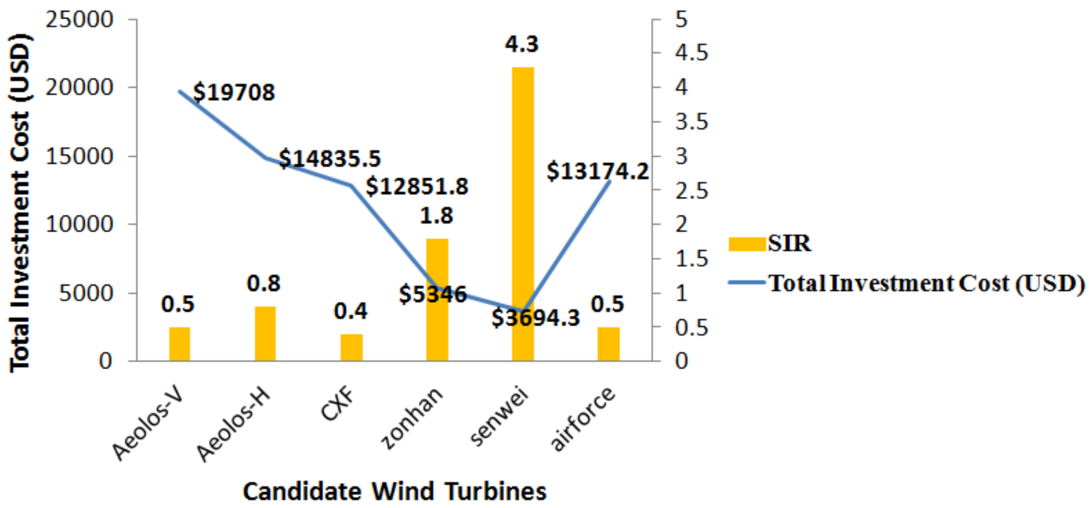


Figure 24: Savings to Investment Ratio vs Price at 8m/s Wind Speed

SW-1kW with SIR= 3.3 and simple payback period= 1.9 is more affordable than ZH-1kW with SIR= 1.4 and simple payback period= 4.6 at 8 m/s wind speed.

Table 13: NPVs, SIRs and SPs of Wind Turbines at 9m/s

Turbines	Aeolos – H	Aeolos – V	Maglev CXF – V	Zonhan - H	Snewei - V	Airforce1
Net Present Value (NPV)	$1720	-$6661	-$5630	$7045	$14275	-$5046
Savings-to-Investment Ratio	1.1	0.7	0.5	2.3	4.8	0.6
Simple Payback (years)	7.6	12.8	15	3.6	1.7	13.7
Total Investment Cost (USD)	14835.5	19708	12851.8	5346	3694.3	13174.2

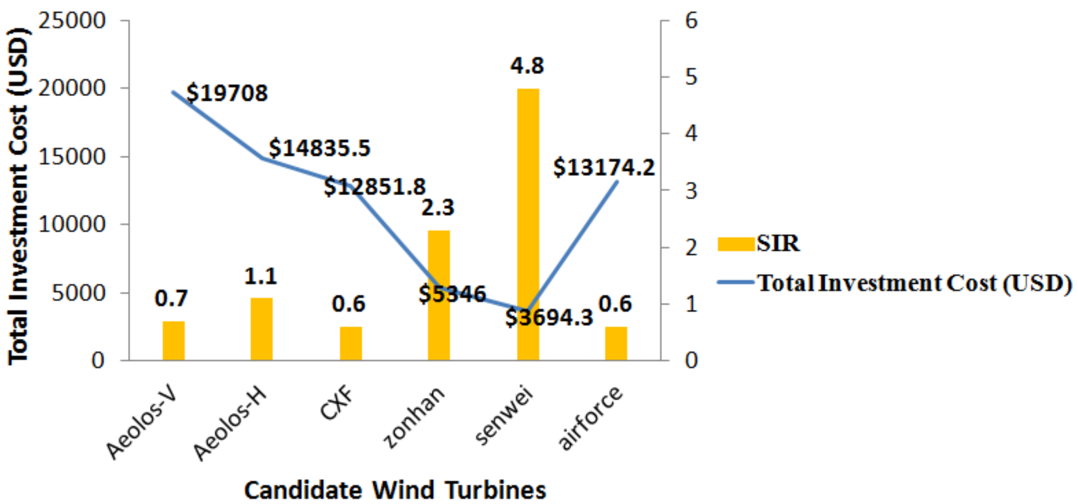


Figure 25: Savings to Investment Ratio vs Price at 9m/s Wind Speed

SW-1kW, ZH-1kW and Aeolos-H are economically feasible at 9 m/s wind speed with SIR above than 1 and positive NPV values.

Table 14: NPVs, SIRs and SPs of Wind Turbines at 10m/s

Turbines	Aeolos – H	Aeolos – V	Maglev CXF – V	Zonhan - H	Snewei - V	Airforce1
Net Present Value (NPV)	$5167	-$3381	-$3166	$12623	$14768	-$3080
Savings-to-Investment Ratio	1.3	0.8	0.8	3.3	4.9	0.8
Simple Payback (years)	6.3	10.2	11.2	2.5	1.7	11
Total Investment Cost (USD)	14835.5	19708	12851.8	5346	3694.3	13174.2

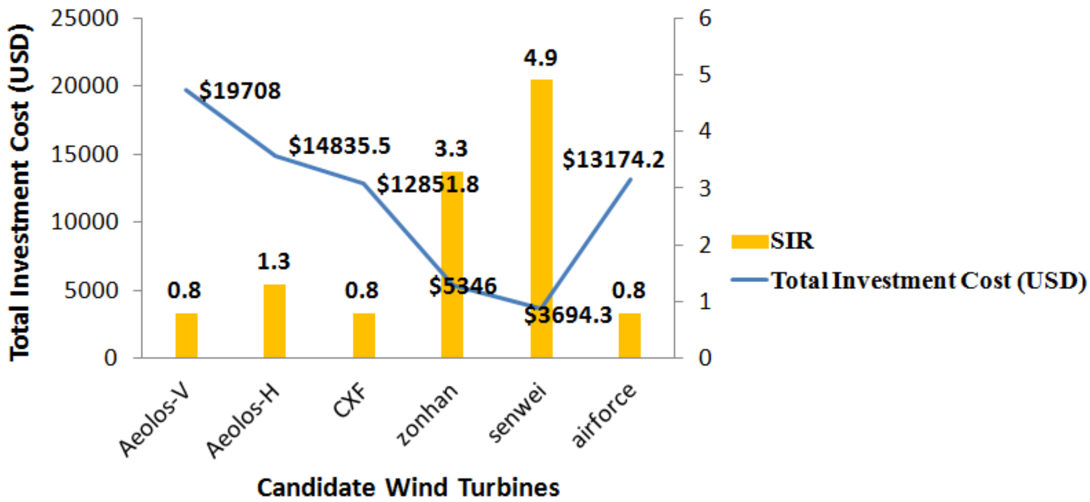


Figure 26: Savings to Investment Ratio vs Price at 10m/s Wind Speed

At 10 m/s wind speed Aeolos-H with SIR=1.3, ZH-1kW with SIR=3.3 and SW-1kW with SIR=4.9 are affordable micro wind turbines.

According to these results with considering the feed in tariff at 4m/s wind speed which is mean wind speed of Cyprus with this range of prices there is no feasibility of 1kW micro wind turbines, SW-1kW, VAWT is profitable for sites with wind speed above than 4 m/s. At 7 m/s and above than this wind speed ZH-1kW HAWT also becomes economically feasible. Aeolos-H which is the HAWT is affordable at 9 and 10 m/s wind speed.

6.2 Scenario B: Results without Considering Feed in Tariff

The below tables and figures are for economic analysis results for without considering feed in tariff, in this case feasibility starts from 6 m/s mean wind speed with SW-1kW wind turbine model and it continues with ZH-1KW at 8m/s mean wind speed.

Table 15: NPVs, SIRs and SPs of Wind Turbines at 3m/s

Turbines	Aeolos – H	Aeolos – V	Maglev CXF – V	Zonhan - H	Snewei - V	Airforce1
Net Present Value (NPV)	-$14468	-$19395	-$12819	-$4418	-$3774	-$12962
Savings-to-Investment Ratio	0	0	0	0.2	0	0
Simple Payback (years)	282.6	428	978.1	45.2	-	385.6
Total Investment Cost (USD)	14835.5	19708	12851.8	5346	3694.3	13174.2

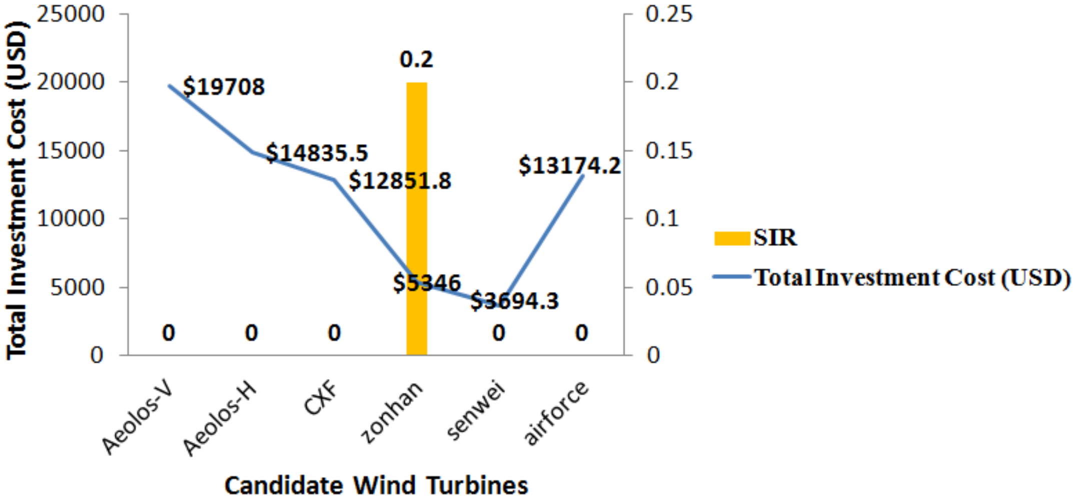


Figure 27: Savings to Investment Ratio vs Price at 3m/s Wind Speed

According to economic feasibility analysis that have been done for six micro scale wind turbines we can conclude that these six models are not economically feasible at 3 m/s wind speed.

Table 16: NPVs, SIRs and SPs of Wind Turbines at 4m/s

Turbines	Aeolos – H	Aeolos – V	Maglev CXF – V	Zonhan – H	Snewei - V	Airforce1
Net Present Value (NPV)	-$13808	-$18834	-$12595	-$3748	-$2097	-$12638
Savings-to-Investment Ratio	0.1	0	0	0.3	0.4	0
Simple Payback (years)	114.1	176	326	27.1	18.8	182.3
Total Investment Cost (USD)	14835.5	19708	12851.8	5346	3694.3	13174.2

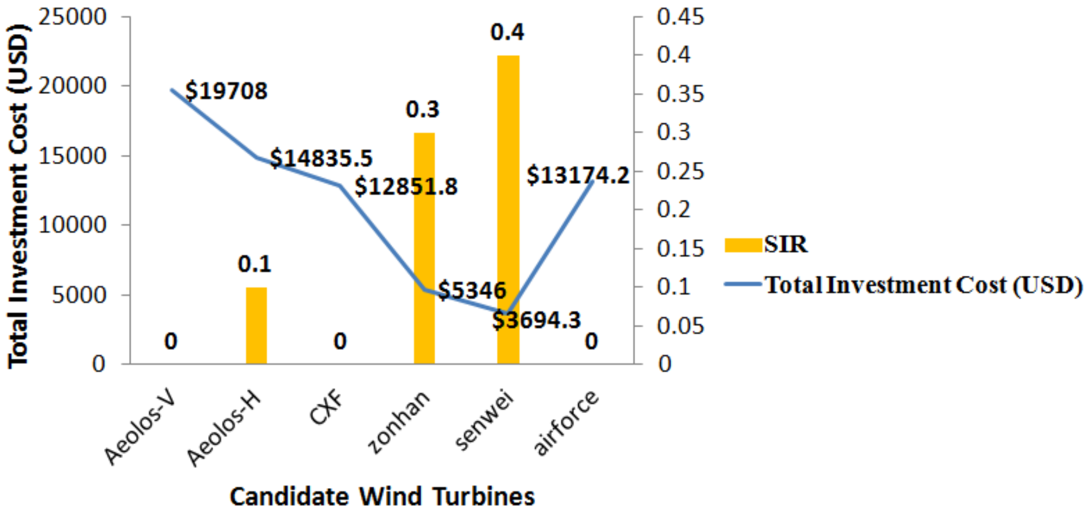


Figure 28: Savings to Investment Ratio vs Price at 4m/s Wind Speed

At 4 m/s mean wind speed of Cyprus among these six models there are not any suitable one.

Table 17: NPVs, SIRs and SPs of Wind Turbines at 5m/s

Turbines	Aeolos – H	Aeolos – V	Maglev CXF – V	Zonhan - H	Snewei - V	Airforce1
Net Present Value (NPV)	-$12633	-$18110	-$12204	-$3188	-$306	-$12134
Savings-to-Investment Ratio	0.2	0.1	0.1	0.4	0.9	0.1
Simple Payback (years)	55.4	100	150.5	20.3	9.1	100.3
Total Investment Cost (USD)	14835.5	19708	12851.8	5346	3694.3	13174.2

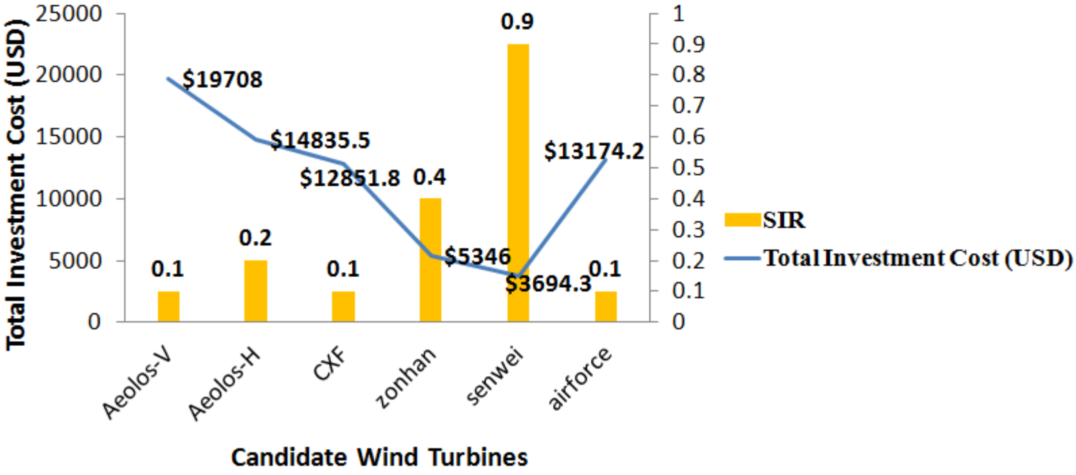


Figure 29: Savings to Investment Ratio vs Price at 5m/s Wind Speed

As we can see in table 16 and figure 28 there is not feasible turbine in the site with 6 m/s among these models.

Table 18: NPVs, SIRs and SPs of Wind Turbines at 6m/s

Turbines	Aeolos – H	Aeolos – V	Maglev CXF – V	Zonhan - H	Snewei - V	Airforce1
Net Present Value (NPV)	-$10977	-$17326	-$11812	-$1957	$1819	-$11184
Savings-to-Investment Ratio	0.3	0.1	0.1	0.6	1.5	0.2
Simple Payback (years)	32.1	68.2	97.8	13.1	5.6	54.2
Total Investment Cost (USD)	14835.5	19708	12851.8	5346	3694.3	13174.2

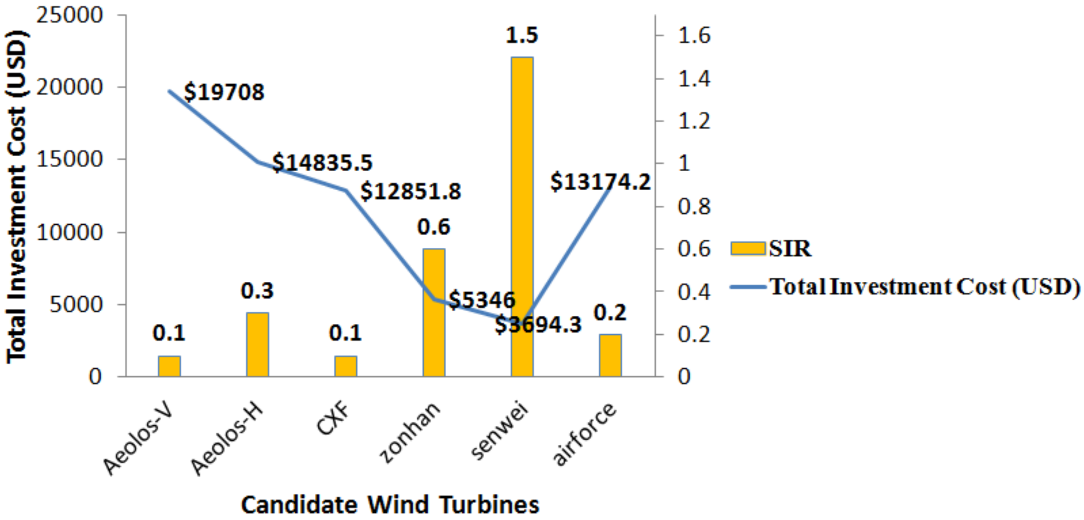


Figure 30: Savings to Investment Ratio vs Price at 6m/s Wind Speed

At 6m/s SW-1kW micro wind turbine is suitable model as we see in the table and figure.

Table 19: NPVs, SIRs and SPs of Wind Turbines at 7m/s

Turbines	Aeolos – H	Aeolos – V	Maglev CXF – V	Zonhan - H	Snewei - V	Airforce1
Net Present Value (NPV)	-$9042	-$15312	-$10806	-$391	$4616	-$10065
Savings-to-Investment Ratio	0.4	0.2	0.2	0.9	2.2	0.2
Simple Payback (years)	21.5	37.5	51.5	9	3.7	35.2
Total Investment Cost (USD)	14835.5	19708	12851.8	5346	3694.3	13174.2

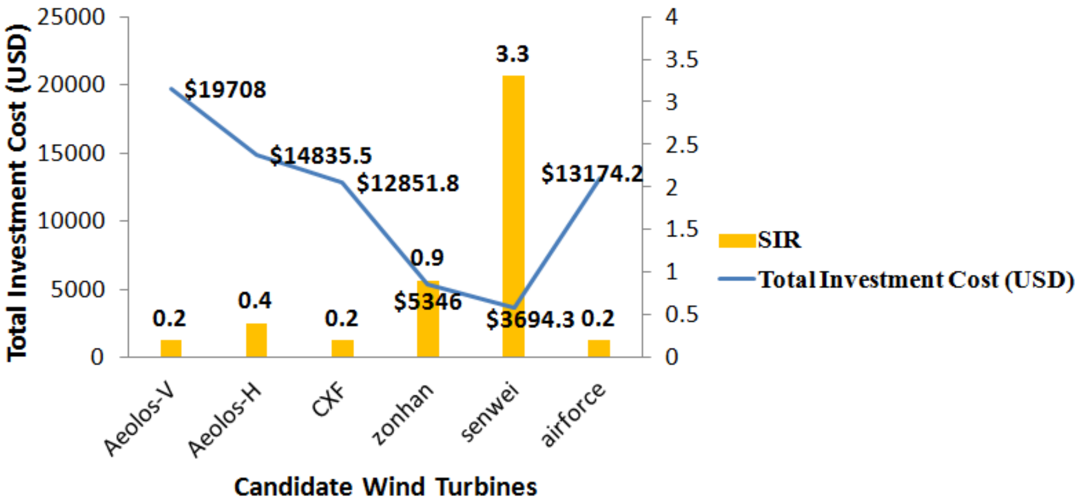


Figure 31: Savings to Investment Ratio vs Price at 7m/s Wind Speed

SW-1kW vertical axis wind turbine at 7 m/s with SIR= 3.3 and simple payback period= 3.7 is the feasible model.

Table 20: NPVs, SIRs and SPs of Wind Turbines at 8m/s

Turbines	Aeolos – H	Aeolos – V	Maglev CXF – V	Zonhan - H	Snewei - V	Airforce1
Net Present Value (NPV)	-$6301	-$13300	-$9577	$1287	$7301	-$8890
Savings-to-Investment Ratio	0.6	0.3	0.3	1.2	2.9	0.3
Simple Payback (years)	14.7	25.9	32.6	6.8	2.8	25.7
Total Investment Cost (USD)	14835.5	19708	12851.8	5346	3694.3	13174.2

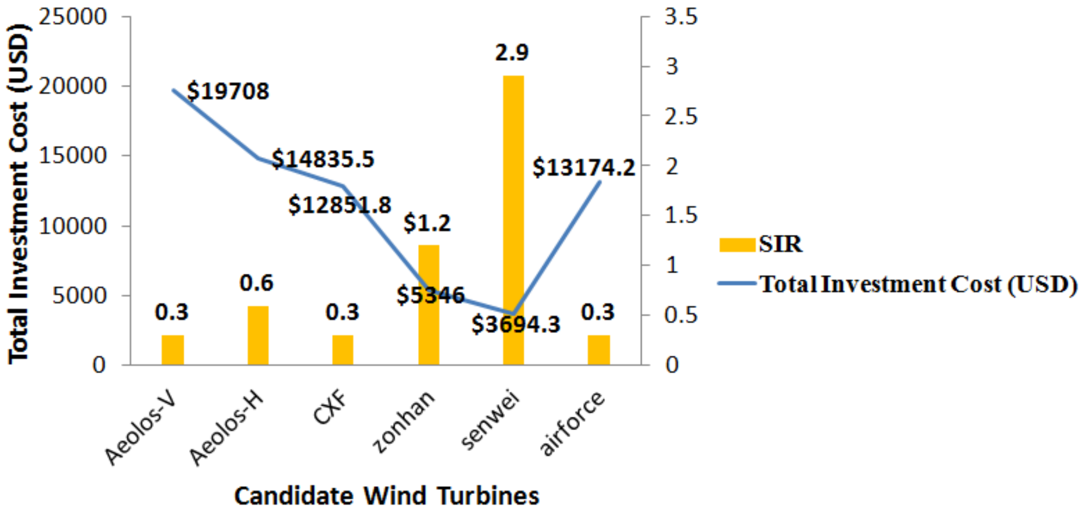


Figure 32: Savings to Investment Ratio vs Price at 8m/s Wind Speed

At 8 m/s wind speed respectively SW-1kW and ZH-1kW candidate micro scale wind turbine are economically feasible.

Table 21: NPVs, SIRs and SPs of Wind Turbines at 9m/s

Turbines	Aeolos – H	Aeolos – V	Maglev CXF – V	Zonhan - H	Snewei - V	Airforce1
Net Present Value (NPV)	-$3571	-$10838	-$7953	$3077	$8531	-$7660
Savings-to-Investment Ratio	0.8	0.5	0.4	1.6	3.3	0.4
Simple Payback (years)	11.1	18.7	22	5.4	2.6	20.1
Total Investment Cost (USD)	14835.5	19708	12851.8	5346	3694.3	13174.2

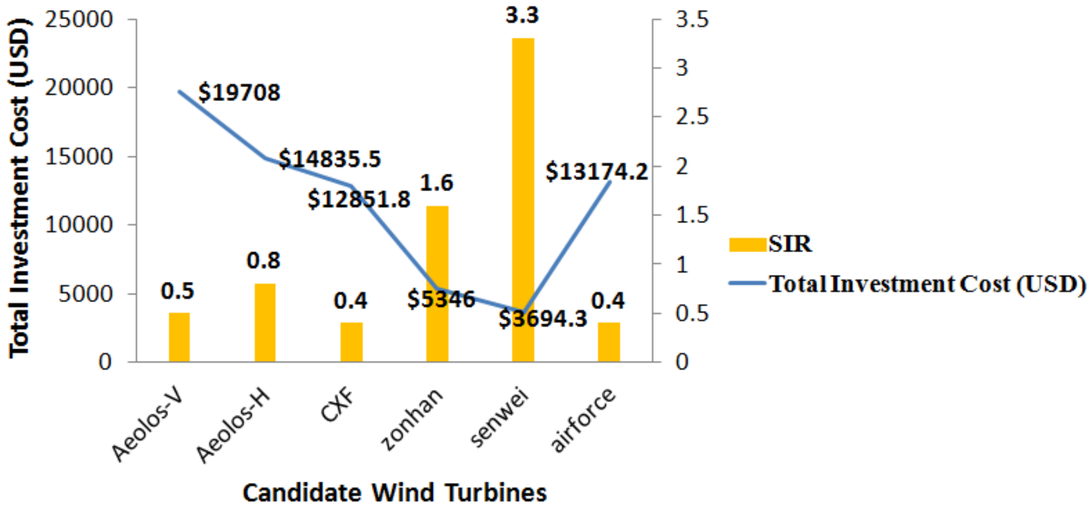


Figure 33: Savings to Investment Ratio vs Price at 9m/s Wind Speed

At 9m/s SW-1kW and ZH-1kW respectively VAWT and HAWT are feasible with SIR above than 1 and positive NPV.

Table 22: NPVs, SIRs and SPs of Wind Turbines at 10m/s

Turbines	Aeolos – H	Aeolos – V	Maglev CXF – V	Zonhan - H	Snewei - V	Airforce1
Net Present Value (NPV)	-$1223	-$8600	-$6275	$6880	$8867	-$6317
Savings-to-Investment Ratio	0.9	0.6	0.5	2.3	3.3	0.5
Simple Payback (years)	9.2	15	16.4	3.7	2.5	16.2
Total Investment Cost (USD)	14835.5	19708	12851.8	5346	3694.3	13174.2

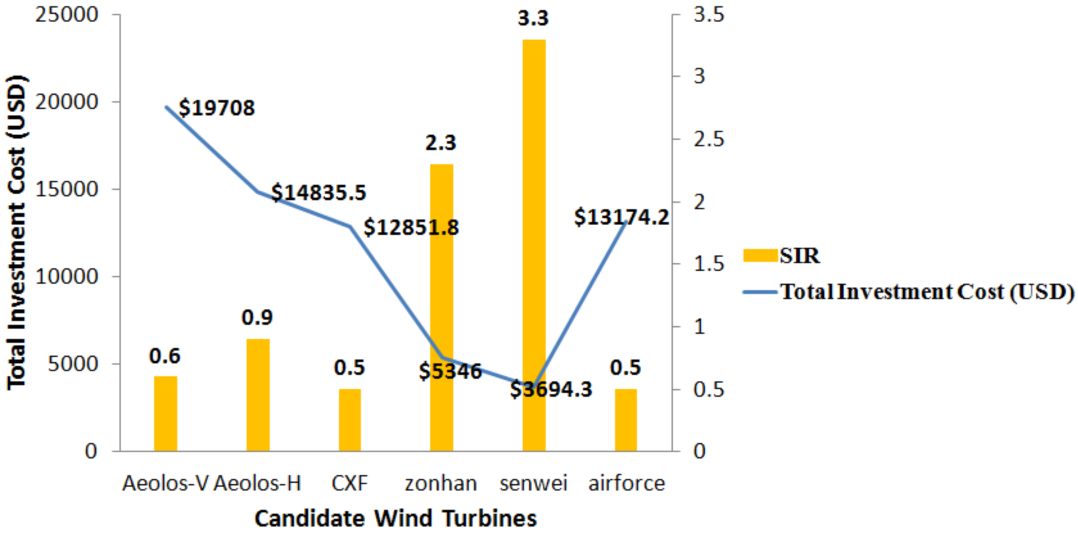


Figure 34: Savings to Investment Ratio vs Price at 10m/s Wind Speed

At 10 m/s wind speed SW-1kW with SIR=3.3 and ZH-1kW with SIR =2.3 are feasible micro wind turbines.

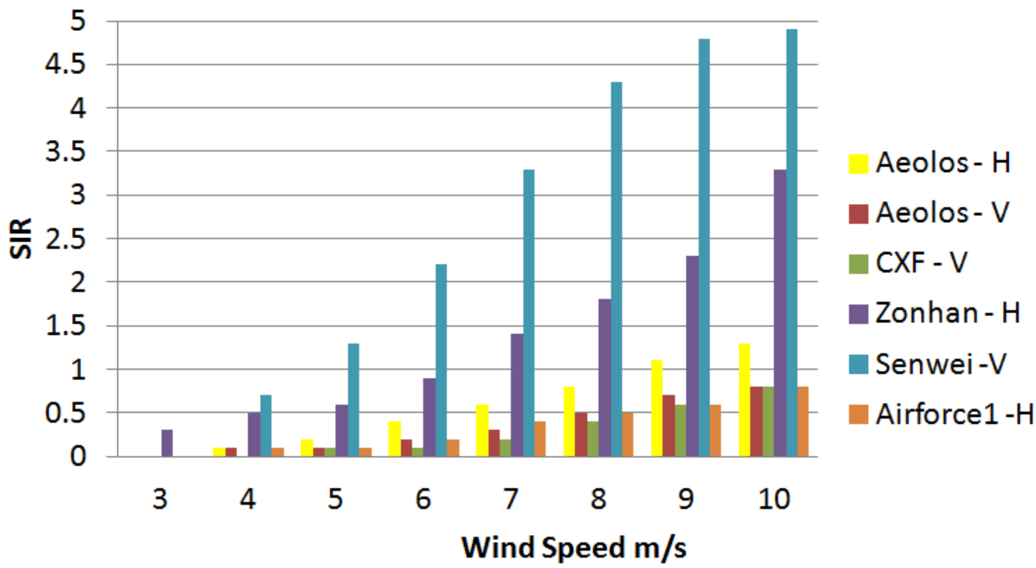


Figure 35: SIR vs wind speed in scenario A

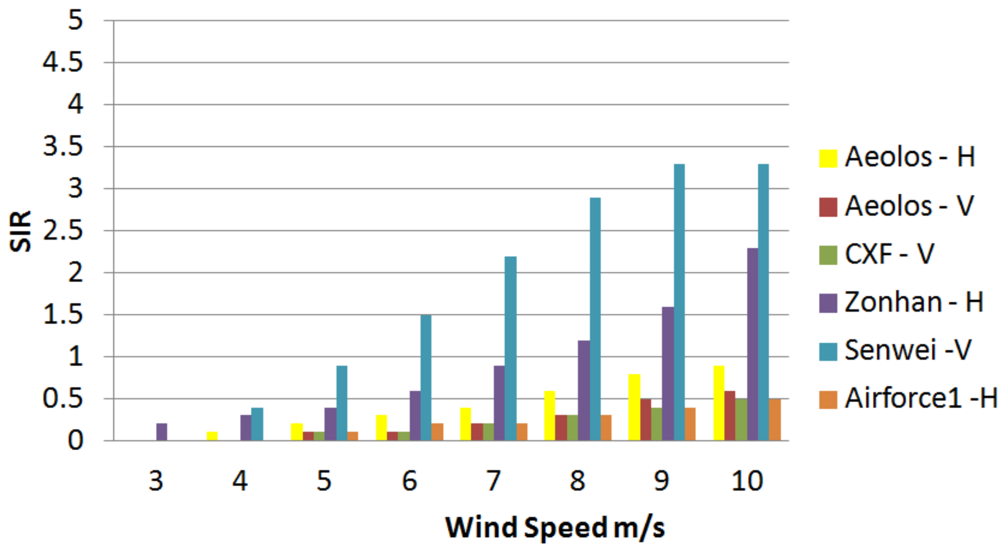


Figure 36: SIR vs wind speed in scenario B

The candidate micro wind turbines, in this range of price, are not feasible for the site with 4m/s wind speed. In order to find feasibility of these wind turbines, economic analysis has been done for different wind speed as explained before. According to the results SW-1kW which is VAWT is feasible for sites with 5m/s and above than this wind speed when provide feed in tariff for wind turbines system, without feed in tariff assumption SW-1kW is feasible at 6 m/s wind speed. Other model ZH-1kW which is HAWT is profitable at 7 m/s and above than this wind speeds in scenario A, it is affordable at 8 m/s in scenario B. in scenario A with feed in tariff assumption Aeolos- H is feasible at 9 m/s but in scenario B it is not feasible at these wind speeds.

Chapter 7

CONCLUSION

The use of renewable energy resources such as wind can help to reduce emissions of CO_2 and economic burden of using fossil fuels. For decades, numerous countries have experienced using wind energy. Accordingly, economic feasibility of wind turbines was studied for the North Cyprus.

Economic assessment was carried out on six dissimilar wind turbine models of Snewei-V, Zonhan-H, Maglev CXF-V, Airforce1, Aeolos-V and Aeolos-H. Accordingly, Savings-to-Investment Ratio and Simple Payback analysis were carried out.

According to the obtained results it became clear that at an average 4 m/s wind speed, the wind turbines in question will not have SIR values greater than 1 and NPV positive, therefore, they are not affordable for Northern Cyprus, whereas SW-1kW, ZH-1kW and Aeolos-H respectively are feasible with SIR greater than 1 and positive NPV at 5m/s, 7m/s and 9 m/s mean wind speeds with the information of feed in tariff, and SW-1kW and ZH-1kW respectively are affordable at 6 m/s and 8 m/s without feed in tariff assumption.

Due to this study for implementing wind energy, there are some important barriers. The small scale wind turbines are expensive but there is a steep declining unit cost curve ($\$/kW$) as the size of wind project and the size of a wind turbine enlarges. The cost of wind turbines (< 10 kW to 10 MW) is reduced by 8000 $/kW to 2000 $/kW. The references represent a wide range of $O\&M$ costs for wind systems, and $O\&M$ costs do not essentially reduce with enhanced installed project size at the DG scale. Older installations intend to contain higher yearly $O\&M$ costs. However, newer wind turbines are better designed and have lower lifetime and installed $O\&M$ costs than machines set up in the recent decade. Total installed costs for utility scale wind projects are currently obtainable, though, more challenging to find for smaller systems.

The other barrier of using wind energy is the high cost of importing wind turbines. When the costs of transportation and customs and other marginal costs are added to the factory price of wind turbine, the investment becomes economically impossible. Therefore, a large amount of costs will be saved if a solution is found to get rid of the importing cost to the country, transportation cost and tax— which can be achieved by the production of domestic turbines. Moreover, the investment on micro wind turbines to produce electricity using renewable wind energy can be economically viable.

Additionally, to put the micro wind turbines in use, these turbines can be utilized in areas where the wind speed is higher than 4 m/s. This means, in areas where the wind blows faster such as the sites around the city, on the mountains and near the beach.

Given that Northern Cyprus has a very significant resource of solar energy; hybrid wind turbines (wind turbine and solar photovoltaic panels) can be utilized in order to utilize the wind turbines effectively and economically. Solar-Wind hybrid power system is the mixture of power generating system by solar energy panel and wind mill. Intermittent energy sources and energy sources unbalance are the most significant reason to install a hybrid energy supply system. Hybrid systems are normally constructed for design of systems with lowest possible cost as well as maximum trustworthiness. Wind energy complements solar energy and the feasibility of a Hybrid solution has to be analyzed.

It is attempted to choose the turbines in a restricted range of acceptability and suitability according to the wind features of the region. Recommendations for further research would be as providing feed in tariff for wind turbine systems, examining solar-wind hybrid power system, producing domestic wind turbines and implement these turbines in places where the wind speed is high.

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APPENDICES

Appendix A: Background Information on Wind Energy and Micro Scale Wind Turbines

Source of Wind Energy

According to its general definition, wind is referred to air natural movement throughout sea or lands. The reason of its generation is the Earth's rotation and irregular heating up and cooling down of its surface. The Earth and its watery regions are shined by the Sun at various rates depending on the region's location. The air existing around the warm regions starts to rise because of becoming warmer and becoming less dense. As a result, air rising makes a region become law in pressure. Cooler air existing around the region with higher pressure travels to the area with low pressure. This air motion is defined as wind. On the other hand, the Earth's rotation makes the direction of air flow changed; this causes the generation of prevailing winds. Valleys and mountains as the example of surface elements may affect the pace and direction of prevailing winds [19].

The speed of wind is 0 m/s at ground level. However, this speed enhances slowly in order to get to the geostrophic boundary layer, in which ground roughness contains no efficacy. The Hellmann power equation is considered as the most well-known and frequently utilized method for estimating wind in different heights [20]. This equation comes as follows:

$$\nu(z) = \nu(z_0)(\frac{z}{z_0})^a \qquad (1)$$

in which $\nu(z)$ is considered as the wind speed and $[m/s]$ is verified at a height which is higher than the level of ground. Moreover, $\nu(z_0)$ works as the recognized speed of wind at a height with z_0 meters, and α works as the coefficient of wind-shear. By means of empirical data for every site, the wind shear coefficient is usually identified. However, thanks to inaccessibility of data and the flatness of the ground, we may estimate it as $\alpha = 1/7$ [20].

History of Wind Energy

Wind has been as the source of energy for people for more than hundred years. It poses a significant and noteworthy role in human civilization history. We may trace the initial utilizing of wind as energy source back to 5000 years in Egypt, wherein, people took advantage of sails in their boats to move from a coast to another coast. In twelfth century this Egyptian technology entered the western countries and started its role as Dutch-style windmills. By seventeenth century in Europe, it was considered as one of the major sources of power. Nearly one hundred years ago, windmill technology was started to be used in North America by farmers to pump water up. Nowadays, in a wind energy system, the spinning rotors are still employed to pump, and to embark a generator for producing electricity.

Figure A1: Dutch-style windmills [43].

Wind Energy Status of the World

After the 1973 and 1979 oil crises, Wind energy became the focus of a considerable and global notice. In order to expand wind energy power missions, numerous researchers and scholars from different countries in America and Europe did manifold researches and assessments on wind energy power potential. As a matter of fact, the capacity of cumulative worldwide wind energy production reached 39,000 MW and passed 39,294 MW in the year 2003. Based upon the reports from the American Wind Energy Association (AWEA) and the European Wind Energy Association (EWEA) in year 2003, nearly 8,133 MW modern facilities in capacity were employed globally, which has been a twenty six percent growth. Moreover, by the end of year 2009, this growth reached a double-digit number annually which was resulted in the installation of 159’213MW wind energy capacity by late that year [19]. Figure 5 suggests the cumulative installed and conducted capacity for the missions of wind energy power in worldwide between 2000 and 2016.

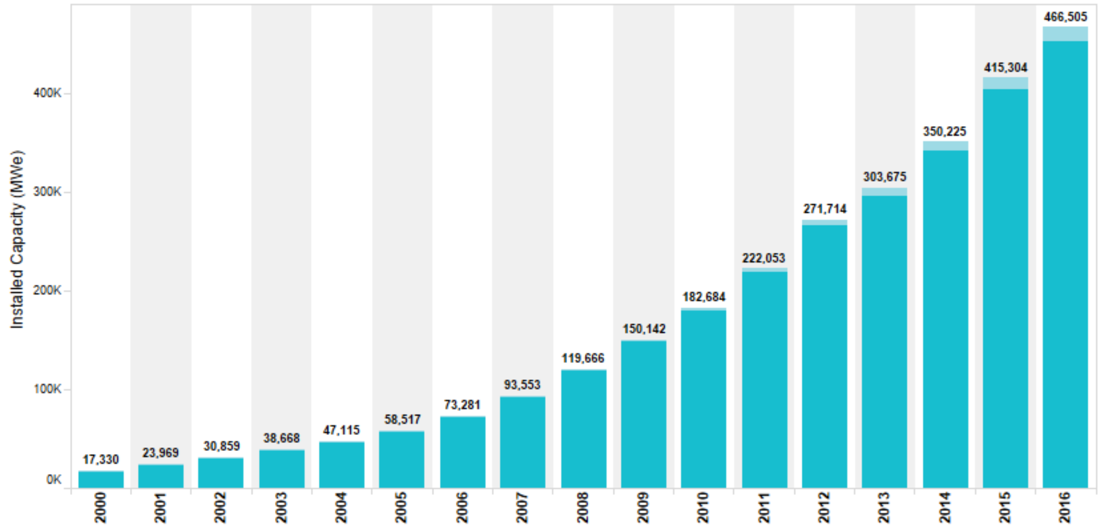

Figure A2: Cumulative conducted capacity for wind energy through worldwide between 2000 and 2016 [23].

Figure 6 shows the comparison of the last five-year installed capacities in the first top ten countries. At the summit of this ranking China, as the leading country in wind energy with 75,324MW installed capacity, is standing. Besides, the United States, Germany, Spain and India stand at the other first five ranks for wind energy power missions. Europe's total wind capacity was 107GW by the year 2012. Germany stands at the top of European countries with 31,038MW installed capacity for total wind energy. In the following of the European ranking, Spain, the UK, Italy, France and Portugal appear after Germany respectively. The United States had 12,999MW additional installed capacity in 2012 and was able to attain the utmost wind capacity of 59,882MW. Japan, India, China, Pakistan, South Korea, and Turkey (the majority of the wind fields in Turkey have been located in its Asian section) are six Asian countries which have had wind energy missions by 2012. Moreover, Pakistan in 2012 as a new comer in this field commenced and installed $100MW$. Africa also installed $1074MW$ wind energy by the year 2012 in which Egypt had the upmost rank with 550MW. Following Egypt, Morocco with 291MW and Tunisia with 104MW as well as Ethiopia with 51MW are ranked [19-20].

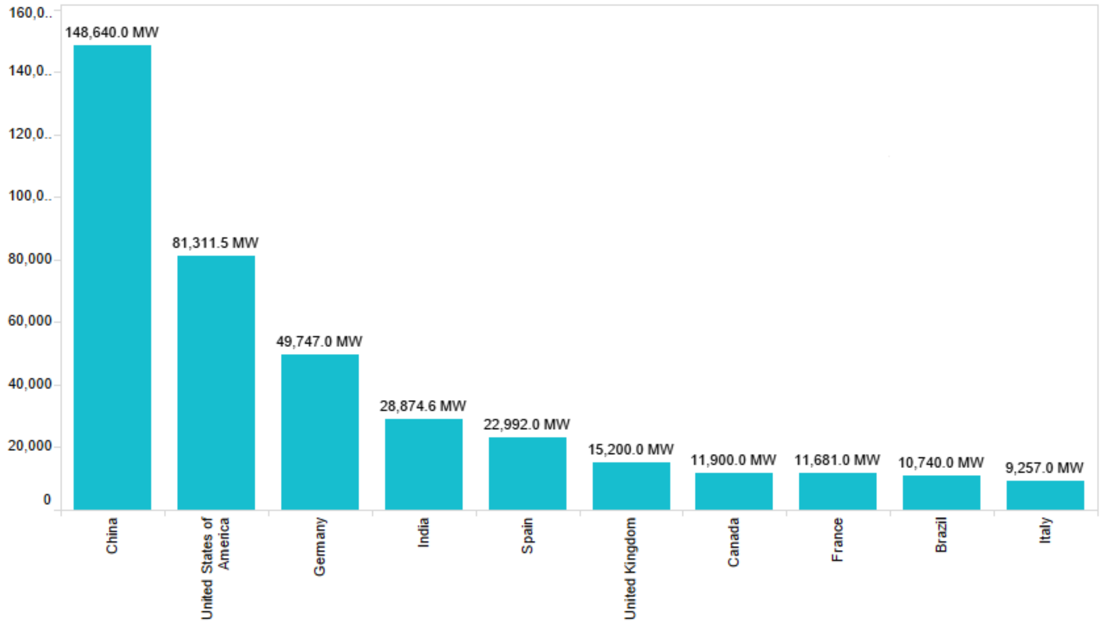

Figure A3: The Comparison of wind installed capacity in the first top ten countries in 2016 [23].

Wind Speed Probability Distribution

For a specified site, wind speed distribution plays the role of a significant factor for evaluation of wind source. In order to distribute the wind speed data, various theoretical models are used including Gamma, Rayleigh, Lognormal and Weibull. Besides, different researches (e.g., Ramos & Iglesias 2014, Rehman et al. 2012, Kitaneh, Alsamamra, & Aljunaidi 2012, Ucar & Balo 2009) proved the Weibull distribution model proved as the finest existing model thanks to its acceptable simplicity and flexibility. Weibull introduced The Weibull distribution model for the first time in 1951. It initially aimed to express not wind speed distributions but material strengths and particle distribution. This distribution model commenced to be applied on wind distributions since 1976. Nevertheless, since 1978 this model was accompanied by several criticisms because of its empirical and simple function, in addition to, its inaccurateness in capturing the proportion of calm wind speeds. The function of Weibull distribution for Wind speed data is as follows in general:

$$f(V) = \left(\frac{k}{c}\right)\left(\frac{V}{c}\right)^{k-1} \exp\left[-\left(\frac{V}{c}\right)^{k}\right] \tag{2}$$

Where $f(V)$ shows the function of probability density for studied wind speed data. Moreover, c ($m\,s^{-1}$) and k (dimensionless) are respectively the scale and shape parameters. In order to calculate c and k different methods have been introduced like graphical method, standard deviation, method of moments and maximum likelihood. For our ongoing study the maximum likelihood method is chosen as the desired method. The reason of this selection is generally low mean squared errors related to model parameter approximations for big samples [14-15-16].

For a specific turbine model and wind source, a Weibull distribution might be utilized for determination of the Annual Energy Production (AEP) which is estimated by the equation as follows:

$$AEP = (8766.25) \int_0^\infty P\,(\nu) f(\nu\colon \lambda, k)\, d\,\nu \tag{3}$$

where 8766.25 shows the quantity of hours in each year, $P(\nu)$ shows the function that explains power generated by specific wind speed and $f(\nu\colon c, k)$ shows defined the Weibull distribution [20].

Wind Energy Calculation

By the evaluation of wind sources and wind power, the kinetic energy of the moving gases becomes noteworthy. The following equation is of use for calculation of the kinetic energy of a particle:

$$E_{Particle} = \frac{1}{2} m_p {v_p}^2 \tag{4}$$

in which the kinetic energy of a particle $[J]$ is shown by $E_{Particle}$; the mass of the particle $[kg]$ is shown by m_p; and finally, the velocity of the particle $[m/s]$ is shown by v_p. However, the wind flow shows up as a flux of many particles. If the energy obtained from a big number of particles travelling harmoniously throughout an area like wind is considered, the mass might be explained as follows:

$$m = \rho v A t \tag{5}$$

Where ρ as the air density $[kg/m^3]$, A as the flux area $[m^2]$, and t as the duration of the flux $[s]$ are considered. By substitution of Equation 5 into Equation 4, we will have:

$$E_{wind} = \frac{1}{2} \rho A t v^3 \tag{6}$$

Through explaining the energy as power ($P = {}^{E}/_{t}$) (i.e explaining energy rate in a specific time period), the above-mentioned equation may be more simplified:

$$P_{wind} = \frac{1}{2} \rho A v^3 \tag{7}$$

By considering a turbine's swept area, air density (usually presumed 1.225 kg/m^3) and A, the determination of total kinetic power which is presented in a wind turbine will be achievable [19-20].

The preferred output may maximize profits when designing or building a wind turbine follows the goal of producing the maximum electricity economically. Infrastructure missions of energy generally are judged according to their Levelized Cost of Electricity ($LCoE$) which can be expressed in an equation as follows:

$$LCoE = \frac{c_0 + \sum_{n=1}^{N} \frac{C_n}{(1+d)^n}}{\sum_{n=1}^{N} \frac{Q_n}{(1+d)^n}} \tag{8}$$

Where C_n is generally considered as the annual total cost, by the ending stage of investment in year$N$. Likewise, Q_n shows the energy generation in year n. Moreover, d is considered as the rate of discount for the mission. Dollars per megawatt-hour or cents per kilowatt-hour are generally the considered units to describe the LCoE. An element of discount is utilized in the LCoE denominator; this is mainly due to an algebraic result of the derivation from the LCoE equation not due to expressing the discount for the annual production of energy.

The Capacity Factor (CF) which shows an amount of time operated in a rated capacity is expressed as follows:

$$CF = \frac{AEP}{P_r t} \tag{9}$$

Where P_r shows a turbine's rated power (generator capacity); and the number of hours in a year is shown by t. Moreover, CF is used to describe that how well a turbine is coordinated with a specific site.

Wind Turbines

Wind turbines are mechanical structures in which the kinetic energy obtained from wind is changed to mechanical energy. This happens via the provoked rotation of aerofoil-formed rotors. Subsequently, the rotational force obtained from the rotors would be utilized for running a generator and for generating electricity used for consumption [20].

Human beings throughout the history have taken advantage of wind power for numerous centuries. The Persians were the first documented users of windmills in nearly 900 AD. Windmills showed up in Europe through the middle ages. They were utilized for manifold mechanical jobs including powering tools, grinding grain, pumping water, sawing wood, etc. In addition, windmills were extensively utilized in the west and other rural areas of America for pumping water used by cattle and for the steam railroads [22].

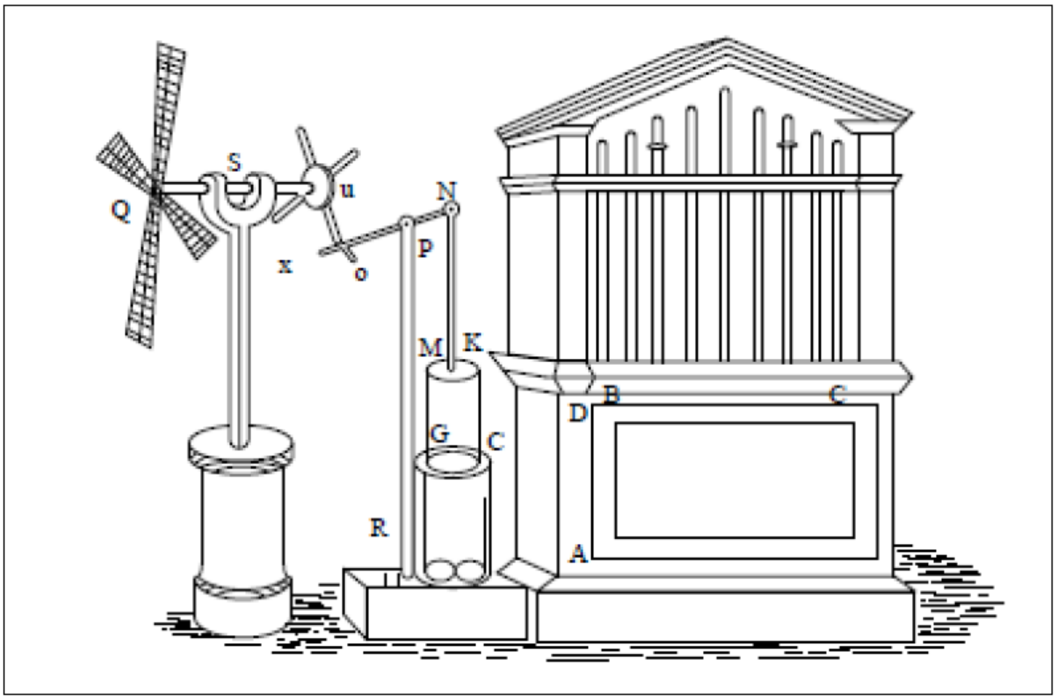

Figure A4: Hero’s Windmill [44]


Figure A5: Persian Windmill [44]

By the invention of electrical generators, it seemed to be quite normal for inhabitants to turn the generators on by windmill rotors. American people in rural districts showed great interest in these micro wind turbines. In order to develop the central electrical grid, in the 1930s the Rural Electrification Administration was launched. This act caused a conclusion for the wind turbines for a quite few decades. However, this was not the end of the story for wind turbines because, wind energy utilization re-emerged following the oil crisis occurred in 1970s and 1980s. Attentions to wind energy collapsed in the United States because of lower cost of energy in the 1990s. Nevertheless, in Europe not only did it not collapsed but also continued to be supported and developed. [19.

Over the years numerous designs for wind turbines were suggested and constructed. The horizontal axis wind turbines (HAWT) have been confirmed to be the most efficient one. The Darrieus design is the nearest competitor to the HAWT. The Darrieus design bears several advantages including the capability to place most of the weighty equipment at ground level, though; it does not work as effectively as HAWT in getting energy from the wind. The modern high speed two-blade and three-blade and curves come out from horizontal axis designs. Therefore, all commercially accessible big wind turbines, nowadays, are originated from the HAWT [11]. The different types of wind turbines are to be talked in the next chapter.

Micro Scale Wind Turbines

In general, wind turbines vary based upon power output ranging from some Watts to tens of megawatts. The safety standard for micro wind turbines is considered by theIEC. For instance $IEC\ 61400-2$ is a tiny turbine that has not as much of than

200 m^2 rotor swept area; this is quite similar to P\50 kW. All sizes of turbines have the same basic operating principles. Moreover, micro wind turbines are usually placed in a location where the power is accessible or placed near the house of the owner; this location is usually far from windy places [29].

Dissimilar to larger utility-scale turbines, small/Micro-scale wind turbines– at their rated wind speed– generate the electricity in the range of 300 W to 10 kW and are usually lower than 30 m in hub-height. These wind turbines are flexible in their owing to their size, sitting, maintenance and cost. They are also able to offer wind energy to the areas which are not suitable enough for direct availability to the grid system [45].

Figure A6: Micro wind turbine [46]

Appendix B: Life Cycle Cost Analysis

Determining the feasibility of energy projects:

In energy projects we have:

a) A reference application (usually referred to as the "old" system)

b) A challenging technology (usually referred to as the "new" system)

c) We need to determine if the life cycle costing of the challenger (new system) is less than the reference application (old system)

d) In the analysis the capital cost, the energy savings and the O/M costs play an important role

TABLE 1

Year	New	Old	Net Amount
0			$0
1			$0
2			$0
3			$0
4			$0
5			$0
6			$0
7			$0
8			$0
9			$0
10			$0
11			$0
12			$0
13			$0
14			$0
15			$0
16			$0
17			$0
18			$0
19			$0

Figure B1: life cycle cost analysis schedule steps 1 and 2

In life cycle cost analysis, first two step is that determine the new cost which means total investment cost of project, Also determining annual operation and maintenance cost of system.

In the next step it is time to determine the annual savings; in this project annual savings is annual energy output (kWh) of system in different wind speeds multiply by electricity price which is 0.15 USD in North Cyprus. Forth step is determining the discount rate; it is 10% in North Cyprus. Next one is residual value, according to candidate wind turbine systems cost it is assumed to be $500 in this study.

TABLE 2

Annual Savings		(from Step 3)
Discount Rate		(from Step 4)
Analysis period (years)		(from Step 5)
Residual value		(from Step 6)

Figure B2: Life cycle cost analysis schedule steps 3, 4, 5 and 6

Life Cycle Cost Analysis: Calculations & Outputs

The outputs in life cycle cost analysis are net present value, savings to investment ratio, simple payback and internal rate return.

a) Calculate present value of annual savings.

b) Calculate present value of investments.

c) Calculate net present value.

d) Calculate savings-to-investment ratio and internal rate of return.

TABLE 3: Savings Calculations	Formula: PV Annual Savings = Annual Savings / (1 + Discount Rate)^{year}					(from Step 7)					
Year	0										
Annual Savings	$0										
PV Annual Savings	$0										
□ PV Annual Savings	$0										

TABLE 4: Investments	Formula: PV Life Cycle Investment = Life Cycle Investment / (1 + Discount Rate)^{year}						(from Step 8)				
Year	0										
Net Life Cyle Investments	$0										
PV Life Cycle Investments	$0										
□ PV Life Cycle Investments	$0										

Net Cash Flows	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0

TABLE 5: Results	OUTPUTS	
Net Present Value (NPV)	$ 0	(from Step 9)
Savings-to-Investment Ratio		(from Step 10)
Internal Rate of Return (IRR)		(from Step 10)
Simple Payback (years)		

Figure B3: Life cycle cost analysis, calculations and outputs

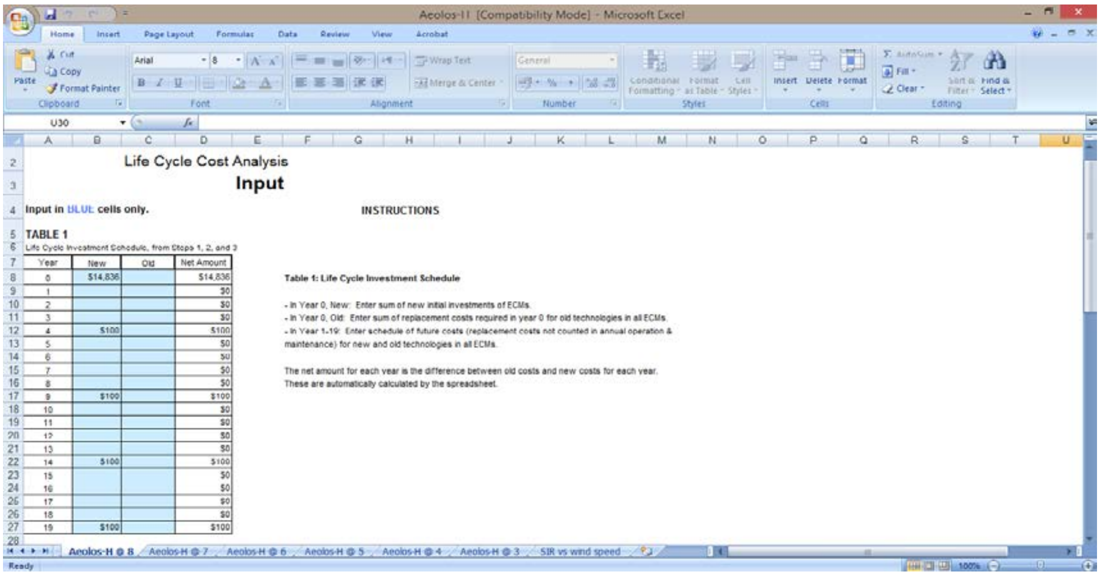

Figure B4: Life cycle analysis inputs

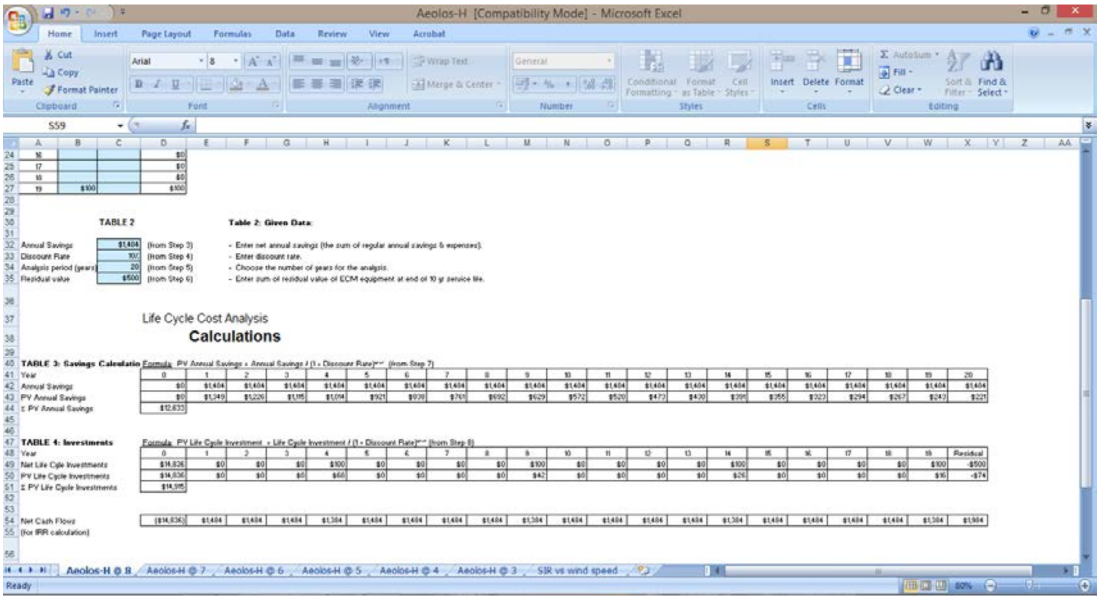

Figure B5: Life cycle analysis calculations

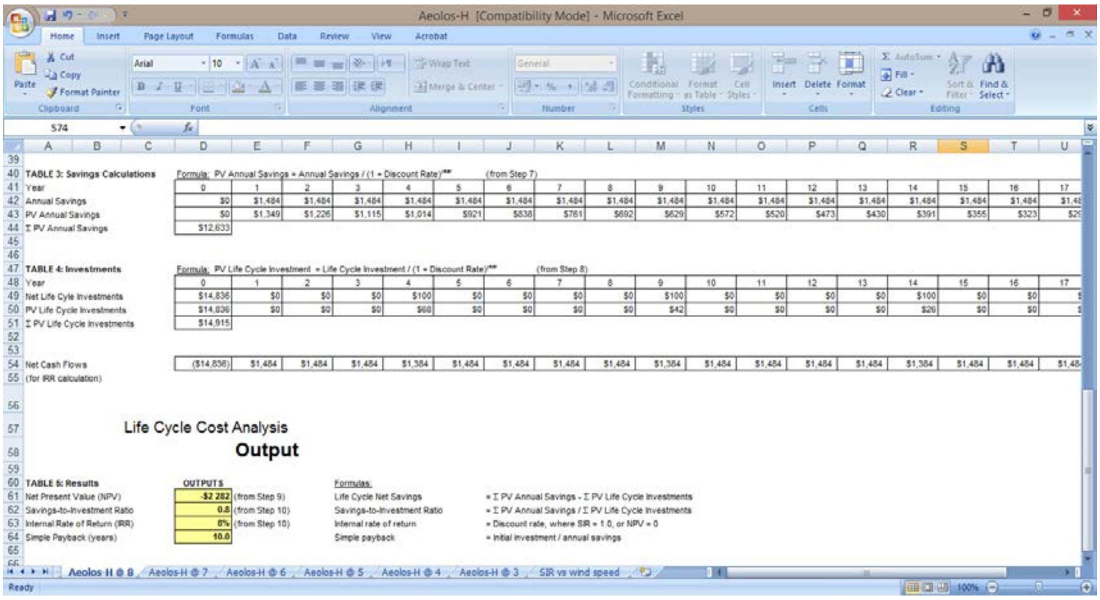

Figure B6: Life cycle analysis outputs