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Renewable sources of energy in developing countries

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V Praze dne ………………… 2008

Prohlášení

Prohlašuji, že předloženou bakalářskou práci na téma „Renewable sources of energy in developing countries“ jsem vypracoval samostatně s použitím uvedené literatury.

V Praze, dne 14. května 2007 . . . .

Marek Šnajdr

Poděkování

Za odborné vedení a pomoc při psaní této bakalářské práce bych chtěl vyjádřit své velké poděkování vedoucímu bakalářské práce doc. Ing. Vladimíru Kreplovi, CSc., který mi poskytoval mnoho zajímavých podnětů i informací a byl mi všestrannou oporou.

Anotační záznam

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Zdroje znovuobnovitelné energie v rozvojových zemích – bakalářská práce s. 61
Praha, 2008

Bakalářská práce se nám snaží v širším pojetí přestavit využití všech nejdůležitějších znovu obnovitelných zdrojů energie v rozvojových zemích jako je slunce, voda, vítr, biomasy geotermální energie. Více detailně se však zaměřuje na méně prozkoumané využití energie získané z moří a oceánů.

Klíčová slova: obnovitelné zdroje energie; energie slunce, větru, vody, biomasy; rozvojové země.

Annotation

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This bachelor thesis attempts to present more generally the use of the most important renewable sources of energy such as sun, water, wind, biomass, and geothermal energy in development countries. It concentrates in greater detail at less examined use of energy gained from seas and oceans.

Keywords: renewable energy sources; energy of sun, wind, water, biomass; developing countries.

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1. Introduction

There is a clear societal need for energy. This need is not a new phenomenon. Studying history shows that energy is one of the main factors shaping the development of society. What is a new in historical terms is the explicit need for renewable energy at the moment. Renewable sources as wind have already been use for a long period in history e.g. for transport on sealing ships and work with windmills, but with conventional techniques the need will not be covered. As a societal need for energy increases more than conventional system can supply, there is a need for renewable but also for innovation.

Renewable source of energy is a usable energy source, the energetically potential of which renews due to natural processes. This is, therefore, energy of sun, wind, water, biomass, and energy of atmosphere and rock environment. Natural – primary – sources of energy and technologies of their exploitation are distinguished. Other relevant terms are defined as follows:

"Renewable sources of energy" are renewable non-fossil energy sources (wind, sun energy, geothermal energy, energy of waves and flow, energy of water, biomass, gas from dump, from sewage treatment plants and biogases); [30]

"Biomass" is biologically degradable part of products, waste and remainders from agriculture (including plant and livestock material), forestry and related industries, as well as biologically degradable segment of industrial and communal waste; [30]

"Electric energy produced from renewable energy resources" is electric energy generated in plants which make use exclusively of renewable sources of energy and part of electric energy produced from renewable sources of energy in hybrid establishments which use also conventional sources of energy, including renewable electric energy used to recharge storage systems; however, excluding electric energy produced as a result of these storage systems; [30]

"Electric energy consumption" is domestic production of electric energy including own production, adding imports and subtracting exports (gross domestic consumption of electric energy); [30]

The renewable energy sources can be divided into:

- Solar energy
- Wind energy
- Biomass
- Hydro power
- Geothermal energy

This bachelor thesis will briefly discuss all possible resources, nevertheless, the main aim is to describe less known and less examined (though in my opinion important and beneficial for the future) resources such as energy of seas and oceans.

This bachelor thesis will focus on renewable energy sources as a key factor in solving environmental problems. It will focus on the technologies and strategies to convert sustainable energy sources like wind, water, sun and biomass into useful energy forms like transportation fuel, gas and electricity. An overview will be presented of the current status and technological challenges that need to be overcome to realize a renewable energy supply. Important issues are the potential of the source, the technologies to convert the source into useful energy forms and the ease of integration within the current infrastructure. To assess potential and transformation efficiency basic concepts of thermodynamics will be introduced.

2. Present state of examined issues

Many important sources were used in the process of gathering information for this bachelor thesis. Some of them are in the form of a book, the rest are electronic in the form of lectures and information. Internet as a great source of data has been fully utilized as well particularly in order to acquire graphs, pictures and figures that enhance imagination of the reader of the thesis. There are several firms nowadays that deal with the topic of energy from renewable resources. However, this fact does not mean that sources of information about this topic are easily accessible in book form. On the contrary, most companies dealing with this subject own well elaborated internet pages and links (also to their services and product orders).

"Alternative energy for your house" is a book dealing with the issue of renewable resources in the Czech Republic. It describes basic principles of using solar, wind and water energy, biomass energy and low potential (geothermal) energy, including practical examples, schemes and photos. Each chapter includes a section on information sources particularly the internet ones. The conclusion of the book is devoted to economics of projects, evaluation of heat consumption and heating expenses.

The book *"Solar energy for your house"* uncovers practical aspects of using energy from solar radiation. Emphasis is placed on the currently most widespread applications of solar energy: water heating and supplementary heating.

"Renewable resources of energy" (Cenka et al. 2001). Both these books are written in great detail, perhaps in certain passages they are even too scholarly and incomprehensible and therefore useless for wide public. Both books rely on the reader's very good knowledge of the given field. These books are indeed too detailed for the purpose of this bachelor thesis. I believe that they suit perfectly the needs of master and dissertation theses which require greater expertise as well as practical experience.

Lectures "*Alternative sources of energy"* in electronic form are high quality source of information since they are written in a comprehensible way and at the same time scholarly enough for the purposes of this thesis.

Only those foreign sources available on the internet were accessible due to the high purchase prices of publications.

3. Objective of Work

Objective of this thesis is to describe different renewable resources of energy in detail and simultaneously in the most comprehensible way. Emphasis is placed on less known and less investigated renewable resources of energy such as for example energy of oceans. Furthermore, description of principles of these resources and their proper and efficient use is presented. Finally, a short analysis of possibilities of exploitation of these alternative resources such as energy of biomass, sun energy, wind energy, and energy of water, in Greece is carried out.

4. Methodology

Methods applied in the thesis were not extremely complicated; however, they were by no means simple. Summarization of information and data in relation to the topic of renewable energy resources, subsequent translation of acquired information into a comprehensible form, and finally choosing the most important materials were the core methods. As was mentioned before, information attained for the purpose of this thesis were extensive and of high quality and expertise level. Possibility to search for data on internet portals was used particularly in order to complete data obtained from documents by photos, graphs and figures. The greatest difficulty occurred when it came to reduction of useless data especially with regards to undesirable wide range of the bachelor thesis. Many useful advices from the thesis supervisor were applied to enhance the overall structure of the thesis.

5. Results and discussion

5.1 Developing countries

5.1.1 Basic information on developing countries

A developing country is that country which has a relatively low standard of living, an undeveloped industrial base, and a moderate to low Human Development Index (HDI) score and per capita income, but is in a phase of economic development. Usually all countries which are neither a developer country nor a failed state are classified as developing countries, despite the above facts, this is not true for all countries as some developing countries are far more developed than some developer countries.

Countries with more advanced economies than other developing nations, but which have not yet fully demonstrated the signs of a developer country, are grouped under the term newly industrialized countries. Other developing countries which have maintained sustained economic growth over the years and exhibit good economic potential are termed as emerging markets. The Big Emerging Market (BEM) economies are Argentina, Brazil, China, Egypt, India, Indonesia, Mexico, Poland, Russia, South Africa, South Korea and Turkey. The application of the term developing country to any country which is not developed is inappropriate because a number of poor countries have experienced prolonged periods of economic decline. Such countries are classified as ether least developer countries or failed states.

Development entails a modern infrastructure (both physical and institutional), and a move away from low value added sectors such as agriculture and natural resource extraction. Developed countries, in comparison, usually have economic systems based on continuous, self-sustaining economic growth in the tertiary and quaternary sectors and high standards of living.

5.2 Renewable energy

In the 1970s, oil shortages pushed the development of alternative energy sources. In the 1990s, the push came from a renewed concern for the environment in response to scientific studies indicating potential changes to the global climate if the use of fossil fuels continues to increase.

5.3 Solar energy

Solar energy is also called electromagnetic energy. Almost every reaction that happens on the surface of the Earth is the result of energy coming to the Earth from the Sun. Radiant energy is also called electromagnetic energy because it is made up of two combined fields. One of the fields is electrical and the other is magnetic.[1]

Solar radiation is a real source of most renewable types of energies. It is used either instantly in the primary form of electromagnetic radiation or later, transformed in a certain manner into a different type of energy. Except for nuclear (and thermonuclear) energy, all other sources of energy available to human kind originated in Sun and its radiation. [2]

5.3.1 The Sun

The sun is a star. It is the largest object in our solar system and one of the larger stars in our galaxy.

In terms of astronomic classification of stars in Hertzsprung-Russel diagram, Sun is a regular star without any extraordinary characteristics.

The source of energy in the Sun is at its core where hydrogen (the basic component of the star) is converted to helium at extreme conditions (temperatures generally hundreds of millions Celsius degrees and similarly large pressures in Pascals) in a self-regulated thermonuclear reaction.

At this reaction four nuclei of hydrogen atoms merge into one nucleus of helium atom during each partial synthetical process and a certain amount of energy is generated.

This energy travels from the core to the surface of the Sun and is released into space primarily as light. The energy that comes to the Earth is in 2 main forms, heat and light.

The Sun is approximately 4.6 billion years old, and is expected to remain on its sequence for another 4.4 billion years so can be considered as a sustainable source of energy for the time being. To understand its potential as direct energy supplier we have to understand the characteristics of the solar energy as it is received by us and then we have to consider how it can be converted into useful energy. The sun is almost the only energy supplier we have at earth, not only driving all other energy cycles like biomass, wind power but is also stored in fossil energy. [3]

All renewable energy (except tidal and geothermal power), and even the energy in fossil fuels, ultimately comes from the sun. The sun radiates 174,423 000 000 000 kW to the earth, or in other words, the earth receives 1,74 x 10^{17} watts of power. About 1 to 2 % of the energy coming from the sun is converted into wind energy. And only 0,02 % is converted into biomass by all plant on earth.

The sun has produced energy for billions of years. Solar energy is the sun's rays (solar radiation) that reach the earth.[4]

After the 1973 oil embargo, there was a resurgence of interest in solar energy. Faced with a possibility of scarce oil resources, the United States government allocated $400 million per year, from a mere $1 million per year, for solar energy research. The expenditure is small compared to the expenditure on nuclear research. Currently, there is a need for allocating increased resources in solar research. Compared to the old forms of depletable energy (coal, oil, nuclear), solar energy offers a clean renewable form of energy.[5]

5.3.2 Solar constant

The solar constant is the amount of energy received at the top of the Earth's atmosphere on a surface oriented perpendicular to the Sun's rays (at the mean distance of the Earth from the Sun). The generally accepted solar constant of 1368 W/m^2 is a satellite measured yearly average.[6]

The solar constant is an important value for current studies of global radiation balance & climate models. The problem that faces scientists studying Earth's radiation budget and climate is that while satellites can "accurately" measure solar irradiance and calculate a solar constant, the surface insolation is much more difficult to assess. When the solar constant is calculated there are four major problems in trying to relate this radiation intensity to its effect on the Earth's surface or surface insolation. [6]

5.3.3 Solar radiation

Solar radiation is the heat and light and other radiation given off by the Sun. Nuclear reactions in the interior of the Sun maintain a central temperature of 16 million °C, and a surface temperature of 5700°C. Like all hot objects, the Sun's surface radiates energy at a rate and a color (wavelength range) which depends on its temperature. The Sun emits radiation at a rate of 3.8×10^{11} Watt, of which only two parts in a thousand million arrive at the Earth, with the rest disappearing into space or warming the other planets in our solar system.[7]

The amount of energy from the sun that falls on Earth's surface is enormous. All the energy stored in Earth's reserves of coal, oil, and natural gas is matched by the energy from just 20 days of sunshine. Outside Earth's atmosphere, the sun's energy contains about 1,300 watts per square meter. About one-third of this light is reflected back into space, and some is absorbed by the atmosphere (in part causing winds to blow).

Solar energy is received as radiation with particular spectral characteristic and defined direction of origin. The sun can be considered as a black body radiator emitting radiation due to its average surface temperature T_S of about 5800 K (more accurate 5762 K).[8]

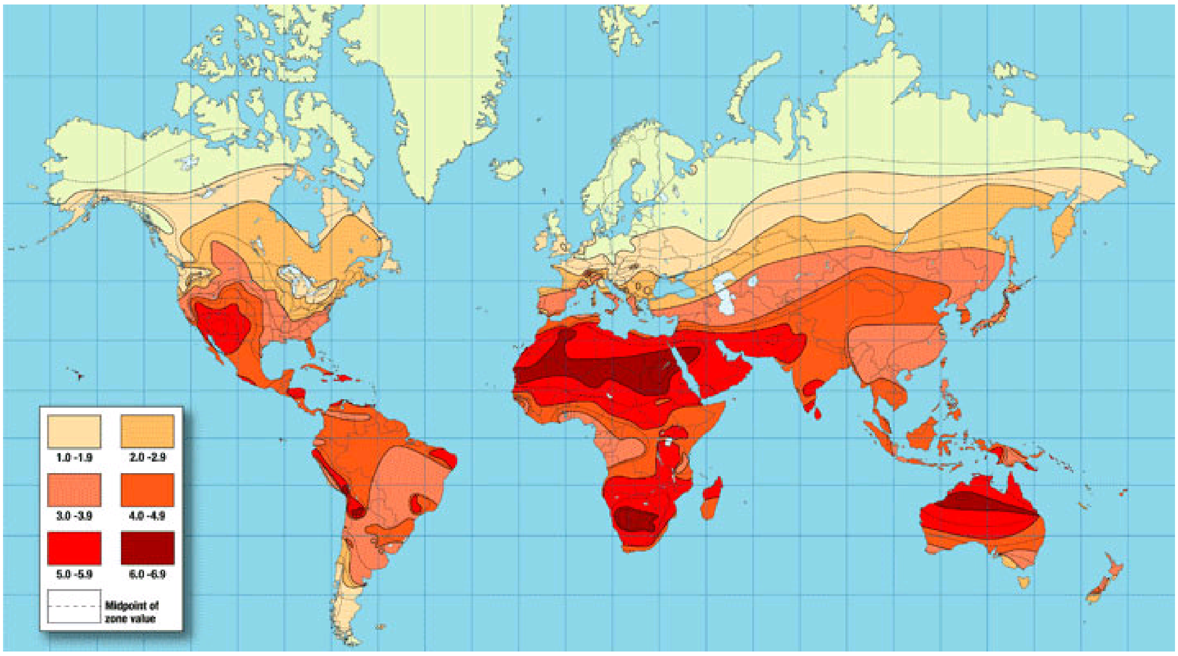
Approximately only two billionths of energy radiated by Sun reach the surface of Earth. Part of the incident radiation bounces back into the Universe, part of the energy is spent on heating the atmosphere and water evaporation, fractional part is spent on photosynthesis of the biomass. The character of radiation changes as it reaches the Earth. Ultra-violet radiation turns into infra-red which radiates back into the Universe. This is necessary, otherwise the temperature of our planet would constantly grow and the situation would be similar to the one on Venus where the temperature is around 400-500 °C.[9]

Incident Sun radiation on the surface of Earth comprises of two components. First component is the so called direct radiation. These are almost unchanged direct sun rays. The second component, on the other hand, is the so called diffuse radiation. This is diffused light after reflection from gas molecules, dust and clouds. It comes to the earth surface from different directions and it also has different spectral distribution and therefore different energetic potential. [9]

5.3.4 Solar radiation quantities measured

Solar irradiation intensity is measured at a horizontal surface to compare irradiation at various dates and locations. The early sum of irradiation, so the received solar energy in a year, is measured to be in average about 3500 MJm^{-2} in Netherlands. Of course this varies for different locations in the Netherlands and for different years, but it is presented as a typical value. It is equivalent with the energy content (combustion value) of about 100 m^3 of natural gas (100 NGE) or about 1000 kWh electrical energy. These order of magnitude figures can be used to easily judge the yield of various solar collectors or PV cells. As can be seen in figure, all over the world the early average of daily solar radiation varies considerably.

Figure 1 : World Insolation Map



Source: http://www.highplainswind.com/solar.htm

Solar energy received at the Earth's surface can be separated into two basic components: direct solar energy and diffuse solar energy. Direct solar energy is the energy arriving at the Earth's surface with the Sun's beam. The Sun's beam is quite intense, and hence has also been described a "shadow producing" radiation.

Diffuse solar energy is the result of the atmosphere attenuating, or reducing the magnitude of the Sun's beam. Some of the energy removed from the beam is redirected or scattered towards the ground - the rate at which this energy falls on a unit horizontal surface per second is called the diffuse solar irradiance.[10]

The remaining energy from the beam is either scattered back into space, or absorbed by the atmosphere. Absorption only occurs at specific wavelengths, for example, UVB solar energy is absorbed by ozone in the stratosphere. Scattering occurs at all wavelengths; hence the mechanism by which solar energy is scattered from water droplets and ice particles makes possible those majestic satellite pictures of clouds. The combination of both forms of solar energy incident on a horizontal plane at the Earth's surface is referred to as global solar energy and all three quantities (specifically their rate or irradiance) are linked mathematically by the following expression:

$$E_g = E_d + E_b \cos z$$

where: E_g = global irradiance on a horizontal surface, E_d = diffuse irradiance, E_b = direct beam irradiance on a surface perpendicular to the direct beam, z = Sun's zenith angle. By measuring the three components independently, a useful quality assurance test is immediately available by comparing the measured quantity with that calculated from the other two. [10]

5.3.5 Distribution of solar radiation around the world

Solar radiation is very variable. It varies from place to place, and from time to time. As we move from the poles towards the equator, the power of the sunlight increases. This is partly because the sun is more directly overhead, and therefore has a shorter path length through the atmosphere, and partly because there are more clouds at higher latitudes. There is in fact less solar energy at the equator than at the tropics because of the equatorial rain clouds. Figure 3 shows the average solar power around the world. These power data are obtained by measuring the average solar energy received in one year and dividing by the number of seconds in a year, so the averages include day and night. Note that in the UK we receive an average power of about 125 Wm^{-2} whilst the Sahara Desert gets 250-300 Wm^{-2} - a much smaller difference than most people would guess.

North of the equator, the highest radiation levels in the world are found in the Sahara desert, the Arabian Gulf area, and the deserts of California and New Mexico. South of the equator the Kalahari and Australian desert areas have the highest levels. These areas all average about 250-300 Wm^{-2}. Southern Europe has a radiation level of about 200 Wm^{-2}, as does most of the “sun belt” of the world, between latitudes 40°N and 40°S.

5.3.6 Availability of sun radiation

If solar energy was used in the universe, there would be no problems with its availability and exploitation. However, the situation is different on the surface of earth. Although solar energy can be found everywhere on Earth, there are differences between various locations. Decisive factors are following:

- Geographical latitude – The most intensive energy reaches the Earth in the area of equator and on the contrary, the least comes to in the area of poles.
- Season – The amount of sun radiation varies during the course of the year. Day is shorter and Sun is low in the sky in winter which together with more frequent occurrence of cloudiness significantly constrains the energetic profit of solar facilities.
- Local clime and cloudiness – Part of the radiation is absorbed during the passage through terrestrial crust. Clouds play an essential role in this regard. When the sky is clear 75% of the radiation reaches the Earth, when the sky is overcast the number is less than 15%. Furthermore, pollution of the atmosphere and other local impacts such as fogs influence the amount of energy possible to generate from solar radiation. Besides that, cloudiness causes dispersion of solar radiation which lowers the utility of certain solar systems.
- Slope and exposure of surface – It is obvious that maximum amount of energy can be acquired from solar radiation on a surface perpendicular to the incident rays. It is therefore optimal to skew the system towards the sun in a way that the rays do not cease to come vertically. Solar collectors or photovoltaic cells are usually installed under the angle 45° to south which guarantees good yearlong gains. To get a better gain the angle is increased to 60° in winter and decreased to 30° in summer.[11] Murtinger, Truxa 2006: 2-3).

5.3.7 Solar energy use

Incident solar radiation can be used in a variety of ways. Significant dilution of the energy is a disadvantage – the energy must therefore be collected or concentrated from a vast surface. Another disadvantage is (as has been noted above) day and night rotation, the fact that the Sun can be covered by clouds and low intensity of sun radiation in autumn and winter days.[9] Thermal energy of solar radiation is used on Earth or it is converted into electric energy either directly or indirectly.[9]

5.3.7.1 Use of solar energy for heating

Solar water heating devices are a relatively simple technology, with well-understood materials and manufacturing. Worldwide, they are extremely prevalent - anecdotally displacing approximately 6% of annual residential energy consumption in Israel, for instance.[12]

Solar Heating Devices directly absorb the sun's radiation with specially-coated absorbers to heat air or water for use in a building. Solar water heaters can be used in large commercial applications (e.g. hotels or breweries) solar water heaters racked for commercial installation or in attractive, low-profile installations on residences anywhere.[12]

Water heating can constitute 15% to 25%, or more, of the energy use of a home.

Solar water heaters are available that can reduce annual operating costs by 50% to 80% or more using "free energy" from the sun. These systems typically are cost-competitive with electric water heaters and also can be cost-competitive with natural gas-fired water heaters. Solar water heaters come in two distinct designs: active and passive systems.[13]

5.3.7.2 The basic equipment of the solar system

Solar water heaters are available that can reduce annual operating costs by 50% to 80% or more using "free energy" from the sun. These systems typically are cost-competitive with electric water heaters and also can be cost-competitive with natural gas-fired water heaters. Solar water heaters come in two distinct designs: active and passive systems.

Obtaining heat from solar radiation is not a problem. Any dimly black surface is sufficient. The basic problem of all solar systems is how to prevent from heat losses and how to dissipate created heat and store it for later usage. It is possible to say that these problems were tackled by majority of research and development in the area of solar energy. The problem of decreasing losses and ensuring accumulation significantly influence prices of solar systems.[11]

Every solar system contains these main components:

- Collector – collects radiation and turns it into heat.
- Reservoir – here the heat is stored for later use.
- Transport system – transports heat from collector to the reservoir or directly to the area of use (distributions, pumps or ventilators, valves etc.).
- Regulation device – ensures that the heat is transferred from collector to the reservoir and not the other way around.
- Spare source of heat – covers the consumption at the lack of sunshine [11]

5.3.7.3 Possibilities of usage

Conversion of light radiation to heat (the so called photo-thermal conversion) can be passive (realized with the help of passive solar components of buildings: glassed-in facades, winter gardens etc.) or active (realized with the help of auxiliary technical equipment such as solar collectors).[14]

In the case of passive system the amount of gained energy depends on the position, architectural design and particularly on the type of building, used materials, heating system (degree of utilization of gains from insolation). The use of passive solar system is conditional upon finding a solution to the risk of thermal stress (proper ventilation, possibility to accumulate into building constructions etc.). With new buildings it is necessary to adapt the entire architectural design. Older buildings can be suitable reconstructed (build glass enlargements, glassed-in porches etc.). [14]

A "passive" system combines the solar collector and storage in one complete unit separate from the conventional gas or electric water heater storage tank. The storage can be directly coupled with the collector (an integral collector/storage system, as shown in Figure 2 or located above the collector using the natural flow of heated water upwards to drive fluid circulation (thermo siphon system). Passive system design requires no pumps or controls for operation as sunlight heats water all day. When hot water is used in the home, water from the passive solar storage tank is drawn into the conventional gas or electric water heater storage tank, thereby avoiding the need for electric or gas fired heat to turn on. Providing energy-efficient houses with solar water heating systems provides peace-of-mind that home owners are contributing to environmental stewardship while helping their bottom-line expenses.[13]

Figure 2: A passive water heater system

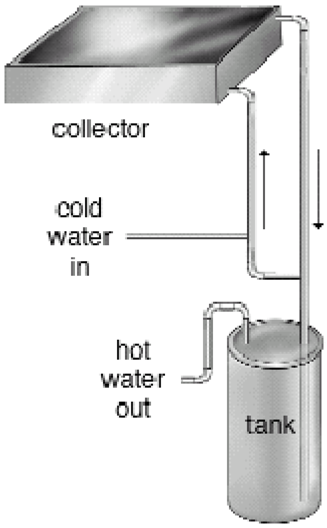
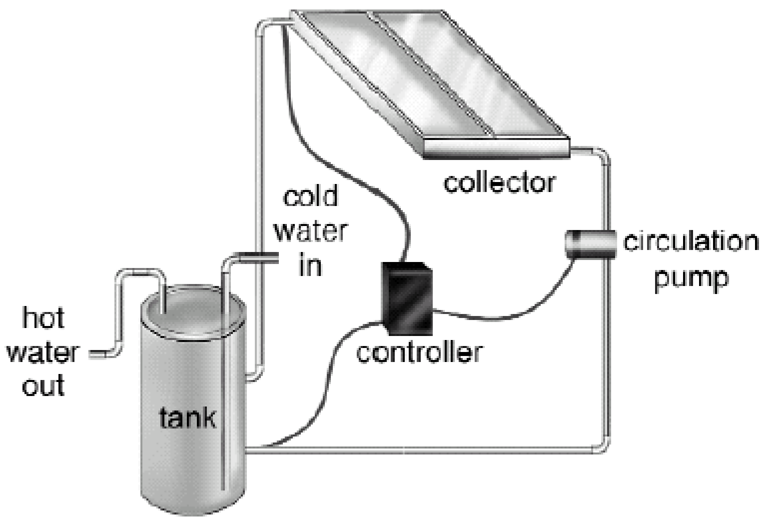


Figure 3: A active water heater system



It is almost always possible to additionally install active systems on a current building. Active systems are used for perennial preparation of domestic hot water, for heating swimming pool waster and for additional heating of buildings by hot water or hot air heating. With regards to the seasonal character of solar radiation it is also possible to accumulate thermal energy in reservoirs (water, gravel etc.) in the long term. The longer the accumulation time, the more expensive and less efficient the system becomes. This is the reason why short-term accumulation together with flexible heating systems able to exploit immediate solar gains. Sun energy is used particularly in active solar systems with flat liquid collectors with the purpose of preparing domestic hot water in family houses, agriculture, services and heating swimming pool water. They are to a much lesser extent used for additional heating or as heat accumulating source. Hot air collectors are mainly used for drying in agriculture and less for additional heating in buildings. [14]

In an "active" system, when sunlight heats one or more solar collectors sufficient for water heating, sensors and a controller activate a pump to circulate a fluid: either potable water from the storage tank or a food-grade antifreeze solution in climates exposed
to freezing conditions. As shown in Figure 1, the fluid is drawn from the colder bottom portion of the storage tank up to the collector for solar heating, and then circulated back to the top of the storage tank. Where antifreeze solutions are used, the solar heat is transferred to water in the storage tank through a heat exchanger. When the water in the storage tank is warmer than the collector, the controller and sensor switch off the pump. In many active systems, the solar system has its own water storage tank, allowing it to serve as a "pre-heater" for the primary water heater (gas or electric). [13]

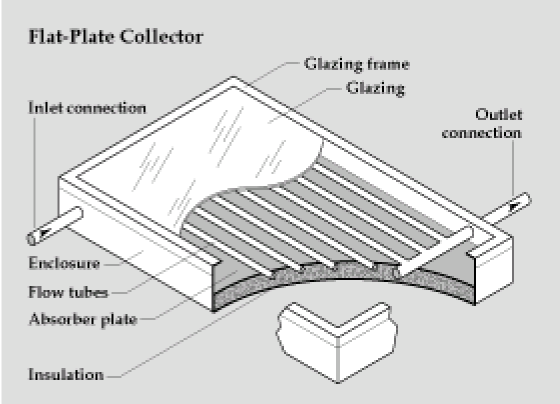
5.3.7.4 Division of solar collectors

Not only are there many different ways that solar energy can be applied, but there are also many different methods for collecting the solar energy from incident radiation. Below is a listing of some of the more popular types of solar collectors.[15]

Flat-plate collectors

Flat-plate collectors are the most common solar collector for solar water-heating system in homes and solar space heating. A typical flat-plate collector is an insulated metal box with a glass or plastic cover (called the glazing) and a dark-colored absorber plate. These collectors heat liquid or air at temperatures less than 82°C.

Figure 4: Flat-Plate Collector



Source: http://www1.eere.energy.gov/solar/sh_basics_collectors.html

Liquid flat-plate collectors heat liquid as it flows through tubes in or adjacent to the absorber plate. The simplest liquid systems use potable household water, which is heated as it passes directly through the collector and then flows to the house. Solar pool heating also uses liquid flat-plate collector technology, but the collectors are typically unglazed as in figure 5 below.

Figure 5: Unglazed Solar Collector

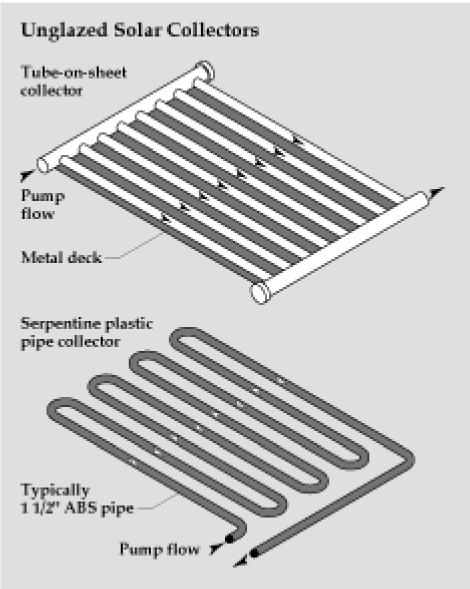
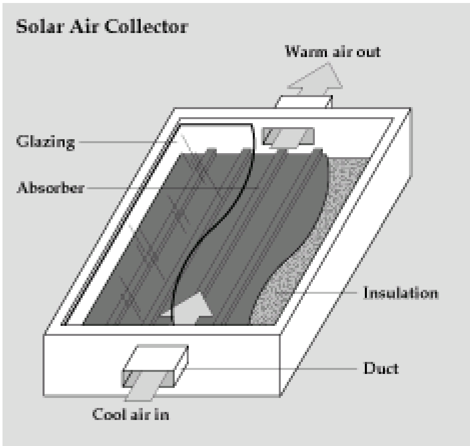


Figure 6: Solar Air Collector



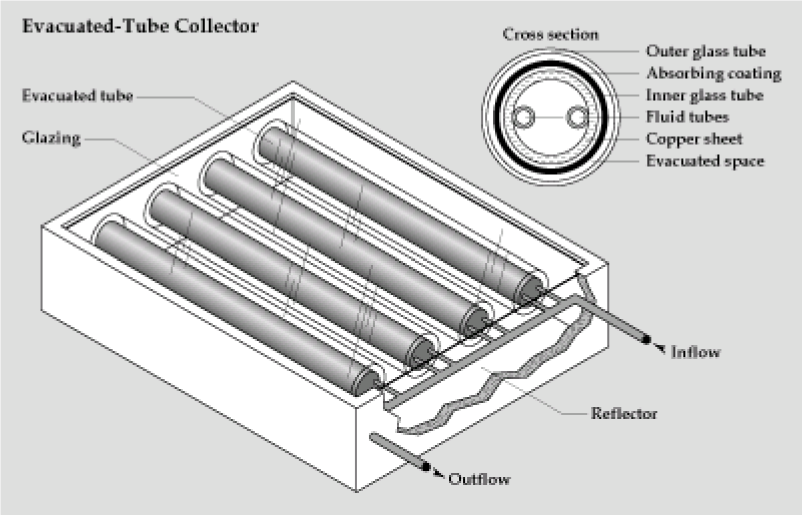
Source: http://www1.eere.energy.gov/solar/sh_basics_collectors.html

Air flat-plate collectors are used primarily for solar space heating. The absorber plates in air collectors can be metal sheets, layers of screen, or non-metallic materials. The air flows past the absorber by using natural convection or a fan. Because air conducts heat much less readily than liquid does, less heat is transferred from an air collector's absorber than from a liquid collector's absorber, and air collectors are typically less efficient than liquid collectors.[15]

Evacuated-tube collectors

Evacuated-tube collectors can achieve extremely high temperatures (76°C to 176°C), making them more appropriate for cooling applications and commercial and industrial application. However, evacuated-tube collectors are more expensive than flat-plate collectors, with unit area costs about twice that of flat-plate collectors. [15]

Figure 7: Evacuated-tube collectors



Source: http://www1.eere.energy.gov/solar/sh_basics_collectors.html

The collectors are usually made of parallel rows of transparent glass tubes. Each tube contains a glass outer tube and metal absorber tube attached to a fin. The fin is covered with a coating that absorbs solar energy well, but which inhibits radiative heat loss. Air is removed, or evacuated, from the space between the two glass tubes to form a vacuum, which eliminates conductive and convective heat loss. [15]

A new evacuated-tube design is available from the Chinese manufacturers, such as: Beijing Sunda Solar Energy Technology Co. Ltd. The "Dewar" design features a vacuum contained between two concentric glass tubes, with the absorber selective coating on the inside tube. Water is typically allowed to thermosyphon down and back out the inner cavity to transfer the heat to the storage tank. There are no glass-to-metal seals. This type of evacuated tube has the potential to become cost-competitive with flat plates. [15]

Concentration solar collectors

These collectors are modified so that their front or reflection surface concentrates radiation onto a smaller absorption surface. This leads to achieving higher temperatures. These collectors usually reach 90% efficiency. These systems belong in this category of collectors:

Parabolic dish systems - A parabolic dish collector is similar in appearance to a large satellite dish, but has mirror-like reflectors and an absorber at the focal point. It uses a dual axis sun tracker. [15]

A parabolic dish system uses a computer to track the sun and concentrate the sun's rays onto a receiver located at the focal point in front of the dish. In some systems, a heat engine, such as a Stirling engine, is linked to the receiver to generate electricity. Parabolic dish systems can reach 1000 °C at the receiver, and achieve the highest efficiencies for converting solar energy to electricity in the small-power capacity range. [16]

Parabolic trough system - Parabolic troughs are devices that are shaped like the letter "u". The troughs concentrate sunlight onto a receiver tube that is positioned along the focal line of the trough. Sometimes a transparent glass tube envelops the receiver tube to reduce heat loss.

Parabolic troughs often use single-axis or dual-axis tracking. In rare instances, they may be stationary. Temperatures at the receiver can reach 400 °C and produce steam for generating electricity.[16]

Power tower system - A heliostat uses a field of dual axis sun trackers that direct solar energy to a large absorber located on a tower. To date the only application for the heliostat collector is power generation in a system called the power tower.

A power tower has a field of large mirrors that follow the sun's path across the sky. The mirrors concentrate sunlight onto a receiver on top of a high tower. A computer keeps the mirrors aligned so the reflected rays of the sun are always aimed at the receiver, where temperatures well above 1000°C can be reached. High-pressure steam is generated to produce electricity. [16]

5.3.7.5 Choice of suitable locations

Solar system works best if designed for real local conditions (dimensioning, collector positioning, and way of utilization). Dimensioning for example requires the knowledge of hot service water consumption, whether the swimming pool will be heated, whether supplementary heating will be requested, manner of connection to a traditional source of energy, way of regulation, and other input data:

- Number of hours of sunshine and intensity of solar radiation,
- Course of yearly outside temperatures, wind or other unfavorable meteorological phenomenon.
- Exposure towards south is ideal (eventually with a slight diversion max. ±45°).
- Slope of solar collectors 45° is optimal for perennial running.
- Number of shadowing obstacles.
- Length of pipeline distributions should be as short as possible.

Above mentioned parameters allow for determining the amount of produced energy from the entire system per year. Computer programs exist for more detailed calculations. [14]

5.3.8 Use of solar energy for electricity production

Obtaining heat from solar radiation is not very complicated. A completely different situation arises when obtaining electric energy. Generally there are two ways:

- Produce heat, and then transform it into mechanical energy and eventually into electricity.
- Transform solar radiation into electricity directly.

First way is theoretically simple; in practice it carries a few difficulties. One of the problems is the fact that heat cannot be transformed into electricity with 100% efficiency. The second part of the process is not without problems either. Transformation of heat into electricity is done by using some kind of a thermal machine such as for example steam turbine. Such solution is suitable rather for large solar power plants.

Transformation of solar radiation directly into electric energy with the help of photovoltaic cells has relative advantages compared to the transformation through heat:

- Transformation efficiency can be substantially higher.
- The appliance does not have any mobile components and does not need to skew towards the Sun (it is advantageous if it skews though)
- It is a modular system which can be enlarged as necessary and can be manufactured in large series.

There is probably only one disadvantage and that is highly sophisticated technology and high price of photovoltaic cells. [11]

5.3.8.1 Photoelectric effect

The photoelectric effect refers to the emission, or ejection, of electrons from the surface of, generally, a metal in response to incident light.

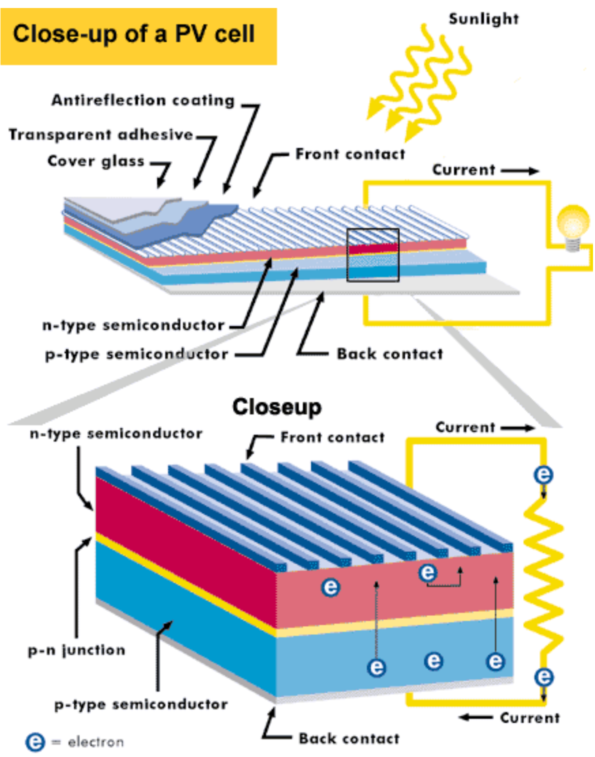
This is a phenomenon enabling the construction of photovoltaic cell. It was discovered by A.H. Becquerel already in 1839. Basically, electric voltage occurs at the interface of two materials exposed to light radiation. Closing the circuit leads to generating electric current.

5.3.8.2 Photovoltaic Cells

Visible light can be converted directly to electricity by a space-age technology called a photovoltaic cell, also called a solar cell. Most photovoltaic cells are made from a crystalline substance called silicon, one of the Earth's most common materials. Solar cells are typically made by slicing a large crystal of silicon into thin wafers and putting two separate wafers with different electrical properties together, along with wires to enable electrons to travel between layers. When sunlight strikes the solar cell, electrons naturally travel from one layer to the other through the wire because of the different properties of the two silicon wafers. [17]

A single cell can produce only very tiny amounts of electricity-barely enough to lightup a small light bulb or power a calculator. Nonetheless, single photovoltaic cells are used in many small electronic appliances such as watches and calculators.

Figure 8: Photovoltaic Effect



Source: http://www.uesusa.org/assets/images/catalyst/Catalyst_FA05_SolarPVdiagram.gif

Type of Photovoltaic Cells:

The three basic types of solar cells made from silicon are single-crystal, polycrystalline, and amorphous.

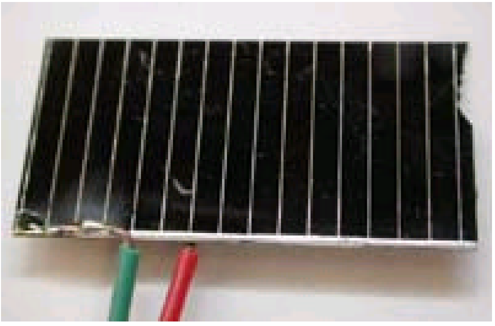
Single-crystal cells are made in long cylinders and sliced into round or hexagonal wafers. While this process is energy-intensive and wasteful of materials, it produces the highest-efficiency cells—as high as 25 percent in some laboratory tests. Because these high-efficiency cells are more expensive, they are sometimes used in combination with concentrators such as mirrors or lenses. Concentrating systems can boost efficiency to almost 30 percent. Single-crystal accounts for 29 percent of the global market for PV.

Polycrystalline cells are made of molten silicon cast into ingots or drawn into sheets, then sliced into squares. While production costs are lower, the efficiency of the cells is lower too - around 15 percent. Because the cells are square, they can be packed more closely together. Polycrystalline cells make up 62 percent of the global PV market.

Amorphous silicon (a-Si) is a radically different approach. Silicon is essentially sprayed onto a glass or metal surface in thin films, making the whole module in one step. This approach is by far the least expensive, but it results in very low efficiencies - only about five percent.

A number of exotic materials other than silicon are under development, such as gallium arsenide (Ga-As), copper-indium-dieseline (CuInSe2), and cadmium-telluride (CdTe). These materials offer higher efficiencies and other interesting properties, including the ability to manufacture amorphous cells that are sensitive to different parts of the light spectrum. By stacking cells into multiple layers, they can capture more of the available light. Although a-Si accounts for only five percent of the global market, it appears to be the most promising for future cost reductions and growth potential.[18]

Figure 9: Photovoltaic Cells



Source: http://www.re-energy.ca/t-i_solarelectricity.shtml

5.3.8.3 Photovoltaic Arrays

To capture and convert more energy from the sun, photovoltaic cells are linked to form photovoltaic arrays. An array is simply a large number of single cells connected by wires. Linked together in an array, solar cells can produce enough electricity to do some serious work! Many buildings generate most of their electrical needs from solar photovoltaic arrays, including the Toronto Healthy House, which gets 80% of its power from the sun. [17]

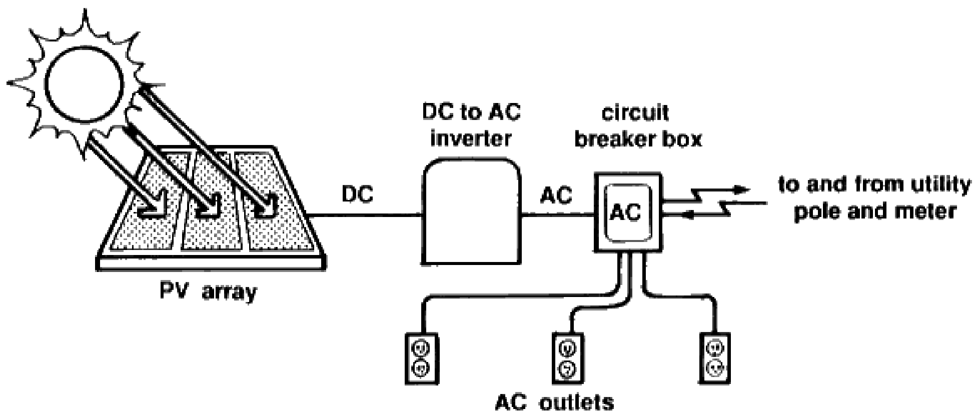
Photovoltaic arrays are becoming a familiar sight along roadsides, on farms, and in the city, wherever portable electricity is needed. They are commonly used to provide power for portable construction signs, emergency telephones, and remote industrial facilities. They are also becoming popular as a way of supplying electricity for remote power applications such as homes and cabins that are located away from power lines, for sailboats, recreational vehicles, telecommunications facilities, oil and gas operations, and sometimes entire villages-in tropical countries, for example. [17]

5.3.8.4 Division of photovoltaic systems

Photovoltaic systems can be divided with respect to application into autonomous, hybrid and directly connected to network. Autonomous system in general requires accumulators and is used particularly in places without access to public electricity network. They are usually used for water pumping (systems exist with power 2 to 3 kW with appropriate converters), alarm and telecommunication systems etc. [2]

Hybrid system contains a photovoltaic field and one or several auxiliary generators such as diesel aggregates or windmill generating stations, and one or more batteries. It requires more complicated regulators (in comparison to other systems) and control elements optimizing the use of properties of all sources. All elements of these systems are very reliable in long-term operation.[2]

Figure 10: Utility-Intertied Photovoltaic System



5.3.8.5 Choice of suitable locations

Just as in the case of solar energy transformation into heat, it holds for transformation into energy that the photovoltaic system works best if properly and carefully designed. Dimensioning requires the knowledge of purpose, considered energy consumption (production), type and operation hours of connected appliances, whether the system will be connected to the network or not, the manner of connection to auxiliary energy source and other input data:

- Number of hours of sunshine and intensity of solar radiation, which changes according to atmosphere pollution (town, countryside, mountains)
- Exposure towards south is ideal (eventually with automatic skewing of panels towards the Sun)
- Slope of solar collectors 45° is optimal
- Number of shadowing obstacles – day long Sun exposure is necessary[14]

5.3.9 Future of solar energy

Solar energy technologies are poised for significant growth in the 21st century. More and more architects and contractors are recognizing the value of passive solar and learning how to effectively incorporate it into building designs. Solar hot water systems can compete economically with conventional systems in some areas. And as the cost of solar PV continues to decline, these systems will penetrate increasingly larger markets. In fact, the solar PV industry aims to provide half of all new world electricity generation by 2025.[19]

5.4 Wind energy

Non-traditional sources of energy non-polluting the environment are nowadays often at the focus various ecological initiatives but also technicians, energetic experts, economists and also handy men. Energy of wind belongs among these resources. (Cenka et al. 2001: 91).

Wind energy converts kinetic energy that is present in the wind into more useful forms of energy such as mechanical energy or electricity. Wind energy is a pollution-free, infinitely sustainable form of energy. It doesn't use fuel; it doesn't produce greenhouse gasses, and it doesn't produce toxic or radioactive waste.[20]

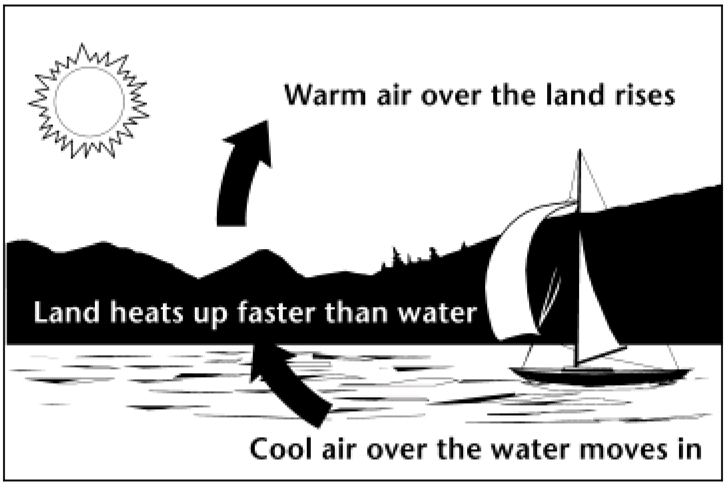
Growing concern about emissions from fossil fuel generation, increased government support, and higher costs for fossil fuels (especially natural gas and coal) have helped wind power capacity grow substantially over the last 10 years.

5.4.1 Wind and origin of wind

Wind is simple air in motion. It is caused by the uneven heating of the earth's surface by the sun. Since the earth's surface is made of very different types of land and water, it absorbs the sun's heat at different rates.[21]

About 1 to 2 per cent of the energy coming from the sun is converted into wind energy. The regions around equator, at 0° latitude are heated more by the sun than the rest of the globe. Hot air is lighter than cold air and will rise into the sky until it reaches approximately 10 km altitude and will spread to the North and the South. If the globe din not rotate, the air would simply arrive at the North Pole and the South Pole, sink down and return to the equator.[22]

Figure 11 : The Origin of Wind



Source: http://www.eia.doe.gov/kids/energyfacts/sources/renewable/wind.html

Since the globe is rotating, any movement on the Northern hemisphere is diverted to the right, if we look at it from our own position on the ground. (In the southern hemisphere it is bent to the left). This apparent bending force is known as the Coriolis force. (named after the French mathematician Gustave Gaspard Coriolis 1792 – 1843). [22]

During the day, the air above the land heats up more quickly than the air over water. The warm air over the land expands and rises, and the heavier, cooler air rushes in to take its place, creating winds. At night, the winds are reversed because the air cools more rapidly over land than over water.

In the same way, the large atmospheric winds that circle the earth are created because the land near the earth's equator is heated more by the sun than the land near the North and South Poles.[21]

Today, wind energy is mainly used to generate electricity. Wind is called a renewable energy source because the wind will blow as long as the sun shines.[21]

Harnessing the wind is one of the cleanest, most sustainable ways to generate electricity. Wind power produces no toxic emissions and none of the heat trapping emissions that contribute to global warming. This, and the fact that wind power is one of the most abundant and increasingly cost-competitive energy resources, makes it a viable alternative to the fossil fuels that harm our health and threaten the environment.[23]

5.4.2 Wind speed

How fast it blows, how often, and when–plays a significant role in its power generation cost. The power output from a wind turbine rises as a cube of wind speed. In other words, if wind speed doubles, the power output increases eight times. Therefore, higher-speed winds are more easily and inexpensively captured.

Wind speeds are divided into seven classes–with class one being the lowest, and class seven being the highest. Wind turbines operate over a limited range of wind speeds. If the wind is too slow, they won't be able to turn, and if too fast, they shut down to avoid being damaged. Ideally, a wind turbine should be matched to the speed and frequency of the resource to maximize power production.

Table 1: Classes of Wind Power Density at Heights of 10 m and 50 m

Classes of Wind Power Density at Heights of 10 m and 50 m				
	10 m		*50 m*	
Wind Class	*Wind Power Density (W/m²)*	*Speed (m/s)*	*Wind Power Density (W/m²)*	*Speed (m/s)*
1	0	0	0	0
	100	4,4	200	5,6
2	150	5,1	300	6,4
3	200	5,6	400	7
4	250	6	500	7,5
5	300	6,4	600	8
6	400	7	800	8,8
7	1000	9,4	2000	11,9

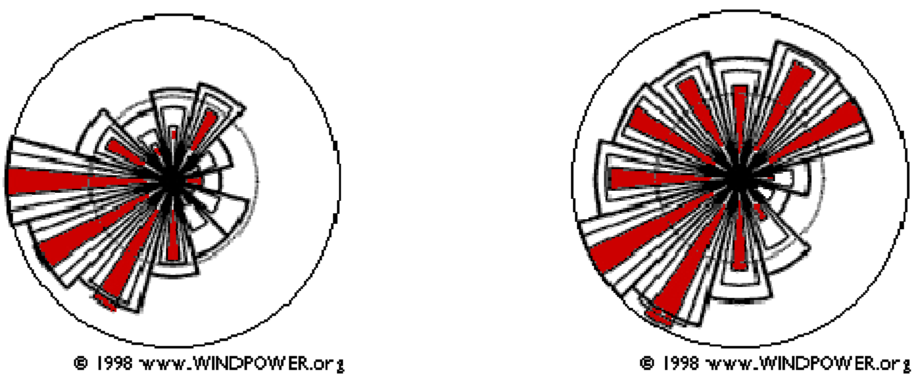
Source:http://www.ucsusa.org/clean_energy/renewable_energy_basics/how-wind-energy-works.html

5.4.2.1 Wind speed variation over location

Strong winds usually come from a particular direction. To show the information about the distributions of wind speed, and the frequency of the varying wind directions, one my draw a so-called wind rose on the basis of meteorological observations of wind speeds and wind directions.[22]

Wind rose provide information on the relative wind speeds in different directions, i.e. each of the three sets of data (frequency, mean, wind speed, and mean cube of wind speed) has been multiplied by a number which ensures that the largest wedge in the set exactly matches the radius of the outermost circle in the diagram.[22]

Figure 12 : Two examples of Wind Rose



These diagrams chart the wind patterns at a given turbine location, based on prevailing wind speed from various directions. Most turbines will have an "upwind" side where little sound propagates.

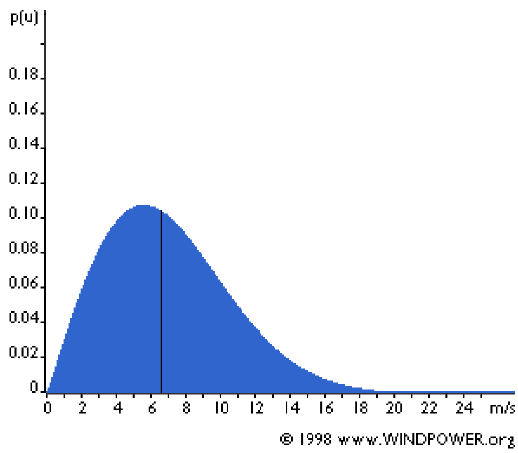
Wind roses vary from one location to the next. They actually are a form of meteorological fingerprint. Wind roses from neighboring areas are often fairly similar, so in practice it may sometimes be safe to interpolate (taken a average) of the wind roses from surrounding observations. If you have complex terrain, i.e. mountains and valleys running in different directions, or coastlines facing in different directions, it is generally not safe to make simple assumptions like these. The wind rose, once again, only tells you the relative distribution of wind directions, not the actual level of the mean wind speed.[22]

A look at the wind rose is extremely useful for siting wind turbines. If a large share of the energy in the wind comes from the particular direction, then you will want to have as a few obstacles as possible, and as smooth a terrain as possible in that direction, when you place wind turbines in the landscape. You should note, however, that wind patterns may vary from year to year, and the energy content may vary (typically by some ten per cent) from year to year, so it is best to have observations from several years to make a credible average. Planners of large wind parks will usually rely on one year of local measurements, and then use long-term meteorological observations from nearby weather station.[22]

5.4.2.2 Wind speed variation over time

The wind is highly dynamic phenomenon not only on the short term due to turbulence, but also on the long term due to the varying weather conditions. So there is not only a locations dependency but the wind also varies at time. It is very important for the wind industry to be able to describe the variation with time of wind speed. Turbine designers need the information to optimize for design of the turbines, so as to minimize generating cost. Turbine investors need the information to estimate their income from electricity generation. The probability of the occurrence of a certain wind speed can be described with the Weilbull distribution.[22]

Figure 13: The Weilbull Distribution



5.4.3 Possibilities of usage

Two possibilities of using wind energy exist:

- Direct transformation of energy of wind to mechanical work, e.g. water pumping
- Direct transformation of wind energy into electricity which can then be supplied to the network or used in the given locality.

Systems independent of the network (grid-off) – autonomous systems – serve to local supplies of electricity (micro power plants). Bigger autonomous systems make use of traditional windmill generating stations with back-up sources (with accumulation) modified for island operation. Emphasis is placed on minimum energy losses and using energy saving appliances. [14]

Systems supplying energy into the network (grid-on) – are the most widespread and used in areas with high wind potential. They serve solely for commercial electricity production. It is an unsteady power source (similarly as in the case of solar energy), usually used as a complement of classic energy sources. Its disadvantage is dependence on weather, day time and season. [14]

5.4.4 Division of wind engines

Today's wind turbines are much more lightweight than the turbines used on windmills of old. The wind turbine is usually standard in design, consisting of three rotor blades. The energy output of a wind turbine is determined largely by the length of the blades, which installers and engineers call "sweep."[24]

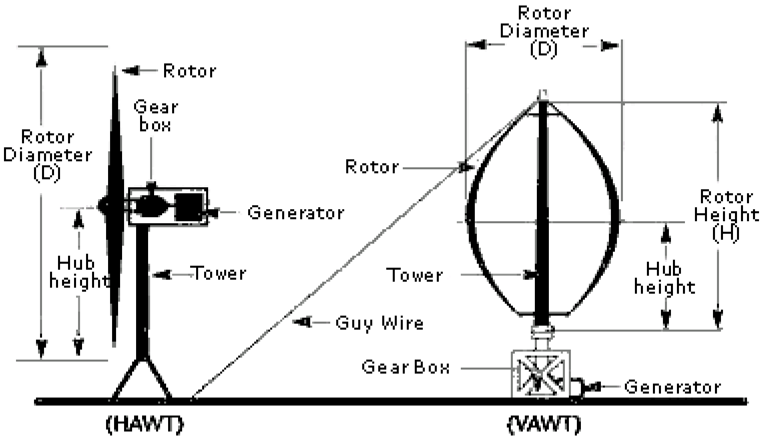
Wind turbines can be separated into two types based by the axis in which the turbine rotates. The most popular turbine design is the horizontal axis wind turbine (HAWT). Vertical axis wind turbines (VAWT) are less frequently used. The HAWT is more practical and popular than the VAWT, and that is the assumed focus of most wind turbine discussions.

ith the horizontal axis, there are two ways of positioning the turbine, either upwind or downwind:

- a horizontal upwind turbine, the wind hits the turbine blade before it hits the tower
- a horizontal downwind turbine, the wind hits the tower first.

These have varying effects on turbine wear and tower stress.[24],[25]

Figure 14: Types of Wind turbines based by the axis in which the turbine rotates

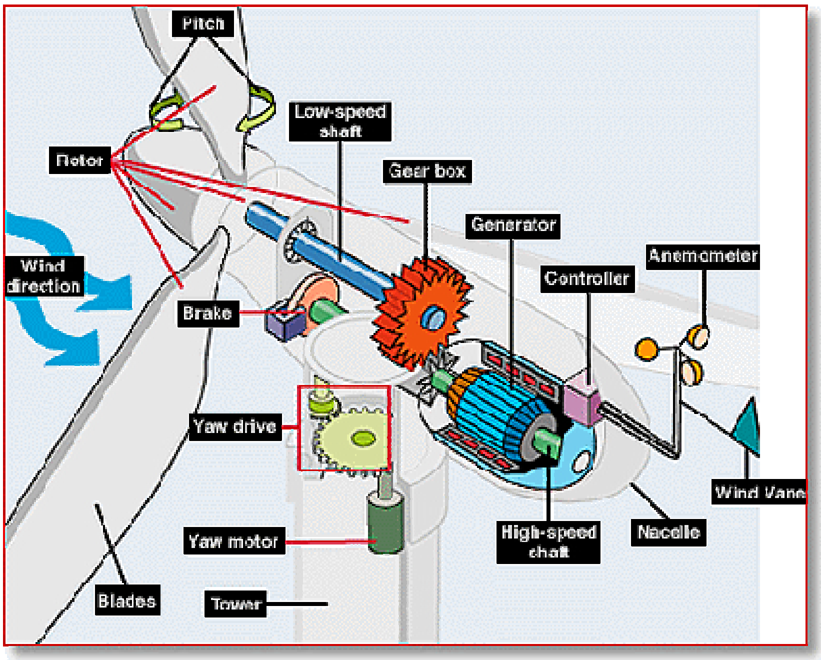


Source: http://www.thesolarguide.com/wind-power/turbine-types.aspx

5.4.5 The Mechanics of Wind Turbines

Modern electric wind turbines come in a few different styles and many different sizes, depending on their use. The most common style, large or small, is the "horizontal axis design" (with the axis of the blades horizontal to the ground). On this turbine, two or three blades spin upwind of the tower that it sits on.

Figure 15: The Mechanics of Wind Turbines



Source:http://www.ucsusa.org/clean_energy/renewable_energy_basics/how-wind-energy-works.html#The_History_of_Wind_Power

5.4.6 Choosing the best site

Decisive indicators of assessing a concrete locality (for using wind potential) are two basic parameters:

- average wind speed,
- occurrence of wind direction

It is suitable to set a distribution characteristic in order to assess a concrete locality. This is a division of wind speed frequency ascertained by continual measurement of speed in the height of rotor axis. At least yearly measurement compared to long-term indicators from near meteorological stations is ideal. Individual years can show significant differences. Of the above follows that these input data are important:

- measured average speeds of wind including direction occurrence
- amount and parameters of obstacles causing turbulence and preventing laminar streaming of wind (vegetation, trees, buildings, houses)
- course of yearly outside temperatures or other unfavorable meteorological phenomenon (e.g. icing causing cut offs)
- altitude (air density)
- possibility to locate suitable technology
  - bearing capacity of subsoil
  - accessibility of location for heavy mechanisms
  - distance from connection to VVn[3] with sufficient capacity
  - distance from habitation which should be sufficient to minimize disturbance of inhabitants
  - degree of interference with the surroundings
  - property rights to the lot [14]

5.4.7 Wind and environment

The most serious environmental drawbacks to wind machines may be their negative effect on wild bird populations and the visual impact on the landscape. To some, the glistening blades of windmills on the horizon are an eyesore; to others, they're a beautiful alternative to conventional power plants.[21]

5.5 Water energy

Total amount of water on Earth is estimated to 1 337 mil. km^3. Yearly totals of accessible fresh water represent approximately 0,015% of total amount of water on Earth. [9]

Water energy can be divided into:

- energy of sea
- energy of sea streams
- energy of rivers, streams and brooks

World Ocean is a term used for all water that can be found on Earth surface except for water on continents like rivers, lakes and groundwater. World oceans concentrate 97% of total amount of water on Earth. Water surface of minimum 11 600 km^2 is called sea. Upper layer with variable temperature is called ocean troposphere. Lower layer, more thermally homogeneous is labeled ocean stratosphere. The border between them varies between 100 to 1000 m of depth. Temperature varies between 29° a -2 °C when ice begins to form.[9]

5.5.1 Ocean Energy

The ocean can produce two types of energy: thermal energy from the sun's heat, and mechanical energy from the tides and waves.[26]

Energy exists in the oceans in several different forms, which have different origins. Generating technologies for deriving electrical power from the ocean include tidal power, wave power, ocean thermal energy conversion, ocean currents, ocean winds and salinity gradients. Three of the most significant forms are marine currents, caused by tidal effects and thermal and salinity differences, ocean waves, generated by the action of winds blowing over the ocean surface and ocean thermal energy conversion.

Tidal power requires large tidal differences which, in the world, occur only in some places. Ocean thermal energy conversion is limited to tropical regions, such as Hawaii, and to a portion of the Atlantic coast. Wave energy has a more general application, with potential along the California coast.[27]

5.5.1.1 Marine Currents

Kinetic energy from tidal currents can be harnessed using relatively conventional techniques, following similar principles to those for extracting energy from the wind. A number of submarine converters akin to ‘underwater windmills’ have been proposed, although this option requires further development.[27]

Several of the technologies proposed to exploit marine current energy make use of conventional engineering components and systems, but further work is required to:

• develop efficient converters which produce electrical energy at low unit costs.

• prove the reliability and durability ('survivability') of these converters at low operational and maintenance costs.[27]

5.5.1.2 The Marine Currents Resource

The fastest oceanic non-tidal currents are derived by a complex process involving the adsorption of solar radiation in the ocean and atmosphere. This is followed by a transformation and redistribution from the Equator towards the poles by moving currents of air and water, and finally a focusing of the oceanic currents on the western edges of ocean basins (or the eastern coasts of continents) by the Earth's rotation. The Gulf Stream in the Atlantic, the Kuroshio off Japan and the Agulhas-Somali system on the east African coast form the main current systems.

Tidal currents are the consequent flow of ocean water due the rise and fall of tides. Other factors such as salinity and local temperature differences also make a contribution to the movement of ocean water. This can be magnified by underwater topography, particularly in the vicinity of land, or in straits between islands and mainlands.[27]

The tides are generated by the rotation of the earth within the gravitational fields of the moon and sun. The relative motions of these bodies cause the surface of the oceans to be raised and lowered periodically, according to a number of interacting cycles:

- A half-day (semi-diurnal) cycle, due to the rotation of the earth within the gravitational field of the moon. This results in a period of 12 hours 25 minutes between successive high waters.
- Daily (diurnal) tides occur in some regions such as the Gulf of Mexico. These have only one high tide and one low tide in a 24-hour period.
- A 14-day cycle, resulting from the superposition of the gravitational fields of the moon and sun. At new moon and full moon, the sun's gravitational field reinforces that of the moon, resulting in maximum tides or spring tides. At quarter phases of the moon, there is no reinforcement, resulting in minimum or neap tides. The range of a spring tide is typically about twice that of a neap tide.[27]

The tides create movements of water into and out of bays and estuaries. These movements can create currents, significant tidal ranges or both. In some (amphidromic) regions there is no tidal range but sizeable marine currents can still occur. The processes by which these currents are formed depend on the local topography and vary widely. The currents created by the movements are known as tidal streams or marine currents.[27]

The total power of ocean currents is estimated to be about 5 TW (Isaacs and Seymour, 1973) which is of the same order as global electricity consumption. However, energy extraction is practical only in a few areas where the currents are concentrated near the periphery of the oceans, or through straits and narrow passages between islands and other landforms. Thus, only a small part of the total energy can be converted to electrical or other useful forms of energy.

The power of a current is proportional to the cube of the current velocity. For tidal currents close to the shoreline in estuaries, and in channels between mainland and islands, the velocity varies sinusoidally with time, with a period relating to the different tidal components. Sites of the most interest for exploitation - that is, where exploitation is likely to be most economic - have a maximum current velocity in excess of 1.5 m/s^2. For sites with non-oscillating currents, the maximum current velocity may need to exceed 1.0 m/s before the site is considered economic.[27]

5.5.1.3 Technology of Marine Currents

The technique most commonly considered for exploitation of marine currents employs a turbine, set normal to the flow direction and mounted either on the seabed or suspended from a floating platform. The extractable power, as a function of the turbine rotor diameter for several current velocities, is shown in Figure 11. An alternative concept, comprising a reciprocating wing design, has recently been proposed. This device comprises wings whose attitude to the water is controlled in such a way that the arms reciprocate against a power take-off restraint, such as an hydraulic ram.[27]

Figure 16: Extractable power from marine currents of a given velocity

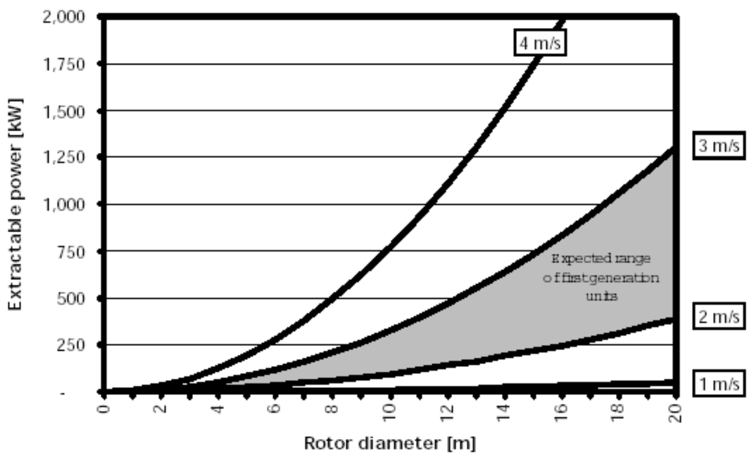
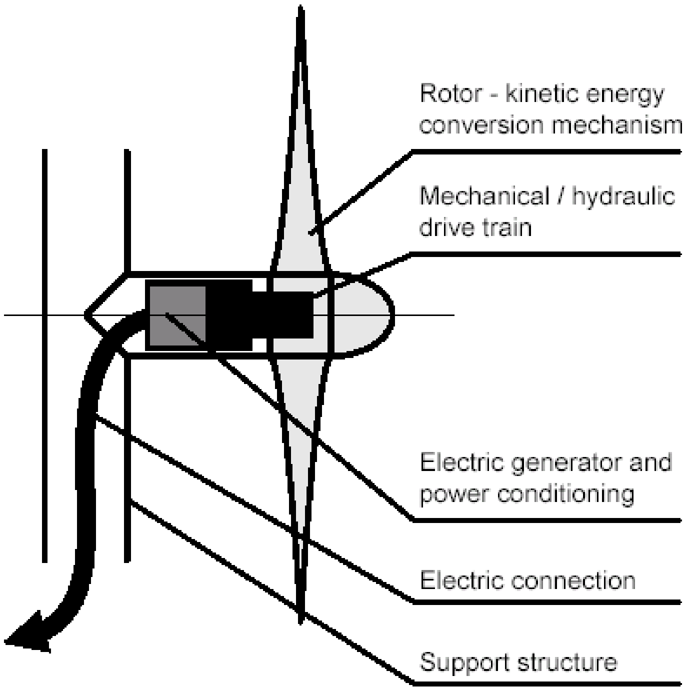


Figure 17: Schematic layout of the components for a marine current turbine



Source : http://www.energy.ca.gov/development/oceanenergy/

As with wind energy conversion, two types of rotor are being considered for tidal stream devices: axial-flow rotors (propeller-type, horizontal axis) and the cross-flow rotors (Darrieustype, vertical-axis). These may have a fixed geometry, or their blades pivoted to allow the pitch to be adjusted. A schematic layout of the principal components of a (horizontal-axis) marine current turbine is shown in Figure 12. The support structure holding the turbine in position may be either fixed to the seabed or floating within a suitable mooring system. The former is most suitable for installation in shallow waters (20-30 m water depth), while floating structures could find application in both shallow and deep water sites (50 m depth or greater).[27]

The first generation of tidal stream conversion systems will be based on the use of conventional engineering components and systems in order to achieve reasonable reliability at low costs. A medium-sized turbine, of 10-15 m diameter and 200-700 kW rated power, deployed in as shallow water as possible (i.e. 20-30 m water depth), is likely to be the most economic overall solution for first generation machines (CEC, 1996). The greatest technical problems are likely to arise from the need for adequate operational lifespan and low maintenance costs from machinery operating in the relatively harsh marine environment.[27]

Second generation systems may follow these, introducing specialized components such as low speed multi-pole electrical generators, hydraulic transmission systems, etc.

Some novel concepts are currently under developed, including advanced rotor designs and control techniques. The devices which ultimately employ these systems may be considered third generation systems.[27]

5.5.1.4 Economics and Environmental Impacts of Marine Currents

The predicted cost of energy from the tidal stream devices proposed is strongly dependent on:

- the size of machine
- the load factor of the power take-off system
- the running costs
- the choice of economic parameters[27]

The environmental impacts of submerged marine current turbines will be low. The main areas of concern are likely to be with regard to navigation and fishing. Large-scale installations, whereby the downstream current velocity is altered significantly across the width of an estuary, may have consequences for the transport of sediments and downstream ecosystems. In the development of demonstration and later commercial plants, site-specific environmental impact assessments will be needed to fully evaluate such effects.

5.5.1.5 Wave Energy

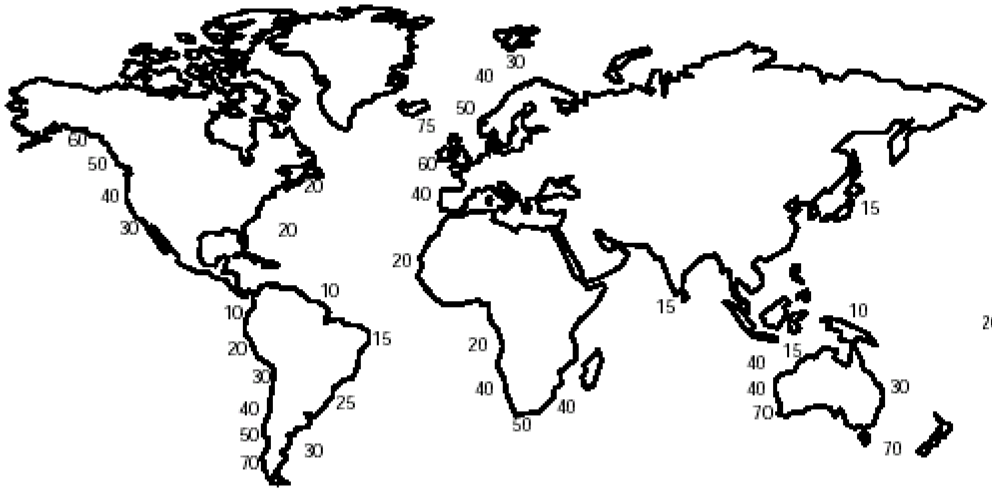
Converting the kinetic energy present in ocean waves to electrical energy or other useful products is a formidable engineering challenge, and requires the development of new technologies to a greater extent than harnessing some of the other renewable energy sources.[27]

5.5.1.6 The Wave Energy resource

Wave energy can be considered a concentrated form of solar energy. Winds are generated by the differential heating of the earth, and as they blow over large areas of water, part of their energy is converted to waves. The amount of energy transferred, and the size of the resulting waves, depends on the wind speed, the length of time for which the wind blows, and the distance over which it blows, (the 'fetch'). Energy is concentrated at each stage in the conversion process, so that original solar power levels of typically 100 W/m^2 can be converted to waves with power levels of 10-50 kW per meter of the wave crest length, (the standard form of measurement). Within or close-to the generation area, storm waves known as the 'wind sea' exhibit a very irregular pattern, and continue to travel in the direction of their formation, even after the wind turns or dies down. In deep water, waves can travel out of the storm areas with a minimal loss of energy, and progressively becoming regular, smooth waves or a ‘swell’, which can persist for great distances (i.e. tens of thousands of kilometers) from the origin.

Consequently, coasts with exposure to the prevailing wind direction and long fetches tend to have the most energetic wave climates - e.g. the western coasts of the Americas, Europe and Australia/New Zealand, as shown in Figure 13 .[27]

Figure 18: Global distribution of offshore annual wave power level in kW/m



Source: http://www.energy.ca.gov/development/oceanenergy/

5.5.1.7 Technology of Wave Energy

A large number of different wave energy concepts are currently being investigated by companies and academic research groups around the world. There is no consensus on the best technology, although a gradual convergence towards a few fundamental approaches is expected to emerge in time. Although many working designs have been developed, and numerical and laboratory tests (particularly wave tank-tests) carried out, only a few device concepts have so far progressed to sea testing. Several large demonstration plants with reasonable prospects for commercial viability have recently been built or are currently being built.

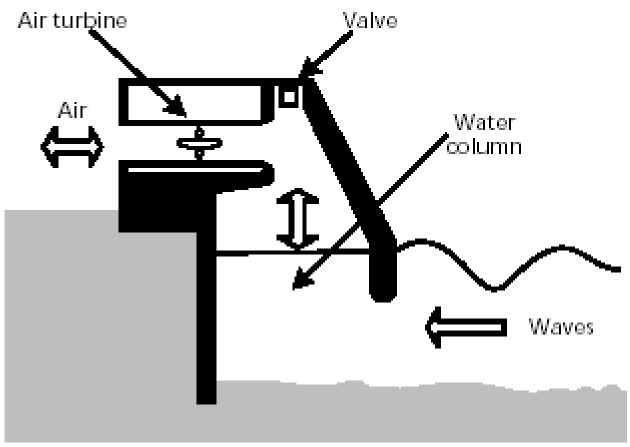
The literature presents several different ways of classifying wave energy devices, e.g. by their energy extraction method, size, etc. For the general review here, it is convenient to adopt a categorization with respect to device location:

- shoreline devices
- near-shore devices (bottom-fixed)
- offshore devices[27]

Shoreline devices

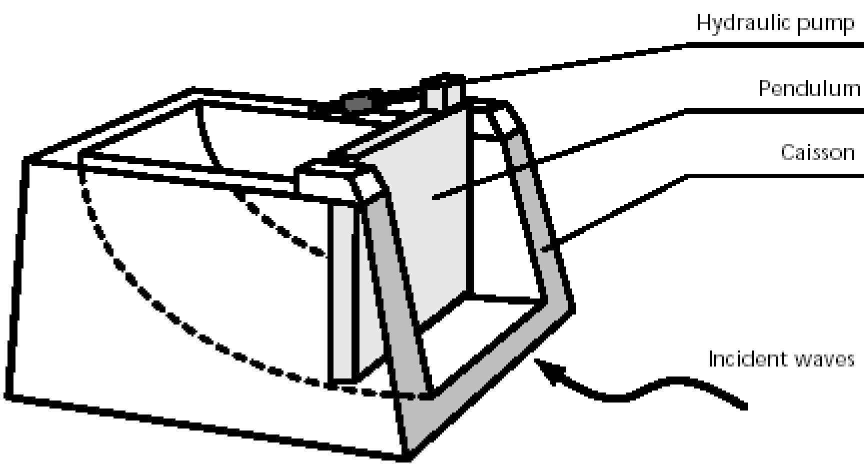
Shoreline devices have the advantage of relative ease-of-access for maintenance and installation, and do not require deep-water moorings, nor very long sub-sea electrical cables. The less energetic wave climate at the shoreline can be partly compensated by natural wave energy concentration due to refraction and/or diffraction. The main types of shoreline device are the oscillating water column (OWC). Another type of shoreline (or bottom-fixed near-shore) device is the Pendulor.[27]

Figure 19: Oscillating Water Column device



Source: http://www.energy.ca.gov/development/oceanenergy/

Figure 20: Schematic of Pendulor



Source: http://www.energy.ca.gov/development/oceanenergy/

Bottom-fixed near-shore devices

Bottom-fixed near-shore devices are intended for shallow waters (typically 10-25 m water depth). The OWC is again the main type of bottom-fixed near-shore device. A way of building the power plant at relatively low costs consists of incorporating it into a breakwater, whose primary purpose is harbor or coastal protection.[27]

Offshore devices

Offshore wave energy devices are intended to exploit the greater energy content of waves found in deeper water, (e.g. deeper than 50 m). While various analyses and model tests of device designed for offshore use suggest they have good prospects for commercial development, no full-scale offshore device has yet been demonstrated at sea.[27]

5.5.1.8 Economics and Environmental Impacts of Wave Energy

It is difficult to estimate realistically the unit costs of electrical energy produced from the waves since the few existing schemes have been prototypes with the additional costs incurred by such a stage of development. However, the estimated costs have shown a steady decrease with time, despite the little financial support received in recent years. It should be noted that the cost of energy produced is a function of local wave climate and, in the case of shoreline devices, is site specific. The costs of a number of devices have been evaluated in the last UK review of wave energy, as reported by Thorpe (2000). This shows that there have been significant reductions in the predicted generating costs of devices. It appears that several devices already have the potential to provide cheaper electrical energy for small islands and remote coastal communities, which depend on relatively expensive diesel generation.[27]

Wave power generation is generally considered environmentally benign. For shoreline power plants, the main negative impacts are visual intrusion and noise from some designs of air turbines. Near-shore and offshore plants may constitute obstacles to coastal marine traffic and, when deployed in large numbers, may promote modifications to coastal dynamics. Other impacts - on the ecosystems, fishing and recreation - may also occur. Most of these effects can be minimized and, in some cases, eliminated. A detailed environmental impact assessment (EIA) will often be required. A strategy for the assessment and quantification of environmental impacts needs to be developed, although the underlying principles of EIA are well developed.[27]

5.5.1.9 Ocean Thermal Energy Conversion (OTEC)

OTEC, or Ocean Thermal Energy Conversion, is an energy technology that converts solar radiation to electric power. OTEC systems use the ocean's natural thermal gradient—the fact that the ocean's layers of water have different temperatures—to drive a power-producing cycle. As long as the temperature between the warm surface water and the cold deep water differs by about 20°C, an OTEC system can produce a significant amount of power, with little impact on the surrounding environment. The oceans are thus a vast renewable resource, with the potential to help us produce billions of watts of electric power. This potential is estimated to be about 10 13 watts of base load power generation, according to some experts.[28]

Types of OTEC

There are basically three types of OTEC processes:

- closed-cycle
- open-cycle and
- hybrid-cycle.

In the *closed-cycle system*, heat transferred from the warm surface sea water causes a working fluid (such as ammonia, which boils at a temperature of about -33°C at atmospheric pressure), to turn to vapor. The expanding vapor drives a turbine attached to a generator which produces electricity. Cold sea water passing through a condenser containing the vaporized working fluid turns the vapor back into a liquid which is then recycled through the system.[29]

Open-cycle OTEC uses the warm surface water itself as the working fluid. The water vaporizes in a near vacuum at surface water temperatures. The expanding vapor drives a low-pressure turbine attached to a generator which produces electricity. The vapor, which has lost its salt and is almost pure fresh water, is condensed back into a liquid by exposure to cold temperatures from deep ocean water. If the condenser keeps the vapor from direct contact with sea water, the condensed water can be used for drinking water, irrigation or aquaculture. A "direct contact" condenser produces more electricity, but the vapor is mixed with cold sea water and the discharge water is salty. That mixture is returned to the ocean. The process is repeated with a continuous supply of warm surface sea water.[29]

Hybrid systems use parts of both open- and closed-cycle systems to optimize production of electricity and fresh water.[29]

5.6 Greece

5.6.1 Factual information

5.6.1.1 Geography & population

Greece has a surface area of 131940 km^2, including an archipelago of more than two thousand islands. Greece is a peninsular country located at the southern part of South-East Europe. There are several mountains leaving arable land which corresponds to only 21.1 % of total surface. Greece has a coastal line of 14,220 km. Greece's climate is temperate and mild, with wet winters and hot dry summers.

Greece counts 11 million inhabitants and approximately 4.7 million households.

5.6.1.2 Economy and Energy Demand

Greece is since 1981 a member of the European Union and since 2002 a member of the European Monetary Union. Greece has a market economy with the public sector accounting for 40% of GDP and with per capita GDP slightly above 70% of the leading euro-zone economies. Tourism provides 15% of GDP, agriculture 7% and industry 22%. In purchasing power parity, Greece's GDP per capita was 15 thousand Euros in 2004.

Over the last five years GDP growth was steadily higher than 3.5% per year, in real terms. Inflation is constantly around 3% on an annual basis. Unemployment is high, exceeding 10% of active population. Public debt, being higher than 110% of GDP, and public budget deficit which exceeds the EU stability pact criterion of 3% of GDP are the most important problems of the Greek economy. Public debt, inflation and unemployment are all above the euro-zone average.

The services sector accounts for 70% of total value added and manufacturing accounts only for 11.7%. There exist no more than 200 industrial plants that are heavy energy users, among which only 50 are directly connected to high voltage power. Iron and Steel, nickel and other metals, aluminum melting, cement and basic chemicals are the most important heavy energy-using industrial activities.

The use of primary energy per capita is 75% of the EU-15 average but energy intensity is higher by 25% of the EU-15 average. Electricity consumption per capita is in Greece at 80% of the EU-15 average. Energy intensity has improved by 8% over the last 15 years, but deteriorated in houses and in the tertiary sector by more than 15% over the same period. The use of electricity is expected to grow over the next ten years at rates slightly above GDP growth, as it was the case over the last fifteen years. There is a significant potential for more rational use of energy in buildings and in the transportation sector.

5.6.1.3 Energy Supply

Greece has large endowments of lignite of low calorific value, but has little hydrocarbon resources. These lignite endowments have a large influence on the energy balance and as a consequence on the environmental issues as well.

Estimations of Greece fossil reserves:

Lignite: 3.5 Gt (exploitable through open air mines) which implies more than 50 years of reserve at current utilization level; however opening of new lignite mines involves considerable environmental damages and is very unlikely given the current land use constraints; despite their low calorific value (0.125 toe per ton) the lignite resources extracted from the currently open mines are very competitive in economic terms;

Hydrocarbons: The proven oil reserves are 1.2 Mt and those of gas 1 Gm3.

Greece has a considerable technical potential of renewable energy resources. The hydro potential is estimated at 84 TWh/year, but generation from lake reservoirs is very unlikely to exceed 4500 GWh annually. The deployment of small hydro generation is very limited due to environmental restrictions. The wind potential is important (theoretically up to 10,000 MW) but very little exploited mainly due to the fact that most of the windy areas are deprived from high voltage power grid. Solar radiation is also important in Greece.

Natural gas was introduced into the Greek energy balance since the late 90s after the construction of a gas pipeline of 8 bcm capacity which goes from the North to the South of Greece and a LNG gasification terminal in the Attiki region. Despite this infrastructure, gas is penetrating very slowly in final energy consumption. Currently 2.1 bcm of gas are imported from Russia and 0.5 bcm of LNG gas from Algeria. Most of this gas (77%) is used in power generation. Gas is the fastest expanding energy form. This is expected to continue in the next two decades. Energy imports of Greece are expected to increase significantly in the future, consisting mainly of gas to be used mainly in power generation and crude oil to be used mainly in transportation.

Import dependency of Greece, being 67% in 2000, may reach 75% over the next twenty years. Gas imports are considered an important policy issue, given the high dependence of incremental power generation on gas and the current dependence on a single supplier and a single pipeline. This explains the efforts to diversify gas imports by origin and to expand the LNG terminal as well as the priority given to new projects of gas interconnection, linking

Greece with Turkey and with Italy. The new gas linkage to Turkey is under construction (expected to finish by 2008).

The production of crude oil is negligible and covers less than 1 % of the oil needs. Crude oil imports come for 50% from Russia, 25% from Saudi Arabia and 13% from Iran. With 4 refineries with a quasi-stable capacity (0.40 Mbl/d since 1990), Greece is largely over-equipped compared to its needs. The modernization of its refineries allows the country to export light products (gasoline, jet fuel) but import diesel and heavy oil.

The main energy balances and indicators are summarized in the table below.

Table 2: The main energy balances and indicators

[Mtoe]	2000	2005	[Mtoe]	2000	2005
Gross Inland Consumption (=TPES)	**28,08**	**32,39**	**Final Energy Demand (TFC) by Sector**	**18,48**	**21,77**
Solids	9,04	9,95	Industry	4,4	5,49
Oil	15,93	19,97	Residential	4,48	5,03
Natural Gas	1,71	2,34	Tertiary	2,4	2,89
Nuclear	0	0	Transport	7,2	8,35
Electricity	-0,01	0,5	**Final Energy Demand (TFC) by Fuel**	**18,48**	**21,77**
Renewable energy forms	1,41	1,97	Solids	0,89	0,82
Net imports	**21,98**	**25,71**	Oil	12,46	12,95
Import Dependency [%]	**70%**	**70%**	Gas	0,24	1,64
Energy Intensity Indicators (1990 = 100)			Electricity	3,71	4,63
Industry (Energy on Value Added)	94,52	92,63	Heat	0,19	0,32
Residential (Energy on Private Income)	110,35	104,74	Other	0,99	1,4
Tertiary (Energy on Value Added)	126,46	120,87			
Transport (Energy on GDP)	98,38	91,97			

5.6.1.4 Electricity

In 2004, 57 TWh of electricity were produced in Greece of which 52 TWh in the mainland (Greece's interconnected system) and 5 TWh in non-interconnected islands. In the same year, net imports were 3 TWh and transit flows to Italy were 1.5 TWh. Net generation electricity was 49 TWh in the mainland and 4.5 TWh in the non-interconnected islands. Electricity was mainly generated from lignite (32.5 TWh), followed by gas (8 TWh), hydro-reservoir (4.9 TWh) and oil products (2.7 TWh). In the non-interconnected islands almost all electricity was generated by using oil. Renewables (except hydro-reservoirs) contributed by 0.9 TWh only.

Peak electricity demand takes place in July and is increasing faster than total electricity demand because of the fast penetrating air conditioning systems. On July 12, 2004, Greece experienced a severe black out which was due to insufficient generation capacity, mainly in the South of the country near Athens, where most of the load is located. At the moment of power supply disruption the peak load attained 9370 MW, which is the maximum load ever seen. Estimations say that peak demand could have been 9600 MW if the disruption was not taken place.

The disruption revealed two fundamental problems of the Greek power supply system. First, the geographical imbalance between generation plants mainly located in the North (where lignite and hydro is located) and demand load mainly concentrated in the South. Grid reinforcements and measures aiming at managing reactive power proved not sufficient to prevent the disruption. The second problem is lack of investment in new generation plants, a failure which is attributed to the incomplete and distorted electricity market liberalization.

All power plants currently in operation in Greece date from the times of centralized planning of investment, as implemented by the state-owned monopoly company (PPC SA) until 2000. Except small scale renewables, not a single new plant was constructed on a private basis since 2000. The electricity market is fully controlled by the dominant vertically integrated company, namely PPC SA, who owns almost 100% of current generation capacity, holds 97% of electricity customers and owns the entire transportation and distribution grid. Although, since 2004 all customers, except the residential users and those located in non-interconnected islands, are eligible, few customers changed supplier. Currently, the few competitors of PPC are electricity traders who import up to 200 MW in total from Bulgaria. They are supplying peak needs of few industrial customers.

The installed power generation capacity of about 13.7 GW (gross) is mainly based on lignite firing plants (5.2 GW), followed by hydro-reservoir plants (3 GW), oil plants (2.7 GW of which 1.6 GW located on non-interconnected islands) and gas plants (1.9 GW of which 1 GW corresponds to modern combined cycle gas plants). Small-scale renewables have a total capacity of 710 MW of which 590 MW are wind parks. Cogeneration is poorly developed in Greece: 110 MW of CHP plants in industrial users, 90 MW in refineries and a small scale CHP district heating from lignite power plants in the North of Greece.

All analytical studies have identified lack of generation capacity especially in the South of Greece. Expansion of the generation park is expected to take place over the next 10 years mainly through combined cycle gas plants. Currently two new combined cycle plants of a total capacity of 800 MW are under construction by PPC SA and the state-controlled dominant refinery company. These plants are expected to be commissioned in 2006. It has been identified that an additional capacity of 1200 to 1500 MW of combined cycle gas plants are necessary in the coming 3-7 years. According to the amended electricity law (in 2003), financial incentives will be set in place to attract private generation companies for the delivery of this additional capacity. This policy package has not been yet implemented, so there is still uncertainty about the deployment of this private investment. The same law allowed PPC to replace old power plants by new ones up to a total capacity of 1600 MW. It is expected that PPC will build in the future 1200 MW of combined cycle gas plants and a new 400 MW lignite plant. New coal plants are expected to emerge beyond 2015. New hydro-reservoir lakes are practically not possible. There are no prospects about the deployment of nuclear energy in Greece.

Despite its considerable wind power potential and the subsidization support schemes that are in place, the development of wind power is progressing slowly. This is mainly due to two reasons: the implementation difficulties related to land use planning and other administrative procedures, and; to the lack of high voltage power grid in the windy areas. More than 4,000 MW of wind parks are in the pipeline, but it is expected that less than 2,000 MW will be effectively constructed in the next 510 years. The realistic potential for small hydro plants is not higher than 200 MW. The development of biomass plants is also slowly progressing, except for plants exploiting landfill gas. There are prospects for the development of high enthalpy geothermal energy (up to 100 MW), but this is expected beyond 2010.

Since 2002, Greece is linked with Italy through a 500 MW of DC power interconnection. This cable has allowed for extensive transit flows from the Balkans to Italy, an activity which is expected to continue in the future. It is expected that by 2008 Greece will also be connected with Turkey through a new high voltage line currently under construction. The total capacity of power imports of Greece from the northern system cannot exceed 750 MW (this is the NTC capacity) although the physical interconnections have a capacity of 1500 MW. This limited capacity and the constraints from the transit flows to Italy restrict the overall contribution of imported electricity to the Greek electricity balance to less than 7-8%. This is not likely to change unless new interconnections with the North are built, a process which might take more than 7-8 years.

The electricity system of Greece, as well as the Balkan grid, are operating, since 2004, under the full synchronous mode of UCTE.

The main electricity balances and indicators are summarized in the table below.

Table 3: The main electricity balances and indicators

	2004	**2005**
Electricity Net Imports [TWh]	0	3,5
Electricity Generation [TWhe]	**53,4**	**62,2**
Hydro	2,11	3,82
Small scale reneables	0,9	1,9
Thermal	49,3	57
- of which lignite	34,2	34,4
- of which gas	5,4	10,7
- of which oil	9,2	11,4
Grid losses [TWhe]	**4,3**	**4,3**
Self consumption including pumping [TWhe]	**4,3**	**4,6**
Efficiency for thermal electricity production [%]	**32**	**33**

5.6.1.5 Environmental issues

As mentioned before, the rich lignite endowments put a considerable load on the environment, both by the mining industry as by the electricity production. Greece has a commitment to limit the increase of greenhouse gas emissions in 2010 to a level of 25% compared to the 1990 level. This commitment has been reflected in the recently approved National Allocation Plan submitted to the European Commission. Achieving this objective raises important policy concerns regarding power generation from lignite. The current national plan states that generation from solid fuels should stagnate over the next 20 years.

The main balances and indicators concerning the C02-emissions are summarized in the table below.

5.6.2 Policy

5.6.2.1 General Framework

Greece's energy policy fits in the EU-integration and the fulfillment of international obligations concerning environmental issues. The energy policy is based on four objectives:

- Security of energy supply
- Economic efficiency – low prices
- Environmental protection
- Regional development

Despite the considerable lignite reserves of Greece, security of supply is an important policy issue because of dependence on imports of hydrocarbons. In relation to environmental policy restrictions, natural gas is considered as the strategic fuel for the medium term, since natural gas is expected to cover the rather fast growing incremental energy needs of Greece, including incremental needs for power generation. Security of supply of gas imports, increase of competition in the upstream gas supply and new interconnections are among the key issues of the energy policy.

The public administration involves the Ministry of Development who has probably the entire decisional power to set the legislation, supervise and control the state-owned companies (who control all energy markets in Greece) and regulate the market and the prices, including the supply prices of gas and electricity. The Regulatory Authority for Energy (RAE) has been established in 2000, but its decisional powers have been extremely limited. In most cases, RAE is only allowed to submit an opinion to the Minister who takes the decisions. The new electricity and gas directives have not yet been transposed to the Greek legal system. The three state-owned energy companies, namely PPC (electricity), DEPA (gas) and ELPE (oil) are dominating the energy markets.

5.6.2.2 Electricity and gas market policy

Since February 2001, liberalization started in the electricity sector. Until July 2004 only customers connected to high and medium voltage grids were allowed to select their supplier. From July 2004, all consumers except the residential ones became eligible. However, a very small number of industrial customers have bought electricity from non PPC supply and all of them for small amounts on top of their current PPC supply contracts. The Greek electricity TSO is an independent state-owned company with no ownership of the grid. To provide third party access, the TSO rents the grid from PPC according to regulated tariffs.

The lack of private investments in power generation is probably the most important policy issue. It was expected that such investments would enable both security of electricity supply and competition in the electricity market. This expectations proved to be wrong for various reasons, such as: a) the dominance of PPC in the supply market; b) the regulation of supply prices to a low level, below the costs calculated with private rates of return on capital, and c) the difference between PPC's power mix which hedge against price variability (as lignite has a substantial part in the mix) and the mix of private competitors which is based on gas produced electricity and little imports. This policy failure explains the reform of the power market organization that took place in 2003 but has not been yet implemented. According to the new amended electricity law, a mandatory electricity pool will be established in Greece. The pool will probably operate in 2006 and will involve all PPC's plants, one plant of the state-owned refinery company and few traders who import electricity. In 2006, no more than 600 MW over a total of 12,000 MW will be managed by non PPC entities. The amended law also envisages the establishment of a capacity certificate system which will impose on suppliers the obligation to hold an adequate number of certificates issued by Greek power plants. The certificates will be tradable and the possible contracts for differences may provide financial security to future investors. In addition, the Greek TSO who will also be manager of the pool will put in place partial revenue guarantees for some of the new power plants to be constructed by private entities. It is expected that these incentives will be put in place in 2006. Their outcome is however still uncertain.

In the gas market, the entire infrastructure is owned by a vertically integrated state-owned company (DEPA). The gas market is still under a monopoly regime, as Greece being considered as a gas emerging market got an exemption from the previous gas directive. The tariffs for gas transportation and LNG are five times more expensive than in the rest of the EU because of the investment cost of the over-dimensioned infrastructure as compared with the current gas consumption. This is one of the major obstacles to rapid expansion of the use of gas in power generation. However, in order to facilitate gas procurement from new power generation investors, the amended law of 2003 provided for gas market liberalization for power generation users by 1st July 2005. The legislation about gas market organization is still pending. Regarding gas distribution in the cities, a monopoly regime is established which will last for thirty more years.

The most important policy development in Greece relates to the establishment of an internal energy market in the South East of Europe. It is expected that in late 2005, a legally binding treaty will be signed to establish the so-called Energy Community of South East Europe.

5.6.2.3 Environmental policy

Greece has a target for renewable electricity generation of 14% of total electricity in 2010. This is considered as a very ambitious target. Policy measures in place provide for a system of feed-in tariffs for renewable electricity, except large hydro, and for small scale CHP. In addition, subsidies are provided to capital costs of renewable, CHP and energy efficiency investments, covering up to 40% of investment costs. The available funds for subsidization are significant.

As mentioned, Greece participated to the EU emission trading scheme and is expected to be a net buyer of emission rights.

6. Discussion:

The most important authors of books dealing with the issue of renewable resources of energy are Cenka “Renewable sources of energy”, Beranovský “Alternative energyyou’re your house” and Jiříček and Rábl “Alternative sources of energy”. All of them agree that it is necessary to think more deeply about the problem of environmental pollution by current ways of energy production an to search for alternative ways and solutions to present crisis. They emphasize depletion of fossil fuels. Furthermore, they mention the greenhouse effect as one of the most serious problems of this planet which may lead to enormous melting of glaciers and set off a chain reaction resulting in transformed clime of our planet. Renewable resources are very environmentally friendly and their usage would therefore lead to improved environmental quality. For that reason their exploitation should begin as soon as possible.

All authors agree that it is possible to include and exploit renewable resources of energy in any conditions because the range of possibilities of acquiring energy from alternative sources is wide enough. Only the conditions at the given location determine which kind of renewable source of energy would best suit the location in terms of resource availability and realization as well as from the economic point of view in terms of investment returns.

7. Conclusion

This bachelor thesis attempted to point out the great energetic potential of renewable resources of energy. Alternative sources of energy are successfully used in some countries of the world for many years now. In Europe these are above all developed countries as Germany, Netherlands, Great Britain, France, Sweden etc. Other European countries such as the Czech Republic for example basically begin with this kind of energy sources' usage. Although many projects exist already, they could more precisely be labeled as get-acquainted ones. Then there are countries which either do not take the possibility of using non-traditional energy sources into consideration or do not know about it. These are mostly developing countries who deal with serious crises and their greatest problem is financial provision.

As has been mentioned above in the discussion, firstly it is necessary to tackle this delicate problem, eventually try a solution hand in hand with renewable resources. Alternative resources of energy do not harm the environment (as exploiting and using fossil fuels does) and because a wide range of these sources exist. As such they are a very good choice for any developing country to increase its energetic income.

Solar energy is a good choice either used to produce electricity or heat everywhere where the intensity of solar radiation and the angle between incident rays and collector surface or photovoltaic cells are sufficient.

Second energy source in the form of wind power carries a small question mark. According to Cenka installation of a windmill generating station pays off in locations where average yearly wind speed reaches minimum 4.8 m/s. Other internet servers give sufficient average yearly speed of wind around 12 m/s. A problem could be incorporation of windmill generating stations into the landscape as they represent an unusual and unfitting element.

The last source of alternative energy in the form of water energy is to my opinion the most problematic. There are many possibilities for usage, however, they have not been sufficiently explored yet.

To conclude, I would like to say that renewable resources are a very interesting topic with a great impact on the future of the civilization. This thesis was beneficial for me personally both from the methodical point of view and as a source of new highly attractive information. I believe I accomplished the given goal and I clarified the principles of these issues.

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[28] http://www.otecnews.org/whatisotec.html

[29] http://hawaii.gov/dbedt/info/energy/renewable/otec

Annex 1 – List of used abbreviations:

°C	-	Degree of Celsius – temperature unit
A	-	Amper – basic unit of el. current in SI system
h	-	hour – unit of time (1h = 60 minutes = 3600 seconds)
ha	-	hectar - acreage (1 ha = 10 000m2)
J	-	joule – unit of energy, labor
kg	-	kilogram – basic unit of mass in SI systém
l	-	litre – unit of capacity
m	-	meter – basic unit of length in SI systém
m^2	-	square meter – acreage
m^3	-	cubic meter – basic unit of kapacity in SI systém
min.	-	minute – time unit
Pa	-	pascal – pressure unit
s	-	second - basic time unit in SI systém
ton	-	ton – mass unit (1 ton = 1000 kg)
V	-	volt – basic unit of electric pressure in SI systém
W	-	watt – unit of power
CZ	-	Czech republic
EU	-	European union
GDP	-	Gross Domestic product
Mt	-	Mega tons
Gt	-	Giga tons
Gm3	-	Mega cubic meters
MW	-	Mega Watt
GW	-	Giga Watt
MWh	-	Mega Watt hour
TWh	-	Terra Watt hour
LNG	-	Liquefied natural Gas
PPC SA	-	Public Power Corporation of Greece (electricity)
DEPA	-	Public Gas company (Greece)
ELPE	-	Public Oil company (Greece)
CHP	-	Combined Heat and Power
DC	-	Direct current
RAE	-	The Regulatory Authority for Energy