



MARMARA UNIVERSITY
INSTITUTE FOR GRADUATE STUDIES
IN PURE AND APPLIED SCIENCES



**DESIGN AND SIMULATION OF THE
REQUIRED STORAGE SYSTEM OF A
CAMPUS TO SUPPLY TOTAL ENERGY
NEEDS FROM WIND AND SOLAR ENERGY**

UĞUR BAŞ

MASTER THESIS

Department of Mechanical Engineering

Thesis Supervisor

Prof. Dr. Tanay Sıdkı UYAR

İSTANBUL, 2015



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Uğur BAŞ, a Master of Science/Doctor of Philosophy student of Marmara University Institute for Graduate Studies in Pure and Applied Sciences, defended his/her thesis entitled “**Design and Simulation of the Required Storage System of a Campus to Supply Total Energy Needs From Wind and Solar Energy**”, on 8 / 6 /2015 and has been found to be satisfactory by the jury members.

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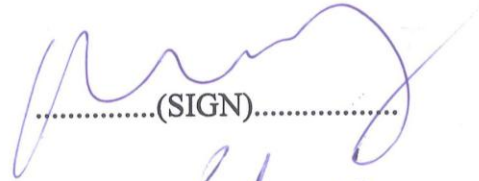
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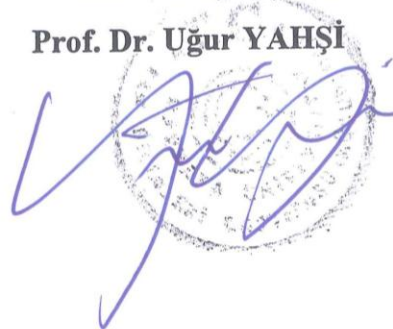
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APPROVAL

Marmara University Institute for Graduate Studies in Pure and Applied Sciences Executive Committee approves that Uğur BAŞ be granted the degree of Master of Science in Department of Mechanical Engineering, Energy Section on 17/08 /2015 (Resolution no: 2015/18-02)

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UĞUR BAŞ

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ABSTRACT

DESIGN AND SIMULATION OF THE REQUIRED STORAGE SYSTEM OF A CAMPUS TO SUPPLY TOTAL ENERGY NEEDS FROM WIND AND SOLAR ENERGY

The aim of this thesis study can be best summarized by the sentence, “Energy must be produced from right sources using right technologies and must be used efficiently.”

The renewable energy sources must be used instead of fossil fuels such as coal, petroleum, natural gas.

Conventional energy sources have caused many environmental and healthy problems such as global warming, polluted nature and many types of diseases like cancer. It is well known fact that changing is not an easy task. We live in a world we are accustomed and even have benefits to maintain the current status.

However, we all know another fact that change is continuous and perhaps, from the time of beginning the world we live in a continuous change.

The fact is that, technical and economical limits and insufficiencies are not in any way for reason behind the inability of renewable technologies to rapidly replace fossil resources. Among the renewables, especially solar and wind energies are studied in detail rather than the other kinds such as geothermal, biomass, wave energy.

We tried to design and simulate to supply sufficient energy from PV panels and wind turbines.

Wind turbines are planned to install on Marmara Island and the PV panels are planned to placed on Göztepe Campus of Marmara University.

The results show the fact that if required number of PV panels and wind turbines are installed, the energy (electrical and thermal) need of the campus may be supplied by renewable sources.

ÖZET

BİR KAMPÜSÜN TOPLAM ENERJİ İHTİYACININ KARŞILANMASI İÇİN GEREKLİ DEPOLAMA SİSTEMİNİN RÜZGAR VE GÜNEŞ ENERJİSİNDEN ELDE EDİLMESİNİN TASARIM VE SİMÜLASYONU

Bu tez çalışmasının amacı en iyi şu cümleyle özetlenebilir: “Enerji doğru kaynaklardan, doğru teknolojiler kullanılarak elde edilmeli ve verimli kullanılmalıdır.”

Kömür, petrol ve doğalgaz gibi fosil yakıtlar yerine yenilenebilir kaynaklar kullanılmalıdır. Alışlagelmiş enerji kaynakları küresel ısınma, kirlenmiş doğa gibi çevresel sıkıntılar ve kanser gibi hastalıklara neden olmaktadır. Değişimin kolay olmadığı iyi bilinir. Çıkarların varolan durumu sürdürmeye alışık olduğumuz bir dünyada yaşıyoruz. Bununla beraber değişimin sürekli olduğunu biliriz ve başlangıcından beri sürekli değişen bir dünyada yaşıyoruz.

Yenilenebilir teknolojilerin fosil kaynaklarla hızlı bir biçimde yer değişmesinin önünde teknik ve ekonomik kısıtlar olmamalı. Jeotermal, biomas ve dalga enerjisinden çok özellikle güneş ve rüzgar enerjisi üzerinde durulmuştur.

PV panellerden ve rüzgar türbinlerinden elde edilen enerji ile bir tasarım ve simülasyon yapılmaya çalışıldı. Rüzgar türbinlerinin Marmara adasına kurulması ve PV panellerinde Marmara Üniversitesi Göztepe Yerleşkesine konulması tasarlanmıştır.

Sonuçlar gösteriyor ki eğer gerekli sayıda rüzgar türbini ve PV paneli kullanılırsa, yerleşkenin tüm elektrik ve ısı enerjisi ihtiyacı karşılanabilir.

SYMBOLS

a	: Acceleration (m/s^2)
A	: Area (m^2)
A_C	: Area of solar cell (m^2)
C_P	: Power ratio
E	: Energy (kWh)
f	: Frequency (s^{-1})
f_{PV}	: Decreasing factor (%)
\overline{G}_T	: Solar radiation on PV panel (kW/m^2)
$\overline{G}_{T,STC}$: Radiation under standard conditions (kW/m^2)
h	: Height (m)
I	: Current (A)
I_S	: Solar radiation (kWh/m^2)
I_{SC}	: Short circuit current (A)
I_{max}	: Maximum current (A)
m	: Mass (kg)
n_s	: Slowing ratio
P	: Power (W)
P_{PV}	: Power obtained from PV panel (kW)
P_w	: Wind power (W)
q	: Charge (C)
t	: Time (s)
T_C	: Temperature of PV panel ($^{\circ}\text{C}$)
$T_{C,STC}$: Temperature of PV panel under standard conditions (25°C)
u_1	: Wind speed at the height of h_1 , (m/s)
V	: Potantiel difference (Volt)
V_{OC}	: Open circuit voltage (Volt)
V_w	: Wind speed (m/s)
x	: Distance (m)
Y_{PV}	: Output power under standard conditions (kW)
α	: Coefficient
θ	: Incident angle ($^{\circ}$)
ρ	: Density of air (kg/m^3)
λ	: Wavelength (m)
ψ	: Zenith angle ($^{\circ}$)
η	: Efficiency

ABBREVIATIONS

AC	: Alternating Current
BIPV	: Building Integrating Photovoltaic Cell
BOS	: Balance of System
CCC	: China Composite Center
CCS	: Carbon Capture and Storage
COE	: Cost of Energy
CO ₂	: Carbon Dioxide
CSP	: Concentrated Solar Power
CuO	: Copper Oxide
DC	: Direct Current
DSC	: Die Solar Cell
EREF	: European Renewable Energies Federation
ETSAP	: Energy Technology Systems Programming
EWEA	: European Wind Energy Association
FF	: Filling Factor of a Cell
GDP	: Gross Domestic Product
GHG	: Green House Gas
H ₂	: Hydrogen
H ₂ O	: Water
HAWT	: Horizontal Axis Wind Turbines
HOMER	: Hybrid Optimization Model for Electric Renewables
HVDC	: High Voltage Direct Current
kW	: Kilowatt
LCC	: Life Cycle Cost
Li-Ion	: Litium - Ion
Li-Poly	: Litium - Polymer
LOCA	: Loss of Cooling Accident
MW	: Megawatt
NiCd	: Nickel Cadmium
Ni-MH	: Nickel Metal Hydrid
NREL	: National Renewable Energy Laboratory
Pb-Acid	: Lead-Acid
PMSG	: Permanent Magnet synchronous generator
PV	: Photo Voltaic
SEA	: Sustainable Energy Association
SCIG	: Squirrel Cage Induction Generator
Si	: Silisium
STC	: Standard Test Conditions
WECS	: Wind Energy Conversion System
WRIG	: Wound Rotor Induction Generator
WRSG	: Wound Rotor Synchronous Generator
WT	: Wind Turbine
WWEA	: World Wind Energy Association
Zn-Air	: Zinc-Air

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CHAPTER 1 - INTRODUCTION

1.1. General

The most important problem on the world is energy problem. Why is energy so vital for humanity? Today, energy causes wars between countries and in international political arena energy is still most important issue. From the beginning of human history, energy had been needed for heating, cooking and transportation. Before the industrial revolution, our energy needs were modest. For heat, we relied on the sun and burned wood, straw, and dried dung when the sun failed us. For transportation, the muscle of horses and the power of the wind in our sails took us to every corner of the world. For work, we used animals to do jobs that we couldn't do with our own labor. Water and wind drove the simple machines (in 5000 B.C the Egyptians had used the wind energy to move their boats on the river Nile). Simple machines based on the ability to harness the power of steam have been dated by some sources as far back as ancient Alexandria.

The evolution of the steam engine continued over time and significantly ramped up in the 17th and 18th centuries. But it was the significant adaptations of Thomas Newcomen and James Watt in the mid 1700s that gave birth to the modern steam engine, opening up a world of possibility. A single steam engine, powered by coal dug from the mines of England, could do the work of dozens of horses. More convenient than wind and water, and less expensive than a stable full of horses, steam engines were soon powering locomotives, factories, and farm implements. Coal was also used for heating buildings and smelting iron into steel. In 1880, coal powered a steam engine attached to the world's first electric generator. By the late 1800s, a new form of fuel was catching on: petroleum. For years it had been a nuisance, contaminating wells for drinking water.

Horseless carriages were a rich man's toy until Henry Ford perfected the assembly-line method of mass production for his model T.

Energy use grew quickly, doubling every ten years. The cost of energy production was declining steadily, and the efficient use of energy was simply not a concern.

1.2. Aim of the study

The aim of this thesis study is to inform the readers about the history of energy, types of energy and especially solar and wind energies. Then, this study is searching to design and simulation of the required storage system of a campus to supply total energy needs from wind and solar energy. The design is considered into two parts. One is solar energy design and the other is wind energy design.

In solar energy design, sufficient number of photovoltaic panels are used for the roofs of the buildings in Göztepe campus of the university.

In wind energy design of this study, sufficient number of wind turbines are installed at Marmara Island. Since the university has stations for wind measurements at the island, the wind speeds and directions are known.

Using HOMER program, the results of the different cases can be obtained as output.

Therefore it can be understood whether the system is sufficient or not.

CHAPTER 2 - MATERIAL AND METHOD

2.1. General view to energy

Before 1973 the energy used in the world was mostly petroleum. In factories, in power plants, in daily life almost only petroleum was being used. After 1973 everything begun to change, nothing would be the same as before.

In 1973, American support for Israel in the Arab-Israeli war led the Arab oil-producing nations to stop supplying oil to the United States and some developed countries. Countries which use large amount of oil begun to look for other energy sources. Many nuclear power plants on the world started to build in this period (1973-1978). For example, United States which is the biggest energy consumer on the world, has not built new nuclear power plant since 30 years. And has begun to decommission some of their nuclear power plants and improved the output of the relicensed nuclear power plants.

Since the climate disasters which are caused by fossil fuels (oil, coal especially) many countries have diverted to renewable energy sources. Most people agree with the following sentence; “Energy must be produced from right sources using right technologies and must be used efficiently.” The amount of energy that is used to heat the unit volume in Turkey, is 46% greater than that of in France and 230% greater than that of in Sweden. Although these two countries are colder than Turkey [1].

To produce energy is important but to use it efficiently is more important. According to a search, 60% of the all deseases and 90% of all cancers in the world are caused from environmental problems. For many years and still, fossile fuels (oil, coal, natural gas) burned and large amount of C emitted to atmosphere. CO₂ behaves like a blanket. This effect is called “Green House Effect”. On the other side SO₂ which forms from burning fossil fuels causes “Acid rain”.

2.2. Types of Energy

2.2.1. Nuclear energy

Nuclear energy is the energy stored in the center or the nucleus of an atom. After we bombard the nucleus in two parts, two different elements are formed along with the

emission of high energy. The process is called fission. There is another reaction called fusion, which produces almost one tenth of the energy as produced during fission. Fission is the chain reaction which needs uranium-235. There are many disadvantages of nuclear energy such as:

Radioactive Waste:

The waste produced by nuclear reactors needs to be disposed off at a safe place since they are extremely hazardous and can leak radiations if not stored properly. Such kind of waste emits radiations from tens to hundreds of years. The storage of radioactive waste has been major problem for the expansion of nuclear programs.

Today many nuclear powered countries are looking for a place to put their nuclear wastes. To protect their own people from vitally hazardous effects of nuclear wastes, some governments tend to give money or other things to undeveloped countries which have no nuclear affairs to deposit their nuclear wastes.

A 1000 MW nuclear power plant produces 30 tons of waste annually, this amount is 340,000 times the nuclear bomb fell to Hiroshima [1].

The nuclear wastes contain radio isotopes with long half-live. This means that the radio isotopes stay in the atmosphere in some form or the other. These reactive radicals make the sand or the water contaminated.

An important specialist in energy policy Mark Holt wrote a report to American Congress. The following part is taken from that report:

Nuclear energy issues facing Congress include reactor safety and regulation, radioactive waste management, research and development priorities, federal incentives for new commercial reactors, nuclear weapons proliferation, and security against terrorist attacks. The earthquake and resulting tsunami that severely damaged Japan's Fukushima Daiichi nuclear power plant on March 11, 2011, raised questions in Congress about the disaster's possible implications for nuclear safety regulation, U.S. nuclear energy expansion, and radioactive waste policy. The tsunami knocked out electric power at the six-reactor plant, resulting in the overheating of several reactor cores, loss of cooling in spent fuel storage pools, major hydrogen explosions, and releases of radioactive material into the environment. The Nuclear Regularity

Commission (NRC) issued orders to U.S. nuclear plants March, 12, 2012, to begin implementing safety improvements in response to Fukushima.

Significant incentives for new commercial reactors were included in the Energy Policy Act of 2005 (EPACT05, P.L. 109-58), such as tax credits and loan guarantees. Together with volatile fossil fuel prices and the possibility of greenhouse gas controls, the federal incentives for nuclear power helped spur renewed interest by utilities and other potential reactor developers. License applications for as many as 31 new reactors were announced, and NRC issued licenses for four reactors at two plant sites in early 2012. However, falling natural gas prices, safety concerns raised by the Fukushima accident, and other changing circumstances have made it unlikely that many more of the proposed nuclear projects will move toward construction in the near term.

Four U.S. reactors were permanently closed in 2013, and another shutdown has been announced for late 2014. Three reactors were closed because of the need for major repairs, and the other two because electricity prices fell below their generating costs.

DOE's nuclear energy research and development program includes advanced reactors, fuel cycle technology and facilities, and infrastructure support.

Disposal of highly radioactive waste has been one of the most controversial aspects of nuclear power. The Obama Administration halted work on a long-planned waste repository at Yucca Mountain, NV, and established the Blue Ribbon Commission on America's Nuclear Future (BRC) to recommend new approaches to the waste problem. The BRC issued its final report to the Secretary of Energy on January 26, 2012. In response to the BRC report, and to provide an outline for a new nuclear waste program, DOE issued a strategy for the Management and Disposal of Used Nuclear Fuel and High-Level Waste in January 2013. The DOE strategy calls for a new nuclear waste management entity to develop consent-based storage and disposal sites, similar to recommendations by the BRC. No funding has been requested or appropriated since FY2011 to continue NRC licensing of the Yucca Mountain repository, although the House voted to provide DOE with \$150.0 million and NRC \$55.0 million for Yucca Mountain licensing activities in FY2015 [2].

Nuclear Accidents:

While so many new technologies have been put in place to make sure that such disaster like the ones Chernobyl or more recent Fukushima does not happen again but the risk associated with them are relatively high. Even small radiation leaks can cause devastating effects. People who work at nuclear power plants and live near those areas are at high risk of facing nuclear radiations, if it happens.

Nuclear Radiation:

There are power reactors called breeders. They produce plutonium. It is an element which is not found in the nature however it is a fissionable element. It is a by-product of the chain reaction and is very harmful if introduced in the nature. It is primarily used to produce nuclear weapons. Most likely, it is named as “Dirty bomb”.

High Cost:

Another practical disadvantage of using nuclear energy is that it needs a lot of investment to set up a nuclear power station. It is not always possible by the developing countries to afford such a costly source of alternative energy. Nuclear power plants normally take 5-10 years to construct as there are several legal formalities to be completed and mostly it is opposed by the people who live nearby.

National Risk:

Nuclear energy has given us the power to produce more weapons than to produce things that can make the world a better place to live in. We have to become more careful and responsible while using nuclear energy to avoid any sort of major accidents. They are hot targets for militants and terrorist organisations. Security is a major concern here. A little lax in security can prove to be lethal and brutal for humans and even for this planet.

Major impact on human life:

We all remember the disaster caused during the Second World War after the nuclear bombs were fallen over Hiroshima and Nagasaki. Even after five decades of the mishap, children are born with defects. This is primarily because of the nuclear effect. Do we have any remedy for this? The answer is still no.

Not renewable:

Nuclear energy uses uranium which is a scarce source and is not found in many countries.

Instead of nuclear energy human being must use renewable energies such as solar, wind, biomass, geothermal etc.

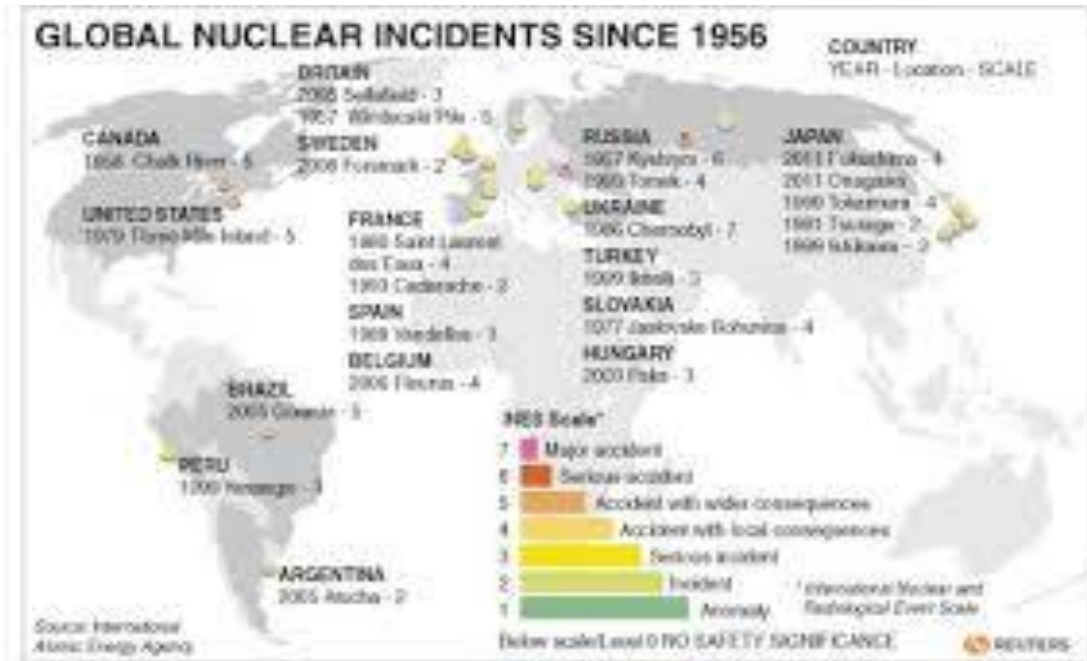


Figure 2.1. Nuclear accidents [20]

2.2.2. Solar energy

Photovoltaics is the process of converting sunlight directly into electricity using solar cells. The first photovoltaic device was demonstrated in 1839 by Edmond Becquerel, as a young 19 year old working in his father’s laboratory in France. However, the understanding and exploitation of this effect was to depend on some of the most important scientific and technological developments of the 20th century. One is the development of quantum mechanics, one of the major intellectual achievements of the 20th century. Another, dependent on the first, is the development of semiconductor technology, which has been responsible for the pervasive electronics revolution and the photonics revolution now gathering place. An interesting history of modern photovoltaic developments is given by Loferski and the early history, reaching back to 1839, is described in more technical detail by Crossly [3].

Fortunately, given its pedigreed background, the simplicity and reliability of use of solar cells is one of the technology's great strengths. To understand the photovoltaics, one must know the nature of light. Newton's mechanistic view of light as being made up of small particles prevailed. By the early 1800s, experiments by both Young and Fresnel had shown interference effects in light beams, indicating that light was made up of waves. By the 1860s, Maxwell's theories of electromagnetic radiation were accepted, and light was understood to be part of a wide spectrum of electromagnetic waves with different wavelengths. In 1905 Einstein explained the photoelectric effect by proposing that light is made up of discrete particles or quanta of energy. This complementary nature of light is now well accepted. It is referred to as the particle-wave duality, and is summarised by the equation;

$$E = h.f = \frac{h.c}{\lambda}$$

where light, of frequency f or wavelength λ , comes in 'packets' or photons, of energy E , h is Planck's constant and c is the velocity of light.

In defining the characteristics of photovoltaic or solar cells, light is sometimes treated as waves, other times as particles or photons.

2.2.2.1. The sun and its radiation

The sun is a hot sphere of gas heated by nuclear fusion reactions at its center. Internal temperatures reach a very warm 20 million K. The intense radiation from the interior is absorbed by a layer of hydrogen ions closer to the sun's surface. Energy is transferred by convection through this optical barrier and then re-radiated from the outer surface of the sun, the photosphere. This emits radiation approximating that from a blackbody with a temperature of nearly 6000 K [4].

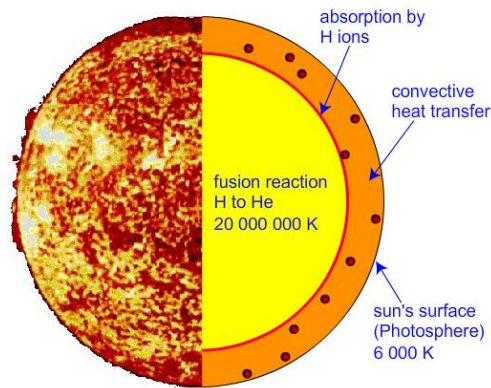


Figure 2.2. Regions in the sun's interior [21]

Although radiation from the sun's surface is reasonably constant by the time it reaches the earth's surface it is highly variable owing to absorption and scattering in the earth's atmosphere.

When skies are clear, the maximum radiation strikes the earth's surface when the sun is directly overhead, and sunlight has the shortest pathlength through the atmosphere.

As shown in the figure, this pathlength can be approximated by $1/\cos\theta_z$, where θ_z is the angle between the sun and the point directly overhead. This pathlength is usually referred to as the Air Mass through which solar radiation must pass to reach the earth's surface. Therefore

$$\text{Air Mass} = 1/\cos\theta_z$$

This is based on the assumption of a homogeneous, non-refractive atmosphere, which introduces an error of approximately 10% close to the horizon.

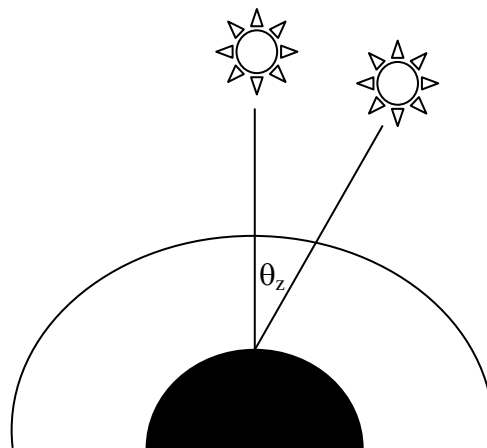


Figure 2.3. Sun's positions

The sun that is the main energy supplier for the earth has a diameter of 1.39 million km and is far from the earth 150 million km. The sun entirely consists of hydrogen. Fusion reactions occur at the nucleus of the sun and during these reactions hydrogen is converted to helium. 700×10^{12} MWh energy passes from the earth's atmosphere annually and this is called "The radiation of the sun". This amount of energy is about 10,000 times the energy which is used all over the world. 30% of solar radiation is reflected by the earth atmosphere, 50% of the radiation is emitted by the atmosphere, land and oceans. The amount of solar energy falls on 1 m^2 surface perpendicular to the solar radiation at a place outer side of the earth atmosphere is called "extraterrestrial radiation", denoted by $I_o^*(\text{W}/\text{m}^2)$

$$I_o^* = 1353 \text{ W}/\text{m}^2$$

Earth's rotation about its axis lasts 24 hours and day and night occur. Earth rotates around the sun in an elliptic orbit on which one of its focuses is the sun. This rotation causes the seasons. Because of these facts the amount of radiation coming from the sun to the earth's surface varies daily and seasonally. The self rotating axis of the earth makes an angle 23.5 degree with the elliptic plane. For this reason the intensity of solar radiation varies along the path of the earth. The sun is made up of 92.1% hydrogen, 7.8% helium and the rest is other elements. In fusion reaction 4 hydrogen atoms are converted to one helium atom. The energy appears during this reaction is solar radiation. The sun can be considered as a "Fusion reactor" which combines hydrogen atoms to produce helium atom. In every second 564 million tons hydrogen atom is converted to 560 million tons helium atoms. Four million tons difference is converted to 38×10^{22} kJ energy [4].

The energy which comes from the sun travels in the form of electromagnetic waves. Electromagnetic radiation means electric and magnetic fields are perpendicular each other. If charged particles move with an acceleration then they create "electromagnetic waves". When the photons strike gas molecules, they are spreaded equally in all directions. This is called "Rayleigh spreading". Ozon layer that is at 25 km height from the ground absorbs ultraviolet lights. Which has wavelengths smaller than $0,32 \mu\text{m}$. This absorbation is vitaly important because ultraviolet lights are very harmful for eyes and skins. After this absorbation lights which $\lambda = 0.3 - 0.4 \mu\text{m}$ can reach to the earth.

Some amount of lights come from the sun collide gas molecules and dust clouds and are spreaded in all directions. Therefore some of the light coming from the sun come back to space. Outer side of atmosphere, the radiation for 1 m² surface is,

$$I_t = I_0 \left[1 + 0.034 \cos \left(\frac{360.n}{365.25} \right) \right]$$

where, I: Total radiation in W/m²

I₀ : Solar constant

n: Number of days from 1st january

In a cloudless day 75-85% of total solar radiation is direct radiation.

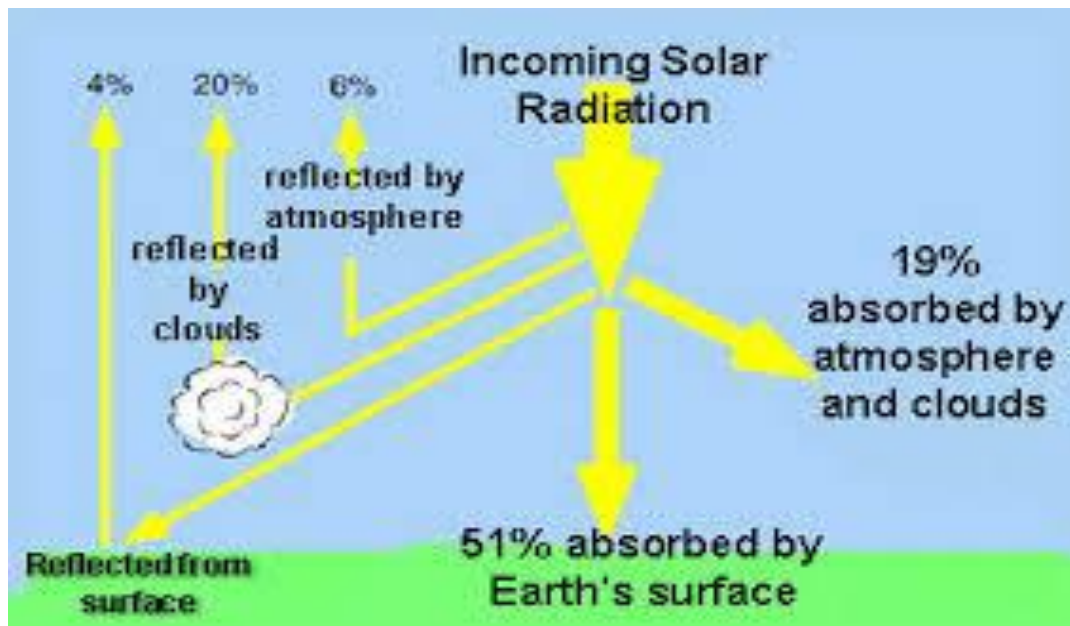


Figure 2.4. Light from the Sun [22]

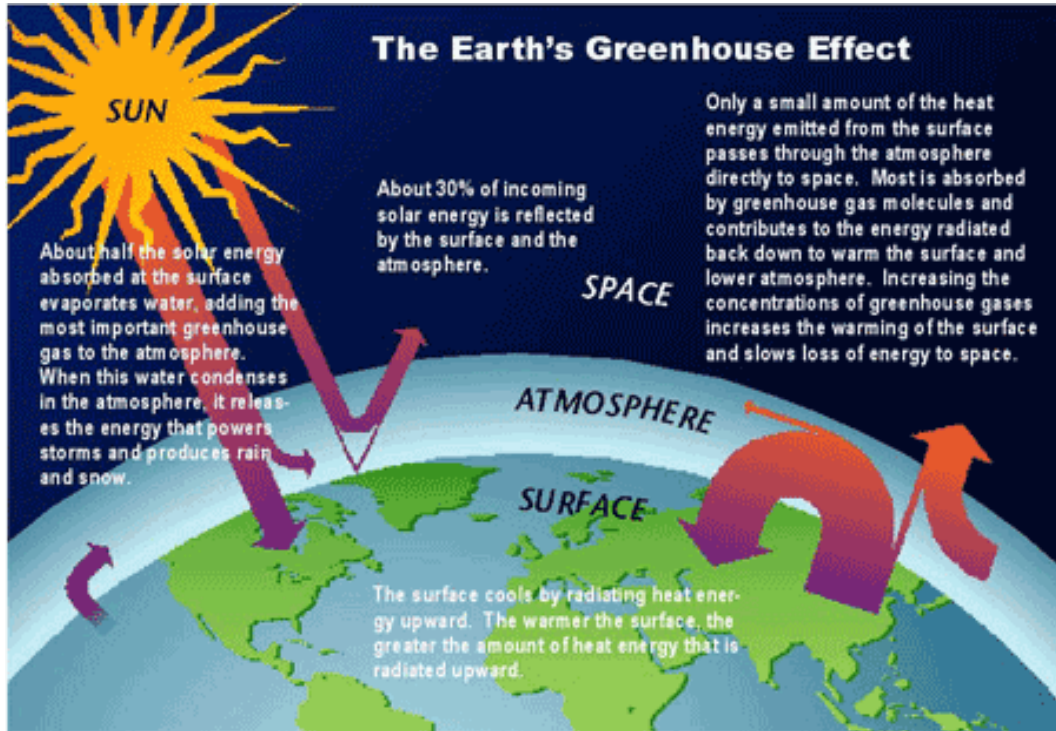


Figure 2.5. The Greenhouse Effect [23]

The following equation is valid for solar radiation:

$$\alpha + \beta + \gamma = 1$$

where, α : Percentage of the light that is absorbed

β : Percentage of the light that is reflected

γ : Percentage of the light that passes

For solids and liquids : $\alpha + \beta = 1$

For all gases : $\alpha + \gamma = 1$

Blackbody is a body which can absorb the light entirely

Whitebody is a body which can reflect the light entirely

Greybody is a body which can absorb some part and reflect the rest of the light.

The solar radiation differs from place to place. In Turkey the solar radiation according to regions is shown following table.

Table 2.1 says that Southeast Anatolia is the richest region in our country. For one metersquare 1460 kWh solar energy comes from the sun in one year. Daily radiation time is 8.2 h/day.

Table 2.1. Annually Regional Distribution of Solar Radiation in Turkey

	Total Solar Radiation (kWh/m²-year)	Average Radiation Time (h/day)	Radiation Time (h/year)
Southeast Anatolia	1460	8.2	2993
Mediterrain Region	1390	8.7	2956
East Anatolia	1365	6.5	2664
Central Anatolia	1314	7.5	2628
West Anatolia	1304	8.2	2738
Marmara Region	1168	6.8	2409
Blacksea Region	1120	5.3	1971

Source: www.eie.gov.tr/solarenergy

The average radiation time for Turkey is 2640 hours/year.

80 Mtep radiation comes from the sun to our country annually.

(1 Mtep means 1 Megaton equivalence of petroleum)

Therefore Turkey has 80 Megaton petroleum energy every year.

Monthly radiation in Turkey is shown in the following Figure 2.6.

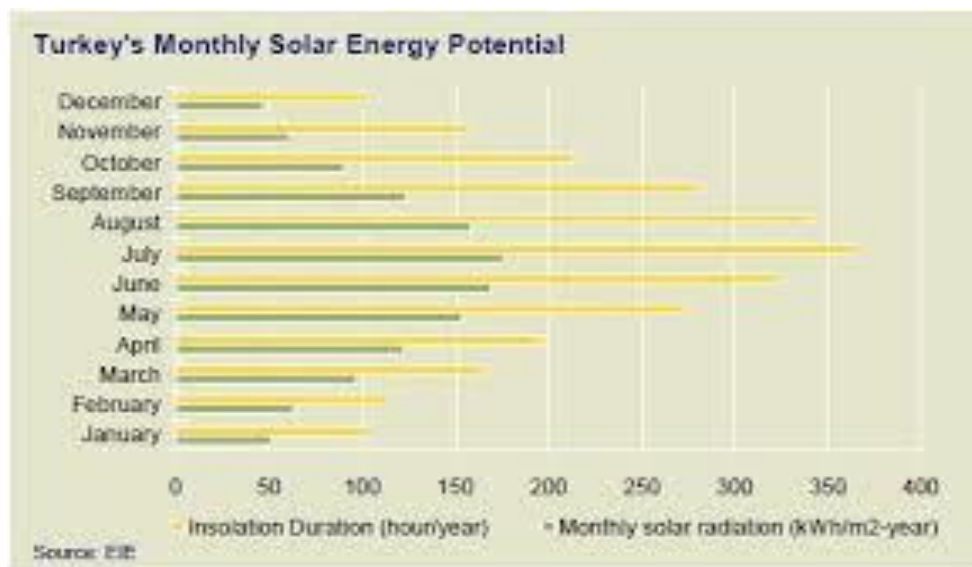


Figure 2.6. Monthly distribution of radiation in Turkey [24]

Turkey is located on “Solar region” on the earth. Our country is located between 36°-42° north parallels. Solar energy is not used sufficiently in Turkey. Only water heating systems are widely used in southern cities like Adana, Mersin, Antalya. The main and the most effective usage of solar radiation is producing electricity. Producing electrical energy from solar radiation is not common because of the lack of manufacturing units of PV panels and other renewable energy technology are supported and encouraged in Turkey.

Advantages:

- The solar source is an infinite source of power
- It is a clean energy for human health and for environment
- It can be available wherever needed
- It is more feasible compared to other countries
- Operating cost is nearly zero

Disadvantages:

- Large land surfaces are required for producing large amount of energy
- Especially night time the radiation almost zero therefore storage devices are needed
- In winters the average solar radiation decreases with respect to that of summers
- Investment cost is high since the critical components have to be imported

The solar potential of Turkey is shown in the following map.

SOLAR MAPS OF TURKEY

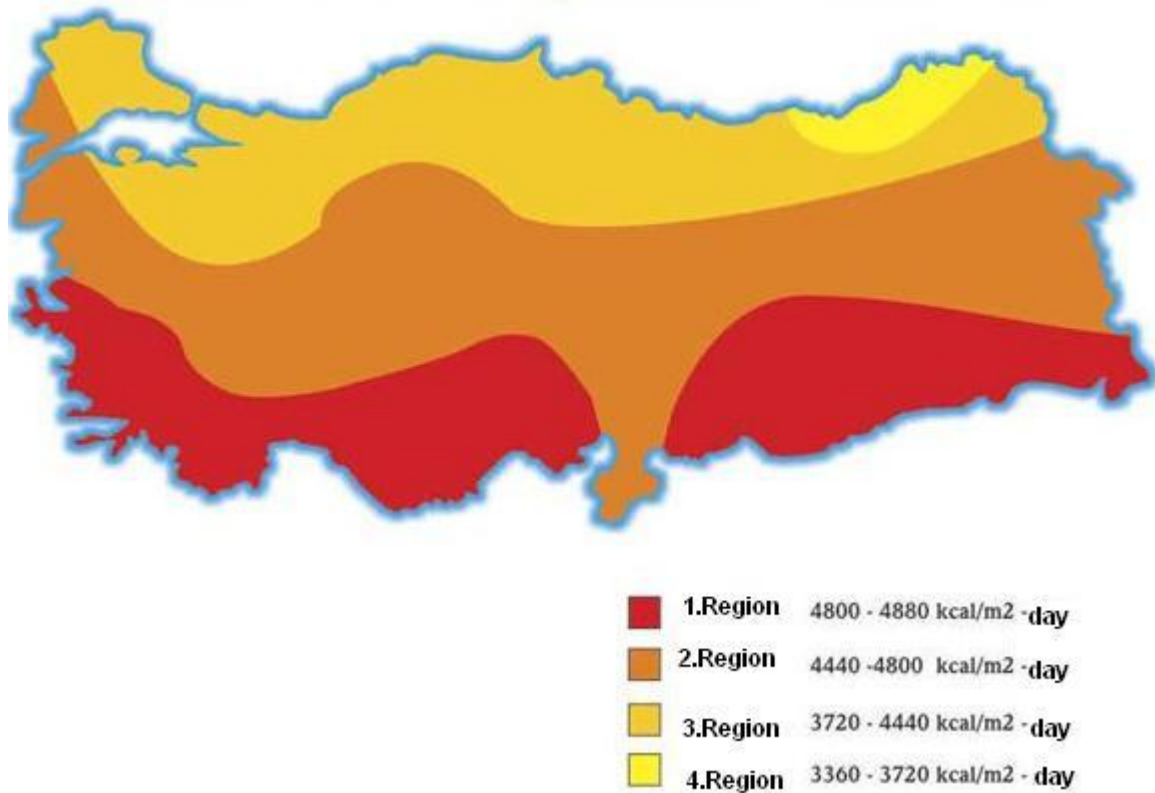


Figure 2.7. The Solar Potential of Turkey [24]

1 kW-h = 860 kcal

In producing electricity from solar radiation the important criteria is the duration of solar radiation. How many hours does the radiation occur in a day?

Table 2.2. Solar radiation (Monthly) in Turkey

	Total monthly radiation (kWh/m²)	Monthly duration (h/month)	Hourly duration h/day
January	51.75	103	3.3
February	63.27	115	4.1
March	96.65	165	5.3
April	122.23	197	6.5
May	153.86	273	8.8
June	168.75	325	10.8
July	175.38	365	11.8
August	158.40	343	11.0
September	123.28	280	9.3
October	89.90	214	6.9
November	60.82	157	5.2
December	46.87	103	3.3
Total	1311	2640	Ave: 7.2

Table 2.2 indicates that the average daily solar radiation is 7.2 h/day. Strickly speaking this means that electrical energy can be produced almost 7 hours in a day.

2.2.2.2. PV technologies

In 1839 Becquerel observed that certain materials, when exposed to light, produced an electric current. This is known as photovoltaic effect, and is the basis of the operation of photovoltaic or solar cells.

Solar cells are manufactured from semiconductor materials; that is, materials that act as insulators at low temperatures, but as conductors when energy or heat is available. At present, most solar cells are silicon-based, since this is the most mature technology. However, other materials are under active investigation and may supersede silicon in the long term. The first semiconductor material was CuO. Among many elements some are convenient to use in producing PV cells such as Silisium, Galium, Arsenik, Cadmium and Tellur elements. The electrical properties of semiconductors can be explained using two models, the bond and the band models. The bond model uses the covalent bonds joining the silicon atoms to describe semiconductor behavior.

The following figure illustrates the bonding and the movement of electrons in a silicon crystal lattice.

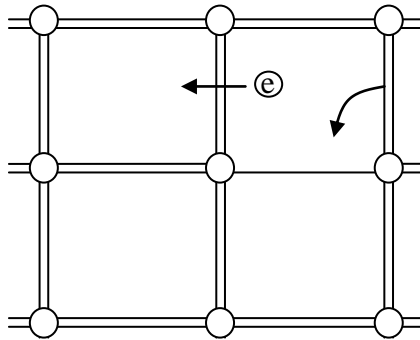


Figure 2.8. Schematic representation of covalent bonds in a silicon crystal lattice

At low temperatures, the bonds are intact and the silicon behaves as an insulator. At high temperatures, some bonds are broken and conduction can occur by two processes:

- Electrons from broken bonds are free to move
- Electrons from neighbouring bonds can also move into the ‘hole’ created in the broken bond, allowing the broken bond or hole to propagate as if it had a positive charge.

The concept of a moving hole is analogous to that of a bubble in a liquid. Although it is actually the liquid that moves, it is easier to describe the motion of the bubble going in the opposite direction.

Another model, the band model describes semiconductor behaviour in terms of the energy levels between valance and conduction bands. The following figure illustrates:

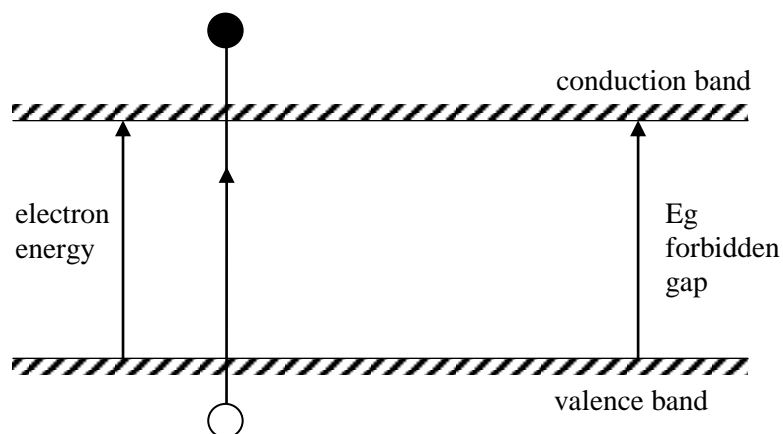


Figure 2.9. Schematic of the energy bands for electrons in a solid

The electrons in covalent bonds have energies corresponding to those in the valence band. In the conduction band the electrons are free. The forbidden gap corresponds to the minimum energy needed to release an electron from a covalent bond to the conducting band where it can conduct a current. The holes remaining conduct in the opposite direction in the valence band, as described for the bond model.

It is possible to shift the balance of electrons and holes in a silicon crystal lattice by 'doping' it with other atoms. Atoms with one more valence electron than the semiconductor are used to produce n-type material. Pure semiconductor element, such as silicon must be added with some special elements to be used as photovoltaic cell.

For n-type, Phosphorus is added to silicon. Silicon has 4 electrons at the outer orbit and P (Phosphorus) belongs to fifth group elements with 5 electrons at outer orbit. P gives its excess electron to crystal structure. For this reason 5th group elements are called n-type adding materials.

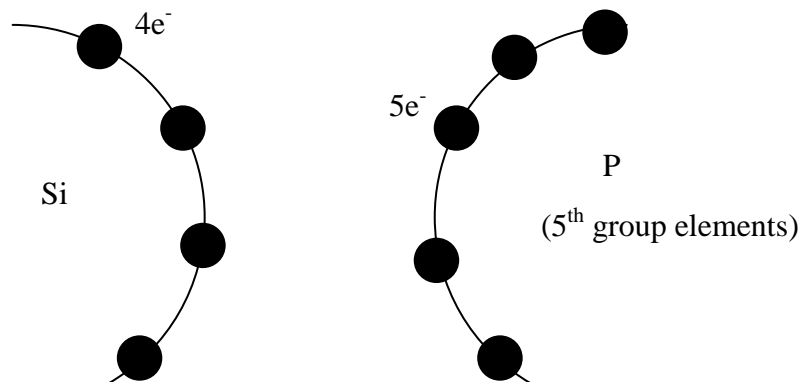


Figure 2.10. n-type

To obtain p-type silicon, an element from the 3rd group elements such as Al, In or B must be added to pure silicon. There are three electrons at the outer orbits of these elements. For this reason a hole occurs which is considered to carry positive charge. 3rd group elements are called p-type adding materials.

The figure below indicates the number of atoms at the outer orbits.

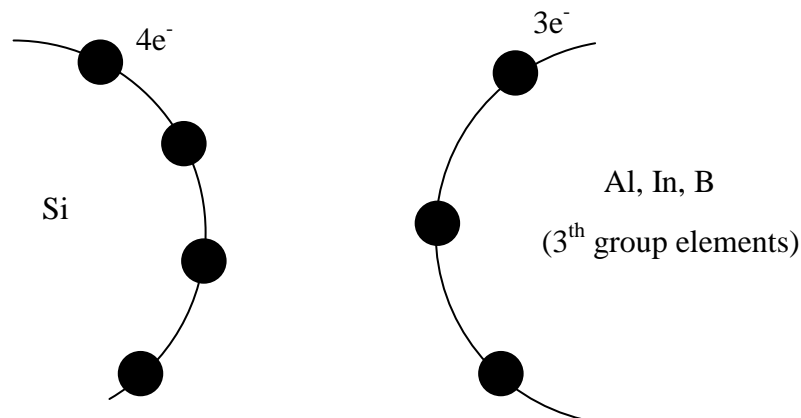


Figure 2.11. p-type

Silicon and other semiconductor materials used for solar cells can be crystalline, multicrystalline, polycrystalline, microcrystalline or amorphous. Microcrystalline material has grains smaller than 1 μm , polycrystalline smaller than 1 mm and multicrystalline smaller than 10 cm. Crystalline silicon has an ordered crystal structure, with each atom ideally lying in a pre-ordained position. It is, however, the most expensive type of silicon, because of the careful and slow manufacturing processes required. The cheaper multicrystalline or polycrystalline silicon (poly-silicon), and amorphous silicon are therefore increasingly being used for solar cells, despite their less ideal qualities. The techniques for production of multicrystalline or polycrystalline silicon are less critical, and hence cheaper, than those required for single crystal material. The grain boundaries reduce the cell performance by blocking carrier flows, allowing extra energy levels in the forbidden gap, thereby providing effective recombination sites, and providing shunting paths for current flow across p-n junction.

Amorphous silicon can be produced, in principle, even more cheaply than polysilicon. With amorphous silicon, there is no long-range order in the structural arrangement of the atoms, resulting in areas within the material containing unsatisfied bonds. These in turn result in extra energy levels within the forbidden gap.

Amorphous silicon and other thin film technologies for solar cell manufacture, where films of very thin semiconductor material are deposited onto glass or other substrates, are used in many small consumer products [4].

When light falls onto semiconductor material, photons with energy less than the bandgap energy interact only weakly with the semiconductor, passing through it as if it were transparent. However, photons with energy greater than the bandgap energy interact with electrons in covalent bonds, using up their energy to break bonds and create electron-hole pairs, which can then wander off independently.

When the light is switched off, the system must return to a state of equilibrium and the electron-hole pairs generated by the light must disappear. With no external source of energy, the electrons and holes wander around until they meet up and recombine. Any defects or impurities within or at the surface of the semiconductor promote recombination. The carrier lifetime of a material is defined as the average time for recombination to occur after electron-hole generation. For silicon, this is typically 1 μ s. Similarly, the carrier diffusion length is the average distance a carrier can move from point of generation until it recombines. For silicon, this is typically 100-300 μ m. These two parameters give an indication of material quality and suitability for solar cell use. However, no power can be produced from a semiconductor without a means of giving directionality to the moving electrons.

Therefore, functional solar cells are typically produced from semiconductor material by the addition of a rectifying p-n junction. A p-n junction is formed by joining n-type and p-type semiconductor materials, as shown in the figure below.

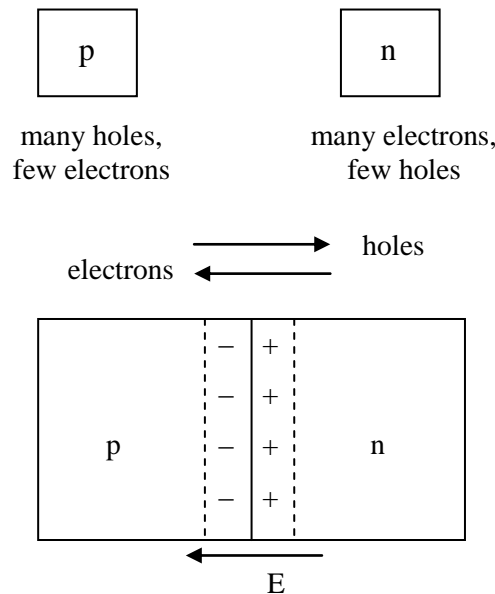


Figure 2.12. Formation of p-n junction

When joined, the excess holes in the p-type material flow by diffusion to the n-type material, while electrons flow by diffusion from the n-type material to the p-type material as a result of the carrier concentration gradients across the junction. The electrons and holes leave behind exposed charges on dopant atom sites, fixed in the crystal lattice. An electric field (E) therefore builds up in the so-called depletion region around the junction to stop the flow.

Depending on the materials used, a built-in potential (V_{bi}) owing to E will be formed. Once E is no longer large enough to stop the flow of electrons and holes, a current is produced.

$$I = I_0 \left[\exp\left(\frac{qV}{kT}\right) - 1 \right] \quad (2.1)$$

Where: I is the current, I_0 is the dark saturation current (the diode leakage current in the absence of light), V is the applied voltage, q is the charge on an electron, k is Boltzmann's constant and T is absolute temperature.

A silicon solar cell is a diode formed by joining p-type (typically boron doped) and n-type (typically phosphorous doped) silicon. Light shining on such a cell can behave in a number of ways, as illustrated in figure below.

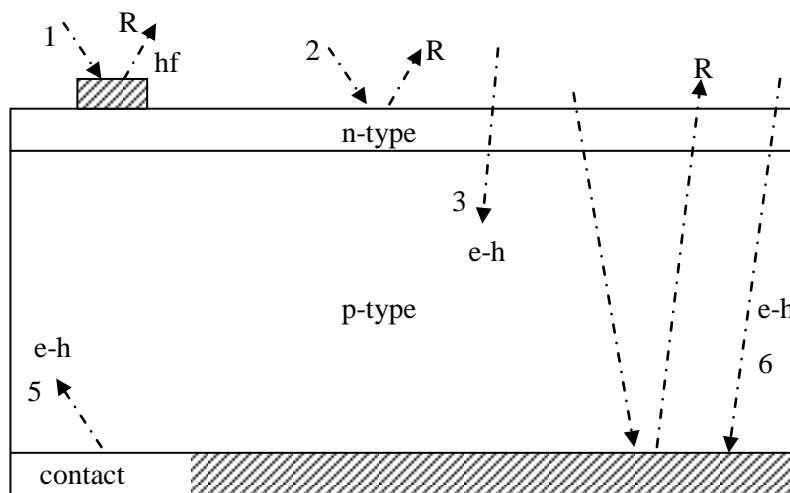


Figure 2.13. Behaviour of light shining on a solar cell

In figure, (1) Reflection and absorption at top contact, (2) Reflection at cell surface, (3) Desired absorption, (4) Reflection from rear out of cell-weakly absorbed light only, (5) Absorption after reflection. (6) Absorption in rear contact.

In p-type the negative energy levels are equal to the number of holes, in n-type the positive energy levels are equal to the number of electrons. When p and n types come together electrons move from n-type to p-type. This electron movement continues until the charge balance exists. In a p-n junction, negative charges accumulate at the p side and positive charges accumulate at n side of the junction [4].

Most of the PV modules are made up from Si element. When the sun light (solar radiation) falls on to the surface of PV, the valance electrons at the outer orbit of Si atom become negatively charged. Light is made up from tiny particles which are called “Photon”.

Photons can be considered as billard balls that made up pure energy. When photons strike an atom, the outermost electron of the atom, leaves the atom. These free electrons have electrical potential energy called voltage. This energy can be used to charge a battery or after passing through an inventor can be used as AC (Alternating current). The important point is to get these free electrons out of PV modules.

While millions of photons fall on to PV module, the electrons that gained energy (Energized electrons) flow in to the electro-static area and then they flow out of PV module. This electron flowing is DC (Direct current). Solar cells are rarely used individually. Rather, cells with similar characteristics are connected and encapsulated to form modules which, in turn, are the basic building blocks of solar arrays. Since the maximum voltage from a single silicon cell is only about 600 mV (0.6 volt), cells are connected in series to obtain the desired voltage.

Usually about 36 series cells are used for a nominal 12 V charging system. In practice, all cells have unique characteristics, and the module output is limited by that of the cell with the lowest output. The difference between the maximum output of the component cells and the output actually achieved is called the mismatch loss. Mismatched cells connected in parallel are show in the figure.

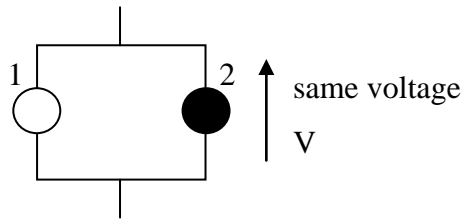


Figure 2.14. Mismatched cells connected in parallel

Mismatched cells connected in series are shown in the figure below.

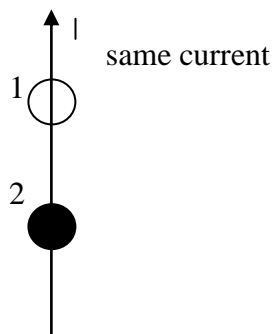


Figure 2.15. Mismatched cells connected in series

Cells or modules with the same current rating, but from different manufacturers, are likely to show different spectral responses and therefore lead to mismatching problems.

In PV cell production it is very important to choose the material that diodes are made up. The absorption layer can absorb most of solar radiation. In solar spectrum, the energy of red ray is about 1.7 eV, the energy of blue ray is about 2.7 eV. The materials that have energy interval between 0.5 eV and 3.3 eV can be used in PV cell production. Among the all elements only silicon and germanium whose energies 1.1 eV and 0.6 eV respectively satisfy the required condition. Other semi-conductor materials that are used in this interval are compound semi-conductors such as GaAs has the energy 1.43 eV.

Looking at the efficiency of solar cells, some features must be considered.

FF: Filling Factor is the factor that determines the total value of the diode.

V_{oc} : Open Circuit Voltage is the voltage measured when the resistance between the ends of the diode has infinite value

V_{SC} : Short Circuit Voltage is the voltage measured when the resistance between the ends of the diode is zero.

$$FF = \frac{V_{max} \cdot I_{max}}{V_{oc} \cdot I_{sc}} = \eta \frac{I_s \cdot A_c}{V_{oc} \cdot I_{sc}} \quad (2.2)$$

The efficiency of a solar cell is defined as the solar radiation power divided by electrical power that is produced.

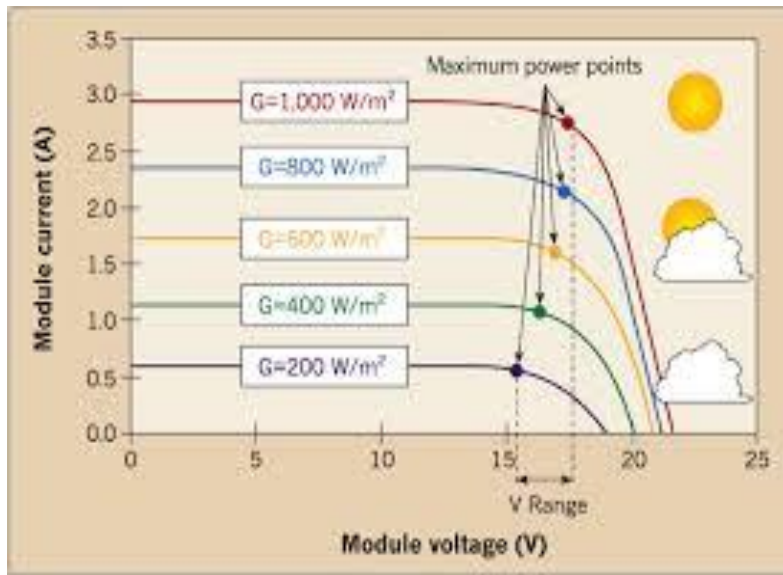


Figure 2.16. Potential-current relation of a cell at constant temperature [25]

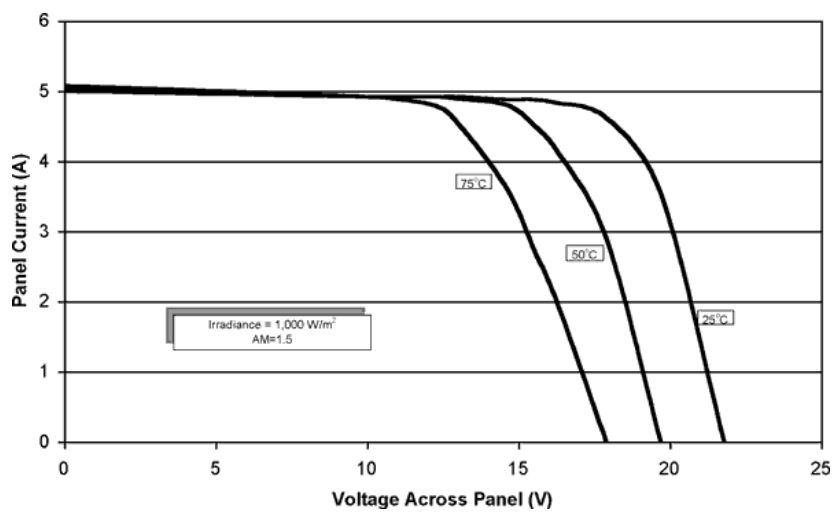


Figure 2.17. Module potential-current relation at constant radiation

$$\eta = \frac{P_m}{I_s \cdot A_c} \quad (2.3)$$

Where, A_c is the area of the solar cell (m^2)

I_{max} is maximum current (A)

I_{sc} is short circuit current (A)

I_s is power of solar radiation per unit area (W/m^2)

P_{max} is maximum output power (W)

V_{max} is maximum voltage (V)

V_{oc} is open circuit voltage (V)

η is the efficiency of solar cell

There are some factors that affect the efficiency of solar cell.

- Absorption process isn't realised completely
- The energy of photons isn't used completely
- Not using appropriate material
- Dirtiness of the surface of the cell
- Collection losses of radiation
- The temperature of PV cells

A cell can produce about 1-2 watt power. To get more and more power, cells must be connected each other to form module.

Modules are also connected each other to get panels.

First cells are connected in series to reach desired potential and then to increase the current they are connected in parallel.

The nucleus of PV panel is PV cell, cells are connected to form modules and modules are connected to form PV panel.

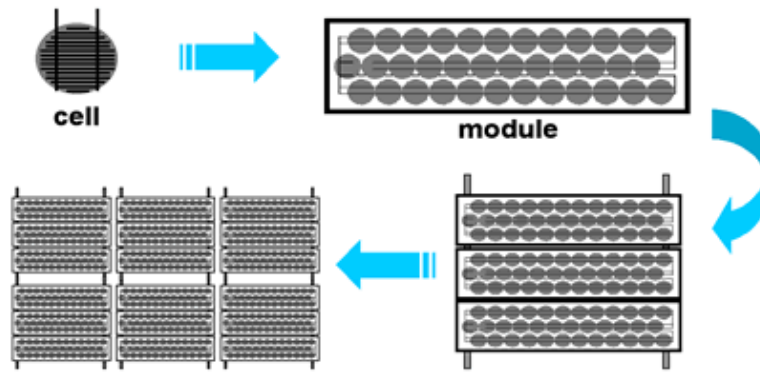


Figure 2.18. Cell-module-panel [26]

PV panels can be installed on the roofs statically. The sun light must fall on the surface of panel with angle 0° . This angle is the angle between the ray and the normal of PV surface. Sun rays must fall on the surface perpendicularly. Since the earth rotates about the axis itself and around Sun, the solar ray falls on the surface of PV only at noon.

There are some systems that can track the sun. These systems may be one-axis or two-axes. The figures below show one and two axes tracking systems.

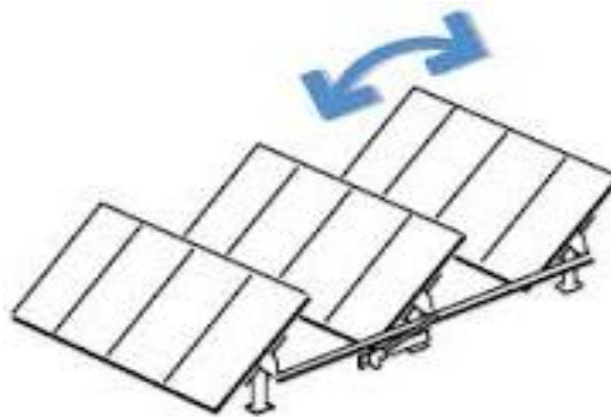


Figure 2.19. One axis sun tracking system [27]

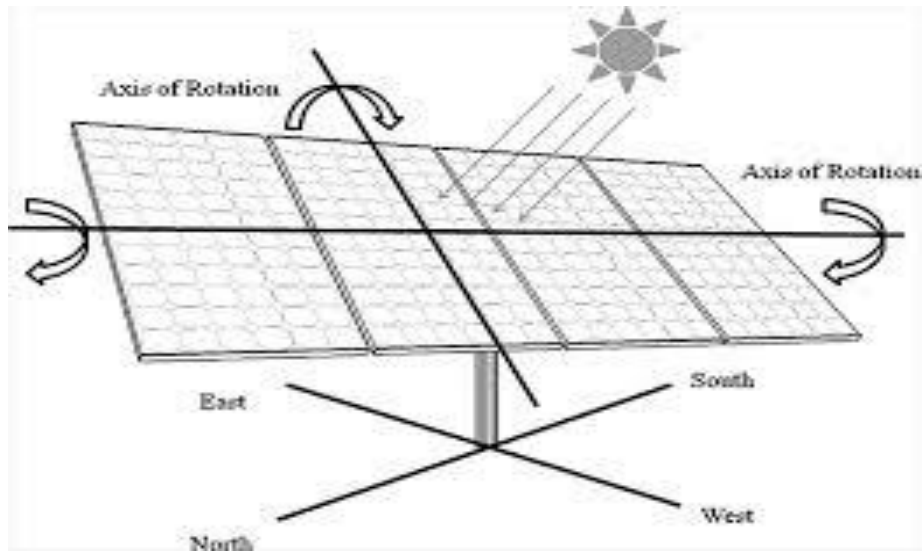


Figure 2.20. Two axes tracking system [28]

Modern tracking systems are computer controlled and any time the incident angle is 0° , Because the system can track the sun continuously. Tracking the sun is a good solution to obtain maximum radiation at any time, but these systems are expensive. Instead, PV panels is installed on the roof of a building. The efficiency may be low but it is cheaper than the tracking system.



Figure 2.21. PV panels on a roof [29]

The electricity produced by PV cells is DC. Many appliances need AC to work. Some devices are necessary to change the electricity from DC to AC.

These devices are called “Inverters”. Inverters may be classified in two types. With transformer and without transformer. An inverter with transformer changes the electricity first to modified or full sine AC current and then by using transformer changes to high voltage AC. In an inverter without transformer the input voltage must be close to output voltage. Inverters can be used to change the electricity stored in battery system to AC. The electrical energy is stored in battery system in chemical form. When needed a battery gives electricity 12, 24 or 48 V DC. The inverter converts this current to 220V, 50Hz AC.

Inverters can be classified in order to waves of electricity.

- Square wave
- Modified sine wave
- Full sine wave (exact sine wave)

First two types of waves inverters are cheaper but they cause the lose in efficiency especially in fluoresant lambs, in laser printers and sensitive music instruments. On the other hand, full sine inverters are more expensive but they don't create any problems in instruments. If the electrical energy produced from PV panels is transferred to the grid, full sine inverter must be used for quality of electricity. Required number of inverters can be calculated from the formula:

$$n = \frac{P_{\max}}{(P_{\max})_{\text{inv.}}} \quad (2.4)$$

where, n is the number of inverters

P_{\max} is maximum power (W)

$(P_{\max})_{\text{inv.}}$ is maximum power of inverters (W)

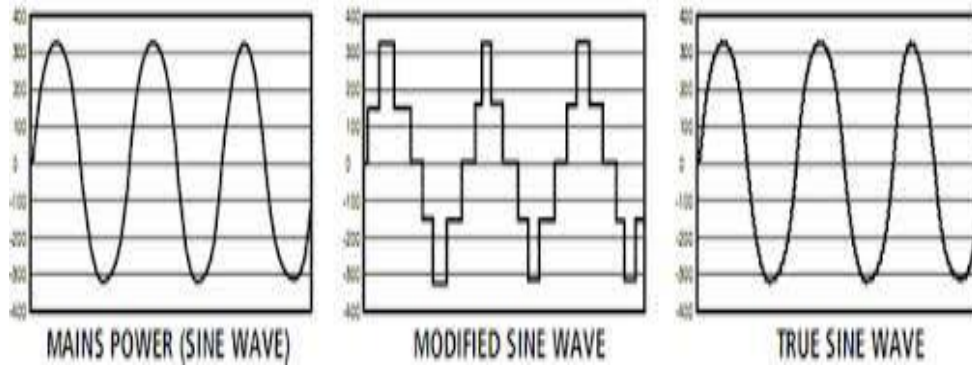


Figure 2.22. Types of waves

Solar cells generally have a parasitic series and shunt resistance associated with them. Both types of parasitic resistance act to reduce the fill factor. Figure below shows the PV equivalent circuit

where, I_L is the current that produced by light

R_S is the inner resistance against I [ohm]

R_{SH} is the shunt resistance

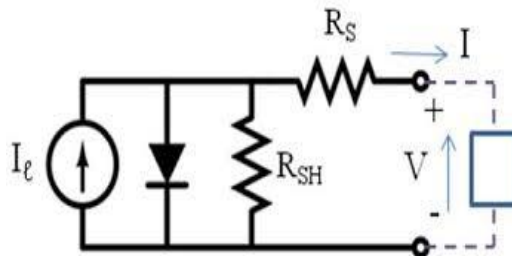


Figure 2.23. PV equivalent circuit

The energy produced by a PV system depends on not only the efficiency of PV cells, but also depends on the efficiencies of other components such as inverter, regulator and batteries.

The amount of energy that can be produced by PV system can be formulated as;

$$E_{PV} = \eta_p \cdot \eta_c \cdot A \cdot G \quad (2.5)$$

where, E_{PV} is the energy produced by PV panel (kWh)

η_p is the efficiency of panels (%)

η_c is the efficiency of other components of the system

A is the area of PV panel (m^2)

G is solar energy per unit area (kWh/m^2)

The other important component of a PV system is battery system. While the level of solar radiation is low such as nights and in winters the battery system supplies energy that was stored before. There are many types of batteries potentially available for use in PV systems, including lead-acid, nickel-cadmium, nickel-metal-hydride, rechargeable alkaline manganese, lithium-ion, lithium-polymer etc. At present, the most commonly used is lead-acid. There exist many other battery technologies, such as zinc-bromide, zinc-chloride, magnesium-lithium, sodium-sulphur and nickel-hydrogen.

Batteries can be used for:

- Power conditioning
- Short-term storage, to effectively redistribute the load over a 24 hour period
- Long-term storage, to ensure system availability throughout periods of low insolation.

Battery maintenance can be a major limitation for PV systems typical requirements for a battery system to be used for long-term storage are:

- long life
- very low self discharge
- long duty cycle (long periods of low charge)
- high charge storage efficiency
- low cost
- low maintenance

There is considerable importance placed on the efficiency of batteries, owing to the relatively high cost of both the batteries and photovoltaic array. Battery efficiency can be characterised as follows:

- 1- Coulombic, or charge efficiency

is usually measured at a constant discharge rate, referring to the amount of charge able to be retrieved from the battery, relative to the amount put in during charging. Self-discharge will affect coulombic efficiency.

2- Voltage efficiency

is also measured at a constant discharge rate and reflecting the fact that charge is retrieved from the battery at a lower voltage than was necessary to put the charge into the battery.

3- Energy efficiency

is the product of the coulombic and voltage efficiencies.

Typical average charge storage efficiencies are 80-85% for stand-alone PV systems, with winter efficiencies increasing to 90-95%, owing to:

- higher coulombic efficiencies when the battery is at a lower state of charge (85-90%)
- most of the charge going straight to the load, rather than into the batteries. (95% coulombic efficiency has been measured experimentally).

The power rating of a battery is defined as the maximum rate of charge and discharge, measured in amperes (A).

Battery capacity is the maximum amount of energy that can be extracted from a battery without the battery voltage falling below a prescribed value. The battery capacity is measured in kWh. (Kilowatt-hours) or A.h (Ampere-hours) [5].

The rate of discharge affects capacity. PV systems typically have a 300 hours discharge rate which, for lead-acid batteries, gives them approximately double the capacity specified at a 10 hour rate. Battery capacity is affected by environmental temperature, falling by about 1% per degree below 20°C. At the other extreme, however, high temperatures accelerate aging, self-discharge and electrolyte use. Depth-of-discharge is the percentage of the rated capacity withdrawn from the battery. Since battery life is a function of the average state of charge of the battery, a compromise must be made when designing a system between cycling depth and size of the battery. Batteries are connected in two ways. Serial and parallel connections. In serial connection the current

is the same and voltages are added. In parallel connection of the batteries voltages must be the same. Following figures show these connections.

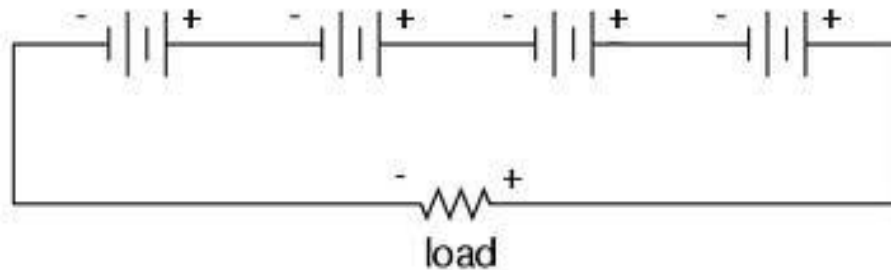


Figure 2.24. Batteries in serial connection [8]

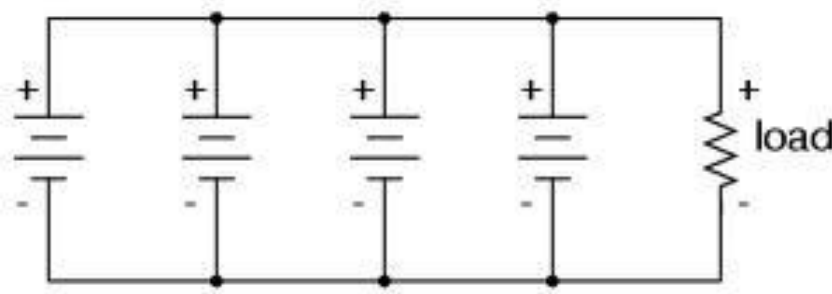


Figure 2.25. Batteries in parallel connection

2.2.3. Hybrid systems

The word hybrid means mixed, more than one together. Hybrid energy systems are used to obtain more efficient, more stable and continuous systems. For any type of energy source it is desired to be continuous. Solar radiation decreases and is zero at nights, wind doesn't blow continuously, therefore for nonstop energy it is an obligation to use sources together. There are types of hybrid sources. Solar and wind energy are most used sources in hybrid combinations.

Well known hybrid systems are the followings:

Solar-wind hybrid system

Solar-wind-hydro hybrid system

Solar-hydrogen hybrid system

Solar-wind-hydrogen hybrid system

Solar-wind-diesel generator hybrid system

Wind-diesel generator hybrid system

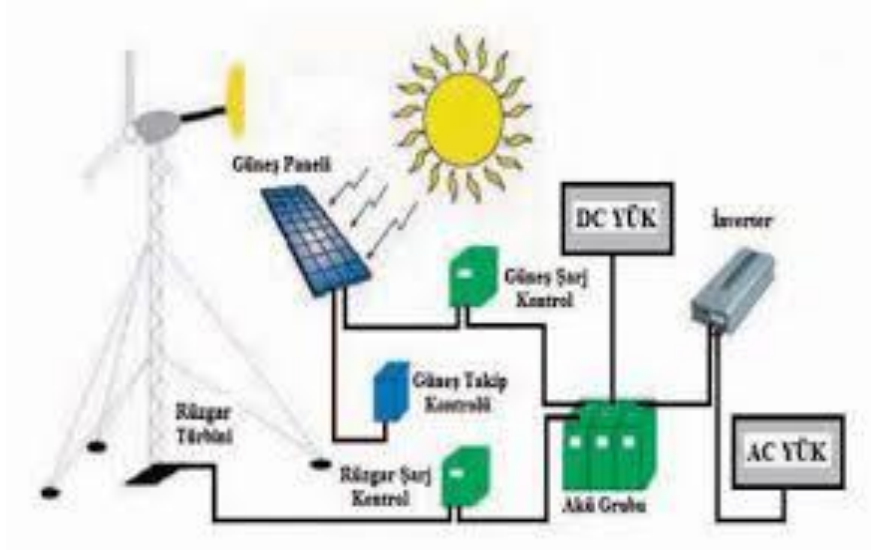


Figure 2.26. Solar-wind hybrid system [30]

In solar-wind hybrid energy system PV cells produce DC electricity, this current is converted to AC in the inverter and then goes to Load. Wind turbine produces directly AC and this current goes to Load directly. To store the energy since the batteries use DC to store then current from PV panels goes directly to batteries.

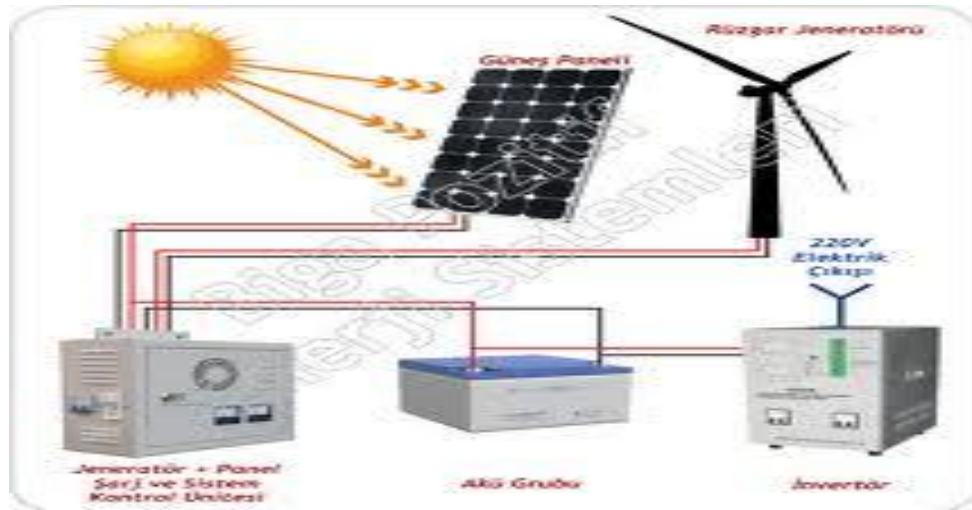


Figure 2.27. Solar-wind-diesel generator hybrid [30]

In solar-wind-diesel generator hybrid system when there is no energy in batteries at nights if the speed of wind isn't sufficient to produce electricity, generator starts to work and energy is given to load and to battery system (of course the energy produced by diesel generator is AC then it must first converted to DC for storage in the batteries.)

When PV panels start to produce or wind turbine starts to produce electricity, the diesel generator does not run.

In all hybrid systems the main energy sources are renewable ones, diesel generator must be thought the last source.

In solar-wind-hydrogen hybrid system, to electrolyze the water for obtaining hydrogen gas, is supplied by solar cells and the wind turbine. Hydrogen gas is stored to use when it is needed.

In wind-diesel generator hybrid system, when the speed of wind is insufficient to produce electricity generator produces electricity some of this electricity is used by loads, the rest of production is first converted to DC and goes to be stored in battery system. When the speed of wind is enough to rotate the rotor of the turbine, generator does not work until needed.

If the energy production system is independent from the grid (off grid) then “charge regulator” is required. Strictly speaking, this device controls the charge level of the battery system. If the charge level of the battery system is above a definite level (over capacity) the regulator cuts the energy from turbine and PV modules to protect the battery system. If the charge level of the battery system is lower than a definite level (little amount of charge position) the regulator stops to give energy to load. If the energy producing system is connected to grid (on grid), in this case there is no need to use the charge regulator, because the energy is not stored in battery system. Therefore, the main function of a charge regulator is to charge and to discharge the battery system at most suitable conditions. This device cuts the energy coming from PV modules and the wind turbine when the batteries are charged fully. Charge regulator also cuts the energy coming from batteries when the batteries have low level charge to prevent the storage group [6].

The energy balance of a hybrid system;

E_1 : Energy consumed in loads [kW]

E_{PV} : Energy produced by PV modules

E_{wt} : Energy produced by wind turbines

$E_{gen\ or\ grid}$: Energy received from generator or from grid

E_{bat} : Energy stored in battery system

$E_1 < E_{PV} + E_{wt} + E_{genorgrid} + E_{bat}$ Energy drawn from battery

$E_1 < E_{PV} + E_{wt} + E_{genorgrid} - E_{bat}$ Energy stored in battery

The power obtained from PV modules can be formulated as:

$$P_{PV} = Y_{PV} \cdot f_{PV} \left(\frac{\bar{G}_T}{\bar{G}_{T,STC}} \right) \cdot [1 + \alpha_p (T_C - T_{C,STC})] \quad (2.6)$$

where,

P_{PV} is the power obtained from PV modules (kW)

Y_{PV} is the output power under standard conditions (kW)

f_{PV} is decreasing factor

\bar{G}_T is the solar radiation on PV modules (kW/m²)

$\bar{G}_{T,STC}$ is the radiation under standard conditions (kW/m²)

α_p is temperature coefficient

T_C is the temperature of PV modules (°C)

$T_{C,STC}$ is the temperature of PV modules under standard conditions (25°C)

Temperature coefficient α_p indicates the variation of PV modules output power with respect to the temperature of the cells. The decreasing factor f_{PV} indicates the lose of the output power with respect to temperature, dirtiness etc of PV surfaces.

2.2.4. Wind energy

Wind has been used by people for over 3000 years for grinding grain and pumping water. Windmills were an important part of life for many communities beginning around 1200 B.C. Wind energy was first used for electricity generation in the late 19th century.



Figure 2.28. An old windmill [31]

Wind energy is increasing at a rate of approximately 30% annually. Wind is the stabilizing of areas of high and low atmospheric pressure, created by the uneven heating of the earth's surfaces: land, water, and air. The greater the pressure difference between these areas, the harder the wind blows. Wind also exists as the circulation of air around a high or low pressure area. Wind energy is the converting of wind power to electrical power through the use of windmills or turbines. Wind energy is a true option to fossil fuels, and nuclear energy. Wind energy decreases the need for fossil fuels to generate electricity. It is a clean, variable, and unlimited source with no waste products or pollutants for environment.

Negative attributes of wind energy according to its opponents as follows:

- Turbines are large, bulky, noisy (55 dB)
- Wind turbines are expensive (their investment costs are high compared to their operation costs)
- Turbine maintenance is needed regularly
- Limited wind speeds
- Transmission lines connect wind farms to the power grid and are limited to a maximum voltage

- Turbines are hazardous to wildlife. Especially for birds. (In fact the hunters and the earplanes are hazardous for birds.)

Wind energy can have a positive, immediate affect on the earth's atmosphere by reducing how much CO₂ is produced, only if wind farms replace electricity generated by coal, oil, and naturel gas. Wind energy is a renewable source that benefits the local communities (villages, towns, and cities) by providing people with jobs and clean electricity. Wind energy can decrease CO₂ in the atmosphere and slow global warming. Countries can use this technology to help the environment and meet electricity demands [6].



Figure 2.29. Wind energy in transportation [32]

The re-emergence of the wind as a significant source of the world's energy must rank as one of the significant developments of the late 20th century. The advent of the steam engine, followed by the appearance of other technologies for converting fossil fuels to useful energy, would seem to have forever relegated to insignificance the role of the wind in energy generation. In fact, by the mid 1950s that appeared to be what had already happened. During the start of the 21st century development trend in wind energy has continued, with European countries (and manufacturers) leading the increase via government policies focused on developing domestic sustainable energy supplies and reducing pollutant emissions. Table shows the wind potentials of OECD countries [7].

Table 2.3. Wind potential in OECD countries (in 1993)

Country	Area (x1000 m²)	Suitable area for wind farm (km²)	Technical potential for wind energy (MW)
Turkey	781	9,960	83,000
England	244	6,840	57,000
Spain	505	5,160	43,000
France	547	5,080	42,000
Norway	324	4,560	38,000
Italy	301	4,160	35,000
Greek	132	2,640	22,000
Ireland	70	2,680	22,000
Sweden	450	2,440	20,000
Iceland	103	2,080	17,000
Denmark	43	1,720	14,000
Germny	357	1,400	12,000
Portugal	92	880	7,000
Finland	337	440	4,000
Holland	41	400	3,000
Belgium	31	280	2,000
Austria	84	200	2,000
Switzerland	41	80	1,000
Luxemburg	3	0	0
TOTAL	4,486	51,000	424,000

As seen from Table 2.3, our country is very lucky with 83,000 MW technical potential.

The wind map of Turkey indicates the regions that are more suitable for installing wind power plants.

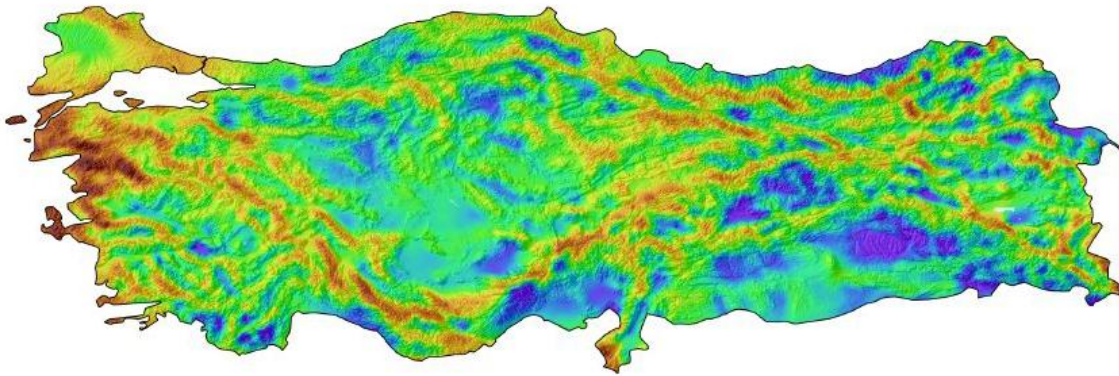


Figure 2.30. Turkey's wind map

In Figure 2.30 the orange (or red) regions show the intensity of the wind.

In general the Marmara Region has higher wind capacity, also the west shore of Turkey has many places to install wind power plants.

Turkey can theoretically meet all of its domestic energy needs with its technical potential of 83,000 MW. Following assessment of the most attractive sites, a series of six wind regions were determined in Turkey. Table 2.4 indicates that turkey's wind potential is seven times that of Germany. Germany is Europe leader in wind energy. Due to its geographic location, Turkey is under the influence of different pressure systems. In winter, the Island high pressure system expands its impact area to southern latitudes of Turkey, causing strong, gusting winds from the north and especially north eastern directions. Anatolia, especially the western side, is under the influence of western and north western winds. In summer, Turkey is influenced by the Azores high pressure center, causing constant winds from the north, especially in the western regions of Turkey [8].

Table 2.4. Regional wind speeds and intensities

Region	Wind power Intensity (W/m ²)	Average Wind Speed (m/s)
Southeast Anatolia	29.33	2.69
Mediterrain Region	21.36	2.45
East Anatolia	13.19	2.12
Central Anatolia	21.14	2.46
West Anatolia	23.47	2.65
Marmara Region	51.91	3.29
Blacksea Region	21.31	2.38

2.2.4.1. Wind turbines

Wind turbines are devices that convert the kinetic energy in air flow to electrical energy. In general there are some forces acting on wind turbines and they cause the rotor of the turbine to rotate about its axis. In order to understand how wind turbines work, two important forces must be known. First “drag force” and the other is “lift force”. Drag force acts in the direction of air flow. The maximum drag force is created when the air flows at 90° on a surface. Minimum drag force acts on a surface when the air flows at parallel direction to the surface. The force perpendicular to the direction of flowing air is called as lift force. (The force that can lift earplanes)

Wind turbines can be classified in order to its axis:

Vertical axis wind turbines are used rarely since, they are not commercially well. Their axis is in vertical position like a post and for balancing this pole is tied with steel strings to ground. Gear box and the generator are on the ground level, this is an advantage to maintainence.

Savonius type and Darrieus type are two kinds of vertical axis wind turbines. Since their efficiency is low for this reason vertical axis wind turbines are not used in power generation.

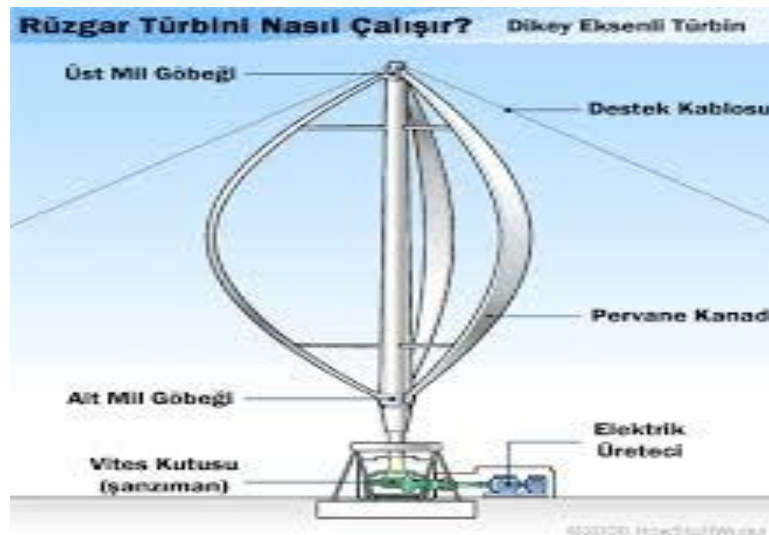


Figure 2.31. Vertical axis wind turbine

Horizontal axis wind turbines are commonly used. Almost every turbine that produces electricity is this type. These turbines work at a definite height since the speed of wind increases as the height increases. There is a strong relation between the height and the wind speed. This relation can be formulated as:

$$U' = U \cdot \left(\frac{h_2}{h_1} \right)^\alpha \quad (2.7)$$

where, h_1 is the height at which the speed is measured [m]

U is the wind speed at the height h_1

U' is the wind speed calculated for h_2

α is the coefficient of wind

α varies with temperature and the form of the land.

Using the above formula, if the speed of wind is known at a given height we can calculate the new speed for a new height.

WECS (Wind Energy Conversion Systems) are devices which convert the kinetic energy in the wind to electrical energy.

The wind speed can be measured by using anemometer which installed at a definite height.

Wind turbines can be classified according to their position against the wind: Up-wind and Down-wind turbines. Many turbines are up-wind type of wind turbines. When the direction of the wind changes, the all body of a turbine turns and provides that the wind blows from the front of the wind turbine. In other words, turbines follow the direction of wind.

The following figure shows the up-wind and down-wind turbines.

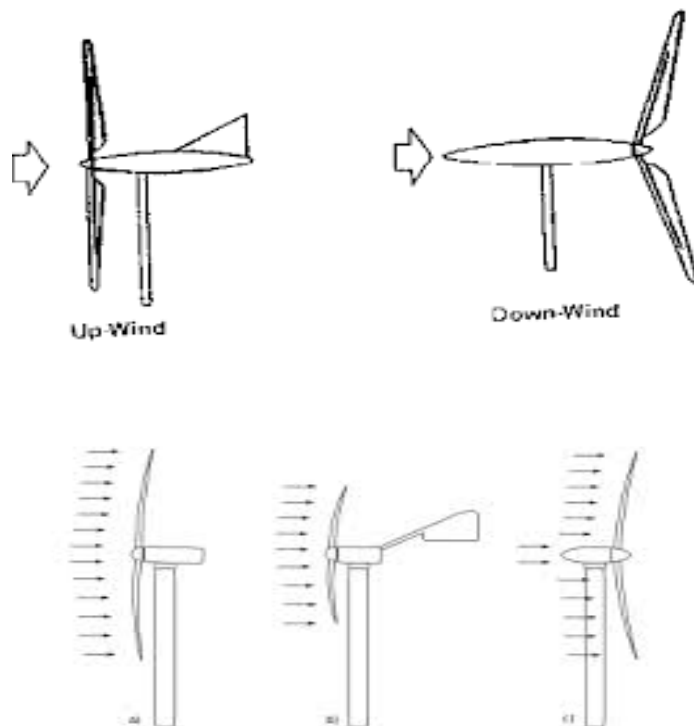


Figure 2.32. Up-wind and Down-wind Turbines

Up-wind type turbines receive air flow from front and down-wind type turbines receive air flow from back side.

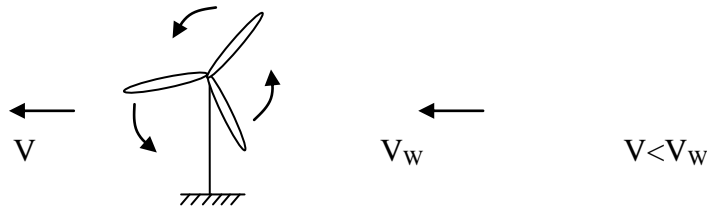
Another classification about wind turbines can be made in order to the number of wings. One wing, two wings, three wings and so. The commonly used type is with three wings.

Poul La Cour (1846-1908) from Denmark was the first person who had made the first wind turbine in 1891. In 1918, there were 120 wind turbines to produce electricity in Denmark. These turbines had supplied 3% of electricity of the country. During the second world war a Danish firm produced turbines with two and three wings. These turbines were producing DC as the turbines before. In 1951, 35 kW asynchrony wind turbines had been begun to be produced.

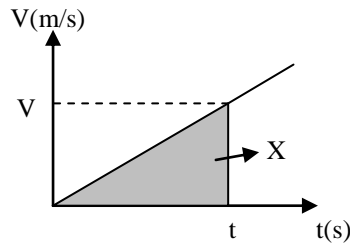
The first wind turbine that can produce AC electricity installed at Gedser shore and had produced 200 kW power in 1957. Denmark produced 2.2 million kWh energy with this turbine in the years 1956-1957 [9].

2.2.4.2. The Efficiency of Wind Turbine

The first calculations were done by German physicist Albert BETZ related with the efficiency of a wind turbine. According to Albert BETZ, rotor has infinite number of wings and the drag force doesn't exist. Of course, this is an ideal case. BETZ theory valids for only horizontal axis wind turbines.



A constant force applied on air molecules and these infinite number of molecules have kinetic energy.



The shaded area under the V-t graph gives the distance.

$$X = \frac{1}{2} V.t$$

The kinetic energy of the air mass, $E = F.X$

Where $F = ma$ substituting $E = m.a.X = m.a.\frac{1}{2} V.t$

$$a.t = V \quad E = \frac{1}{2} mV^2$$

Therefore the kinetic energy of wind (before turbine) is $E_w = \frac{1}{2} mV_w^2$ (2.8)

Since power is the derivative of energy with respect to time, then:

$$P_w = \frac{d}{dt} \left(\frac{1}{2} m V_w^2 \right) \quad (2.9)$$

Suppose the speed of air flow is constant.

$$P_w = \frac{1}{2} V_w^2 \frac{dm}{dt} \quad \frac{dm}{dt} = \dot{m} = \rho \cdot A V_w$$

Substituting this value, we get;

$$P_w = \frac{1}{2} \rho A V_w^3$$

The power of turbine:

$$P_T = \frac{1}{2} \rho A \left(\frac{V_w + V}{2} \right) (V_w^2 - V^2) \quad (2.10)$$

$$\text{Since } \frac{1}{2} \rho A = \frac{P_w}{V_w^3}$$

$$P_T = \frac{P_w}{V_w^3} \cdot \frac{1}{2} V_w \left(1 + \frac{V}{V_w} \right) \cdot V_w^2 \left[1 - \left(\frac{V}{V_w} \right)^2 \right] \quad (2.11)$$

$$P_T = \frac{1}{2} P_w \left(1 + \frac{V}{V_w} \right) \left[1 - \left(\frac{V}{V_w} \right)^2 \right]$$

Where the power factor $C_p = \frac{P_T}{P_w}$ and slow factor $n_s = \frac{V}{V_w}$

Putting these values into the equation, we get

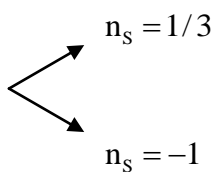
$$P_T = \frac{1}{2} P_w (1 + n_s) (1 - n_s^2) \quad \text{since } \frac{P_T}{P_w} = C_p \quad (2.12)$$

$$C_p = \frac{1}{2}(1+n_s)(1-n_s^2) = \frac{1}{2}(1-n_s^2+n_s-n_s^3) \quad (2.13)$$

The power factor $C_p = \frac{1}{2}(-n_s^3 - n_s^2 + n_s + 1)$

To get maximum power, the derivative of C_p with respect to n_s must be zero.

$$\frac{dC_p}{dn_s} = 0 \quad \frac{1}{2}(-3n_s^2 - 2n_s + 1) = 0 \quad 3n_s^2 + 2n_s - 1 = 0$$

Factorizing $(3n_s - 1)(n_s + 1) = 0$ 

n_s must not be negative, therefore $n_s = -1$ is rejected.

For this value of n_s the power will be maximum.

Putting this $n_s = 1/3$ value into $C_p = \frac{1}{2}(-n_s^3 - n_s^2 + n_s + 1)$

$$C_p = \frac{1}{2} \left(-\frac{1}{27} - \frac{1}{9} + \frac{1}{3} + 1 \right) = \frac{16}{27} = 0.592$$

Since $0.592 \approx \frac{2}{3}$

As a result, in ideal conditions the rotor uses about $\frac{2}{3}$ of wind power. In real conditions the efficiency is lower than this value.

The reasons of this low efficiency:

- There exist turbulent flow behind the rotor
- The number of wings of the turbine isn't infinity (Generally three wings)
- The aerodynamics friction

- The energy loss at the end of the wings.
- Energy losses at gear system, at generator and cables.

As seen in calculations the power of a wind turbine is proportional with the cube of speed of wind. And is proportional with the square of the turbine radius. The figure shows how the power produced is related with radius or diameter of the turbine.

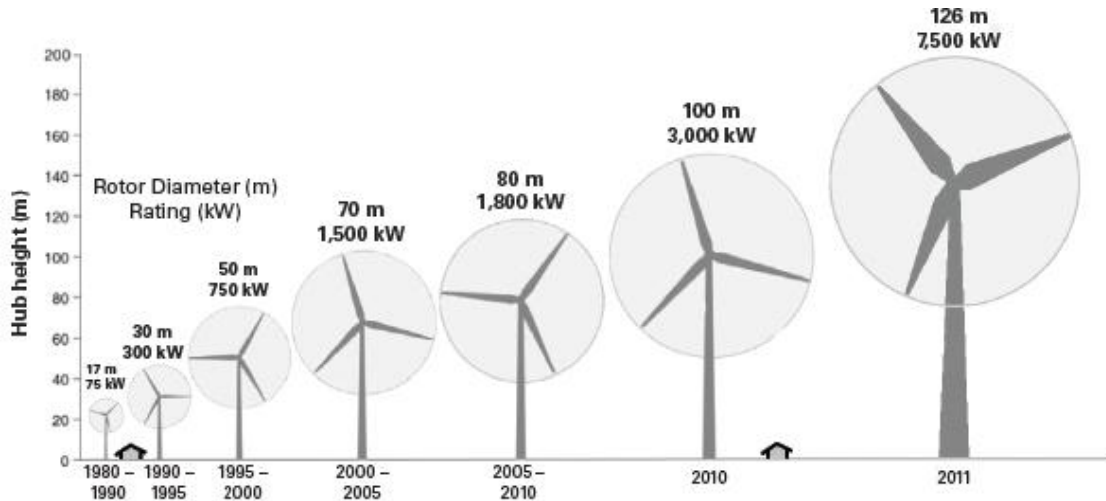


Figure 2.33. Wind turbine posts and diameters

The following graphic shows the investment in wind energy of some countries. As shown in the figure China is world leader, United States comes after China. Germany and Spain have increased their investments in wind industry [10].

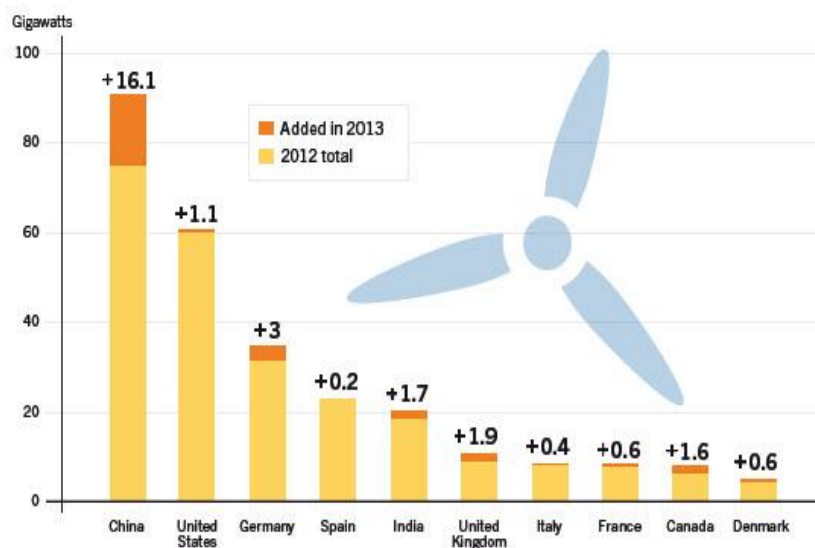


Figure 2.34. Countries in wind investment

There are many wind turbine producers in the world. The rotor diameter and related to this, the power of the turbines increases continuously. Especially Germany, and Denmark are big capacity turbine producer countries. Nowadays the new model of turbines have rotor diameter greater than 100 m.

Wind turbines can be classified according to their powers:

1. Small size wind turbines 0-10 kW
2. Medium size wind turbines 10-100 kW
3. Big size wind turbines >100 kW

The magnitude of wind turbine must be chosen according to the power that the load need. If the magnitude of the turbine is chosen greater than the load need, the turbine does not work at low speed of wind. On the other hand, if the magnitude of the turbine is chosen smaller than the load need, the turbine starts to produce electricity at high speeds of wind.

In the following table, the biggest wind turbine producing companies are shown:

Table 2.5. Some Turbine Producers

Firm	Model	Power (kW)	Rotor Diameter (m)	Pole hight (m)
GE	1.5 sl	1500	77	61.4-64.7-80-85
Vestas	V82	1650	82	70-80
Enercon	E70	2300	71	58-113
Fuhrlander	FL1500	1500	70	65-80-100
Nordex	S70	1500	70	65-85
Siemens	SWT 2.3.82	2300	82.4	80

It has been mentioned before that Turkey has technical wind capacity of 83,000 MW but according to installed power, Turkey is about at the end of the list. Figure shows the places and installed capacities of wind power plants in Turkey:

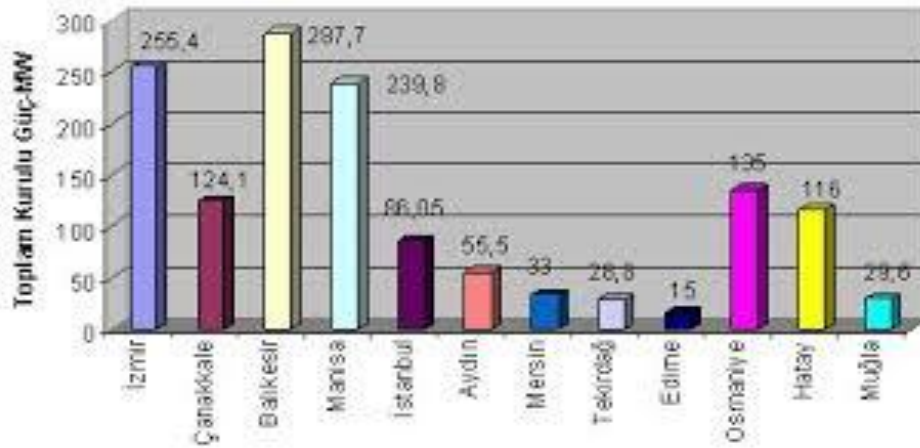


Figure 2.35. Total installed power plants in Turkey [33]

Let's look at the structure of a wind turbine: There are many parts of a turbine. First the tower which carries the turbine is made of steel.

The height of a tower (pole) indicates the radius of the rotor. The hub height of a turbine must be greater than the radius. Turbine includes many parts such as rotor, main shaft, gearbox, break system, yaw system and generator. Following figure shows clearly the inside structure of a turbine.

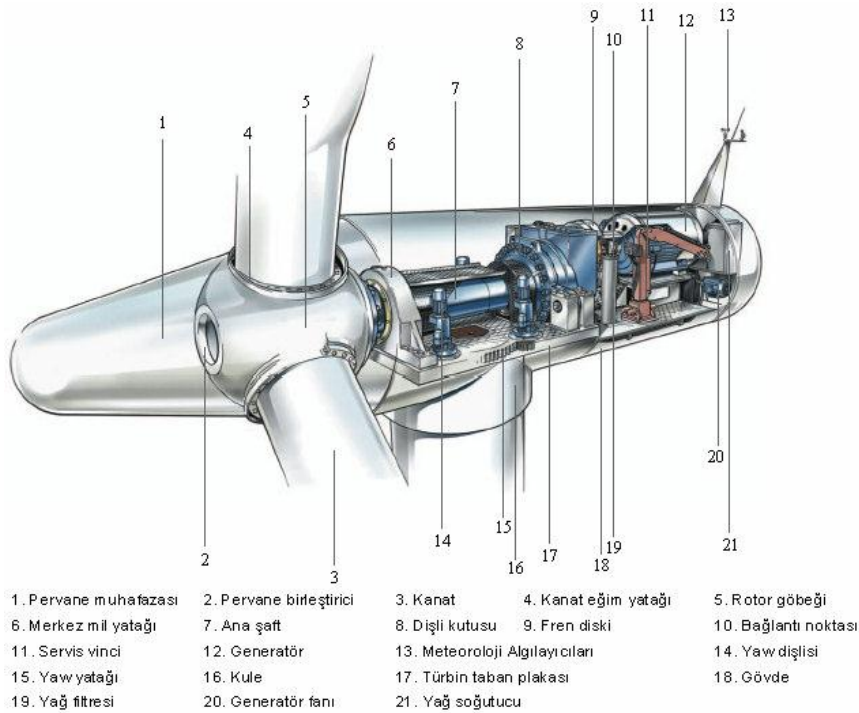


Figure 2.36. Inside structure of a turbine [24]

The rotor of a turbine rotates at 30-60 rev/min, low speed shaft is coupled with the rotor. Gearbox increases the rotating speed to high levels. The high speed shaft is between the gearbox and the generator. The types of generators such as:

SCIG: Squirrel Cage Induction Generator

WRIG: Wound Rotor Induction Generator

PMSG: Permanent Magnet Synchronous Generator

WRSG: Wound Rotor Synchronous Generator

Gearbox causes some problems since there are matching gears in gearbox. To solve gearbox problems costs much money, for this reason some new turbines have no gearbox.

These are called “Direct drive” systems.

Gearbox problems are responsible for many turbine failures. According to data collected by Germanische Lloyd (GL), 26% of turbine down time are due to the gearbox, another 13% to the shaft and couplings and 17% to the generator.

Turbines without gearboxes have important advantages compared to turbines with the conventional drive train:

- Maintenance requirements are reduced close to zero
- The downtime due to gearbox failure or breakdown does not exist
- Lifetime for bearings is increased and lubrication requirements are reduced due to low speed operation
- Therefore the availability of Direct Drive is very high
- Energy yield increases about 10%
- The overall efficiency is about 10% higher, as there are no losses in the gearbox

In wind turbines the rotor rotates with high torque but with low angular speed, but the generator rotates with low torque and high angular speed.

Every wind turbine has two critical speeds, one is the speed to start rotating (cut in speed) the other is the cut off speed. For example 4 m/s is the minimum wind speed to rotate the rotor, and 25 m/s is the maximum speed (cut off speed).

Under these conditions the turbine doesn't work at speeds smaller than 4 m/s and higher than 25 m/s. At the speeds higher than 25 m/s, the wings change their positions (pitch angle) and don't rotate. Thus the electric production is possible at the wind speeds between 4 m/s and 25 m/s.

Figure below shows the power curve of a wind turbine:

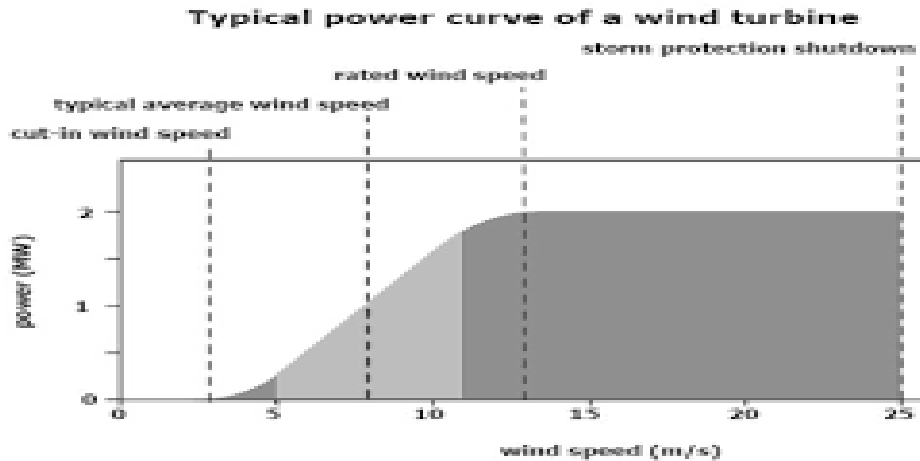


Figure 2.37. Power curve of a wind turbine

The first region in the figure is insufficient wind region. No electricity can be produced in this region. Second region is typical average wind speed region. The third region is rated wind speed region. According to the figure at the speed of 25 m/s the rotor shutdown to protect the turbine parts from storm [9].

There is direction control unit in wind turbines. Horizontal axis wind turbines are designed as the turbine axis is parallel to air flow (wind). But the wind direction varies in time, therefore the turbine must follow the wind direction.

Vertical axis wind turbines don't need any system like this, because they can able to accept the wind from any direction.

In horizontal axis wind turbines, there are some techniques to follow the wind direction, "Tail plate" is usually used in turbines which have the wing diameter up to 6 m.

Wind turbines can be installed not only on the ground, but also on a roof of a house. Figure shows such an assembly.



Figure 2.38. Wind turbines on a house [35]

Even on a ship, wind turbines can work and produce electricity as shown in the figure:



Figure 2.39. Wind turbines on a ship [36]

Some wind turbines produce electricity in the sea. Such turbines called “Off-shore wind turbines”. Especially Denmark uses turbines installed at sea. Off-shore wind turbines must not be installed on the sea transportation line. Off-shore wind turbines are not far from the land. The produced electricity is carried to the land by the cables from the bottom of the sea. The reason for preferring off-shore wind turbines is the higher wind speed at the sea [10].

Off-shore wind turbines are shown in the following figure:



Figure 2.40. Off-shore wind turbines [37]

Small wind turbines are defined as those whose swept area is less than 200 square meters at 350 W/m^2 . The tower is usually no higher than 20 m [11].

The German Wind energy Association defines small wind turbines as those having an installed capacity of up to 100 kW. These are however only small in relation to large-scale industrial wind turbines. For domestic use the upper limit for wind turbines would be about 30 kW; this is also the limit defined in the German Renewable Energy Act. Small wind turbine is getting more attention all over the world, and some markets have reached remarkable sizes. In 2020, WWEA expects that the total installed small wind capacity will reach 3,800 Mw, representing an almost tenfold increase compared with 2010. The market for new small wind turbines will have a volume of around 750 MW in the year 2020.

The position of the axis (horizontal or vertical) is by the small wind turbines obvious, Horizontal Axis Wind Turbines (HAWTs) can be further divided into these with rotors rotating in front of the tower (windward) and those rotating behind the tower (leeward) vis-a-vis the direction of the wind. Savonius turbines are used whenever cost or reliability is much more important than efficiency. Aerodynamically, they are drag-type devices, consisting of two or three scoops. Looking down on the rotor from above, a

two-scoop machine would look like an “S” shape in cross section. The Darrieus type is theoretically just as efficient as the propeller type if wind speed is constant, but in practice this efficiency is rarely realized due to the physical stresses and limitations imposed by a practical design and wind speed variation.

Some of the key findings from the “Small Wind World Report 2012” are:

- Almost 700.000 small wind turbines have been installed worldwide
- China is by far the largest market for small wind turbines
- Today, more than 330 manufacturers of small wind turbines have been identified in 40 countries on all continents, and another estimated 300 companies are manufacturing equipment for the small wind industry. Most of the manufacturers are still small and medium sized companies. More than half of these manufacturers can be found in only five countries, namely in China, and the USA, as well as in Germany, Canada and the U.K.

The total number of small wind turbines installed all over the world reached 656.000 units as of the end of 2010, after 521.000 in 2009 and 460.000 in 2008. These small wind turbines represent a total capacity of around 440 MW (end of 2010), compared with a total capacity of 240 GW of large wind turbines.

In 2020, WWEA expects that the total installed small wind capacity will reach 3.800 MW, representing an almost tenfold increase compared with 2010. The market for new small wind turbines will have a volume of around 750 MW in the year 2020.

In spite of a vibrant small wind sector in many countries, only few governments are offering specific support policies for small wind. Less than ten countries are offering sufficient feed-in tariffs for small wind, and there is almost a complete lack of support schemes in the development countries, where the demand for small wind turbines would be huge, especially in non-electrified areas. Only in China, small wind turbine contributes today on a large scale to rural electrification, which is also thanks to the relatively modest price level of small wind turbines in the country [17].

To use wind energy, one must start the measuring of wind speed. The energy produced by wind is directly proportional with the cube of wind speed. A 10% mistake made in measuring the wind speed, results about 30% change in the power produced.

To choose right wind turbines we must trust the data which is obtained the measurement of wind speed. The topographic features of the land have to be considered as main features, because these features affect the speed of wind. Speed measurements must be done places at which no turbulence exists. The measurements are done on different times (day and night, every month) and the average values are used [13].

Figure below shows turbulence around an obstacle:

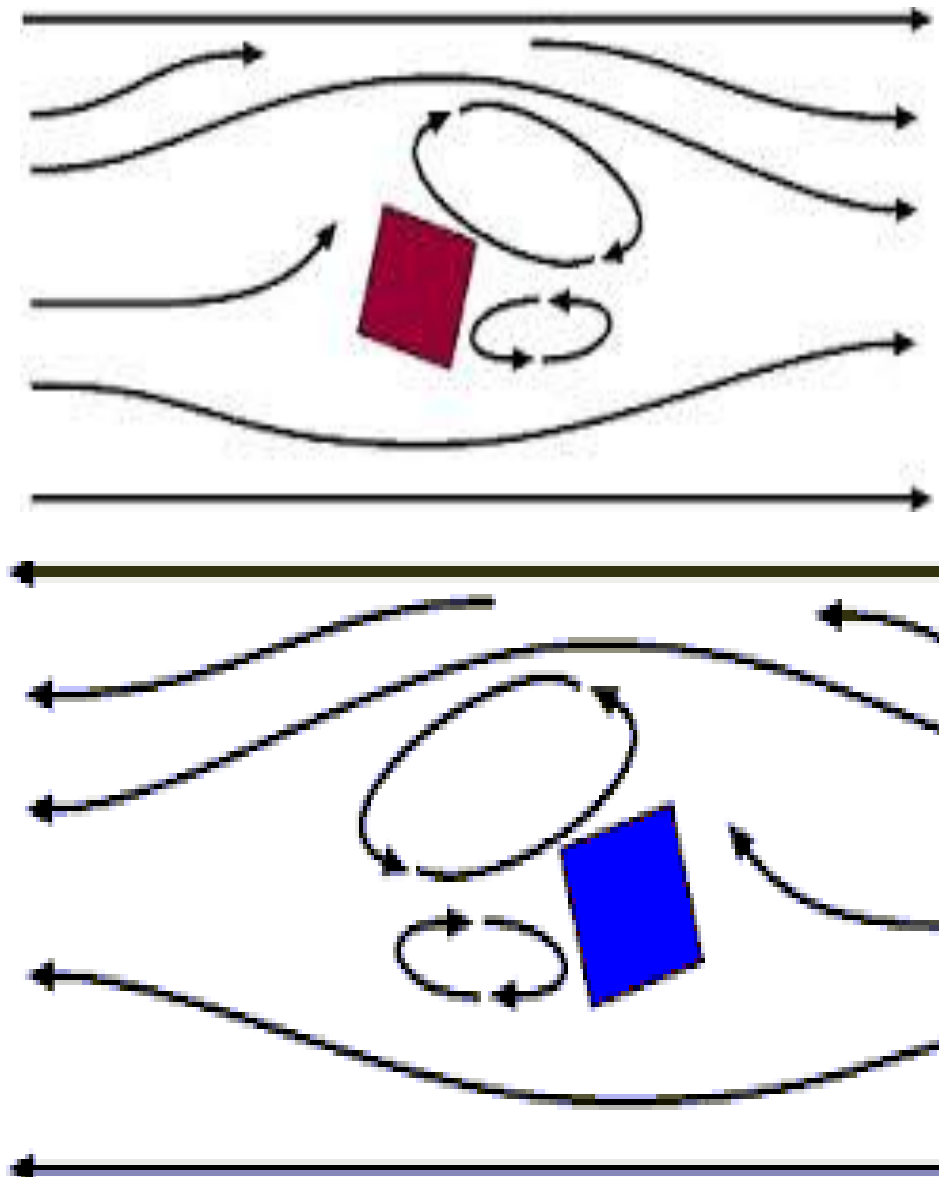


Figure 2.41. Effects of Obstacles to Wind Blowing

Because of the variations in the wind speed it can not be possible to make frequency stable. For this reason the output current of the turbine is converted to DC.

Turbines with two wings are produced for the places have high speed of wind and the turbines with three wings are produced for the places have low wind speed [18].

The potential which the wind has naturally is called as “Natural Potential” and some part of this that can be converted to energy is called as “Technical Potential”, and some of technical potential that can be used economically is called “Economic Potential”.

According to WMO (World Meteorology Organisation) standards, the wind speed is measurement at 10 m height.

$$\text{Energy Balance} = \frac{\text{Total energy required to build a power plant}}{\text{Total energy produced by the power plant}}$$

Energy balance of a wind turbine is about 1/70. This means that a wind power plant can produce 70 times energy than that of installing energy.

Weibull Distribution is a statistical probability function which is used to determine the variations in wind speed.

Weibull equation is as follows:

$$f = \frac{k}{c} \left(\frac{v}{c} \right)^{k-1} \cdot e^{-\left(\frac{v}{c} \right)^k} \quad (2.14)$$

where, f is the frequency

V is the wind speed (m/s)

c is a scale parameter (m/s)

k is a parameter with no unit

The Social Cost of Carbon:

Estimates of the social cost of carbon (dioxide emissions), or the marginal damage cost of climate change are an essential ingredient to any assessment of climate policy. The social cost of carbon (SCC) is a first estimate of the Pigou tax that should be placed on carbon dioxide emissions. Indeed, if the SCC is computed along a trajectory in which the marginal costs of emission reduction equal the SCC, the SCC is the Pigou tax. Few would argue that climate policy should be set by cost-benefit analysis alone, but most

economists would feel queasy if climate policy would drift too far from its optimum although analysts in other disciplines are less compelled by the branch of utilitarianism that is common in economics. The total cost estimates omit some impacts of climate change; they tend to ignore interactions between different impacts, and neglect higher order effects on the economy and population; they rely on extrapolation from a few detailed case studies; they often impose a changing climate on a static society; they use simplistic models of adaptation on climate change; they often ignore uncertainties; and they use controversial valuation methods and benefit transfers.

The table shows social costs of energies:

Table 2.6. Social Costs [1]

Source of energy	Social cost (c\$/kW/h)
Solar Energy	0.00 - 0.40
Wind Energy	0.01 - 0.10
Natural Gas	0.78 - 1.10
Nuclear Energy	2.91 - 2.97
Coal	2.80 - 6.80
Petroleum	3.00 - 7.90

CHAPTER 3 - RESULTS AND DISCUSSIONS

3.1. Introduction to HOMER Program

There are many computer programs such as RAPSIM, HYBRID2, VIPOR and HOMER. In this study, HOMER (Hybrid Optimization Model for Electric Renewables) is used which was developed by NREL (National Renewable Energy Laboratory).

First input data about renewable energy sources and about loads are given to the program, at the end of the running, HOMER can give us the situation hourly (for 8760 hours) and changing levels of the batteries at that hour.

HOMER displays the all possible systems that can be installed if the sufficient data is given to the program.

On the screen, the system that has lowest cost is displayed at the first raw. All outputs can be displayed on the screen numerically and graphically.

HOMER simplifies the task of evaluating designs of both off-grid and grid-connected power systems for a variety of applications. When you design a power system, you must make many decisions about the configuration of the system: What components does it make sense to include in the system design? How many and what size of each component should you use? The large number of technology options and the variation in technology costs and availability of energy resources make these decisions difficult.

HOMER's optimization and sensitivity analysis algorithms make it easier to evaluate the many possible system configurations.

To use HOMER, the model with input is provided, which describe technology options, component costs, and resource availability. HOMER uses these inputs to simulate different system configurations, or combinations of components, and generates results that you can view as a list of feasible configurations sorted by net present cost. HOMER also displays simulation results in a wide variety of tables and graphs that help you compare configurations and evaluate them on their economic and technical merits. You can export the tables and graphs for use in reports and presentations.

3.2. Simulation for a house

Consider a house that has electric consumption as follows:

Table 3.1. Electric consumption of a house

Load	Daily Working (h)	Power (W)	Daily Consumption (Wh)
Refrigerator	8	1500	12,000
Dishwasher	1	1500	1500
Washing Machine	1	1500	1500
Electric Sweeper	1	1100	1100
Oven	1	1500	1500
Computer	5	200	1000
Music Player	3	200	600
Television	4	150	600
Iron	1	1000	1000
Climatisation	1	2000	2000
Lightning	7	200	1400
Heating	6	1500	9000
TOTAL			33,200 kWh

According to the table, daily consumption is 33,200 kWh. Lets design a system consists of wind turbine, PV panel, diesel generator and battery. The load and sources are shown in the Figure 3.1 below:

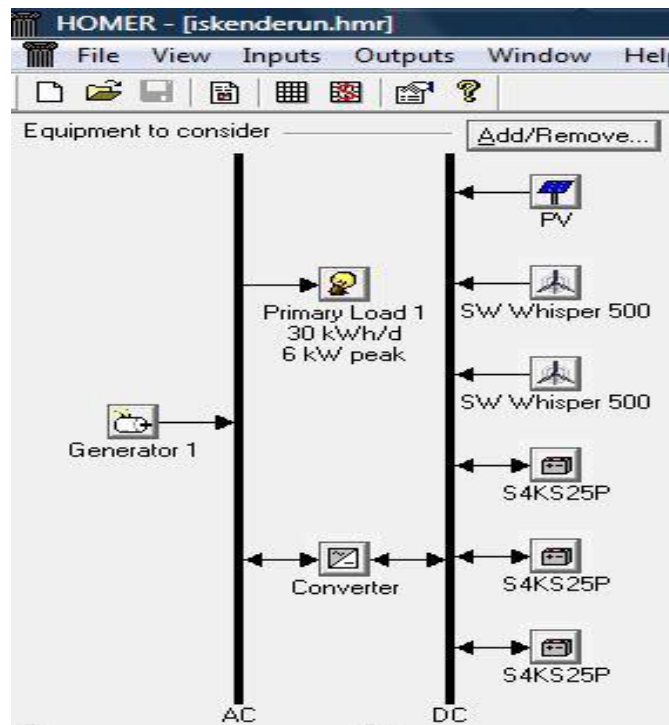


Figure 3.1. HOMER main page.

The following Figure 3.2 shows the solar source of our design. As shown from the figure the radiation level is high in June.

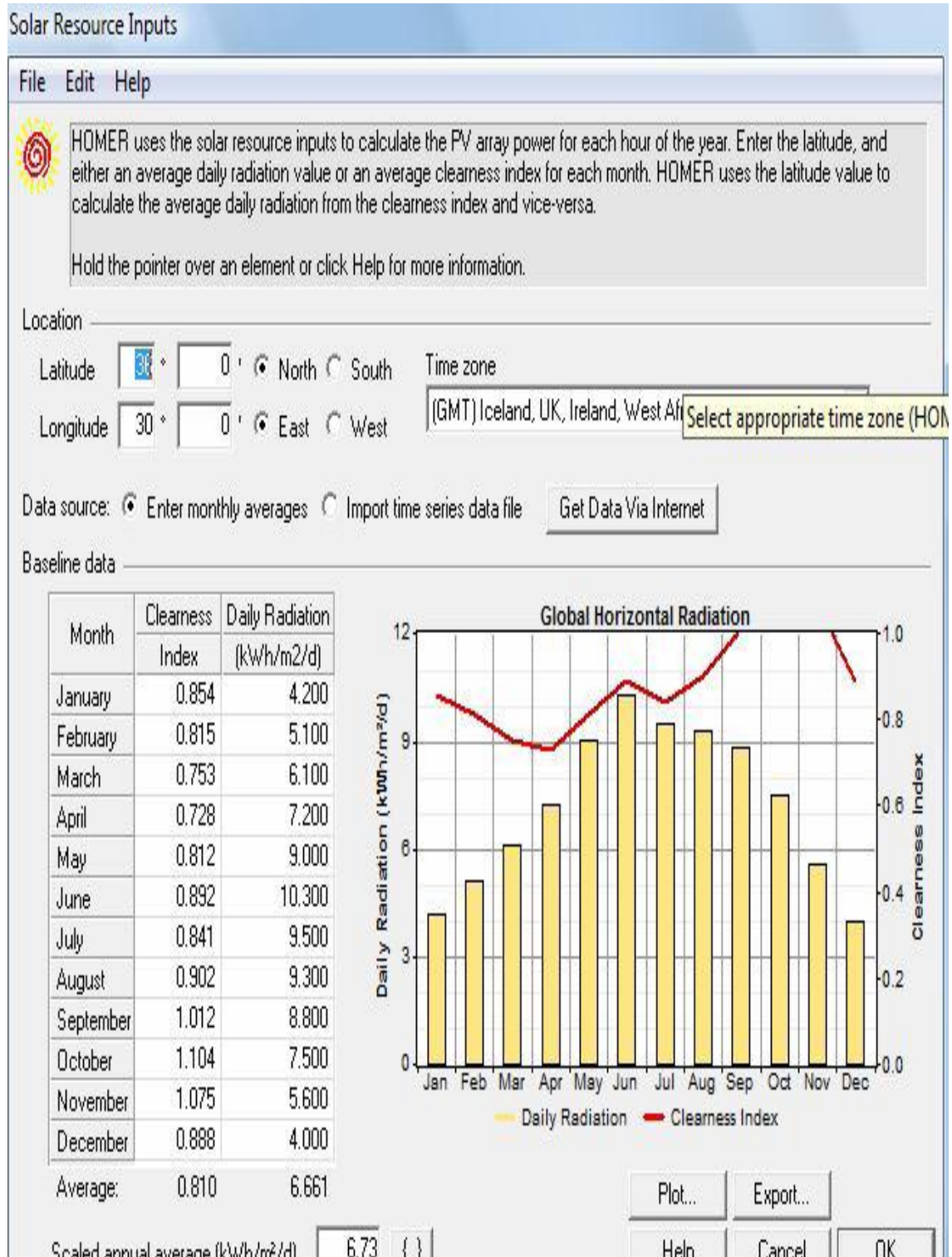


Figure 3.2. Solar source page

Figure 3.3. shows wind source page of HOMER.

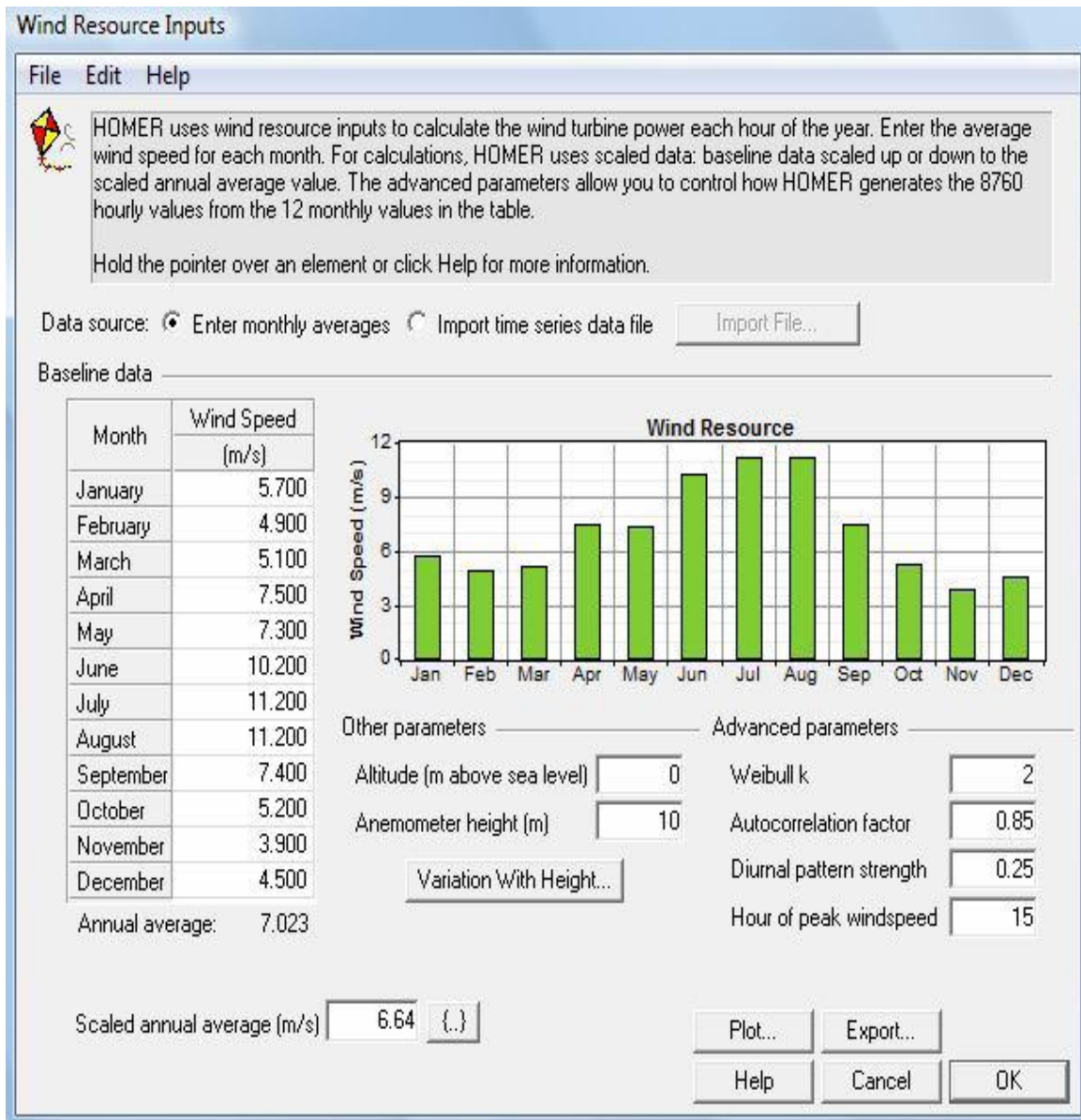


Figure 3.3. Wind source page

In figure one can see the wind parameters. The most windy months are July and August. (The height of anemometer is 10 m.)

The figure below shows economic parameters.

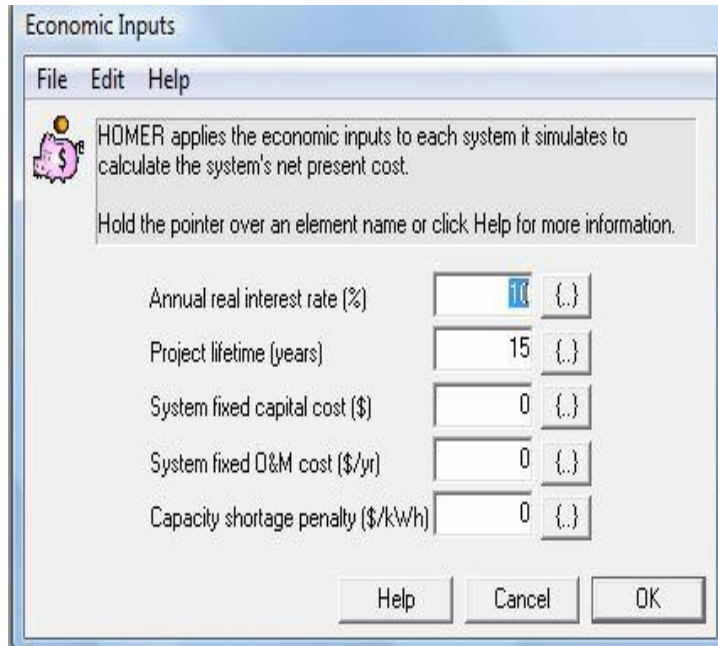


Figure 3.4. Economics parameters

Figure 3.5 shows the PV input page is shown.

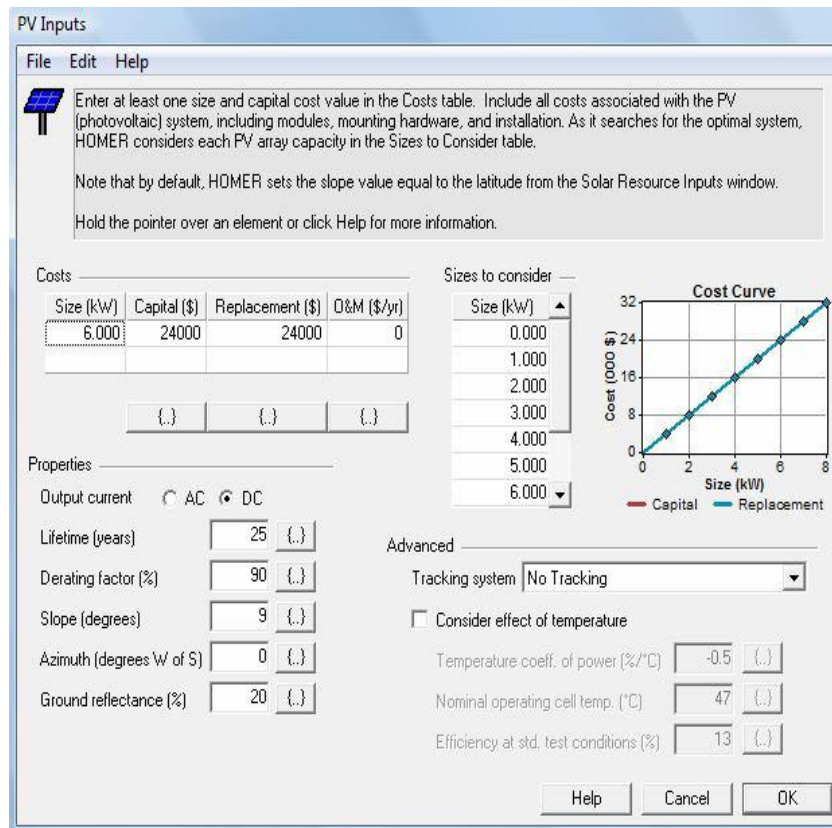


Figure 3.5. Input data of PV

Two wind turbines are used in the design. Investment cost is 6300\$ for one turbine. or two turbines this cost is not $(6300\$) \cdot 2 = 12,600 \$$, but 12,000 \$. (600 \$ discount) The lifetime of a wind turbine is 15 years. The hub height is 25 m. In figure 3.6, one can see that the maximum power is produced when the speed of wind is about 13 m/s, and it is about 3.3 kW. Besides the power curve, the cost curve is also displayed. Wind turbine type is SW Whisper 500 abbreviated as W500. The rated power is 3.3 kW DC. (Must be converted to AC)

Figure below shows the page of wind turbine.

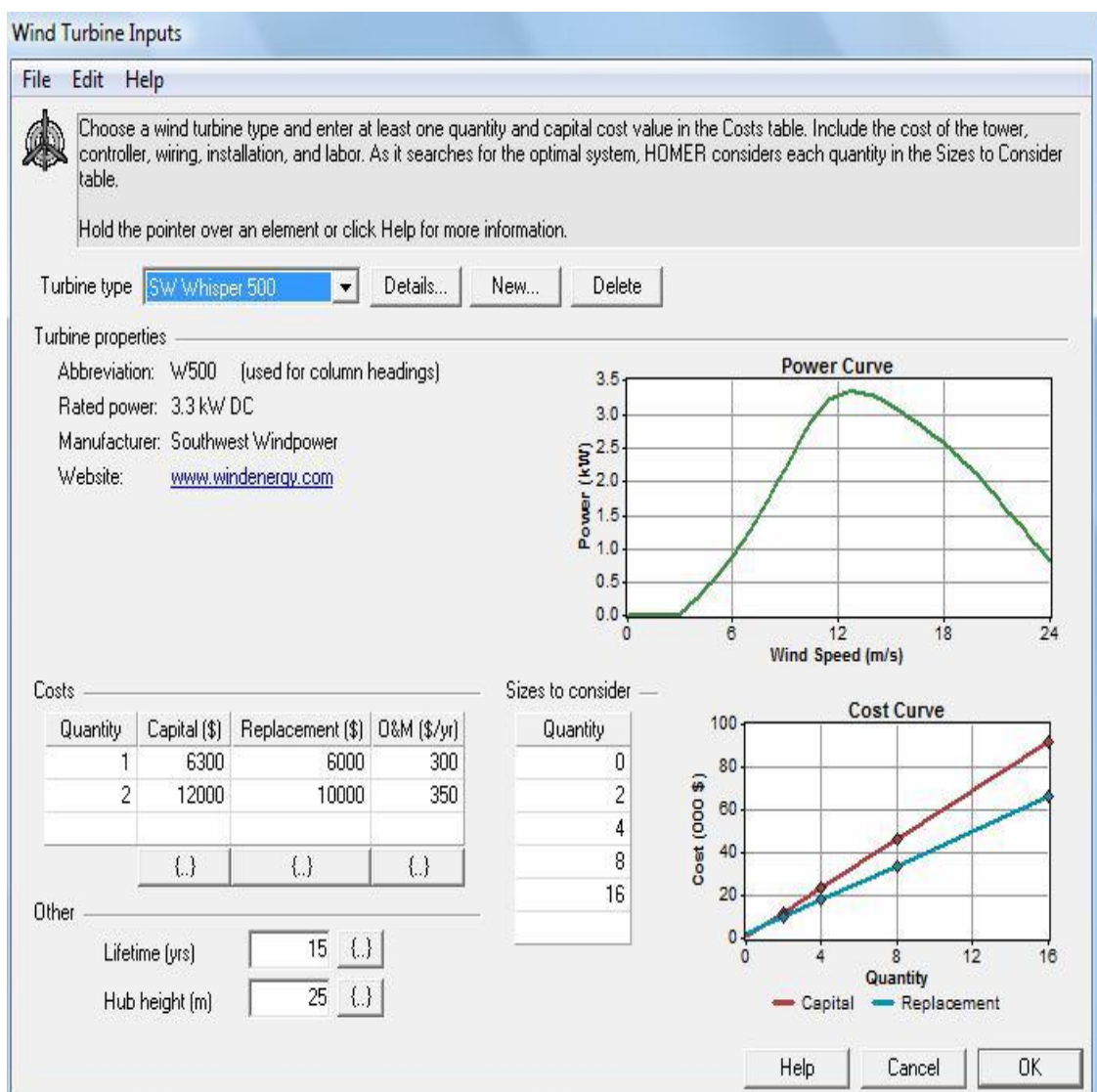


Figure 3.6. Input data of wind turbine

In the system 3 batteries are used to store DC electricity. The price of one battery is 1350 \$, but the price of 3 is not $(1350 \$) \cdot 3 = 4050 \$$ but the price is 3900 \$ (150 \$ discount). The type of battery is 4KS25P. Minimum battery life is 4 years. The nominal voltage is chosen as 4 Volts. Nominal capacity is 1,900 Ah (7.6 kWh). The cost curve of the battery is show in the figure.

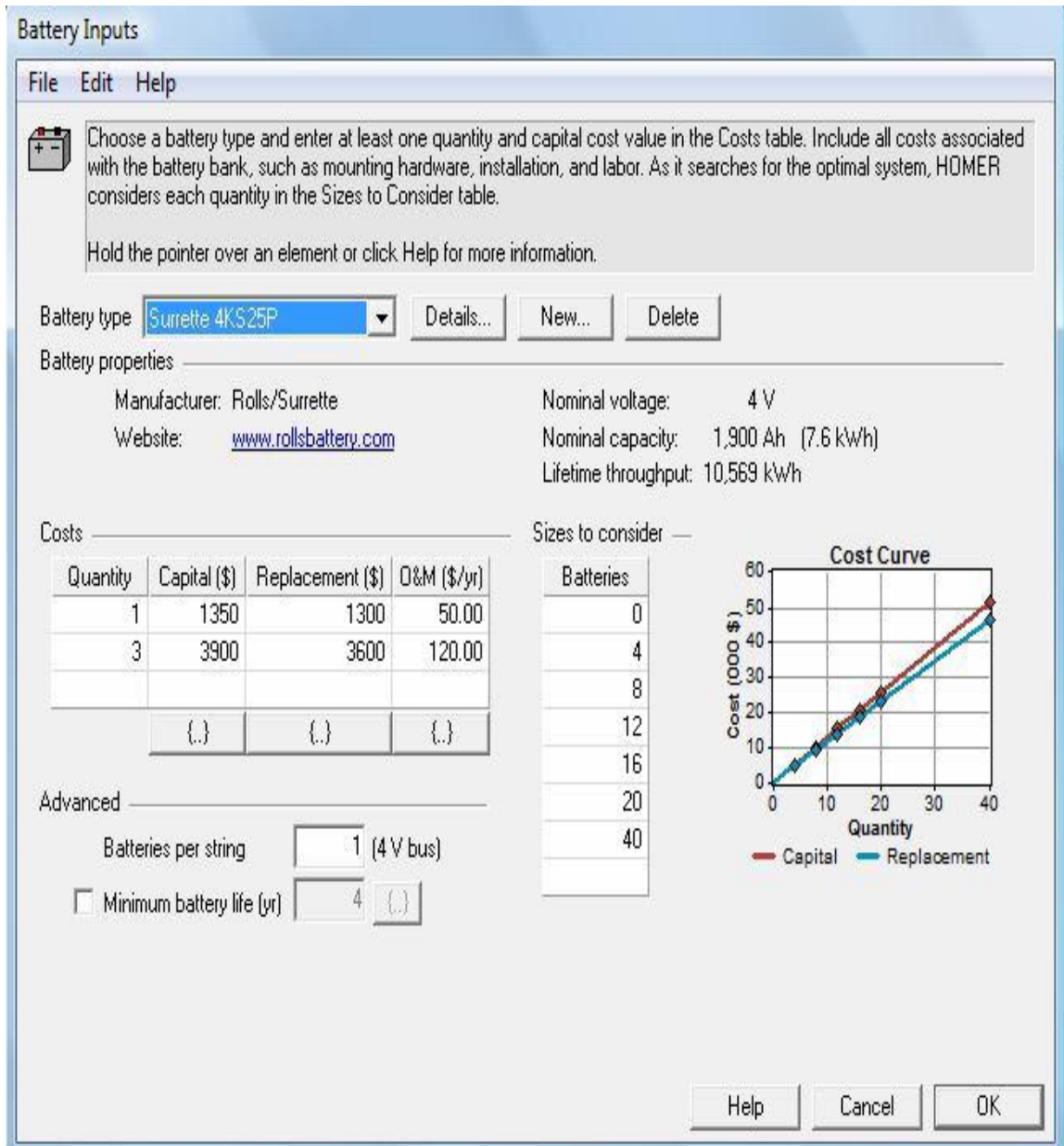



Figure 3.7. Input data of the battery

We must choose a converter to convert DC to AC. The power of the converter is 10 kW. And the cost of the converter is 12500 \$, replacement cost is also 12500 \$. The lifetime of the converter is 20 years. Its efficiency is 90 \$.

Converter Inputs

File Edit Help

 A converter is required for systems in which DC components serve an AC load or vice-versa. A converter can be an inverter (DC to AC), rectifier (AC to DC), or both.

Enter at least one size and capital cost value in the Costs table. Include all costs associated with the converter, such as hardware and labor. As it searches for the optimal system, HOMER considers each converter capacity in the Sizes to Consider table. Note that all references to converter size or capacity refer to inverter capacity.

Hold the pointer over an element or click Help for more information.

Costs

Size (kW)	Capital (\$)	Replacement (\$)	O&M (\$/yr)
10.000	12500	12500	100

{.} {.} {.}

Sizes to consider

Size (kW)
0.000
2.000
4.000
6.000
8.000
16.000

Cost Curve

Cost (0000 \$)

Size (kW)

— Capital — Replacement

Inverter inputs

Lifetime (years) {.}

Efficiency (%) {.}

Inverter can operate simultaneously with an AC generator

Rectifier inputs

Capacity relative to inverter (%) {.}

Efficiency (%) {.}

Help Cancel OK

Figure 3.8. Input data of converter

Let's input the features of diesel generator. The power of the generator is 8 kW and its capital cost is 6500 \$. The replacement cost of the generator is 5500 \$ and it consumes fuel 0.2 \$/h. Its lifetime (operating hours) is 15000 h.

Generator Inputs

File Edit Help

Choose a fuel, and enter at least one size, capital cost and operation and maintenance (O&M) value in the Costs table. Note that the capital cost includes installation costs, and that the O&M cost is expressed in dollars per operating hour. Enter a nonzero heat recovery ratio if heat will be recovered from this generator to serve thermal load. As it searches for the optimal system, HOMER will consider each generator size in the Sizes to Consider table.

Hold the pointer over an element or click Help for more information.

Cost Fuel Schedule Emissions

Costs

Size (kW)	Capital (\$)	Replacement (\$)	O&M (\$/hr)
8.000	6500	5500	0.200

Sizes to consider

Size (kW)
0.000
8.000

Properties

Description: Generator 1 Type: AC DC

Abbreviation: Label

Lifetime (operating hours): 15000

Minimum load ratio (%): 30

Cost Curve

Cost (000 \$)

Size (kW)

Capital Replacement

Help Cancel OK

Figure 3.9. Input data of generator

The last step in designing the system is to input the load characteristics. The type of load is AC. In figure 3.10 the daily profile of the load is shown. The maximum power is needed between 17 pm and 22 pm.

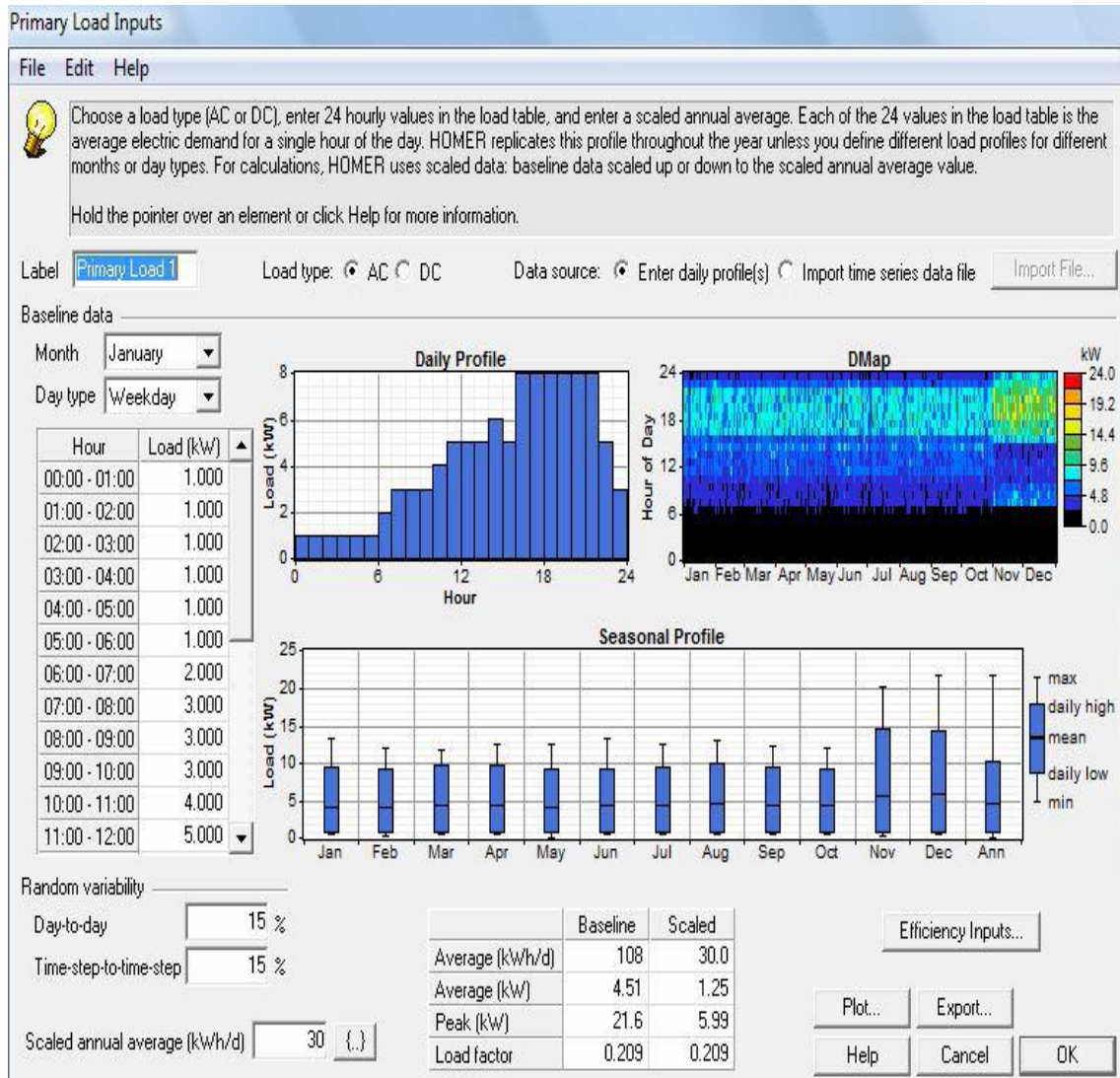


Figure 3.10. Load characteristics

Figure 3.11 shows the optimization results. The most convenient raw is the first raw.

Calculate		Simulations: 19440 of 19440 Progress: <input type="text"/>		Sensitivities: 1 of 1		Status: Completed in 7:01.												
Sensitivity Results															Optimization Results			
Double click on a system below for simulation results.																		
															Categorized		Overall	Export...
		PV (kW)	W500	W500	Label (kW)	S4KS25P	S4KS25P	S4KS25P	Conv. (kW)	Initial Capital	Operating Cost (\$/yr)	Total NPC	COE (\$/kWh)	Ren. Frac.	Capacity Shortage	Diesel (L)	Label (hrs)	
			2					2	4	\$ 19,625	480	\$ 23,279	0.336	1.00	0.24			
		1	2						4	\$ 23,675	392	\$ 26,655	0.378	1.00	0.21			
		6							8	\$ 39,275	-186	\$ 37,864	0.579	1.00	0.24			
		2	4						4	\$ 36,400	350	\$ 39,062	0.539	1.00	0.24			
			2		8				4	\$ 28,675	1,636	\$ 41,115	0.494	0.90	0.00	1,268	942	
		1	2		8				4	\$ 32,675	1,231	\$ 42,042	0.505	0.93	0.00	943	692	
		2			8				4	\$ 22,175	3,986	\$ 52,490	0.630	0.37	0.00	3,659	2,526	
			8						4	\$ 51,200	651	\$ 56,149	0.758	1.00	0.19			
					8				8	\$ 19,275	5,957	\$ 64,587	0.775	0.00	0.00	5,481	3,212	
		2		3	8				4	\$ 37,200	4,359	\$ 70,352	0.845	0.86	0.00	3,532	2,825	
			4		8				4	\$ 34,900	4,707	\$ 70,699	0.849	0.87	0.00	3,690	2,956	
		4			8				2	\$ 25,000	8,717	\$ 91,301	1.096	0.39	0.00	7,407	5,861	
					8					\$ 6,500	13,487	\$ 109,084	1.310	0.00	0.00	11,004	8,760	

Figure 3.11. The results of optimization

3.3. Calculation for the University Campus

Natural gas consumption (6,661,039 kWh/year)

- October : 864,000 kWh
- November : 970,000 kWh
- December : 1,183,689 kWh
- January : 1,420,850 kWh
- February : 1,238,000 kWh
- March : 984,500 kWh

Electric consumption (1,944,850 kWh/year)

- January : 193,500 kWh
- February : 190,800 kWh
- March : 191,700 kWh
- April : 187,900 kWh
- May : 161,500 kWh

June : 146,400 kWh
 July : 117,500 kWh
 August : 81,900 kWh
 September : 131,500 kWh
 October : 174,700 kWh
 November : 182,750 kWh
 December : 184,700 kWh

Total consumption = 8,605,889 kWh/year

Electric production by using wind energy

Turbine power : 1000 kW
 Hub height : 50 m
 Diameter : 50 m
 Number of Turbines : 2

Turbines must be installed at Radartepe which has wind about 11 hours a day.

Energy produced \cong 8,000,000 kWh/year

Electric production by using solar energy

Table 3.2. Montly Solar Radiation at Kadıköy [24]

Month	Solar Radiation (kWh/m ² -day)	Radiation Duration (hour)
January	1.40	3.36
February	2.29	4.28
March	3.19	5.30
April	4.39	6.70
May	5.58	8.61
June	5.99	10.11
July	5.71	10.70
August	5.21	9.74
September	4.10	8.00
October	2.79	5.24
November	1.70	3.90
December	1.20	3.05

Source: www.eie.gov.tr

The efficiency of PV panels (%):

Monocrystalline silicon: 16.8

Polycrystalline silicon: 14.5

Average efficiency can be accepted 15.5 %.

Panel dimensions = (99 cm) . (129 cm) \cong 1,3 m²

3000 panels = (3000) (1,3 m²) = 3900 m² [38]

Table 3.3. Montly Energy Consumption (kWh)

Month	Natural Gas (kWh)	Electric (kWh)	Total (kWh)
January	1,420,850	193,500	1,614,350
February	1,238,000	190,800	1,428,800
March	984,500	191,700	1,176,200
April	–	187,900	187,900
May	–	161,500	161,500
June	–	146,400	146,400
July	–	117,500	117,500
August	–	81,900	81,900
September	–	131,500	131,500
October	864,000	174,700	1,038,700
November	970,000	182,750	1,152,750
December	1,183,689	184,700	1,368,389
Total	6,661,039	1,944,850	8,605,889

As seen from Table 3.3 the maximum consumption is in January.

Energy produced by PV panels:

January

$$\left(1,40 \frac{\text{kWh}}{\text{m}^2 - \text{day}} \right) \cdot (30 \text{ day}) \cdot (0,155) \cdot (3900 \text{ m}^2) = 25,389 \text{ kWh}$$

February

$$\left(2,29 \frac{\text{kWh}}{\text{m}^2 - \text{day}} \right) \cdot (30 \text{ day}) \cdot (0,155) \cdot (3900 \text{ m}^2) = 41,529 \text{ kWh}$$

March

$$\left(3,19 \frac{\text{kWh}}{\text{m}^2 - \text{day}} \right) \cdot (30 \text{ day}) \cdot (0,155) \cdot (3900 \text{ m}^2) = 57,851 \text{ kWh}$$

April

$$\left(4,39 \frac{\text{kWh}}{\text{m}^2 - \text{day}}\right) \cdot (30 \text{ day}) \cdot (0,155) \cdot (3900 \text{ m}^2) = 79,612 \text{ kWh}$$

May

$$\left(5,58 \frac{\text{kWh}}{\text{m}^2 - \text{day}}\right) \cdot (30 \text{ day}) \cdot (0,155) \cdot (3900 \text{ m}^2) = 101,193 \text{ kWh}$$

June

$$\left(5,99 \frac{\text{kWh}}{\text{m}^2 - \text{day}}\right) \cdot (30 \text{ day}) \cdot (0,155) \cdot (3900 \text{ m}^2) = 108,629 \text{ kWh}$$

July

$$\left(5,71 \frac{\text{kWh}}{\text{m}^2 - \text{day}}\right) \cdot (30 \text{ day}) \cdot (0,155) \cdot (3900 \text{ m}^2) = 103,551 \text{ kWh}$$

August

$$\left(5,21 \frac{\text{kWh}}{\text{m}^2 - \text{day}}\right) \cdot (30 \text{ day}) \cdot (0,155) \cdot (3900 \text{ m}^2) = 94,483 \text{ kWh}$$

September

$$\left(4,10 \frac{\text{kWh}}{\text{m}^2 - \text{day}}\right) \cdot (30 \text{ day}) \cdot (0,155) \cdot (3900 \text{ m}^2) = 74,353 \text{ kWh}$$

October

$$\left(2,79 \frac{\text{kWh}}{\text{m}^2 - \text{day}}\right) \cdot (30 \text{ day}) \cdot (0,155) \cdot (3900 \text{ m}^2) = 50,596 \text{ kWh}$$

November

$$\left(1,70 \frac{\text{kWh}}{\text{m}^2 - \text{day}}\right) \cdot (30 \text{ day}) \cdot (0,155) \cdot (3900 \text{ m}^2) = 30,829 \text{ kWh}$$

December

$$\left(1,20 \frac{\text{kWh}}{\text{m}^2 - \text{day}}\right) \cdot (30 \text{ day}) \cdot (0,155) \cdot (3900 \text{ m}^2) = 21,762 \text{ kWh}$$

Total production from PV = 789,77 kWh/year

Energy from wind = 8,000,000 kW/year

Energy from PV = 789,770 kWh/year

Total production = 8,789,770 kWh/year

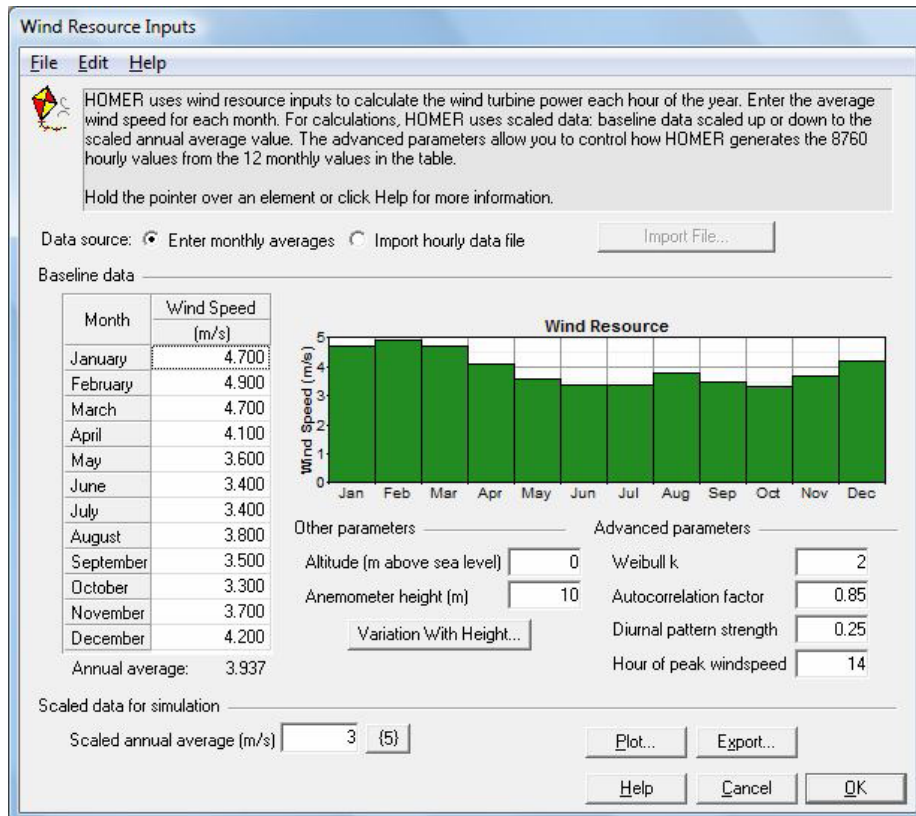


Figure 3.12. Wind speeds (Monthly)

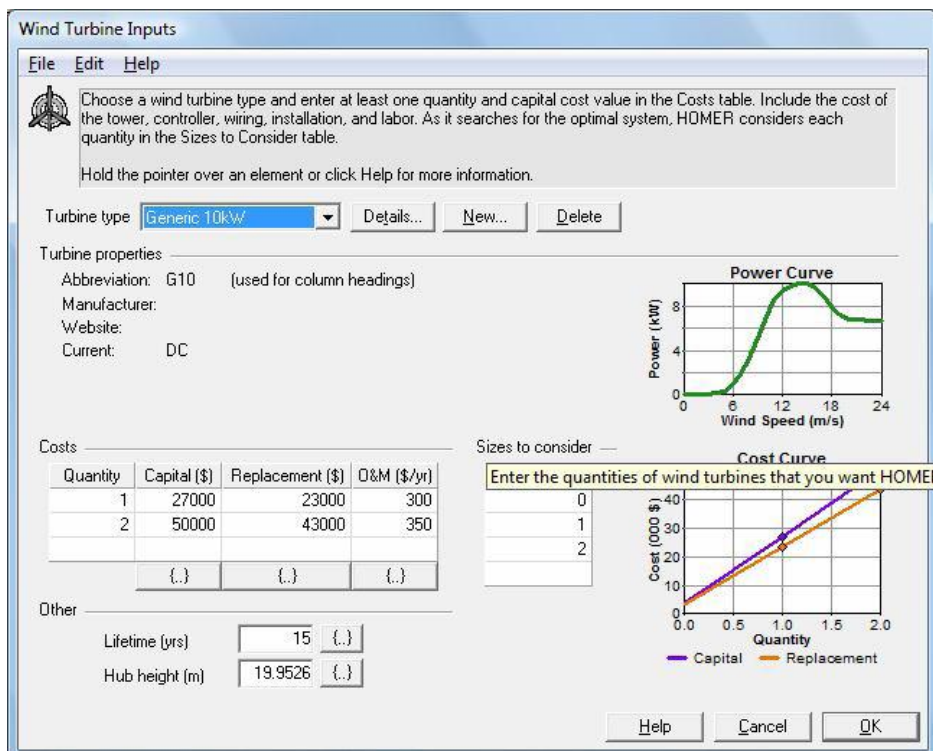


Figure 3.13. Wind turbine curves

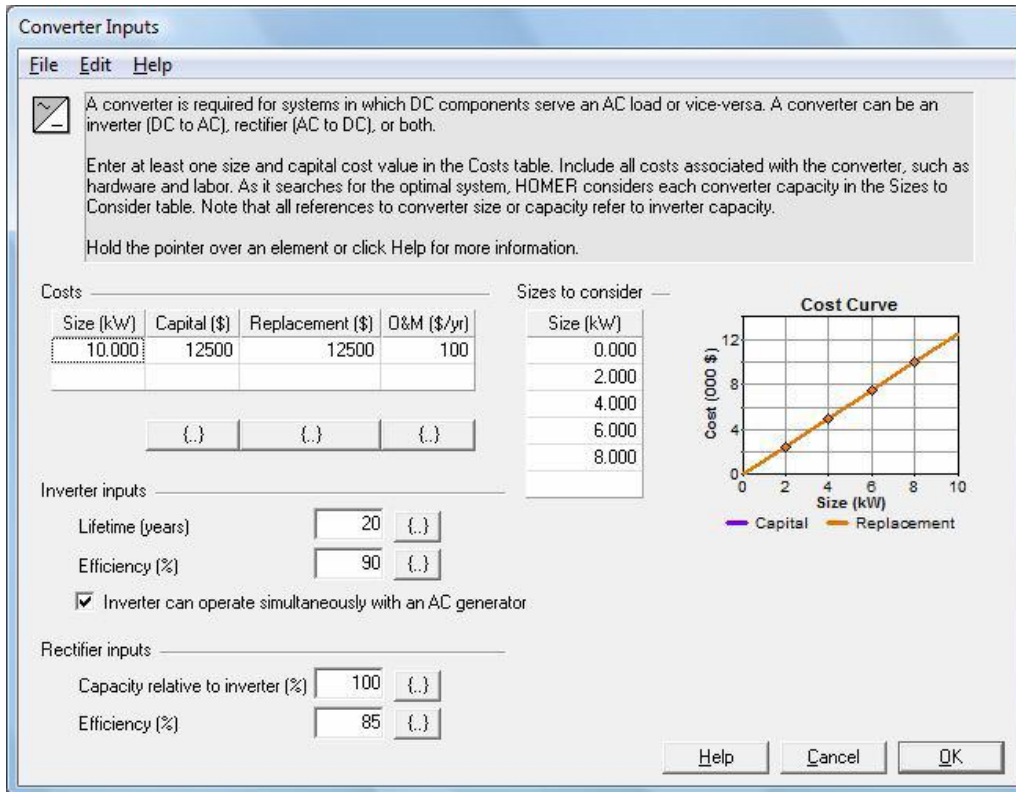


Figure 3.14. Converter curve

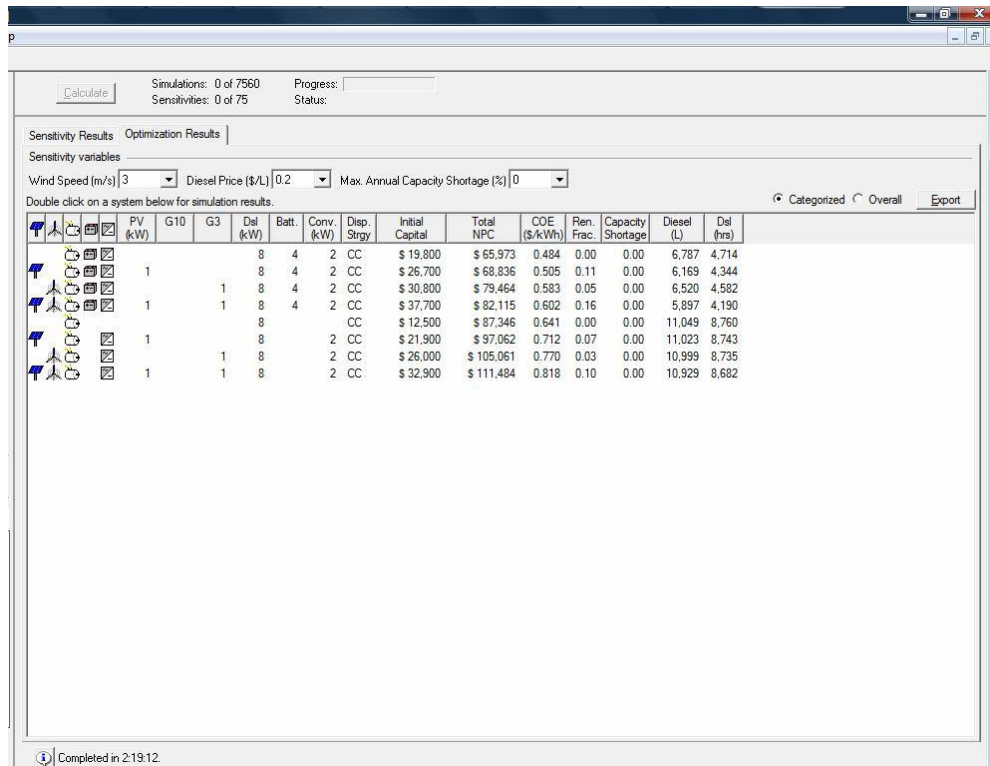


Figure 3.15. Simulation

CHAPTER 4 - CONCLUSIONS

Climate change is one of the biggest problems that affect all of our life and future generation globally. Nowadays, we use natural resources 25% faster than refresh rate of the world itself. The level of Greenhouse gases (GHG) in atmosphere increases 1000 times much than acceptable level of the nature.

Potential effect of the GHG; drought, decrease of water supply, extinction of 30% species in the world, difficulties to find foods and farming, migration, epidemic disease, premature aging, increasing hereditary disease and these effects are noticeable all of the world.

Total energy need of the Marmara University Göztepe campus is 8,605,889 kWh/year

Total possible production of the renewable energy is 8,789,770 kWh/year

Excess energy is 183,881 kWh/year.

This excess energy can be sold to electric distributor firm from the price of 7.3 \$ cent/kWh.

The amount of money that the University can get every year is $(183,881) \cdot \frac{7.3}{100} = 13,423\$$.

And now lets calculate the amounts of excess or need of energies every month.

January

From wind	≅	666,667 kWh	922,294 kWh must be taken from the grid.
From PV	=	25,389 kWh	
Total Production	=	692,056 kWh	
Consumption	=	1,614,350 kWh	

February

From wind	≅	666,667 kWh	720,604 kWh must be taken from the grid.
From PV	=	41,529 kWh	
Total Production	=	708,196 kWh	
Consumption	=	1,428,800 kWh	

March

From wind	≅	666,667 kWh	451,682 kWh must be taken from the grid.
From PV	=	57,851 kWh	
Total Production	=	724,518 kWh	
Consumption	=	1,176,200 kWh	

April

From wind	≅	666,667 kWh	558,379 kWh can be given to the grid.
From PV	=	79,612 kWh	
Total Production	=	746,279 kWh	
Consumption	=	187,900 kWh	

May

From wind	≅	666,667 kWh	606,360 kWh can be given to the grid.
From PV	=	101,193 kWh	
Total Production	=	767,860 kWh	
Consumption	=	161,500 kWh	

June

From wind	≅	666,667 kWh	628,896 kWh can be given to the grid.
From PV	=	108,629 kWh	
Total Production	=	775,296 kWh	
Consumption	=	146,400 kWh	

July

From wind	≅	666,667 kWh	652,718 kWh can be given to the grid.
From PV	=	103,551 kWh	
Total Production	=	770,218 kWh	
Consumption	=	117,500 kWh	

August

From wind	≅	666,667 kWh	679,250 kWh can be given to the grid.
From PV	=	94,483 kWh	
Total Production	=	761,150 kWh	
Consumption	=	81,900 kWh	

September

From wind	≅	666,667 kWh	609,520 kWh can be given to the grid.
From PV	=	74,353 kWh	
Total Production	=	741,020 kWh	
Consumption	=	131,500 kWh	

October

From wind	≅	666,667 kWh	
From PV	=	50,596 kWh	321,437 kWh
Total Production	=	717,263 kWh	must be taken from the grid.
Consumption	=	1,038,700 kWh	

November

From wind	≅	666,667 kWh	
From PV	=	30,829 kWh	455,254 kWh
Total Production	=	697,496 kWh	must be taken from the grid.
Consumption	=	1,152,750 kWh	

December

From wind	≅	666,667 kWh	
From PV	=	21,762 kWh	679,960 kWh
Total Production	=	688,429 kWh	must be taken from the grid.
Consumption	=	1,368,389 kWh	

1 kWh natural gas causes 450 gr CO₂ (and NO_x) gas in the earth atmosphere.

The annual consumption of the campus is 8,605,889 kWh, and this means that every year $(8,605,889) \left(\frac{450}{10^6} \text{ tons} \right) = 3,873 \text{ tons}$ of gas isn't permitted to go to atmosphere.

Like solar and wind energies, all renewable energies (biomass, tide energy, geothermal etc.) prevent our earth from green house effects.

The current price of natural gas = 0,38 \$/m³

Annual gas consumption = 6661,039 kWh ≅ 612,000 m³

$(612,000 \text{ m}^3) \cdot 0,38 \text{ \$/m}^3 = 232,560 \text{ \$}$

The current price of electricity = 12.3 c \$/kWh

Annual electricity consumption = 1,944,850 kWh

$(1,944,850 \text{ kWh}) \cdot 12,3 \text{ c \$/kWh} = 239,216 \text{ \$}$

Finally, if we look at some other countries, Germany produces electric energy 30,000 GWh/year from PV and 47,000 GWh/year from wind.

In May 9-11, 2014 in Germany 67% of total consumption was produced from PV + wind.

In USA, the installed capacity of wind was 65 GW in 2010. And 12 GW PV in 2013.

The goal of EU (European Union) for 2030 is 40-27-27. This means: Decreasing of CO₂ by 40%, 27% of total energy from renewable energies and energy need will be decreased by 27% [7].

APPENDIX

TANUL ASESAS
 TANUL ANADOLU YAKASI ELEKTRİK
 İRAKEREDE SATIŞ A.Ş. GENEL MÜDÜRLÜĞÜ
 AĞLARBAŞI MAH. REFAHÇEVLER SK.
 BLOK NO: 2/1 MALTEPE/İSTANBUL
 ÜÇÜKYALI V.D. 4810577635
 İL : 0216 5790500
 İKS: 0216 5790530
 ERGİS NO : 0481057763500017
 C.SIC.NO : 845982
 www.aesas.enerjisa.com
 Üşteri Adı Soyadı/Unvanı: **HARMARA ÜNİVERSİTESİ ATATÜRK EG.FK**
 Adresi: **Etilim Mah. SARAYONU Cd. No:7/1**
MERKEZ-KADIKÖY, İSTANBUL
 D.No: **6120066328**

RESMİ VE SATIŞ KODLARI
444 6 186
 HİZMET BİREKODU
ALO 186

MALİYE BAKANLIĞI T.C.
34

FATURA
 Seri, Sıra No: **A 059601**

D.No: **6120066328**

İTURA TARİHİ	28.02.2015	FATURA DÖNEMİ	02/2015	DOSYA NO.	A01A1060	OKUMA SAATI	11:48
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AYMANLIK/OTOMATİK ÖDEME TALİMATI: **HARMARA ÜNİVERSİTESİ / YUKTUR**
 ÜŞTERİ GRUBU: **4 Holu Tek Zamanlı Ticarethane AG./ Yıllık tükentiniz : 407.455,600 kWh dir**

ÜŞTERİ NO.	204447849	SAYAÇ BİLG.	AKTİF S.	ENDÜKTİF S.	KAPASİTİF S.	A. TRF. ORANI	1000.0 / 5.0	SÖZLEŞME GÜCÜ
İZ. HES. NO.	1005940151	SERİ NO.	9000212	9000212	9000212	G. TRF. ORANI		500,000
İSİSAT NO.	4005164877	MARKA/TİP	DHA	DHA	DHA	KURULU GÜÇ	833,330	

PERAKENDE SATIŞ BEDELİ								
AKTİF	SON ENDEKS	İLK ENDEKS	ENDEKS FARKI	ÇARPAN	TÜK. (kWh)	İLAVE TÜK.	BİRİM FİYAT	TOPLAM
GÜNDÜZ	9.583,000	9.553,000	30,000	200,000	6.000,000			
PUANT	3.464,000	3.453,000	11,000	200,000	2.200,000			
GECE	3.766,000	3.755,000	11,000	200,000	2.200,000			
İK ZAMANLI AKTİF					10.400,000		0,26093600	2.713,73
e/Cu)			AKTİF	GÜNDÜZ	PUANT	GECE	REAKTİF	TOPLAM
KAYBI	TÜKETİM							
B. KAYBI	TÜKETİM							
AÇAK-CEZA		KAÇAK TÜKETİM		BİRİM FİYAT		KAÇAK TUTARI		
							TOPLAM 1	2.713,73

İRİM FİYAT	K. K. BEDELİ	PER. SATIŞ HİZ. BED.	PSH SAYAÇ DK. BED.	İLETİM BEDELİ	DAĞITIM BEDELİ		
	0,00739700	76,93	0,592	0,00874000	0,03607500		
İTAR	SAY. DEMAND DEG.	ÇARPAN	DEMAND	GÜÇ AŞIMI	G. A. BR. FİYAT	GÜÇ AŞIMI TUTARI	
ÜÇ AŞIM TUTARI							TOPLAM 2
ÜÇ TUTARI	ANLAŞMA GÜCÜ		GÜÇ BR. FİYAT		GÜÇ TUTARI		
EAKTİF	SON ENDEKS	İLK ENDEKS	ENDEKS FARKI	ÇARPAN	TÜK. (KVARH)	İLAVE TÜKETİM	
NDÜKTİF	1.573,000	1.567,000	6,000	200,000	1.200,000		
APASİTİF	919,000	917,000	2,000	200,000	400,000		
İTURA EDİLEN REAKTİF							TOPLAM 3

K OKUMA TARİHİ	29.01.2015	TOPLAM	3.257,41
ON OKUMA TARİHİ	06.02.2015	ENERJİ FONU	27,14
ONRAKİ OK. DON.	3/2015	TRT PAYI	54,27
ON.ORT.TÜK.(kWh)	1.300,000	ELEKTRİK TÜKETİM VERGİSİ	135,69
KIP	A21	GEÇİKME ZAMMI	
		KESME/BAĞLAMA BEDELİ	
		FATURA GÖNDERİM BEDELİ	
		SAYAÇLA İLGİLİ BEDELLER	
		KDV MATRAHI	3.474,51
		KATMA DEĞER VERGİSİ	625,41
		FATURA TUTARI	4.099,92
		MUHTELİF MAHSUP	
		ÖNCEKİ DON. YUVARLAMA FARKI	
		YUVARLAMA FARKI	
		DAMGA VERGİSİ	-32,94

İTURA TUTARI	0,00739700	SON ÖDEME TARİHİ	18.03.2015	ÖDENECEK TUTAR	4.066,98 TL
İK ÖDEME TARİHİ	28.02.2015				
SKİ BORÇ/BAKİYE	0 TL. Teşekkür ederiz.				

Değerli müşterimizden avantajlı tarifede(tek zamanlı/pok zamanlı) olup olmadığınızı kontrol etmek için 444 4 371'i arayabilirsiniz (Hafta içi 08:30 - 17:30)

Elektrik faturalarınızı www.epdk.gov.tr adresinden kontrol edebilirsiniz.

aturanızın 842,51 TL'si vergi ve fonlardan oluşmaktadır.

The invoice of electricity

İstanbul **AESAS**

İSTANBUL ANADOLU YAKASI ELEKTRİK
ERAKENDE SATIŞ A.Ş. GENEL MÜDÜRLÜĞÜ
AGLARBAŞI MAH. BEFAHEVLER SK.
BLOK NO: 2/1 MALTEPE/İSTANBUL
ÜÇÜKYALI V.D. 4810577635
İL : 0216 5790500
AKS: 0216 5790530
İERSİS NO: 0481057763500017
C.SIC.NO : 845982
www.aesas.enerjisa.com

PERAKENDE SATIŞ HESAPLARI
444 6 186
ARIZA-ÇAĞIRI HİZMETLERİ
ALO 186



FATURA

Seri, Sıra No:

A 059513

Müşteri Adı Soyadı/Unvanı: **MARMARA ÜNİVERSİTESİ TEKNİK EĞ. FAK.**
dresi: ****BÜSÜS-2994** KAYISDAĞI CD**

D./No: 6120066328

TURTA TARİHİ	28.02.2015	FATURA DÖNEMİ	02/2015	DOSYA NO.		ÖLÇÜ NO	001A1060	OKUMA SAATI	11:47
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AYMANLIK/OTOMATİK ÖDEME TALİMATI: **MARMARA ÜNİVERSİTESİ / YÜKÜTÜR**
MÜŞTERİ GRUBU: 4 Rolu Tek Zamanlı Ticarethane ÖG./Yıllık tükettiminiz : 680.607,000 kWh dir

MÜŞTERİ NO.	204037735	SAYAÇ BİLG.		AKTİF S.		ENDÜKTİF S.		KAPASİTİF S.		A. TRF. ORANI	75.0 / 5.0	SÖZLEŞME GÜCÜ	
İZ. HES. NO.	1005365096	SERİ NO.	60004615	60004615	60004615	60004615	60004615	60004615	60004615	G. TRF. ORANI	10000 / 100	1.104,000	
SİSAT NO.	4006084699	MARKA/TİP	DHA	DHA	DHA	DHA	DHA	DHA	DHA	KURULU GÜÇ	1.260,000		

PERAKENDE SATIŞ BEDELİ

AKTİF	SON ENDEKS	İLK ENDEKS	ENDEKS FARKI	ÇARPAN	TÜK. (kWh)	İLAVE TÜK.	BİRİM FİYAT	TOPLAM
GÜNDÜZ	2.430.570	2.424.240	6.322	1.500,000	9.483,000			
PUANT	702.599	700.773	1.826	1.500,000	2.739,000			
GECE	567.925	566.028	1.897	1.500,000	2.845,500			
K ZAMANLI AKTİF					15.067,500			0,26093600
a/Cu)								3.931,66
KAYBI	TÜKETİM	AKTİF	GÜNDÜZ	PUANT	GECE	REAKTİF	TOPLAM	
B. KAYBI	TÜKETİM							
ÇAK-CEZA	KAÇAK TÜKETİM	BİRİM FİYAT	KAÇAK TUTARI					
								TOPLAM 1
								3.931,66

K. K. BEDELİ	PER. SATIŞ HİZ. BED.	PSH SAYAÇ OK. BED.	İLETİM BEDELİ	DĞİTİM BEDELİ	TOPLAM 2			
	0,00739700		0,00874800	0,03607500				
RİM FİYAT								
TAR	111,45	5,922	131,81	543,56				
Ç AŞIM TUTARI	SAY. DEMAND DEĞ.	ÇARPAN	DEMAND.	GÜÇ AŞIMI	G. A. BR. FİYAT	GÜÇ AŞIM TUTARI		
Ç TUTARI	ANLAŞMA GÜCÜ	GÜÇ BR. FİYAT	GÜÇ TUTARI	TOPLAM 2				
AKTİF	SON ENDEKS	İLK ENDEKS	ENDEKS FARKI	ÇARPAN	TÜK. (kWh)	İLAVE TÜKETİM	BİRİM FİYAT	TOPLAM 3
DÜKTİF	693,103	691,112	1,991	1.500,000	2.986,500			
PASİTİF	358,085	358,066	0,019	1.500,000	28,500			
TURA EDİLEN REAKTİF								

OKUMA TARİHİ	29.01.2015	TOPLAM	4.229,40
N OKUMA TARİHİ	06.02.2015	ENERJİ FONU	39,32
NRAKİ OK. DON	3/2015	TRT PAVİ	78,60
N.ORT.TÜK.(kWh)	1.883,438	ELEKTRİK TÜKETİM VERGİSİ	196,58
P	A21	GEÇİME ZAMMI	
EME YERLERİ:		KESME/BAĞLAMA BEDELİ	
ŞE: Akbank,Albaraka		FATURA GÖNDERİM BEDELİ	
rk,Finansbank,İng		SAYAÇLA İLGİLİ BEDELLER	
nk,Kuveyt		KDV MATRAHI	5.038,93
rk,Şekerbank,Türkiye		KATMA DEĞER VERGİSİ	907,01
nans,PTT,Diğer ödene		FATURA TUTARI	5.945,94
nalları için		MUHTELİF MAHSUP	
H. aesas.enerjisa.com		ÖNCEKİ DÖN: YUVARLAMA FARKI	
		YUVARLAMA FARKI	
		DAMGA VERGİSİ	-47,77

TURTA TUTARI	BEŞİNDEN ÖZÜYÜZKİREŞTİLDÜKSANDARTIR	ÖDEME TARİHİ	20.02.2015	SON ÖDEME TARİHİ	18.03.2015	ÖDENECEK TUTAR	5.898,17 TL
İİ BORÇ/BAKİYE	0 TL. Teşekkür ederiz.						

Değerli müşterimiz; en avantajlı tarifede (tek zamanlı/çak zamanlı) olup olmadığınızı kontrol etmek için 444 4 371'i arayabilirsiniz (Hafta içi 08:30 - 17:30)

Elektrik faturalarınızı www.epdk.gov.tr adresinden kontrol edebilirsiniz.
İnanızın 1.221,54 TL'si vergi ve fonlardan oluşmaktadır.

The invoice of electricity

TANBUL ASESAS

TANBUL ANADOLU YAKASI ELEKTRİK
ŞİRKETİ GENEL MÜDÜRLÜĞÜ
AĞLARBAŞI MAH. REFAHİYELER SK.
BLOK NO: 2/1 MALTEPE/İSTANBUL
ÜÇÜKYALI V.D. 4810577635
İL : 0218 5790500
KİŞİ : 0218 5790530
ERSİS NO : 0481057763500017
C.SIC.NO : 845982
www.aesas.enerjisa.com

PERAKENDE SATIŞ HİSSE NO
444 6 186
ARACI-DİĞER HİSSE NO
ALO 186



FATURA

Seri, Sıra No:

A 059603

İşleteni Adı Soyadı/Unvanı: T.C. HARRARA ÜNİVERSİTESİ
İşleteni Adresi: **HSDS-2640**GÖZTEPE KAMPUSU

D.No: 6120066328

TURA TARİHİ	28.02.2015	FATURA DÖNEMİ	02/2015	DOSYA NO.	A01A1060	OKUMA SAATI	11:08
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AYMANLIK/OTOMATİK ÖDEME TALİMATI: HARRARA ÜNİVERSİTESİ / YÖKTÜR

İŞLETENİ GRUBU: 4 Nolu Tek Zanaatlı Ticarethane DE. / Yıllık tükettiniz : 2.686.524,660 kWh dir

İŞLETENİ NO.	204453124	SAYAÇ BİLG.	AKTİF S.	ENDÜKTİF S.	KAPASİTİF S.	A. TRF. ORANI	30.0 / 5.0	SOZLEŞME GÜCÜ
ÖZ. NES. NO.	1005778798	SERİ NO.	60019731	60019731	60019731	G. TRF. ORANI	34500 / 100	1.575,000
SİSİT NO.	4005104066	MARKA/TİP	DMR	DMR	DMR	KURULU GÜÇ	1.575,000	

PERAKENDE SATIŞ BEDELİ

AKTİF	SON ENDEKS	İLK ENDEKS	ENDEKS FARKI	ÇARPAN	TÜK. (kWh)	İLAVE TÜK.	BİRİM FİYAT	TOPLAM
GÜNDÜZ	2.278,810	2.263,973	14,837	2.070,000	30.712,590			
PUANT	709,597	704,516	5,081	2.070,000	10.517,670			
GECE	618,420	611,830	6,590	2.070,000	13.641,300			
K ZAMANLI AKTİF					54.871,560		0,26003600	14.317,97
e/Cu)								
KAYBI	TÜKETİM			GÜNDÜZ	PUANT	GECE	REAKTİF	TOPLAM
B. KAYBI	TÜKETİM							
ÇAÇ-GEZA		KAÇAK TÜKETİM						KAÇAK TUTARI

K. K. BEDELİ	PER. SATIŞ HİZ. BED.	PSH SAYAÇ DK. BED.	İLETİM BEDELİ	DAĞITIM BEDELİ			TOPLAM 1.	14.317,97
RİM FİYAT	0,00739700		0,00874800	0,03607500				
İTAR	405,88	5,922	480,02	1.979,49				
İÇ AŞIM TUTARI	SAY. DEMAND DEG.	ÇARPAN	DEMAND	GÜÇ AŞIMI	G. A. BR. FİYAT	GÜÇ AŞIM TUTARI		
İÇ TUTARI	ANLAŞMA GÜCÜ		GÜÇ BR. FİYAT		GÜÇ TUTARI		TOPLAM 2	
AKTİF	SON ENDEKS	İLK ENDEKS	ENDEKS FARKI	ÇARPAN	TÜK. (KVARH)	İLAVE TÜKETİM		
İDÜKTİF	236,614	234,927	1,687	2.070,000	3.492,090		BİRİM FİYAT	TOPLAM 3
İPASİTİF	524,470	524,437	0,033	2.070,000	60,310			

TURA EDİLEN REAKTİF								
OKUMA TARİHİ	29.01.2015							
İN OKUMA TARİHİ	06.02.2015							
İNRAKİ OK. DON.	3/2015							
İN ORT.TÜK.(KWh)	6.858,945							
İP	021							
İME YERLERİ:								
ŞE:	Akbank, Albaraka							
irk,	Finansbank, Ing							
ink,	Kuveyt							
irk,	Şekerbank, Türkiye							
nans,	PTT, Diğer ödeme							
nalıları için								
u. aesas.enerjisa.com								
TOPLAM								17.189,28
ENERJİ FONU								143,18
TRT PAYI								286,36
ELEKTRİK TÜKETİM VERGİSİ								715,90
GEÇİKME ZAMMI								
KESME/BAĞLAMA BEDELİ								
FATURA GÖNDERİM BEDELİ								
SAYAÇLA İLGİLİ BEDELLER								
KDV MATRAHI								18.334,72
KATMA DEĞER VERGİSİ								3.300,25
FATURA TUTARI								21.634,97
MUHTELİF MAHSUP.								
ÖNCEKİ DÖN. YUVARLAMA FARKI								
YUVARLAMA FARKI								
DAMGA VERGİSİ								-173,81

TURA TUTARI	YİRİMİRİBİRALTYÜZÜTÜZDÖRTİLDÖKSAN YEDİKR							
ÖDEME TARİHİ	28.02.2015	SON ÖDEME TARİHİ	18.03.2015	ÖDENECEK TUTAR				21.461,16 TL
Kİ BORÇ/BAKİYE	0 TL. Teşekkür ederiz.							

Değerli müşterimiz; en avantajlı tarifedeki (tek zamanlı/gök zamanlı) olup olmadığınızı kontrol etmek için 444 4 371'i arayabilirsiniz. (Hafta içi 08:30 - 17:30)

Elektrik faturalarınızı www.epdk.gov.tr adresinden kontrol edebilirsiniz.

ürünüzün 4.445,69 TL'si vergi ve fonlardan oluşmaktadır.

The invoice of electricity

İstanbul **Aesas**

İTANBUL ANADOLU YAKAŞI ELEKTRİK
ERAKENDE SATIŞ A.Ş. GENEL MÜDÜRLÜĞÜ
AĞLARBAŞI MAH. REFAHİEVLER SK.
BLOK NO: 2/1 MALTEPE/İSTANBUL
ÜÇÜK YALI / V.D. 4810577695
EL : 0216 5790500
AKS: 0216 5790530
İERİSİS NO: 0481057769500017
İC.SİC NO: 845982
www.aesas.enerjisa.com

PERAKENDE SATIŞ HİZMETLERİ
444 6 186
ARALIK-DIŞTANIM HİZMETLERİ
ALO 186



FATURA

Seri, Sıra No:

R 059639

İşleri Adı Soyadı/Ünvanı: **MARMARA ÜNİVERSİTESİ REK.**
dresi: **KADIKÖY GÖZTEPEKAMPUSU İSTİ MERKEZİ**

D.No: **KUYUKAŞI 40/6120066328**

ATURA TARİHİ	28.02.2015	FATURA DÖNEMİ	02/2015	DOSYA NO.	001A1060	OKUMA SAATI	11.33
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AYMANLIK/OTOMATİK ÖDEME TALİMATI: **MARMARA ÜNİVERSİTESİ / YOKTUR**

İŞTERİ GRUBU: **4 Kolu Tek Zanaatlı Ticarethane A6 / Yıllık tüketiminiz : 76.044,548 kWh dir**

İŞTERİ NO.	204172330	SAYAÇ BİLG.	AKTİF S.	ENDÜKTİF S.	KAPASİTİF S.	A. TRF. ORANI	150.0 / 5.0	SOZLEŞME GÜCÜ
ÖZ. HES. NO.	100539668	SERİ NO.	01426654	01426654	01426654	G. TRF. ORANI		70,000
ESİSAT NO.	0005059255	MARKA/TİP	ELEKTRONED	ELEKTRONED	ELEKTRONED	KURULU GÜÇ	116,660	

PERAKENDE SATIŞ BEDELİ

AKTİF	SON ENDEKS	İLK ENDEKS	ENDEKS FARKI	ÇARPAN	TÜK. (kWh)	İLAVE TÜK.	BİRİM FİYAT	TOPLAM
GÜNDÜZ	899,518	833,883	66,435 ✓	30,000	1.993,050			
PUANT	262,813	244,297	18,516	30,000	555,480			
GECE	144,466	137,058	7,408 ✓	30,000	222,240			
İK ZAMANLI AKTİF					2.770,770		0,26993600	772,99
e/Cu)			AKTİF	GÜNDÜZ	PUANT	GECE	REAKTİF	TOPLAM
KAYBI	TÜKETİM							
B. KAYBI	TÜKETİM							
KAÇAK-CEZA		KAÇAK TÜKETİM		BİRİM FİYAT		KAÇAK TUTARI		TOPLAM 1
								772,99

	K. K. BEDELİ	PER. SATIŞ HİZ. BED.	PSH SAYAÇ OK. BED.	İLETİM BEDELİ	DAĞITIM BEDELİ			
İRİM FİYAT		0,00739700		0,00874800	0,03607500			
İTAR		20,50	0,592	24,24	99,96			
İÇ AŞIM TUTARI	SAY. DEMAND DEĞ.	ÇARPAN	DEMAND	GÜÇ AŞIMI	G. A. BR. FİYAT	GÜÇ AŞIM TUTARI		TOPLAM 2
İÇ TUTARI	ANLAŞMA GÜCÜ		GÜÇ BR. FİYAT		GÜÇ TUTARI			
İKTİF	SON ENDEKS	İLK ENDEKS	ENDEKS FARKI	ÇARPAN	TÜK. (kVarh)	İLAVE TÜKETİM	BİRİM FİYAT	TOPLAM 3
NDÜKTİF	190,705	179,162	11,543	30,000	346,290			
APASİTİF	96,220	91,058	5,162	30,000	154,860			
İTURA EDİLEN REAKTİF								

K OKUMA TARİHİ	29.01.2015	TOPLAM	869,28
JN OKUMA TARİHİ	06.02.2015	ENERJİ FONU	7,25
JNRAKİ OK. DÖN.	3/2015	TRT PAYI	14,46
JN.ORT.TÜK.(kWh)	346,346	ELEKTRİK TÜKETİM VERGİSİ	36,15
İP	A21	GEÇİKME ZAMMI	
ÖDEME YERLERİ:		KESME/BAĞLAMA BEDELİ	
İŞE: Akbank, Albaraka		FATURA GÖNDERİM BEDELİ	
rk, Finansbank, Ing		SAYAÇLA İLGİLİ BEDELLER	
ank, Kuveyt		KDV MATRAHI	926,12
rk, Şekerbank, Türkiye		KATMA DEĞER VERGİSİ	166,70
inans, PTT, Diğer ödene		FATURA TUTARI	1.092,82
analları için		MUHTELİF MAHSUP	
ih. aesas.enerjisa.com		ÖNCEKİ DÖN. YUVARLAMA FARKI	
		YUVARLAMA FARKI	
		DAMGA VERGİSİ	-0,78

İTURA TUTARI	BİNDOKSANİKİTLSEKSEMİKİRK		
K ÖDEME TARİHİ	28.02.2015	SON ÖDEME TARİHİ	18.03.2015
Kİ BORÇ/BAKİYE	160,13 TL	ÖDENECEK TUTAR	1.084,04 TL

Değerli müşterimiz/en avantajlı tarifede(tek zamanlı/çok zamanlı) olup olmadığınızı kontrol etmek için 444 4 371'ı arayabilirsiniz (hafta içi 08:30 - 17:30)

Elektrik faturalarınızı www.epdk.gov.tr adresinden kontrol edebilirsiniz.

turanızın 224,54 TL'si vergi ve fonlardan oluşmaktadır.

The invoice of electricity

TANUL ASES

TANUL ANADOLU YAKASI ELEKTRİK
PERAKENDE SATIŞ A.Ş. GENEL MÜDÜRLÜĞÜ
AĞLARBAŞI MAH. BEFAHEVLER SK.
BLOK NO: 2/1 MALTEPE/İSTANBUL
UCUKYALI V.D. 4810577693
İL: 0216 5790500
KŞ: 0216 5790530
ERSİS NO: 0481057763500017
C.SIC.NO: 845982
www.asesas.enerjisa.com

RESMİ MÜHÜR NO: 444 6 186
E-İMZA NO: ALO 186



FATURA

Seri, Sıra No:

A 462362

Üsteri Adı Soyadı/Unvanı: HARMARA ÜNİVERSİTESİ REKTÖRLÜĞÜ
İfresi: **8888-2727** GÖZTEPE KAMPÜSÜ

D./No: 6129066328

İTURA TARİHİ 28.02.2015 FATURA DÖNEMİ 02/2015 DOSYA NO: 801A1100 OKUMA SAATI 10:51

YMANLIK/OTOMATİK ÖDEME TALİMATI: HARMARA ÜNİVERSİTESİ / YÖKÜR

ÜŞTERİ GRUBU: 4 Nolu Tek Zamanlı Ticarethane B5. / Yıllık tükentiniz : 2.204.447,980 kWh 61p

ÜŞTERİ NO.	205313993	SAYAÇ BİLG.	AKTİF S.	ENDÜKTİF S.	KAPASİTİF S.	A. TRF. ORANI	20.0 / 5.0	SOZLEŞME GÜCÜ
İZ. HES. NO.	1004790475	SERİ NO.	60019913	60019913	60019913	G. TRF. ORANI	34500 / 300	900,000
SISAT NO.	4004585160	MARKA/TİP	BHA	BHA	BHA	KURULU GÜÇ	1.000,000	

PERAKENDE SATIŞ BEDELİ

AKTİF	SDN ENDEKS	İLK ENDEKS	ENDEKS FARKI	ÇARPAN	TÜK. (kWh)	İLAVE TÜK.	BİRİM FİYAT	TOPLAM
GÜNDÜZ	2.946,728	2.927,534	19,144 ✓	1.380,000	26.418,720			
PUANT	923,808	918,115	5,693	1.380,000	7.856,340			
GECE	1.037,442	1.029,946	7,496 ✓	1.380,000	10.344,480			
K ZAMANLI AKTİF					44.619,540		0,24093600	11.642,85

e/Cul	AKTİF	GÜNDÜZ	PUANT	GECE	REAKTİF	TOPLAM	
KAYBI	TÜKETİM						
B. KAYBI	TÜKETİM						
ÇAK-CEZA	KAÇAK TÜKETİM				KAÇAK TUTARI		
			BİRİM FİYAT			TOPLAM 1	11.642,85

	K. K. BEDELİ	PER. SATIŞ HİZ. BED.	PSH SAYAÇ OK. BED.	İLETİM BEDELİ	DAĞITIM BEDELİ			
RİM FİYAT		0,00739700		0,00874800	0,03607500			
İTAR		330,05	5,922	390,33	1.609,65			
İÇ AŞIM TUTARI	SAY. DEMAND DEG.	ÇARPAN	DEMAND	GÜÇ AŞIMI	G. A. BR. FİYAT	GÜÇ AŞIM TUTARI	TOPLAM 2	
İÇ TUTARI	ANLAŞMA GÜCÜ		GÜÇ BR. FİYAT		GÜÇ TUTARI			
AKTİF	SDN ENDEKS	İLK ENDEKS	ENDEKS FARKI	ÇARPAN	TÜK. (kVarh)	İLAVE TÜKETİM	BİRİM FİYAT	TOPLAM 3
ÜDÜKTİF	395,145	392,241	2,904	1.380,000	4.007,520			
APASİTİF	119,911	119,861	0,050	1.380,000	69,060			

İTURA EDİLEN REAKTİF							
K OKUMA TARİHİ	29.01.2015					TOPLAM	12.978,80
İN OKUMA TARİHİ	06.02.2015					ENERJİ FONU	116,43
İNRAKİ OK. DON.	3/2015					TRT PAVİ	232,86
İN.ORT.TÜK.(kWh)	5.577,443					ELEKTRİK TÜKETİM VERGİSİ	582,14
İP	A21					GEÇİKME ZAMMI	
						KESME/BAĞLAMA BEDELİ	
						FATURA GÖNDERİM BEDELİ	
						SAYAÇLA İLGİLİ BEDELLER	
						KDV MATRAHI	14.910,23
						KATMA DEĞER VERGİSİ	2.683,84
						FATURA TUTARI	17.594,07
						MUHTELİF MAHSUP	
						ÖNCEKİ DÖN. YUVARLAMA FARKI	
						YUVARLAMA FARKI	
						DAMGA VERGİSİ	-141,35

İTURA TUTARI	BNYEDİTİNEŞYÜZDOKSANDÖRTTLYEDİKR						
K ÖDEME TARİHİ	28.02.2015	SON ÖDEME TARİHİ	18.03.2015	ÖDENECEK TUTAR			17.452,72 TL
SKİ BORÇ/BAKİVE	0 TL. Teşekkür ederiz.						

Değerli müşterimizden avantajlı tarifede (tek zamanlı/pok zamanlı) olup olmadığınızı kontrol etmek için 444 4 371'i arayabilirsiniz (Hafta içi 08:30 - 17:30)

Elektrik faturalarınızı www.epdk.gov.tr adresinden kontrol edebilirsiniz.

İfresinin 3.615,27 TL'si vergi ve fonlardan oluşmaktadır.

The invoice of electricity

Güncellediniz mi?

Kimlik
ari müşterilerimizin
alresi ve Vergi Numarasını
emesi yasal zorunluluktur.*



Bilgi Güncelleme Noktalarımız:
• 444 36 36 numaralı İGDAŞ Çağrı Merkezi
• İGDAŞ Vezneleri
• İGDAŞ Hizmet Binalarındaki Pazarlama Departmanları
*5490 Sayılı Nüfus Hizmetleri Kanunu ve bu kanuna istinaden çıkarılan 2006/33 Sayılı Başbakanlık Genelgesi

İGDAŞ
"Gökyüzüne Arkadaş"
İstanbul Gaz Dağıtım
Sanayi ve Ticaret A.Ş.
Kazım Karabekir Cd.No:4
34060 Alibeyköy / İstanbul
Ticaret Sicil No: 229806
B.Mükellefler V.D.4700022607
www.igdas.com.tr

DOĞALGAZ FATURASI



Y Sayın. Blg.-Md.
Adres: T.C MARMARA ÜNİVERSİTESİ GÖZTEPE KAMPUSU
EĞİTİM Mah. F.KERİM GÖKAY Cad.
MAR ÜNV REKTÖRLÜK 155/1/888
V.D./NO /KADIKÖY

TESİSAT NUMARASI	30274930888
ÖDENECEK TUTAR	22.599,00
SON ÖDEME TARİHİ	23/03/2015
Sayaç Numarası	
Fatura Tarihi / Numarası	0650474
İlk Okuma Tarihi / Endeks	17/02/2015 - R3257876
Son Okuma Tarihi / Endeks	21/01/2015 - 318396
Fatura Gün Sayısı	17/02/2015 - 332792
Sayaçtan Ölçülen Hacim (m ³)	27
Düzeltilme Katsayısı	14396
Ort.Fiili Üst Isıl Değer (kwh/m ³)	1,273000
Tüketilen Enerji Miktarı (kwh)	10,897,000 - 32
Tük.Dönemi Per.Stg.Fiy.(TL/kwh)	203.487,71
Toplam Tüketim Bedeli	0,09411603
Diğer Bedeller (1)	19.151,86
K.D.V. % ()	0,00
FATURA TÖTARİ	3.447,33
Cari Hesap Borcu (2)	22.599,19
Cari Hesap Alacağı (3)	0,00
Yuvarlama	0,13

D.V. 181.56

Sayı Sayın Abonemiz, faturanızı ödemeye bildiğ tarihten bir gün sonra gidiniz.
"GÜVENLİĞİNİZ İÇİN BACALARINIZIN TEMİZLİK VE BAKIMINI YAPTIRINIZ."
Başlık İGDAŞ İstanbul Gaz Dağıtım San. ve Tic. A.Ş. Kazım Karabekir Cd.No:4 Alibeyköy / İstanbul F-M-03_05.R11
Bölüm Büyük Mükellefler V.D.4700022607 Adanma Tarihi:
LÜ LÜTFEN ARKA SAYFAYI OKUYUNUZ

The invoice of natural gas



DOĞALGAZ FATURASI

Seri Sıra No 3D-103657-

İL KODU 34 SAYAÇ NO

TESİSAT NO 32011350888

Sayın 32011350888 7073732006

Adres: T.C. MARMARA ÜNİVERSİTESİ GOZTEPE KA
EGİTİM Mah. HIZIRBEY Cad
T.C. MARMARA ÜNİ. GÖZTEPE KAM. 120/888

Tebliğ Tarihi 03/03/2015 (Okuyucu Kod)

Fatura No	Fatura Tarihi
N15/60012073	3/03/2015

İlk Okuma Tarihi	İlk Endeks	Son Okuma Tarihi	Son Endeks
31/01/2015	171736	31/01/2015	180522

Sayaçtan Ölçülen Hacim (m³) 184081

Düzeltilme Katsayısı 2,095071

Ort.Fiili Üst Isıl Değer (kwh/m³) 10,908068

Tüketilen Enerji Miktarı (kwh) 2.007.968,09

Tük.Dönemi Per. Stş.Fiyatı (TL/kwh) 0,07858515

Toplam Tüketim Bedeli 157.796,47

Diğer Bedeller⁽¹⁾ 0,00

K.D.V. % () 28.403,36

FATURA TÜRARI 186.199,83

Cari Hesap Borcu⁽²⁾ 0,00

Cari Hesap Alacağı⁽³⁾ 0,18

Yuvarlama 0,35

TOPLAM ÖDENECEK BEDEL 186.200,00

İLK / SON ÖDEME TARİHİ 3/03/2015 - 23/03/2015

Cor.İlk.G.: 3503245 Cor.Son.G.: 3687326
Düz. Tuk. : 188716 Kul. Bas. : 1.000,000
(3) DİĞER TENZİLAT BEDELLER 0,18
Sn. ABONEMİZ,
ÖDEMELERİNİZİ DENİZBANK VEKNELERİNDEN VEYA
BANKACILIK SİSTEMİ ÜZERİNDEN TESİSAT NUMARANIZI
BELİRTMEK SURETİYLE YAPABİLİR VEYA OTOMATİK
ÖDEME TALİMATI VERESİLİRSİNİZ.

D.V. 1495,91

F-01-06.R4 LÜTFEN ARKA SAYFAYI OKUYUNUZ

FATURA TÜRARI	2.185,87
Cari Hesap Borcu (2)	14.329,60
Cari Hesap Alacağı (3)	0,00
Yuvarlama	0,00
	-,41

D.V. 115,12

Sayın Abonemiz, faturanızı ödemeye tebliğ tarihinden bir gün sonra gidiniz.
"GÜVENLİĞİNİZ İÇİN BACALARINIZIN TEMİZLİK VE BAKIMINI YAPTIRINIZ."
Bazım: DOĞAL Gaz Dağıtım San. ve Tic. A.Ş. Kazım Karabekir CENK-4 Alibeyköy / İstanbul F-M-03_05.R11
Büyük Müktefelik No: 4750022807 Anlaşma Tarihi:
LÜTFEN ARKA SAYFAYI OKUYUNUZ

The invoice of natural gas

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VITA

Uğur Baş was born in 1958. After completion of high school study at Adana Science Lycee, he graduated from Middle East Technical University and Yıldız Technical University as a Mechanical Engineer. He has been doing his MSc in Marmara University Department of Mechanical Engineering.