Wind

Introduction

Man has been using wind energy for thousands of years. The Egyptians were the first to experiment sailing on the Nile 5,000 years ago, while the first wind mills were made by the Babylonians and date back to the seventeenth century B.C. In the centuries that followed, wind mills spread all over the Middle East. Between 1200 and 1300 they were used in Europe too, especially in the northern countries. Even Leonardo da Vinci worked at perfecting these machines. In 1887, the French Duc de La Peltrie built the first aero generator to produce electrical energy. Today aero generators are utilised to obtain energy from the wind. These modern wind mills exploit the wind to make the blades of a big propeller rotate: the latter is connected to a generator that transforms mechanical energy (deriving from the movement of the blades) into electrical energy. Aero generators vary in size and shape. In fact, they can have one, two or three blades of varying lengths: those with 50-centimetre-long blades are used as battery chargers; those with 30-metre-long blades are capable of producing energy to satisfy the daily electricity requirements of about 1000 households. When many aero generators are connected they form a wind-farm, which are real power stations. There are both on shore and off-shore wind farms.

Aeolian knowledge

What is it

Aeolian energy is the energy that derives from the wind.
Men have used its power since ancient times to navigate or to move windmill blades, to grind cereals, to squeeze olives or pump water. Only in the last few decades wind energy has been used to produce electricity.
The word “Aeolian” comes from Aeolus, the Greek god of wind, whose name “aiolos” means “fast”.
Electric power is obtained by exploiting the kinetic energy of the wind that makes the propeller blades move. These are connected to a generator that transforms mechanic energy (blade rotation) into electric power. These modern windmills are called aerogenerators.

Wind formation

Wind is an atmospheric phenomenon due to the heating of the sun. The sun radiates on the Earth a power of 1.74×10^{17} Watts: about 2% of it is converted into wind energy.
The Earth releases the heat received from the Sun, but this is hardly homogeneous. In those areas where less heat is released, the pressure of atmospheric gases increases, while in those areas where more heat is released, the air becomes hot and the gas pressure is reduced. As a consequence, high-pressure areas and low-pressure areas are formed, which are also influenced by the Earth’s rotation. When different masses of air get in contact, the area with a higher pressure tends to transfer air towards the area with lower pressure. It is the same as when we let a balloon deflate. The high pressure inside the balloon tends to transfer air outside, where the pressure is lower, originating a small airflow. Therefore wind is a more or less rapid air transfer between different pressure areas. The higher is the pressure difference, the faster is the air displacement and the stronger is the wind.

How to measure the wind

A wind is described by two parameters: the strength (related to speed) and direction.
We all know that the wind is not constant, as its strength and direction change.
The wind direction can be observed by simply using a weathercock. In order to class the wind according to its direction people name it after the place the wind comes from. Sometimes the name refers to the geographical origin (Grecale if it comes from Greece; Libeccio if it comes from Libia, Scirocco if it comes from Siria). Some other times, like in the “Wind rose”, winds are referred to by using cardinal points (North-eastern wind, South-western wind).

The wind strength can be indicated either by measuring its speed, i.e. in knots that correspond to miles per hour (1 knot = 1 mile per hour = 1.85 km/h), or by the Francis Beaufort scale.
Speed is measured by the anemometer, a simple wheel exposed to the strength of the wind to measure its rotation speed.
Cup anemometer
One of the most used anemometers is the cup anemometer, where the wind, blowing into the cups, makes them rotate around a vertical axis. An electric or mechanic meter measures the number of turns that take place in a certain time interval. By means of adequate calibration charts it is possible to calculate the wind speed

Wind circulation on the Earth

Air masses are moved by solar heating and in particular by the difference in temperature (gradient) between equatorial and tropical areas.
Solar radiation in equatorial areas is more intense than in tropical areas.
Tropical air, warmer and less dense, tends to go up attracting cold air from tropical areas. When it arrives at the tropics, the warm air cools down and starts to go down. And in this way a continuous equator-poles cycle takes place. Without any other factor, the circulation of winds on the Earth would follow a regular process, like the one that has just been described.
Factors that affect wind circulation
In reality, other geographic-astronomic factors act on air circulation, modifying its movement.
The inclination of the Earth's axis and the revolution of the Earth around the Sun seasonally displace the areas of higher irradiation between the two tropics. Moreover, the Earth's rotation contributes to the alternation of solar irradiation and its surface, scarcely homogeneous, has a different absorption capacity and heat exchange. The Earth's rotation causes another factor that is fundamentally important to understand the wind circulation: Coriolis' acceleration, that produces the typical spiral or rotation movement of air masses.
Another factor determining the direction and the power of the wind is the friction on the Earth's surface, as the wind uses energy to overcome it, as well as the presence of mountain chains, that block or divert the wind path.

The wind and land roughness

The speed of the wind depends, as well as on atmospheric parameters, on land conformation. The rougher the land, the more sudden inclination variations it has, the more forests, buildings and mountains, the more obstacles the wind will meet, the more its speed will be reduced.
In order to define the conformation of a land, four types of roughness have been detected:

- **roughness 0**: the soil is flat, such as the sea, the beach and the snow
- **roughness 1**: open soil with non-farmed land, low vegetation and airports
- **roughness 2**: agricultural areas with few buildings and few trees
- **roughness 3**: rough soil with many variations in soil inclination, forests and villages.

Usually the best position for an aerogenerator is on a land with a low roughness degree.

A bit of history

Man learned how to use the kinetic energy of the wind thousands of years ago. Sailing dates back to at least 10,000 years ago. The first wind mills of which rests were found were Persian and date back to 200 B.C. They were built in a very simple way, with sails mounted on wooden frames. During the following centuries, windmills became common all over the Middle East and became a commonly used machine in the agricultural sector.

Then, between 1200 and 1300 they reached Europe, especially the northern countries. Leonardo da Vinci himself contributed to the evolution of such machines.
More sophisticated technologies were introduced around 1600: the shape of the vanes was improved, and the vanes were streamlined to exploit the wind strength better.
In the Encyclopedie by Diderot and D'Alambert, written towards the end of the 1700s, contains a picture of them. At that time wind power was not exploited to grind cereals but rather to reclaim flooded land.
The invention of the dynamo by the Belgian Gramme in the mid-twentieth century opened up new horizons to the use of water- and wind-energy, and in 1887 the French Duc de La Peltrie built the first aerogenerator in Europe for the production of power: the exploitation of wind energy for the industry was born. In the same period, the United States produced the first "windmill" for the production of electricity (Charles Brush, Ohio, 1890).
The production of electric power from wind energy developed between 1920 and 1930, after the creation of turbines for the processing of hydraulic energy
After a period of oblivion, the oil crisis of 1973 led to a revival of the interest in renewable energy sources, including wind power, which in certain cases is competitive against fossil fuels. Modern mills are faster and more efficient than at the beginning of the 20th century. They have fewer blades and can reach a speed up to five time great than that of the wind, with an energy output doubled as compared to traditional wind mills.

Aeolian plants

Wind generator

The most important way to use wind power is to produce electric power through wind generators, namely aerogenerators.
Electric power is obtained by exploiting wind kinetic energy: airflows move at more than 10 km/h speed making the blades of a propeller turn. They are connected to a generator that transforms mechanic power into electric power. There are different types of aerogenerators, that differ in shape and dimension. They can have one, two or three blades, of different length. Those with 50 cm length are used as battery chargers, while those with 30 cm blades can supply 1,500 kW power, managing to satisfy the daily power need of around 1000 households.
The most popular aerogenerator is made up of a steel tower of 60-100 meter height, with two or three blades that are around 20 metres long. It generates a power of 600 kW, which equals the daily power need of 500 families.
The blades of the wind generator are fixed on a mechanical element called hub and form the rotor. According to the position of the axis, it is possible to distinguish between horizontal and vertical axis rotors. The first ones are the most common and popular; while the second ones have been used since ancient times but only recently they have been subject to studies and researches to improve their efficiency (the main advantages of vertical axes are: their constant functioning regardless of the wind direction, a better resistance even when the wind is strong and turbulent).
The structure of a wind generator with horizontal axis is simple: a support (foundations and tower) with a gondola or nacelle on the top. Inside there is a slow-driving shaft, as well as a turn multiplier, the fast shaft, the power generator and auxiliary devices (braking system and control system).
The rotor (consisting of the hub, on which the blades are mounted) is fixed at the extremity of the slow shaft.
The shape of the blades is designed in such a way that the incoming airflow activates the rotor.
From the rotor, the wind kinetic energy is transmitted to a power generator. The wind generator works according to the strength of the wind. Under 4/5 metres per second it cannot start. The minimum speed allowing the device to provide power is 10/12 metres per second to produce a few hundred kilowatts. When the speed is high (20/25 m/s) the generator is switched off for safety reasons.
The progress made in the design of aeolian rotors in the last 10 years allow them to work at lower wind speed, catching a higher quantity of energy also at higher levels, increasing the quantity of wind power that can be exploited.
Rotors with "mobile" blades have been created: by changing the blade inclination with a different wind speed it is possible to keep the quantity of power produced by the aerogenerator constant.

Onshore wind farm

Several aerogenerators connected together form the wind-farms, which are real electric plants. A wind farm is based on a group of aeolian turbines, placed in the same area, interconnected by a middle-voltage linking net. This net gathers the energy created by each turbine, convoying it to a collection station. Here a transformer converts the middle-voltage electric energy in high-tension electric current, introducing it in the distribution system. A large wind farm may have dozens of aeolian generators and more than one hundred of single turbines, being placed on an area of several km^2: however, being the space of each generator very little, all the places between the turbines could be used for agriculture or livestock holdings.
United States of America currently own the most quantity of wind farms, followed by Germany, Spain and Denmark. Italy is on the fourth place; then we have the United Kingdom, Portugal, France and Ireland. . World's largest wind farm onshore is placed in Roscoe, Texas. This plant owns 627 turbines with a power of 781 MW. The European largest plant is the new Glasgow (Scotland) farm, with 140 turbines, that will give their energy to 180.000 houses, with an effective power of 322 MW.

Offshore wind farm

The most recent wind farms are usually placed offshore, on the sea, far from the coasts, where it is possible to exploit the strong winds not delayed by obstacles. This happens on the sea surface, but also on the great lakes.
Unluckily, the realisation and maintenance costs of these offshore wind farms are more elevated than the onshore ones, because of the transportation costs, the great building problems, the difficulty to anchor their towers on the bottom and, in the end, the corrosive action of the sea water on their structures. For instance, it would be possible to work on a maximum depth of 200 meters, but usually no more than 20 m or not beyond than 20 km from the coast, to allow low costs. Anyway, these marine plants have great productivity advantages. On the sea surface, as matter of fact, winds blow without any obstacle, with a higher speed and with less changeableness. The offshore placement of great wind farms also solve the acoustic and aesthetical problems, the tower being placed beyond the line of the horizon, at least 3 km from the coast. This would solve the danger for the most part of bats and birds, migratory and birds of prey, too.
Some researchers affirm that the creation of undersea platforms and pylon and cable systems could realize, after some time, restocking and biodiversity areas on the sea bottom, like it currently happens with the anchorages of the offshore rigs.
Therefore, the offshore plants represent, according to the most part of the specialists of this sector, the true future of the aeolian energy, for what concerns both the environmental problem and the production potential.
In 2007, the offshore plants produced about the 3,5% of the European aeolian energy, owned for the most part from Denmark and United Kingdom, followed by Holland and Sweden; in 2008 the largest aeolian offshore production happened in the UK, followed by Denmark. At present, the largest offshore wind farm is placed off the Lincolnshire coasts (Great Britain), with an installation power of 194 MW.
Nowadays, we may see great projects for the offshore aeolian: the United Kingdom planned to enlighten every house of the country with the wind farm offshore energy within 2020, while Canada is planning to build an offshore wind farm on the Great Lakes. One of the world's largest offshore wind farm, called London Array, will be built on the estuary of the Thames, with an installed power of 630 MW (then, 1 GW). This plant will give energy to 750.000 houses, about ¼ of the London houses, with 341 turbines placed 12 nautical miles from the coast. Even this European offshore wind farm will be interconnected, also connected with all the onshore farms.

Wind map

In order to produce enough electric power the place where the aerogenerator is installed has to be very windy.
The assessment of the output potential of a wind power plant is a difficult and complex operation, depending on the characteristics of the winds that blow in the area where the plant is to be created. The conformation of a land affects the speed of the wind. Obstacles can strongly influence the speed, power, direction and distribution of winds. For example, as regards mountains, it has been shown that whereas steep slopes create turbulences that are dangerous in terms of

stability and negative in terms of plant efficiency, more gradual slopes favour the concentration of the wind.
In general, the ideal position for an aerogenerator is a land with a limited number of obstacles with an inclination between 6 and 16 degrees.
The wind must be faster than 5.5 metres a second and blow constantly during most of the year.
As for the off-shore wind sites, the best are the ones where the wind exceeds 7-8 metres a second, which have shallow waters (between 4 and 40 metres) and are more than 3 km far from the coast.
The creation of a plant presumes the knowledge of the "wind map" of the area, that shows how and how much wind blows in the interested site.
Moreover, before building a plant, the power, speed and paths of the winds blowing in the selected areas are systematically recorded for extended periods of time.

Types of wind plants

Electric power can be used through two types of plants: plants for isolated users and plants to be connected to already-existing electric networks.
The first type of plant is the one to produce "utility" electric power supplied by small aerogenerators with less than 1 kilowatt power (1-2 metre rotor) to feed equipment in isolated areas, like radio relay stations, detectors, signalling systems, etc. these systems often compete or are used together with photovoltaic systems.
Moreover electricity is produced to supply isolated houses or settlements that are not connected to the network. These installations are made up of small aerogenerators (3-20 kilowatts) and a system (battery) that accumulates electric power when the wind is favourable.
These applications have a limited distribution in industrialized countries, but they could have interesting perspectives in developing countries with strong winds.
The second type of Aeolian installations is connected to the network and divided into two categories: one to produce power to supply small networks and one connected to the national network. The first are plants located on small islands or remote areas that are supplied by power systems not connected to the national network. Also for this type of systems it is possible to use wind power and photovoltaic power together (hybrid plants) that could integrate on an annual basis.
The most interesting application for wind power is the supply of large national networks. For this reason medium-large sized machines or wind-farms have been used for a total power of some megawatts or a few tens of megawatts.

Mini wind power plants

Generally, using nominal power as a criterion for classification, we speak of mini wind power plants when the power ranges from 20 kW to 200 kW (plants with powers lower than this are considered micro-wind power plants). In the case of larger amounts, the power plants are classified as large-scale wind power plants.
Current technologies include two macro-types of wind generators: Horizontal Axis Wind Turbines (HAWT) which are the conventional turbines whose axis is parallel to the direction of the wind, and Vertical Axis Wind Turbines (VAWT) whose axis is perpendicular to the direction of the wind. There are many types of turbines, depending on the number of blades they are made of (one-bladed, two-bladed, three-bladed, multi-bladed). To date, the technology that is used the most is the three-bladed horizontal axis system, even though it is not uncommon to find installations with two-bladed vertical axis turbines.
There are numerous advantages for those who install mini wind power plants. The main applications of mini wind power are:

- Systems connected with the main network (grid – connected systems).
- Exchange on site: excess energy, that is not utilized, is sent to the main network, it is accounted for and credited when energy is taken from the network at a later time. Resolution AEEG n°186 issued in 2009, gives the user the possibility to be paid for the excess electricity by GSE - Gestore dei Servizi Elettrici (the Italian company for electric services).

- Sale of energy (all inclusive rate): energy is paid for at a rate equal to 0.3e/kWh, which includes the incentive. In this situation the installation of an inverter is necessary, which transforms the current from continuous into alternating current, according to the standards of the distribution network, thus making the exchange possible. Furthermore, the installation of special meters is necessary, which in the case of an exchange in on a site (two-directional), enable the calculation of the balance of energy that is released to and energy that is drawn from the main network.
- Off-grid systems, feeding isolated users.
- For homes or small industries (single turbines or stand-alone systems, or systems coupled with cogeneration or photovoltaic plants, hybrid systems).
- To serve telecommunication systems (signal repeaters, antennas).
- Air quality monitoring systems.
- Water pumping plants.
- Sea water desalination plants (drinking water).

Aeolian distribution

Aeolian production worldwide

In the last years we have assisted at an exponential growth of aeolic power installed and production of electricity generated by wind. In 2015 a power of 63 GW has been installed worldwide, a 22% increase if compared to previous year, reaching a total power rising up to 433 GW: biggest contributors were China (129.3 GW), USA (74 GW), Germany (45 GW), India (25.1 GW), Spain (23 GW), with Europe as a whole covering 32.7% of world aeolic power. The 81% of installed power in the world is located in just ten countries: China, USA, Germany, India, Spain, Great Britain, Canada, France, Italy and Brazil.
Traditionally, since the beginning of aeolic era, the countries that invested and produced more have been Germany, Spain and the USA: Germany has always been the first in the ranking, but in 2011 it was overtaken by China and the United States. In the last five years a new important "outsider" has broken through, China, which from 2010 became the first country in the ranking, making it the main emerging country in the wind sector. In 2015, the greatest effort to incentivize installed wind power came from China, which registered a 30.8% increase with respect to 2014, with a production equal to 30% of the world installed power; and from the USA, which registered a 8.6% increase, with a production equal to 17% of the world installed power. Italy has always been in the vanguard in this sector and in 2013, it held the honourable 9th position in the classification of installed power, after China, the USA, Germany, India, Spain, Great Britain, Canada and France.
In 2015 worldwide aeolic energy production covered 3.7% of the total amount of electricity produced; nevertheless, in some countries it is an important part of national electricity balance: as an example, at the end of 2015, in Spain, 18% of power consumed was produced by aeolic sources, in Denmark 42%, in Ireland and in Portugal 23%.
(*Source: Renewables 2015 – Global Status Report; EWEA – Wind in power: 2015 European Statistics*)

Aeolic production in Europe

Wind power installed in Europe by end of 2015 reached 142 GW. The field is monitored, in Europe, by the European Wind Energy Association (EWEA), a non-profit NGO established in 1982, counting up to 700 members among which the main firms in aeolic plants making, and the most influential research institutes: it is the biggest sustainable resources association in the world. In 2015, installed wind power in Europe increased of 13,805 MW, from 134,252 MW to 147,772

MW. However there still are great disparities in the various European countries: Germany (30.4% of the total in Europe), Spain (15.6%), Great Britain (9.2%), France (7%) and Italy (6%) and together account for 68.2% of the production of wind power in Europe.
(*Source: EWEA – Wind in power: 2015 European Statistics*)

A significant contribution

Directive 2009/28/EC of the European Parliament and Council (which replaced previous Directives 2001/77/EC and 2003/30/EC) aims to establish a common framework for the production and promotion of energy from renewable sources. For each Member State, the Directive sets a target, share of energy from renewable sources, out of the final overall consumption of energy before 2020, which is coherent with the global target “20-20-20” (which means a 20% reduction in greenhouse gas emissions, 20% energy saving and a 20% consumption of energy from renewable sources) of the EC. With regard to the transportation sector, energy from renewable sources must be equal to at least 10% of overall energy consumption, by the year 2020. In 2013 the renewable sources reached 13.5% of the world demand of energy, and hydroelectric power and biomasses were the most common sources (the latter is due to the contribution of the poorer countries where biomasses are widely used for domestic heating, for cooking and for lighting). At the end of 2015, the production of wind energy in the world amounted to approximately 3.7% of global electric energy consumption. This may not seem a very significant amount, however there are constant increases in the production of wind energy every year.
(*Source: ewea.org*)

Aeolic production in Italy

In 2015 Italy was at 9th place of biggest aeolian energy producers' ranking, with an installed capacity of 8,958 MW. A placement that deserves respect, if we think at country's smallness if compared to "giants" like USA, China or India. Moreover, conditions for aeolian production in Italy aren't the most favourable, given the peculiar shape of the country with this long and stretched territory, presence of high mountains such as the Alps which offer a barrier to winds; however there are many ideal places locally, especially on the Adriatic side of the Apennines and on the islands, and there are big potentials for offshore plants.
In Italy many associations care about management, research and diffusion of aeolic energy, as the "Associazione Nazionale Energia del Vento", ANEV (National Association Energy of the Wind, NAEW), which has subscribed agreements with Greenpeace and Legambiente for a sustainable and environmentally respectful development, or the "Associazione Produttori Energia da Fonti Rinnovabili", APER (Association of Producers of Energy from Renewable Sources, APERS) and an important cooperation is on stage with the "Gestore Servizi Energetici", GSE (Energetic Services Manager, ESM), to integrate aeolic-generated electricity with the national grid.
The aeolian energy production actually started in 1994, just with pilot plants or experimental ones, in the national energy balance. From this year, it persevered to give significant increases. In 1994, the aeolian energy (with a production of 6 GWh) represented the 0,02 % of the total renewable source energy amount, while in 2001, with a production of 1.179 GWh, this amount increased to the 2,14% and, in 2006, to the 5,6%, producing 2.971 GWh. In 2007 we saw the real "quality leap": the aeolian energy produced, 4.034 GWh, representing the 8% of our renewable sources energy, and the 1,2% of the national electric balance, based on the produced and imported energy. The growth of wind power has continued during years and in 2014 reached 15,178 GWh per share.
In the end of 2014, Italy owns 1,847 installed aeolian plants. Anyway, because of the morphological features of our land and the consequent wind rate, their distribution is not uniform for every region. The highest concentration of aeolian plants is in Puglia (572 farms), followed by Basilicata (263), Campania (221), Sicily (191), Sardinia (118), Calabria (111), Tuscany (89), Molise (35), Marche (35), Liguria (33), Abruzzo (29), Lazio (24), Veneto (17), Piedmont (15), Umbria (13), Trentino (9), Lombardy (7), Friuli Venezia Giulia (5) e Aosta Valley (4).

About the efficient gross power, in 2014 it was of 8, 703 MW, so distributed: Puglia (2.339 MW, the 26.9% of the national aeolian power), Sicily (1,747MW, the 20.1% of the national aeolian power), Campania (1, 251 MW, the 14.4%), Calabria (1,000 MW, the 11.5%), Sardinia (997 MW, the 11,5%), Basilicata (475 MW, the 5.5%), Molise (370 MW, the 4.2%), Abruzzo (231 MW, the 2.7 %), Tuscany (121.9 MW, the 1.4%), Liguria (58 MW, the 0.7%), Lazio (51 MW, lo 0.6 %), Emilia Romagna (19 MW, the 0.2%) e Piedmont (19 MW, the 0.1%) Veneto (9.5 MW, the 0.1%), Marche (9 MW, the 0.1%), Aosta Valley (3 MW, the 0.1%).
The energy produced in 2014 amounted to 15,178 GWh - 28.3% came from the Puglia region, 19.3% from Sicily, 13.5% from the Campania region, 12.6% from Calabria, 10.9% from Sardinia, 5.4% from Basilicata, 4.5% from Molise, 2.2% from Abruzzo and 1.5% from Tuscany.
In all the other Italian regions, the production of wind energy was less than 1%.Therefore, we can easily see how the regions of Southern and Central Italy are the most productive ones, thanks to the propitious wind conditions along the Apennine Crest and on the islands' relieves, while the Alps negatively influence the wind exploitation in the regions placed under this mountain chain.
(*Souce: GSE, Rapporto statistico "Energia da Fonti Rinnovabili in Italia – 2014")*

Future scenarios

According to *OWEMES* (*Offshore Wind and other marine renewable Energy in Mediterranean and European Seas),* future scenarios of wind energy systems indicate the Puglia Region as the region with the greatest extension in sq. km, that can be used for offshore plants (2,932 sq. km), followed by the Marche region (2,717 sq. km), Sicily (1,772 sq. km), Sardinia (1,270 sq. km), Abruzzo (952 sq. km), Tuscany (727 sq. km), Emilia Romagna (369 sq. km), Molise (292 sq. km) and Lazio (6 sq. km), for a total amount of 11,686 sq. km that can be dedicated to the development of wind energy. In the larger islands there is the possibility of counting on places where the speed of the wind is greater (approximately 7-8 m/s) than the average in other sites (6-7 m/s), and the Puglia region is one of the regions with the largest number of marine offshore wind parks being developed.

Trends and evolution

Research is trying to solve what at present is the major problem of the production of wind energy: the discontinuous nature of the supply of energy due to the irregular wind regime. It must be pointed out that the gross efficiency of wind power plants, expressed in MW, defines the quantity of energy that can be produced in a determined period of time in which the plant operates, and it is the parameter that is considered in order to compare the productive possibilities of wind power generators with one another. However it must be considered that due to various factors, and first of all the variability of the wind, a wind power generator never operates for 24 hours a day for the whole year, but only for a certain number of hours. When the wind blows at speeds that are too low (v < 5-4 m/s) the generator does not produce energy, while when the wind speed is too high (v > 20-25 m/s) the plants must be shut down for safety reasons. Therefore, a very important factor, in order to determine the productivity of the plants, is the number of hours of operation. In Italy the plants that operate for the greatest number of hours generally operate for about 3,200 hours a year (i.e. for about 38% of the time, considering that in a year there are 8,760 hours). However, the Italian national average is much lower, it amounts to 1,700 hours a year. In order to solve this problem and increase the number of hours of utilization, research is trying to develop rotors that can produce energy and operate safely also with very low or very high speed winds. However there are limits beyond which no further improvement is possible, especially with regard to the efficiency at low speeds.

Environment and territory

Advantages and limits of wind

However wind energy has some disadvantages. First of all it is an intermittent source, that varies with the seasons and from day to day. For this reason installing 100MW of wind turbines does not mean having 100MW power constantly available, but less power. The actual annual capacity is equal to 45% of the nominal power in the more windy areas, and an average of 30% on a global scale. In other words in order to have a power of 100MW available, 250MW must be

installed.
Another problem that needs to be faced regards power transmission and distribution networks that the wind power plants are connected to. These must be designed to receive an intermittent medium voltage flow of electricity. The distribution networks that are currently present in the industrialized countries are designed in an entirely different manner, because these are connected to few large high-voltage wind power plants where the flow of energy is controlled and predictable. The different production of energy coming from numerous small scale wind power plants and also from other sources, requires suited and costly changes in the electricity distribution network.

Visual impact

The visual impact of an aerogenerator of a 40-60 metre tall wind power plant is obvious, but it can be downsized by building plants at a certain distance from the nearest urban centre. Today the visual impact is reduced by positioning the machines on a single row and using neutral colours (like white).
The lowest impact on the environment and landscape can be obtained by positioning the plants in the open sea, in places that are not visible from the coast. At the moment some less visible building solutions are being studied also with regard to installations on the land. It is possible to use chromatic tricks by painting wind towers with same colour as the surrounding landscape (for example the lower part could be green like the surrounding countryside, while the higher part could be light blue like the sky), or adapting shapes of wind plants to already existing structures.

Land occupation

The necessary land to build a wind power plant is generally wide, since the distance between the generators must be accounted for. From this point of view, the power density (10 watts per square metre) is rather low. However, if we consider that windmills and flanking works only cover 2-3% of the territory, the density grows to hundreds of watts per square metre and the space between the two machines can be used for cattle or rearing purposes.

Noise

The potential acoustic pollution caused by aerogenerators determines two types of noise: mechanical noise that comes from the generator and aerodynamic noise caused by the rotor blades.
With regard to noise, in terms of decibels, the humming of aerogenerators is far lower than town noise. The decibels that one can hear at three hundred metres from a wind farm are the same one would normally hear amidst traffic or near an industry. At the moment high-technology aerogenerators are very quiet. It was calculated that, at a distance of around 200 metres, the noise of rotation originated by rotor blades can be confused with wind noise that blows into the surrounding vegetation.

Electromagnetic effects

Possible interferences with telecommunication devices are irrelevant. Like any other obstacle, also the wind machine can interfere with telecommunication services, but a suitable distance makes the interference irrelevant.

Effects on plant and animal life

With regard to possible changes in plant and animal life, based on the available information, it has been reported that possible relevant interferences have been noted only with regard to the birds' impact with the machine rotors. Generally collisions are rare, and mostly limited to birds of prey. Migratory birds instead seem to adapt to the presence of these obstacles.
According to the US Fish and Wildlife Service the leading cause of mortality in the birds are cats (about one billion birds a year), followed by buildings (a little less than a billion), hunters (about 100 million a year) and lastly vehicles, telecommunication towers, pesticides and high-tension lines (each category accounts for about 60-80 million birds a year); the contribution of wind power plants appears to be an extremely modest fraction.
The impact on plants is noted specially when setting up the power plant, with the construction of roads and foundations, and when handling materials on site. Some measures are taken to reduce the impact on the territory, for example planting plants when the site has been completed, or compensating the impact with improvements in the surrounding

areas, in order to have a positive overall balance.
Concluding, if some measures are taken when designing a wind farm, among all the energy producing industries, wind power plants are among the cleanest and safest. During operation they do not produce polluting substances, dusts and heat, even after they are dismantled, the former pristine state can be restored without leaving any traces in the environment nor on the people.