WIND HOME SYSTEM: A CASE STUDY IN GÜZELYURT, NORTHERN CYPRUS

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

By
ALMONSEF ALHADI SALEM MOSBAH

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

NICOSIA, 2020

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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 Mechanical Engineering

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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.

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Finally, to my parents, brothers and sisters, I say thank you for all your supports through prayers and advice of encouragements to hold on, especially when my morale was low.

To my parents….

ABSTRACT

The contemporary capabilities to address the limited fossil energy sources (coal and oil) and the possibility of future depletion go to two main directions. These directions are deal with energy sources and our needs in a scientific way to reduce the rates of depletion of current sources and adapt to the data that will certainly be imposed by alternative energy sources The wind energy has been at the forefront as a candidate for some short-term human energy needs with the potential for future contributions to expand. Therefore, the objective of this work is to design and wind systems for a single-family houses in Güzelyurt, Northern Cyprus. Based on Wind Atlas Map, the wind home system can be considered one of the best solutions to reduce electricity consumption and green gas emissions in the selected region. Therefore, the Techno-economic evaluation of a 2kW grid/grid-off connected wind system has been made. It is found that the average percentage of reduction in electric consumption generated by diesel fuel is about 40% per year. The results concluded that the proposed renewable system could be used as a power generating for small households in Güzelyurt.

Keywords*:* Güzelyurt; grid/grid-off connected; wind home system; Techno-economic; Renewable system

ÖZET

Sınırlı fosil enerji kaynaklarını (kömür ve petrol) ve gelecekteki tükenme ihtimalini ele alan çağdaş yetenekler iki ana yöne gider. Bu yönelimler, enerji kaynaklarıyla ve ihtiyaçlarımızla, mevcut kaynakların tükenme oranlarını azaltmak ve alternatif enerji kaynaklarının kesinlikle uygulayacağı verilere uyum sağlamak için bilimsel bir yolla ele alınmaktadır. kısa vadeli insan enerjisinin gelecekteki katkılarının artması potansiyeli olan ihtiyaçlar. Bu nedenle, bu çalışmanın amacı, Kuzey Kıbrıs'ta Güzelyurt'ta bir müstakil ev için tasarım ve rüzgar sistemleri üretmektir. Rüzgar Atlası Haritasını temel alan rüzgâr sistemi, seçilen bölgedeki elektrik tüketimini ve yeşil gaz emisyonlarını azaltmak için en iyi çözümlerden biri olarak kabul edilebilir. Bu nedenle 2kW grid / grid-off bağlantılı rüzgar sisteminin Tekno-ekonomik değerlendirmesi yapılmıştır. Dizel yakıtın ürettiği elektrik tüketimindeki ortalama düşüş yüzdesinin yılda yaklaşık% 40 olduğu bulunmuştur. Sonuçlar, önerilen yenilenebilir sistemin Güzelyurt'ta küçük haneler için enerji üreten bir güç olarak kullanılabileceği sonucuna varmıştır.

Anahtar Kelimeler*:* Güzelyurt; ızgara / ızgara bağlantısı kapalı; rüzgarlı ev sistemi; Techno-ekonomik; Yenilenebilir sistem

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C_L	Lift coefficient
C_D	Drag coefficient
$c\ (r)$	Local chord
D	Drag force
L	Lift force
M	Torque
r	Radial position of the control volume
V_{rel}	Relative velocity
V_0	Axial velocity
T	Thrust
β	Twist of the blade
θ	Local pitch of the blade
θ_p	Pitch angle
Ωr	Rotational velocity

CHAPTER 1
INTRODUCTION

1.1 Background

Global warming is a serious environmental phenomenon that threatens the quality of life on the Earth's surface (Burton, 2019). This phenomenon is also called global warming. It means the global warming dramatically and transforms it into a greenhouse, that is, to retain heat and increase its surface temperature (Daniels, 2009). This phenomenon has been clearly observed in the mid-twentieth century and serious work has been started to find appropriate solutions to eliminate it and minimize its negative impacts (Daniels, 2009; Burton, 2019).

Continuous environmental changes are likely to lead to global warming, the depletion of strategic oil reserves and the ongoing threats of a potential problem of access to electricity, all of which have recently led to contemplation of alternative energies, including wind.

Wind energy is a local renewable energy and produces no greenhouse gases such as methane, nitric oxide, and carbon dioxide (Chanda and Bose, 2019; Chen et al., 2019; Rogers et al., 2019). Turbines are devices used to convert the wind energy into electrical energy and can also be placed on tall buildings (Caglayan et al., 2019; Ahmad et al., 2018; Cali et al., 2018; Murray et al., 2019).

Wind energy is the process of converting wind movement to another form of energy that is easy to use. Wind energy is converted into electrical energy by wind turbines, which are the machines that convert kinetic energy in the wind into mechanical energy(Caglayan et al., 2019; Ahmad et al., 2018; Cali et al., 2018; Murray et al., 2019). Energy that can be used directly in pumps, grinding, or turbine recycling to generate electricity Increased awareness of changes in the global climate has increased the importance of renewable energies, increasing the demand for wind energy.

1.2 The Concept of Renewable Energy

Energy is an essential component of the universe and is a form of existence. Energy is usually derived from natural and abnormal sources, so it is divided into two main types: renewable energy, which depends on natural resources, and non-renewable, and depends on abnormal sources, but formed over time and under the influence of a variety of factors (Paletto et al., 2019; Nazir et al., 2019; Topcu and Tugcu, 2019). All kinds of this energy require the existence of special mechanisms, tools and techniques to extract and harness them for the benefit of man. In this research topic we will shed light on renewable energy and everything related to it.

Renewable energy is the energy derived from the natural resources of the environment and does not run out. It produces renewable energy from wind, sun and water, in addition to the energy resulting from tides, or geothermal energy. Renewable energy is environmentally friendly energy unlike conventional energy based on fossil fuels and petroleum, Which cause harm to the environment, cause global warming, cause global warming, and also cause pollution of the environment with their wastes, which affected the lives of living organisms on the surface of the earth, including humans, and caused him many health problems, and appeared a lot of Diseases that were not present before.

1.3 Advantage of Renewable Energy

Renewable energy has a number of advantages over combustion of fossil fuels such as (Nelson and Starcher, 2018)

- Renewable energy is an inexhaustible energy.
- Gives clean energy free from impurities, waste and residues.
- Keeps human health.
- Energy is considered environmentally friendly and does not cause any damage.
- Provides many job opportunities for the unemployed.
- Its cost is simple and low compared to some other types of energies.
- Reduces the rate of natural disasters resulting from global warming.
- Do not cause the production of acid rain harmful to plants.
- They protect various species, especially those that are endangered.
- Protects groundwater, seawater, rivers and fisheries from pollution and extinction.

- Contribute to food security.

1.4 Renewable energy sources

There are many natural sources that produce renewable energy, the most prominent of which are the following (Nayeripour and Kheshti, 2011; Kemp, 2005; Dorsman André et al., 2014)

Wind energy

Wind energy: is the conversion of the kinetic energy generated by the rotation of wind fans by the impact of wind, which in turn move the turbines we get through the rotational movement of electric power as shown in Figures 1.1 and 1.2.

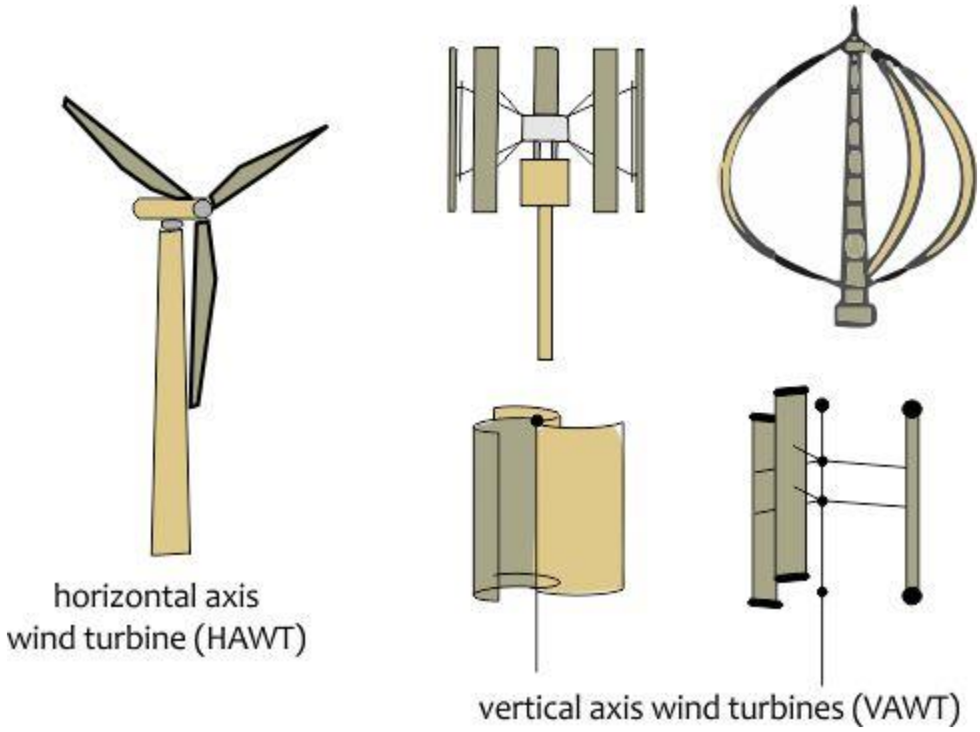


Figure 1.1: Horizontal and vertical axis wind turbine

Geothermal energy

Geothermal energy: is the exploitation of heat energy stored under the surface of the earth in the heating processes in the near-surface layers or the generation of electrical energy through the transfer of high heat to steam turbines in the deep layers (see Figure 1.2).

Figure 1.2: Geothermal energy

Biogas

Biogas: Methane is obtained from fermentation of animal or plant waste (biomass). Biogas is used as an alternative to natural gas in electricity generation, water heating or even in domestic uses (Figure 1.3).

Solar energy

Solar energy: The conversion of sunlight (light + heat) to the earth to heat or electric energy (Figure 1.4).

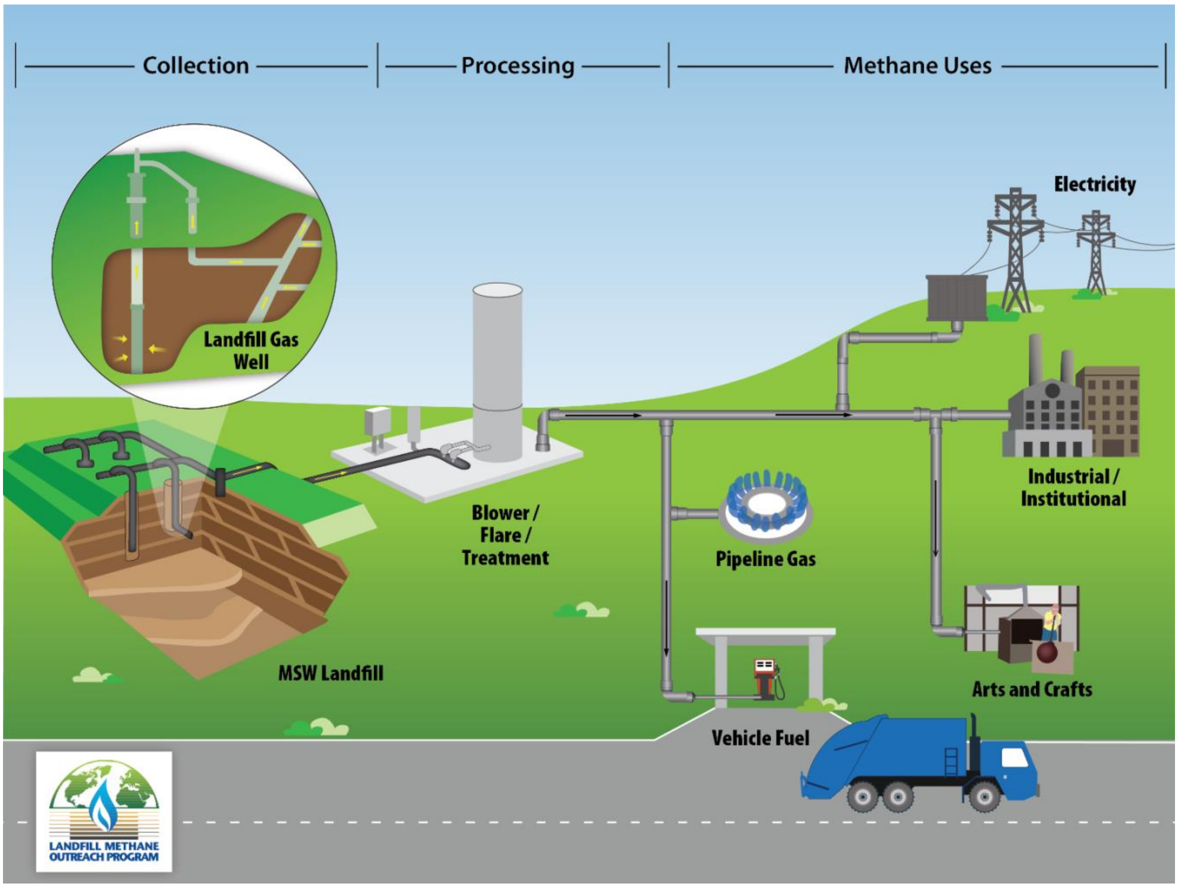


Figure 1.3: Biogas procedure

Figure 1.4: Solar energy

1.5 Wind Energy

Wind energy significantly conserves the environment, because it reduces carbon dioxide emissions. This energy is also free from all pollutants related to nuclear plants and fossil fuels. This energy is also inexpensive. Within weeks, a full air farm with large towers can be made. In addition to this renewable energy, the wind is moving the turbines free of charge. Nor are they affected by fluctuations in fossil fuel prices. It also does not need drilling to be extracted or even transported to the stations. As fossil fuel prices rise around the world, the cost of wind power generation is falling and rising.

In general, wind energy is classified as a renewable energy that does not consume fuel in electricity production, which in turn greatly reduces the harmful emissions from fossil energy generators.

Wind energy poses a threat to many birds and other flying creatures, such as bats. One of these organisms collides with blades on wind turbines to eliminate them, and studies show that the number of birds killed annually in the United States by wind turbines Between 10 thousand to 440 thousand birds. Wind energy cannot provide the transport sector with the energy it extracts, resulting in the transport sector relying solely on petroleum products. Although winds are renewed they are not permanent but seasonal, and at very many times the wind speed does not correspond to the required electrical energy. The wind turbines of this energy produce too much noise to be overlooked. One wind farm or one mill can produce very loud and noisy noise in just 24 hours, which can never be tolerated.

1.6 Aim of the Study

This study aims to propose a 2kW wind system that helps to reduce the electricity consumption which generated by diesel fuel and reduce green gas emissions. Actually, the objectives of this work is divided into three parts

1. Analyzing the wind potential at Güzelyurt location in Northern Cyprus using RETScreen software.
2. Evaluating the performance of 2kW wind system in terms of energy calculation and financial analysis.

1.7 Research Outline

This chapter is discussed the importance of renewable energy to the world. The importance of wind energy, the types of wind turbine and blade element momentum theory are presented in Chapter 2. Moreover, the methodology that used to evaluate the wind potential and design a 2kW wind system for generating electricity in the selected region is explained in Chapter 3. In Chapter 4 all test results are displayed for the proposed system. On the end of the dissertation, the conclusions are presented in Chapter 5.

CHAPTER 2

WIND ENERGY AND THEORIES

2.1 History of wind energy

Since the first sailors set their sails on their boat masts, the wind has begun to use energy that splits seafarers and drives them to travel. About 2,000 years ago, the man began to use wind-powered mills to grind grain and pump water (Hills, 1996) (Figure 2.1). Windmills have not only spread to limited places, but have spread to all ancient civilizations, adjacent to rivers and fields, and even arid places in the American Midwest and Australian slaughter, to pump water for livestock (KOHILO, 2015).

Figure 2.1: Windmills

However, starting in the late 19th century there has been a major shift in the exploitation of wind energy, which has been transformed from mere kinetic energy into electric energy that can be stored and transported over long distances and for use in every field dependent on electricity (KOHILO, 2015)..

In July 1887, the first windmill to produce electric power was built in Scotland by Professor James Blythe of the Anderson Institute (KOHILO, 2015). as shown in Figure 2.2. The mill was 10 meters high, its blades of cloth, and was charging batteries developed by Frenchman Camille Alphonse Four to illuminate a cottage that entered history as the first house to be powered by wind power (KOHILO, 2015).. Blythe offered to use excess electricity to illuminate a street in Mahalla, but residents refused to offer it, out of fear of this strange invention (KOHILO, 2015).

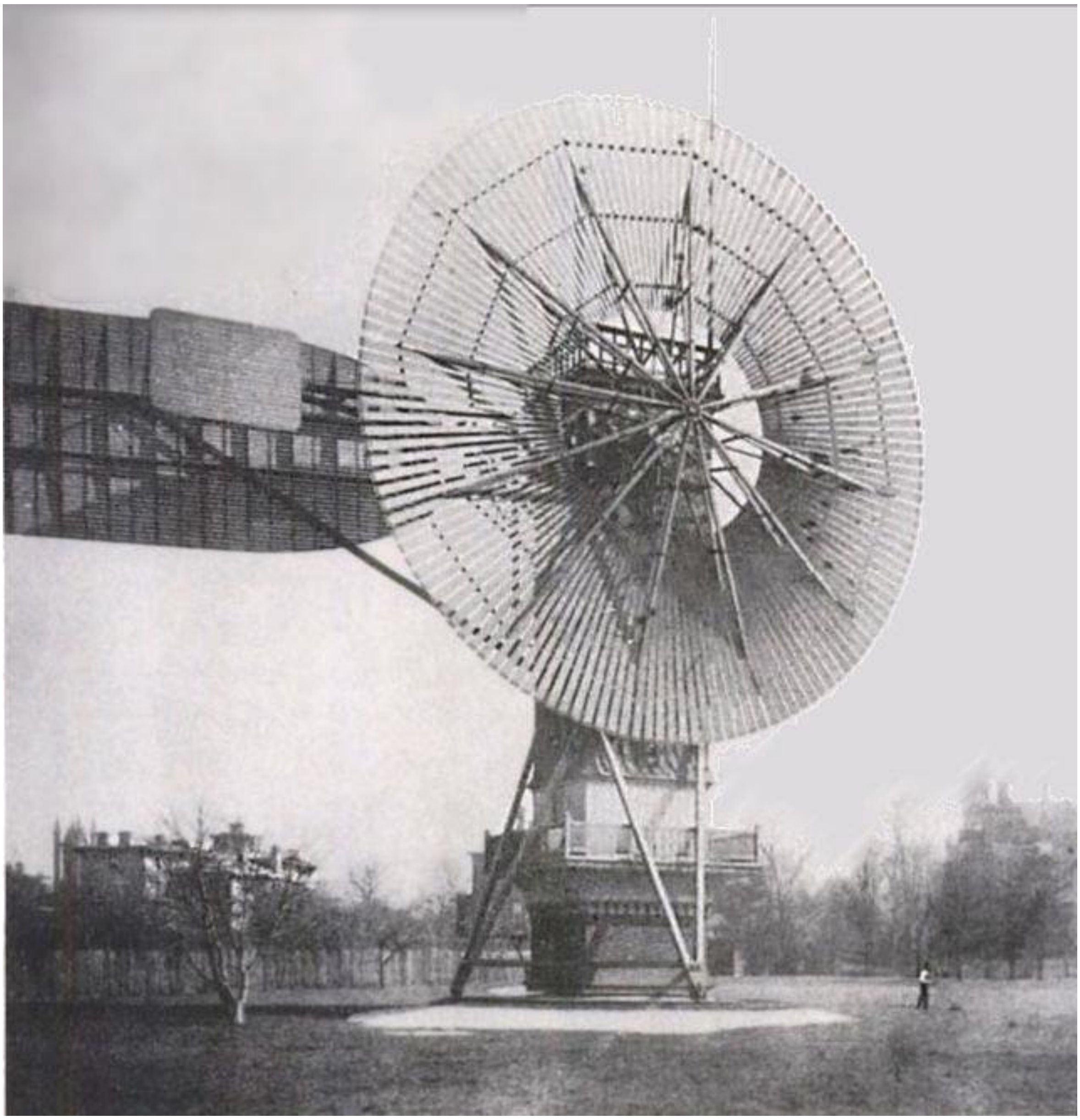


Figure 2.2: First windmill to produce electric power

On the other side of the Atlantic, in 1888, Charles Brasch built a larger electric windmill, which was used to produce electric power until 1900 (KOHILO, 2015).. It was installed on an 18-meter-high pole with a diameter of 17 meters, a capacity of 12 kilowatts, and charged batteries and lighted lamps (KOHILO, 2015). With the advancement of technology in the twentieth century, wind energy was used to illuminate homes and factories at greater distances (KOHILO, 2015) (see Figure 2.3).

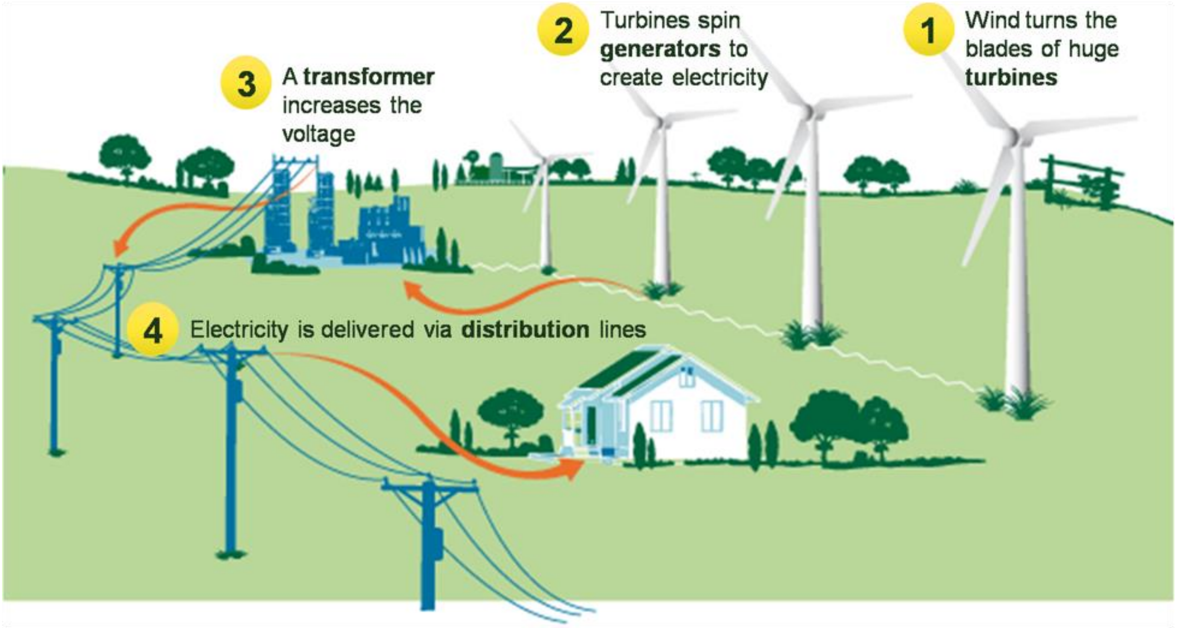


Figure 2.3: Wind turbine and generated electricity

2.2 Wind Energy

Wind energy is defined as a form of energy in which a turbine converts wind kinetic energy into mechanical or electrical energy that can be used to generate power. It is an indirect form of solar energy resulting from a combination of factors including unequal heating of the Earth's atmosphere. Through the sun's rays and differences in topography and rotation of the earth. Wind energy has been used in windmills, pushing sailboats and water pumps.

Wind energy is a source of renewable energy that comes from the air flowing through the surface of the earth. Wind energy is one of the pioneers of the technological breakthrough that could lead to more efficient energy production, and its future looks promising, where the kinetic energy of the wind is used to create mechanical energy, and generators convert this energy into electricity so that it can be used for the benefit of humanity (Shu et al. 2015; Ozay and Celiktas, 2016).

Wind power has many benefits, which explain why it has become one of the fastest growing sectors in energy sources. It is an economically viable source. It is the cheapest energy in its “raw materials” and in generating electricity. It costs between two and six US cents to produce a kilowatt-hour, according to the wind source and the financing of the generating project. They are not subject to supply and demand and the resulting price fluctuations, as happens with other energy sources. In the United States, the number of people working in the sector in 2016 exceeded 100,000. The US Bureau of Labor Statistics says the job of a wind turbine fan is the fastest growing in the past decade. From now until 2050, the sector is able to generate more than 600,000 jobs in the United States (Zayas, 2015). US research also suggests that winds support industry growth and American competitiveness. According to the report's authors, US economic output benefits about $ 20 billion each year. With their skilled workforce, Americans can compete in clean energy (Zayas, 2015).

Wind energy is clean. The wind does not pollute the air, and the fans and turbines to generate wind power do not emit any gases that are harmful to health or cause global warming and acid rain. Wind power is "local" energy wherever you go. And the wind stock in any country, prolific and uninhabitable (Jacobson, 2012). Wind energy is sustainable. It is originally a form of solar energy, because the wind moves from the action of sunlight, the rotation of the earth, and the diversity of the terrain (Jacobson, 2012). As long as the sun shines and the earth rotates, wind power will remain available for investment (Jacobson, 2012).

2.3 Basic Factors Affecting Wind Energy

Generally, the potential energy in the wind is proportional to three basic factors as follow (Goodstal, 2013; Trivedi, 1999):

The speed of wind

In fact, the potential energy in the wind is not directly proportional to the wind speed only, but directly proportional to the speed cube of these wind. In simple terms, it can be concluded that if the wind speed at one site is twice that of another, the potential energy contained in the winds of the first site will be eight times greater than that of the second slower winds. Hence the importance of seeking and mapping the top locations at wind speeds.

Density

The second of these factors is the density of air, which has a proportional relationship to the wind potential. It means that the higher the air density will produce more wind energy. For example, the density in the cooler site is higher than the warmer site.

Swept Area

The third of these factors is the circular area, which the air will pass through the turbine. This circular area is proportional to the square of the length of the turbine blade, which represents the radius of the circular area. Therefore, increase the lengths of turbine blades and thus increase the diameters of rotation of turbine blades are led to increase the wind potential in specific site.

2.4 Wind Turbine Power Calculations

The theoretically available kinetic energy that wind possesses at a certain location can be expressed as the mean available wind power (WPD) (Hicks, 2012).

Under constant acceleration, the kinetic energy of an object having mass m and velocity *v* is equal to the work done (W) in displacing that object from rest to a distance s under a force (F), i.e.:

$$E = W = Fs \tag{2.1}$$

where, E is the kinetic energy in J, W is work done in J, F is force in N and s is distance in m.

According to Newton's Law,

$$F = ma \tag{2.2}$$

where, , m is mass in kg and a is acceleration in m/s^2

Hence

$$E = mas \tag{2.3}$$

Using the third equation of motion

$$V^2 = U^2 + 2as \tag{2.4}$$

Then

$$a = \frac{V^2 - U^2}{2s} \tag{2.5}$$

where, V is wind speed in m/s and U is initial velocity in m/s.
Since the initial velocity of the object is zero, thus

$$a = \frac{V^2}{2s} \tag{2.6}$$

Substituting it in equations (2.3), the kinetic energy of the a mass in motion can be expressed as equation (2.7)

$$E = \frac{1}{2}mV^2 \tag{2.7}$$

The power in the wind is given by the rate of change of energy

$$P = \frac{dE}{dt} = \frac{1}{2}V^2\ \frac{dm}{dt} \tag{2.8}$$

where, P is power in the wind in Watt, $\frac{dE}{dt}$ is energy flow rate in J/s, $\frac{dm}{dt}$ is mass flow rate in kg/s.
As mass flow rate is given by

$$\frac{dm}{dt} = \rho A \frac{dx}{dt} \tag{2.9}$$

$$\frac{dx}{dt} = V \tag{2.10}$$

$$\frac{dm}{dt} = \rho AV \tag{2.11}$$

where, x is distance in m.

Hence from equation (2.8), the power can be defined as

$$P = \frac{1}{2}\rho AV^3 \tag{2.12}$$

Where, A is swept area in m^2 and ρ is air density in kg/m^3.

2.5 Wind Turbine

Wind turbines are devices that used to convert the wind energy into mechanical energy then electrical energy. They are classified into two types: horizontal axis wind turbine (HAWT) and vertical axis wind turbine (VAWT).

2.5.1 Horizontal axis wind turbine

A horizontal axis wind turbine (HAWT) is a lift device composed of one, two or three rotating blades. The blades are connected to a hub assembly; the hub is connected to a low speed shaft (Sørensen, 2016). A gearbox transmits the rotation from the low speed shaft to a high speed shaft attached to a generator as shown in Figure 2.4. The generator converts the rotation of the high speed shaft into electrical energy (Sørensen, 2016). The wind speed data is transmitted to a controller, which turns on the machine by releasing its backing system when wind speeds are within the desired range for power production. A HAWT contains a yaw system that directs the rotor towards the wind direction and a pitch system to adjust the blades angles in order to maximize power output. A pitch system is also used to feather the blades away of the wind direction at extremely high wind speed conditions. A typically HAWT (70 m dia. mounted to a 60 m tall tower) starts to operate in winds of about 5.36 m/s and produces approximately 1.6 MW, the maximum power output is generated at about 12.52 m/s–13.41 m/s. The turbine blades are feathered to stop its rotation when wind speed reaches 22.35 m/s. Figure 2.5 illustrates the separation distance in cross- and downwind directions for HAWTs in a farm.

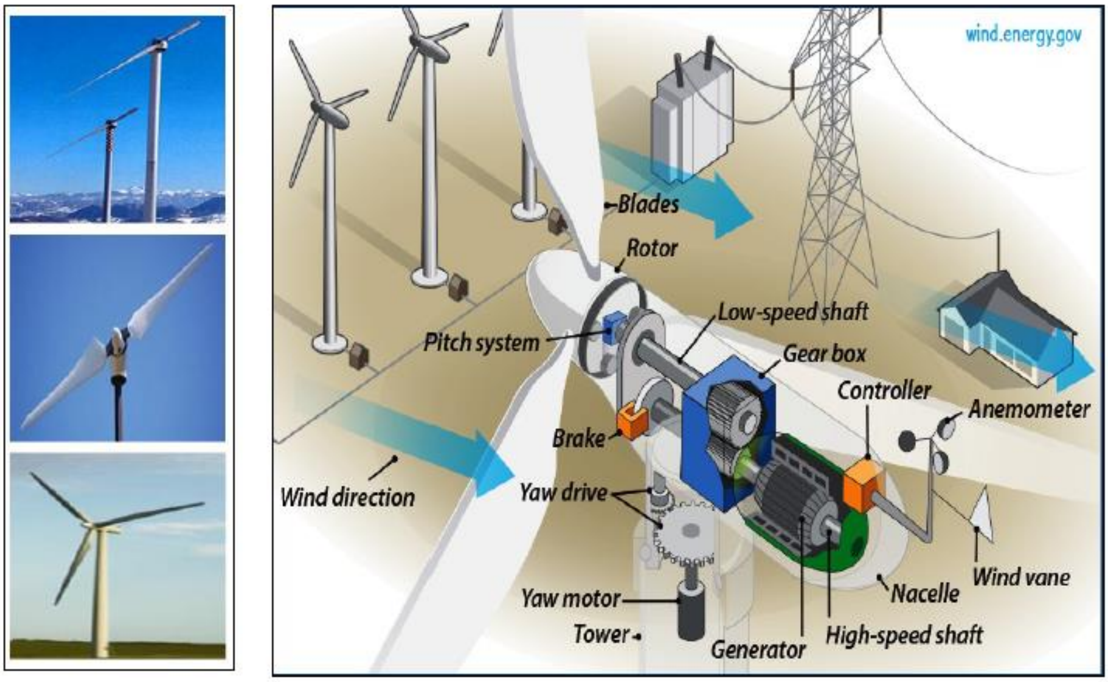


Figure 2.4: Types, Construction and Control System of HAWTs

Figure 2.5: HAWT Separation Distance in Cross and Down-Wind Directions

2.5.2 Vertical Axis Wind Turbines

A vertical-axis wind turbine (VAWT) is a type of wind turbine where the rotating shaft is set vertically and the main components are located at the base of the turbine (Manwell, 2011). This arrangement allows the generator and gearbox to be located close to the ground, facilitating maintenance and repair (Manwell, 2011). VAWTs do not need to be pointed into the wind which eliminates the need for wind sensing and orientation mechanisms. Three types of VAWTs exist, H-rotor, Darrieus and Savonius shown in Figure 2.5. Lift type VAWTs constructed of vertical airfoil blades (H-rotor and Darrieus) gain the interest of most manufacturers (Manwell, 2011). However, drag type VAWTs (Savonius turbines) have the potential to offer significant advantages in high turbulence areas.

a b c

Figure 2.6: Different Types of VAWTs (a) H-Rotor, (b) Darrieus, and (c) Savonius

2.5.3 Difference between HWAT and VAWT

The comparison between HWAT and VAWT is summarized in Figure 2.7. Moreover, the main advantages of VAWTs over HAWTs are (Hemami, 2012):

- Lower cut-in wind speed: VAWTs can start producing electricity at lower wind speeds compared to HAWTs which allows VAWTs to be placed closer to the ground.
- Omni-directional rotor: VAWTs do not need a pitch and yaw system to orient the blades into the wind.
- Lower noise level operation: VAWTs operate at lower tip speed ratios compared to HAWTs; they do not generate as much noise, and have lower vibration levels. Lower construction, installation, and maintenance costs: Construction and installation costs are lower for VAWTs than HAWTs since VAWTs have fewer moving parts. The inverter and generator are located near the ground and a gearbox may not be required (direct generation systems) making a VAWT easier to maintain.

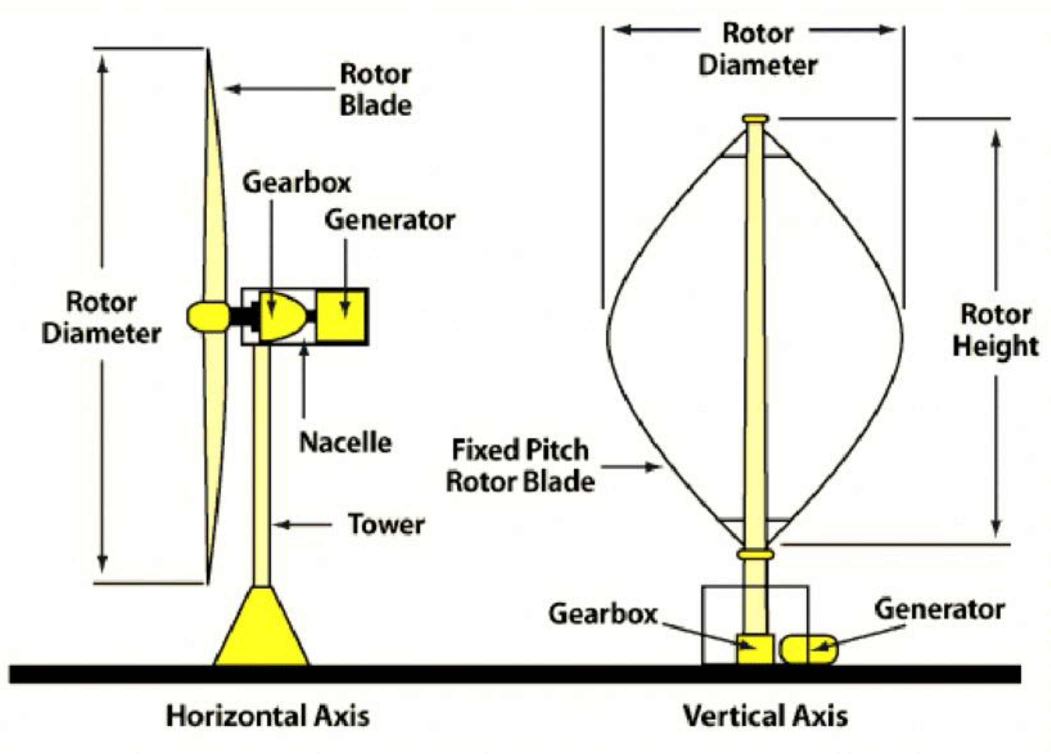


Figure 2.7: Characteristics of different types of wind turbines

2.6 Blade Element Momentum Theory

As mentioned previously, a wind turbine is a machine that converts the kinetic energy in the air into mechanical energy. A wind turbine is a device that extracts kinetic energy from the wind and converts it into mechanical energy. Therefore wind turbine power production depends on the interaction between the rotor and the wind. So the major aspects of wind turbine performance like power output and loads are determined by the aerodynamic forces generated by the wind (Sørensen, 2016)..

The blade element momentum theory (BEMT) for hovering rotors is a hybrid method that was first proposed for helicopter use by Gustafson and Gessow (1946) and Gessow theory approaches. The principles involve the invocation of the equivalence between the circulation and momentum theories of lift. With certain assumption, the BEMT allows inflow distribution along the blade to be estimated (Sørensen, 2016)..

Blade Element Momentum Theory equates two methods of examining how a wind turbine operates. The first method is to use a momentum balance on a rotating annular stream tube passing through a turbine. The second is to examine the forces generated by the aerofoil lift and drag coefficients at various sections along the blade. These two methods then give a series of equations that can be solved iteratively (Sørensen, 2016).

The Blade Element Momentum method combines the Blade Element Theory and the Momentum Theory. In this method, we assume that aerodynamic forces acting on a blade element can be estimated as the force on a airfoil of the same cross-section, advancing through the air with the uniform velocity at the angle of attack α and that the force on the whole blade can be derived by adding the contributions of all the elements along the blade (Sørensen, 2016).

Also, there is no induction between consecutive blade elements except in so far as such induction modifies the characteristics of the same airfoil section. In the Blade Element Theory, we also consider some assumptions related to the blade behavior. These are (Sørensen, 2016):

1. The operation of an element is not affected by the adjacent elements of the same blade.

2. The effective velocity of the element through the air is the vector resultant of the axial velocity (V_0) and the rotational velocity (Ωr).
3. The airfoil characteristics are used for the blade elements.
4. The force from the blades acting on the flow is constant at each annular element. This stands for the rotor with an infinite number of blades.

According to the Blade Element Momentum (BEM) method, the steady loads thrust and power can be calculated for different operation conditions of wind speed, rotational speed and pitch angle. For unsteady purposes to calculate time series of the loads, some engineering models must be implemented.

As mentioned above, the BEM method joins the momentum theory with the local conditions at the actual blades and dividing the stream tube into N annular elements of height dr as shown in Figure 2.8. Therefore, the lateral boundary of these elements consists of streamlines and thus there is no flow across the elements. From the ideal rotor, we obtained the required

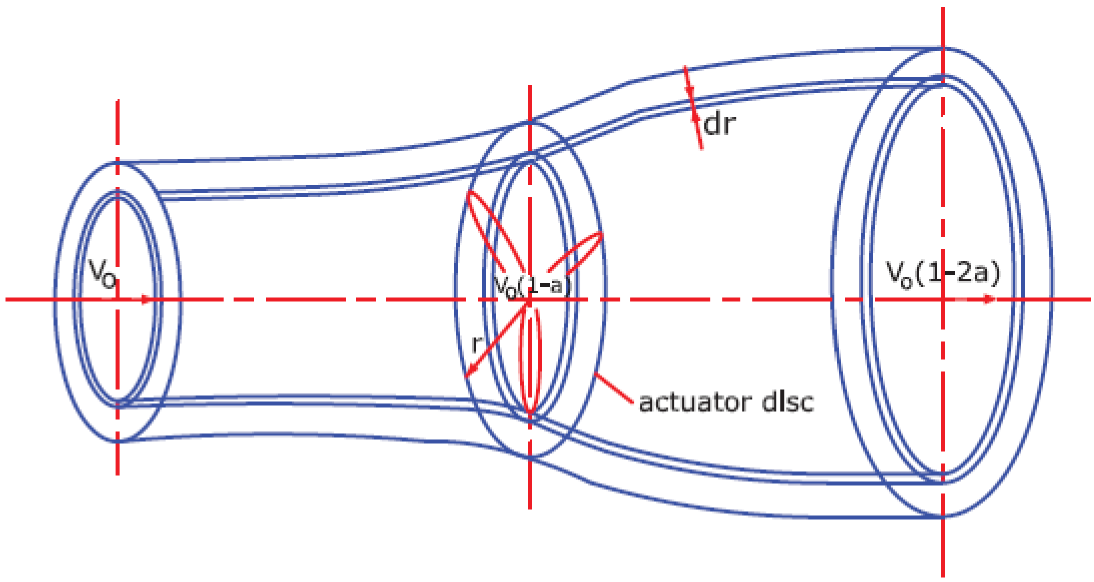


Figure 2.8: Annular control volume

The thrust (T) and torque (M) can be calculated as given below.

$$dT = 4\pi\rho V_0^2 a(1-a)rdr \qquad (2.13)$$

$$dM = 4\pi\rho V_0 \Omega (1 - a) a' r^3 dr \tag{2.14}$$

It is obvious that the relative velocity (V_{rel}) seen by a section of the blade is a combination of the axial velocity $V_0(1 - a)$ and the angular velocity $(1 + a')\ \Omega r$ at the rotor plane as Figure (2.9). By definition, θ is the local pitch of the blade (the angle between the chord line and the plane of rotation). It consists of the pitch angle θ_p (the angle between the tip chord and the rotor plane) and the twist of the blade β which is measured relative to the tip chord. Hence, $\theta = \theta_p + \beta$. Also, ϕ is the angle between the planes of rotation and the relative velocity V_{rel}. According to Figure 2.10, the local angle of attack α is defined as

$$\alpha = \phi - \theta \tag{2.15}$$

Moreover, it is found that

$$tan(\phi) = \frac{1 - a}{1 + a'} \frac{v_0}{\Omega r} \tag{2.16}$$

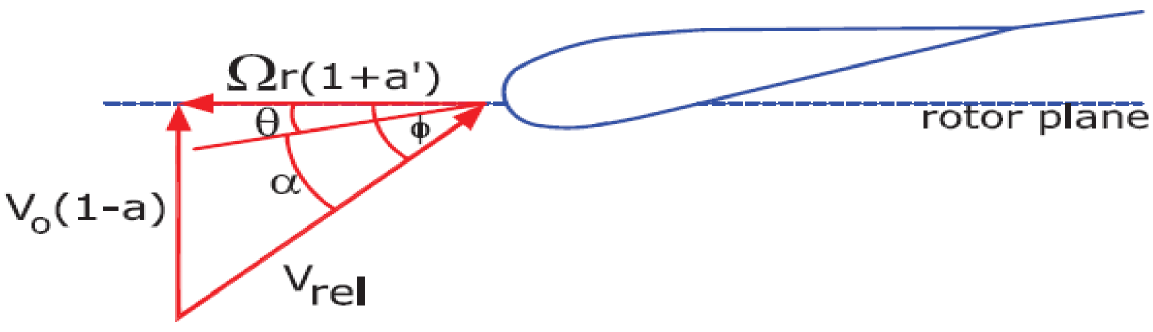
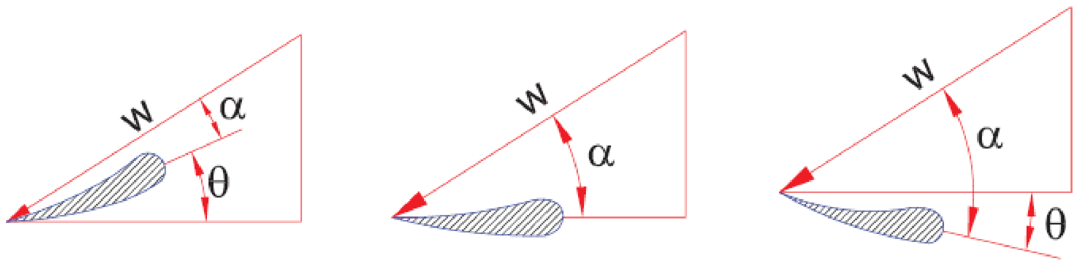


Figure 2.9: Velocities at the rotor plane



(a) positive pitch angle (b) zero pitch angle (c) negative pitch angle

Figure 2.10: Flow and blade angles of a blade element

In addition, by knowing the lift coefficient (C_L), drag coefficient (C_D) and the chord length (c)of each airfoil, the lift (L) and drag (D) forces per length can be computed as

$$L = \frac{1}{2}\rho C_L V_{rel}^2 c \tag{2.17}$$

$$D = \frac{1}{2}\rho C_D V_{rel}^2 c \tag{2.18}$$

By definition, the lift and drag forces are perpendicular and parallel to the velocity seen by the rotor respectively. In order to calculate the forces which are normal and tangential to the rotor plane, we must decompose the above lift and drag forces into these directions as Figure 2.11. Therefore, we get

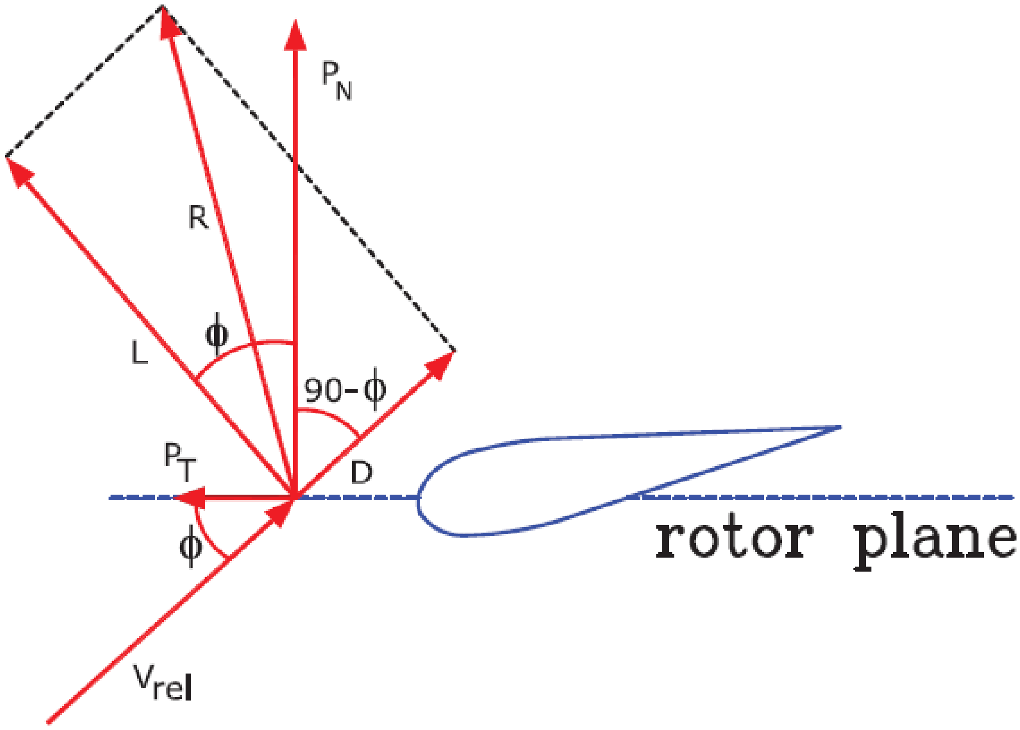


Figure 2.11: Decomposition of the lift L and drag D forces into the rotor plane

$$P_N = L\cos\phi + D\sin\phi \quad (2.19)$$

$$P_T = L\sin\phi - D\cos\phi \quad (2.20)$$

By normalizing the equations. (2.19) and (2.20) with $\frac{1}{2}\rho V_{rel}^2\, c$, it is found that

$$C_n = C_L\cos(\phi) + C_D\sin(\phi) \quad (2.21)$$

$$C_t = C_L\sin(\phi) + C_D\cos(\phi) \quad (2.22)$$

$$C_n = \frac{P_N}{\frac{1}{2}\rho V_{rel}^2\, c} \quad (2.23)$$

$$C_t = \frac{P_T}{\frac{1}{2}\rho V_{rel}^2\, c} \qquad (2.24)$$

From Figure 2.9, it can be seen that

$$V_{rel} sin\phi = V_0\,(1-a) \qquad (2.25)$$

$$V_{rel} cos\phi = \Omega r(1+a') \qquad (2.26)$$

Now, the solidity as the portion of the annular area in the control volume covered by the blades is defined as

$$\sigma\,(r) = \frac{c(r)NB}{2\pi r} \qquad (2.27)$$

where *NB*, *c (r)* and *r* denote the number of blades, the local chord and the radial position of the control volume, respectively. Since PN and PT are forces per unit length, the normal force and the torque on the control volume of thickness *dr* are

$$dT = NBP_N dr \qquad (2.28)$$

$$dM = rNBP_T dr \qquad (2.29)$$

Combination of equations (2.23), (2.25) and (2.28) gives

$$dT = \frac{1}{2}\rho cNB\,\frac{V_0^2(1-a)^2}{sin^2\phi}\,C_n dr \qquad (2.30)$$

Similarly, combination of equations (2.24), (2.25), (2.26) and (2.29) yields

$$dM = \frac{1}{2}\rho cNB\,\frac{V_0(1-a)\Omega r(1+a')}{sin\phi cos\phi}\,C_t r dr \qquad (2.31)$$

Finally, if equations (2.30) and (2.13) for *dT* are equalized and equation (2.27) is applied, then the axial induction factor is obtained as

$$a = \frac{1}{\frac{4sin^2(\phi)}{\sigma C_n} + 1} \quad (2.32)$$

If equation (2.31) and (2.14) for *dM* are equalized, the angular induction factor is obtained as

$$a' = \frac{1}{\frac{4sin(\phi)cos(\phi)}{\sigma C_t} - 1} \quad (2.33)$$

Now, it is assumed that there is no radial dependency for different control volumes in BEM method, so each section can be evaluated separately. The BEM model algorithm includes the following steps:

1. Initialize a and a'; generally $= a' = 0$.
2. Calculate the flow angle ϕ using equation (2.16)
3. Calculate the local angle of attack using equation (2.15).
4. Read $C_L(\alpha)$ and C_D (α) from the table
5. Calculate *Cn* and Ct
6. Calculate a and a$'$
7. If a and a$'$ has changed more than a certain tolerance, go to step (2) otherwise finish.
8. Calculate the local loads on the portion of the blades.

The above steps are shown in Figure 2.12. Because of the assumption which was made at the BEM model, here we need two corrections to the above algorithm.

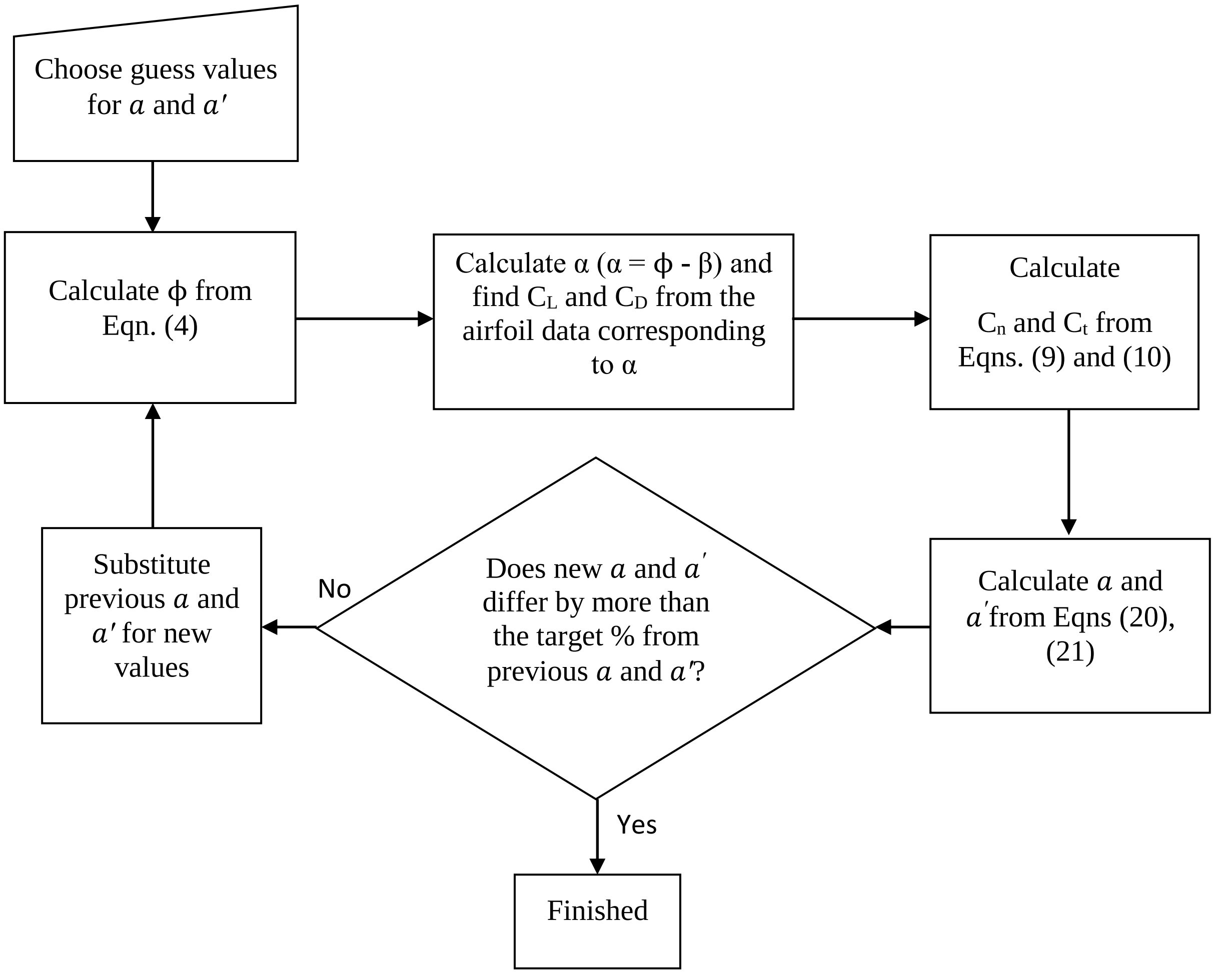


Figure 2.12: BEM model algorithm

The first one corrects the assumption of the infinite number of blades and the second one is an empirical relation between the thrust coefficient C_T and an axial induction factor a when it becomes greater than approximately 0.4. The corrections are:

1- Prandtl's Tip Loss Factor

Prandtl's tip loss factor adjusts the assumption of an infinite number of blades. So, instead of using equations (2.32) and (2.33), the following relations are used for a and a$'$

$$a = \frac{1}{\frac{4F\sin^2(\phi)}{\sigma C_n} + 1} \tag{2.34}$$

$$a' = \frac{1}{\frac{4F sin(\phi) cos(\phi)}{\sigma C_t} + 1} \tag{2.35}$$

where F and f (Glauert Correction) are defined as

$$F = \frac{2}{\pi} arccos\big(exp(-f\ )\big) \tag{2.36}$$

$$f = \frac{NB}{2} \frac{R - r}{r sin(\phi)} \tag{2.37}$$

Recall that NB, R, r and ϕ are defined as the number of blades, rotor radius, local radial position and flow angle, respectively.

2- Glauert Correction

The simple momentum theory is valid only for a small value of axial induction factor and it is not valid for values larger than approximately 0.4. In this condition, empirical relations between the thrust coefficient C_T and would be performed to meet the experiments. The relation is given by

$$C_T = \begin{cases} 4a(1 - a)F & \text{if } a < a_c \\ 4(a_c^2 + (1 - 2a_c)a)F & \text{if } a > a_c \end{cases} \tag{2.38}$$

where a_c = 0.2 and F is Prandtl's tip loss factor. So instead of equations (2.34) and (2.35), for $a < a_c$

$$a = \frac{1}{\frac{4F\sin^2(\phi)}{\sigma C_n} + 1} \tag{2.39}$$

Otherwise

$$a = \frac{1}{2}\Big(2 + K(1 - 2a_c) - \sqrt{(K(1 - 2a_c) + 2)^2 + 4(Ka_c^2 - 1)}\Big) \tag{2.40}$$

where

$$K = \frac{4F\sin^2(\varphi)}{\sigma C_n} \tag{2.41}$$

CHAPTER 3
MATERIAL AND METHOD

3.1 Wind Home System

Wind turbine is direct way to convert the wind energy into electricity, and the electricity amount available for daily use will be determined based on the capacity of wind turbine and wind speed availability. The wind turbine can be mounted on the rooftops to generate electrical power. Figure 3.1 illustrate the configuration of wind home system, which utilized to electricity for domestic household in order to reduce the fuel consumptions and air pollution. A simple wind home system consists of the wind turbine, lead battery, and inverter, as well as the directly connected DC appliances.

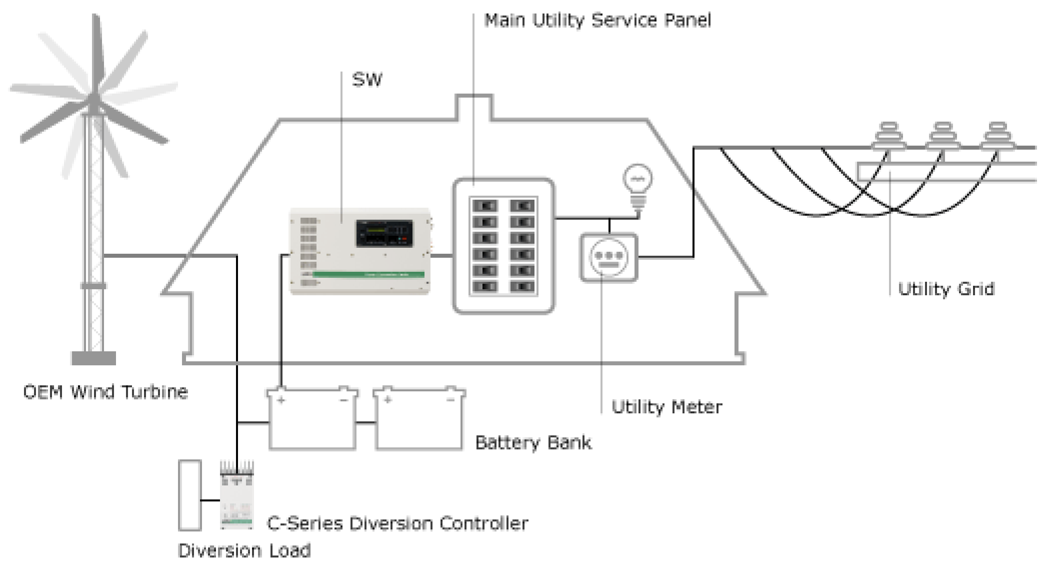


Figure 3.1: Configuration of wind home system

3.2 Selected Region and Electricity Feed-in Tariff in Northern Cyprus

In this study, the data are collected from household in Güzelyurt, Northern Cyprus. Güzelyurt is located in the northwestern part of Cyprus. The location and area-specific information are shown in Figure 3.2 and Table 3.1, respectively. This city has low populations compared to other cities in Northern Cyprus as shown in Figure 3.3. Recently, regarding the development technologies, related activities, and policy making have increased. For instance, the Feed-in tariffs for residential electricity have increased and the value of Feed-in tariffs are summarized and listed in Table 3.2.

Figure 3.2: Map of Cyprus (▭ selected region)

Table 3.1: Güzelyurt, Northern Cyprus information

Region location	
Latitude (°N)	35° 12' 3.528"
Longitude (°E)	32° 59' 26.808"
Elevation (m)	49

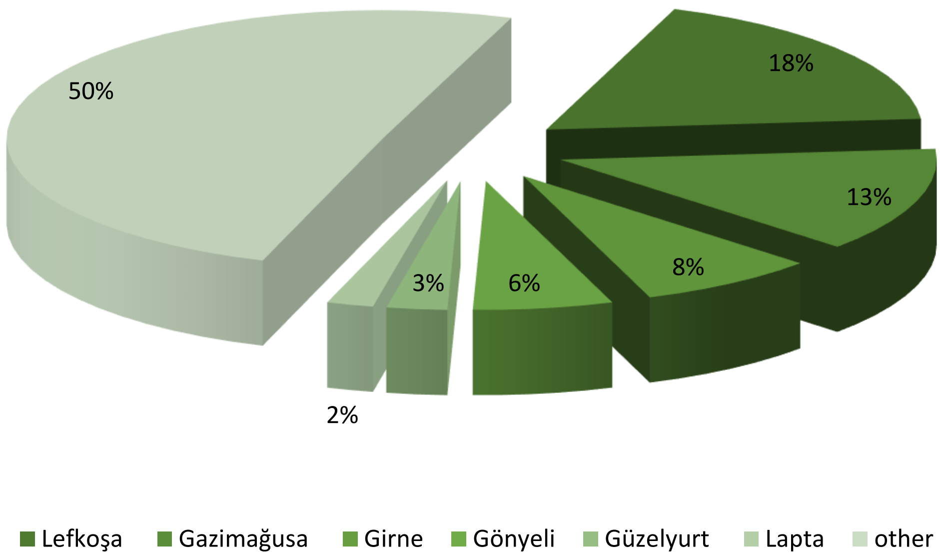


Figure 3.3: Population density in major cities in Northern Cyprus

Table 3.2: Electricity Feed-in tariff in Northern Cyprus [source:

Residential Tariff	Period	Value [TL]	Residential Tariff	Period	Value [TL]
0-250kWh 251-500 kWh 501-750 kWh > 750 kWh	01/01/2015 - 1910/2015	0.44 0.48 0.52 0.54	0-250kWh 251-500 kWh 501-750 kWh > 750 kWh	20/10/2015 - 31/03/2016	0.44 0.48 0.52 0.54
0-250kWh 251-500 kWh 501-750 kWh > 750 kWh	01/04/2016 - 20/10/2016	0.40 0.45 0.49 0.2	0-250kWh 251-500 kWh 501-750 kWh > 750 kWh	21/10/2016 - 20/12/2016	0.44 0.49 0.53 0.56
0-250kWh 251-500 kWh 501-750 kWh > 750 kWh	21/12/2016 - 30/04/2018	0.52 0.60 0.67 0.75			

3.3 Wind Turbine System for Residential Building

Renewable energy systems can be improved energy efficiency and reduced energy demand to provide the dominant contribution to tackling global climate change. Increasing energy demand, environmental pollution, and global warming are the main factors that increase the tendency towards renewable and clean energy resources.

Table 3.3 lists the electrical equipment available in the studied residential home along with their average hours of use daily period of use in hours. The residential house is a typical two bedroom for small family.

Table 3.3: Electrical load available in the residential houses

Selected house	Description	Ratings	Hours of use per day	Energy
House 1	32’’ LED TV	80	12	660
	Washing Machine	480	1	480
	Satellite Receiver	12	12	144
	Refrigerator	300	24	7200
	Laptop	200	5	250
	Vacuum Cleaner	800	1	800
	LED lamps	63	7	1323
	Air-conditioner	750	5	3750
	Clothes iron	1000	1	1000
	Microwave oven	1200	1	1200
	Water pump	500	1	500
	Toaster	800	1	800
House 2	32’’ LED TV	55	10	550
	Washing Machine	480	1	480
	Satellite Receiver	12	10	120
	Refrigerator	750	24	18000
	Laptop	50	10	500
	Vacuum Cleaner	800	1	800
	LED lamps	63	7	1323
	Air-conditioner	750	12	9000
	Clothes iron	1000	1	1000
	Microwave oven	1200	2	2400
	Water pump	500	1	500
	Toaster	800	1	800
	Hair dryer	1000	1	1000

The selected location for this study is a residential Building with small space available on rooftop area (roughly 100 m^2). Figures 3.4-3.6 show the mean monthly electricity consumptions for a period of January 2016- December 2017 for three chosen household with different capacity in selected regions. It is noticed that the highest amount of electricity are recorded in summer and winter seasons. In addition, the average electricity consumption for the selected house is about 512kWh/yr for house 1 and 473kWh/yr for house 2.

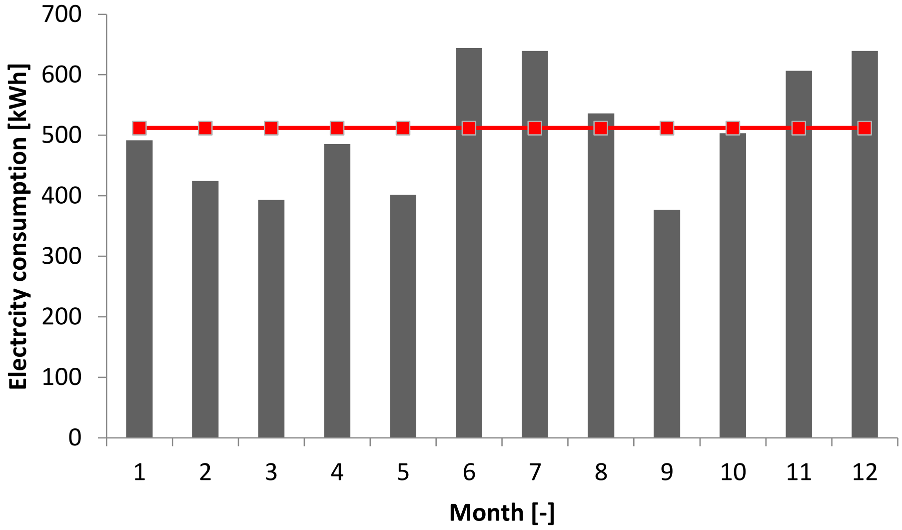


Figure 3.4: Mean monthly electricity consumption for house 1

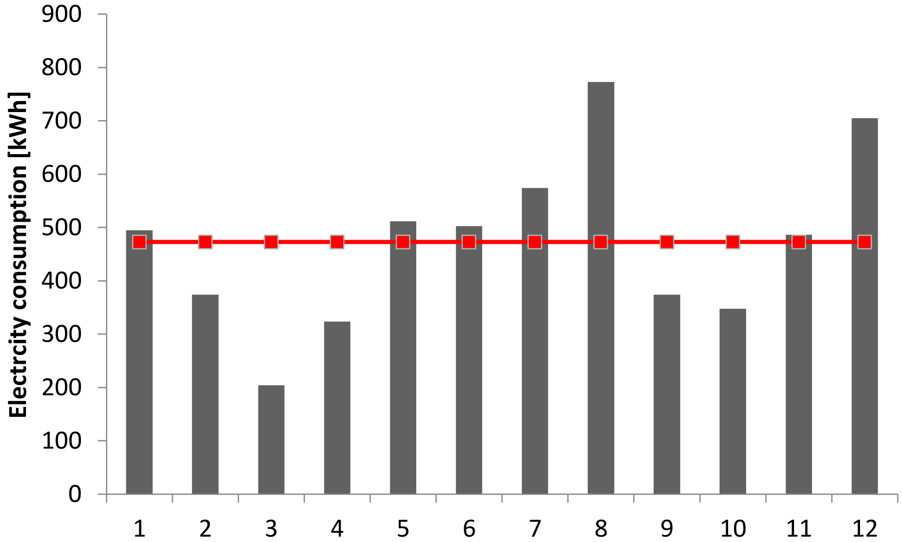


Figure 3.5: Mean monthly electricity consumption for house 2

3.4 Materials

3.4.1 Wind turbine

The selection of a wind turbine is a function of the wind power density of the region and class. It is essential that the wind resources are accurately modeled for region evaluation and sizing of the wind turbine. The amount of electricity that can be produced from the wind turbine depends on the wind speed of the specific region. Therefore, the wind speed measurements of the studied region and the power curve of the selected wind turbine are the most important factors for choosing the best wind turbine for the specific region. In this study, the performance of wind turbine, namely a horizontal axis wind turbine (HAWT) was investigated. Generally, HAWTs are the most commonly used for generating electricity today. The selected wind turbines have chosen after an overall comparison between different types of wind turbines. In addition, the selected turbines are considered for their reasonable cost. The characteristic of the selected wind turbines models is presented in Table 3.4.

Table 3.4: Characteristics of used wind turbine

Parameters	**Value**
Hub height [m]	5
Rated power [kW]	0.4
Rotor diameter [m]	1.1
Design life [years]	20
Cut-in wind speed [m/s]	2
Rated wind speed [m/s]	16
Cut-off wind speed [m/s]	-

3.4.2 Battery

Wind batteries are utilized to store the electrical energy generated by panels during the daylight. Batteries play an important role in load supply during the night or any time that solar irradiation is not sufficient. Table 3.5 lists the characteristics of the batteries used in this study.

Table 3.5: Characteristics of used batteries

Battery company name	Voltage	Capacity
Varta	12	50Ah

3.4.3 Charge controller and inverter

The charge controller is used to control the current from PV panels to the battery. The charging controller can be used as a protection against overcharging or deep charging in PV systems. Specifications of the applied inverter used in this study are presented in Table 3.5.

Table 3.5: Charge controller characteristics

Type	Modular power switch
Nominal charging current	45 A
Nominal voltage	12 V/24 V/48 V
Max panel voltage	30 V in 12 V system 50 V in 24 V system 95 V in 48 V system
Self-power consumption	< 6 mA
Ambient temperature range	25℃ to 50℃
Case protection	IP22
Normal charge temperature	< 80℃

3.5 Energy and Economic Assessment of Wind System

RETScreen software is used to assess the economic and energy of PV solar system for single house family. In this study, Güzelyurt region in Northern Cyprus was selected for the installation of the system. After selecting the location area the complete RETScreen analysis has been conducted. This analysis consist four main steps:

I. Selection of facility type (i.e. single family house as shown in Figure 3.6),
II. Energy analysis (see Figure 3.7)
III. Emissions analysis (see Figures 3.8),
IV. Financial analysis (see Figures 3.9).

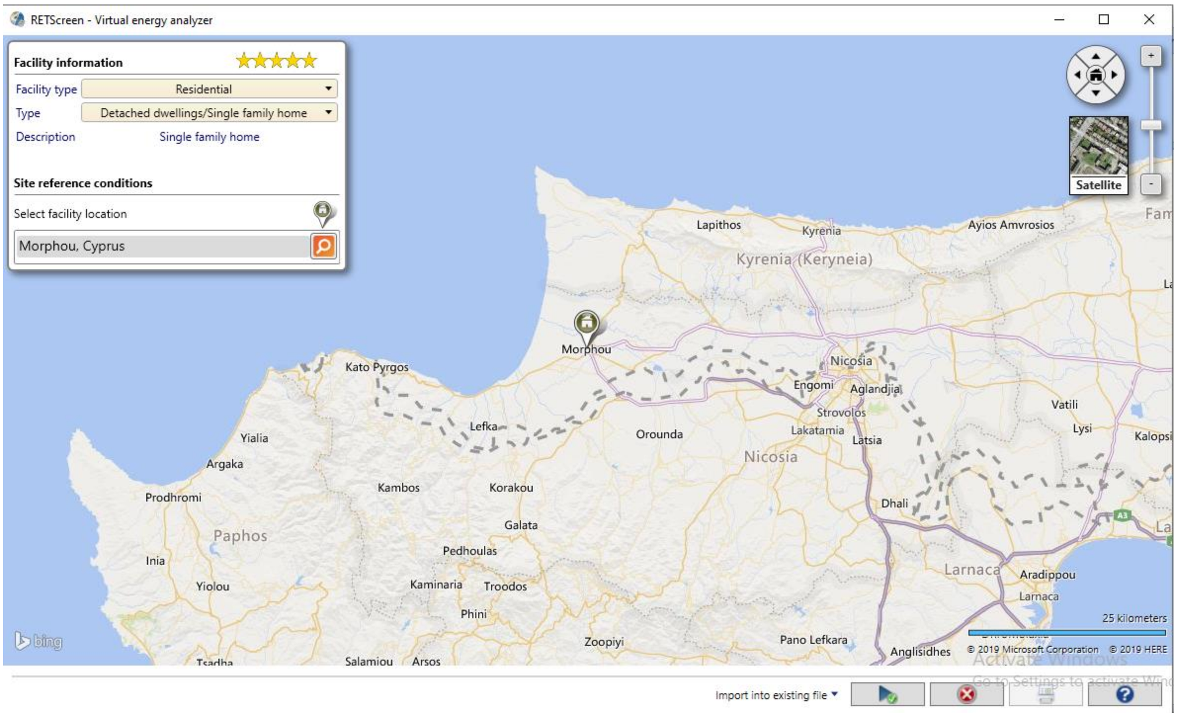


Figure 3.6: Selection of facility type

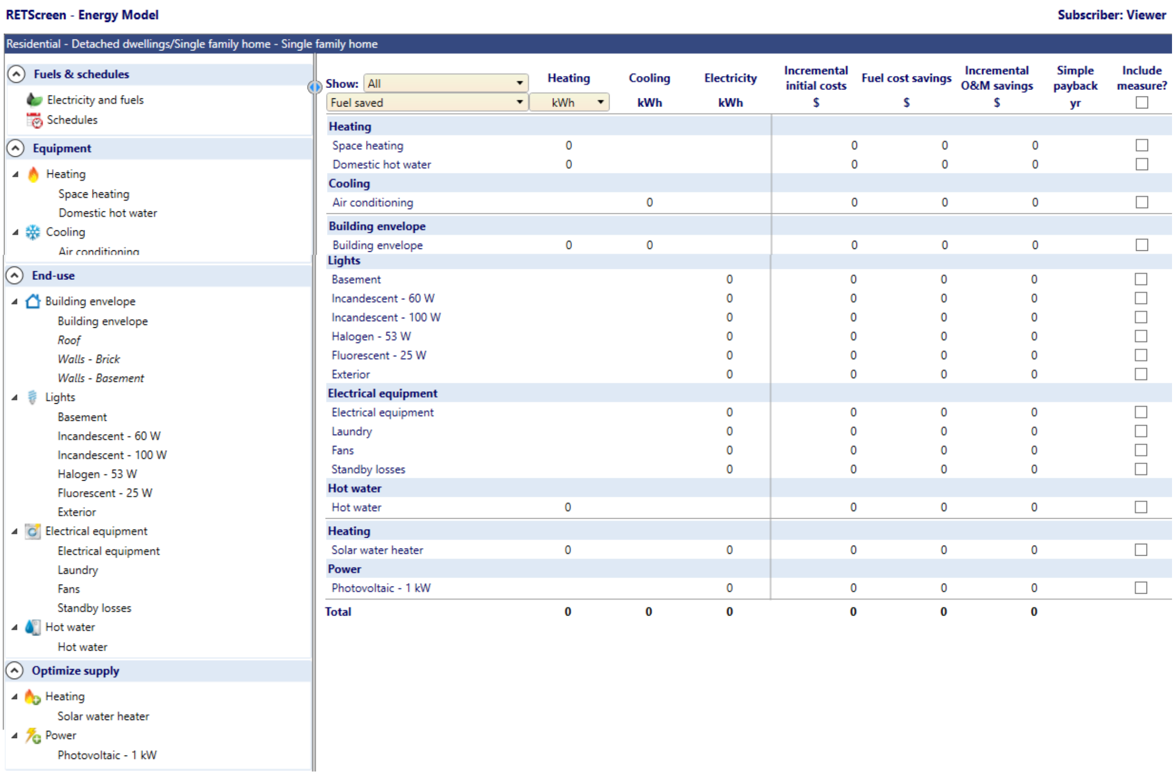


Figure 3.7: Energy analysis

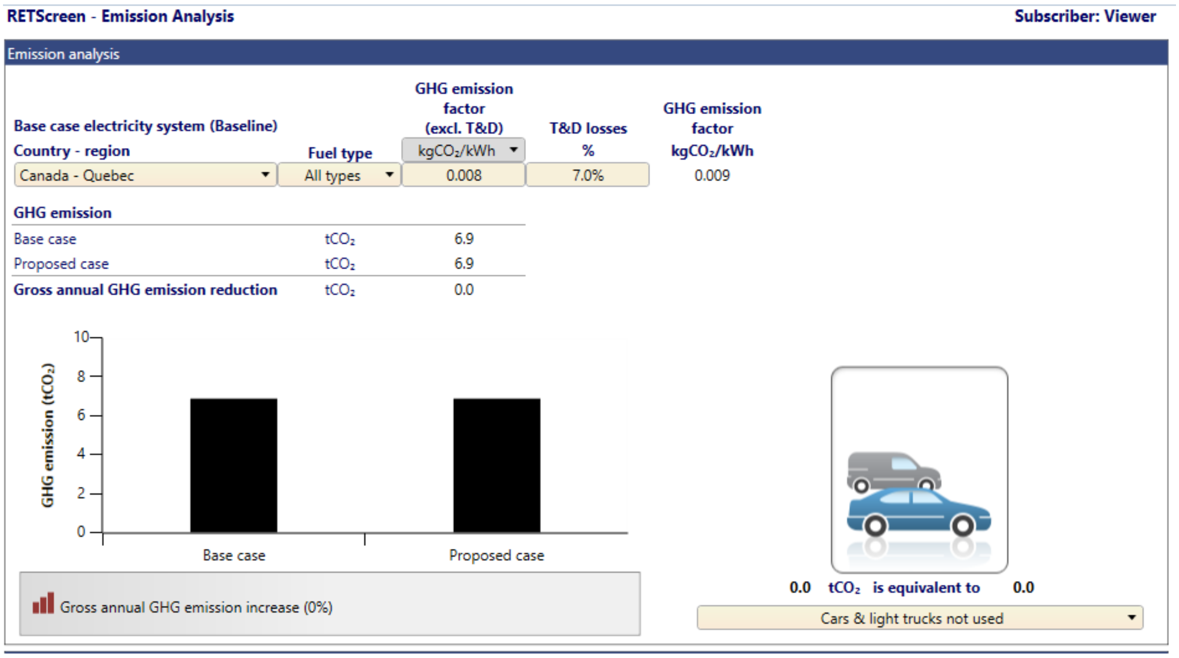


Figure 3.8: Emissions analysis

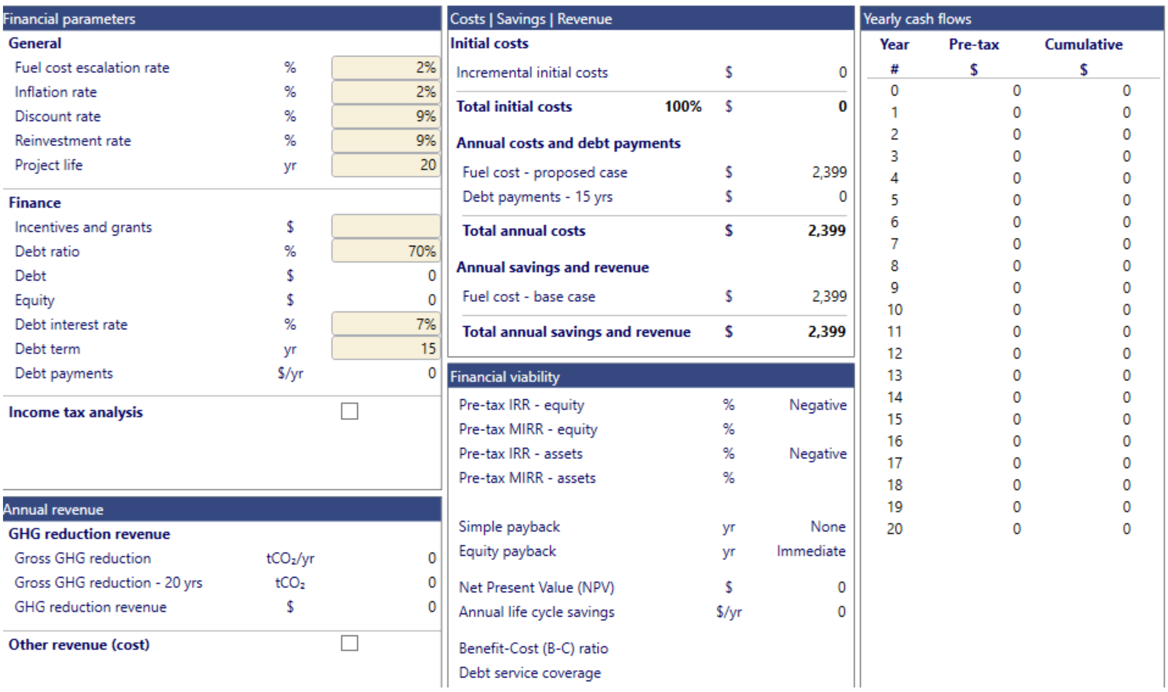


Figure 3.9: Financial analysis

CHAPTER 4
RESULTS AND DISCUSSION

4.1 Wind Potential in the Selected Location

Figures 4.1 and 4.2 show the GeoModel long-term averages of wind resource: mean wind speed (Figure 4.1) and mean wind power density (Figure 4.2). It is found that the mean wind speed values in Güzelyurt region are within the range of 2.5-2.75 m/s. The maximum wind speed is obtained at the mountain areas, approximately ranging from 3.00m/s to 4.89 m/s as shown in Figure 4.1. Moreover, the wind power density values were found in the range of 44-75W/m^2 at 50 m height as shown in Figure 4.2.

Furthermore, based on the wind power classification (Table 4.1), it is noticed that the wind power density at Güzelyurt is categorized as poor wind power. It can be concluded that the wind power density in Northern Cyprus is considered as poor except at some area, which can be classified as marginal.

Understanding wind resource is crucial for the development of wind energy applications. In particular, for the wind power sector, wind turbine technology typically requires an analysis on wind speed. This Global Wind Atlas, the most reliable sources of data currently available are used to generate the wind resource estimates provided, with the objective of supporting policy development of wind power project.

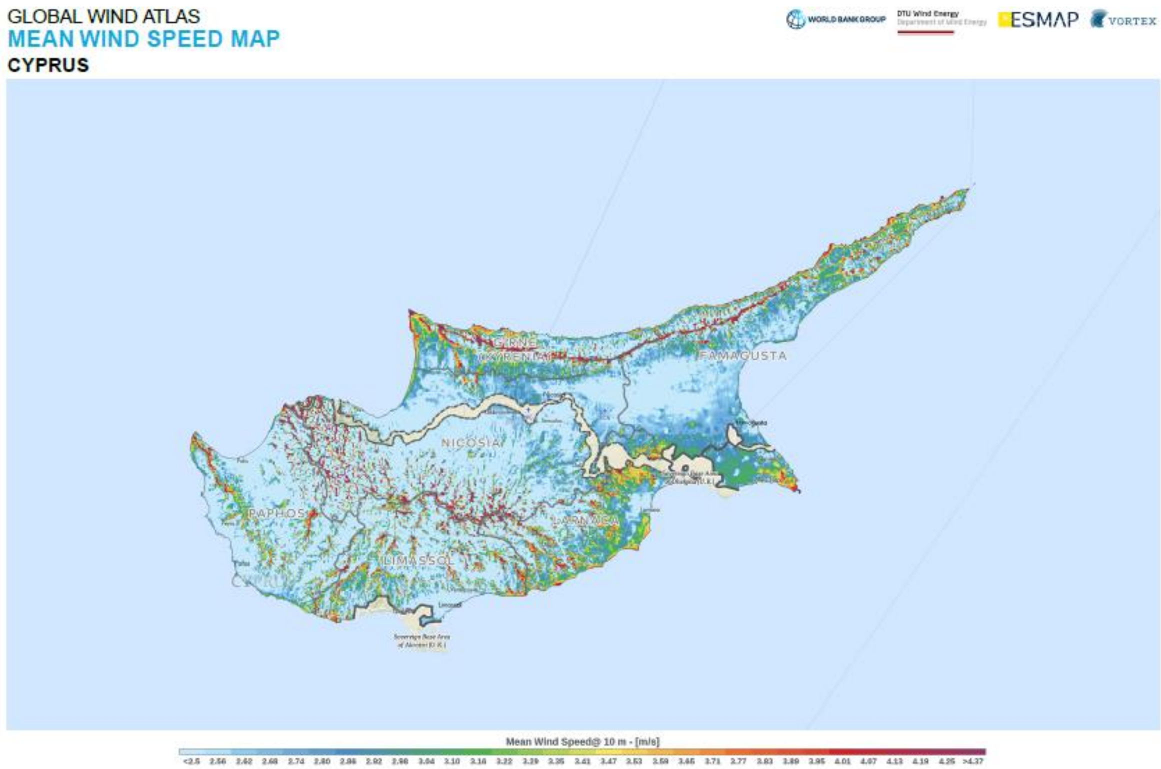


Figure 4.1: Mean wind speed map at 10m height

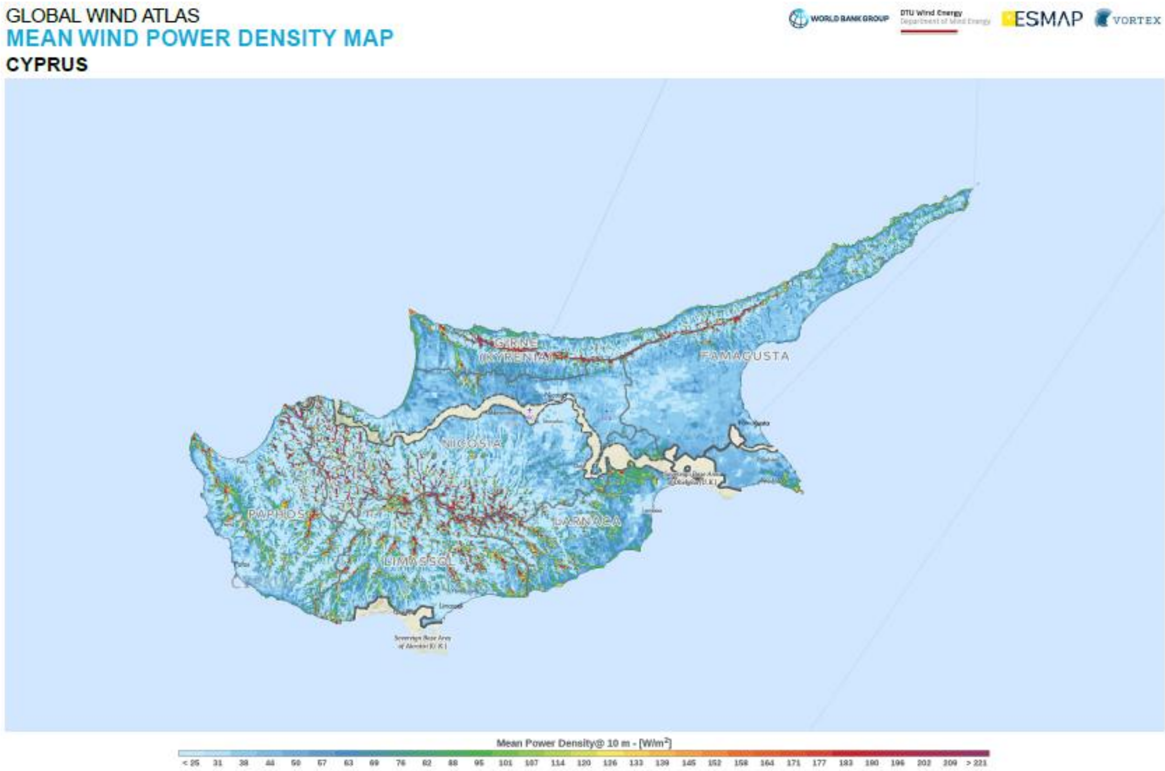


Figure 4.2: Mean wind power density map at 10m height

Table 4.1: Wind power density classification at 10m height

Wind power class		Wind power density[W/m^2]	Resource potential
1	1-	0-100	Very poor
	1+	100-200	
2	2-	200-250	Poor
	2+	250-300	
3	3-	300-350	Marginal
	3+	350-400	
4	4-	400-450	Good
	4+	450-500	
5	5-	550-550	Very Good
	5+	550-600	
6	6-	600-700	Excellent
	6+	700-800	

4.2 Description of Wind Speed Data based on Wind Atlas Map

The descriptive statistics of the selected location including maximum, minimum, mean, median, standard deviation (SD), coefficient of variation (CV), Skewness and Kurtosis is presented in Table 4.2. It is found that the mean wind speed data are varied from 2.58m/s to 4.18m/s. The maximum wind speed is found to be 15.49 m/s in 2017. In addition, the CV are low, ranging from 50.81% to 73.6%. In addition, it is noticed that all Skewness values are positive which indicate that all distributions are right skewed. The Kurtosis values are moderately high, ranging from 1.67 to 5.90. Furthermore, the annual mean wind speed is found to be 3.16m/s, indicating that the selected location has low wind speed due to the number of constrictions and populations.

Moreover, the hourly wind speed data of Beirut is illustrated in Figure 4.3. It is observed that the maximum wind speed of 15.49 m/s is occurred on 7 January 2017 at 21:00pm.

Furthermore, Figure 4.4 shows the mean monthly wind speed data for the elected location. During the investigation period (2015-2017), it is found that the highest and lowest mean daily wind speed are recorded in December 2017 and September 2016 with a value of 5.95 m/s and 1.99 m/s, respectively. In addition, it is found that the annual wind speed value is found to be 3.16 m/s.

Table 4.2: Descriptive statistics of wind speed series

Variable	Mean [m/s]	SD [m/s]	CV [%]	Minimum [m/s]	Median [m/s]	Maximum [m/s]	Skewness [-]	Kurtosis [-]
2015	2.48	1.31	50.81	0.065	2.36	10.32	0.83	1.14
2016	2.63	1.60	58.73	0.00	2.56	12.52	1.56	5.42
2017	3.15	2.36	56.42	0.08	3.78	14.98	1.18	1.62

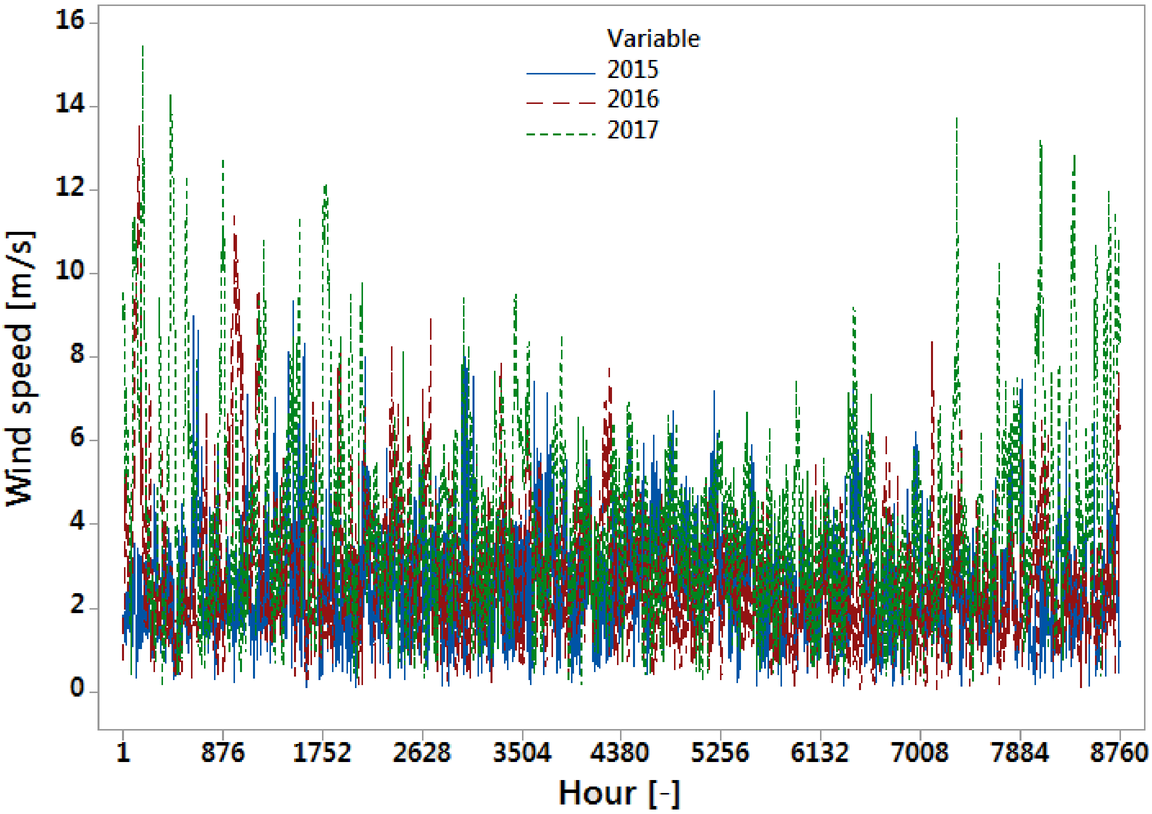


Figure 4.3. Hourly wind speed in Güzelyurt, Northern Cyprus

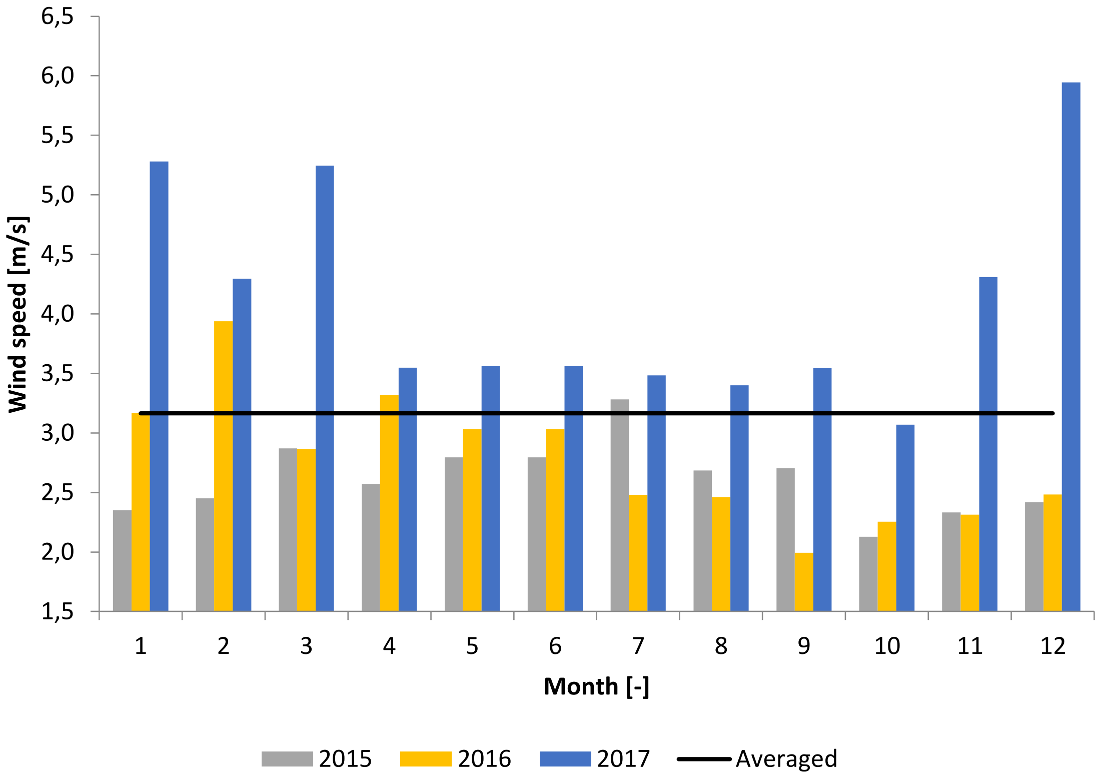


Figure 4.4: Mean monthly wind speed in Güzelyurt, Northern Cyprus

4.3 Description of Weather Data and selected wind turbine based on RETScreen

Table 4.3 lists the weather data of the selected location based on NASA source. It is found that the mean air temperature, relative humidity and global solar radiation are 20.416℃, 68.148% and 5.46 $kWh/m^2/d$, respectively. Furthermore, the annual mean global solar radiation is found to be 226.06W/m^2, indicating that the selected location has high solar radiation. Moreover, Furthermore, it is found that the wind speed values are varied from 3.1 to 4.5 with average value of 3.6m/s.

Moreover, Figure 4.5 shows the relationship between the wind speed and relative humidity. It is observed that the wind speed is decreased as the relative humidity increases. In addition, it is found that increasing of global solar irradiation and temperature lead to decrease the wind speed of the selected region as shown in Figures 4.6 and 4.7.

Table 4.3: Weather parameters of the selected region measured at 10m

Month	Air temperature [°C]	Relative Humidity [%]	Wind speed [m/s]	Global horizontal irradiance [kWh/m^2/d]
J	12.1	63.1	4.3	2.65
F	11.7	62.4	4.5	3.63
M	13.4	61.5	4.0	5.07
A	16.7	61.8	3.5	6.27
M	20.3	62.3	3.1	7.49
J	24.5	57.8	3.3	8.41
J	27.8	52.9	3.4	8.23
A	28.0	54.1	3.4	7.40
S	25.8	54.1	3.4	6.22
O	22.2	55.4	3.2	4.59
N	17.6	58.9	3.7	3.11
D	13.7	62.8	3.9	2.32
Annual	19.5	58.9	3.6	5.46

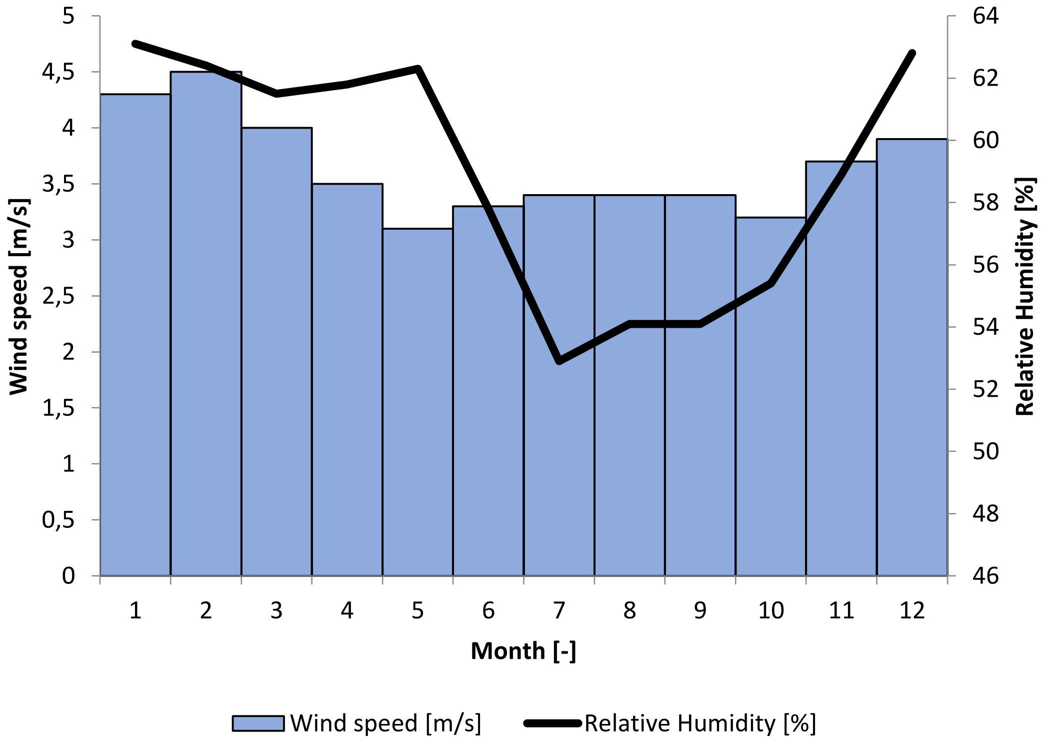


Figure 4.5: Monthly variation of wind speed and relative humidity

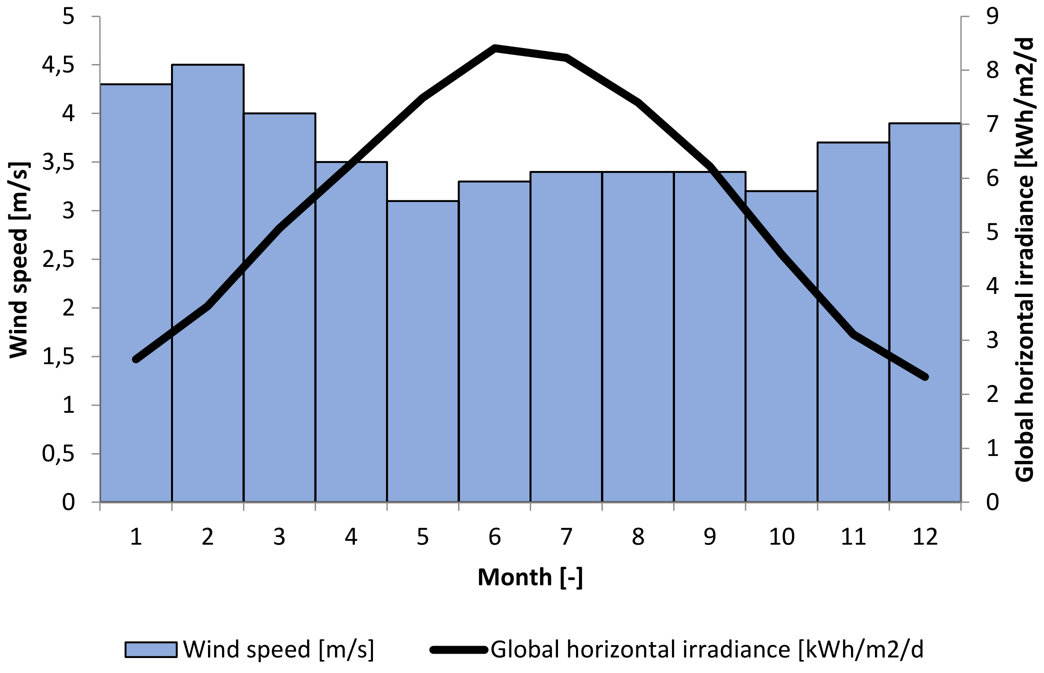


Figure 4.6: Monthly variation of wind speed and daily global horizontal irradiance

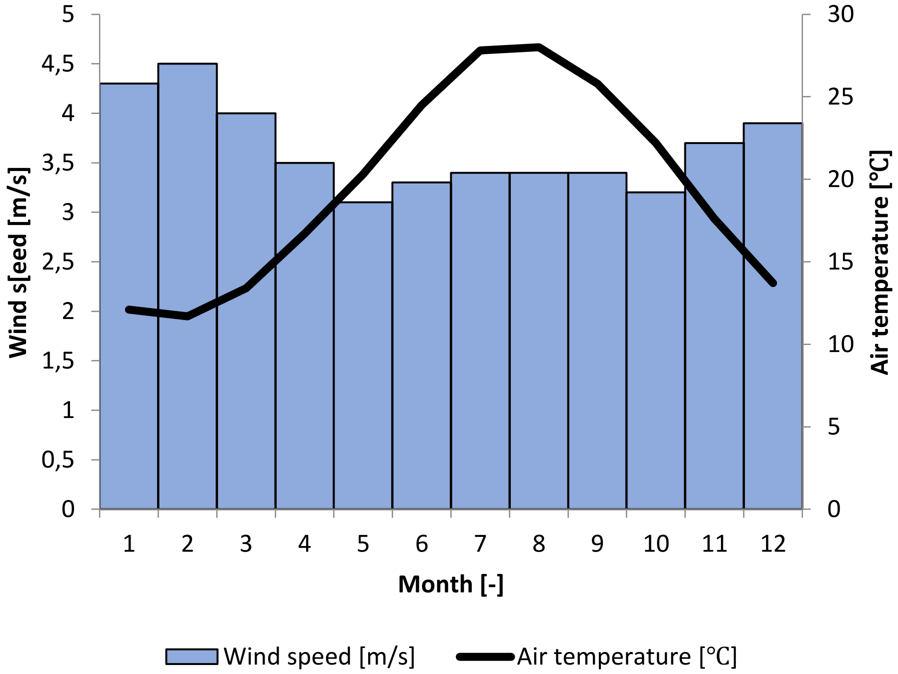


Figure 4.7: Monthly variation of wind speed and air temperature

The selected wind turbines that satisfy the estimated annual energy for the selected location are shown in Table 4.5. In this study, the selected wind turbine, Stealth Gen D400 / 0.4 kW Wind Turbine with the capacity of 400W has chosen after an overall comparison between different types of wind turbines.

Table 4.5: Specification of the selected wind turbine

Characteristics	**Stealth Gen D400 / 0.4 kW**
Hub height [m]	5
Rated power [kW]	0.4
Rotor diameter [m]	1.1
Design life [years]	20
Cut-in wind speed [m/s]	2
Rated wind speed [m/s]	16
Cut-off wind speed [m/s]	-
Number of blades	3
Generator	3 Phase AC PMG
Maximum RPM	1200
Break System	Electrical
Blade material	Glass reinforced nylon
Output voltage [V]	12/24
Minimum operation temperature [℃]	-20
Maximum operation temperature [℃]	12

The wind turbine number that can be installed in the location is estimated based on the distance between the turbines i.e. 6 to 9 times the diameter of the horizontal axis wind turbine and 3 to 5 times the diameter of the vertical axis wind turbine. The number of wind turbines that could be installed on the roof of the building is found to be to be 5 turbines. Moreover, the amount of the time that the wind project is able to generate electricity over an investigation period of the time divided by the total amount of available time during the period is called availability factor. Figure 4.8 shows the power-speed curve of the selected wind turbine, which indicates the amount of power produced by the wind turbine models for each wind speed value.

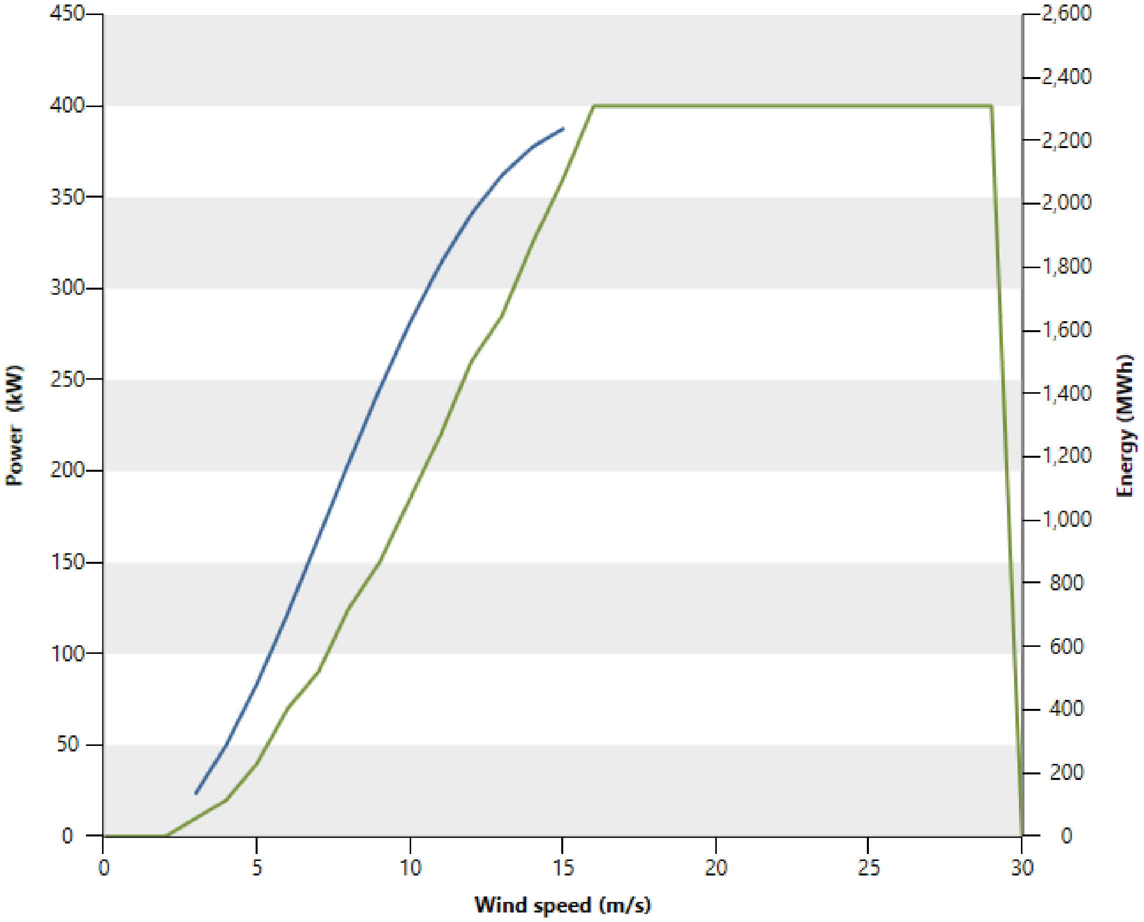


Figure 4.8: Power and energy curves for the selected wind turbine

4.4 Economic Analysis

In order the estimate the solar potential in the selected region, the geographical location of the selected study is entered. Figure 4.9 shows the coordinate and weather parameters of the selected study. The results indicate the selected region has high wind potential (i.e. selected region has a mean wind speed of 3.6m/s.

	Unit	Climate data location	Facility location	Source
Latitude		35.2	35.2	
Longitude		33.0	33.0	
Climate zone		3A - Warm - Humid		NASA
Elevation	m	40	0	NASA – NASA
Heating design temperature	°C	7.6		NASA
Cooling design temperature	°C	31.1		NASA
Earth temperature amplitude	°C	14.6		NASA

Month	Air temperature	Relative humidity	Precipitation	Daily solar radiation - horizontal	Atmospheric pressure	Wind speed	Earth temperature	Heating degree-days 18 °C	Cooling degree-days 10 °C
	°C	%	mm	$kWh/m^2/d$	kPa	m/s	°C	°C-d	°C-d
January	12.1	63.1%	81.44	2.65	98.8	4.3	14.5	183	65
February	11.7	62.4%	72.97	3.63	98.6	4.5	14.5	176	48
March	13.4	61.5%	48.09	5.07	98.5	4.0	16.5	143	105
April	16.7	61.8%	51.25	6.27	98.4	3.5	20.1	39	201
May	20.3	62.3%	24.15	7.49	98.3	3.1	24.4	0	319
June	24.5	57.8%	4.94	8.41	98.1	3.3	28.8	0	435
July	27.8	52.9%	0.36	8.23	97.8	3.4	32.1	0	552
August	28.0	54.1%	1.90	7.40	97.9	3.4	32.2	0	558
September	25.8	54.1%	14.19	6.22	98.3	3.4	29.5	0	474
October	22.2	55.4%	40.53	4.59	98.6	3.2	25.2	0	378
November	17.6	58.9%	79.10	3.11	98.7	3.7	20.0	12	228
December	13.7	62.8%	103.15	2.32	98.8	3.9	16.0	133	115
Annual	**19.5**	**58.9%**	**522.07**	**5.46**	**98.4**	**3.6**	**22.9**	**686**	**3,478**

Figure 4.9: Weather data of selected region

In this study, 5 wind turbines with a capacity of 400W are used for a total power generation capacity of 2kW. The simulation results indicate that the capacity factor of the proposed wind turbine project is 16.5%. In addition, the initial cost of the proposed system is about 1000$ as shown in Figure 4.10.

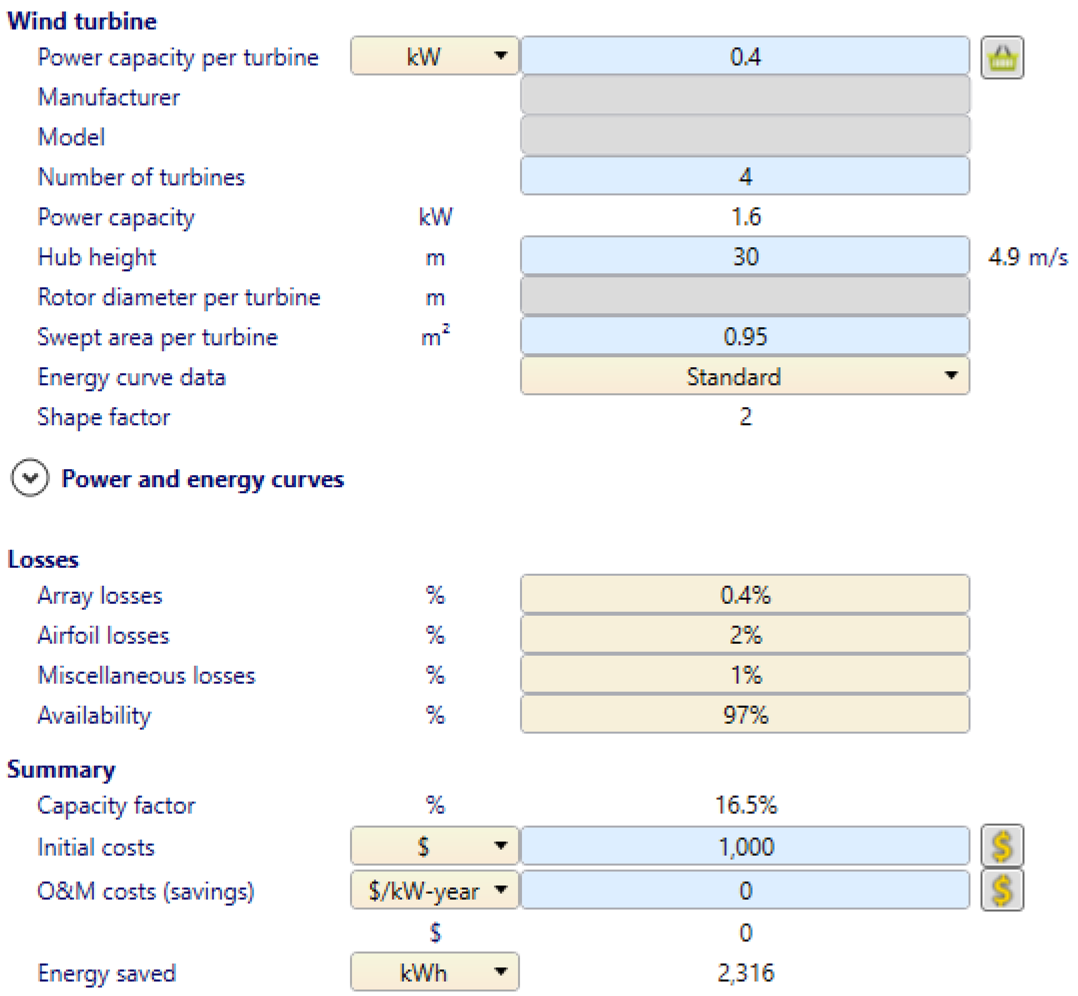


Figure 4.10: Technical data of wind turbine

This work describes the wind turbine system for a single-family house in Northern Cyprus. The electrical equipment along with the load and number of hours used during a day in the selected house is shown in Figures 4.11 and 4.12.

Electrical equipment

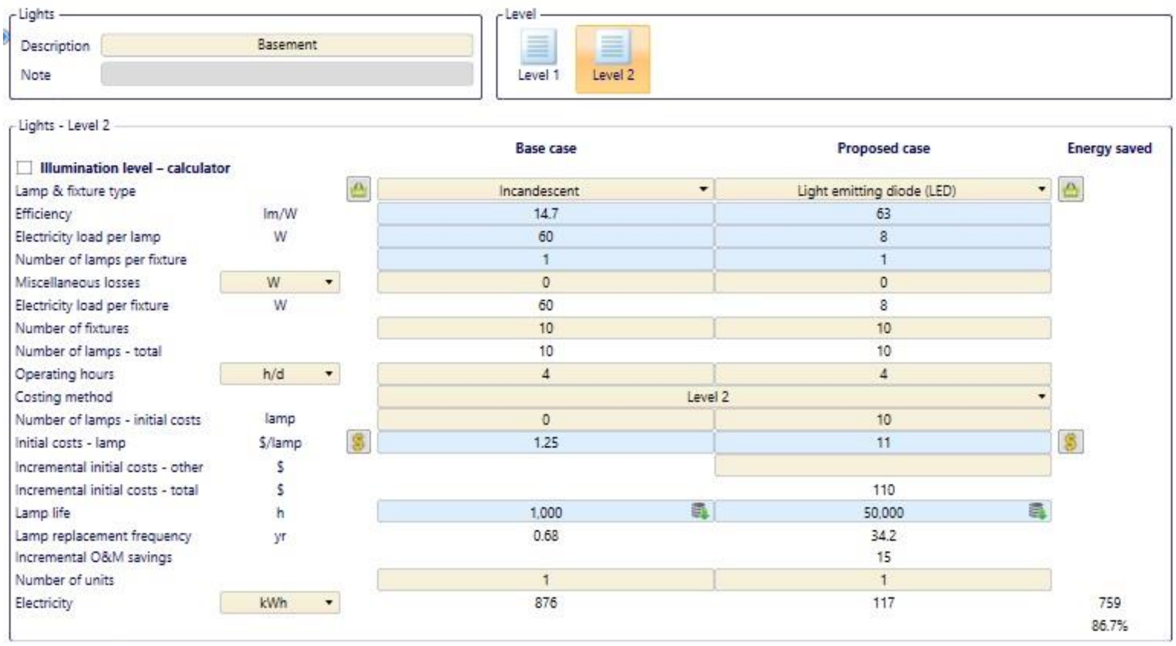
Description	Electrical equipment
Note	

Electrical equipment

Description	Electricity load - typical (W)	Base case: Quantity	Base case: Operating hours (h/d)	Base case: Electricity load (W)	Base case: Duty cycle (%)	Proposed case: Quantity	Proposed case: Operating hours (h/d)	Proposed case: Electricity load (W)	Proposed case: Duty cycle (%)	Incremental initial costs ($)
TV	80 - 300	1	12	80	100%	1	12	80	100%	
Clothes washer	350 - 500	1	1	480	30%	1	1	480	30%	
Refrigerator	300 - 725	1	24	300	30%	1	24	300	30%	
Computer	200 - 300	1	5	200	100%	1	5	200	100%	
Vacuum cleaner	800 - 1440	1	0.5	800	30%	1	0.5	800	30%	0
Air-conditioner - window unit	750 - 1100	1	5	750	75%	1	5	750	75%	
Clothes iron	1000 - 1800	1	0.2	1,000	50%	1	0.2	1,000	50%	
Microwave oven	750 - 1200	1	1	750	100%	1	1	750	100%	
Receiver		1	12	12	100%	1	12	12	100%	
Water pump	250 - 1100	1	3	250	100%	1	3	250	100%	
Toaster	800 - 1400	1	1	800	100%	1	1	800	100%	
Total										0

		Base case	Proposed case	Energy saved
Incremental initial costs	$		0	
Incremental O&M savings	$			
Electricity	kWh	3,555	3,555	0 0%

Figure 4.11: Electrical equipment's in the selected house



Lights

Description	Basement
Note	

Level: Level 1, Level 2

Lights - Level 2

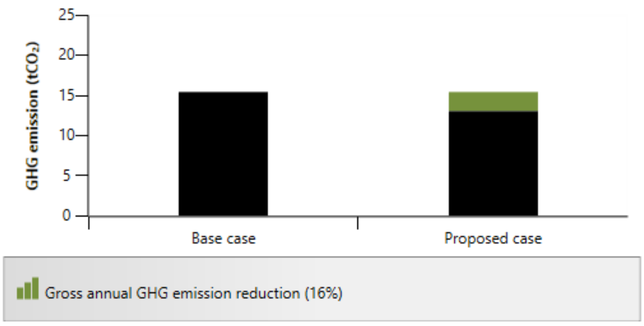
Illumination level – calculator		Base case	Proposed case	Energy saved
Lamp & fixture type		Incandescent	Light emitting diode (LED)	
Efficiency	lm/W	14.7	63	
Electricity load per lamp	W	60	8	
Number of lamps per fixture		1	1	
Miscellaneous losses	W	0	0	
Electricity load per fixture	W	60	8	
Number of fixtures		10	10	
Number of lamps - total		10	10	
Operating hours	h/d	4	4	
Costing method		Level 2		
Number of lamps - initial costs	lamp	0	10	
Initial costs - lamp	$/lamp	1.25	11	
Incremental initial costs - other	$			
Incremental initial costs - total	$		110	
Lamp life	h	1,000	50,000	
Lamp replacement frequency	yr	0.68	34.2	
Incremental O&M savings			15	
Number of units		1	1	
Electricity	kWh	876	117	759 86.7%

Figure 4.12: Lamp characteristics used in this study

The analysis of emissions of greenhouse gases, a proposed case is determined by using 2kW wind turbine system. Figure 4.13 shows the analysis of CO_2 emissions avoided by using wind energy. It is found that CO2 emission is reduced by 16%. And the reduction of total annual emissions of greenhouse is 125$/tCO2 as shown in Figure 4.14. Moreover, the cumulative cash flows and Pre-tax are shown in Figure 4.15. This reflects that investment in proposed system based in PV, is profitable with positive profit margins after 4.1 years of operation.

Base case electricity system (Baseline)		GHG emission factor (excl. T&D)	T&D losses	GHG emission factor
Country - region	Fuel type	tCO_2/MWh	%	tCO_2/MWh
Cyprus	All types	0.732	7.0%	0.787

GHG emission		
Base case	tCO_2	15.5
Proposed case	tCO_2	13.0
Gross annual GHG emission reduction	tCO_2	2.5



2.5 tCO_2 is equivalent to 2.5

People reducing energy use by 20%

Figure 4.13: Analysis of CO2 emissions avoided by the use of wind turbine system

Financial parameters		
General		
Fuel cost escalation rate	%	2%
Inflation rate	%	2%
Discount rate	%	3%
Reinvestment rate	%	9%
Project life	yr	20
Finance		
Incentives and grants	$	
Debt ratio	%	70%
Debt	$	777
Equity	$	333
Debt interest rate	%	7%
Debt term	yr	15
Debt payments	$/yr	85.31
Income tax analysis		☐

Annual revenue		
GHG reduction revenue		
Gross GHG reduction	tCO_2/yr	3
Gross GHG reduction - 20 yrs	tCO_2	50
GHG reduction revenue	$	0
Other revenue (cost)		☐
Clean Energy (CE) production revenue		☐

Costs | Savings | Revenue			
Initial costs			
Incremental initial costs	100%	$	1,110
Total initial costs	**100%**	**$**	**1,110**
Annual costs and debt payments			
Fuel cost - proposed case		$	1,698
O&M costs (savings)		$	-15
Debt payments - 15 yrs		$	85
Total annual costs		**$**	**1,768**
Annual savings and revenue			
Fuel cost - base case		$	2,015
Total annual savings and revenue		**$**	**2,015**

Financial viability		
Pre-tax IRR - equity	%	78.6%
Pre-tax MIRR - equity	%	21.4%
Pre-tax IRR - assets	%	25.1%
Pre-tax MIRR - assets	%	14.3%
Simple payback	yr	3.3
Equity payback	yr	1.3
Net Present Value (NPV)	$	4,641
Annual life cycle savings	$/yr	312
Benefit-Cost (B-C) ratio		14.9

Yearly cash flows		
Year	**Pre-tax**	**Cumulative**
#	$	$
0	-333	-333
1	253	-80
2	260	179
3	266	446
4	273	719
5	281	1,000
6	288	1,288
7	295	1,583
8	303	1,886
9	311	2,197
10	319	2,516
11	327	2,842
12	335	3,177
13	343	3,521
14	352	3,873
15	361	4,234
16	455	4,689
17	464	5,153
18	473	5,626
19	483	6,109
20	493	6,601

Figure 4.14: Analysis of financial for proposed system

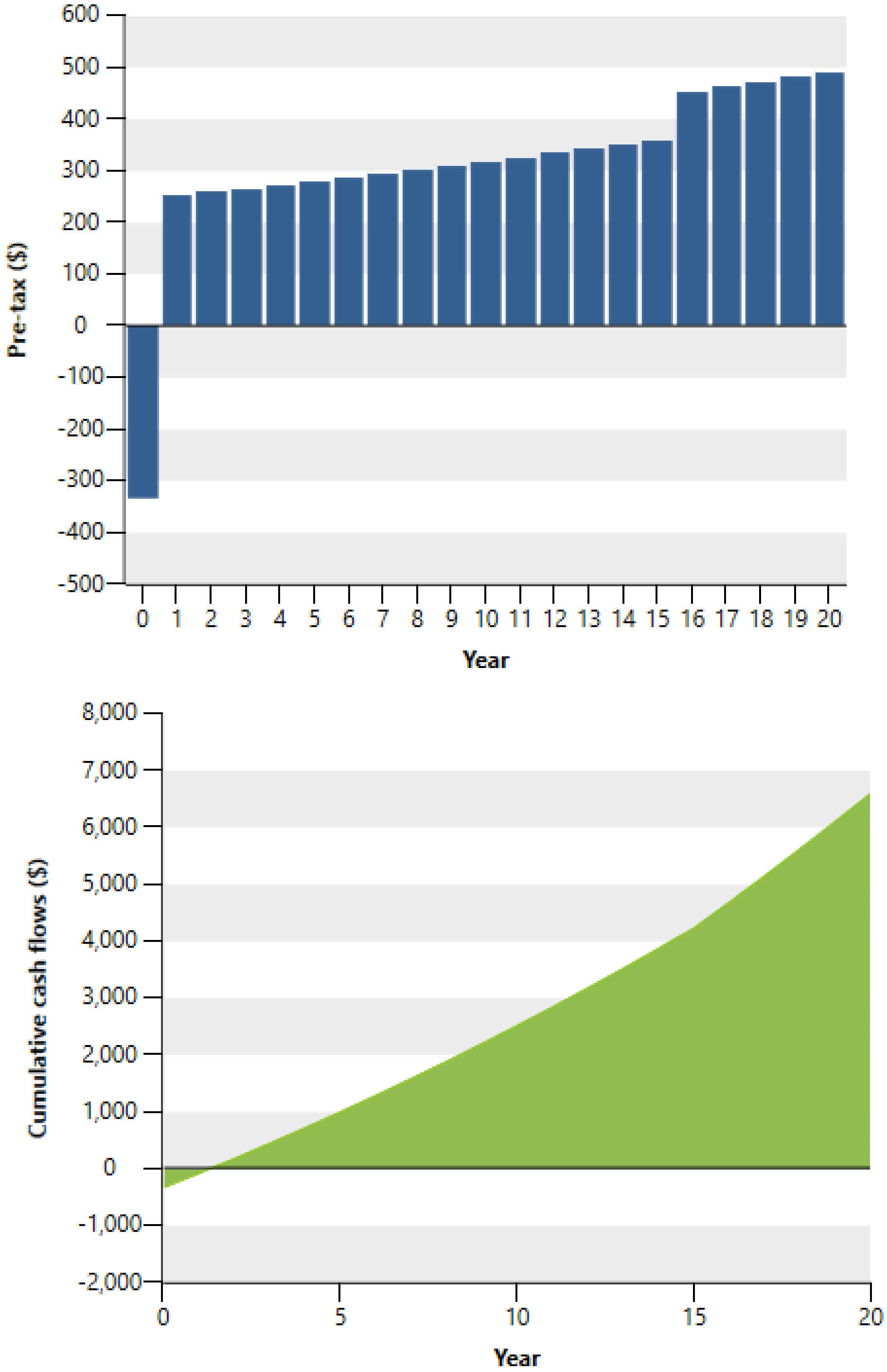


Figure 4.15: Cumulative cash flows and Pre-tax

4.5 AC and DC Output of Wind Turbine with Capacity of 400W

As mentioned previously, the best angle for the proposed 2kW and the maximum and minimum energy production are measured in June and November, respectively. Therefore, Figures 4.16-4.19 illustrate the AC and DC output for the proposed system for June and November, which are measured experimentally (see Appendix 1). Moreover, it is noticed that the maximum energy output in terms of AC and DC output is recorded for the first day and last day in June and November, respectively. The AC and DC output for these days are shown in Figures 4.20 and 4.21. It is observed that the system starts storage electricity or generate electricity during the period of 06:00 am-19:00 pm for June and 06:00 am-17:00 pm for November.

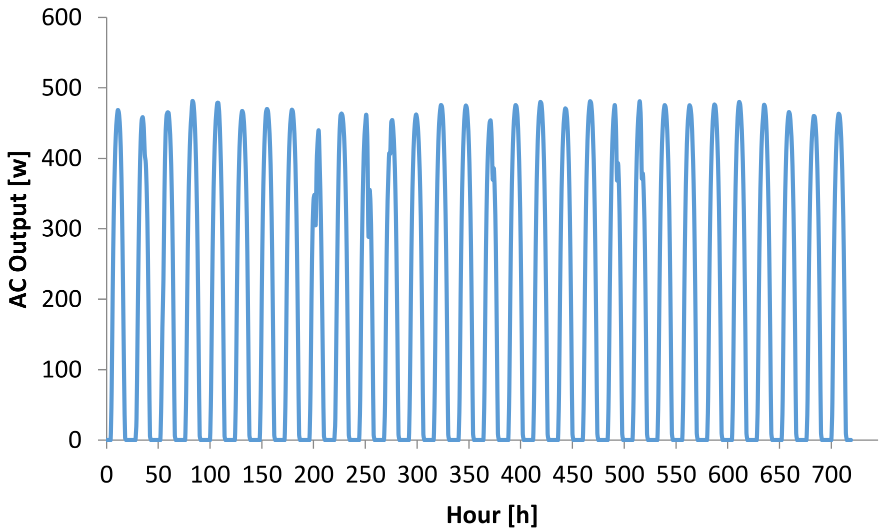


Figure 4.16: AC output for June

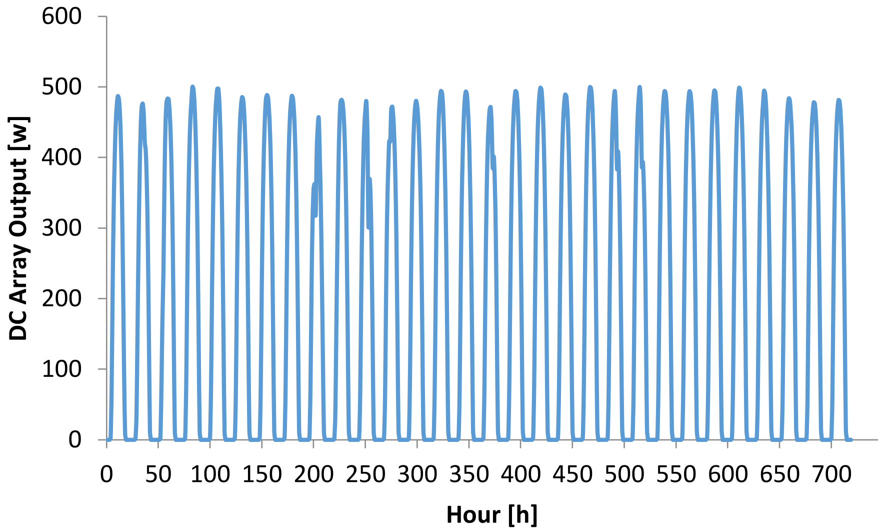


Figure 4.17: DC array output for June

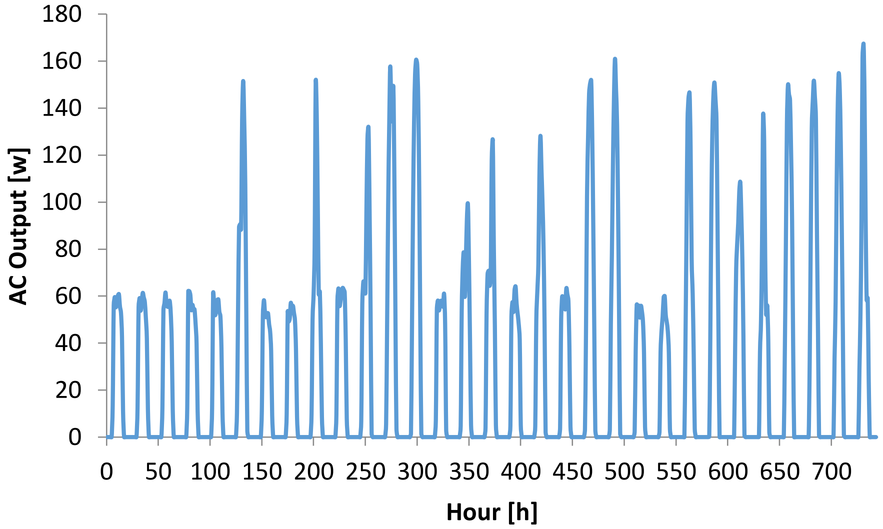


Figure 4.18: AC output for November

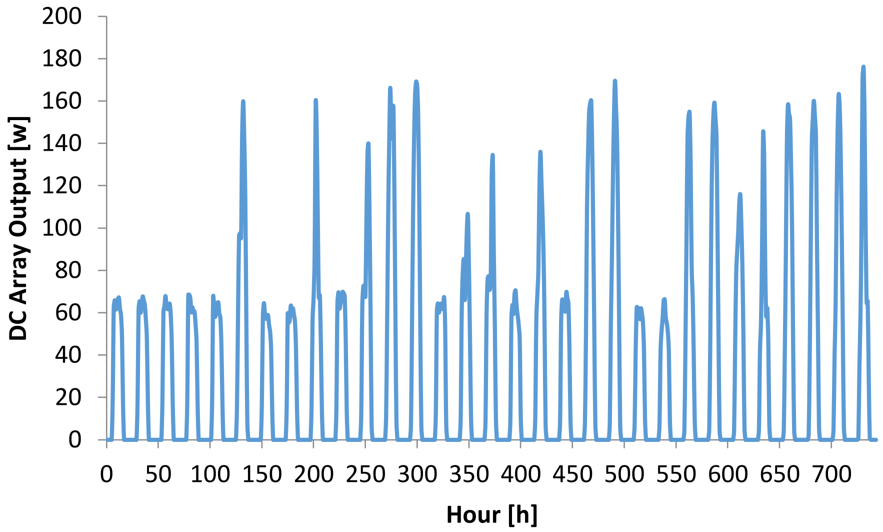


Figure 4.19: DC array output for November

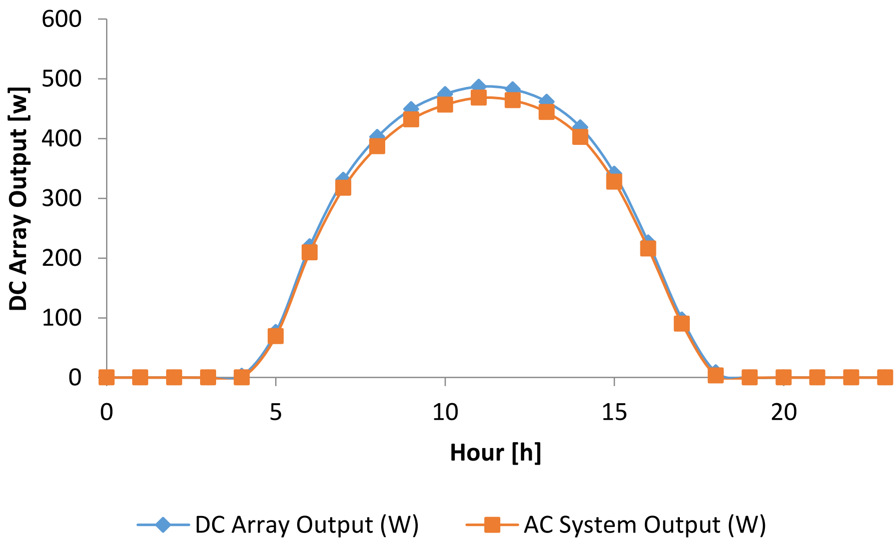


Figure 4.20: AC and DC output for first day in June

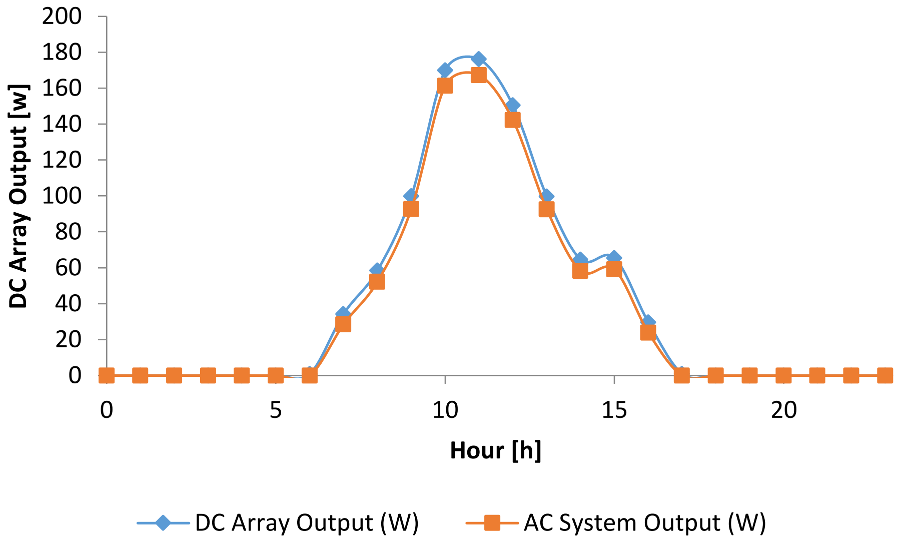


Figure 4.21: AC and DC output for the last day in November

4.6 Diesel Fuel vs PV system

Figures 4.22 and 4.23 illustrate the monthly electricity consumption using diesel fuel and electricity production using wind system for the selected houses. It is found that the annual wind electricity production is 2361kWh. In addition, it is observed that the maximum electricity production for the proposed system is recorded in winter season (January and February).

Moreover, the percentage of reduction is shown in Figures 4.22 and 4.23 for both houses. It is found that the average percentage of reduction is about 40% per year. It is concluded that Due to the high energy demand of the house, the use of wind energy can be helped to reduce the demand into 100% of clean energy.

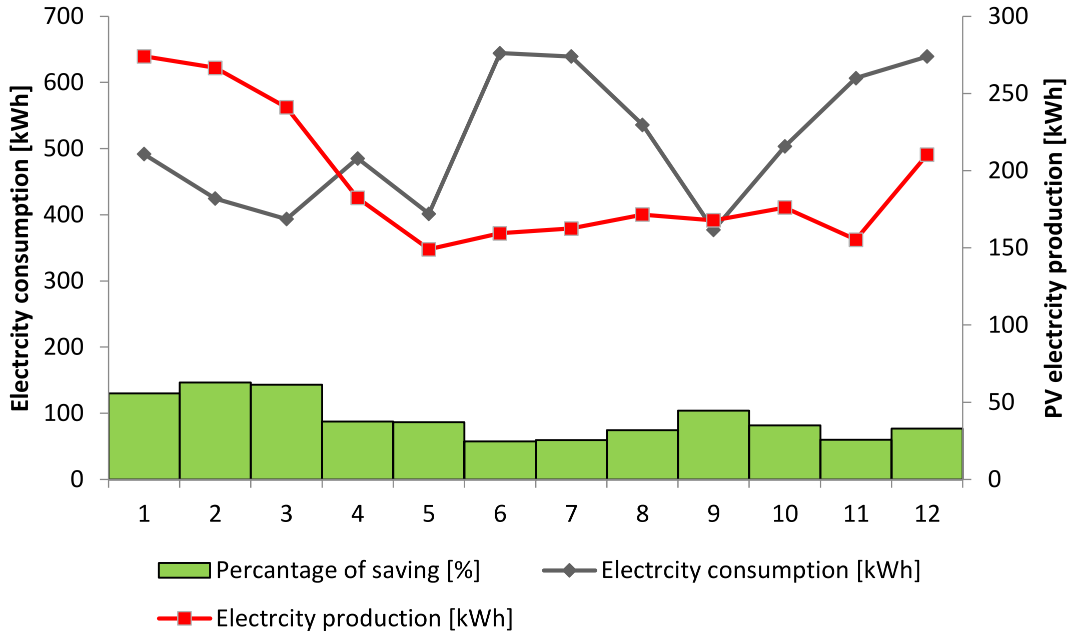


Figure 4.22: Percentage of electric reduction for house 1

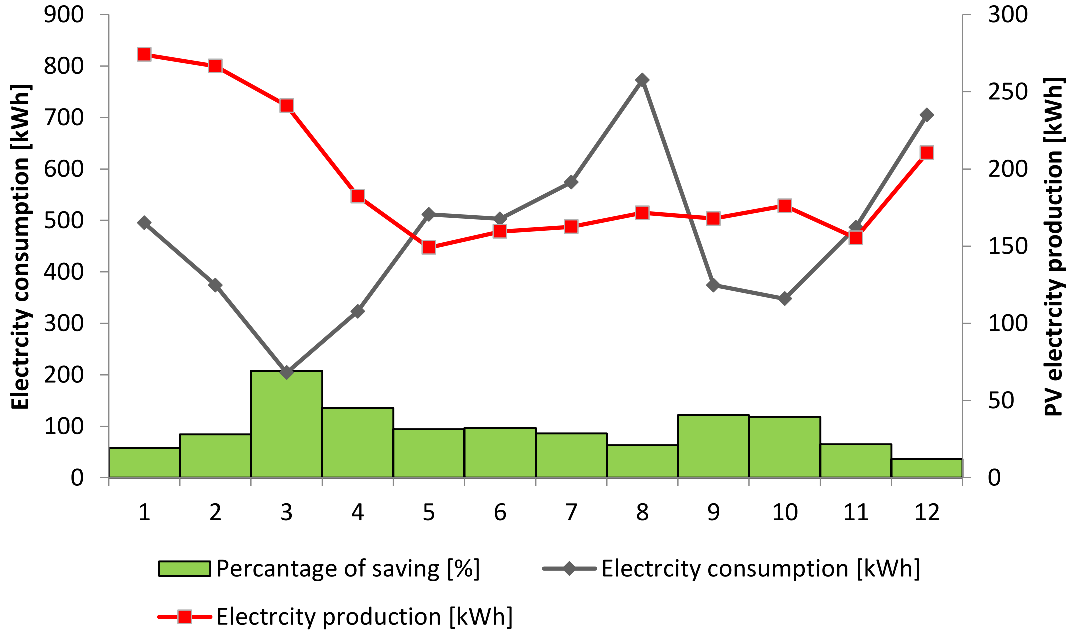


Figure 4.23: Percentage of electric reduction for house 2

CHAPTER 5
CONCLUSIONS

5.1 Conclusions

The wind energy moves the blades of the fans and makes them rotate, and this when they turn the turbines that lead to the generation of electrical energy. This energy source is growing rapidly around the world. Adding to its appeal is that its technology is modest and not complex. Two decades of effort have succeeded in making technical progress that has led to the production of sophisticated wind turbines that are highly adjustable, easy and quick to install. A single turbine now produces as much energy as twice as much as a single turbine two decades ago. Now, wind farms provide as much energy as conventional power plants. Therefore, the techno-economic evaluation of 2kW gird/grid-off connected wind system for a small household was made in this study. The AC and DC output of the proposed system were measured experimentally and the RETSCreen simulation tool was used to estimate the reduction of CO2 emissions. In order to investigate the performance of the proposed system, the generated electricity is compared with the electrical consumption of two selected houses in the chosen region. The significant findings are summarized below.

- The wind power density in Northern Cyprus is considered as poor except at some area, which can be classified as marginal.
- It is found that the highest and lowest mean daily wind speed are recorded in December 2017 and September 2016 with a value of 5.95 m/s and 1.99 m/s, respectively. In addition, it is found that the annual wind speed value is found to be 3.16 m/s.
- Based on simulation results, it is found that the wind speed values are varied from 3.1 to 4.5 with average value of 3.6m/s.
- The simulation results indicate that the capacity factor of the proposed wind turbine project is 16.5%.
- It is found that CO2 emission is reduced by 16%. And the reduction of total annual emissions of greenhouse is 125$/tCO2

- It is found that the average percentage of reduction is about 40% per year. It is concluded that Due to the high energy demand of the house, the use of wind energy can be helped to reduce the demand into 100% of clean energy.

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APPENDICE

RENEWABLE ENERGY

YE-1050 WIND AND SOLAR ENERGY (COMBINED) TRAINING SET

GENERAL EXPLANATION

This training set is designed to teach the combined working system of simple wind turbines and photovoltaic panel circuit

EXPERIMENTS

1. Wind turbine power generation-air velocity relationship
2. Calculation of turbine efficiency
3. Calculation of solar cell electrical capacity
4. Experimental study of solar cell angle dependent of current-angle change

DIMENSIONS

Control Panel
A x B x H : 880 x 450 x 1500 mm

Solar Panel
A x B x H : 1270 x 750 x 1130 mm

Wind Turbine
A x B x H : 800 x 750 x 1595 mm

OPTIONAL FEATURES

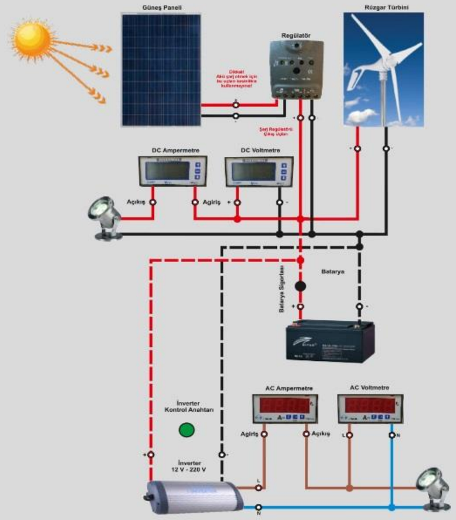
- Touch LCD Display
- USB Computer Connection
- Computer Control

PACKAGE INCLUDED

Device, device cover, 1 printed experiment report, circuit diagram and product catalog

TECHNICAL SPECIFICATION

The combined training set teaches the connection of wind turbine and solar panel. Calculation the power generation and the efficiency of the wind turbine depend on the air velocity and the change of the power, efficiency and power of the solar cell is examined.



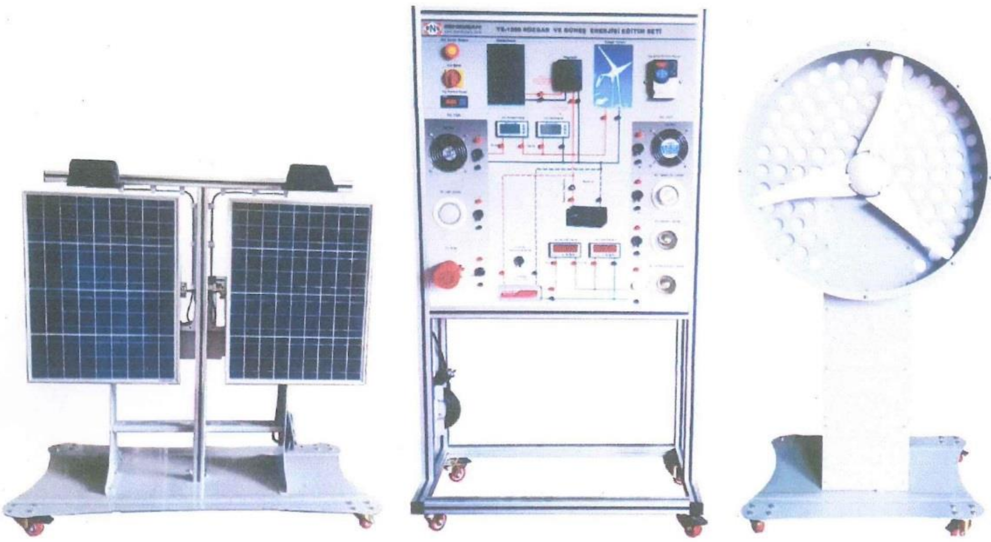
TECHNICAL DETAILS

- Wind turbine
- Solar panel
- Regulator
- Inventors
- Fan
- Siren
- Lamp
- Halogen lamp
- Battery

DENEYSAN

YE-1050 WIND AND SOLAR ENERGY (COMBINED)TRAINING SET

EXPERIMENTAL MANUAL



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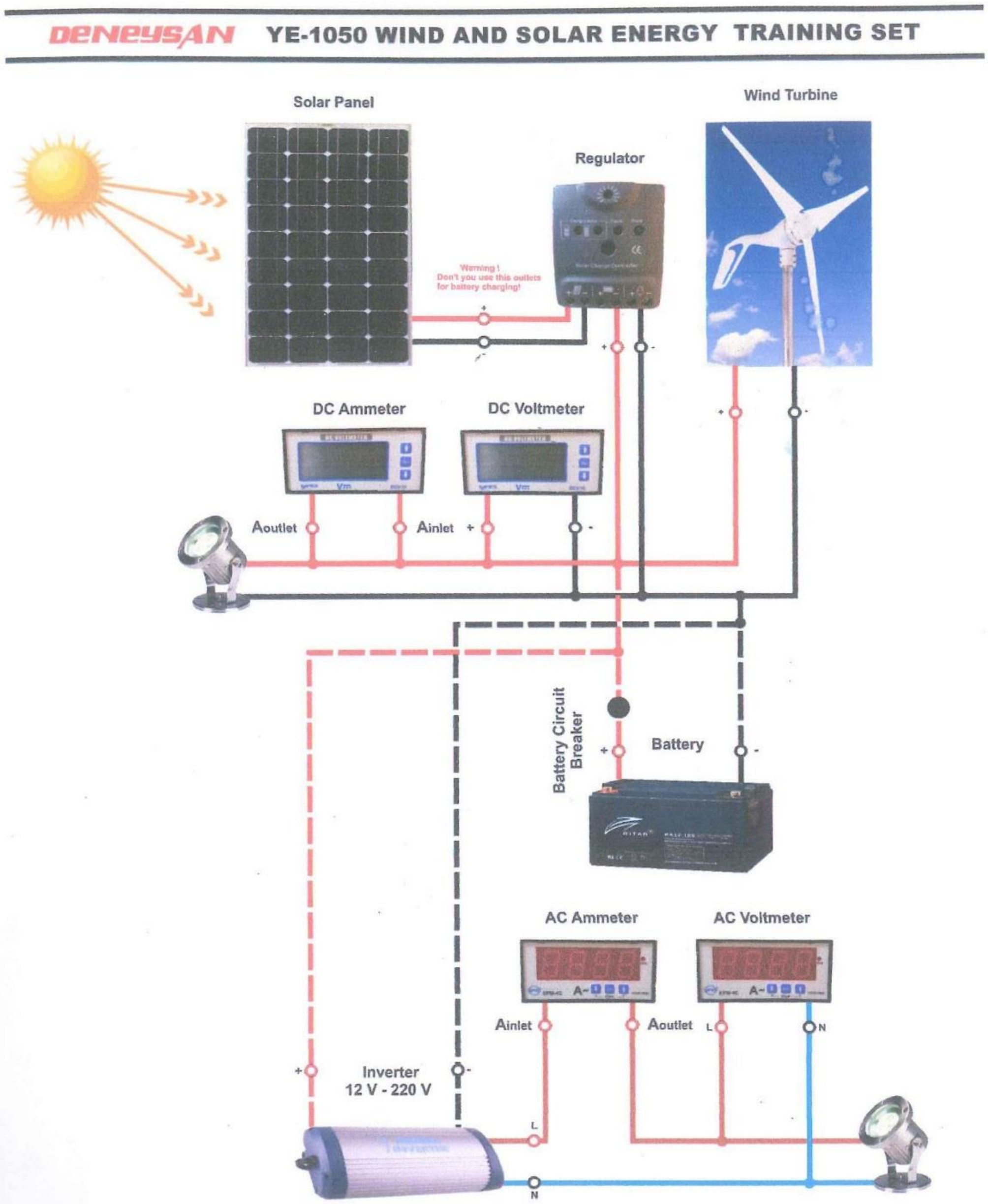
CONTENTS

YE-1050 CIRCUIT DIAGRAM



TECHNICAL FEATURES

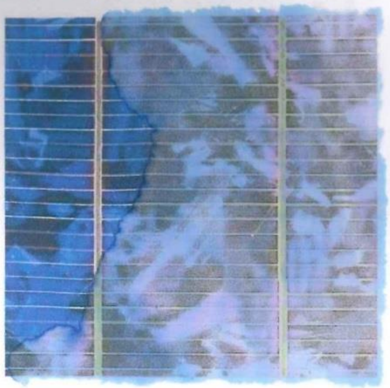
MATERIALS	FEATURES
Wind Turbine	Rotor diameter: 1.15 m, voltage: 12 VDC, power: 400 W
Inside regulator	Monthly kWh energy: 38 kWh 5.4 m/s
Solar cell	50 W, 2 pieces
Inverter	Mono phase, output power 300 W, output voltage 220 VAC
Accumulator	Eurostar 12V, 7Ah

DEVICE USER MANUAL

1. Close the top of the solar cells when the device is not in use.
2. When the wind turbine is not used close the wing.
3. Clean the top of the solar cells with a damp cloth and place them where the sun's rays are comfortable to see.

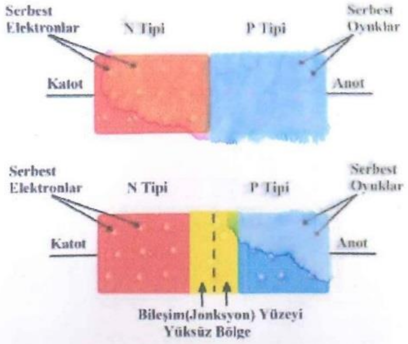
Generate electricity from the sun

In addition to being capable of generating electricity from solar energy in different ways, the most advanced technology in this regard is the generation of energy through solar panels (photovoltaic panels). In this technology, energy conversion is achieved by the use of semiconducting materials when the sunlight reaches the panel surface.



Working principal of solar cells

The photovoltaic effect is a simple physical process in which the Solar Pole transforms the sun's rays into electrical energy. It consists of particles of sunlight, photon or solar energy. Photons from the sunlight are composed of different wave lengths and contain various amounts of energy corresponding to these different wave lengths.

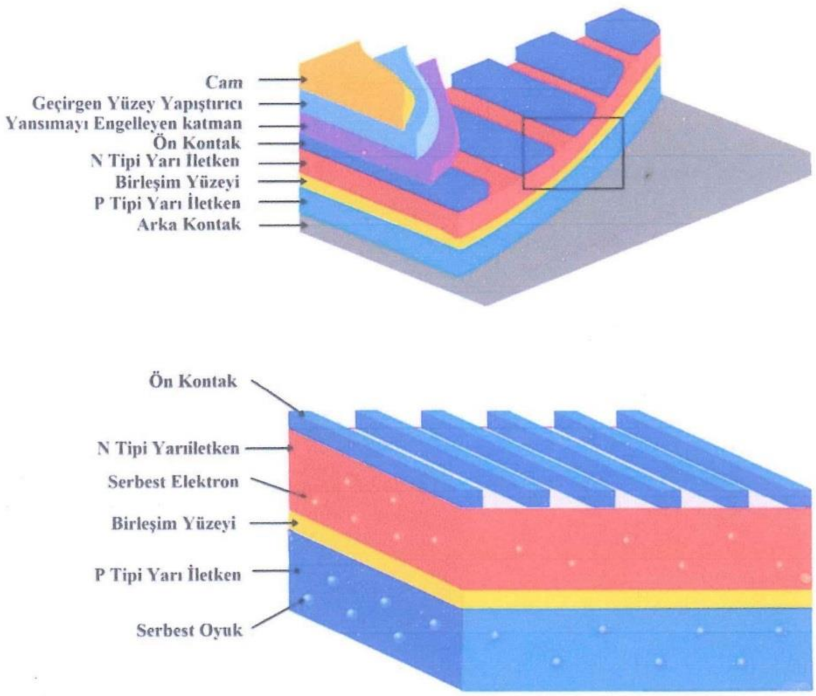


Bir yarıiletkende p-n ekleminin gösterimi

There are three possible conditions that can occur when the photons strike the PV surface. The photon can be reflected, absorbed, or passed directly. Only absorptive photons can produce electricity. In this case, the photon's energy is transferred to the electron in the struck cell. With this energy that the electron acquires, it escapes its normal position and transforms the sunlight into electric energy by forming a part of the current in an electric circuit.

The structure of solar cells

To bring the electric field inside a PV cell into the square, the two separate semiconductors are compressed together. Pure semiconductor materials do not transmit electricity well nor badly. For this reason, the number of electrons in the valence band is limited. Conductivity can be increased by increasing the number of electrons and cavities of a pure semiconductor. This is done by adding a pure semiconducting additive. There are two types of semiconductors formed by adding additive material. These are positive (p) and negative (n) type semiconductors. A PV cell consists of positive (p) and negative (n) type semiconducting materials.

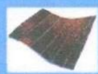


Display of layers of a solar cell

Types of solar cell

Different types of solar batteries are available depending on the materials used in production. Solar cell types are given comparative examples.

	Tek kristalli	Çok Kristalli	İnce Film
			
Avantajları	• Yüksek dereceli silikondan yapıldığı için en yüksek verimlilik • Yer kazanımı, ince film güneş pillerinin ürettiğinin 4 katına kadar üretim yapabilir • En uzun ömür, 25 yıl garanti • Düşük ışınım durumlarında en iyi performans	• İmalat süreci daha basit ve ucuzdur • Tek kristalli hücrelerle kıyaslandığında daha az atık silikon vardır	• Seri üretim daha basit, potansiyel olarak kristal esaslı hücrelere göre daha ucuz • Homojen görüntüleri görsel olarak daha estetiktir • Bir çok yeni uygulama alanına sebebiyet verecek şekilde esnek imal edilebilirler • Yüksek sıcaklıklar ve gölgeleme güneş paneli performansını daha az etkiler • Yer problemi olmayan durumlarda ünce film güneş panellerini kullanmak avantajlıdır
Dezavantajları	• En pahalı hücrelerdir • Eğer güneş paneli kısmi olarak gölge, kir veya kar ile kaplanırsa tüm devre kesilebilir (elektrik üretimi durabilir) • Tek kristal silikon imalatı için The Czochralski yöntemi kullanılmaktadır. Çok büyük silindirik silikon bloklar halinde üretilmektedirler. Bu silindir blokların dört köşesi silikon alttaş yapımı için kesilir. Önemli miktarda silikon atık haline gelir	• Düşük silikon saflığı yüzünden, çok kristalli hücreler tek kristalli güneş hücreleri kadar verimli değildirler. • Düşük yer verimi • Parçalı mavi görünüme sahip çok kristalli güneş hücrelerine göre, tek kristalli ve ince film güneş hücreleri daha düzgün bir yapıya sahip olduklarından estetik olarak daha güzel görünürler	• Genel olarak konutlarda kullanım için çok uygun değildirler. Ucuzdurlar ancak çok fazla yere ihtiyaç duymaktadırlar. • Düşük yer verimi demek PV ekipmanlarının fiyatlarının artacağı anlamına gelmektedir (örn. destek malzemesi ve kablolar) • Tek kristalli ve çok kristalli hücrelere göre daha hızlı degrade olurlar. Bu yüzden daha kısa süreli garantiler ile satılırlar

	Tek kristalli	Çok kristalli	Amorf	CdTe	CIS/CIGS
					
Tipik modül verimi	%15-20	%13-16	%6-8	%9-11	%10-12
En iyi araştırma hücresi verimi	%25,0	%20,4	%13,4	%18,7	% 20,4
1 kWp için gerekli alan	6-9 m²	8-9 m²	13-20 m²	11-13 m²	9-11 m²
En düşük fiyat	0,75 $/W	0,62 $/W	0,69 $/W		
Sıcaklık dayanımı	Yüksek sıcaklıklarda performansı %10-15 düşmektedir	Tek kristalli hücrelere göre sıcaklık dayanımı daha azdır	Yüksek sıcaklıklara dayanabilir	Diğerleriyle kıyaslandığında göreceli olarak performans üzerinde etkisi daha azdır	
İlave detaylar	En eski ve en yaygın kullanılan hücre teknolojisidir	İmalat aşamasında daha az silikon atığı vardır	Kristal esaslı güneş hücrelerine göre daha hızlı performans kaybı olmaktadır Piyasada bulunması zordur		

Solar cell systems

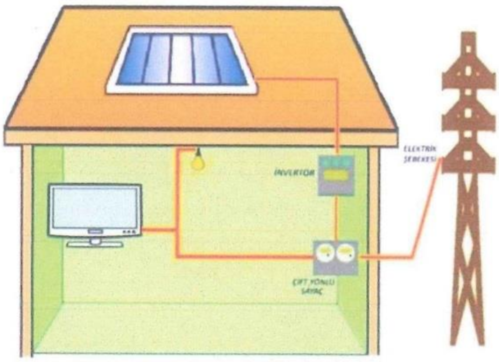
Solar battery systems can be used in any application where people need electrical energy. Depending on the applications of the solar cell module, it is built together with control devices such as inverters, accumulators, regulators, and various electronic support circuits. Applications of the solar system can be divided into two main groups;

i. On grid systems

ii. Off grid systems

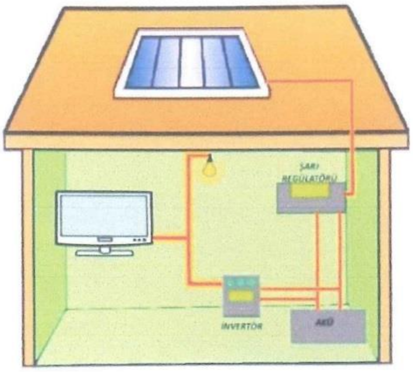
i. On grid systems:

Grid-connected solar cell systems can be in the form of large power systems (power plant size) or small power systems in buildings. Once the energy obtained in the small power systems meets the electric energy requirement of the system in which it is installed, the excess electric energy is sold to the electricity grid. In this case, however, the generated DC electricity is converted to AC and made suitable for the network. In the case where sufficient electricity cannot be produced, the electricity from the network is taken. There is no need for a battery pack because there is no storage in these systems.



ii. Off grid systems

The power obtained from the solar panels meets the needs of the system, while the excess energy is stored in the cells. This stored energy is used when solar energy is inadequate, especially during the night. A regulator is used to prevent damage to the battery due to overcharging and discharging. In systems, the regulator's task is to either stop the current draw of the system or cut the current from the solar cell by looking at the current situation.



Why should we use solar energy?

It is necessary to have enough knowledge about these systems in order to spread the systems working with Solar Energy. Naturally, solar energy systems also have advantages and disadvantages, as each energy is in the mirror and in the production system. The advantages and disadvantages for this purpose are listed below.

Advantages

- As in other renewable energy sources in our world where fossil fuels are starting to be consumed, solar energy is also an infinite, renewable and unlimited source of energy. This is the most important advantage of solar energy.
- In an environment of increasing global warming, carbon emissions do not come into play as they generate energy from solar energy. Environment is a system that does not have pollutant wastes, is environmentally friendly, and can be easily changed depending on energy need when needed.
- Another environmentalist feature of solar energy is that it does not cause noise pollution since it does not produce sound during operation.
- Solar energy provides many applications such as hot water, heating, cooling, industrial applications, electricity production without fuel cost.
- Solar energy systems are easy to install systems according to energy needs. In addition, systems can be expanded quickly and easily in case of increased energy requirements.
- It does not create much maintenance cost in use after production and installation costs in solar energy systems. Solar powered systems can be easily transported and installed. The use of solar batteries is more economical in rural areas where there is no electricity grid or where the mains line is expensive.
- Although solar systems have high initial installation and production costs, there is a recycling of initial cost relative to fossil fuels when considered in the long run.
- The solar battery is durable, reliable and long lasting. Each house can meet its energy with solar batteries installed in its roof. Thus, transmission and energy transport costs and losses are coming to an end.

Disadvantages

- The most important disadvantage is that the production and installation costs of photovoltaic panels and tracking system collectors are high.
- It depends on the sunshine state of the solar energy systems. Cloudy weather, environmental pollution, sunshine direction directly affect the efficiency in some systems.
- Especially in collectors who produce electricity, large areas are needed to prevent shading. Solar energy systems need storage systems to provide night energy continuity.
- The efficiency of the solar cells is low (around 15%).
- The solar collectors used in the buildings can cause some problems in appearance and space.
- Semiconducting materials used in photovoltaic cells can cause environmental pollution after the end of life.
- Solar energy technology is not yet enough for transportation applications. It is a developing technology.

What is Wind Energy?

It's hard to imagine that air is a fluid. Because the air is invisible. Unlike liquids, the air moves more quickly and covers every part of the environment. With the rapid placement of air, the particles move quickly. The process of converting this characteristic of air into kinetic energy is called wind energy.

In the same sense, hydroelectricity is called hydroelectricity by using the displacement property of liquids such as water, and the produced center is called hydroelectric power plant. The centers that produce electricity from wind energy are also called wind power plants.

After the wind power plants have been installed, the propellers turn the curtain they are attached to by the movement of the wind (air). With a suitable generator this energy is converted into electricity energy.

Wind energy starts with the sunrise. Near parts of the cold air layer that is formed at night begin to warm up with the rays of the sun. As you recall from the physics classes, the warming air expands and rises. The cold air layer in the atmosphere descends to this place. Wind is generated by the change of hot and cold air.

Wind turbine

Propeller Wings

When the wind blows, the wind hits the wing of the propeller and starts to rotate it. In this view, kinetic (motion) energy is obtained by wind energy. Propellers are designed to turn in the same direction when the wind is blowing.

Shaft

When the propellers turn, the shaft connected to it also begins to turn. Rotation of the shaft also creates movement in the motor and electrical energy is provided at the output of the motor.

Generator

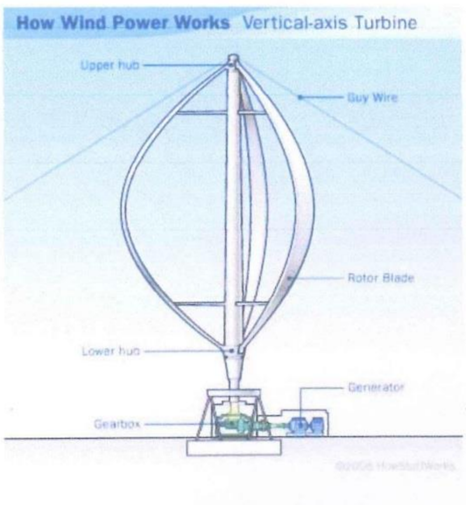
There is a very simple way of working. Electric energy is produced by electromagnetic induction. Small toy cars are similar to the electric motor. There are magnets in it. In the middle of these magnets is also a section wrapped with thin wires. When the propeller shaft rotates, this winding region in the engine begins to rotate in the middle of the magnets around it. This results in an alternating current (AC).

Today's wind turbines are more complex than windmills that are used in fields. Windmills are not widely used in our country. Now let's continue to recognize modern wind turbines.

How Wind Turbines Work

Modern Wind Turbine Technology

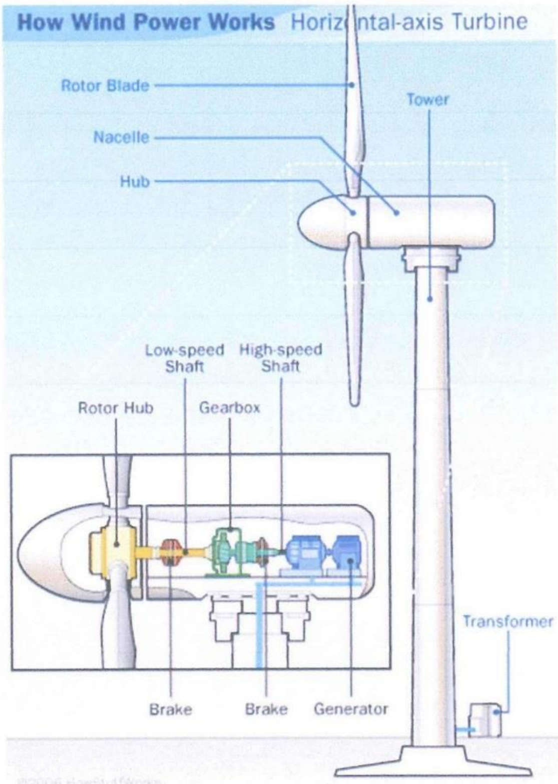
Wind Turbines now face two different designs. The first one is the design that turns around the vertical axis as you see it in the bottom photo.



Vertical Axis Wind Turbine

The vertical axis is designed to be perpendicular. It is always adjusted according to the direction of the future of the wind. There is no need to adjust the earth axis according to the wind. In general, it requires an electric motor as the first movement. The turbine is fixed through the auxiliary wire axis. In places near the sea level, the efficiency of the device is lower because it receives less wind. However, although all necessary equipment is an advantage at the ground level, the negative impact on agricultural land is high.

Another important design is the horizontal axis wind turbine. The rotation axis is designed parallel to the axis. With the help of an electric motor, the direction of the propeller can be adjusted according to the direction of the wind. Structurally, it is not different from an electric motor. It must be about 80 meters above sea level to be able to operate efficiently.



Rotor Blades: It turns wind energy into rotational motion.
Shaft: It transmits the rotational motion to the generator.
Gear Box: It increases the speed between the propeller and the shaft and helps to transmit a faster movement.
Generator: The part that generates electricity from the rotational motion.
Breaks: It helps to stop the propeller when there is an overload and a problem.
Electrical Equipment: It ensures that the electricity generated is transmitted to the relevant centers.

Advantages

1. Wind energy is not a new discovery. It is the best known method for generating mechanical energy using kinetic energy (wind). For thousands of years the Persians and then the Romans were using windmills to draw water and grind grain.

2. The meaning of wind energy in the sense of renewable energy is that the planet is constantly generating wind and this energy is infinite and it is not an obstacle for people to use it by transferring it to the system.

3. Wind energy is cheap. Considering factors such as the manufacturer, distribution network and installation site, it can be bought at an average of 4-6 cents / kWh (USA).

4. The use of wind energy instead of electricity production with coal means the reduction of the gases released to the environment, and thus the contribution to the environment.

5. The wind is available everywhere in the world, maybe some countries or places get more wind, but they are generally available everywhere. Natural gas, oil, coal, etc. to obtain energy transfer is not required, so even the most remote corner can be established.

6. In general, wind farms take up less space than coal-fired power plants. Although some people are against the wind turbines, there will certainly not be a coal plant behind their homes.

7. Wind turbines can fit into any climate and can use agricultural areas, animal areas. The wind turbines do not need to be alone, they can share the area.

8. The wind energy is advantageous in the places where there is no network, in the mountains and in the third world countries to give electricity to the region.

9. Wind turbines are not only used for commercial purposes and need not be used, and at the same time their use in household needs is increasing rapidly.

Disadvantages

1. Wind energy is not an uninterrupted or balanced source of energy, thus providing unbalanced power to the grid. Turbines can be damaged in very strong windy regions of the wind and in areas where there are many hurricanes, such as the American Gulf region.

2. For some people, it disrupts their view. The images are not good.

3. Wind power is not the same in every region and country. For this reason, wind maps with more accurate measurements are needed.

4. Although government subsidies support tax reductions (in some countries), the high initial investment cost and return on investment is a question.

5. Generally, the distances from the settlement areas constitute the problem of network connection.

6. More research and development is needed to use batteries, hydrogen or other systems to store the energy produced in wind turbines.

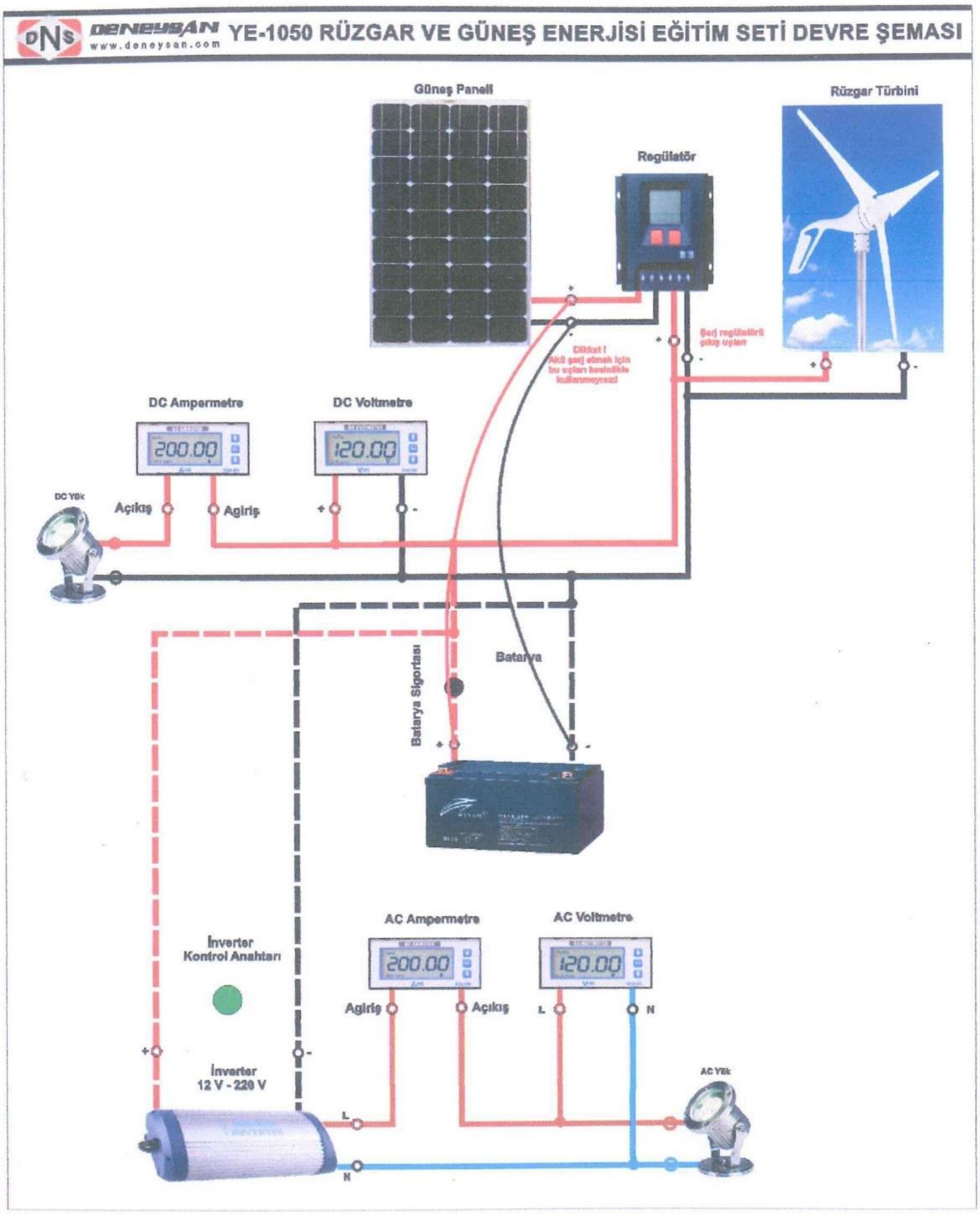
7. Some environmentalists believe that large-scale wind turbines will change the flight paths of migratory birds.

8. The wind turbine may be a factor in living near or difficulty working because of the noise caused by the tap.

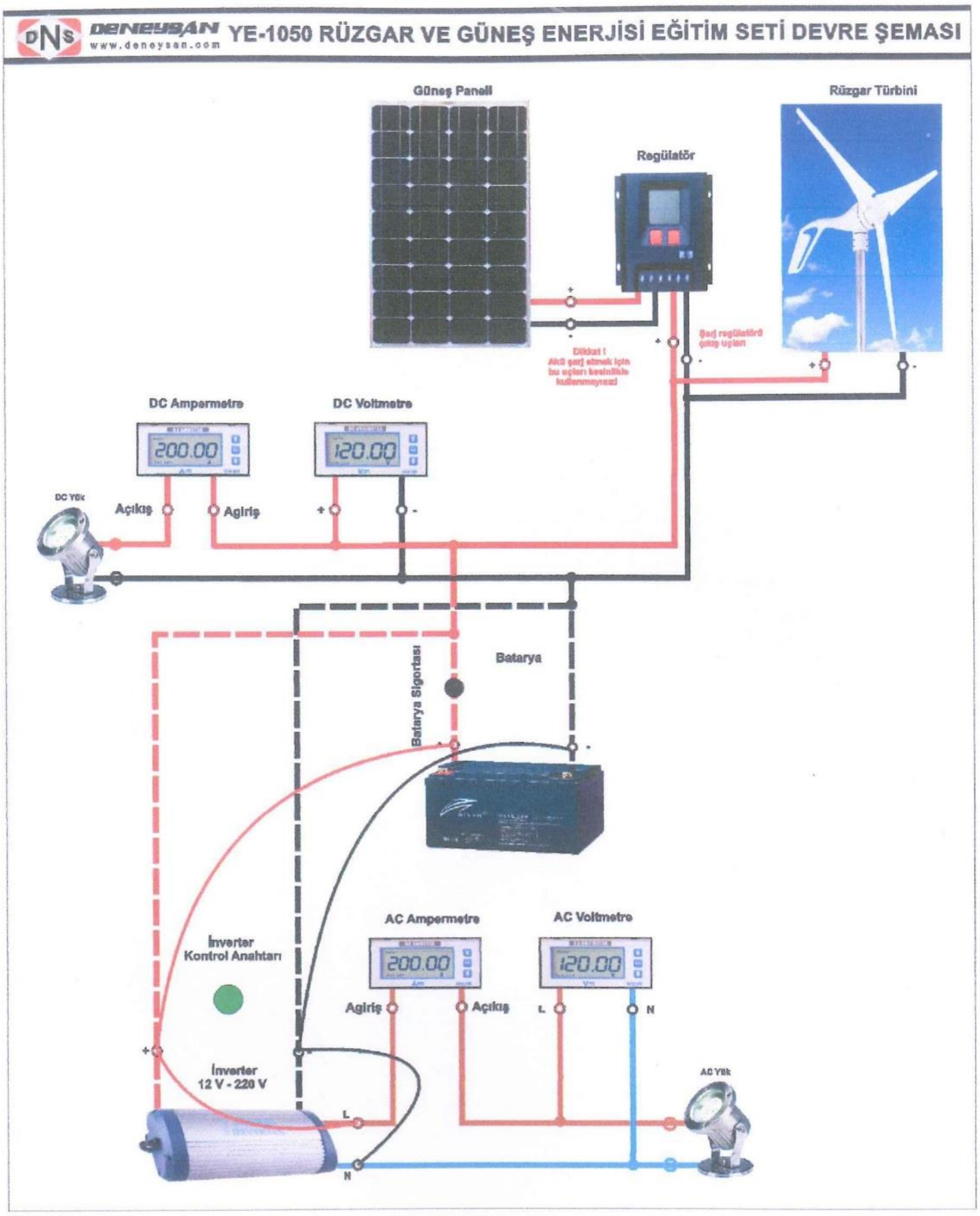
9. Although wind power has reduced electricity production costs, it still does not have an advantage over low-cost fossil-based fuels.

10. Large-capacity wind farms may cause degradation of the area TV signals around 2-3 km.

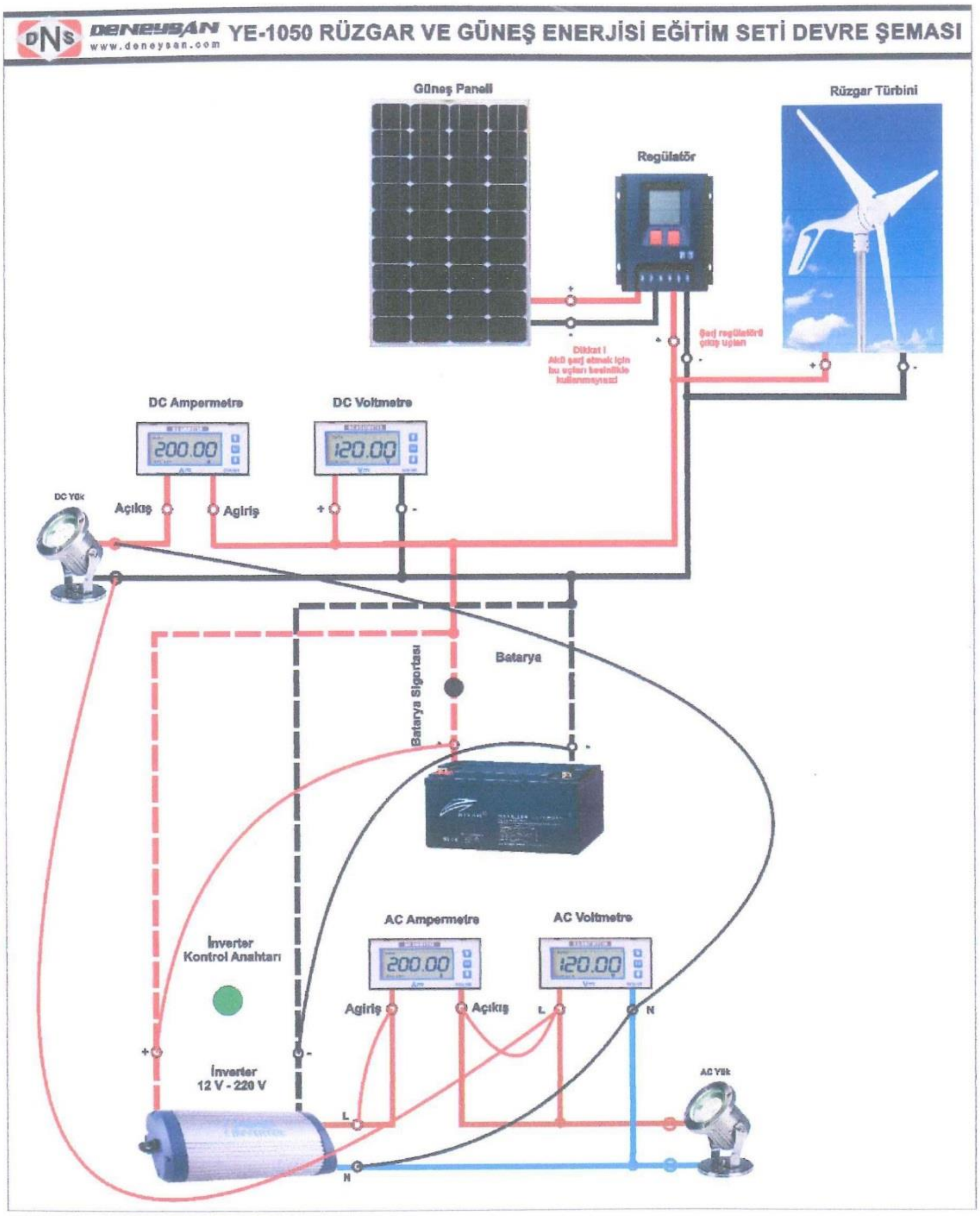
IMPORTANT NOTES:



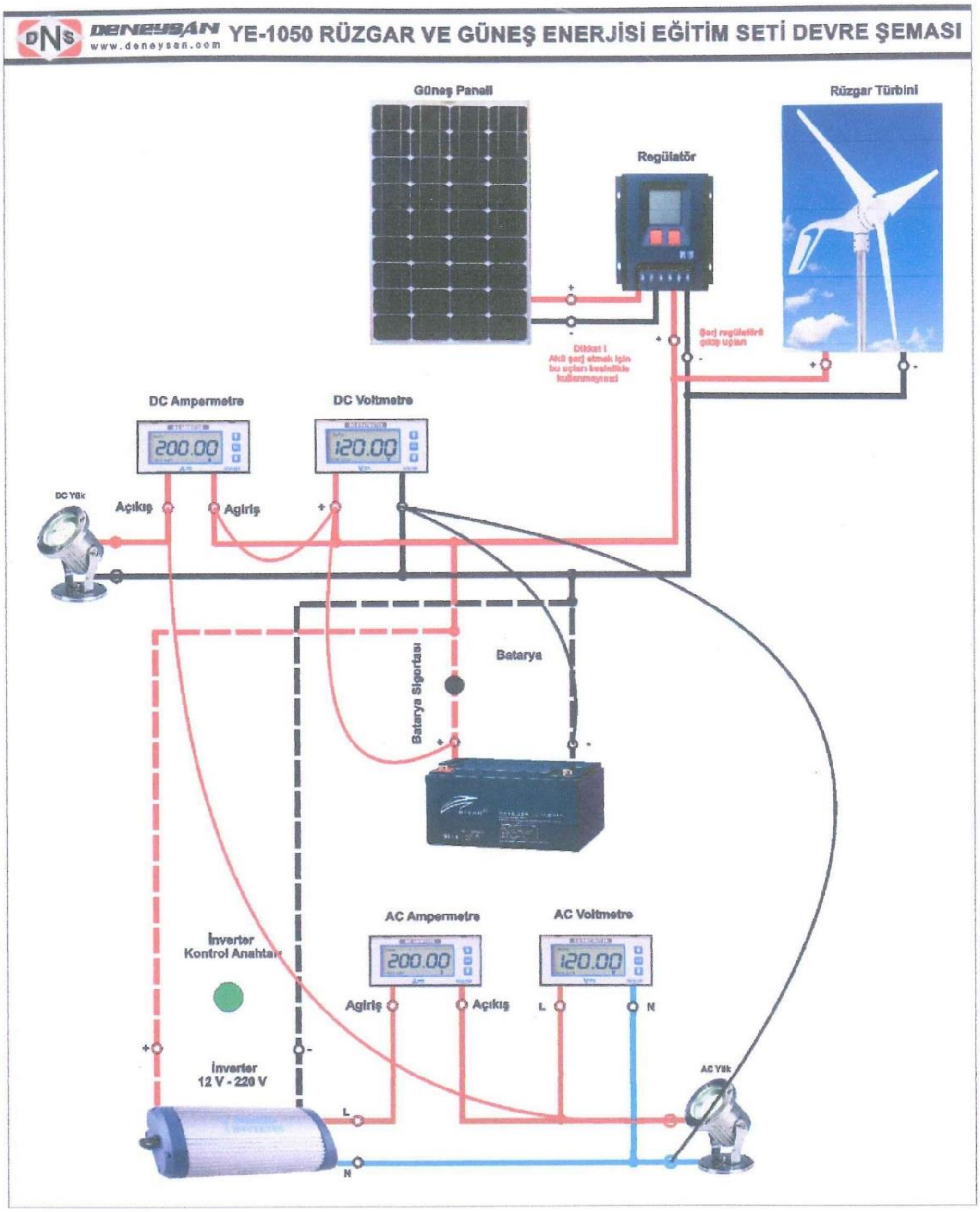
To charge the battery certainly do not connect to the solar panel. This is because the battery draws a certain current according to the incoming voltage, which can cause the battery to overheat or fuse explosion if it rises above normal. In addition, if you make such a connection, the battery will continuously charge itself and will not apply any interruption. In this case the same hazards may arise.



Never make connections to the L (phase) and N (Neutral) terminals of the inverter from the connection to the + and - terminals of the battery inverter. Because either the battery fuse or the fuse inside the inverter will damage the system.



If AC connections are made, attempting to operate a DC lamp or DC fan will cause the voltage to be too high, causing the lamp to explosion or cause the fan to burn.



If DC connections are made, if the AC lamp or the AC fan is tried to be operated, the incoming voltage will be low so that the lamp can be fried or not at all, and the fan will not turn at all.

When the motor is de-energized and re-energized, the motor drive F004 trips and stops output. For this reason, system energy is cut and after being expected 15-20 sec. should be given again.

EXPERIMENT NO: YE-1050-01

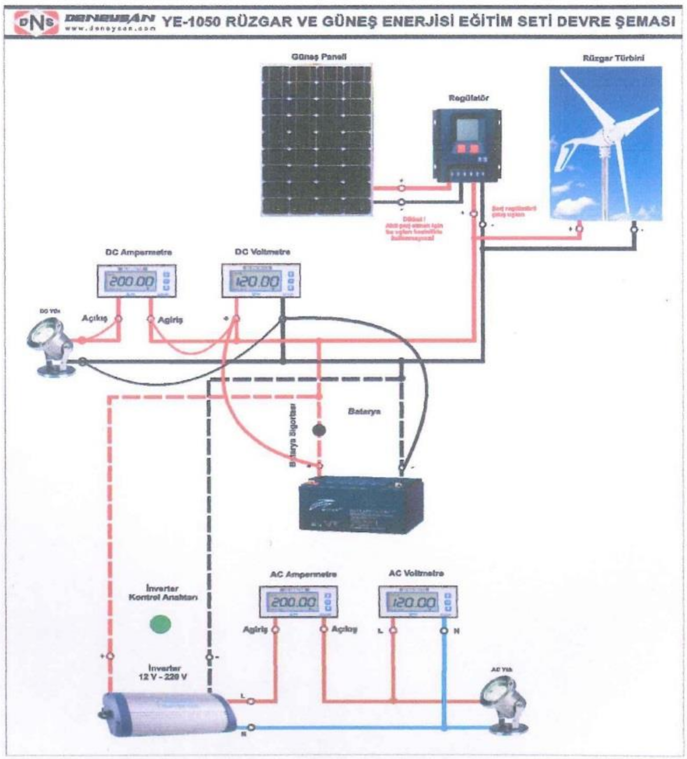
EXPERIMENT NAME: **Wind turbine and solar panel working principle connection diagram**

PURPOSE OF EXPERIMENT: To learn the connection of the wind turbine and the solar panel.

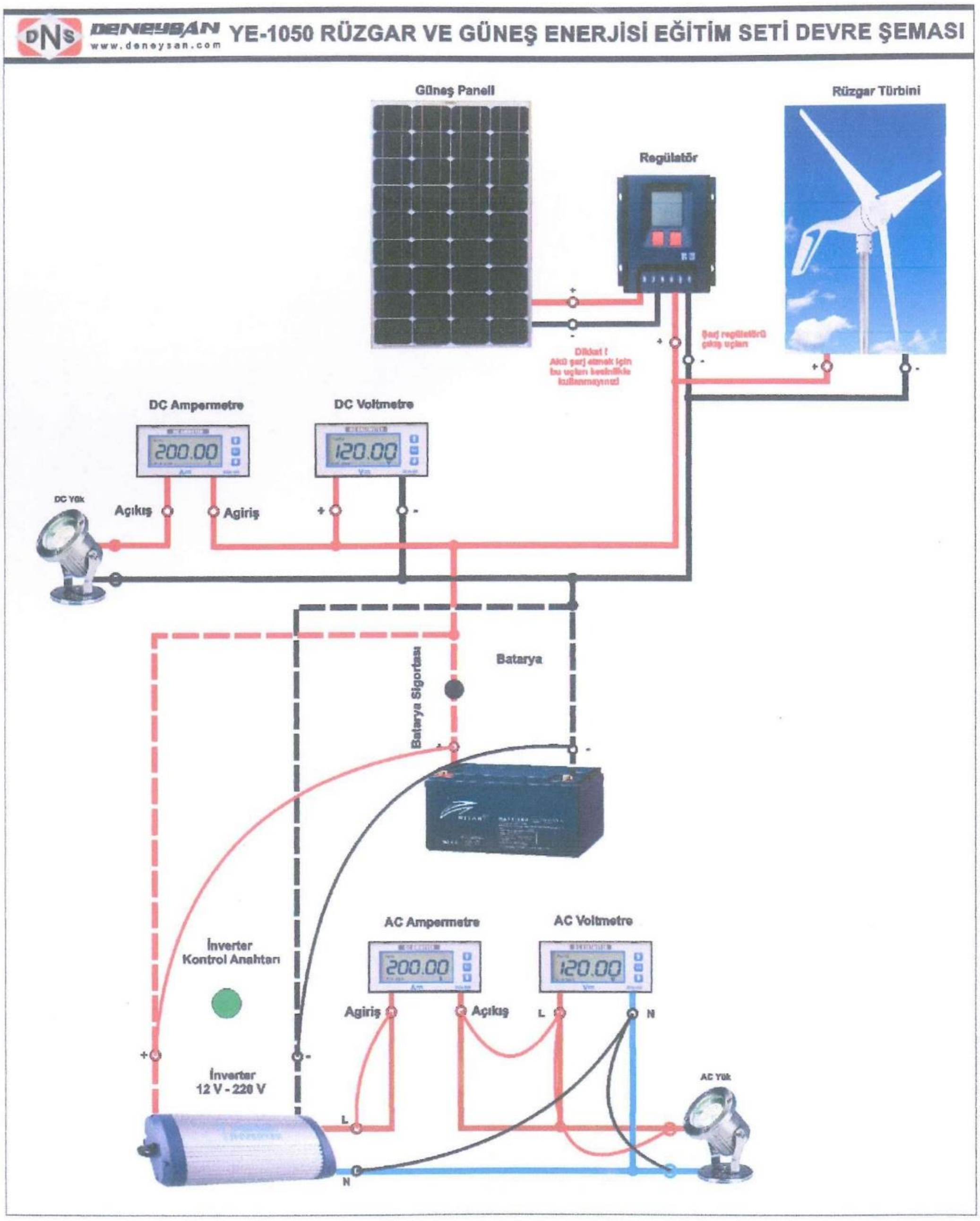
NECESSARY TOOLS AND MATERIALS

- Cable connection jacks

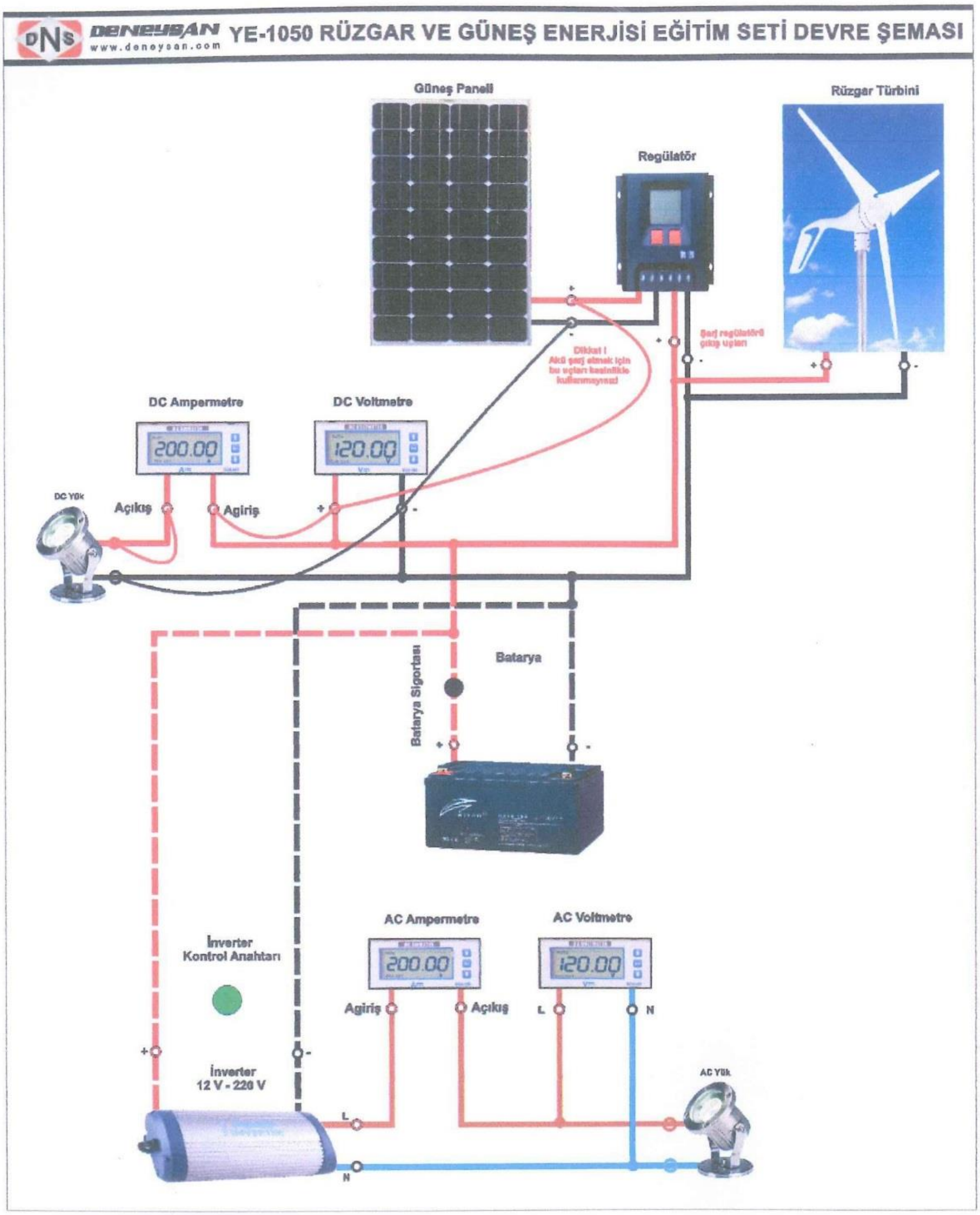
EXPERIMENT PROCEDURE:



The DC load connection via the battery can be made in the same way for other components (DC lamp, fan and siren).



The AC load connection via the battery can be made in the same way for other components (AC lamp, fan and siren).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Batarya
Batarya Sigortası
İnverter
Kontrol Anahtarı
AC Ampermetre
AC Voltmetre
Agiriş
Açıkış
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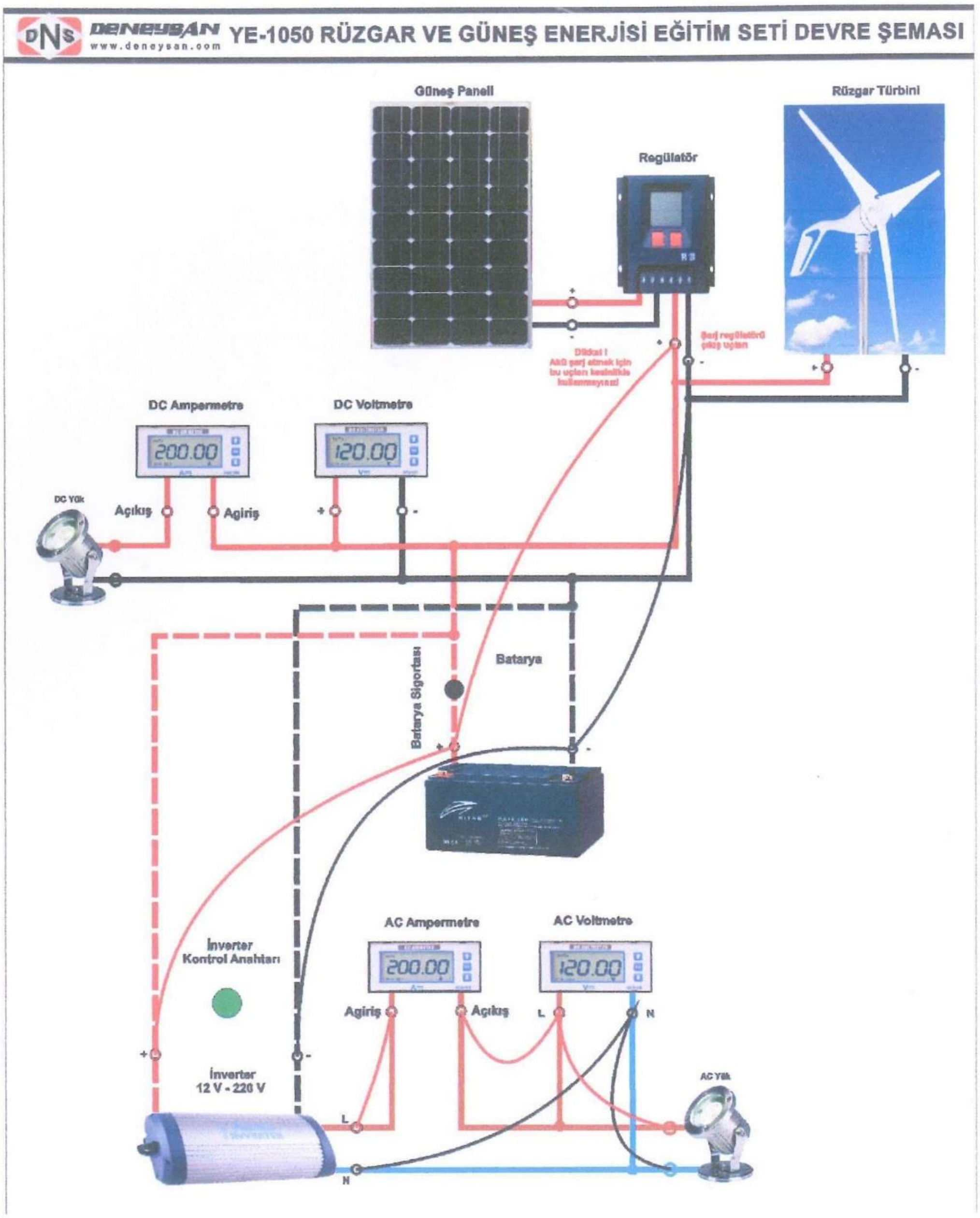
İnverter
12 V - 220 V
AC Yük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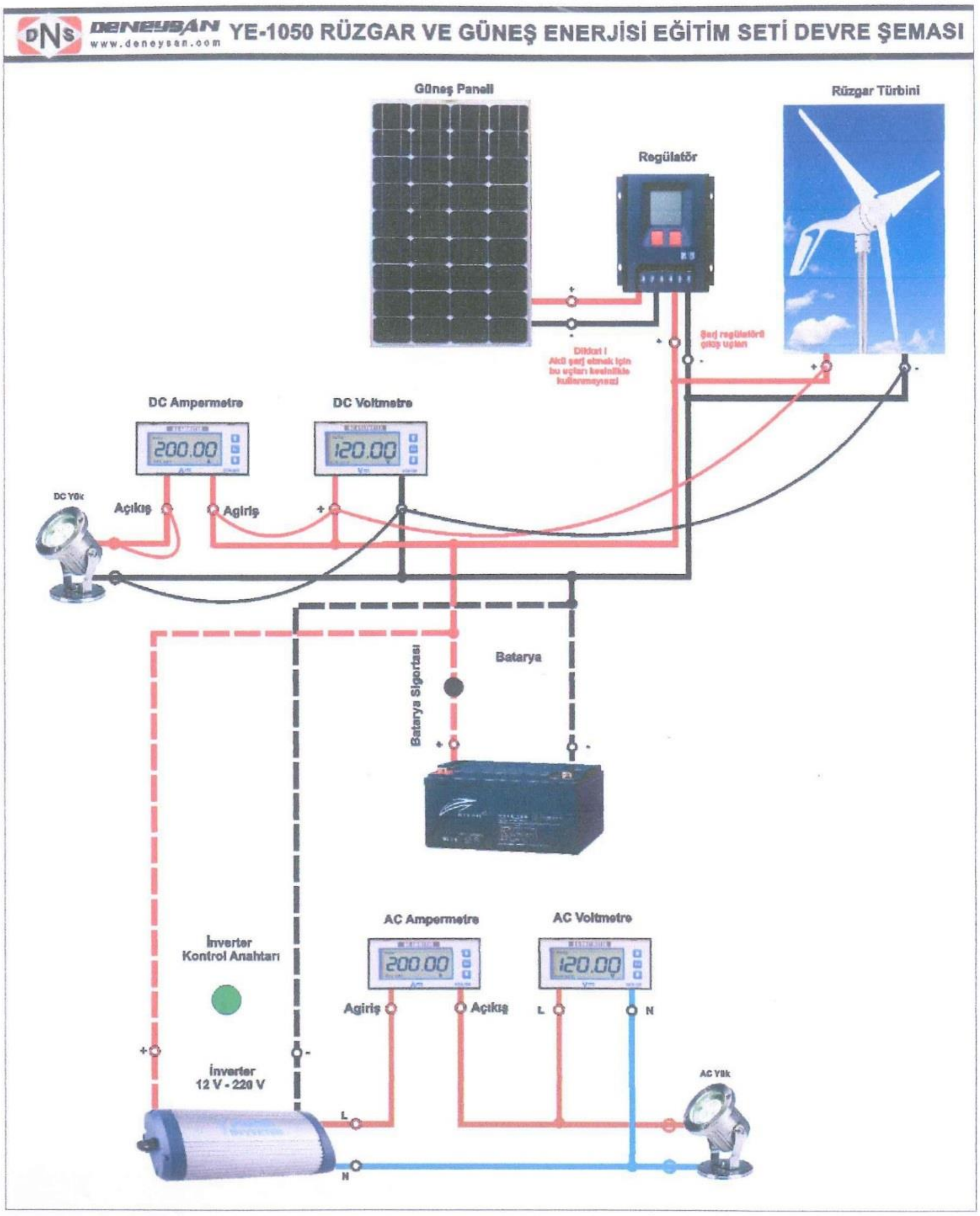
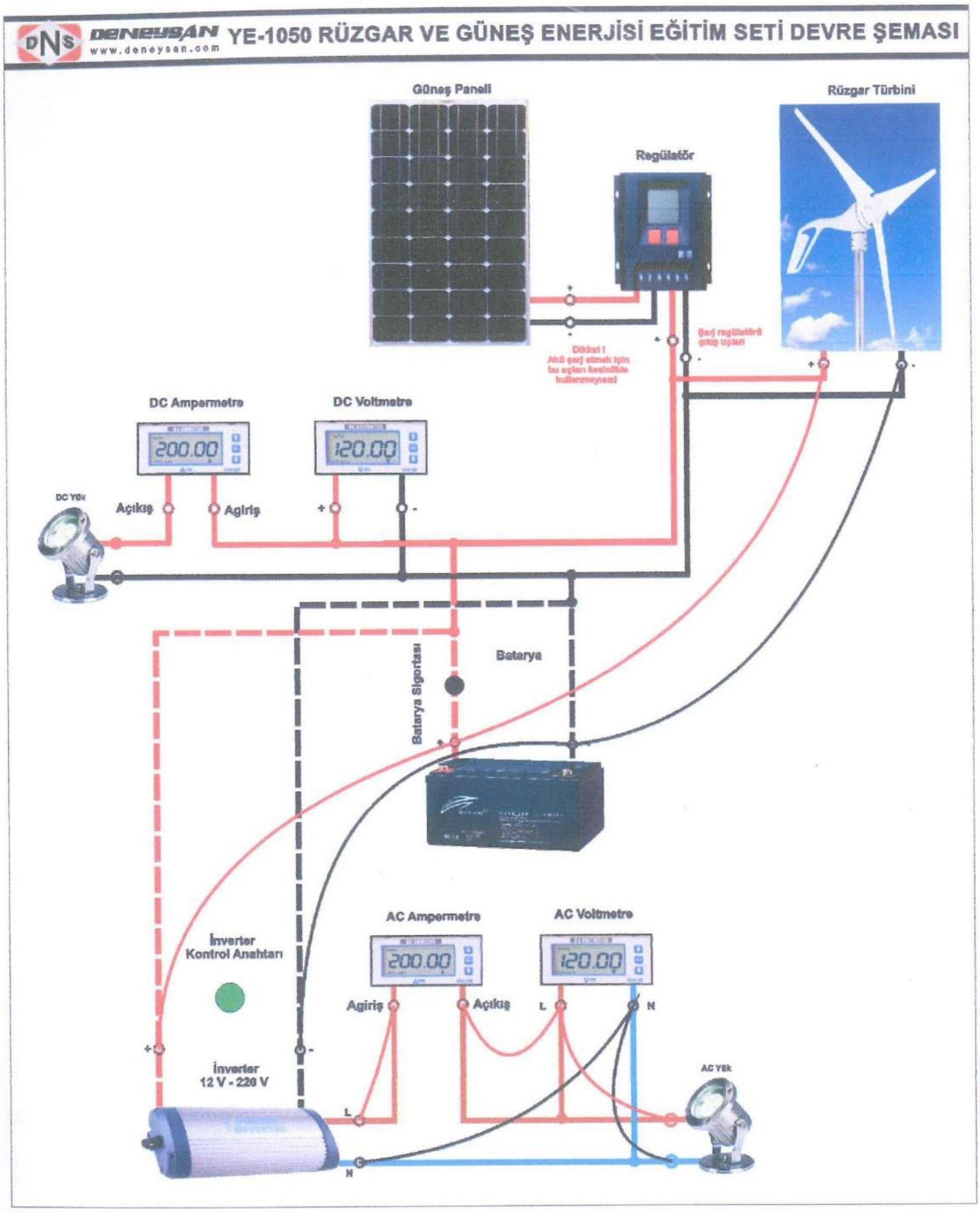
İnverter Kontrol Anahtarı
İnverter 12 V - 220 V
AC Ampermetre
AC Voltmetre
Agiriş
Açıkış
AC Yük



The DC load connection via the wind turbine can be made the same for other components (DC lamp, fan and siren). (Make sure the panel connection of the wind turbine is done.)



The AC load connection via the wind turbine can be done in the same way for other components (AC lamp, fan and siren). (Make sure the panel connection of the wind turbine is done.)

EXPERIMENT NO: YE-1050-02

EXPERIMENT NAME: **Wind turbine power generation-air velocity relationship**

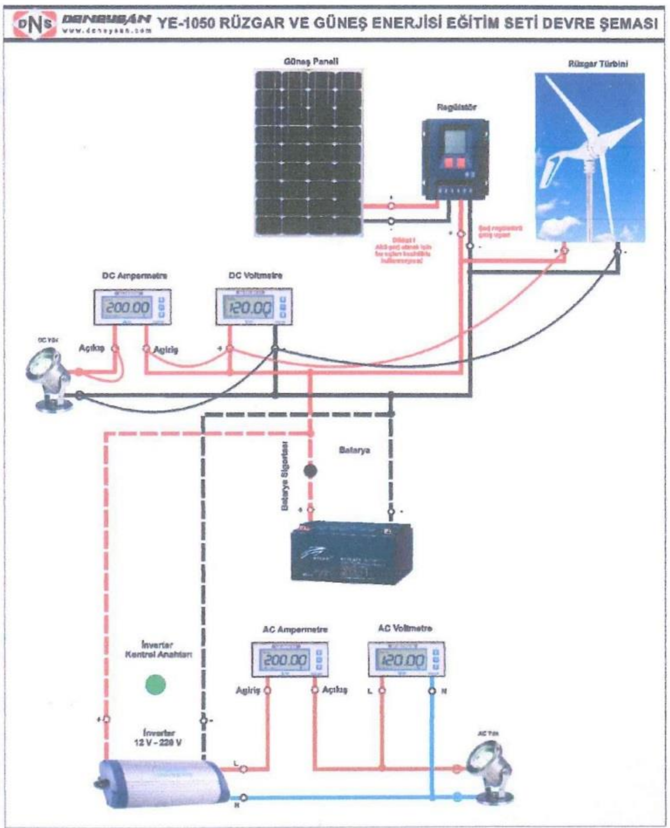
PURPOSE OF EXPERIMENT: To interpret the current and voltage values generated by a wind turbine at a certain air velocity.

NECESSARY TOOLS AND MATERIALS

- Cable connection jacks

EXPERIMENT PROCEDURE:

1. Make the cable connection to the wind turbine.
2. On the inverter doing cable connections of wind turbine.
3. Apply the following connection scheme by the help of jack cables.
4. Record the measurement values in the table
5. Calculate the efficiency at different air speed.



NOTE: This schematic is given as an example. Other DC loads can also be used if wanted.

REQUESTED ON REPORT: Experiment no, name and purpose, efficiency calculations and interpretation based on air speed.

Number of Measurement	1	2	3	4
Average wind velocity, (V) m/s				
Voltage, (U)				
Current, (I_c)				
Power (P) kW				

CALCULATION

Power Inlet: P=U*I (kW)

Speed (average wind speed)	3	4	5	6	7	8	9	10	11	12	12,5

Velocity that using in the calculations can be taken from table below.

EXPERIMENT NO: YE-1050-03

EXPERIMENT NAME: **Calculation of turbine efficiency**

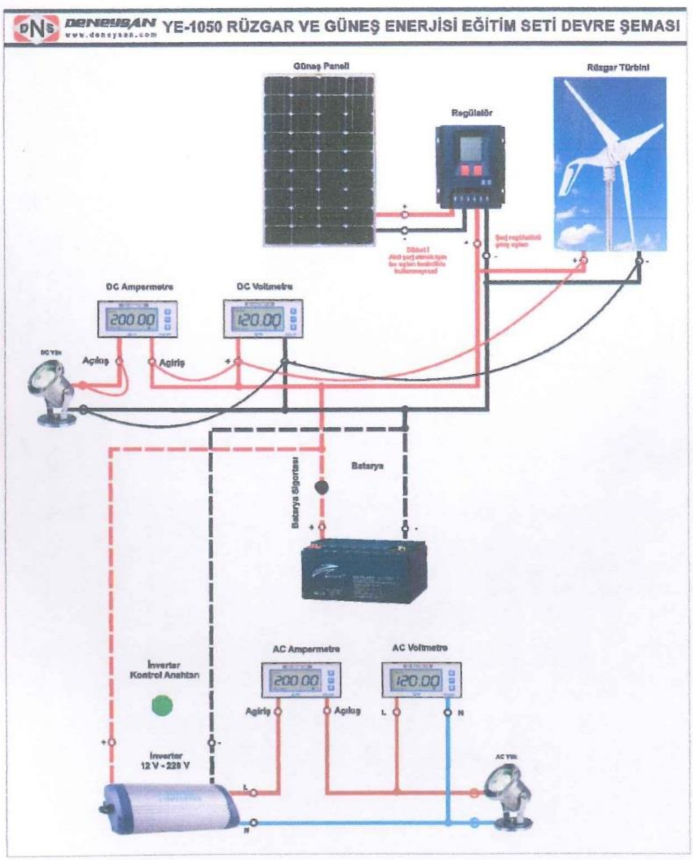
PURPOSE OF EXPERIMENT: Understanding the calculation methods of turbine efficiency.

NECESSARY TOOLS AND MATERIALS

- Cable connection jacks

EXPERIMENT PROCEDURE:

1. Make the cable connection to the wind turbine.
2. On the inverter doing cable connections of wind turbine.
3. Starting the turbine by potentiometer on the inverter.
4. Apply the following connection scheme by the help of jack cables.
5. Record the measurement values in the table
6. Calculate the efficiency at different air speed.



REQUESTED ON REPORT: Experiment no, name and purpose, efficiency calculations and interpretation based on air speed.

Measurements	1	2	3	4
Average wind speed, (V) m/s				
Voltage, (U)				
Current, (I_c)				
Power (P) kW				

CALCULATIONS:

$$C_{PBetz} = \frac{P}{0{,}5\, q\, A\, V_r^3}$$

P= Power (W)
C_{pBetz} = Efficiency (Betz efficiency coefficient)
q = Density of air, (kg/m^3)
V_r^3 = Average wind speed (m/s)
A= Cross sectional area, (m^2)
A= $\pi.D^2/4$
D= Diameter (m)

EXPERIMENT NO: YE-1050-04

EXPERIMENT NAME: **Calculation of solar cell electrical power**

PURPOSE OF EXPERIMENT: Investigation of current, voltage values of solar cells at certain angles.

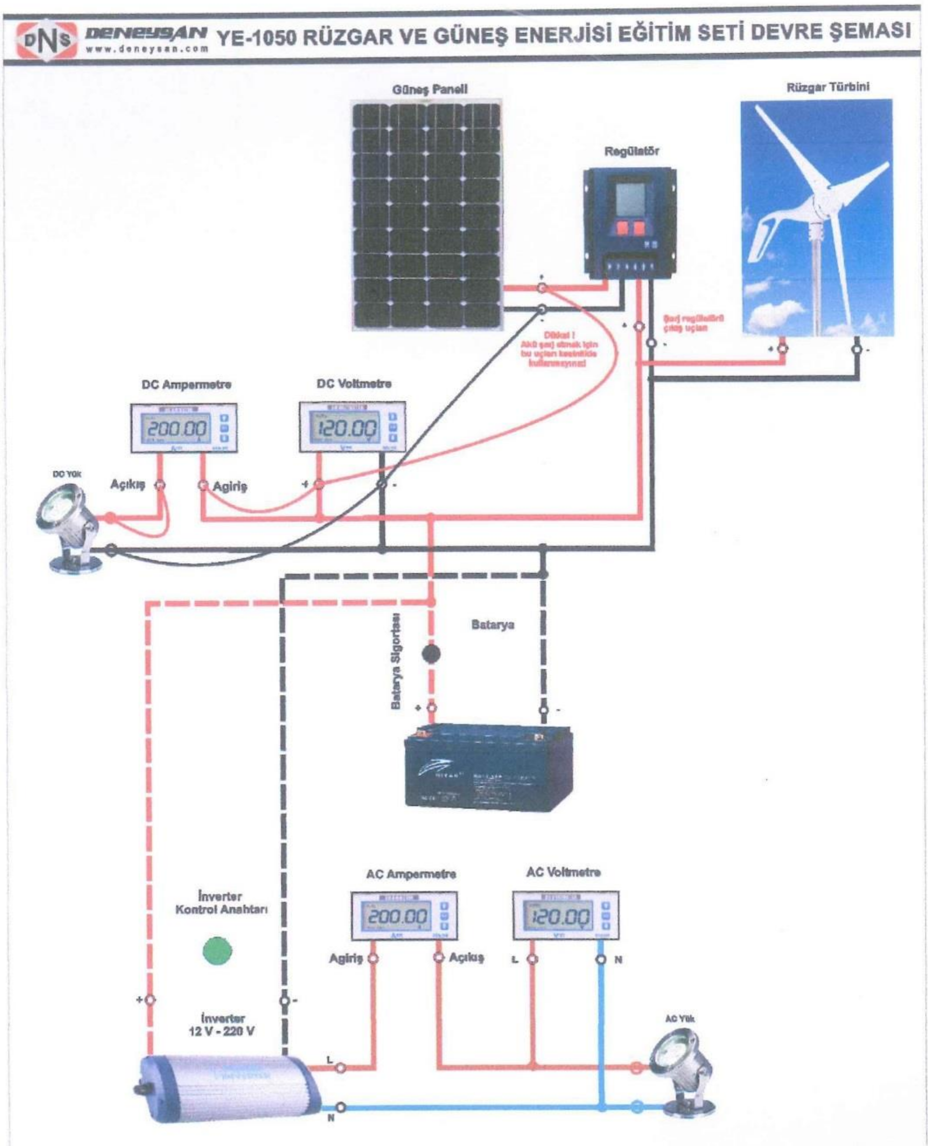
NECESSARY TOOLS AND MATERIALS

-Cable connection jacks

EXPERIMENT PROCEDURE:

1. Make the solar cell cable connection.
2. Adjust the tilt angle so that the sun lights come with a 90° angle.
3. Connect the cables as shown in the following figure
4. Record the measured values in table.
5. You can repeat the above operations with fan connection.

REQUESTED ON REPORT: Experiment no, name and purpose, transfer of the results of the current-voltage values at the specific angle onto the graph and table



CALCULATIONS:

Power input: P=U*I (kW)

MEASUREMENTS	1	2	3
Voltage, (U)			
Current, (I_c)			
Power (P) kW			

EXPERIMENT NO: YE-1050-05

EXPERIMENT NAME: **Finding solar cell efficiency**

PURPOSE OF EXPERIMENT: Investigation of how yield values of solar cells are calculated.

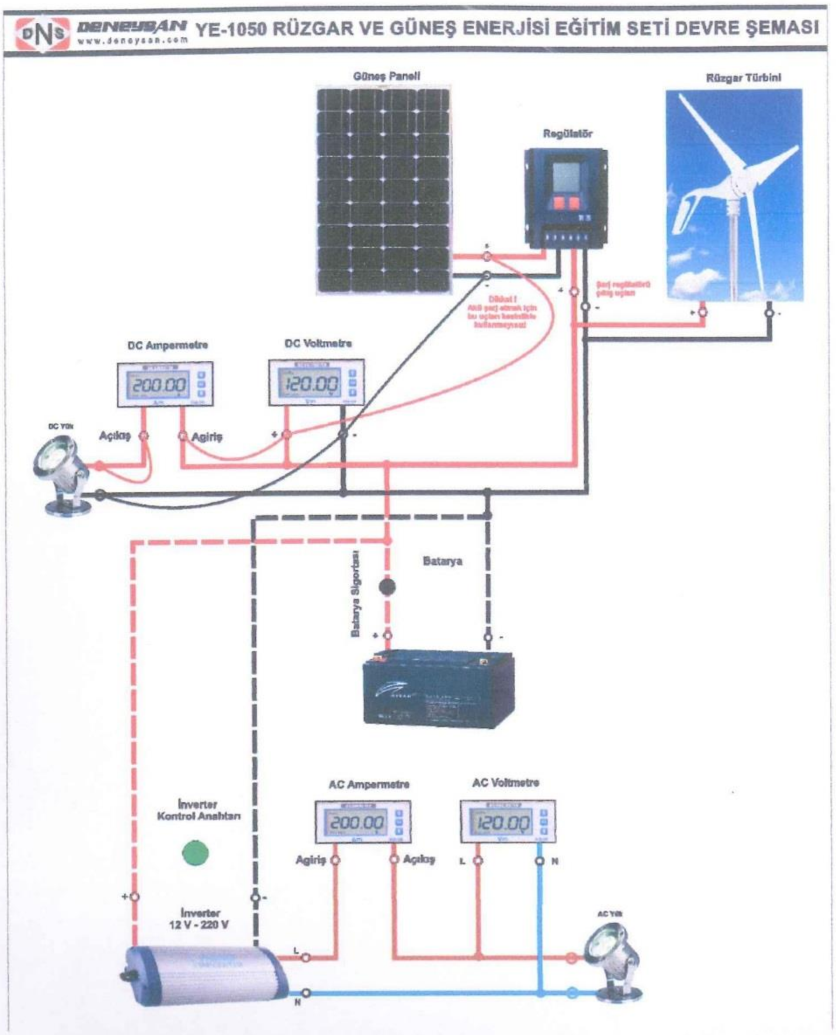
NECESSARY TOOLS AND MATERIALS

- Solar radiation sensor and indicator

EXPERIMENT PROCEDURE:

1. Make the solar cell cable connection.
2. Adjust the tilt angle so that the sun lights come with a 90° angle.
3. Connect the cables as shown in the following figure
4. Record the measured current and voltage values in table..
5. Calculate the efficiency.
6. You can repeat the above operations with fan connection.

REQUESTED ON REPORT: Experiment no, name and purpose, comparison of electrical output values at certain angles.



MEASUREMENTS	1	2	3
Voltage, (U)			
Current, (I_c)			
Solar radiation sensor measurement, R (W/m^2)			
Efficiency (%)			

CALCULATIONS:

$$1\ lux = 0.0081\ W/m^2$$

$$\text{Panel area} = 0{,}312\ m^2$$

$$\text{Efficiency: } \eta = \frac{U\ I_c}{R}\ [\%]$$

EXPERIMENT NO: YE-1050-06

EXPERIMENT NAME: **Investigation of the change of solar cell power depending on angle**

PURPOSE OF EXPERIMENT: Investigation of current, voltage values of solar cells at certain angles.

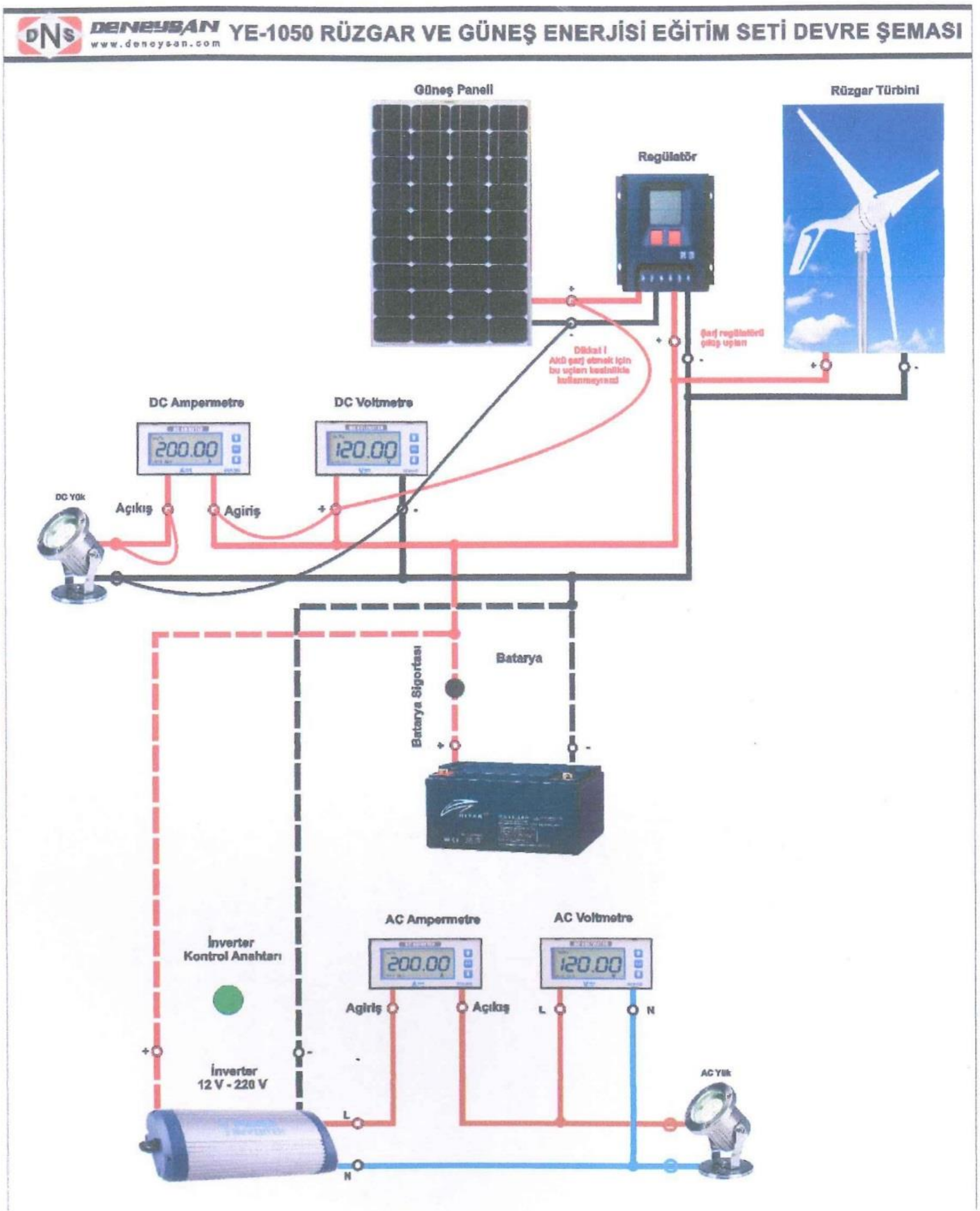
NECESSARY TOOLS AND MATERIALS

- Cable connection jacks

EXPERIMENT PROCEDURE:

1. Make the solar cell cable connection.
2. Adjust the tilt angle so that the sun lights come with a 90° angle.
3. Connect the cables as shown in the following figure.
4. Record the measured current and voltage values in table.
5. Do the same procedure at other angles and record the table.
6. You can repeat the above operations with fan connection.

REQUESTED ON REPORT: Experiment no, name and purpose, comparison of electrical output values at certain angles.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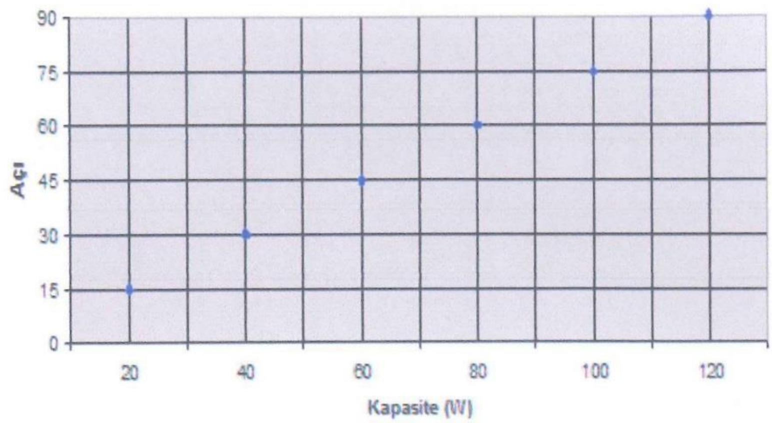
Regülatör
DC Ampermetre
DC Voltmetre
200.00
120.00
DC Yük
Açıkış
Agiriş
Batarya
Batarya Sigortası
AC Ampermetre
AC Voltmetre
İnverter Kontrol Anahtarı
İnverter 12 V - 220 V
Agiriş
Açıkış
L
N
AC Yük

Angles	0^0	30^0	45^0	60^0	90^0
Voltage, (U)					
Current, (I_c)					
Power ($U.I_c$)					



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