“Gheorghe Asachi” Technical University of Iasi
Faculty of Electrical Engineering, Power Engineering and Applied Informatics
Department of Power Engineering

RENEWABLE ELECTRICAL ENERGY SOURCES

WIND MODELLING AS A SELF REPAIRABLE SYSTEM

Supervisor:
Prof. Florin Munteanu, MSc, PhD

ERASMUS Student:
Alvaro Teja Solana
University of Cantabria
Spain

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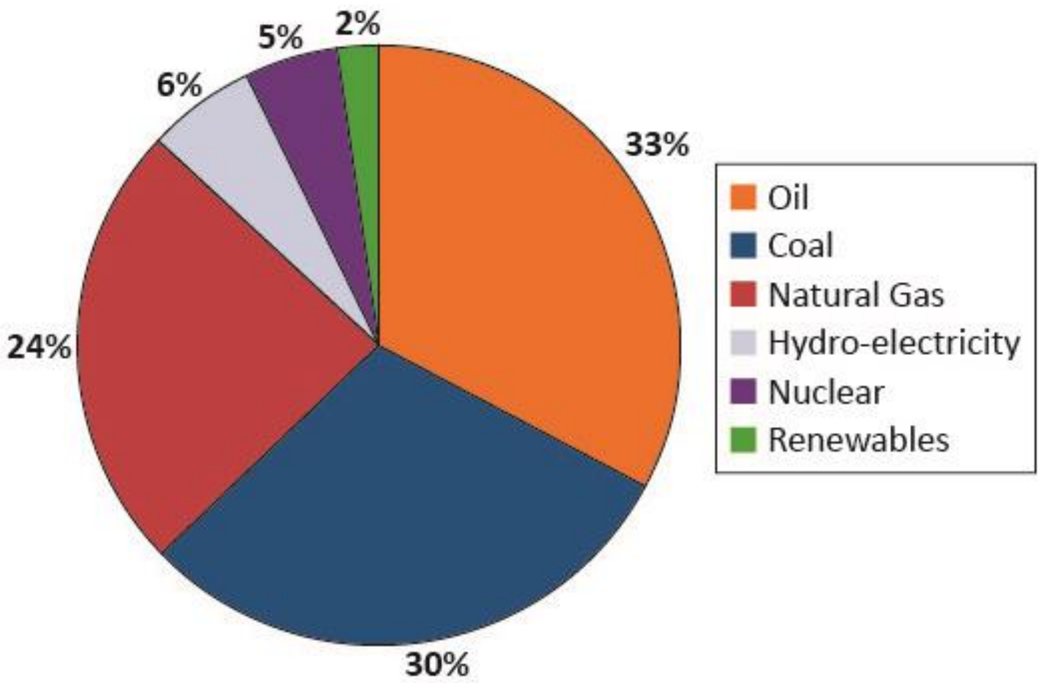
1. Introduction

Throughout this work will focus on renewable energy and particularly in wind as more advanced renewable energy source, and the paper show how the wind source can help, with the rest of renewables sources, to reduce or even stop the emission of CO_2 into the atmosphere and, therefore, stop the greenhouse effect. But first let see what are the different energy sources that exist, how it are affecting our planet and what are the best options to reduce the hole in the ozone layer.

Finally it shows a study of a case to check the availability of a self-repairable wind system from the data collection in the database of Power Systems Reliability Laboratory in the Faculty of Electrical Engineering, Power Engineering and Applied Informatics in "Gheorghe Asachi "Technical University of Iași.

Main energy sources.

The energy sources of the world can be classified into those which are non-renewable and renewable or clean energy, the latter being those that are gaining importance in recent years.



1.1. Main energy sources of the world, approximately in 2013.
Source: http://cornerstonemag.net/

Renewable energy sources.

Renewable energies are those obtained from inexhaustible natural sources, either by the immense amount of energy they contain, or because they are able to regenerate by natural means. These would be the main sources of renewable energy:

- Solar Power: Provided by the sun
- Wind Power: Provided by the wind
- Hydropower: Provided by water
- Geothermal energy: Provided by the earth's subsurface
- Biomass energy: Provided by organic matter

Non-renewable energy sources.

The non-renewable energy sources are those that are limited by nature in time. It is, after all depleted stocks may not be substituted, since there is no system economically viable production or extraction. These are the main sources of non-renewable energy:

- *Nuclear energy* is the, if not the most cost-effective energy source more power. Its two main problems are:
    - Long-lived radioactive waste and high development devastating accident.
    - The environmental impact study must be carried out by analysing the whole process of production of nuclear energy.
- *Coal* is a major source of energy. It comes from plants that were buried 300 million years ago. It is easy to obtain and use, but at this rate we will consume the reserves for the year 2300 approximately. Coal is the most abundant fossil fuel in the world. It is found mostly in the Northern Hemisphere. And the biggest coal deposits are in North America, Russia and China.

  There are different types of coal which are: peat, lignite, hard coal. Few are higher pressures and temperatures, a more compact and rich in carbon and higher calorific value coal originates.

  Coal mining and burning cause significant environmental problems and have negative consequences for human health. The mines have great visual impact and fluids that emerge are usually highly polluting.

- *Petroleum*, is a hydrocarbon mixture liquid. In oil refineries separate different components as petrol, diesel, fuel oil and asphalt, which are used as fuels. Other products from which plastics, fertilizers, paints, pesticides, medicines and synthetic fibers are obtained are also removed.

  Petroleum is formed when large amounts of aquatic organisms die and are buried in the bottom sediments of marshes, in a low-oxygen environment. When these sediments are covered by other rock layers that are forming the lining, pressure and temperature and a little known process, oil is formed.

  About half the world's oil is in the Middle East. And you can say that there are reserves for about 100 years.

  Petroleum pollution causes both the use and the produce and transport.

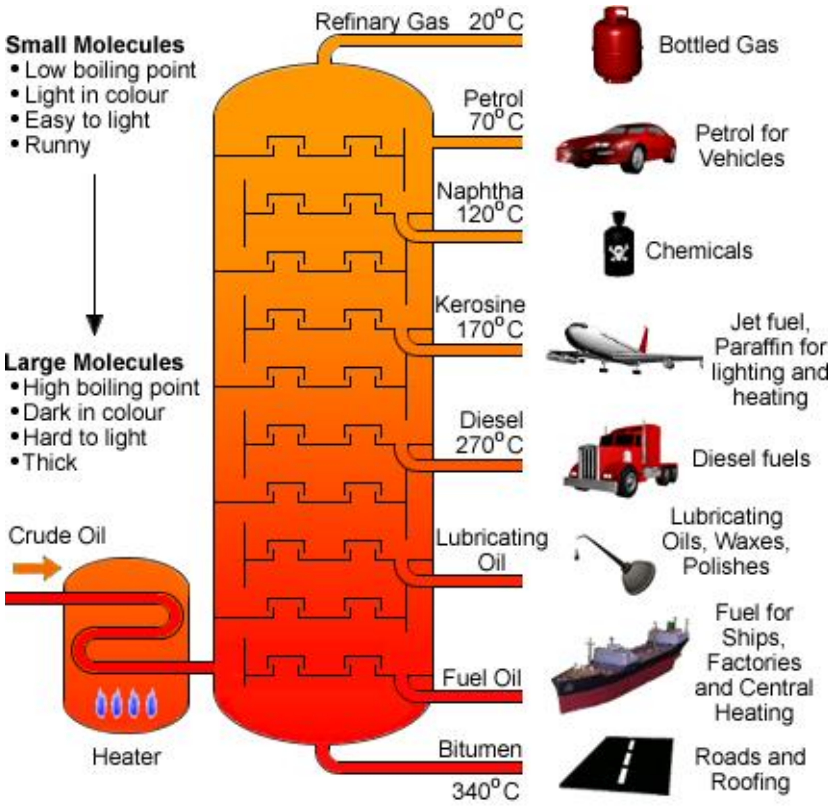
- *Natural gas* is extracted in the same areas where petroleum or petroleum pockets are. It is on top of the petroleum bag. Its main use is as a domestic fuel. Natural gas consists of a small group of hydrocarbons, primarily methane with a small amount of propane and butane. Propane and butane are separated from the methane and used as fuel for cooking and heating, distributed in cylinders. Methane is used as fuel in both: homes and industries, and this is normally distributed by pipeline pressure gas. The gas ran out in 2150.

- *Electricity*, category of physical phenomena caused by the existence of electrical charges. When an electric charge is stationary, or static, it produces electrical forces to the loads situated in the same region of space; when in motion, also it produces magnetic effects. The particles may be neutral, positive or negative. Electricity is concerned with positively charged, such as protons, particles that repel each other. However, the positive and negative particles attract each other. This behaviour can be summarized by saying that the charges repel and unlike charges attract each sign.

Use of energy sources.

Non-renewable energy have been for years the combustion engine of our planet and indeed both coal to a lesser extent, as petroleum are the energies that most are used in some countries, either to produce steam to power industrial machinery and trains, power plants in generating electricity. Also in heating buildings and homes.

Petroleum is the major source of energy in the world, is also an element which together with its derivatives are used in all industries, petrochemical and air, sea, river and auto transport. It is also used to generate electricity and for making things that we can use daily.



1.2.Petroleum uses.
Source: science-resources.co.uk

A non-renewable energy mentioned we must add, the case of wood in ancient times was considered another energy source and is now in disuse, but was widely used for heating, cooking, etc. In very rural areas still they use.

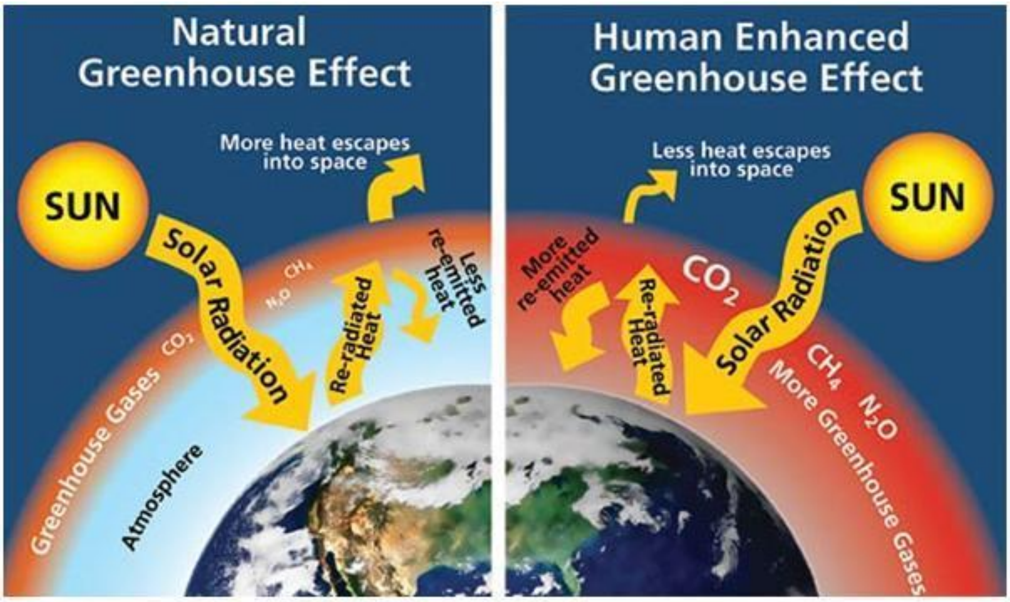
As for non-renewable energy, we must note that is mainly used for power generation, and in particular is used to meet the needs of lighting, operation of industries, mass transportation, meet the overall needs of households, etc...

Major problems due to energy sources & how we can reduce the CO2 emissions.

At present the energy used is at least 85% of fossil origin. The fossil fuel reserves seem ample to satisfy our needs for a good fraction of the next millennium. So, what is the problem? Most of the easily accessible sources of oil and gas have already been tapped. What is left is getting progressively more expensive to extract. Thus, one part of the problem is economical. Another is political—most of the fuel used by developed nations is imported. This creates an undesirable vulnerability. The major problem, however, is ecological. Fossil fuels are still the most inexpensive and most convenient of all energy resources, but their use pollutes the environment, and we are quickly approaching a situation in which we can no longer dismiss the problem or postpone the solution. By far, the most undesirable gas emitted is carbon dioxide whose progressively increasing concentration in the atmosphere (from 270 ppm in the late 1800 to some 365 ppm at present) constitutes a worrisome problem.

It is sad to hear influential people (among them, some scientists) dismiss this problem as inconsequential, especially in view of the growing signs of a possible runaway ecological catastrophe. For instance, in the last few decades, the thickness of the north polar ice has decreased by 40% and on the first year of the current millennium, a summertime hole appeared in the polar ice. Since increased concentrations of CO_2 can lead to global warming, some people have proposed increasing the emission of SO_2 to stabilize the temperature because of the cooling effect of this gas. Even ignoring the vegetation-killing acid rain that would result, this proposal is equivalent to balancing a listing boat by piling stones on the other side.

Public indifference with the CO_2 problem may partially be due to the focus on planetary temperature rise. Although the growth in CO_2 concentration is very easily demonstrated, the conclusion that the temperature will rise, although plausible, is not easy to prove. There are mechanisms by which an increase of greenhouse gases would actually result in a cooling of Earth. For instance, increasing greenhouse gases would result in enhanced evaporation of the tropical oceans. The resulting moisture, after migrating toward the poles, would fall as snow thereby augmenting the albedo of the planet and, thus, reducing the amount of heat absorbed from the sun.



1.3. Greenhouse effect.
Source: greenfriendswoodlands.wordpress.com

Some scientist and engineers who are less concerned with political correctness, are investigating techniques to reduce (or at least, to stabilize) the concentration of atmospheric carbon dioxide. This can, in principle, be accomplished by reducing emissions or by disposing carbon dioxide in such a way as to avoid its release into the air. Emissions can be reduced by diminishing overall energy consumption (a Utopian solution), by employing alternative energy sources, by increasing efficiency of energy use, and by switching to fuels that yield more energy per unit amount of carbon emitted.

So we can say the best way to reduce the emissions and thus stop to increase the greenhouse effect is implement the renewable energies as a principals sources of energy.

2. Renewable energy sources

2.1. Renewables Importance:

In this point we are going to see a general view of different benefits of renewable energies, and for a better vision we focus in data from U.S., and the different environmental impacts that the installations for renewable energies cause.

Benefits of renewable energies:

Renewable energy — wind, solar, geothermal, hydroelectric, and biomass — provides substantial benefits for our climate, our health, and our economy:

Each source of renewable energy has unique benefits and costs; we are going to explore the many benefits associated with these energy technologies, and we will see the environmental impacts.

2.1 Renewable energies.

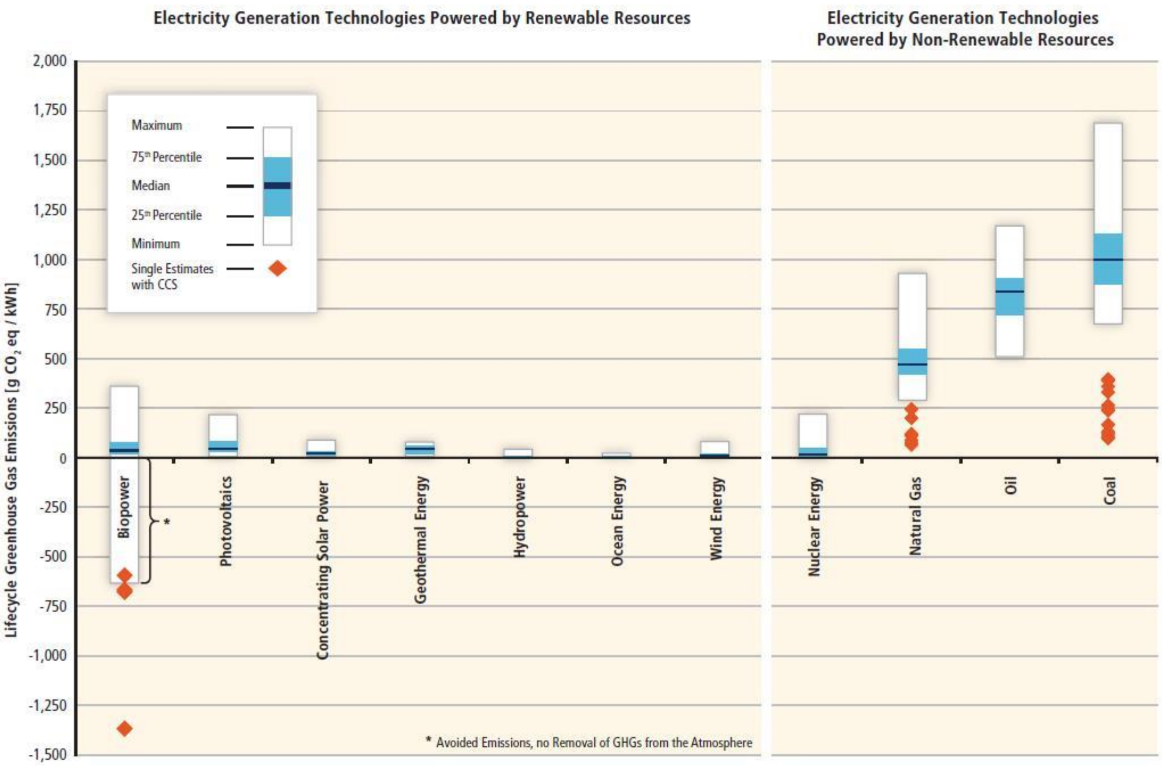
- *Little to No Global Warming Emissions.*

Human activity is overloading our atmosphere with carbon dioxide and other global warming emissions, which trap heat, steadily drive up the planet's temperature, and create significant and harmful impacts on our health, our environment, and our climate.

Electricity production accounts for more than one-third of U.S. global warming emissions, with the majority generated by coal-fired power plants, which produce approximately 25 percent of total U.S. global warming emissions; natural gas-fired power plants produce 6 percent of total emissions [source: *Environmental Protection Agency. 2012. Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2010; Energy Information Agency (EIA). 2012.*

How much of the U.S. carbon dioxide emissions are associated with electricity generation?]. In contrast, most renewable energy sources produce little to no global warming emissions.

According to data aggregated by the International Panel on Climate Change, life-cycle global warming emissions associated with renewable energy—including manufacturing, installation, operation and maintenance, and dismantling and decommissioning—are minimal [source: *Intergovernmental Panel on Climate Change (IPCC). 2011. IPCC Special Report on Renewable Energy Sources and Climate Change Mitigation. Prepared by Working Group III of the Intergovernmental Panel on Climate Change [O. Edenhofer, R. Pichs-Madruga, Y. Sokona, K. Seyboth, P. Matschoss, S. Kadner, T. Zwickel, P. Eickemeier, G. Hansen, S. Schlömer, C. von



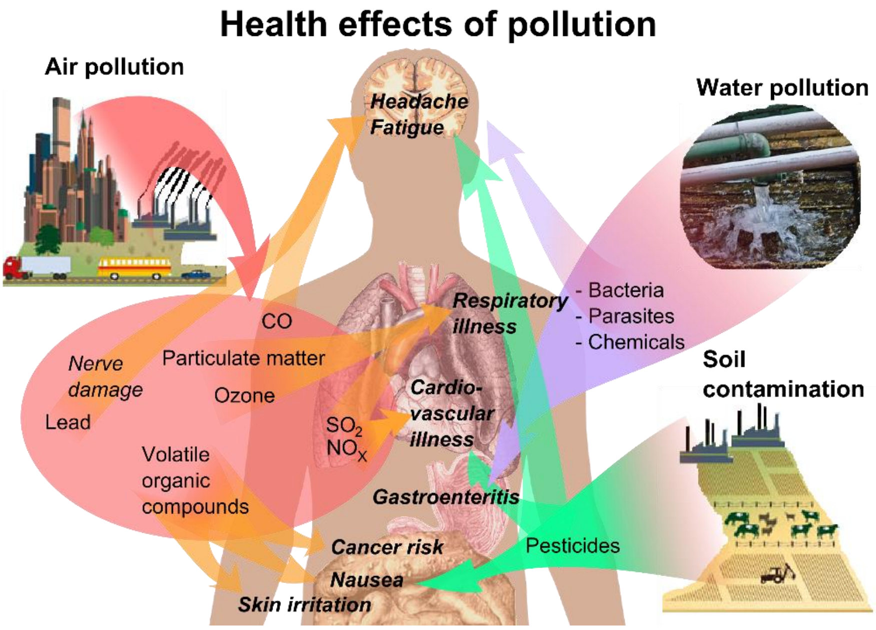
2.2. Electricity generation technologies powered by renewable resources.
Source: IPCC, 2011: IPCC Special Report on Renewable Energy Sources and Climate Change Mitigation. Prepared by Working Group III of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 1075 pp. (Chapter 9).

Stechow (eds)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 1075 pp. (Chapter 9)*].

Compared with natural gas, which emits between 0.6 and 2 pounds of carbon dioxide equivalent per kilowatt-hour (CO_2E/kWh), and coal, which emits between 1.4 and 3.6 pounds of CO_2E/kWh, wind emits only 0.02 to 0.04 pounds of CO_2E/kWh, solar 0.07 to 0.2, geothermal 0.1 to 0.2, and hydroelectric between 0.1 and 0.5. Renewable electricity generation from biomass can have a wide range of global warming emissions depending on the resource and how it is harvested. Sustainably sourced biomass has a low emissions footprint, while unsustainable sources of biomass can generate significant global warming emissions.

Increasing the supply of renewable energy would allow us to replace carbon-intensive energy sources and significantly reduce U.S. global warming emissions. For example, a 2009 UCS analysis found that a 25 percent by 2025 national renewable electricity standard would lower power plant CO_2 emissions 277 million metric tons annually by 2025—the equivalent of the annual output from 70 typical (600 MW) new coal plants [source: *Union of Concerned Scientists (UCS). 2009. Clean Power Green Jobs.]*. In addition, a ground-breaking study by the U.S. Department of Energy's National Renewable Energy Laboratory explored the feasibility and environmental impacts associated with generating 80 percent of the country's electricity from renewable sources by 2050 and found that global warming emissions from electricity production could be reduced by approximately 81 percent [source: *National Renewable Energy Laboratory (NREL). 2012. Renewable Electricity Futures Study. Volume 1, pg. 210*].

- *Improved Public Health and Environmental Quality.*
  Generating electricity from renewable energy rather than fossil fuels offers significant



2.3.. Health effects of pollution.
Source: www.ourair.org

public health benefits. The air and water pollution emitted by coal and natural gas plants is linked to breathing problems, neurological damage, heart attacks, and cancer. Replacing fossil fuels with renewable energy has been found to reduce premature mortality and lost workdays, and it reduces overall healthcare costs [source: Machol, Rizk. 2013. Economic value of U.S. fossil fuel electricity health impacts. Environment International]. The aggregate national economic impact associated with these health impacts of fossil fuels is between \$361.7 and \$886.5 billion, or between 2.5 percent and 6 percent of gross domestic product (GDP).

Wind, solar, and hydroelectric systems generate electricity with no associated air pollution emissions. While geothermal and biomass energy systems emit some air pollutants, total air emissions are generally much lower than those of coal- and natural gas-fired power plants.

In addition, wind and solar energy require essentially no water to operate and thus do not pollute water resources or strain supply by competing with agriculture, drinking water systems, or other important water needs. In contrast, fossil fuels can have a significant impact on water resources. For example, both coal mining and natural gas drilling can pollute sources of drinking water. Natural gas extraction by hydraulic fracturing (fracking) requires large amounts of water and all thermal power plants, including those powered by coal, gas, and oil, withdraw and consume water for cooling.

Biomass and geothermal power plants, like coal- and natural gas-fired power plants, require water for cooling. In addition, hydroelectric power plants impact river ecosystems both upstream and downstream from the dam. However, NREL's 80 percent by 2050 renewable energy study, which included biomass and geothermal, found that water withdrawals would decrease 51 percent to 58 percent by 2050 and water consumption would be reduced by 47 percent to 55 percent [source: *Renewable Electricity Futures Study. 2012*].

- *A Vast and Inexhaustible Energy Supply.*

Throughout the worldwide, strong winds, sunny skies, plant residues, heat from the earth, and fast-moving water can each provide a vast and constantly replenished energy resource supply. These diverse sources of renewable energy have the technical potential to provide all the electricity the nation needs many times over.

Estimates of the technical potential of each renewable energy source are based on their overall availability given certain technological and environmental constraints [source: *NREL. 2013. U.S. Renewable Energy Technical Potentials: A GIS-Based Analysis*]. In 2012, NREL (National Renewable Energy Laboratory) found that together, renewable energy sources have the technical potential to supply 482,247 billion kilowatt-hours of electricity annually. This amount, for example in U.S., is 118 times the amount of electricity the nation currently consumes. However, it is important to note that not all of this technical potential can be tapped due to conflicting land use needs, the higher short-term costs of those resources, constraints on ramping up their use such as limits on transmission capacity, barriers to public acceptance, and other hurdles.

Today, renewable energy provides only a tiny fraction of its potential electricity output in the worldwide. But numerous studies have repeatedly shown that renewable energy can be rapidly deployed to provide a significant share of future electricity needs, even after accounting for potential constraints [source: *Renewable Electricity Futures Study. 2012*].

- *Jobs and Other Economic Benefits.*

Compared with fossil fuel technologies, which are typically mechanized and capital intensive, the renewable energy industry is more labor-intensive. This means that, on average, more jobs are created for each unit of electricity generated from renewable sources than from fossil fuels.

Renewable energy already supports thousands of jobs in the United States. For example, in 2011, the wind energy industry directly employed 75,000 full-time-equivalent employees in a variety of capacities, including manufacturing, project development, construction and turbine installation, operations and maintenance, transportation and logistics, and financial, legal, and consulting services [source: *American Wind Energy Association (AWEA). 2012a. AWEA U.S. Wind Industry Annual Market Report: Year Ending 2011. Washington, D.C.: American Wind Energy Association*.]. More than 500 factories in the United States manufacture parts for wind turbines, and the amount of domestically manufactured equipment used in wind turbines has grown dramatically in recent years: from 35 percent in 2006 to 70 percent in 2011 [source: *AWEA. 2012b. Federal Production Tax Credit for Wind Energy; Wiser, Ryan, and Mark Bolinger. 2012. 2011 Wind Technologies Market Report. US Department of Energy*.].

Other renewable energy technologies employ even more workers. In 2011, the solar industry employed approximately 100,000 people on a part-time or full-time basis, including jobs in solar installation, manufacturing, and sales [source: *The Solar Foundation. 2011. National Solar Jobs Census 2011; Solar Energy Industries Association (SEIA). 2013. Solar Industry Data*.]; the hydroelectric power industry employed approximately 250,000 people in 2009 [source: *Navigant Consulting. 2009. Job Creation Opportunities in Hydropower*.]; and in 2010 the geothermal industry employed 5,200 people [source: *Geothermal Energy Association. 2010. Green Jobs through Geothermal Energy*].

Increasing renewable energy has the potential to create still more jobs. In 2009, the Union of Concerned Scientists conducted an analysis of the economic benefits of a 25 percent renewable energy standard by 2025; it found that such a policy would create more than three times as many jobs as producing an equivalent amount of electricity from fossil fuels—resulting in a benefit of 202,000 new jobs in 2025 [source: *UCS. 2009. Clean Power Green Jobs*].

In addition to the jobs directly created in the renewable energy industry, growth in renewable energy industry creates positive economic “ripple” effects. For example, industries in the renewable energy supply chain will benefit, and unrelated local businesses will benefit from increased household and business incomes [source: *Environmental Protection Agency. 2010. Assessing the Multiple Benefits of Clean Energy: A Resource for States*].

In addition to creating new jobs, increasing our use of renewable energy offers other important economic development benefits. Local governments collect property and income taxes and other payments from renewable energy project owners. These revenues can help support vital public services, especially in rural communities where projects are often located. Owners of the land on which wind projects are built also often receive lease payments ranging from $3,000 to $6,000 per megawatt of installed capacity, as well as payments for power line easements and road rights-of-way. Or they may earn royalties based on the project’s annual revenues. Similarly, farmers and rural landowners can generate new sources of supplemental income by producing feed stocks for biomass power facilities.

UCS (The Cisco Unified Computing System) analysis found that a 25 by 2025 national renewable electricity standard would stimulate $263.4 billion in new capital investment for renewable energy technologies, $13.5 billion in new landowner income biomass production and/or wind land lease payments, and $11.5 billion in new property tax revenue for local communities [source: *UCS. 2009. Clean Power Green Jobs*].

Renewable energy projects therefore keep money circulating within the local economy, and in most states renewable electricity production would reduce the need to spend money on importing coal and natural gas from other places. Thirty-eight states were net importers of coal in 2008—from other states and, increasingly, other countries: 16 states spent a total of more than $1.8 billion on coal from as far away as Colombia, Venezuela, and Indonesia, and 11 states spent more than $1 billion each on net coal imports [source: *Deyette, J., and B. Freese. 2010. Burning coal, burning cash: Ranking the states that import the most coal. Cambridge, MA: Union of Concerned Scientists*].

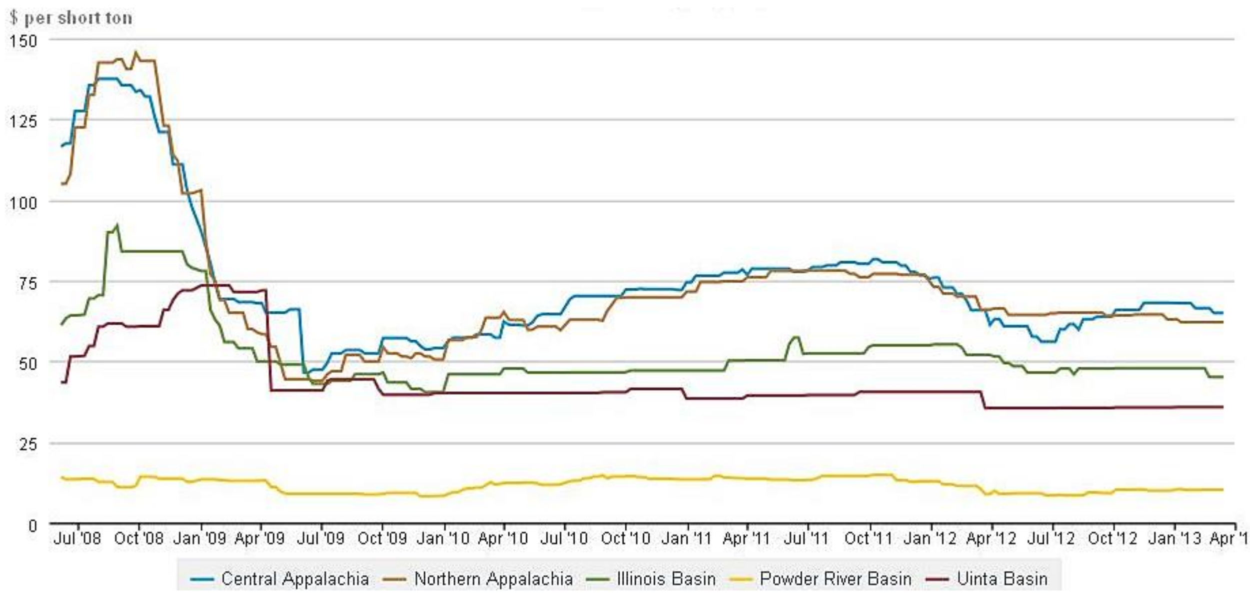
- *Stable Energy Prices.*

Renewable energy is providing affordable electricity across the country right now, and can help stabilize energy prices in the future.

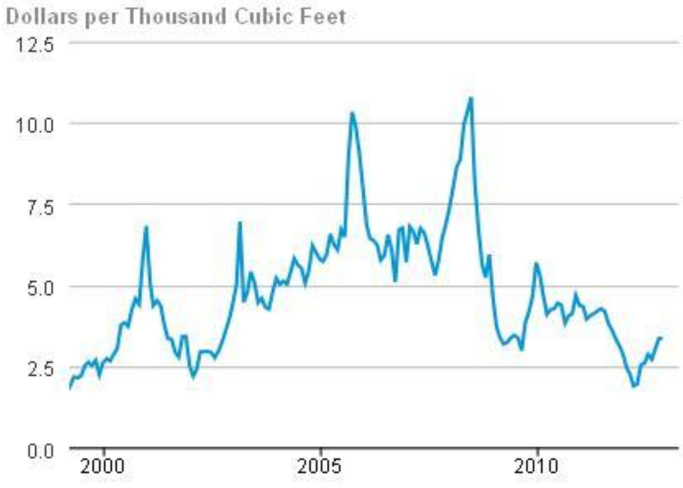
The costs of renewable energy technologies have declined steadily, and are projected to drop even more. For example, the average price of a solar panel has dropped almost 60 percent since 2011 [source: *SEIA. 2012. Solar Market Insight Report 2012 Q3*]. The cost of generating electricity from wind dropped more than 20 percent between 2010 and 2012 and more than 80 percent since 1980 [source: *AWEA. 2012b. Federal Production Tax Credit for Wind Energy*]. In areas with strong wind resources like Texas, wind power can compete directly with fossil fuels on costs [source: *Electric Reliability Council of Texas (ERCOT). 2012. Long-term System Assessment for the ERCOT region*]. The cost of renewable energy will decline even further as markets mature and companies increasingly take advantage of economies of scale.

While renewable facilities require upfront investments to build, once built they operate at very low cost and, for most technologies, the fuel is free. As a result, renewable energy prices are relatively stable over time. UCS's analysis of the economic benefits of a 25 percent renewable electricity standard found that such a policy would lead to 4.1 percent lower natural gas prices and 7.6 percent lower electricity prices by 2030 [source: *UCS. 2009. Clean Power Green Jobs*].

In contrast, fossil fuel prices can vary dramatically and are prone to substantial price swings. For example, there was a rapid increase in U.S. coal prices due to rising global demand before 2008, then a rapid fall after 2008 when global demands declined [source: *UCS. 2011. A Risky Proposition: The financial hazards of new investments in coal plants*]. Likewise, natural gas prices have fluctuated greatly since 2000 [source: *EIA. 2013. U.S. Natural Gas Wellhead Price*].



2.4.. Historic coal prices by region [2008-2013]
Source: Energy Information Administration (EIA). 2013. Coal news and markets report.



2.5. U.S. Natural gas wellhead price.
Source: EIA. 2013. U.S. Natural Gas Wellhead Price.

Using more renewable energy can lower the prices of and demand for natural gas and coal by increasing competition and diversifying our energy supplies. An increased reliance on renewable energy can help protect consumers when fossil fuel prices spike.

In addition, utilities spend millions of dollars on financial instruments to hedge themselves from these fossil fuel price uncertainties. Since hedging costs are not necessary for electricity generated from renewable sources, long-term renewable energy investments can help utilities save money they would otherwise spend to protect their customers from the volatility of fossil fuel prices.

- *A More Reliable and Resilient Energy System.*

Wind and solar are less prone to large-scale failure because they are distributed and modular. Distributed systems are spread out over a large geographical area, so a severe weather event in one location will not cut off power to an entire region. Modular systems are composed of numerous individual wind turbines or solar arrays. Even if some of the equipment in the system is damaged, the rest can typically continue to operate.

For example, in 2012 Hurricane Sandy damaged fossil fuel-dominated electric generation and distribution systems in New York and New Jersey and left millions of people without power. In contrast, renewable energy projects in the Northeast weathered Hurricane Sandy with minimal damage or disruption [source: *Unger, David J. 2012. Are renewables storm proof? Hurricane Sandy tests solar, wind. The Christian Science Monitor*].

The risk of disruptive events will also increase in the future as droughts, heat waves, more intense storms, and increasingly severe wildfires become more frequent due to global warming.

Renewable energy sources are more resilient than coal, natural gas, and nuclear power plants in the face of these sorts of extreme weather events.

For example, coal, natural gas, and nuclear power depend on large amounts of water for cooling, and limited water availability during a severe drought or heat wave puts electricity generation at risk. Wind and solar photovoltaic systems do not require water to generate electricity, and they can help mitigate risks associated with water scarcity.

Environmental impacts.

- *Wind power.*

Harnessing power from the wind is one of the cleanest and most sustainable ways to generate electricity as it produces no toxic pollution or global warming emissions. Wind is also abundant, inexhaustible, and affordable, which makes it a viable and large-scale alternative to fossil fuels.

Despite its vast potential, there are a variety of environmental impacts associated with wind power generation that should be recognized and mitigated.

Land Use:

The land use impact of wind power facilities varies substantially depending on the site: wind turbines placed in flat areas typically use more land than those located in hilly areas. However, wind turbines do not occupy all of this land; they must be spaced approximately 5 to 10 rotor diameters apart (a rotor diameter is the diameter of the wind turbine blades). Thus, the turbines themselves and the surrounding infrastructure (including roads and transmission lines) occupy a small portion of the total area of a wind facility.

A survey by the National Renewable Energy Laboratory of large wind facilities in the United States found that they use between 30 and 141 acres per megawatt of power output capacity (a typical new utility-scale wind turbine is about 2 megawatts). However, less than 1 acre per megawatt is disturbed permanently and less than 3.5 acres per megawatt are disturbed temporarily during construction. The remainder of the land can be used for a variety of other productive purposes, including livestock grazing, agriculture, highways, and hiking trails. Alternatively, wind facilities can be sited on brownfields (abandoned or underused industrial land) or other commercial and industrial locations, which significantly reduces concerns about land use.

Offshore wind facilities, which are currently not in operation in the United States but may become more common, require larger amounts of space because the turbines and blades are bigger than their land-based counterparts. Depending on their location, such offshore installations may compete with a variety of other ocean activities, such as fishing, recreational activities, sand and gravel extraction, oil and gas extraction, navigation, and aquaculture. Employing best practices in planning and siting can help minimize potential land use impacts of offshore and land-based wind projects.

Wildlife and Habitat:

The impact of wind turbines on wildlife, most notably on birds and bats, has been widely document and studied. A recent National Wind Coordinating Committee (NWCC) review of peer-reviewed research found evidence of bird and bat deaths from collisions with wind turbines and due to changes in air pressure caused by the spinning turbines, as well as from habitat disruption. The NWCC concluded that these impacts are relatively low and do not pose a threat to species populations.

2.6. Source: ucsusa.org

Additionally, research into wildlife behaviour and advances in wind turbine technology have helped to reduce bird and bat deaths. For example, wildlife biologists have found that bats are most active when wind speeds are low. Using this information, the Bats and Wind Energy Cooperative concluded that keeping wind turbines motionless during times of low wind speeds could reduce bat deaths by more than half without significantly affecting power production. Other wildlife impacts can be mitigated through better siting of wind turbines. The U.S. Fish and Wildlife Services has played a leadership role in this effort by convening an advisory group including representatives from industry, state and tribal governments, and nonprofit organizations that made comprehensive recommendations on appropriate wind farm siting and best management practices.

Offshore wind turbines can have similar impacts on marine birds, but as with onshore wind turbines, the bird deaths associated with offshore wind are minimal. Wind farms located offshore will also impact fish and other marine wildlife. Some studies suggest that turbines may actually increase fish populations by acting as artificial reefs. The impact will vary from site to site, and therefore proper research and monitoring systems are needed for each offshore wind facility.

Public Health and Community:

Sound and visual impact are the two main public health and community concerns associated with operating wind turbines. Most of the sound generated by wind turbines is aerodynamic, caused by the movement of turbine blades through the air. There is also mechanical sound generated by the turbine itself. Overall sound levels depend on turbine design and wind speed.

Some people living close to wind facilities have complained about sound and vibration issues, but industry and government-sponsored studies in Canada and Australia have found that these issues do not adversely impact public health. However, it is important for wind turbine developers to take these community concerns seriously by following "good neighbor" best practices for siting turbines and initiating open dialogue with affected community members. Additionally, technological advances, such as minimizing blade surface imperfections and using sound-absorbent materials can reduce wind turbine noise.

Under certain lighting conditions, wind turbines can create an effect known as shadow

4. Source: ucsusa.org

flicker. This annoyance can be minimized with careful siting, planting trees or installing window awnings, or curtailing wind turbine operations when certain lighting conditions exist.

The Federal Aviation Administration (FAA) requires that large wind turbines, like all structures over 200 feet high, have white or red lights for aviation safety. However, the FAA recently determined that as long as there are no gaps in lighting greater than a half-mile, it is not necessary to light each tower in a multi-turbine wind project. Daytime lighting is unnecessary as long as the turbines are painted white.

When it comes to aesthetics, wind turbines can elicit strong reactions. To some people, they are graceful sculptures; to others, they are eyesores that compromise the natural landscape. Whether a community is willing to accept an altered skyline in return for cleaner power should be decided in an open public dialogue.

Water Use:

There is no water impact associated with the operation of wind turbines. As in all manufacturing processes, some water is used to manufacture steel and cement for wind turbines.

Life-Cycle Global Warming Emissions:

While there are no global warming emissions associated with operating wind turbines, there are emissions associated with other stages of a wind turbine's life-cycle, including materials production, materials transportation, on-site construction and assembly, operation and maintenance, and decommissioning and dismantlement.

Estimates of total global warming emissions depend on a number of factors, including wind speed, percent of time the wind is blowing, and the material composition of the wind turbine. Most estimates of wind turbine life-cycle global warming emissions are between 0.02 and 0.04 pounds of carbon dioxide equivalent per kilowatt-hour. To put this into context, estimates of life-cycle global warming emissions for natural gas generated electricity are between 0.6 and 2 pounds of carbon dioxide equivalent per kilowatt-hour and estimates for coal-generated electricity are 1.4 and 3.6 pounds of carbon dioxide equivalent per kilowatt-hour.

- *Solar Power:*

The sun provides a tremendous resource for generating clean and sustainable electricity without toxic pollution or global warming emissions.

The potential environmental impacts associated with solar power — land use and habitat loss, water use, and the use of hazardous materials in manufacturing — can vary greatly depending on the technology, which includes two broad categories: photovoltaic (PV) solar cells or concentrating solar thermal plants (CSP).

Land Use:

Depending on their location, larger utility-scale solar facilities can raise concerns about land degradation and habitat loss. Total land area requirements varies depending on the technology, the topography of the site, and the intensity of the solar resource. Estimates for utility-scale PV systems range from 3.5 to 10 acres per megawatt, while estimates for CSP facilities are between 4 and 16.5 acres per megawatt.

Unlike wind facilities, there is less opportunity for solar projects to share land with agricultural uses. However, land impacts from utility-scale solar systems can be minimized by siting them at lower-quality locations such as brownfields, abandoned mining land, or existing transportation and transmission corridors. Smaller scale solar PV arrays, which can be built on homes or commercial buildings, also have minimal land use impact.

Water Use

Solar PV cells do not use water for generating electricity. However, as in all manufacturing processes, some water is used to manufacture solar PV components.

Concentrating solar thermal plants (CSP), like all thermal electric plants, require water for cooling. Water use depends on the plant design, plant location, and the type of cooling system.

CSP plants that use wet-recirculating technology with cooling towers withdraw between 600 and 650 gallons of water per megawatt-hour of electricity produced. CSP plants with once-through cooling technology have higher levels of water withdrawal, but lower total water consumption (because water is not lost as steam). Dry-cooling technology can reduce water use at CSP plants by approximately 90 percent. However, the tradeoffs to these water savings are higher costs and lower efficiencies. In addition, dry-cooling technology is significantly less effective at temperatures above 100 degrees Fahrenheit.

Many of the regions in the United States that have the highest potential for solar energy also tend to be those with the driest climates, so careful consideration of these water tradeoffs is essential.

Hazardous Materials:

The PV cell manufacturing process includes a number of hazardous materials, most of which are used to clean and purify the semiconductor surface. These chemicals, similar to those used in the general semiconductor industry, include hydrochloric acid, sulfuric acid, nitric acid, hydrogen fluoride, 1,1,1-trichloroethane, and acetone. The amount and type of chemicals used depends on the type of cell, the amount of cleaning that is needed, and the size of silicon wafer. Workers also face risks associated with inhaling silicon dust. Thus, PV manufactures must follow U.S. laws to ensure that workers are not harmed by exposure to these chemicals and that manufacturing waste products are disposed of properly.

Thin-film PV cells contain a number of more toxic materials than those used in traditional silicon photovoltaic cells, including gallium arsenide, copper-indium-gallium-diselenide, and cadmium-telluride. If not handled and disposed of properly, these materials could pose serious environmental or public health threats. However, manufacturers have a strong financial incentive to ensure that these highly valuable and often rare materials are recycled rather than thrown away.

Life-Cycle Global Warming Emissions:

While there are no global warming emissions associated with generating electricity from solar energy, there are emissions associated with other stages of the solar life-cycle, including manufacturing, materials transportation, installation, maintenance, and decommissioning and dismantlement. Most estimates of life-cycle emissions for photovoltaic systems are between 0.07 and 0.18 pounds of carbon dioxide equivalent per kilowatt-hour.

Most estimates for concentrating solar power range from 0.08 to 0.2 pounds of carbon dioxide equivalent per kilowatt-hour. In both cases, this is far less than the lifecycle emission rates for natural gas (0.6-2 lbs of CO_2E/kWh) and coal (1.4-3.6 lbs of CO_2E/kWh).

- *Geothermal Energy.*

The most widely developed type of geothermal power plant (known as hydrothermal plants) are located near geologic "hot spots" where hot molten rock is close to the earth's crust and produces hot water. In other regions enhanced geothermal systems (or hot dry rock geothermal), which involve drilling into Earth's surface to reach deeper geothermal resources, can allow broader access to geothermal energy.

Geothermal plants also differ in terms of the technology they use to convert the resource to electricity (direct steam, flash, or binary) and the type of cooling technology they use (water-cooled and air-cooled). Environmental impacts will differ depending on the conversion and cooling technology used.

Water Quality and Use

Geothermal power plants can have impacts on both water quality and consumption. Hot water pumped from underground reservoirs often contains high levels of sulfur, salt, and other minerals. Most geothermal facilities have closed-loop water systems, in which extracted water is pumped directly back into the geothermal reservoir after it has been used for heat or electricity production. In such systems, the water is contained within steel well casings cemented to the surrounding rock. There have been no reported cases of water contamination from geothermal sites in the United States.

Water is also used by geothermal plants for cooling and re-injection. All U.S. geothermal power facilities use wet-recirculating technology with cooling towers. Depending on the cooling technology used, geothermal plants can require between 1,700 and 4,000 gallons of water per megawatt-hour. However, most geothermal plants can use either geothermal fluid or freshwater for cooling; the use of geothermal fluids rather than freshwater clearly reduces the plants overall water impact.

Most geothermal plants re-inject water into the reservoir after it has been used to prevent contamination and land subsidence. In most cases, however, not all water removed from the reservoir is re-injected because some is lost as steam. In order to maintain a constant volume of water in the reservoir, outside water must be used. The amount of water needed depends on the size of the plant and the technology used; however, because reservoir water is “dirty," it is often not necessary to use clean water for this purpose. For example, the Geysers geothermal site in California injects non-potable treated wastewater into its geothermal reservoir.

Air Emissions

The distinction between open- and closed-loop systems is important with respect to air emissions. In closed-loop systems, gases removed from the well are not exposed to the atmosphere and are injected back into the ground after giving up their heat, so air emissions are minimal. In contrast, open-loop systems emit hydrogen sulfide, carbon dioxide, ammonia, methane, and boron. Hydrogen sulfide, which has a distinctive “rotten egg” smell, is the most common emission.

Once in the atmosphere, hydrogen sulfide changes into sulfur dioxide (SO_2). This contributes to the formation of small acidic particulates that can be absorbed by the bloodstream and cause heart and lung disease. Sulfur dioxide also causes acid rain, which damages crops, forests, and soils, and acidifies lakes and streams. However, SO_2 emissions from geothermal plants are approximately 30 times lower per megawatt-hour than from coal plants, which is the nation’s largest SO_2 source.

Some geothermal plants also produce small amounts of mercury emissions, which must be mitigated using mercury filter technology. Scrubbers can reduce air emissions, but they produce a watery sludge composed of the captured materials, including sulfur, vanadium, silica compounds, chlorides, arsenic, mercury, nickel, and other heavy metals. This toxic sludge often must be disposed of at hazardous waste sites.

Land Use:

The amount of land required by a geothermal plant varies depending on the properties of the resource reservoir, the amount of power capacity, the type of energy conversion system, the type of cooling system, the arrangement of wells and piping systems, and the substation and auxiliary building needs. The Geysers, the largest geothermal plant in the world, has a capacity of approximately 1,517 megawatts and the area of the plant is approximately 78 square kilometers, which translates to approximately 13 acres per megawatt. Like the Geysers, many geothermal sites are located in remote and sensitive ecological areas, so project developers must take this into account in their planning processes.

Land subsidence, a phenomenon in which the land surface sinks, is sometimes caused by the removal of water from geothermal reservoirs. Most geothermal facilities address this risk by re-injecting wastewater back into geothermal reservoirs after the water's heat has been captured.

Hydrothermal plants are sited on geological "hot spots," which tend to have higher levels of earthquake risk. There is evidence that hydrothermal plants can lead to an even greater earthquake frequency. Enhanced geothermal systems (hot dry rock) can also increase the risk of small earthquakes. In this process, water is pumped at high pressures to fracture underground hot rock reservoirs similar to technology used in natural gas hydraulic fracturing. Earthquake risk associated with enhanced geothermal systems can be minimized by siting plants an appropriate distance away from major fault lines. When a geothermal system is sited near a heavily populated area, constant monitoring and transparent communication with local communities is also necessary.

Life-Cycle Global Warming Emissions

In open-loop geothermal systems, approximately 10 percent of the air emissions are carbon dioxide, and a smaller amount of emissions are methane, a more potent global warming gas. Estimates of global warming emissions for open-loop systems are approximately 0.1 pounds of carbon dioxide equivalent per kilowatt-hour. In closed-loop systems, these gases are not released into the atmosphere, but there are a still some emissions associated with plant construction and surrounding infrastructure.

Enhanced geothermal systems, which require energy to drill and pump water into hot rock reservoirs, have life-cycle global warming emission of approximately 0.2 pounds of carbon dioxide equivalent per kilowatt-hour.

To put this into context, estimates of life-cycle global warming emissions for natural gas generated electricity are between 0.6 and 2 pounds of carbon dioxide equivalent per kilowatt-hour and estimates for coal-generated electricity are 1.4 and 3.6 pounds of carbon dioxide equivalent per kilowatt-hour.

- *Biomass for Electricity.*

Biomass power plants share some similarities with fossil fuel power plants: both involve the combustion of a feedstock to generate electricity. Thus, biomass plants raise similar, but not identical, concerns about air emissions and water use as fossil fuel plants. However, the feedstock of biomass plants can be sustainable produced, while fossil fuels are non-renewable.

Sources of biomass resources for producing electricity are diverse, including energy crops (like switchgrass), agricultural waste, manure, forest products and waste, and urban waste. Both the type of feedstock and the manner in which it is developed and harvested significantly affect land use and life-cycle global warming emissions impacts of producing power from biomass.

Water Use

Biomass power plants require approximately the same amount of water for cooling as coal power plants, but actual water withdrawals and consumption depends on the facility's cooling technology. For biomass plants with once-through cooling systems—which take water from nearby sources, circulate it through the plants cooling system, and then discharge it—water withdrawals range between 20,000 and 50,000 gallons per megawatt-hour with consumption of 300 gallons per megawatt-hour. Biomass facilities that use wet-recirculating cooling systems—which reuse cooling water in a second cycle rather than immediately discharging it—withdraw between 500 and 900 gallons per megawatt-hour and consume approximately 480 gallons per megawatt-hour.

Approximately 75% of existing biomass plants that require cooling use wet-recirculating technology, while 25% of plants use once-through cooling technology. In either case, when withdrawn cooling water is returned to its source, it is much warmer than when it was withdrawn, which often has a negative impact on plant and animal life. As in all thermal plants, this impact must be closely monitored. Dry-cooling systems do not withdraw or consume any water, but the tradeoffs to these water savings are higher costs and lower efficiencies—meaning more fuel is needed per unit of electricity.

Water is also needed to produce some biomass feedstocks. While some feedstock sources—such as agricultural, forest, and urban waste—require no additional water, others—such as energy crops—can be very water intensive. Different energy crops vary in terms of how much water they require. Miscanthus, one type of perennial grass, requires a large amount of water, while switchgrass, another perennial grass, generally requires much less. Water use efficiency of a given crop depends on a number of factors, including soil quality and temperature.

In regions with sufficient rainfall where irrigation is not required, water use for producing energy crops may be less of a concern. However, even in water-rich areas, the increased cultivation of energy crops may harm regional water quality as a result of soil tillage and nutrient runoff. Such water quality impacts can be managed through proper harvesting techniques. Many of these same issues arise in the cultivation of energy crops for biofuels.

Air Emissions

Burning biomass to produce electricity can impact air quality. The level of air emissions associated with biomass power plants varies depending on the feedstock, combustion technology, and types of installed pollution controls, but the most common pollutants include nitrogen oxides (NOx), sulfur dioxide (SO_2), carbon monoxide, and particulate matter. The table below compares air emissions from different types of biomass, coal, and natural gas power facilities with pollution control equipment. In general, biomass facilities emit less SO_2 and mercury (a neurotoxin) than coal.

Nitrogen oxides from biomass are lower than those from coal but higher than natural gas. NOx emissions causes ground-level ozone, or smog, which can burn lung tissue and can make people more susceptible to asthma, bronchitis, and other chronic respiratory diseases. Like SO2, NOx also contributes to acid rain and the formations of harmful particulate matter. Biomass power plants also emit high levels of particulates (soot and ash) and carbon monoxide. Readily available technologies, such as fluidized bed or gasification systems, and electrostatic precipitators, can help reduce NOx, CO, and particulate emissions associated with biomass power.

Land Use

Land use impacts from biomass power production are driven primarily by the type of feedstock: either a waste stream or an energy crop that is grown specifically for generating electricity. Because waste streams are only secondarily available as a result of another activity that would have otherwise occurred—such as logging or farming—there is no marginal increase in land use. However, if not collected properly, using agriculture and forest waste streams for biomass power could lead to land or habitat degradation.

Important safeguards and best practices for removal are needed to ensure that sufficient crop residues are left behind to improve soil carbon storage, maintain nutrient levels, and prevent erosion. Similarly, harvesting of forest waste products can be done sustainably, but proper forest management practices need to be followed to ensure that wildlife habitat is not destroyed and the forest remains healthy.

Impacts associated with the use of energy crops depends greatly on whether the planting leads to land use change or displaced food production. If energy crops are planted on a large scale and displace food production, then new lands may need to be cleared to maintain food supplies. As a result, this could potentially change U.S. or global land use patterns and lead to habitat destruction or increases in food prices. However, it is possible to sustainably increase agricultural efficiency and reduce the land required for food production while also improving soil health, erosion, and eutrophication. Doing so could free up land for energy crops while minimizing food displacement and other land use changes.

Energy crops present many of the same environmental challenges as food crops, and therefore the same principles of sustainable agriculture apply: crop rotation, integrated pest management, and proper soil husbandry to prevent soil erosion. Many energy crops use less fertilizer and pesticides than typical food crops, and perennial grasses do not require annual tilling and planting. These crops can even be advantageous for some farmers; alternating the planting of food and energy crops can help stabilize the soil and provide supplemental farm income.

There are global warming emissions associated with growing and harvesting biomass feedstock, transporting feedstock to the power plant, and burning or gasifying the feedstock. Transportation and combustion emissions are roughly equivalent for all types of biomass. However, global warming emissions from the sourcing of biomass feedstock vary widely. It was once commonly thought that biomass had net zero global warming emissions, because the growing biomass absorbed an equal amount of carbon as the amount released through combustion. It is now understood that some biomass feedstock sources are associated with substantial global warming emissions. Thus, it is important to distinguish between biomass resources that are beneficial in reducing net carbon emissions, those that have an ambiguous impact, and those that increase net emissions.

Beneficial biomass resources include energy crops that do not compete with food crops for land, portions of crop residues such as wheat straw or corn stover, sustainably-harvested wood and forest residues, and clean municipal and industrial wastes. The use of organic waste products for biomass energy is especially beneficial. When organic waste is disposed of in a landfill, it decomposes and releases methane, a potent global warming gas. Thus, diverting these wastes for electricity production reduces landfill volume and reduces methane emissions.

Harmful biomass resources and practices add net carbon to the atmosphere by either directly or indirectly decreasing the overall amount of carbon stored in plants and soils. Such practices include clearing forests, savannas, or grasslands to grow energy crops, and displacing food production for bioenergy production that ultimately leads to the clearing of carbon-rich ecosystems elsewhere to grow food.

For marginal biomass resources, the net carbon impact depends on the circumstances. For example, if grasslands are plowed up or forests cut down to make way for switchgrass farms, there will be an increase in net carbon emissions. This is because grasslands and forests contain large stores of carbon, and total carbon storage increases each year as these ecosystems mature. There could also be a net increase in global warming emissions associated with planting switchgrass on productive agricultural land. On a global level, as food crops are replaced with energy crops, the price of food increases, which gives farmers the incentive to clear more grasslands and forests to make way for food production. Thus, even if switchgrass does not directly displace grasslands and forest, the effect could be indirect. However, plants like switchgrass can have zero or net negative emissions if they are planted in degraded or abandoned agricultural land. Research has shown that switchgrass, when planted in diverse mixtures with other perennial grasses and legumes, can help store carbon in degraded soils.

Forest feedstock is another example of a marginal biomass resource. The use of forest products for biomass feedstock can have net zero global warming emissions if forest managers harvest in a sustainable manner and replant with fast-growing tree species. However, even when following best practices, forest regeneration will not occur instantly, so there can be a long lag-time before the biomass resource achieves carbon neutrality.

Due to all of these factors, the range for estimates for lifecycle global warming emissions of biomass energy is wide. Excluding global warming emissions from land use changes, most estimates are between 0.04 and 0.2 pounds of CO_2 equivalent per kilowatt-hour. To put this into context, estimates of life-cycle global warming emissions for natural gas-generated electricity are between 0.6 and 2 pounds of carbon dioxide equivalent per kilowatt-hour and estimates for coal-generated electricity are 1.4 and 3.6 pounds of carbon dioxide equivalent per kilowatt-hour.

- *Hydroelectric Power.*

Hydroelectric power includes both massive hydroelectric dams and small run-of-the-river plants. Large-scale hydroelectric dams continue to be built in many parts of the world (including China and Brazil), but it is unlikely that new facilities will be added to the existing U.S. fleet in the future.

Instead, the future of hydroelectric power in the United States will likely involve increased capacity at current dams and new run-of-the-river projects. There are environmental impacts at both types of plants.

Land Use

The size of the reservoir created by a hydroelectric project can vary widely, depending largely on the size of the hydroelectric generators and the topography of the land. Hydroelectric plants in flat areas tend to require much more land than those in hilly areas or canyons where deeper reservoirs can hold more volume of water in a smaller space.

At one extreme, the large Balbina hydroelectric plant, which was built in a flat area of Brazil, flooded 2,360 square kilometers—an area the size of Delaware—and it only provides 250 MW of power generating capacity (equal to more than 2,000 acres per MW). In contrast, a small 10 MW run-of-the-rive plant in a hilly location can use as little 2.5 acres (equal to a quarter of an acre per MW).

Flooding land for a hydroelectric reservoir has an extreme environmental impact: it destroys forest, wildlife habitat, agricultural land, and scenic lands. In many instances, such as the Three Gorges Dam in China, entire communities have also had to be relocated to make way for reservoirs.

Wildlife Impacts

Dammed reservoirs are used for multiple purposes, such as agricultural irrigation, flood control, and recreation, so not all wildlife impacts associated with dams can be directly attributed to hydroelectric power. However, hydroelectric facilities can still have a major impact on aquatic ecosystems. For example, though there are a variety of methods to minimize the impact (including fish ladders and in-take screens), fish and other organisms can be injured and killed by turbine blades.

Apart from direct contact, there can also be wildlife impacts both within the dammed reservoirs and downstream from the facility. Reservoir water is usually more stagnant than normal river water. As a result, the reservoir will have higher than normal amounts of sediments and nutrients, which can cultivate an excess of algae and other aquatic weeds. These weeds can crowd out other river animal and plant-life, and they must be controlled through manual harvesting or by introducing fish that eat these plants. In addition, water is lost through evaporation in dammed reservoirs at a much higher rate than in flowing rivers.

In addition, if too much water is stored behind the reservoir, segments of the river downstream from the reservoir can dry out. Thus, most hydroelectric operators are required to release a minimum amount of water at certain times of year. If not released appropriately, water levels downstream will drop and animal and plant life can be harmed. In addition, reservoir water is typically low in dissolved oxygen and colder than normal river water. When this water is released, it could have negative impacts on downstream plants and animals. To mitigate these impacts, aerating turbines can be installed to increase dissolved oxygen and multi-level water intakes can help ensure that water released from the reservoir comes from all levels of the reservoir, rather than just the bottom (which is the coldest and has the lowest dissolved oxygen).

Life-cycle Global Warming Emissions

Global warming emissions are produced during the installation and dismantling of hydroelectric power plants, but recent research suggests that emissions during a facility's operation can also be significant. Such emissions vary greatly depending on the size of the reservoir and the nature of the land that was flooded by the reservoir.

Small run-of-the-river plants emit between 0.01 and 0.03 pounds of carbon dioxide equivalent per kilowatt-hour. Life-cycle emissions from large-scale hydroelectric plants built in semi-arid regions are also modest: approximately 0.06 pounds of carbon dioxide equivalent per kilowatt-hour. However, estimates for life-cycle global warming emissions from hydroelectric plants built in tropical areas or temperate peatlands are much higher. After the area is flooded, the vegetation and soil in these areas decomposes and releases both carbon dioxide and methane. The exact amount of emissions depends greatly on site-specific characteristics. However, current estimates suggest that life-cycle emissions can be over 0.5 pounds of carbon dioxide equivalent per kilowatt-hour.

To put this into context, estimates of life-cycle global warming emissions for natural gas generated electricity are between 0.6 and 2 pounds of carbon dioxide equivalent per kilowatt-hour and estimates for coal-generated electricity are 1.4 and 3.6 pounds of carbon dioxide equivalent per kilowatt-hour.

- *Hydrokinetic Energy.*

Hydrokinetic energy, which includes wave and tidal power, encompasses an array of energy technologies, many of which are still in the experimental stages or in the early stages of deployment.

While actual impacts of large-scale operations have not been observed, a range of potential impacts can be projected. For example, wave energy installations can require large expanses of ocean space, which could compete with other uses—such as fishing and shipping—and cause damage to marine life and habitats. Some tidal energy technologies are located at the mouths of ecologically-sensitive estuary systems, which could cause changes in hydrology and salinity that negatively impact animal and plant life.

In addition, while estimates for life-cycle global warming emissions for wave and tidal power are preliminary, published research suggests that they would be below 0.05 pounds of carbon dioxide equivalent per kilowatt-hour. To put this into context, estimates of life-cycle global warming emissions for natural gas generated electricity are between 0.6 and 2 pounds of carbon dioxide equivalent per kilowatt-hour and estimates for coal-generated electricity are 1.4 and 3.6 pounds of carbon dioxide equivalent per kilowatt-hour.

2.2. Renewable sources classification and characteristics.

Characteristics:

- Are clean so it not generate waste difficult to eliminate.
- The environmental impact is reduced. Produce no emissions of CO_2 and other polluting gases into the atmosphere.
- They are produced continuously so are unlimited.
- Prevent foreign dependence, are native.
- They are complementary.
- They balance inter-regional imbalances.
- Boost local economies by creating five times more jobs than conventional.
- Are viable alternative to conventional energy.

Classification of renewable energy:

The origin of all renewable energy sources are natural sources like the sun, water, wind and organic waste, while the sun is definitely the engine generator of all cycles that give rise to other sources. Renewable energies are then sorted according to the natural source from which they came.

Renewable energy sources:

Energy sources can be divided into two main groups: permanent (renewable) and temporary (non-renewable). In principle, the permanent sources are those solar, in fact, we know that the sun will stay longer than Earth. Still, the concept of renewability depends on the time scale used and the rate of use of resources. So, fossil fuels are considered non-renewable sources and the utilization rate is much higher than the rate of formation of the resource itself.
Renewable energy sources are:

- *Wind power:*

It is obtained from the wind that is by utilizing the kinetic energy generated by the effect of air currents. The wind comes from the Latin term *aeolicus* belonging or relating to Aeolus and Aeolus, god of the winds in Greek mythology and, therefore, belonging or relating to the wind.

Wind energy has been used since ancient times to move boats powered by sail or operate machinery mills to move their blades. Wind energy is related to the movement of air masses that move from areas of high atmospheric pressure to adjacent areas of low pressure, with speeds proportional to (pressure gradient) .The wind energy is an abundant, renewable resource, clean and helps reduce emissions of greenhouse gases by replacing power plants based on fossil fuels, which makes it a kind of green energy.

2.85. Frontal detail of windmill.
Source: http://www.ucsusa.org/

- *So*lar energy:

The parabolic solar collectors concentrate solar radiation increasing the temperature in the receiver. Photovoltaic panels convert light energy directly into electrical energy. Solar energy is the source of life and origin of most other forms of energy on Earth. Each year the solar radiation contributes to Earth energy equivalent to several thousand times the amount of energy consumed by humanity. Properly collecting solar radiation, this can be transformed into other forms of energy as heat or electricity using solar panels.

Direct radiation and diffuse radiation, two components in solar radiation are distinguished. Direct radiation is reaching the solar focus directly, without intermediate reflections or refractions. The diffuse is issued by the daytime sky thanks to the multiple phenomena of reflection and refraction in the solar atmosphere, clouds and other atmospheric and terrestrial elements. Direct radiation can be reflected and concentrated for use, while it is not possible to concentrate the diffused light coming from all directions. However, both direct radiation and diffuse radiation are usable. You can differentiate between active and passive recipients on the first use mechanisms to guide the receiving system to better capture the sun and direct radiation.

6. Worker preparing solar panels.
Source: http://www.ucsusa.org/

- *Biomass:*

Biomass as an energy source, can be classified into natural, waste biomass and energy crops. Natural biomass is produced in nature without human intervention. It is a source of energy from the sun indirectly and can be considered a renewable energy provided that adequate environmental parameters are followed and exploit. The biomass residual is the sub-product or waste generated by agricultural activities (pruning, stubble, etc.), forestry and farming, and waste from the food industry (dregs, bagasse, husks, vinasse, etc.) and processing industry (sawmills, paper mills, furniture, etc.) and as waste water treatment plants and recycling oils. The energy crops are those for the production of biofuels. In addition to existing crops for the food industry (cereals and sugar beet for bioethanol production and oil for biodiesel production), other crops such as forest and herbaceous lignocellulose.

Biomass formation from solar energy is done by a process called photosynthesis plant which in turn is triggering the biological chain. Through photosynthesis, plants containing chlorophyll, transform carbon dioxide and water, mineral products energy, organic materials with high energy content and in turn are food for other living beings. Biomass through these processes short-term stored solar energy in the form of carbon. The energy stored in the photosynthetic process can be further transformed into heat, electricity or fuels of vegetable origin.

- *Tidal power:*

Tidal energy is due to the gravitational forces between the Moon, Earth and the Sun, which cause the tides, that is, the difference in average height of the seas as the relative position between these three stars. This height difference can be utilized in strategic locations such as gulfs, bays and estuaries using hydraulic turbines that stand in the natural movement of water, along with pipeline and storage mechanisms, for movement on an axis.

By coupling to an alternator system you can be used for electricity generation, transforming wave energy into electrical energy, a more useful and usable energy form.

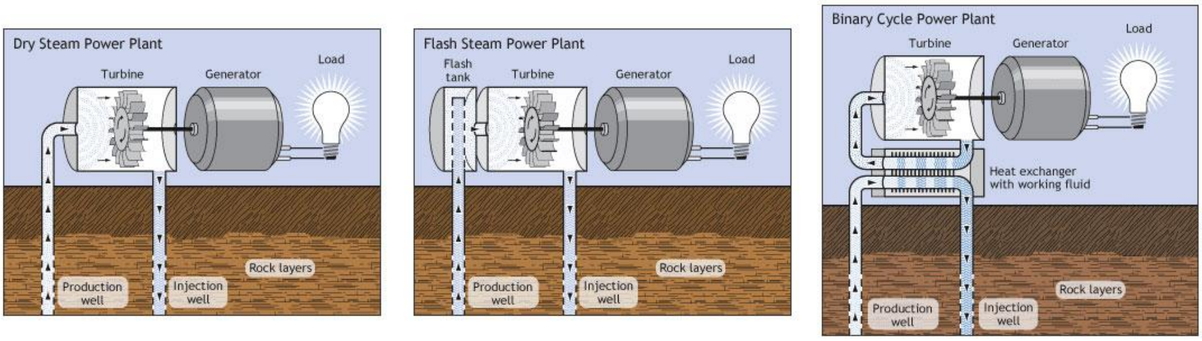
2.10. An attenuator wave energy converter.
Source: http://www.aidea.org/

Tidal energy has the quality to be renewable as long as the primary energy source is not exhausted by exploitation, and is clean, because in the clean energy transformation products produced during the operational phase. However, the relationship between the amount of energy that can be obtained with the current means and the economic cost and environmental impact of installing the devices for processing have prevented a remarkable proliferation of this type of energy.

Other ways to extract energy from the sea are wave energy, which is the energy produced by the motion of the waves; and energy due to ocean thermal gradient, which makes a difference in temperature between the surface and the deep waters of ocean. The tidal energy is obtained by taking advantage of the tides, by coupling to an alternator can use the system to electricity generation, transforming wave energy into electrical energy, a more useful and usable energy form. It is a type of renewable and clean energy.

- *Geothermal energy:*

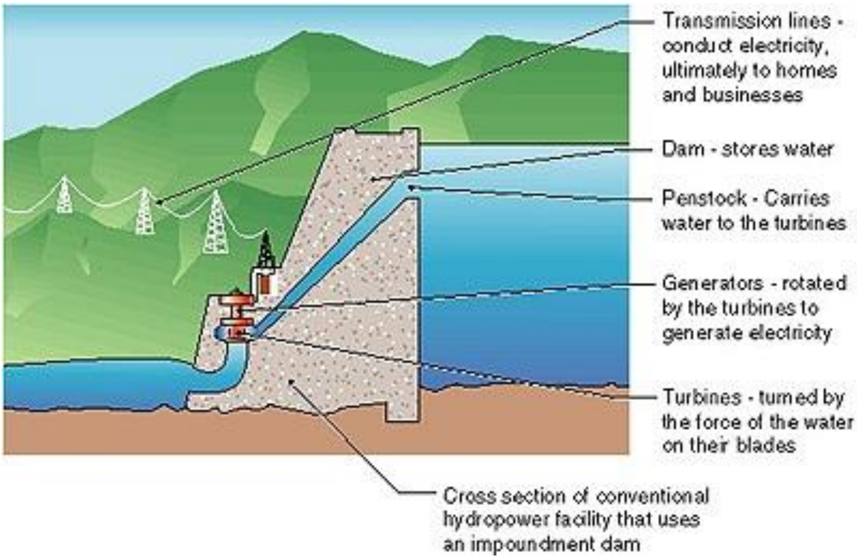
Part of the internal heat of the Earth (5.000ºC) reaching the earth's crust. In some areas of the planet, near the surface, groundwater can reach boiling temperatures, and thus serve to drive electric turbines or to heat. Geothermal energy is energy that can be obtained by man through the use of heat from inside the Earth. The heat inside the Earth to several factors, among which we would highlight the geothermal gradient, the radiogenic value should be, etc. Geothermal comes from the Greek geo, "earth", and thermos, "hot"; literally "heat of the Earth".



2.11. The three basic designs for geothermal power plants: dry steam, flash steam, and binary cycle.
Source: http://energy.gov/

- *Hydropower:*

The accumulated potential energy waterfalls can be transformed into electrical energy. Hydroelectric plants use energy from the rivers to operate turbines that carry an electric generator. However, the latter are not considered forms of green power by producing high environmental impact. It is a kind of green energy when environmental impact is minimal and the water used force without capture it, otherwise it is considered only a form of renewable energy. You can turn on very different scales, they have existed for centuries small farms where the river current moves a rotor blade and generates a motion applied, for example, in rural mills. However, the most significant use is constituted by the hydroelectric dams.



2.12. Main scheme of hydraulic power station.
Source: DOE Office of EEE

- *Biogas*

By simple chemical process of fermentation (rot) of organic waste such as manure, leaves, husks, etc., a known amount of gas is released biogas. With appropriate technology, the biogas can be transformed into other types of energy such as heat, electricity or mechanical energy. Biogas can also be produced in plants of biogas placing organic waste mixed with water in a large closed vessel (digester), where fermentation occurs through anaerobic bacteria. By different processes it can be purified to a quality that resembles that of natural gas, and can be used as fuel, gas or wood biofuel.

Negative Impacts.

Renewable energy can also cause some negative impacts but these are not comparable to those of conventional energy. Some of the drawbacks in using these types of energy are:

- Produce high visual impact.
- Variable and not fully predictable Son.
- The power density is low so sometimes difficult to guarantee the supply and must be complemented with other types of energy.
- Some of them are not sufficiently developed technologically.
- There are difficulties for storage so that it is not exploited to its full potential.
- The support and strong investment in research and development being done with this type of energy is causing them to go on track to disappear or minimize such drawbacks, for the use of renewable energy a reality in the very near future.

Renewable energies therefore presented as a clear alternative to conventional energy in the entire construction process.

3. Wind modelling and specific characteristics as a power source

3.1 Wind modelling (speed, limits, availability and potential).

The atmosphere:

The atmosphere is the gaseous layer that surrounds the Earth. It consists of a mixture of gases, called air, and contains solid and liquid (aerosol) suspended in quantity and variable composition particles.

Compared to the Earth's radius, the thickness of the atmosphere is very small. About 99% of the mass of the atmosphere is within the first 30 km high (0.5% of terrestrial radio).

The gases in the atmosphere can be divided into two groups:

- *Permanent gases*: the proportion is almost constant up to heights of about 80-100 km are nitrogen, oxygen, noble gases and hydrogen..
- *Gases in varying proportions*: are carbon dioxide, water vapour and ozone.

Vertical structure of the atmosphere:

Conventionally the atmosphere is vertically divided into different layers varies according to how the air temperature gradient. There are three main areas:

- Homosphere or lower atmosphere.

It extends from the ground to a height of 80-100 km. In her air composition is nearly constant. It is subdivided into:

- *Troposphere*: The lower part of the atmosphere and it develop meteorological phenomena. It contains approximately 80% of the mass of air. The temperature decreases with height at an average gradient of 6.5 ° C / km. The top of this region is called tropopause. Its height is very variable (of 6-8 km at the poles and about 16-18 km in Ecuador).
- *Stratosphere*: In this zone the temperature increases with height (inversion), which results in great stability because vertical movements are held back by this temperature inversion. The principals of radioactive energy exchanges are kind, and is in this layer where absorption of ultraviolet radiation by ozone takes place (most part between 8 and 30 km high). The upper limit of the stratosphere is called stratopause and placed into 50 km in height.

- *Mesosphere*: In this layer the temperature returns to decrease with height to about 80-90 km altitude where the temperature reaches its lowest values (around -90 C) in the mesopause.

- Heterosphere.

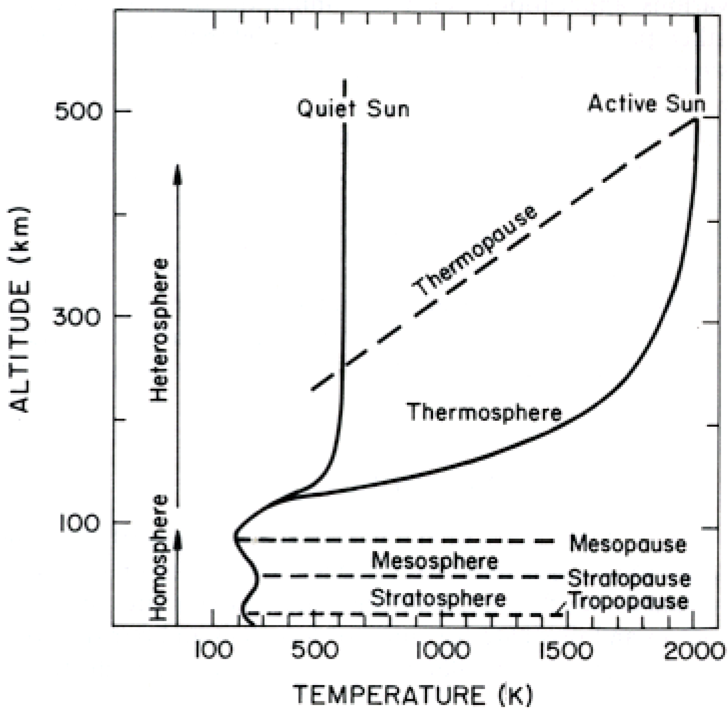
It starts at a height of 90-100 km. very rarefied atmosphere of low density and variable composition due to chemical reactions and diffusion of gases by gravity. The hetersfera comprising:

- Thermosphere: The temperature returns to increase with height, reaching values between 500 and 2000 ° K at the top, depending on the level of solar activity. The air is very thin and barely particles collide. The upper limit of the thermosphere is the termopausa whose height varies between 200 and 500 Km, depending on solar activity.

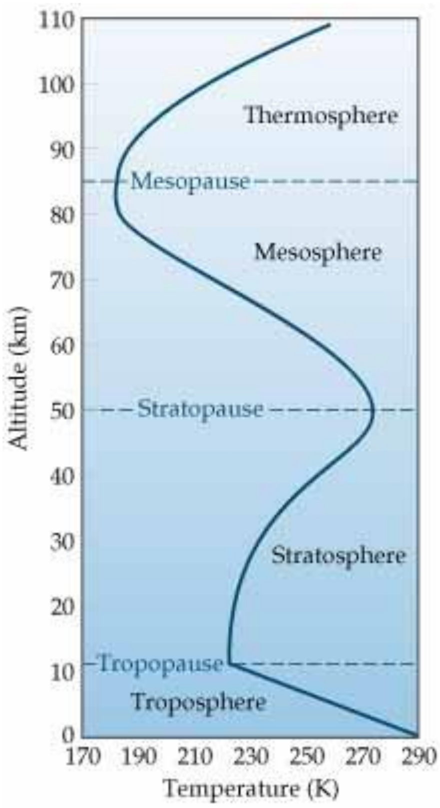
- Metasfera: For over 500 Km point the thermosphere called the magnetosphere, since the movement of particles is influenced by the Earth's magnetic field.

- Exosphere.

It is the most remote area in atmosphere. The gas is very thin, very low density. The particles are ionized. The assembly formed by the heterosphere and exosphere is called upper atmosphere.



3.1. Vertical structure of the earth's atmosphere.
Source: http://www.scopenvironment.org/



3.2. Vertical profile of temperature of the standard atmosphere.
Source: wps.prenhall.com

Air circulation in the atmosphere.

The movement of air in the atmosphere is done mainly in the troposphere and on it the following factors influence:

The solar radiation increased the equator than at the poles.

The rotation of the earth, producing the effect of Coriolisis, diverting the direction of the winds to the right in the Northern Hemisphere and clockwise in the south.

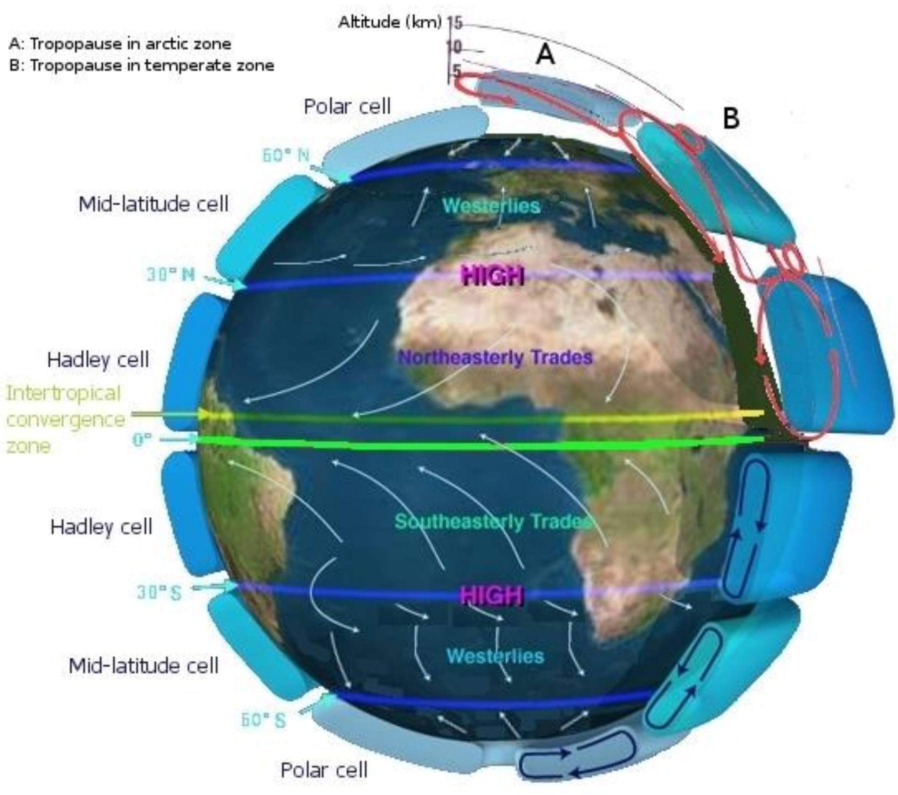
The action on the air masses atmospheric pressure differences, different types of land surfaces (continents and oceans) and relieves.

The air tends to rise in the equatorial regions because of its heating by solar radiation in a band called the intertropical convergence zone.

In Ecuador, the surface level reaches cooler air from the tropics (trade winds). In mid-latitudes, the winds are basically West but with a tendency towards the polar areas.

For a value of the next latitude 50 ° separation between the warm tropical air and cold polar air is produced, forming a polar front that has many undulations resulting frontal depressions. In Polar Regions, cold air tends to move to lower latitudes.

The following figure show the atmospheric general circulation patterns are shown.



3.3. Highly idealised depiction of the global circulation on Earth. Source: wikipedia.org

Wind.

Wind is the movement of air relative to the earth's surface. This movement is mainly horizontal. The wind speed and direction is a result of the longline action of the following forces:

- Force due to the horizontal pressure gradient: this force is directed from high pressure isobars at low pressure, representing a direction perpendicular thereto.
- Force due to the rotation of the earth (Coriolisis force) due to the rotation of the globe from west to east, the path of a moving air mass undergoes a shift to the right in the northern hemisphere (in the opposite direction in the southern hemisphere).
- Centrifugal force due to the curvature of the isobars: eta force acts in the direction of the radius of curvature of the path, away from center of curvature in the same sense.
- Due to friction force: it intervenes in the lower layers of the earth's surface near the atmosphere. It depends on so many factors such as the type of surface or topography of the same.

Depending on the forces considered the following types of winds are distinguished:

- Geostrophic wind. It is the wind resulting from the joint action of the forces due to the pressure gradient and Coriolisis. This kind of wind is parallel to the isobars, in general it can be said that is greater the closer the isobars (gradient of pressure) and for the same pressure gradient decreases with increasing latitude.
- Gradient wind. It is the result of the combination of forces due to the pressure gradient, from Coriolisis and centrifugal.

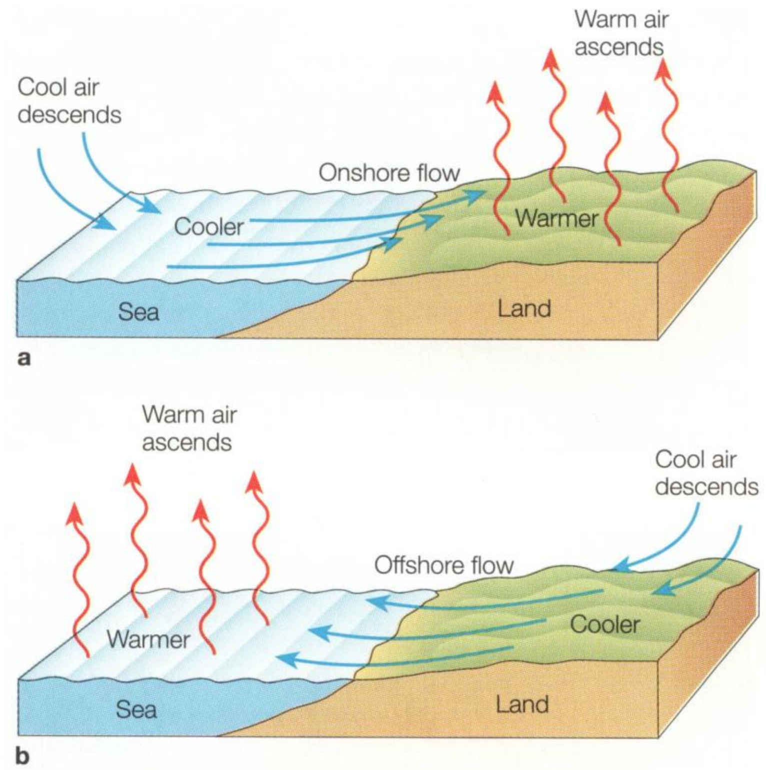
The wind gradient is a good approximation to the true wind in those conditions in which the frictional force is negligible. This situation occurs in layers that are not near the Earth's surface roughness as it introduces relatively large variations in air movement.

Geostrophic wind and gradient predict and describe quite well the actual wind conditions above about 1000 m above ground level. At lower heights, for example of about 100 m, the surface wind is greatly influenced by two factors: the earth's surface roughness and obstacles. For wind energy applications, we are interested in the surface winds because from them is extracted the mechanical energy to drive the turbine.

Winds from particular phenomena: local winds.

There are local climatic conditions causing a type of wind that deviate from the general laws outlined above for large-scale global winds. These include:

Sea breezes and land breezes.

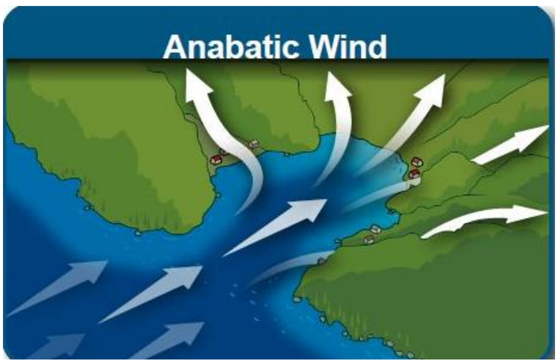


3.4. Valley and mountain breezes
a) Daytime sea-breeze conditions.
b) Nighttime land-breeze conditions.
Source: www.eeb.ucla.edu

Valley and mountain breezes (anabatic and katabatic winds).

In a mountain, in the evening, the air in contact with the highest mountain terrain cools faster than the air over the valley, so it tends to descend into the valley along the hillside. It is called katabatic wind, usually mild in nature.

3.5 Katabatic wind effect.
Source: http://www.ec.gc.ca/

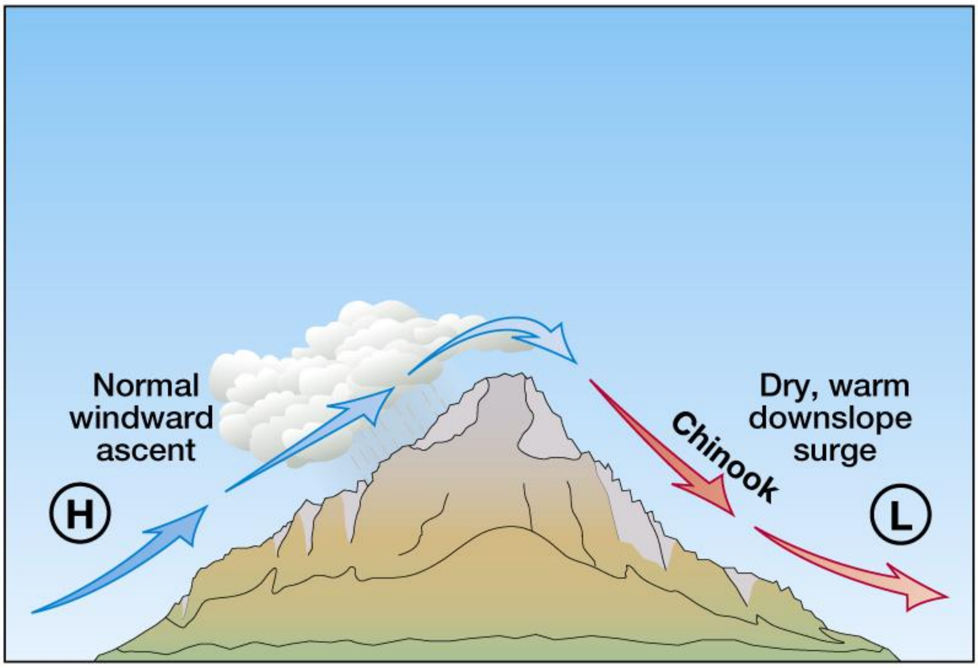


3.6. Anabatic wind effect.
Source: http://www.ec.gc.ca/

During the day, and the effect of solar radiation, the process is reversed and the wind is in contact with the ground located in the vicinity of the valley, which tends to rise along the slope (anabatic wind).

Foehn wind.

It takes its name from a wind from the north of the Alps, and occurs when an air mass is forced to ascend to find a mountain. This makes it decrease its temperature, and the water vapour in the wind start to condensation, and precipitation occurs. When descends for the other side of the mountain air mass has lost its moisture, it is a dry air descending rapidly so increasing air pressure and thus the temperature. Thus what the windward slope is humidity and precipitation, downwind is clear weather and heat.



3.7. Foehn wind.
Source: clasfaculty.ucdenver.edu

Wind speed

Wind speed ***v*** is a vector quantity. Given the characteristics of the wind, the velocity vector varies continuously in random both in magnitude, direction and sense. The measuring instrument is *Anemometer* for read speed and for direction is *vane*, these measured values with a certain sampling frequency (every 1 to 2 seconds) and averaged to every few minutes (usually 10 minutes). Thus, the value obtained represents the average characteristics of instantaneous wind during this period. It is therefore usual for the wind characterize average velocity vector (sometimes called stationary wind or medium) that may overlap random variations.

The velocity vector has three components as the Cartesian trihedral; but wind energy applications are only considered the velocity components in the horizontal plane. Therefore, the wind is characterized by two values: the modulus of the velocity component in the horizontal plane and the direction from which blows.

The speed is usually expressed in meters per second [m / s], and address can be indicated in several ways, all based in different divisions of the circular horizon of 360 degrees, but always indicating the direction from which the wind comes. Being able to specify 8, 10, 12 or 16 divisions respectively and the wind direction is generally expressed in degrees.

Variations in wind speed.

The following variations in wind speed can be distinguished:

Seasonal variations.

In many geographical areas, global winds resulting suffering from various different seasonal variations in solar radiation action, position anticyclones, depressions, etc. In fact, they can be detected more or less pronounced cyclical variations depending on the season's trends.

Daily variations.

The effects of heating or cooling day or night, the proximity of the sea, or the mountainous terrain occur in many areas cyclical variations in the wind. For example, coastal breezes or mountains.

Changes in very short periods: bursts

In short time, wind can suffer considerable variations in speed and direction. Defining burst depends on the one hand, of the instantaneous wind speed relative to the mean wind and, secondly, the duration of the burst itself.

When the instantaneous velocity exceeds about 5-8 m/s the value of the mean wind, we talk burst of 8-15 m/s with gusts and violent gusts if the instantaneous speed exceeds the mean wind speed at 15 m/s.

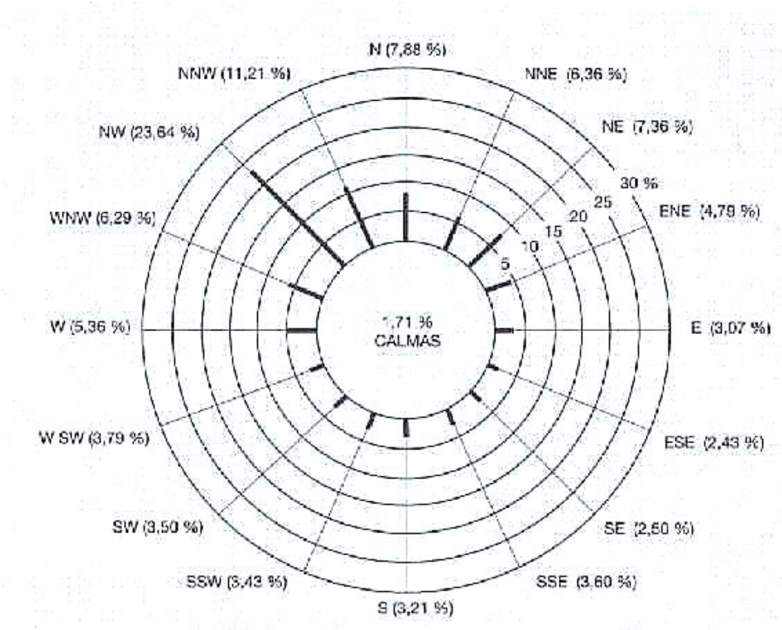
Embodiments of the wind data: speed and direction.

Depending on the measurement method and subsequent treatment of the measures, in practice you can find various forms of data presentation wind.

Graphical representations

The most widely used graphical representation is called the *Rose of the Winds*. It is a polar diagram in which addresses are defined for different or distinctive directions related to the wind speed values. The number of courses, whose main values are mapped to the cardinal points, used to be 8, 12 or 16. The percentage of calms is indicated in the centre of the diagram.

You can set different types of wind roses:

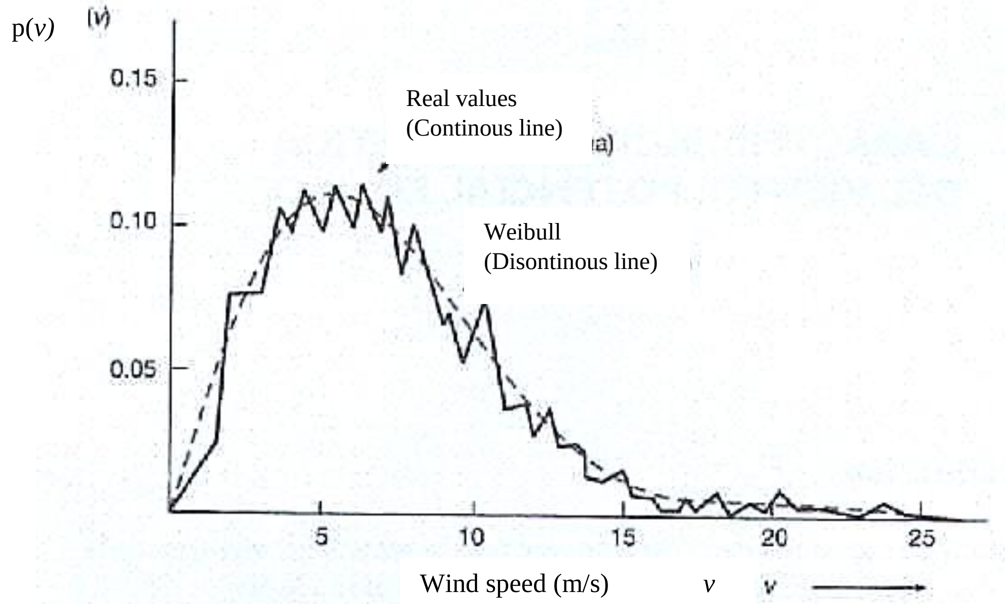


3.8. Percentage of total time the wind proecde a certain direction. Percentage rose frequencies (annual values). Source: http://tipos-de-energia.blogspot.ro/

3.9. Picture of the wind rose 8 and 16 courses. Source: Wikipedia.

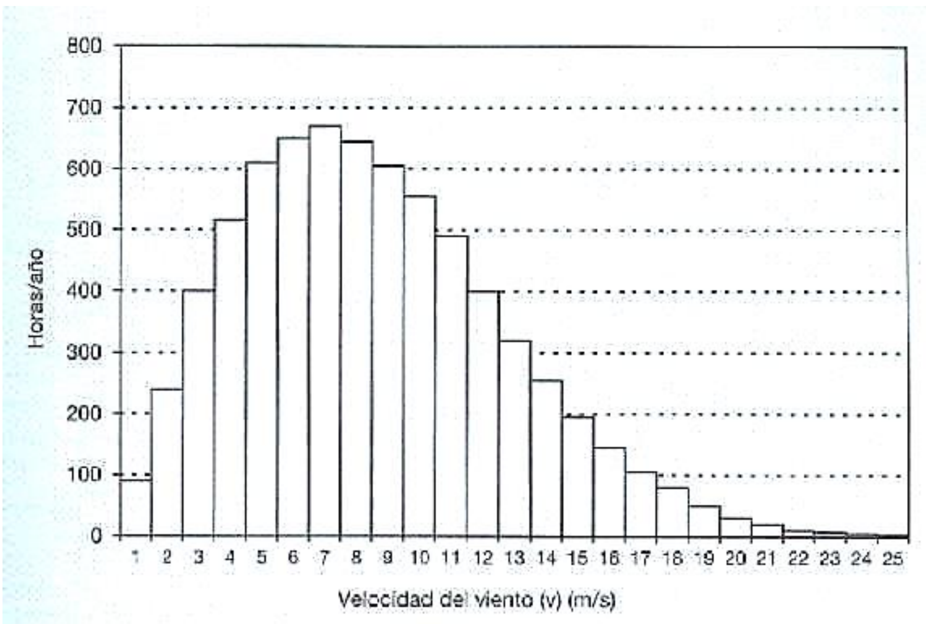
Distribution of wind speed

Probability density function for the wind speed over a period of time (e.g. one year). On line continuous: real values, and on discontinuous: adjustment to a Weibull distribution:



3.10. Probability density function for the wind speed.
Source: http://tipos-de-energia.blogspot.ro/

Example of histogram of wind speeds for an annual period (8760 hours):



3.11. Histogram of wind speeds.
Source: http://tipos-de-energia.blogspot.ro/

The density function corresponding to the law of Weibull probability p (v) is the type of two parameters (k, c) and is given by the expression:

$$p(v) = k/c * (v/c)^{(k-1)} * e^{-((v/c)^k)} \quad [1]$$

Where:

v is the wind speed (m/s).

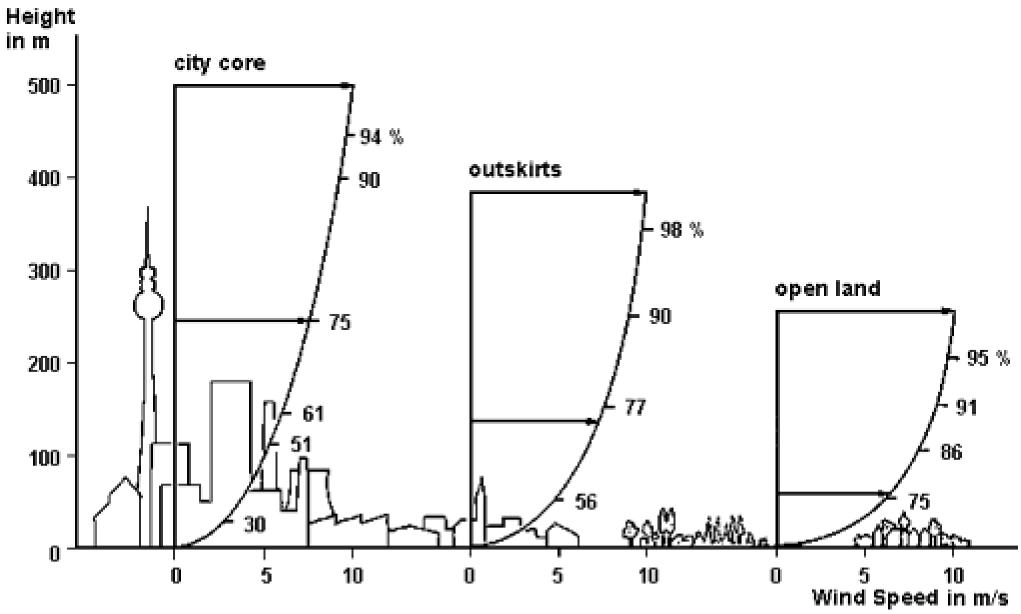
p(v) is the probability density function for Weibull.

c is the scale factor (m/s) value close to the average speed.

k form factor which characterizes the asymmetry to bias the probability function.

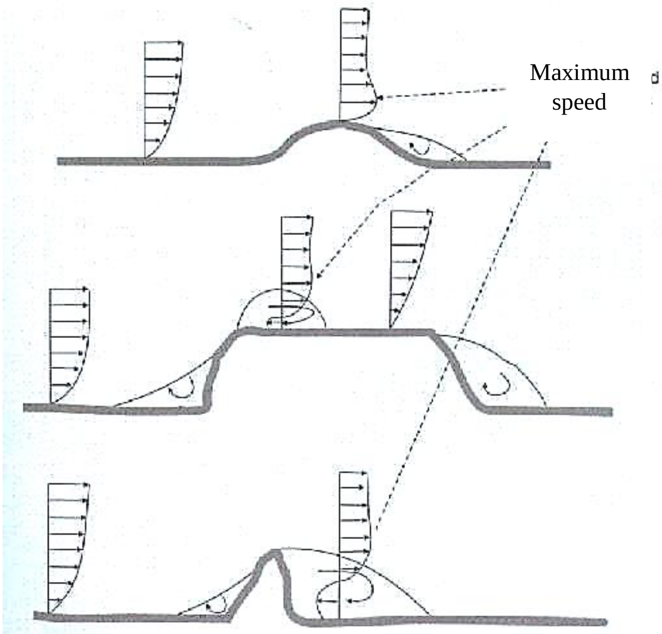
Most of the places where the right conditions for the exploitation of wind energy are given generally have velocity distributions that are close to Weibull distribution with shape parameter k = 2. In cases of areas close to the sea coast or at sea sites, the distribution of winds better distributions with higher values of k, eg k = 3 approaches. These values are only indicative, must be determined for each particular case.

Variation of wind speed with height. Terrain roughness.

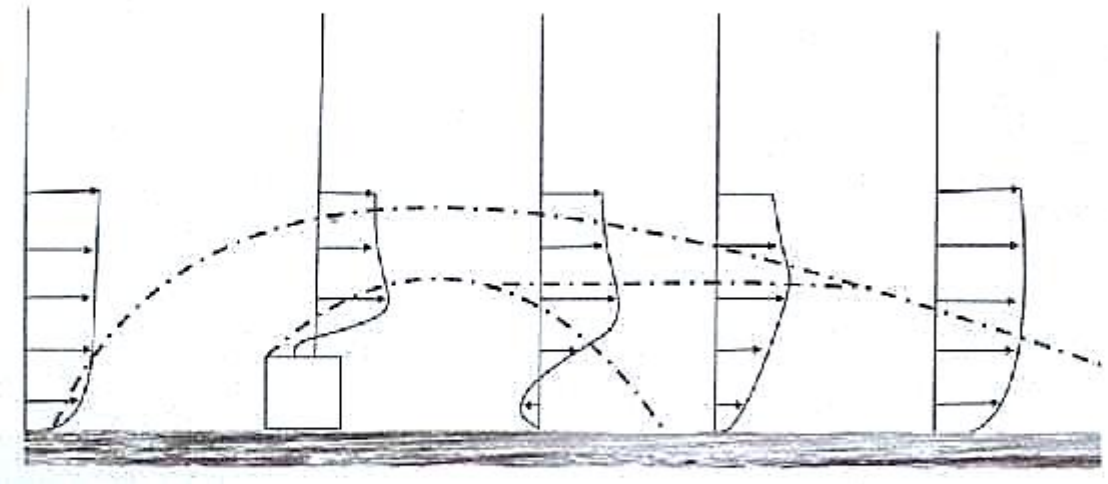


3.12. Different vertical profiles of the wind speed for different kinds of terrain roughness.
Source: www.stadtentwicklung.berlin.de

This parameter is defined as the length of roughness height above ground level in meters, where the wind speed is zero. And depending on this value can be classified in class terrain roughness. The following table shows the classification of land according to the roughness length, the table also includes the energy index to estimate the potential loss of power available depending on the terrain.



3.13 Landform influence on wind speed.
Source: http://tipos-de-energia.blogspot.ro/



3.14. Influence of obstacles in wind speed.
Source: http://tipos-de-energia.blogspot.ro/

Available wind power: wind potential.

An air mass m with a velocity v has a kinetic energy K is given by:

$$Ec = ½*m*v \wedge 2 \quad [2]$$

The air mass flow (m) Density (p) flowing through a surface area (A) perpendicular to the direction of flow is given by the equation of fluid mechanics:

$$M = p*A*v \quad [3]$$

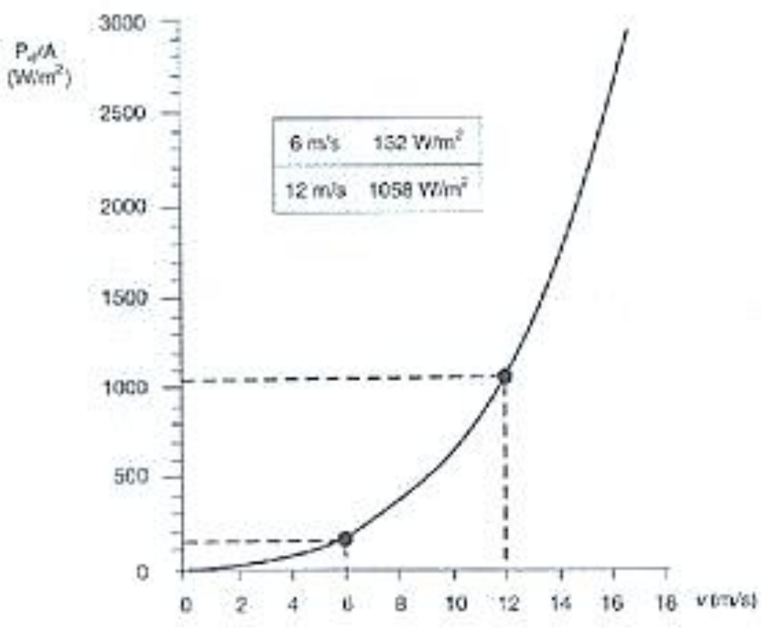
The available power (Pd) associated with the flow of air through that section is:

$$Pd = ½*m*v ^ 2 = ½*p*A*v ^ 3 \qquad [4]$$

The available wind power is the maximum power we could extract the wind if we could convert all of its kinetic energy into useful energy. In practice due to limitations of various kinds (Betz limit, aerodynamic and mechanical friction, electric Generator Speeds performance, etc.) only allows you to leverage the best 40% of the available wind power.

Power density or power per unit area defined (P/A) according to:

$$Pd / A = ½* p* v^3 \qquad [5]$$

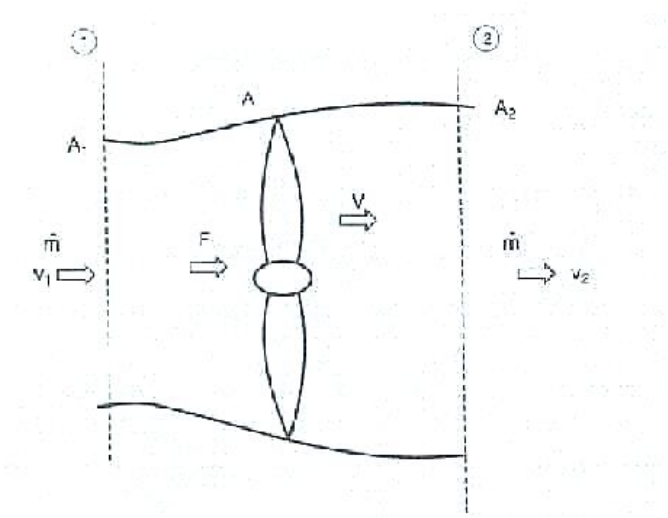


3.15. Graphic wind potential.
Source: http://tipos-de-energia.blogspot.ro/

Evaluation of wind energy resources.

For the assessment of energy resources and mapping of wind potential, the calculation of the annual average available wind power density is required. The calculation process is performed based on the data available. Several situations may occur as the event that is available hourly values or trihourly of wind speed or available only on the annual average rate.

Theoretical maximum power harnessed. Betz Limit.



3.16. Air flow circulating through the area (A) swept by the rotor of a propeller.
Source: http://tipos-de-energia.blogspot.ro/

Consider the airflow indicated in the previous figure flowing through a swept area A by a rotor. Since the pressure and temperature variations are small, we assume that the air behaves as an incompressible fluid (constant density) so that the continuity equation is expressed:

$$V1*A1 = v*A = v2*A2 \qquad [6]$$

Applying the principle of conservation of momentum, the force F fluid mass flow m takes on the rotor is given by:

$$F = m*(v1 - v2) = p*A*v*(v1 - v2) \qquad [7]$$

The potency (pa) which transfers the airflow to the rotor of the machine is the product of force and velocity (Pa = F. V). Combining the above expressions and considering: v = 0.5. (v1 + v2) is obtained:

$$Pa = ¼.*p*A*(v1 + v2)*(\text{^} 2\ v1 - v2\ \text{^} 2) \qquad [8]$$

The maximum power condition occurs for a speed:

$$v2 = 1/3*v1 \qquad [9]$$

Substituting this value of speed in the above expression theoretically the maximum power that can be harnessed in a wind flow speed v1 and is obtained:

$$P_{amax} = 16/27 * Pd = 0.593*Pd \qquad [10]$$

The above expression is the Betz limit, by which the maximum power that can be harnessed in a wind flow is only 59.3% of the available power of the same. In practice, this upper limit is never reached just something may reach values above 0.4 at best.

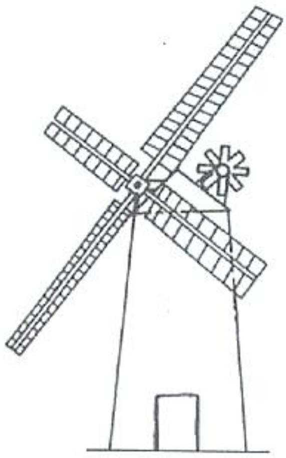
3.2 Wind generators (type, power,…).

Horizontal axis wind turbines

They are the most used and more powerful. Basically three types are distinguished:

Conventional wind mills

They are the classic windmills formerly used and now preserved as historical memory but serve. See figure below:



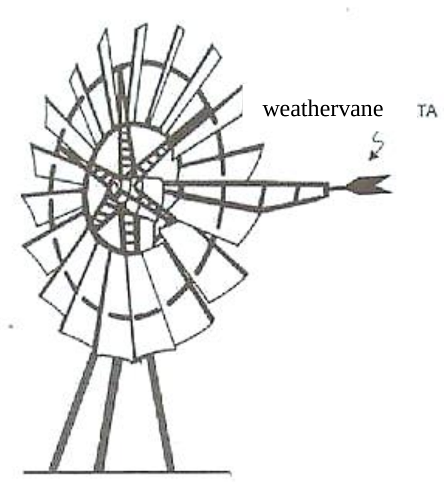
3.17. A scheme of a classic windmill.
Source: http://tipos-de-energia.blogspot.ro/

Its main features are:

- Blade length: between 5 and 15 m, and its width on the order of 20% of its length. The material that is built of wood.
- Speed: varying from 10 to 40 rpm, depending on the length of the blades, corresponding to the lowest values the longer blades.
- The orientation of the paddle wheel to place it perpendicular to the wind incident was carried out by a swivel arm or via a small auxiliary wind acting as vane orientation.

Slow wind turbines

It is a generator with a large number of blades. Generally guidance system is by a rudder-vane makes the plane of the propeller is positioned always perpendicular to the wind direction. See the following figure:



3.18. Outline of a slow wind turbine (18 blades).
Source: http://tipos-de-energia.blogspot.ro/

Key features are:

- High number of shovels, 12 and 24.
- Diameter between 3 and 10 m, limited by the high weight of the rotor.
- They adapt very well to low speed winds. His boot is produced from a wind speed of 2 to 3 m/s.
- Small powers basically two reasons: they use low wind speeds (3 to 7 m/s) and are limited by the weight of the rotor due to the high number of blades diameter.
- Its scope mainly are extraction facilities and water pumping.
- They have a high coefficient of high torque for small values of specified speed.

Quick turbines

In this type of wind turbine blades number is small. Its advantage over the slower is its wind power per unit weight is much higher, so to be lighter generators can be constructed of a much larger radius and positioning the hub or central point of rotation of the rotor at altitudes much higher and therefore the effect of increasing leverage ed wind speed with height. Currently being built wind rotor diameters reaching 90 m with a rated power of 3 MW, which gives an idea of the rotor swept area.

The main features are:

- Reduced number of blades, between 1 and 4, although the most used are of 3 blades.
- Lighter than slower wind, and therefore can be constructed larger machines.

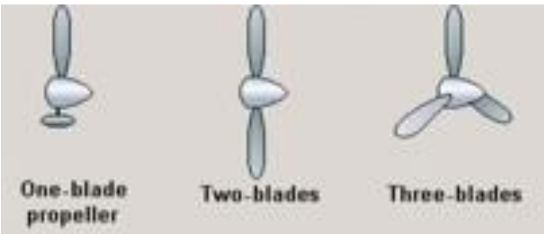
- They require a wind speed for greater wind slow boot (between 4 and 5 m/s). They have a couple of minor startup.
- They reach their rated power for wind speeds between 12 and 15 m/s. From speeds of the order of 25 to 30 m / s rotor stop it occurs to avoid damage on the machine.
- In fast turbines, the maximum power coefficient is placed in the environment Cp= 0.4.

They are used for power generation and may be in isolated or networked systems. The generators used in isolated systems are generally small (3-50 KW) than those who are connected to the mains (250 to 3000 kW).

Classification according to the number of blades

Bladed rotors: Allows greater rotational speed, mass and reducing material costs, blades on the gearbox and generator. They have the disadvantage of requiring a very accurate balanced with a counterweight offset, and there is increased risk of aerodynamic imbalance and vibration with the appearance of fatigue loads. It also increases the generation of noise. The order of twice a bladed rotor.

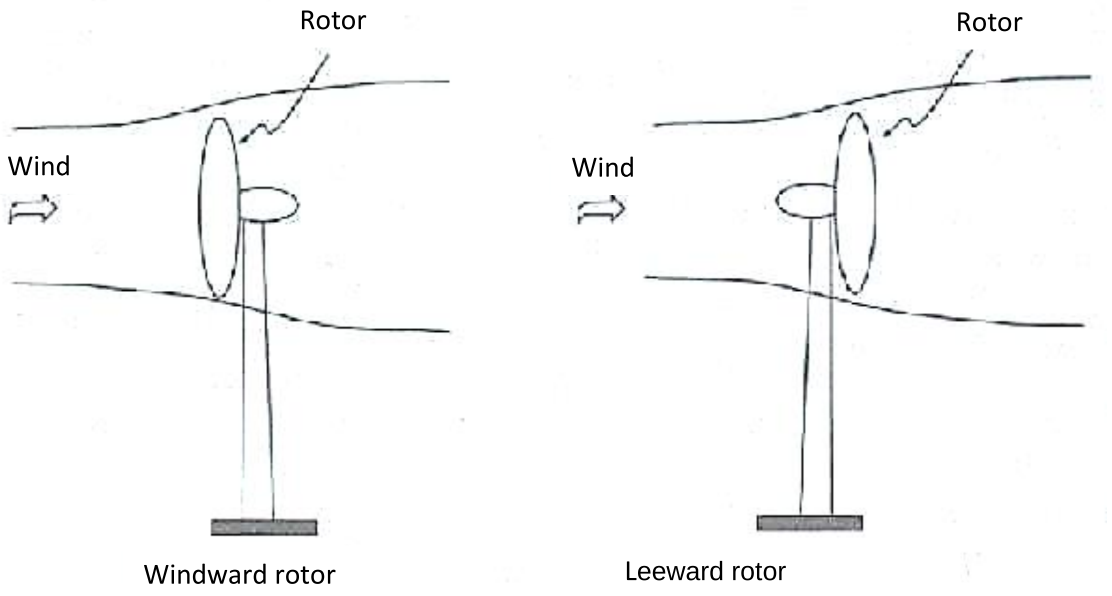
Two-Bladed rotors: Reduces the cost of material and equipment compared to the three-bladed rotor, but also has the disadvantage regarding the latter from a higher level of dynamic stresses. Similar to single-blade rotor mechanical stresses caused by the variation profile of wind velocity with altitude occur. Besides these rotors have three-bladed respect to a higher level of vibration and noise.



3.19. Classification according number of blades.

Three-Bladed rotors: present main advantage of a smoother rotation and uniform properties due to its moment of inertia, so that the induction of stresses on the structure is minimized. Also rotates slower than the mono and two-bladed rotors decrease efforts of centrifugal force, the level of vibration and noise production. Currently the bladed rotor configuration is used in most wind turbines quick engaged generation.

Rotor arrangement relative to the wind.



3.20.. Types available to the rotor of a wind turbine horizontal axis relative to the wind.
Source: http://tipos-de-energia.blogspot.ro/

Windward rotor: first wind impinges on the rotor span and later on the support tower, whereby the shadow effect on the rotor, and the occurrence of vibrations and fatigue stresses on the rotor blades is minimized. This type of arrangement requires a stiffer and more away from the tower to avoid interference between the rotor blades and the tower due to bending of the same by the thrust force of the wind rotor.

This rotor, unlike the rotor downwind, you need a guidance system that always keep the plane of rotation of rotor oriented perpendicular to the wind direction.

Leeward rotor: do not require any type of device orientation. A disadvantage is the shadow effects of the nacelle and the tower on the rotor blades with the consequent loss of power and increased fatigue stresses also may occur in the driver messes cable carrying energy produced by the generator located in the nacelle rotates freely.

Advantage of fast versus slow turbines.

- They are much lighter and economic equality of diameters, so are built with large diameters (40-90 m) and rotors located at high altitudes (up to 100 m). Provided large wind power generators (0.5 to 3 MW). Now you can build rotors that sweep raised areas and benefit from the increase in wind speed with height.
- Better withstand the stresses caused by wind gusts.
- By having fewer blades is easier to incorporate mechanisms that allow the rotation of the blades around the tower to achieve power generating regulate or protect the rotor in case of strong winds.

- The axial thrust due to the wind on the rotor is less stopped in the fast wind is turning when not happening in slow.
- To rotate faster, the size and cost of the gearbox which drives the power generator is reduced. In large wind turbines the rotation speed is in the range of 15 to 50 rpm being the speed of blade tip no more than 65 - 75 m / s.
- Faced with the above advantages, the fast wind have the drawback of having a couple or moment of much less than the wind slow start.

The following figure shows the general appearance of a large three-bladed wind turbine is shown:

3.21. Scheme of a powerful wind turbine.
Source: http://www.reuk.co.uk/

Vertical axis wind turbines

There have been numerous prototypes and experiences with different vertical axis wind, but for technical and economic reasons, their implementation in practice is very limited, so most wind turbines are horizontal axis.

The rotor of vertical axis wind usually basically of the following types:

- Rotor differential feed, with or without screen (Savonius).
- Rotor cyclic variation of incidence (Darrieus).

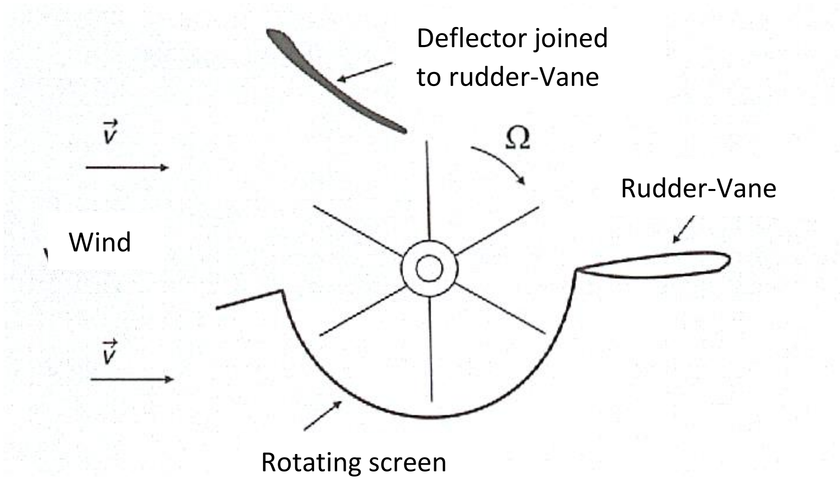
Wind differential feed rotor: rotor Savonius.

This rotor is based on the different aerodynamic force exerted on airflow objects differently.

If a rotor formed by a set of blades in the form of hemispherical cups or semicylindrical placed in the manner indicated in the figure, the action causes wind different forces on the concave and convex of these cups, which gives conceived in a pair that rotates the rotor. Because the force that causes the pair is the difference between the blades or rotor blades, this type of machine is called differential feed.

Generating vertical axis with baffles that prevent backpressure force of the wind on the rotor blades.

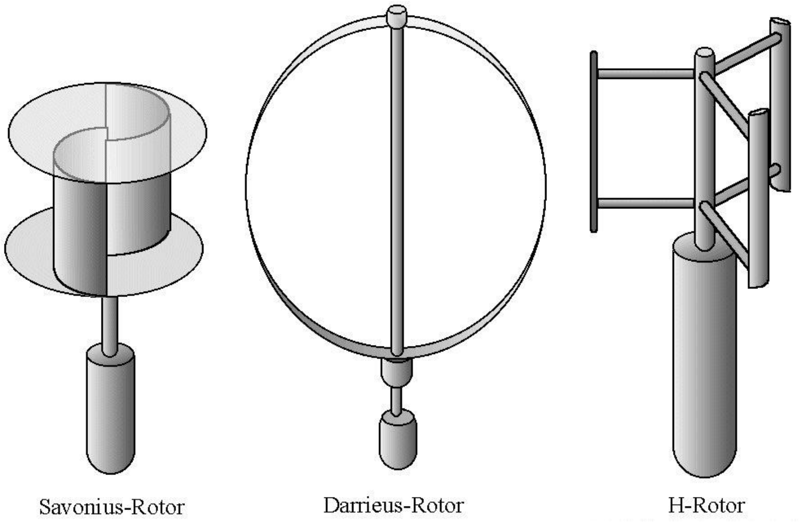
To eliminate the harmful effect of the force acting on the blade or bottom pan (moving in the opposite direction to the wind speed), it can be incorporated into an orientable screen rotor by means of a vane-wheel, along with a system suitable baffles to facilitate the canalization of the airflow over the active blades, as shown in the following figure. The improvement experienced by the computer when the rotor is screened is important.



3.22. Differential feed rotor provided with a rotating screen that prevents the wind on the blades located on the bottom of the figure.
Source: http://tipos-de-energia.blogspot.ro/

Wind rotor cyclic variation of incidence: Darrieus rotor.

The rotor is formed by a set of blades, joined together, which are rotatable about a vertical axis and whose cross section is shaped like an airfoil.



3.23. Vertical axis wind turbines.
Source: www.grund-wissen.de

The blades or vanes are curved with a shape resembling a rope which form rotating about an axis. The blades are biconvex and described by the same surface may have various shapes: spherical, parabolic, cylindrical, etc. Rotor rotation is caused by the aerodynamic action of the wind on the blades, which causes aerodynamic forces which result in torque.

The starting torque of a Darrieus rotor is very small, and in practice requires an auxiliary starter. In various embodiments one Savonius rotor is combined to facilitate the start of the first. The main advantage of the Savonius rotor facing the Darrieus is the simplicity of its construction and the best values for torque at low speeds. It can be said that the Savonius rotor is only useful for low power and very limited applications such as pumping water from wells.

Comparison between generators horizontal axis and vertical axis

The main advantages of horizontal axis wind off the vertical axis are:

- The horizontal axis have a power coefficient (Cp) greater.
- Rapid present horizontal axis wind speed greater than the vertical axis of rotation, so they are more suitable for driving electric generators which rotate at 1000 or 1500 rpm.
- The horizontal axis wind sweeping larger surfaces allow the vertical axis, so that reach much higher powers.
- The horizontal axis exploit the beneficial effect of increase in wind speed with height above ground. The configuration of the vertical shaft prevents reaching high altitudes and therefore can not benefit from this effect.

In contrast, vertical axis wind have the following advantages over the horizontal axis:

- Given its vertical symmetry, guidance systems do not need to align the axis of the turbine with the wind direction, as in the horizontal axis.
- Maintenance is easier, given its low height above the ground.
- When the wind working on an application that requires constant speed, it is not necessary to incorporate any pitch change mechanism.
- Horizontal axis wind are the most used in practice. Vertical Axis Wind is basically used for research.

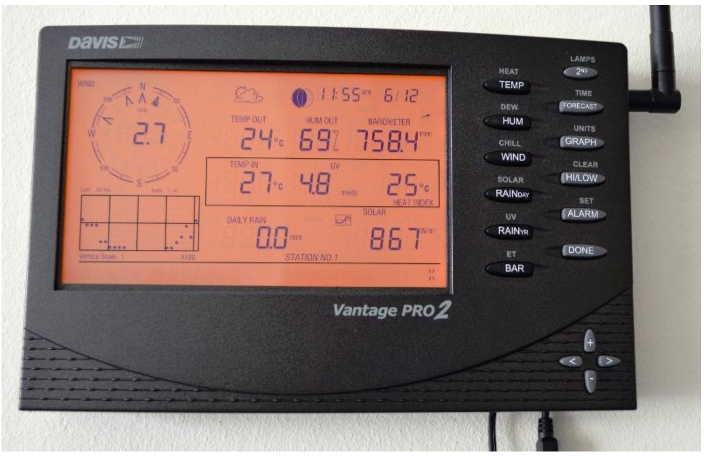
4. First case study: 2 states wind reliability model

4.1. Speed data acquisition, evaluation of data base existing at LACARP – laboratory for applied research and prototype design of Power Engineering.

- Station for data acquisition.

A Vantage Pro2 Plus meteorological station, Fig. 4.1, was used for data acquisition. It was located at 20 m high and belongs to a new research laboratory on renewables, The Vantage Pro2™ Plus Wireless Weather Stations include two components: the Integrated Sensor Suite (ISS) which houses and manages the external sensor array, and a console, Fig. 4.2, which provides the user interface, data display, and calculations.

4.1. Vantage Pro2 Plus Meteo station – left; details of the sensors connection box and wireless transmitter – right. Source: Document Availability Evaluation of Wind as a Repairable System.



4.2. Console for calculations and station and PC communication with a friendly user-interface include meteo prognosis.
Source: Document Availability Evaluation of Wind as a Repairable System.

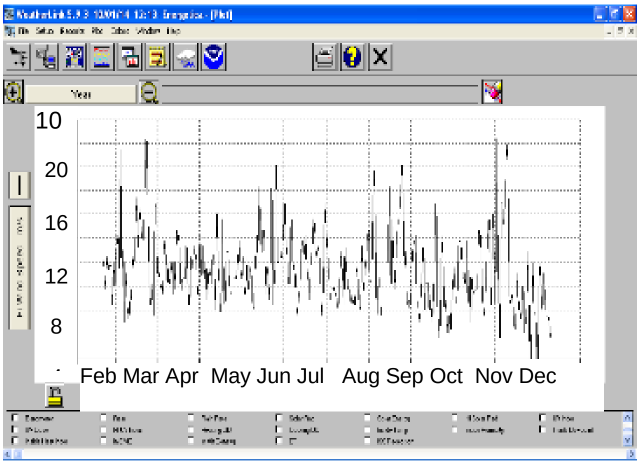
The ISS and Vantage Pro2 console communicate via a FCC-certified, license-free, spread-spectrum frequency (FHSS) transmitter and receiver. User selectable transmitter ID codes allow up to eight stations to coexist in the same geographic area. The frequency spread spectrum technology provides greater communication strength over longer distances and areas of weaker reception. The Wireless Vantage Pro2™ Plus weather station includes two additional sensors that are: the UV sensor and the solar radiation sensor. The wireless ISS is solar powered with a battery backup. WeatherLink™ for Vantage Pro and Vantage Pro2 is the software to for weather station interface with a computer, to log weather data, and to upload weather information to the internet. The station rely on passive shielding to reduce solar-radiation induced temperature errors in the outside temperature sensor readings.

The station can monitor and record weather parameters like: temperature, barometric pressure, dewpoint, evotranspiration, heat index, humidity, moon phase, rainfall, rain rate, solar radiation, sunrise and sunset, temperature/humidity/sun/wind index, ultra violet radiation dose and index, wind chill, direction and speed.

Concerning the wind the station has the following features:

- ***Resolution and units:*** 1 mph, 1 km/h, 0.4 m/s, or 1 knot (user-selectable). Measured in mph, other units are converted from mph and rounded to nearest 1 km/hr, 0.1 m/s, or 1 knot;
- ***Range:*** 2 to 180 mph, 2 to 156 knots, 1 to 80 m/s, 3 to 290 km/h;
- ***Update interval:*** instant reading: 2.5 to 3 seconds, 10-minute Average: 1 minute;
- ***Accuracy:*** ±2 mph (2 kts, 3 km/h, 1 m/s) or ±5%, whichever is greater;
- ***Current display data*** : instant
- ***Current graph data:*** instant; 10-minute and hourly average; hourly high; daily, monthly and yearly;
- ***High with direction of high historical graph data:*** 10-min. and hourly averages; hourly highs; daily, monthly and yearly highs with direction of highs.

Wind speed was recorded every minute between February and December 2013 as Fig. 4.3 shows with corrections near the limit values of 4 m/s and 20 m/s with a view to compensate the meteorological station errors.



4.3. The wind speed (m/s) recorded between Feb and Dec 2013. Source: Document Availability Evaluation of Wind as a Repairable System.

4.2. Evaluation of data base.

The useful wind speed interval was considered between 4 m/s and 20 m/s for a generic wind generator. The “events” means states with speed below 4 m/s or over 20 m/s, equivalent with the “repair states „ of technical systems.

Mean Time Between Events - MTBF and Mean Time to Repair - MTTR are the indices to evaluate based on systematic above mentioned measurements. Finally, the authors identified what is the probability distribution function - PDF which matches, with minimum errors, the primary empiric histogram of the MTBE and MTTR.

The estimated numerical parameters for the most suitable PDF are checked based on goodness-of-fit tests like Chi-Square and Kolmogorov-Smirnov.

Empirical distributions of TBE and TTR.

The main statistical values for MTBE are:

TBE Count = 68

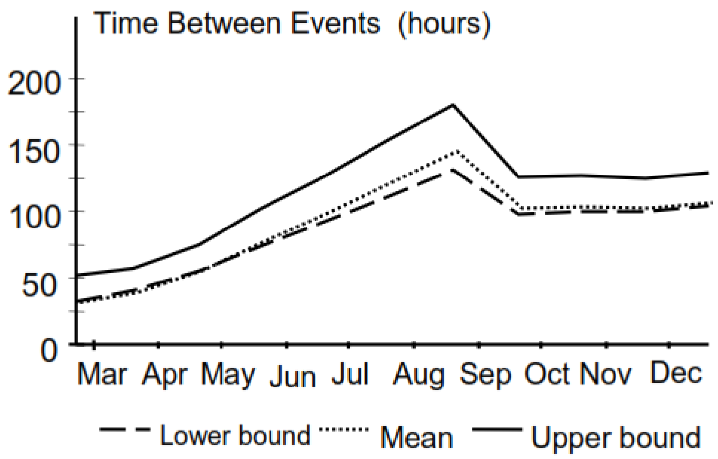
TBE Mean = 109.76 (hours)

TBE Variance = 154388.07 (hours)

TBE Maximum = 3243.07 (hours)

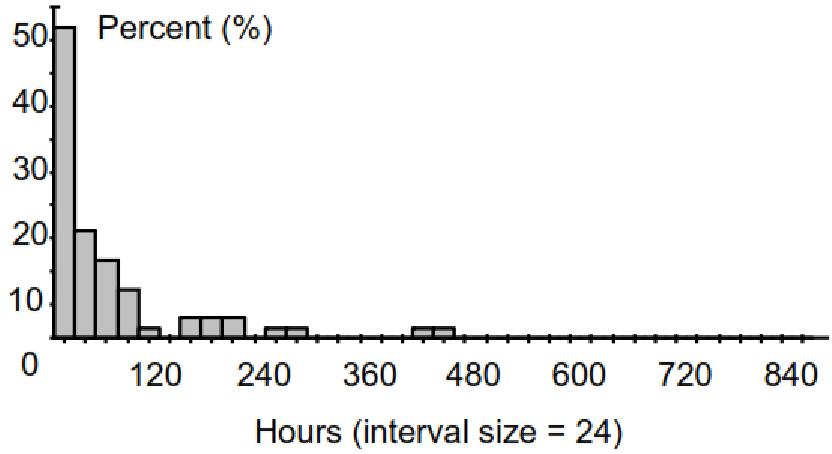
TBE Minimum = 0.18 (hours)

First of all, the time depending values for TBE during a year are depicted in Fig.4.3. This can be useful for dependability of the wind as dynamic system.



4.3. The evolution of MTBE during the year 2013.
Source: Document Availability Evaluation of Wind as a Repairable System.

The empirical distribution of TBE is shown in Fig. 4.3.



7.4. Empirical distribution of TBE.
Source: Document Availability Evaluation of Wind as a Repairable System.

For MTTR, the main statistical values are as it follows:

TTR Count = 69

TTR Mean = 26.61 (hours)

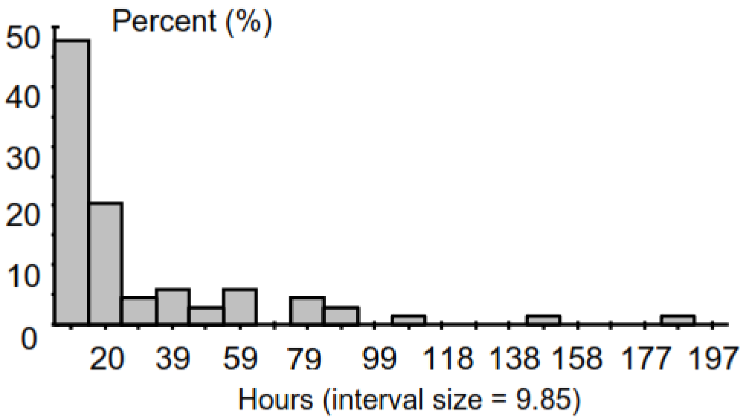
TTR Variance = 1605.66 (hours)

TTR Maximum = 197.00 (hours)

TTR Minimum = 0.20 (hours)

The sample mean - m and sample variance - s2 are to be used as the estimators for calculate parameters in probability distribution functions.

The histogram is shown in Fig.4.5.



8. Empirical distribution of TTR.
Source: Document Availability Evaluation of Wind as a Repairable System.

Probability distribution functions and goodness-of-fit tests

After a qualitative analysis of empirical TBE and TTR distributions, three PDF were selected to be checked for accurate fitting the empirical distributions:

1) Exponential, for the advantages of using Markov method for dependability indices calculation. The PDF and cumulative distribution function -CDF are:

$$f(t) = \lambda e^{-\lambda t} = (1/m)e^{-(1/m)t} \quad [11]$$

$$F(t) = 1 - e^{-\lambda t} \quad [12]$$

where λ is the constant failure rate given by:

$$\lambda = 1/m \quad [13]$$

and *m* is the sample MTBF and t the reference time.

2) Gamma distribution for its relationship with Weibull distribution:

$$f(t) = \left[\beta(\beta t)^{\alpha-1}\right] \cdot e^{-\beta t} / \Gamma(\alpha) \quad [14]$$

$$F(t) = \left(\int_0^t e^{-x} x^{\alpha-1} dx\right) / \Gamma(\alpha) \quad [15]$$

where

$$\beta = m / s^2 \qquad \alpha = m^2 / s^2 \quad [16]$$

3) Weibull distribution, known as a good PDF for wind speed modelling:

$$f(t) = \beta \alpha t^{\alpha-1} e^{-\beta t^{\alpha}} \quad [17]$$

$$F(t) = 1 - e^{-\beta \cdot t^{\alpha}} \quad [18]$$

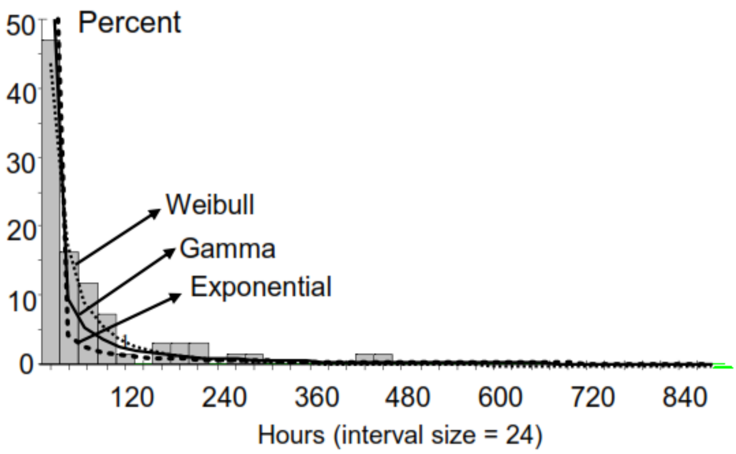
where

$$m^2 / s^2 = [\Gamma(1+1/\alpha)]^2 / \\ / \{\Gamma(1+2/\alpha) - [\Gamma(1+1/\alpha)]^2\} \quad [19]$$

$$\beta = 1/[m/\Gamma(1+1/\alpha)]^2 \quad [20]$$

Equations (3) ÷ (10) are expressed such as they include the function parameters estimators calculated from the sample data [15].

To identify TBE and TTR distributions, χ^2 and Kolgomorov - Smirnov tests were used for the above mentioned PDF: exponential, gamma and Weibull. The results are shown in Fig. 4.5 and Table 1:

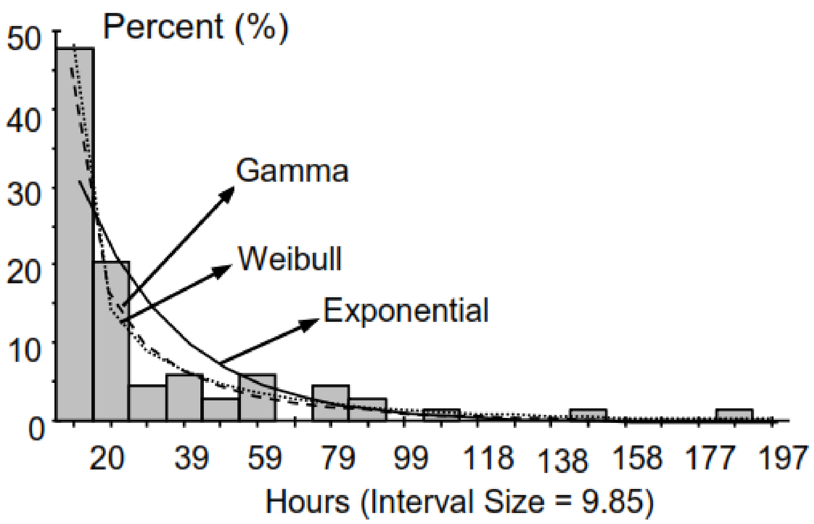


4.6. Probability distribution functions of TBE.
Source: Document Availability Evaluation of Wind as a Repairable System.

Test results	TBE probability distribution function		
	Exponential	Weibull	Gamma
χ^2	= 0.63	= 0.84	= 0
Kolgomorov Smirnov	> 0.05	> 0.05	> 0.00
PDF parameters	λ = 9.11e^{-003}	α = 0.371 β = 7.07e^{-001}	α = 0.078 β = 7.11e^{-004}

TABLE I.
PDF PARAMETERS AND TEST RESULTS FOR TBE.

The similar results but for TTR are illustrated in Fig. 45 and Table 2:



9.7. Probability distribution functions of TTR.
Source: Document Availability Evaluation of Wind as a Repairable System.

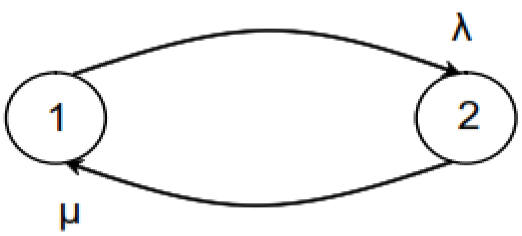
Test results	TTR probability distribution function		
	Exponential	Weibull	Gamma
χ^2	= 0.38	= 0.42	= 0,36
Kolgomorov Smirnov	> 0.2	> 0.2	= 0.31
PDF parameters	λ = 3.76e^{-002}	α = 0.683 β = 1.27e^{-001}	α = 0.441 β = 1.66e^{-002}

TABLE II.
PDF PARAMETERS AND TEST RESULTS FOR TTR.

Wind availability modeling as a repairable system

The Markov chain, first order, homogenous time can be used to find out the availability indices. The 2-state reliability model for wind system is like in Fig. 46 for which we need to solve the general differential equation [16]:

$$\left[p_i^{'}(t)\right] = \left[p_{ij}^{'}(0)\right] \cdot \left[p_i(t)\right] \qquad [22]$$



10.8. The 2 states of the wind as a repairable system.

to obtain the state probabilities. Starting with the equation system derived from [12]

$$\begin{cases} p_1^{'}(t) = -\lambda \cdot p_1(t) + \mu \cdot p_2(t) \\ p_2^{'}(t) = -\lambda \cdot p_1(t) - \mu \cdot p_2(t) \end{cases} \qquad [23]$$

and using the Laplace transform we can write:

$$\begin{cases} s \cdot p_1(s) - p_1(0) = -\lambda \cdot p_1(s) + \mu \cdot p_2(s) \\ s \cdot p_2(t) - p_2(0) = \lambda \cdot p_1(s) - \mu \cdot p_2(s) \end{cases} \quad [24]$$

Considering the initial values,

$$\begin{cases} s \cdot p_1(s) - 1 = -\lambda \cdot p_1(s) + \mu \cdot p_2(s) \\ s \cdot p_2(t) - 0 = \lambda \cdot p_1(s) - \mu \cdot p_2(s) \end{cases} \quad [25]$$

the state probabilities are:

$$\begin{cases} p_1(s) = \mu/(\lambda+\mu) \cdot (1/s) + \lambda/(\lambda+\mu) \cdot (1/(s+\lambda+\mu) \\ p_2(s) = \lambda/(\lambda+\mu) \cdot (1/s) - \lambda/(\lambda+\mu) \cdot (1/(s+\lambda+\mu) \end{cases} \quad [26]$$

In time domain (16) can be written as:

$$\begin{cases} p_1(t) = \mu/(\lambda+\mu) + \lambda/(\lambda+\mu) \cdot e^{-(\lambda+\mu)t} \\ p_2(t) = \lambda/(\lambda+\mu)\left(1 - e^{-(\lambda+\mu)t}\right) \end{cases} \quad [27]$$

Obviously, the steady-state probabilities are

$$\begin{cases} p_1 = \mu/(\lambda+\mu) \\ p_2 = \lambda/(\lambda+\mu) \end{cases} \quad [28]$$

Finally, assuming the exponential PDF for TBE and TTR, the wind availability indices can be calculated as shown in next section.

We can accept the Weibull PDF for both TBE and TTR random variables but, considering the nature of the system analysed which is *pure natural wind,* it is necessary to think about some features associated to this type of distribution according to Table III:

Weibull PDF characteristics for usual technical systems	Accept for wind	Reject for wind
The distribution can handle increasing, decreasing or constant failure-rates and can be created for data with and without suspensions (non-failures).		Yes
The Weibull distribution is flexible and fits to a wide range of data, including Normal distributed data.	Yes	
Life data are related to items that "age" during time to failure.		Yes

The time variable is considered to be a measure of life-consumption. This means that the product gets a higher probability of failure during its life.		Yes
For a correct the life data analysis it is necessary to include both failures and non-failures.		Yes
Uncertainty in estimating the Weibull parameters is, as in any other distribution estimation, related to data.	Yes	
Materials data like stress; shear force etc. can be modeled with the Weibull distribution.		Yes

TABLE III.
Reasons to accept or not the Weibull pdf for tbe and TTR as wind random variables.

The conclusion based on the simple judgments in Table III is Weibull distribution is not suitable for wind availability analysis. Finally, comparing the three distributions, exponential, Weibull and gamma we can accept exponential distribution for TBE and TTR and its small test errors also. It can be used for wind speed modeling.

Weibull distribution cannot model very well the wind availability in the manner here adopted while gamma distribution is not confirmed by goodness-of-fit tests.

The wind availability indices.

Using the values included in Table I and Table II, for a reference time interval T = 8760 h (1 year), the usual availability indices are:

- P, operating probability of the "repairable" system; here means probability that the wind speed is over 4 m/s and lower than 20 m/s:

$$P = \mu/(\lambda + \mu) = 0.976 \qquad [29]$$

- Q, failing probability: speed wind below 4 m/s and over 20 m/s:

$$Q = \lambda/(\lambda + \mu) = 0.024 \qquad [30]$$

- A, availability:

$$A = P \cdot T = 8549.76 \quad \text{(h/year)} \qquad [31]$$

- U, unavailability:

$$U = Q \cdot T = 210.24 \quad \text{(h/year)} \qquad [32]$$

- F, failure frequency

$$F = P \cdot \lambda \cdot T = 938.50 \quad \text{(failures/year)} \qquad [33]$$

- MTBE, mean time between events (or mean up time):

$$MTBE = MUT = A / F = 1/ y = 109.76 \quad \text{(h)} \qquad [34]$$

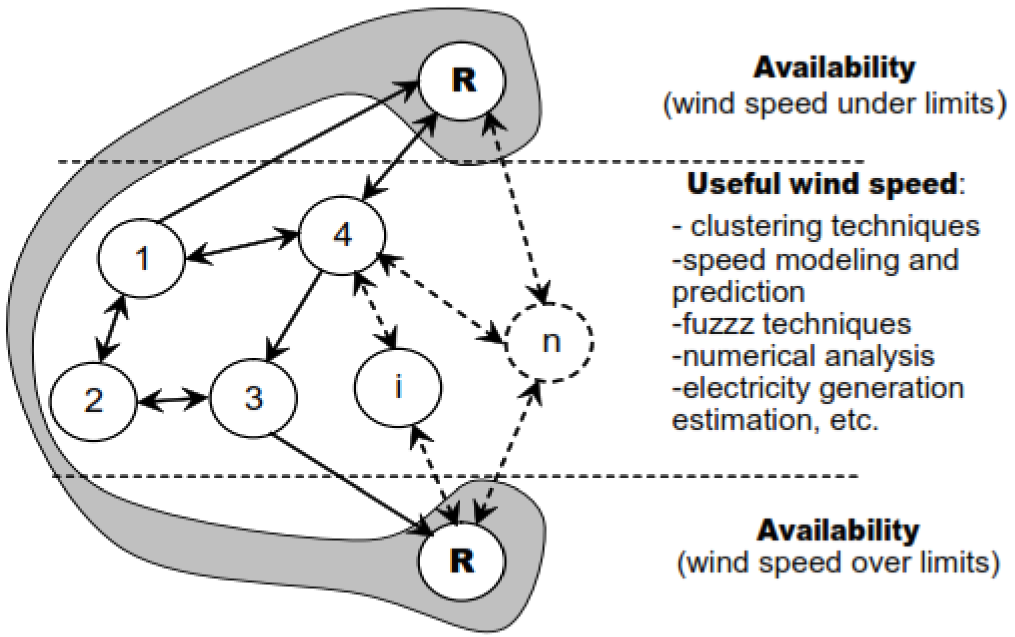
- MTTR, mean time to repair (or mean down time):

$$MTTR = MDT = U / F = 1/ \mu = 26.59 \quad \text{(h)} \qquad [35]$$

The numerical results offered by (20) – (25) shows a relative good and useful availability for the “repairable” wind but, due to many interruptions in the case of a single wind generator the situation could be critical for the given location.

The solution to minimize the risk of supply interruptions is the energy storage. In the case of a wind farm this problem is intrinsically solved.

To have a better view of the aspects presented in this paper, the Fig. 9 separates the much tackled subject of wind speed analysis from here included about wind availability.

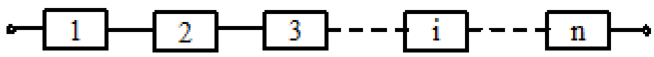


11.9. Wind analysis: shaded area for availability – states R (repair) and ususal speed analysis area – states 1 – n. Source: Document Availability Evaluation of Wind as a Repairable System.

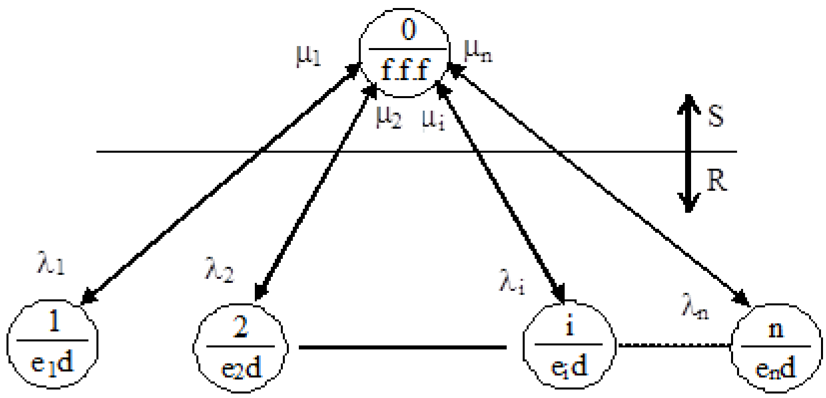
5. Second case study: wind reliability model including the turbulent time intervals (11 states)

5.1 Reliability indices calculation for a system having n different elements.

For this second case is necessary have knowing about Markov chain method, because in this case is going to appear more than two states, thus, is necessary use the Markov chain method for *n* states.



5.1. The system with n series connected elements.



12.2. The state diagram of the system in fig.5.1.

$$
|q_{ij}| = \begin{array}{c|cccccc|}
 & 0 & 1 & 2 & & i & n \\
0 & -\sum_{i=1}^{n}\lambda_i & \mu_1 & \mu_2 & . & \mu_i & \mu_n \\
1 & \lambda_1 & -\mu_1 & & & & \\
 & . & . & -\mu_2 & & & \\
i & \lambda_i & & & . & & \\
 & . & & & & . & \\
n & \lambda_n & & & & & -\mu_n
\end{array}
$$

[36]

$$[q_{ij}]\cdot[p_i]=[0]$$

[38]

$$
\begin{cases}
-\sum_{i=1}^{n}\lambda_i p_0 + \sum_{i=1}^{n}\mu_i p_i = 0 \\
\lambda_1 p_0 + \mu_1 p_1 = 0 \\
- \quad - \quad - \quad - \quad - \\
\lambda_i p_0 + \lambda_i p_i = 0 \\
- \quad - \quad - \quad - \quad - \\
\lambda_n p_0 - \mu_n p_n = 0 \\
\sum_{i=1}^{n} p_i = 1
\end{cases}
$$

[39]

$$p_0 = \frac{1}{1 + \sum_{i=1}^{n} \frac{\lambda_i}{\mu_i}}$$

....

$$p_1 = \frac{\lambda_1}{\mu_1} p_0$$

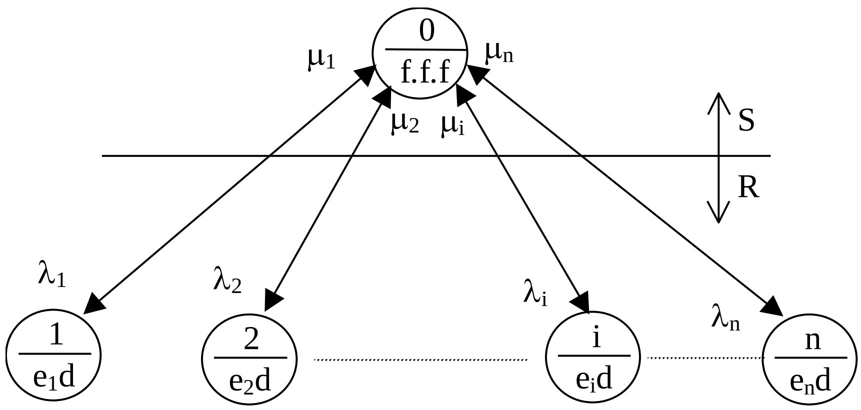
....

$$p_i = \frac{\lambda_i}{\mu_i} p_0$$

....

$$p_n = \frac{\lambda_n}{\mu_n} p_0$$

[40]



Successful states:

$$S = [S0] \qquad [41]$$

Probability of the system successful state:

$$P_{ss} = p_0 = \frac{1}{1 + \sum_{i=1}^{n} \frac{\lambda_i}{\mu_i}} \qquad [42]$$

Failed (refuse) states:

$$R = [S1, S2, \ldots, Sn] \qquad P_R = \Sigma p_i \qquad i = 1, 2, \ldots, n \qquad [43]$$

Probability of the system failure:

$$Q_{ss} = \sum_{i=1}^{n} p_i = p_0 \sum_{i=1}^{n} \frac{\lambda_i}{\mu_i} \qquad [44]$$

Total up time – TUP:

$$TUT = P_{ss} \cdot T = \frac{1}{1 + \sum_{i=1}^{n} \frac{\lambda_i}{\mu_i}} T \qquad [45]$$

Total down time – TDT

$$TDT = Q_{ss} T = p_0 \sum_{i=1}^{n} \frac{\lambda_i}{\mu_i} T \qquad [46]$$

Frequency of the system failure:

$$F_f = p_0 \sum_{i=1}^{n} \lambda_i T \qquad [47]$$

Mean up time - MUP

$$MUT = \frac{TUT}{F_f} = \frac{p_0 T}{p_0 \sum_{i=1}^{n} \lambda_i T} = \frac{1}{\sum_{i=1}^{n} \lambda_i} \qquad [48]$$

Mean down time MDT:

$$MDT = \frac{TDT}{F_f} = \frac{p_0 \sum_{i=1}^{n} \frac{\lambda_i}{\mu_i} T}{p_0 \sum_{i=1}^{n} \lambda_i T} = \frac{\sum_{i=1}^{n} \frac{\lambda_i}{\mu_i}}{\sum_{i=1}^{n} \lambda_i} \qquad [49]$$

The equivalent failure rate of the system:

$$\lambda_{es} = \frac{1}{MUT} = \sum_{i=1}^{n} \lambda_i \qquad [50]$$

The equivalent repair rate of the system:

$$\mu_{es} = \frac{1}{MDT} = \frac{\sum_{i=1}^{n} \lambda_i}{\sum_{i=1}^{n} \frac{\lambda_i}{\mu_i}} \qquad [51]$$

5.2 Study of the five possible cases from the recorder data.

Along the years 2013 to 2015, from February to January, the Vantage Pro2 Plus meteorological station had been registering data to know the behaviour of the wind.

This behaviour means the different velocities that wind have, also the time it spends inside or outside the limits, the limits considerer are between 4 m/s and low than 20 m/s this limits are for a generic wind generator.

Now the eleven states considered for the study is going to depend of the time the wind are outside the limits –Failed Area- , this area could be under 4 m/s or over 20 m/s. It will be considered the intervals:

$t \leq 3$ min.

3 min. $\leq t \leq$ 5 min.

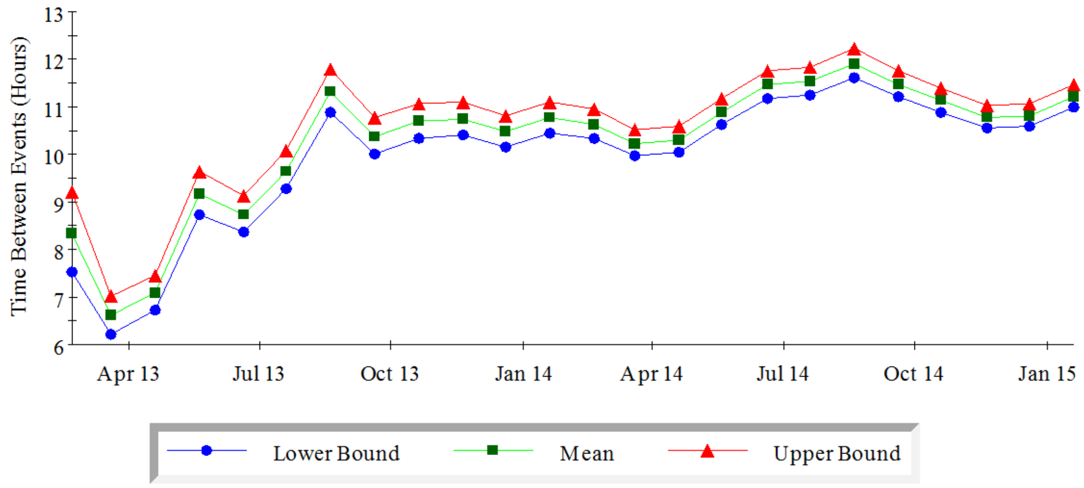
$$5 \text{ min.} \leq t \leq 7 \text{ min.}$$

$$7 \text{ min.} \leq t \leq 10 \text{ min.}$$

$$t \geq 10 \text{ min.}$$

With this recorded data, the calculations that follow now and the constant time of the generator is possible determinate if is a good place with good viability to emplace an wind generator system to generate electricity. Always all of this is depends the kind of system is going to install, is not the same install one windmill for a house that install a farm with tens of windmills.

In the follow figure is show the change of MTBE (Mean Time Between Events) along the two years:

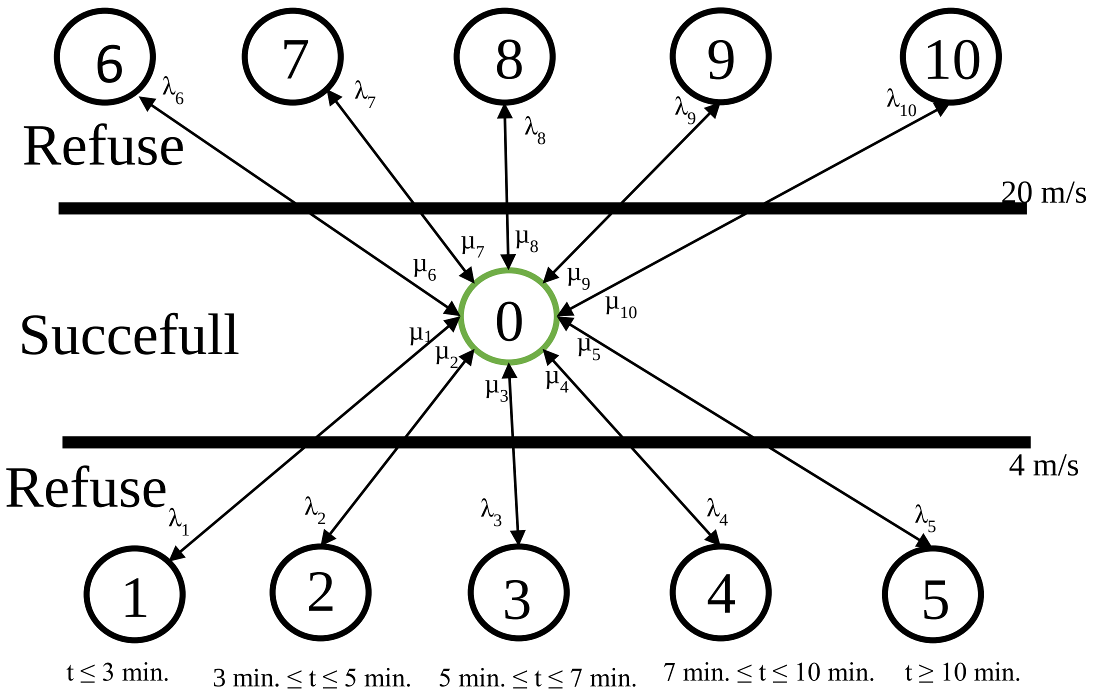


13.3. MTBE between February 2013 – January 2015.

This graphic represent the behaviour of the mean time between events along the two years, it is appreciate along April to Julie of 2013 there was not good conditions being that are only 9 hours of wind in the limits of operation time (successful area). But the rest of the time MTBE vary between 10 to 12 hours inside the operation time.

- Study of the five possible cases:

Case I:



Number of Appearances	λ Intensity of failure $[h]^{-1}$	μ Repair intensity $[h]^{-1}$
1 (778)	0,04612	46,38218
2 (101)	0,00598	14,51168
3 (74)	0,00456	10,04116
4 (66)	0,00413	7,32547
5 (317)	0,01859	0,06269
6 (173)	0,01711	48,07692
7 (12)	0,00118	13,79310
8 (9)	0,00096	10,12145
9 (3)	0,00031	7,69230
10 (26)	0,00259	1,9596

T – refereence time: T= 2 ani = 17520 [h]

$$P_S = P_0 \, [\%]$$

$$P_R = \sum_{i=1}^{n} P_i [\%]$$

- Total up operating time:

$$\boldsymbol{TUT} = P_0 \cdot T = 0{,}908265 \cdot 17520 \quad = \mathbf{15912{,}8028}\ [\boldsymbol{h}]$$

- Total downtime:

$$\boldsymbol{TDT} = P_R \cdot T = 17520 \cdot (0{,}041871 + 0{,}005359 + 0{,}004087 + 0{,}003724 + 0{,}016803 + 0{,}015531 + 0{,}000999 + 0{,}000817 + 0{,}000272 + 0{,}002271) = 17520 \cdot 0{,}091735 = \mathbf{1607{,}1972}\ [\boldsymbol{h}]$$

- Average number of interruptions (failures):

$$\boldsymbol{F_f} = T \cdot P_0 \cdot \sum_{i=1}^{10} \lambda_i = 17520 \cdot 0{,}908265 \cdot (0{,}04612 + 0{,}00598 + 0{,}00456 + 0{,}00413 + 0{,}01859 + 0{,}01711 + 0{,}00118 + 0{,}00096 + 0{,}00031 + 0{,}00259) = 15912{,}8028 \cdot 0{,}10153 = \mathbf{1615{,}626}\ [\boldsymbol{h}]$$

- Average uptime:

$$\boldsymbol{MUT} = \frac{TUT}{F_f} = 15912 \cdot \frac{8028}{1615} \cdot 626 = \mathbf{9{,}8493}\ [\boldsymbol{h}]$$

- Average down time:

$$\boldsymbol{MDT} = \frac{TDT}{F_f} = 1607 \cdot \frac{1972}{1615} \cdot 626 = \mathbf{0{,}99478}\ [\boldsymbol{h}]$$

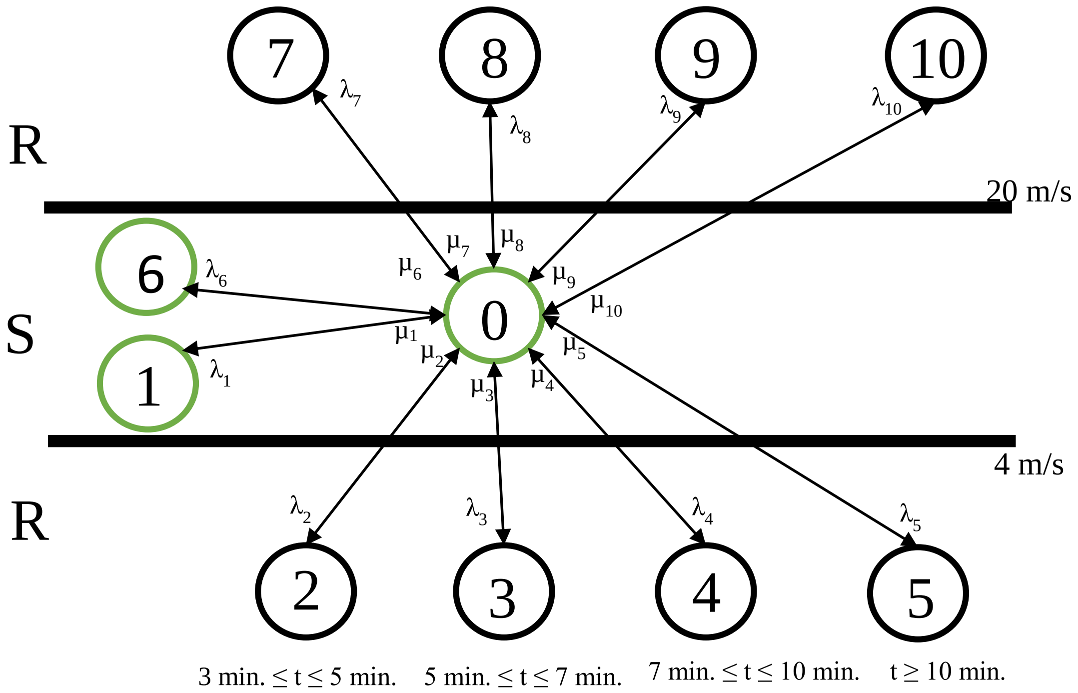
- Intensity equivalent failure:

$$\boldsymbol{\lambda_{equiv}} = \frac{1}{MUT} = \frac{1}{9{,}8493} = \mathbf{0{,}10153}\ [\boldsymbol{h}]^{\mathbf{-1}}$$

- Equivalent rapair rate:

$$\mu_{\boldsymbol{equiv}} = \frac{1}{MDT} = \frac{1}{0{,}99478} = \mathbf{1{,}00524}\ [\boldsymbol{h}]^{\mathbf{-1}}$$

Case II: $\boldsymbol{C_{time}} > 3\ min$



$$\boldsymbol{P_S} = P_0 + P_1 + P_6 = 0{,}908265 + 0{,}041871 + 0{,}015531 = \mathbf{0,965667}\ [\%]$$

$$\boldsymbol{P_R} = \sum_{i=1}^{n} P_i = P_2 + P_3 + P_4 + P_5 + P_7 + P_8 + P_9 + P_{10}$$
$$= 0{,}005359 + 0{,}004087\ + 0{,}003724 +\ 0{,}016803 + 0{,}000999 + 0{,}000817 + 0{,}000272 + 0{,}002271 = \mathbf{0,984469}[\%]$$

- Total up operating time:

$$\boldsymbol{TUT} = P_S \cdot T = 0{,}965667 \cdot 17520 = \mathbf{16918,48584}[\boldsymbol{h}]$$

- Total downtime:

$$\boldsymbol{TDT} = P_R \cdot T = 17520 \cdot (\,0{,}0053587 + 0{,}00408719 + 0{,}0037238 + 0{,}016803 + 0{,}000999 + 0{,}000817 + 0{,}000272 + 0{,}002271) = 17520 \cdot 0{,}984469 = \mathbf{601,504087}\ [\boldsymbol{h}]$$

- Average number of interruptions (failures):

$$\boldsymbol{F_f} = T \cdot P_S \cdot \sum_{i=1}^{10} \lambda_i = 17520 \cdot 0{,}965667 \cdot (0{,}00598 + 0{,}00456 + 0{,}00413 + 0{,}01859 + 0{,}00118 + 0{,}00096 + 0{,}00031 + 0{,}00259) = 16918{,}48584 \cdot 0{,}0383 = \mathbf{622,939}\ [\boldsymbol{h}]$$

- Average uptime:

$$\boldsymbol{MUT} = \frac{TUT}{F_f} = 16918 \cdot \frac{48584}{647} \cdot 978 = \mathbf{27,15915}\ [\boldsymbol{h}]$$

- Average down time:

$$\boldsymbol{MDT} = \frac{TDT}{F_f} = 17247 \cdot \frac{89688}{647} \cdot 978 = \mathbf{0,965591}\ [\boldsymbol{h}]$$

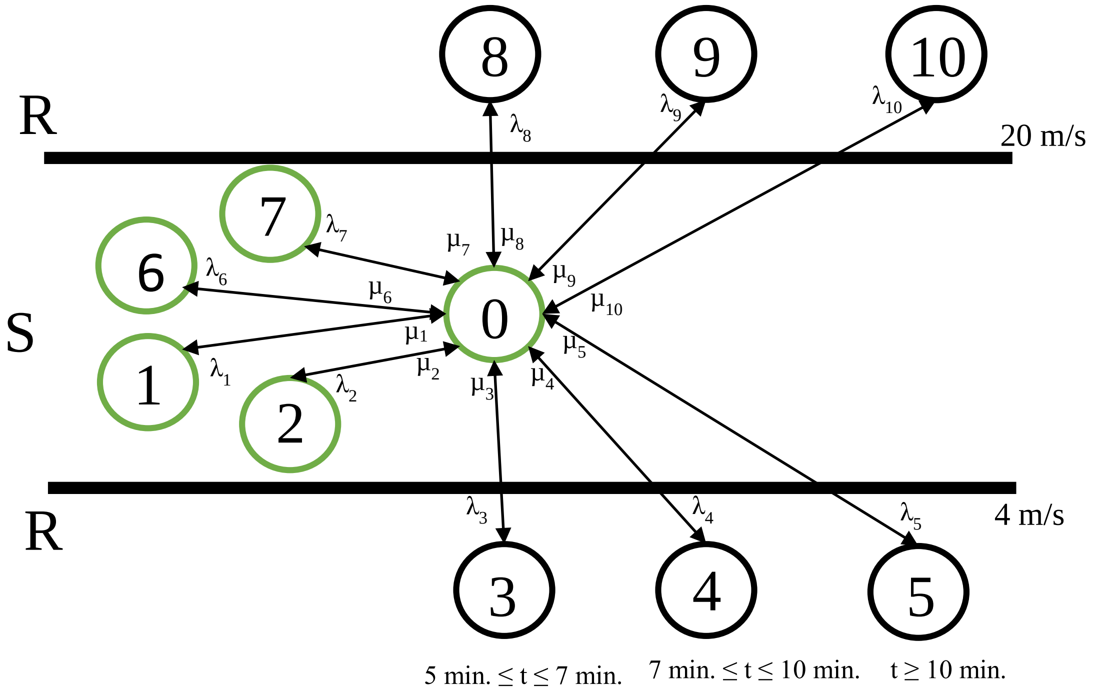
- Intensity equivalent failure:

$$\boldsymbol{\lambda_{equiv}} = \frac{1}{MUT} = \frac{1}{27{,}15915} = \mathbf{0{,}03682}\ [\boldsymbol{h}]^{\mathbf{-1}}$$

- Equivalent rapair rate:

$$\mu_{\boldsymbol{equiv}} = \frac{1}{MDT} = \frac{1}{0{,}965591} = \mathbf{1{,}035635}[\boldsymbol{h}]^{\mathbf{-1}}$$

Case III: $\boldsymbol{C_{time}} > 5\ min$



$$\boldsymbol{P_S} = P_0 + P_1 + P_2 + P_6 + P_7 = 0{,}908265 + 0{,}041871 + 0{,}005359 + 0{,}015531 + 0{,}000999 = \mathbf{0{,}972025}\ [\%]$$

$$\boldsymbol{P_R} = \sum_{i=1}^{n} P_i = P_3 + P_4 + P_5 + P_8 + P_9 + P_{10} = 0{,}004087 + 0{,}003724 + 0{,}016803 + 0{,}000817 + 0{,}000272 + 0{,}002271 = \mathbf{0{,}027974}[\%]$$

- Total up operating time:

$$\boldsymbol{TUT} = P_S \cdot T = 0{,}972025 \cdot 17520 = \mathbf{17029{,}878}[\boldsymbol{h}]$$

- Total downtime:

$$\boldsymbol{TDT} = P_R \cdot T = 17520 \cdot (0{,}004087 + 0{,}003724 + 0{,}016803 + 0{,}000817 + 0{,}000272 + 0{,}002271) = 17520 \cdot 0{,}027974 = \mathbf{490{,}10448}\ [\boldsymbol{h}]$$

- Average number of interruptions (failures):

$$\boldsymbol{F_f} = T \cdot P_0 \cdot \sum_{i=1}^{10} \lambda_i = 17520 \cdot 0{,}972025 \cdot (0{,}00456 + 0{,}00413 + 0{,}01859 + 0{,}00096 + 0{,}00031 + 0{,}00259) = 0{,}972025 \cdot 0{,}07218 \cdot 17520 = \mathbf{530{,}3106}\ [\boldsymbol{h}]$$

- Average uptime:

$$\boldsymbol{MUT} = \frac{TUT}{F_f} = \mathbf{32,11304}\ [\boldsymbol{h}]$$

- Average down time:

$$\boldsymbol{MDT} = \frac{TDT}{F_f} = \mathbf{0,924203}\ [\boldsymbol{h}]$$

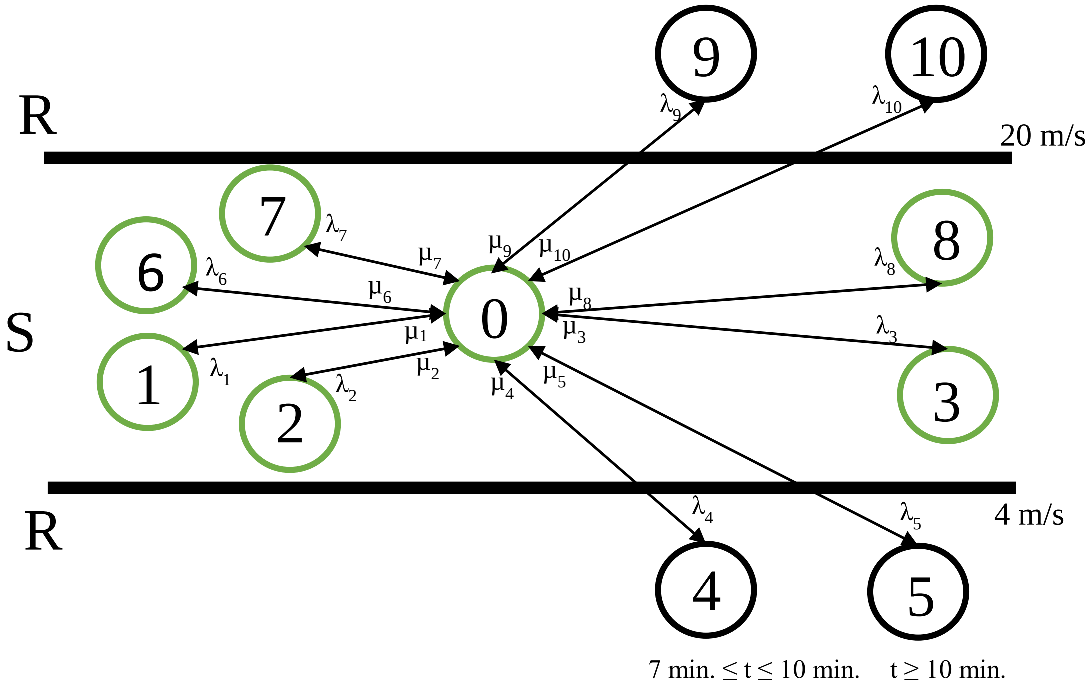
- Intensity equivalent failure:

$$\boldsymbol{\lambda_{equiv}} = \frac{1}{MUT} = \frac{1}{32{,}11304} = \mathbf{0,03114}\ [\boldsymbol{h}]^{-\mathbf{1}}$$

- Equivalent rapair rate:

$$\mu_{\boldsymbol{equiv}} = \frac{1}{MDT} = \frac{1}{0{,}924203} = \mathbf{1,082013}[\boldsymbol{h}]^{-\mathbf{1}}$$

Case IV: $\boldsymbol{C_{time}} > 7\ min$



$$\boldsymbol{P_S} = P_0 + P_1 + P_2 + P_3 + P_6 + P_7 + P_8$$
$$= 0{,}908265 + 0{,}041871\ + 0{,}005359 + 0{,}004087 + 0{,}015531 + 0{,}000999 + 0{,}000817 = \mathbf{0{,}97693}[\%]$$

$$\boldsymbol{P_R} = \sum_{i=1}^{n} P_i = P_4 + P_5 + P_9 + P_{10} = 0{,}003724 +\ 0{,}016803 + 0{,}000272 + 0{,}002271 = \mathbf{0{,}02307}[\%]$$

- Total up operating time:

$$\boldsymbol{TUT} = P_0 \cdot T = 0{,}991099 \cdot 17520 \quad = \mathbf{17115{,}81}[\boldsymbol{h}]$$

- Total downtime:

$$\boldsymbol{TDT} = P_R \cdot T = 17520 \cdot 0{,}008901 = \mathbf{404{,}1853}\ [\boldsymbol{h}]$$

- Average number of interruptions (failures):

$$\boldsymbol{F_f} = T \cdot P_0 \cdot \sum_{i=1}^{10} \lambda_i$$
$$= 17520 \cdot 0{,}991099 \cdot (0{,}00413 + 0{,}00456 + 0{,}00031 + 0{,}00096) = 0{,}97693 \cdot 0{,}00996 \cdot 17520 = \mathbf{438{,}5072}\ [\boldsymbol{h}]$$

- Average uptime:

$$\boldsymbol{MUT} = \frac{TUT}{F_f} = \mathbf{39,03201}\ [\boldsymbol{h}]$$

- Average down time:

$$\boldsymbol{MDT} = \frac{TUT}{F_f} = \mathbf{0,92173}\ [\boldsymbol{h}]$$

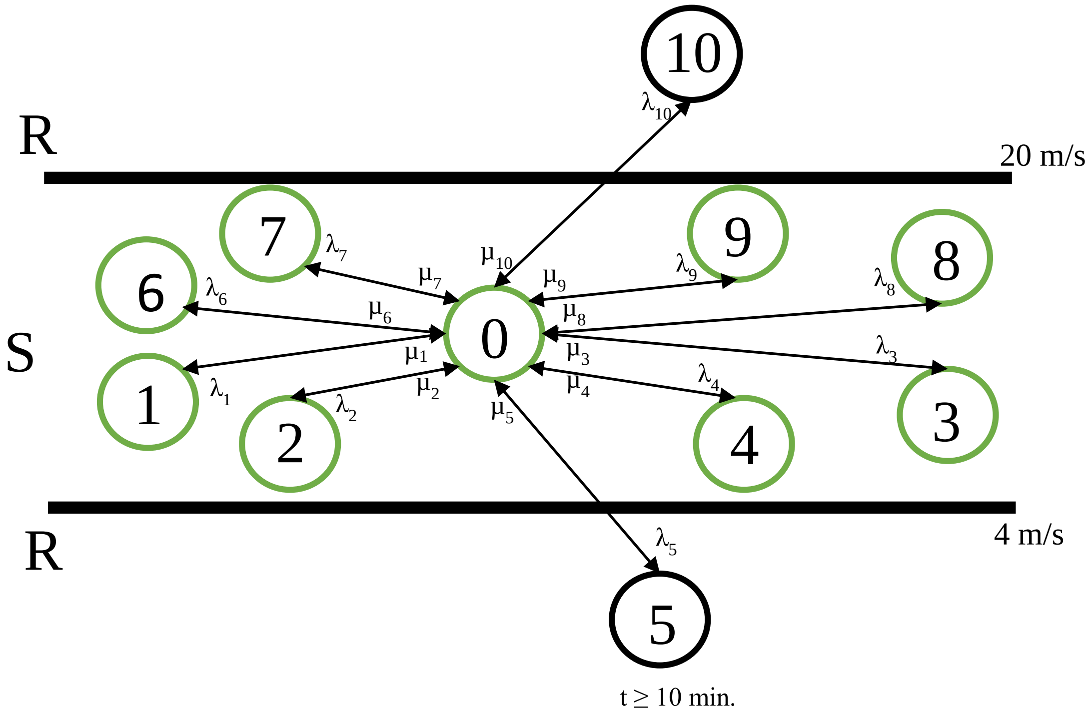
- Intensity equivalent failure:

$$\boldsymbol{\lambda_{equiv}} = \frac{1}{MUT} = \frac{1}{39{,}03201} = \mathbf{0,02562}\ [\boldsymbol{h}]^{-\mathbf{1}}$$

- Equivalent rapair rate:

$$\mu_{\boldsymbol{equiv}} = \frac{1}{MDT} = \frac{1}{0{,}92173} = \mathbf{1,0849164}\ [\boldsymbol{h}]^{-\mathbf{1}}$$

Case V: $\boldsymbol{C_{time}} > 10\ min$



$$\boldsymbol{P_S} = P_0 + P_1 + P_2 + P_3 + P_4 + P_6 + P_7 + P_8 + P_9$$
$$= 0{,}908265 + 0{,}041871\ + 0{,}005359 + 0{,}003724 + 0{,}004087$$
$$+ 0{,}015531 + 0{,}000999 + 0{,}000817 + +0{,}000272$$
$$= \mathbf{0{,}980926}[\%]$$

$$\boldsymbol{P_R} = \sum_{i=1}^{n} P_i = P_5 + P_{10} = \ 0{,}016803 + 0{,}002271 = \mathbf{0{,}019074}[\%]$$

- Total up operating time:

$$\boldsymbol{TUT} = P_0 \cdot T = 0{,}980926 \cdot 17520 = \mathbf{17185{,}8235}[\boldsymbol{h}]$$

- Total downtime:

$$\boldsymbol{TDT} = P_R \cdot T = 17520 \cdot 0{,}019074 = \mathbf{334{,}17648}\ [\boldsymbol{h}]$$

- Average number of interruptions (failures):

$$\boldsymbol{F_f} = T \cdot P_0 \cdot \sum_{i=1}^{10} \lambda_i = 17520 \cdot 0{,}908265 \cdot (0{,}01859 + 0{,}00259)$$
$$= 0{,}908265 \cdot 0{,}02118 \cdot 17520 = \mathbf{47{,}21435}\ [\boldsymbol{h}]$$

- Average uptime:

$$\boldsymbol{MUT} = \frac{TUT}{F_f} = \boldsymbol{47,21435}\ [\boldsymbol{h}]$$

- Average down time:

$$\boldsymbol{MDT} = \frac{TDT}{F_f} = \boldsymbol{0,918057}\ [\boldsymbol{h}]$$

- Intensity equivalent failure:

$$\boldsymbol{\lambda_{equiv}} = \frac{1}{MUT} = \frac{1}{47{,}21435} = \boldsymbol{0,02118}\ [\boldsymbol{h}]^{-1}$$

- Equivalent rapair rate:

$$\mu_{\boldsymbol{equiv}} = \frac{1}{MDT} = \frac{1}{0{,}918057} = \boldsymbol{1,089257}\ [\boldsymbol{h}]^{-1}$$

The terms ‘P_i’ (probability) were calculate with the matrix:

	0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
0	-0,101	46,3821	14,5116	10,0411	7,3254	0,0626	48,0769	13,793	10,1214	7,6923	1,9596
1	0,0461	-46,3821	0	0	0	0	0	0	0	0	0
2	0,0059	0	-14,5116	0	0	0	0	0	0	0	0
3	0,0045	0	0	-10,0411	0	0	0	0	0	0	0
4	0,0041	0	0	0	-7,3254	0	0	0	0	0	0
5	0,0185	0	0	0	0	-0,0626	0	0	0	0	0
6	0,0171	0	0	0	0	0	-48,0769	0	0	0	0
7	0,0011	0	0	0	0	0	0	-13,793	0	0	0
8	0,0009	0	0	0	0	0	0	0	-10,1214	0	0
9	0,0003	0	0	0	0	0	0	0	0	-7,6923	0
10	0,0025	0	0	0	0	0	0	0	0	0	-1,9596

Now with the equation [27]:

$$[q_{ij}]\cdot[p_i]=[0]$$

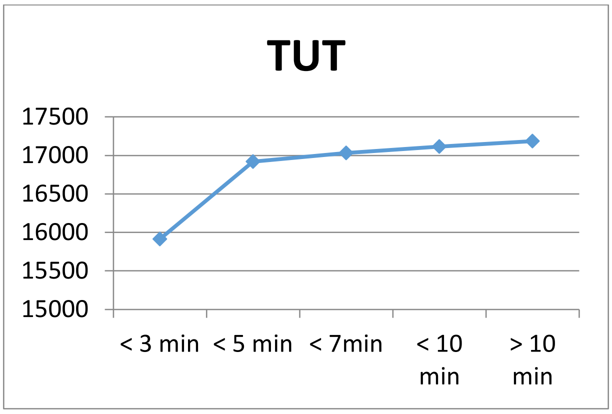
Are obtained the probabilities:

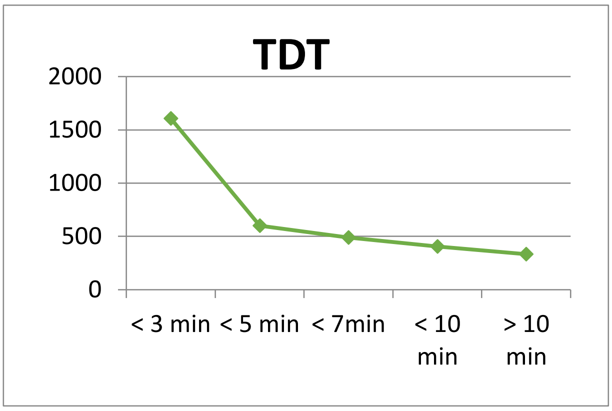
P0	0,908265
P1	0,041871
P2	0,005359
P3	0,004087
P4	0,003724
P5	0,016803
P6	0,015531
P7	0,000999
P8	0,000817
P9	0,000272
P10	0,002271

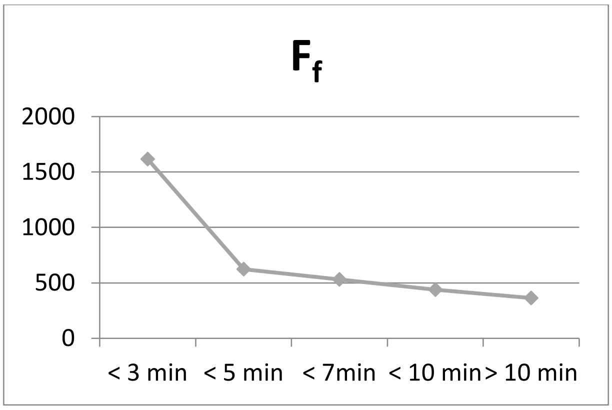
With the probabilities it is able to do all calculates:

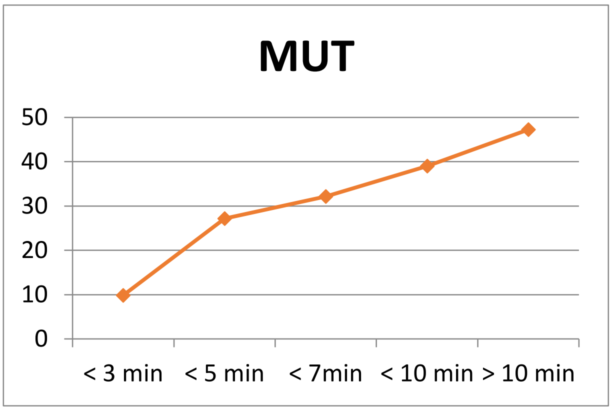
C_{time} or MTC	< 3 min	< 5 min	< 7min	< 10 min	> 10 min
TUT	15912,80654	16918,49591	17029,88556	17115,81471	17185,83106
TDT	1607,19346	601,5040872	490,1144414	404,1852861	334,1689373
F_f	1615,627248	622,9390195	530,3106363	438,507173	363,9959019
MUT	9,849305624	27,15915263	32,11303789	39,03200625	47,21435316
MDT	0,994779868	0,965590641	0,924202548	0,921730159	0,918056867

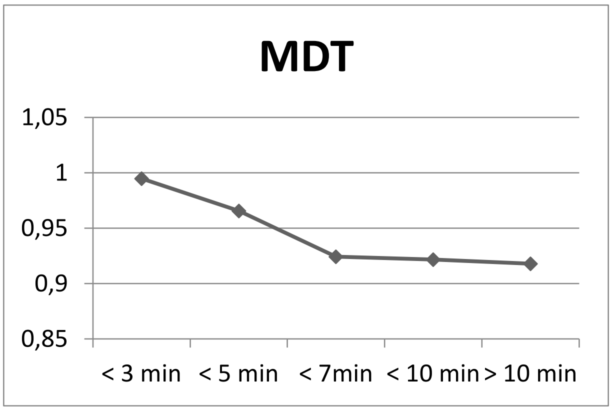
Now it is show all this results in graphics:











6. Conclusions

Throughout the second case study had been show with details the behaviour of something so random like the wind is. This case of study can be used to determinate if in this area where the data have been recorder is a good emplacement to install a wind system to generate electricity, obviously the interpretation is going to depends the kind of system want to be install, cause the Mechanical Time Constant (C_{time} or MTC) is going to depends of the drive assembly from the generator and it is write in the characteristics papers.

So I can say all the study can be used to guess the behaviour of the wind along the next years always with an estimation no like an exact study; this means from this study is possible predict how many time is going to be useful the wind (TUT), how many time is going to be the wind over the limits of usefulness (TDT), the frequency with the wind move outside the limits (F_f), the average of useful time (MUT) and average of down time (MDT).

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