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Resumen

Las emisiones de gases de efecto invernadero (GEI) causantes del cambio climático, son en gran parte generadas por el sector energético, lo que aunado a los actuales estilos de vida que demandan un alto consumo de combustibles fósiles, nos ha llevado a nivel mundial a enfrentar la crisis energética. Lo anterior demanda una transición hacia el uso de las energías renovables, las cuales disminuyen sustancialmente la generación de GEI así como la dependencia de los combustibles fósiles.

Por otra parte, las energías renovables representan una importante alternativa para la generación de energía en zonas aisladas en las que no se cuenta con los recursos ni las tecnologías para cubrir sus demandas energéticas de manera convencional. Como es el caso de SLP, mismo que se ubica como 4º lugar a nivel nacional sin acceso a la electricidad, y como 6º lugar en marginación.

México es un país con un gran potencial solar y eólico identificado; sin embargo, este no ha sido profundamente analizado en todo el país, por lo que se realizó la estimación del potencial eólico de la región del altiplano en el estado de San Luis Potosí, partiendo de la premisa de que, de acuerdo al estudio más reciente (Atlas Solar y Eolico de México -IIE, 2010-), existe un potencial de viento aprovechable (entre 200 y 300 W/m^2) derivado de sus condiciones climáticas y topográficas en determinadas áreas. La evaluación del recurso eólico se llevó acabo mediante el uso del software especializado WasP, con el objeto de identificar áreas con potencial útil en la zona. Se analizaron los datos climáticos de tres estaciones meteorológicas (Matehula, Zacatecas y SLP) entre las que se identificó la de SLP con potencial útil para su aprovechamiento a baja escala. Finalmente se relacionó el potencial identificado con posibles aplicaciones de uso rural vistas como alternativas de desarrollo para las comunidades circundantes.

Palabras clave: energía eólica, potencial eólico, tecnologías eólicas de baja denominación, bombeo de agua, electrificación rural.

Abstract

Emissions of greenhouse gases (GHGs) as the main cause of climate change, are largely generated by the energy sector, which coupled with the current lifestyles that demand a high consumption of fossil fuels, has led us to face a global energy crisis. This demands a transition to the use of renewable energy, which substantially reduced GHG generation as well as the dependence on fossil fuels.

Furthermore, renewable energies represent an important alternative for power generation in remote areas where there is not resources or technology to meet their energy demands.

Mexico is a country with a large identified solar and wind potential. However, its potential has not been thoroughly evaluated in the entire country. Likewise, in the social field, there are throughout the country around 89 thousand marginalized localities without access to electricity, being SLP the 4th at national level without electricity covering as well as the 6th in marginalization.

Mexico is a country with great solar and wind identified potential, but this has not been thoroughly analyzed in the whole country, so it was performed the estimation of wind potential in the Highlands region of the state of San Luis Potosi, starting from the premise that, according to the recent published “Solar and Wind resource Atlas of Mexico”, there is a useful potential –between 200 and 300 W/m^2- derivative of its weather and topographic conditions in certain areas of the State. The wind resource assessment was carried out by using the specialized software WasP, in order to identify wind potential areas. Climate data were analyzed from three weather stations (Matehula, Zacatecas and SLP) resulting only useful potential for small-scale use in surroundings SLP city. Finally the identified potential was associated with possible rural applications as alternative for the development of the surrounding communities.

Keywords: wind potential, wind power, small-scale wind technologies, water pumping, rural electrification.

Zusammenfassung

Für den Ausstoß von Treibhausgasen, die den Klimawandel verursachen, ist zu einem großen Teil der Energiesektor verantwortlich. Einher mit heutigen Lebensweisen geht ein hoher Verbrauch fossiler Brennstoffe, der zur Konfrontation mit einer globalen Energiekrise geführt hat. Dies erfordert eine Umstellung hin zur vermehrten Nutzung erneuerbarer Energiequellen, welche die Erzeugung von Treibhausgasen ebenso wie die Abhängigkeit von fossilen Brennstoffen deutlich reduzieren.

Zudem stellen erneuerbare Energien eine wichtige Alternative zur Energieerzeugung in abgelegenen Gebieten dar, in denen man weder über die Ressourcen noch über die Technologie verfügt, um den Energiebedarf auf herkömmliche Weise zu decken. Dies ist der Fall im Staat San Luis Potosí, der landesweit den viertschlechtesten Zugang zu Elektrizität aufweist und gleichzeitig Platz sechs der höchsten Armut des Landes einnimmt.

Mexikos Potenzial an Solar- und Windenergie wird zwar als hoch eingestuft, wurde jedoch bisher nicht präzise für alle Landesteile nachgeforscht. Basierend auf den klimatischen und topografischen Bedingungen festgelegter Zonen wurde daher das Windenergiepotenzial für die Hochebene des Staates San Luis Potosí abgeschätzt, ausgehend von der mit neueren Studien übereinstimmenden Annahme, dass es nutzbares Windpotential gibt.

Die Bewertung der Ressource Wind wurde mithilfe der fachspezifischen Software WasP durchgeführt, mit der Zielsetzung Bereiche mit ausschöpfbarem Potential in der Region zu identifizieren. Es wurden die Klimadaten von drei Wetterstationen (Matehula, Zacatecas und San Luis Potosí) analysiert, von denen San Luis Potosí brauchbares Potential für Kleinenergieanlagen aufwies. Das ermittelte Potential wurde mit möglichen ländlichen Anwendungen assoziiert, die als alternative Entwicklungsmöglichkeiten für die umliegenden Gemeinden betrachtet werden können.

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Abbreviations

AMDEE	Mexican Association of Wind Energy (Asociación Mexicana de Energía Eólica, A. C.)
ANES	National Association of Solar Energy (Asociación Nacional de Energía Solar)
CFE	Electricity Federal Commission (Comisión Federal de Electricidad)
CIEMAT	Centre for Energy, Environment and Technology (Centro de investigaciones Energéticas, Medioambientales y Tecnológicas)
CONAGUA	National Commision for Water (Comisión Nacional del Agua)
CONAPO	National Population Council (Consejo Nacional de Población)
DTU	Technical University of Denmark
EMAS	Automatic weather stations (Estaciones meteorológicas automáticas)
ESIME	Synoptic weather stations (Estaciones sinópticas meteorológicas)
GWEC	Global Wind Energy Council
INAFED	National Institute for Federalism and Municipal Development (Instituto Nacional para el Federalismo y el Desarrollo Municipal)
INEGI	National Institute of Statistics and Geography

	(Instituto Nacional de Estadística y Geografía)
INIFAP	National Institute of Forest, Agricultural and Livestock Research (Instituto Nacional de investigaciones Forestales, Agrícolas y Pecuarias)
IIE	Electric Power Research Institute (Instituto de Investigaciones Eléctricas)
NREL	National Renewable Energy Laboratory
OLADE	Latin American Energy Organization (Organización Latinoamericana de Energía)
REUK	Renewable Energy UK
SENER	Ministry of Energy (Secretaría de Energía)
SMN	National Weather Service (Servicio Meteorológico Nacional)
USAID	United States Agency - Internacional Development

CHAPTER I INTRODUCTION

Consumption and power generation today is a serious environmental problem in several aspects: on the one hand, the high exploitation of nonrenewable resources such as fossil fuels, which is reaching its limit. On the other hand, emissions of greenhouse gases (GHGs) resulting from excessive consumption of all kind of energy demanded by today's lifestyles (electric, gasoline, diesel, so on), especially in cities where it is impossible to conceive of social and economic development without the use of energy power, since all production activities depend on the use of it. Then, we are facing a high global atmospheric pollution generated from burning fossil fuels, mainly.

Nevertheless, the social and economic development should not be threatened by the scarcity of fossil fuels and other natural resources when today there’s a wide diversity of clean ways for the generation of power. It has been demonstrated in many success cases that this type of energy generation is able to meet high demands efficiently, making use of inexhaustible sources of energy like solar, wind and even the tides, just to mention a few, without generating large amount of pollutants that represent high riks to human health and total environment.

Socially, renewables play an important role as they are able to provide energy in isolated communities, as the main characteristic of renewables is that are produced *in situ*, which means that is generated where the source is present, reducing costs of fossil fuels and transportation, and in many cases it can be harnessed at small-scale to domestic use. The main disadvantage is related to investment costs. However, in countries where it works, the problem has been solved by proper financial schemes which obeys to society needs, and with regard to its own regulation, resources and conditions.

In Mexico, it has already identified large potential for harnessing renewable energy, which represents an important alternative to meet the energy demand in isolated areas that lack electricity service. Related to this, it is estimated 3.2 million Mexicans, distributed in 89 thousand locations, which do not have the service, being San Luis Potosi (SLP) a representative state in this regard that according to CONAPO in 2005 occupied the 6th place of marginalization at the national level and 4th in percentage of population without electricity.

Particulary in eolic, despite having one of the best wind energy potential in the world, both in quantity and quality, development of such energy resources in Mexico has been very limited, mainly due to lack of government incentives to encourage the renewable energy use as well as the lack of a clear regulatory framework to allow greater private sector participation in wind farm development (USAID, 2009).

Getting electricity through wind power is an alternative for clean power, avoiding environmental damage, both locally and at the border that compared to other ways of energy production, it becomes the cleaner, since it generates less environmental impacts. This impacts are visual impact (affecting the lanscape and producing cast shadows according to turbine size) and noise impact (with regard to movement of the blades), as well as the loss of wildlife by coalition of individuals and turbines due to the interference of their air routes with the presence of them (points that nowadays are quite discussed and debatable between scientific community). Wind power plants do not use fuel or any petroleum or natural gas. Nor emit air pollutants or greenhouse gases or consume the water or other natural resources. In addition, when compared with a nuclear power plant, wind farms do not generate hazardous waste or have large-scale risks to the nearby (Gonzalez, et. al, 2006). This confers on the use of wind energy among other advantages, competitiveness against other renewables in terms of investment but are generally higher costs, making it necessary to conduct a feasibility study where is visualized to implement a wind project.

In terms of sustainability it is important to underline that boosting renewables is an act of awareness that responds to the necessity to diversify energy production by free, clean and inexhaustible sources and not only due to the insufficiency of non-renewable resources and the high global pollution we are facing, associated with the high costs it implies. Sustainable energy production must become a fundamental part of human development to live safety, healthy and in harmony with the environment.

This work has the aim to know if there is enough potential for energy production by wind resource using an specialized computing tool known as WasP "Wind Atlas Analysis and Application Program", a program for predicting wind climates, wind resources and power productions from wind turbines based on wind data measured at stations in the same region developed by RISOE DTU Company (Denmark). It was obtained a student’s license for this purposes.

The specific interest of the present research is to perform the study of wind potential in the Highlands Region of San Luis Potosí state of Mexico, based on the premise that the region has an exploitable wind potential and to evaluate the possibility to adjust that potential to needs of communities in there, mostly marginalized and rural, considering the fact that, to reach real energy production by renewables in there, is necessary a higher household budget allocation that can become to an efficient option and contribute to its energy independence.

The work contains six Chapters: Chapter I –the present- that is the Introduction, about to explain motivation of the thesis work as well as the general content and the way to perform it; Chapter II “*Theoretical Framework*” that gives the background about wind power including a brief description of history of wind turbines, wind installed capacity worldwide and in Mexico, the explanation about winds around the global sphere and how can they generate power, basic concepts of wind power as well as factors affecting wind power production and the theoretical basis for wind power calculations. Chapter III describes the *Methodology* of the work, availing of bibliographic, computational and analitic capacity tools mainly. It is described in there how do the employed software work and the results that can be obtained by. That Chapter also provides a description of the area of interest. Chapter IV (“*Estimation of wind potential*”) describes how the research was performed and the limitations found through the task. It includes diagrams (wind roses), graphs, values and maps, as well as the interpretation of the obtained by the computational tool. Chapter V “*Alternatives for rural use*” consists in a discussion of alternatives to focus wind potential from the obtained, including as possible social, economic and environmental aspects. Chapter VI corresponds to the *Conclusions* after estimating wind potential and analizing alternatives of use that has the objective to leave open further research about feasibility and maybe financial schemes to promote wind energy if so, as well as the study of the social aspect.

The present research is an independent project within a context of cooperation between Autonomous University of San Luis Potosi (Mexico) and the Cologne University of Applied Sciences (Germany), supervised and supported by one representant of each university and an external assessor.

The methodological design of the research led to meet quality and synchronous criteria as corresponds to the specific objective, which we state *"Experimenting a software tool to estimate the wind potential in the highlands region of San Luis Potosí for its sustainable use in rural areas"*, which is understood within the general objective *"Providing knowledge for the transition to renewable energy in the field of wind energy"*. To respond to the specific objective, it was noted a sequence of steps to meet the research process, called the particular objectives, that were stated as:

1. To collect meteorological and topographical information as well as to establish its quality;
2. To obtain monthly and annual wind roses from wind direction and wind speed data at the analyzed meteorological stations;
3. To perform the required estimations by using specialized software called WasP to obtain the wind frequency distribution at different heights;
4. To obtain wind power density by each analyzed meteorological station, and
5. To discuss possible rural applications according to identified wind potential.

After analyzing the data from three meteorological stations selected for their location, as well as data from two agroclimatic stations used as reference, was identified the potentiality of a useful area around SLP. In turn was tested a computational tool for this purpose. This allowed to state that there is enough potential in an area around SLP to specific purposes (low-scale), while was possible to find the advantages and disadvantages, as well as the limits of the proven tool. All this is to help improve the infrastructure for harnessing wind energy and cost savings in finding analysis tools.

CHAPTER II THEORETHICAL FRAMEWORK

[Background]

2.1 History of Wind Turbines

The technology of transforming the kinetic energy of the wind into useful mechanical power has been applied by man since antiquity (Andersen, 1997). It is estimated that by the year 5000 B.C. people traveled along the Nile River with boats propelled by wind energy and by 200 B.C., water was being pumped by simple windmills in China (TWC, 2012). Although that speculation, the earliest evidence dates from the year 644 A.D.; according to Hau (2006) they were windmills from the Persian-Afghan border region of Seistan. A later description, including a sketch, dates back to the year 945 and depicts a windmill with a vertical axis of rotation, used traditionally for milling grain. Similar, extremely primitive windmills have survived in Afghanistan up to the present time (Hau, 2006). See Figure 2.1-1.

Figure 2.1-1 Vertical Axis Wind Mill for milling grain, Afganistan. (Hau, 2006)

It is known that some centuries after it was discovered that windmills were also used by the Chinese, although it is uncertain whether it was these or the Persians who used them first. What is known is that windwhells by Chinese were simple structures made of bamboo sticks and fabric sails and that they had a vertical axis of rotation for pumping water (Hau, 2006)

From Asia the use of wind power spread to Europe through civilization (Andersen, 1997). The first windmills built in Europe and inspired by the Middle East ones used an horizontal axis (D’Ambrosio et al, 2010). This type of wind mill was specially designed to adjust the catchment area, according to wind speed, rolling the candles on his “masts”, Its main feature was the use of triangular sails like a shovel (IAE, 2003). Example of this horizontal-axis wind mill is shown in Figure 2.1-2.

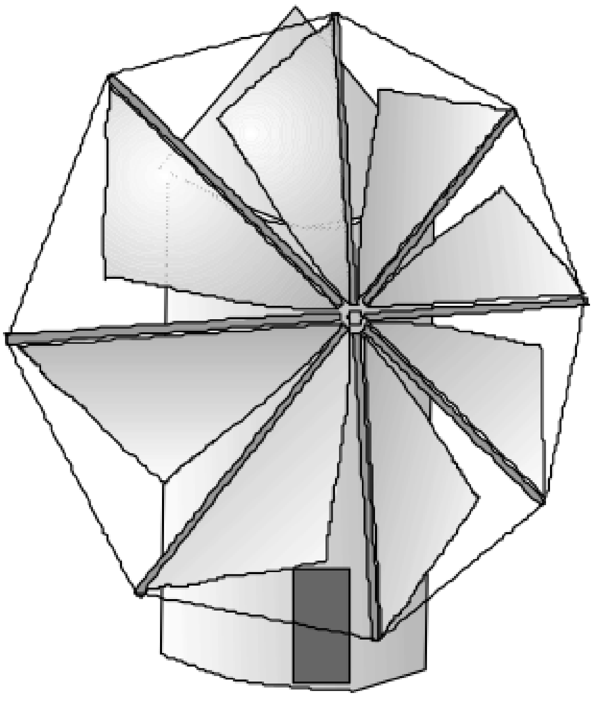


Figure 2.1-2 Horizontal Axis Wind Mill (IAE, 2003)

During the 14th century the Dutch took the lead in improving the mills and began to use them extensively to drain the swampy delta of the Rhine. Then, in the late 15th century, were built the first windmills to oil production, paper and wood processing mills. In the early sixteenth century they began to be used for the drainage of "polders", using machines up to 37 kW (50 HP) each (IAE, 2003).

In the mid-nineteenth century about 9000 mills operated in the Netherlands for different purposes, some up to 65 kW (90 HP). With the introduction of steam engines during the Industrial Revolution it began to decline (IAE, 2003). The wind turbines used in the USA during the 19th century and until the ’30 of 20th century were mainly used for irrigation. They had a high number of steel-made blades and represented a huge economic potential because of their large quantity: about 8 million were built all over the country (D’Ambrosio et al, 2010). In Denmark, at the end of that century, about 3000 mills were used for industrial purposes and nearly 30,000 in home and farms, providing an output equivalent to 200 MW (IAE, 2003).

With the oil boom, these alternatives were relegated in isolated locations or for particular purposes, being replaced by heat engines or electric motors, without any involvement in the energy market. It was until the 70's that within the strong first oil crisis, coupled with the environmental impacts that began to gain importance, that wind resource was taken again as an alternative of energy production at considerable scales.

In 1985, the average rated power of the wind turbines introduced to the market was 20 kW limiting the practice only to supply electricity in remote areas. In 2002, the average rated power of the installed wind turbines was 1.395 kW. Later, in early 2005, the port of Hamburg in Germany inaugurated an installation of a 5,000 MW wind turbine with a rotor diameter slightly greater than 120 meters (61.5 blades meters), which even has a helicopter platform, built on its casing (IIE, 2005).

It is interesting to note that the windmill types which evolved in the course of history were able to maintain their original forms, coexisting with each other right up to the present time. Hau (2006) gives the following description for the main windmill types.

The *hollow post mill* (Figure 2.1-3 a) were made to use post windmills for driving scoop wheels for pumping water, being its main characteristic the pyramid-shaped base. The small rotatable millhouse now contained only the windwheel bearing, with cogwheel and wallower. A hollow post, through which the extended vertical wallower shaft was passed, formed the connection between millhouse and fixed base. This windmill was used mainly for draining, milling grain and sawing wood. Then the *post mill (*Figure 2.1-3 b) which consists of a central main post which is braced by four diagonal quarter bars. It extends upwards into the millhouse to about half its height where it is joined to the so-called meal beam which supports the millstone. The meal beam divides the millhouse into an upper level, the stone floor, and a lower level, the meal floor. They were made almost completely from wood and were used exclusively for milling grain, greatly varying their external shapes according to regional preferences.

The tower windmill consisted in a system in which the wind shaft was supported such that it could be repositioned with some manual effort, to a number of supporting positions thus providing for at least a rough orientation into the wind. In the eastern Mediterranean regions the medieval tower windmills typically had windwheels with triangular sails.

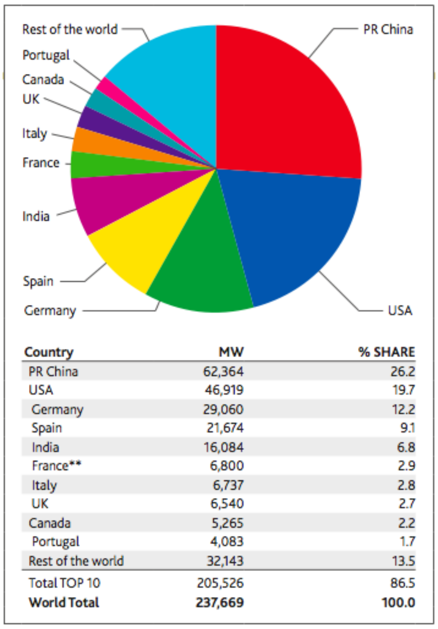
(a)

(b)

Figure 2.1-3 Hollow post mill (a) and post mill (b) by Hau (2006)

2.2 Wind capacity in the World

The global installed wind capacity increased from 6,100 to 235,000 MW from 1996 to 2011 (GWEC, 2011). As regards countries, China has the largest installed capacity with 26.2% followed by the U.S.A. and Germany with 19.7 and 12.2% respectively, as shown in Figure 2.2-1. In Figure 2.2-2, it can be seen how wind capacity in the world grew in that period, being remarkable the fact that since the year 2005, wind capacity has rapidly increased in almost 200 GW in just that six years.



Country	MW	% SHARE
PR China	62,364	26.2
USA	46,919	19.7
Germany	29,060	12.2
Spain	21,674	9.1
India	16,084	6.8
France**	6,800	2.9
Italy	6,737	2.8
UK	6,540	2.7
Canada	5,265	2.2
Portugal	4,083	1.7
Rest of the world	32,143	13.5
Total TOP 10	205,526	86.5
World Total	**237,669**	**100.0**

Figure 2.2-1Top ten installed wind capacity until 2011 (GWEC, 2011)

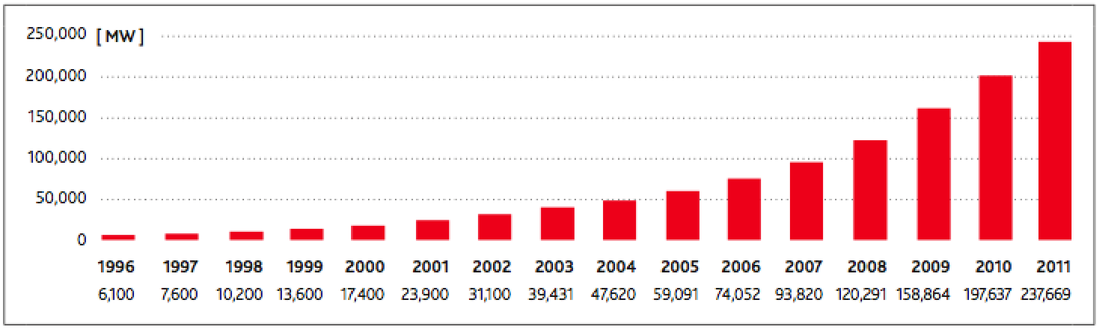


Figure 2.2-2 Global cumulative installed wind capacity 1996-2011

Source: GWEC

2.3 Wind capacity and potential in Mexico

According to CFE, in 2006 Mexico had an installed capacity barely exceeds 589 MW and is considered the most suitable for the development of this kind of energy in Latinamerica, as only in the Tehuantepec Isthmus (Oaxaca) have been quantified over 5000 MW of power. However, important institutions as Instituto de las Americas (2010), state that total potential in the country is approximately 50 GW (gross nominal capacity) of which 6 of them are class I sites (sites with wind speed average of more than 8.5 m/s according to NREL, 2004) –mainly located in the state of

Oaxaca-. Wind potential sites in Mexico (wind potential density at 80 m height) are shown in Figure 2.3-1.

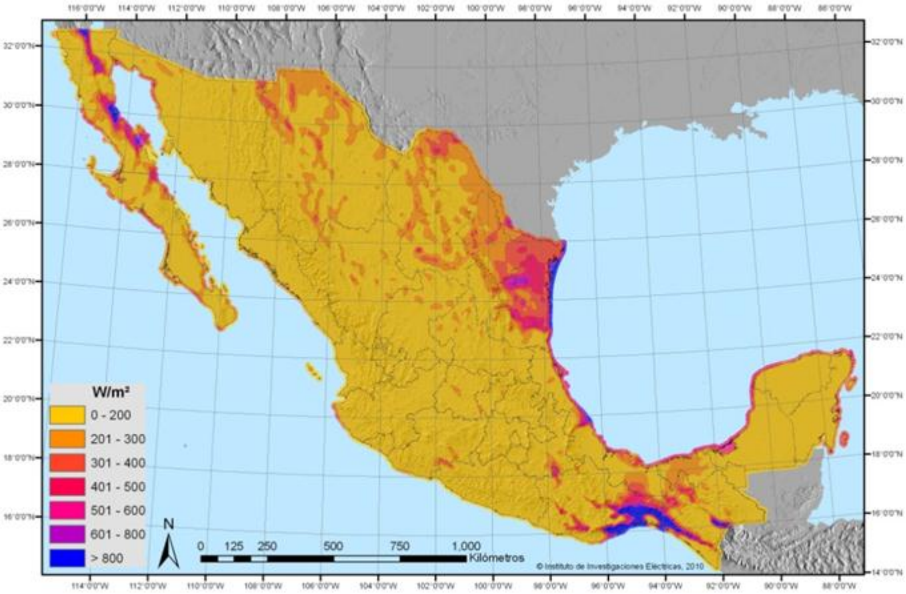


Figure 2.3-1 Wind potential density in Mexico (SENER, 2010)

According to SENER (2010) the country's wind potential has not been evaluated comprehensively. It is just the National Renewable Energy Laboratory of United States who has coordinated the implementation of wind maps of Oaxaca, Baja California Sur, the coasts of Yucatan and Quintana Roo and the borderlands of the states of Baja California, Sonora and Chihuahua.

However, the only information available of the hole country (estimations) is the *Atlas of solar and wind resource in Mexico* recently published (2010) by the IIE and SENER, where SLP present specific areas in the Highlands, with potential between 200 and 300 W/m^2, power considered as useful according to NREL (2004)- See Table 3.3-3 (Chapter of Methodology-Wind classes). According to this approach, the state has not a wind resource larger than this (Figure 2.3-2).

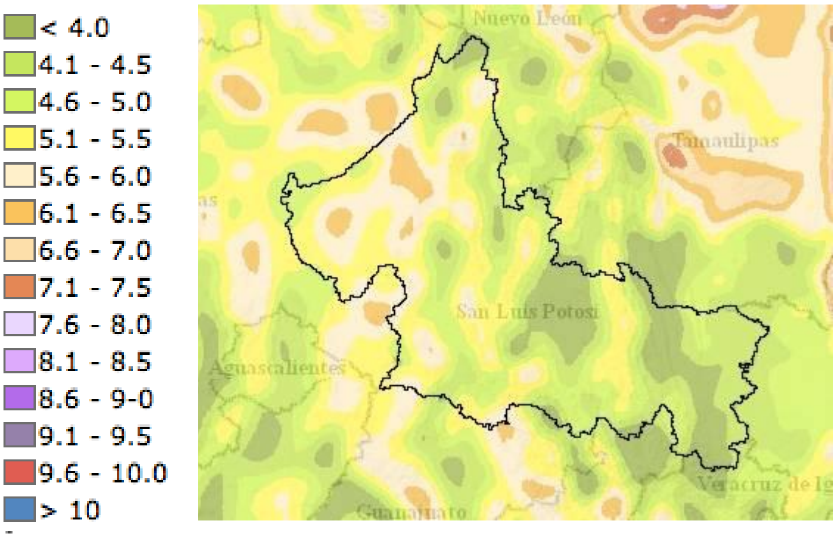


Figure 2.3-2 Wind speed at 50 m in SLP according the Atlas of solar and wind resource in Mexico, 2011 (IIE-SENER)

2.4 The wind power

2.4.1 Coriollis Forces

Wind power is considered an indirect form of solar energy. Between 1 and 2% of energy from the sun becomes wind due to air movement caused by the uneven heating of the earth's surface. The kinetic energy of wind can transform into useful energy, mechanical and electrical.

Due to the Coriolis force (the force caused by rotation of the Earth), the air rises over the Ecuador creating a belt of low pressure. When winds reach the tropopause (layer which defines the troposphere from the stratosphere) stop ascending and expand sideways (to the south in the southern hemisphere and to the north in the northern hemisphere) (Lorenzo, 2009). Coriolis forces in the Earth can be seen in Figure 2.4-1.

From there, the air begins to descend until it reaches the ground (in subtropical areas), and once it reaches the surface, this can continue on the path towards the North or go back to Ecuador. Once the wind hits the ground, rise again in the temperate zones, and upon reaching the tropopause this can be directed to the subtropics or to the poles (Lorenzo, 2009).

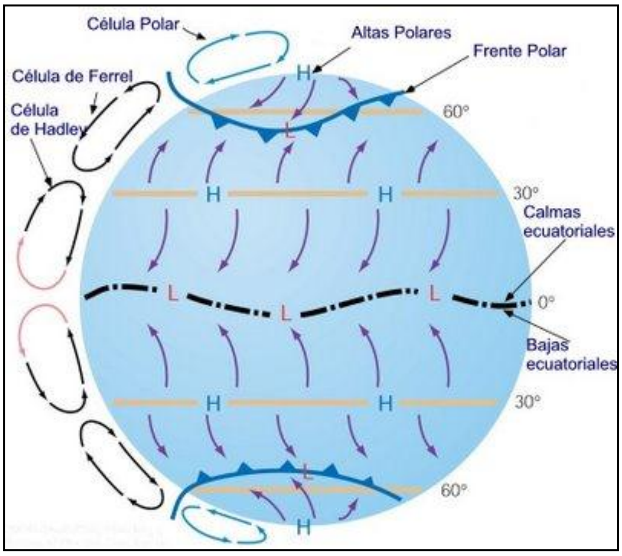


Figure 2.4-1. Coriolis force in the Earth

This motion describes the geostrophic wind, ie global winds which are conditioned to local wind for useful power generation.

2.4.2 Concepts for Wind Power

In order to know whether a site wind resource is exploitable or not, the characteristics at both, short and long term should be known. The first ones are important for the operation of wind turbines while the second ones are able to report energy production over time. This section describes the essential concepts to assess the wind resource, which involves both physical concepts related to air movements and the prevailing conditions as well as statistical analysis of historical data of wind.

The amount of energy that can generate a wind turbine is highly dependent on wind characteristics described above. Wind is a moving air mass and as such has energy. Wind turbines allow to use this energy to generate electricity directly, in function also of its number of blades.

Adding to this, there are specific factors that influence the flow and wind speed, among which include roughness of the terrain, topography of land and the presence of obstacles, among other useful concepts, briefly described below.

2.4.2.1 Mean Annual Wind Speed and Wind Speed Frequency Distribution

The mean annual wind speed, understood to be the "invariable" long-term mean value of the wind speed at one location can only be determined on the basis of measurements taken over decades (Hau, 2006). It is important to take into consideration the reliability of available information in specific periods of time to make the estimations that are not always so long. Hau (2006) states that having the wind speed data for a period is not enogh to know the behavior of wind in a location, it has to be reflected in a frequency analysis to know the most frequent.

As stated by Hau, "*The frequency distribution is generally specified as relative frequency distribution, or as cumulative frequency*". He explains that the relative frequency distribution immediately indicates the occurrence of the most frequent wind speeds while the cumulative frequency indicates as a percentage the period within a year in which the wind speed falls below the value of a certain point on the curve. By using the cumulative frequency, the mean annual wind speed" can be accurately defined and represented geometrically.

But when there's no enough available data about historical wind speed, it can be used as an approximation the Weibull distribution, a distribution curve that allows to know a good approximation in the case of a normal wind regime.

2.4.2.2 Increase in Wind Speed with Altitude

At which rate does the wind speed change with the altitude is a very important factor to involve and has to do with the height at which the turbine will be located. This is why variablity of the wind speed has to be known while normally data are obtained at 10 meters. At higher altitudes, wind speed is higher, so that the height of the facility for wind power will be more expensive at major altitudes. The main reason of this, is the height of the tower which implies more material, and thus, more costs of the facility.

The scientfic explanation of that important phenomena is that the friction of the moving air masses against the earth's surface slows down the wind speed from an undisturbed value at great altitude (geostrophic wind) to zero directly at ground level. Depending on the time of day and atmospheric conditions, the range up to where the wind speed is undisturbed is between 600 and 2000 m above ground and is called the atmospheric boundary layer.

2.4.2.3 Steadiness of the Wind

This factor is important due to the intermitance of the wind resource itself. That means that the wind is not available in intensity and constancy as can be solar radiation. Wind flow varies essentially accordingly mainly to the latitude of the site on the globe and the surrounding distribution of land and water (Hau, 2006). In medium continental latitudes, the wind fluctuates greatly as the low-pressure regions move through. In these regions, the mean wind speed is higher in winter than in the summer months.

2.4.2.4 Wind Turbulence

The turbulence is an inherent characteristic of wind that is defined as the instantaneous, random deviation from the mean wind speed. Turbulence can be described comprehensively with the aid of a statistically deduced turbulence spectrum. For this, the energy content of the wind speed fluctuation about the mean wind speed is plotted in the form of a spectrum vs. frequency. This spectrum must have been determined from wind speed measurements.

According to Hau (2006), to characterise the turbulence, is useful the term of *turbulence intensity* or also called the *degree of turbulence*. The turbulence intensity is defined as "*the ratio of the standard deviation of the wind speed to the mean wind speed in a certain averaging time and is specified in percent*". The turbulence intensity changes with the mean wind speed, with the surface roughness, with the atmospheric stability and with the topographic features.

2.4.2.5 Topography

The smaller the wind turbine and the more the local topography, including trees and buildings (obstacles), differs from the ideal flat and obstacle-free terrain, the greater the importance of the local orographic relief of the immediate surroundings. It is, therefore, useful to get an idea of whether the local terrain can be considered to be obstacle-free (Hau, 2006).

The terrain elevations such as mountains, hills, cliffs, etc., can cause a speed increase if the profile is gently sloping shape and can slow or if it's steep slopes, ridges or sharp edges. For example, rolling hills with slopes devoid of high vegetation or obstacles and rounded tops, are potentially suitable sites for installation of wind turbines because they can take advantage of the accelerating effect of the relief. By contrast, steep slopes, cliffs, and so on, are less desirable locations due to the formation of zones of turbulence, which not only reduces the energy that can get the wind turbine, but also causes fatigue mechanical stress on the machine shortening its life.

According to the author Frost (cited by Hau, 2006), the terrain in the surroundings of a wind turbine can be considered flat if:

- differences in elevation do not exceed 60 m within a radius of 11.5 km
- the ratio of the maximum level difference *hC* to the horizontal distance between these two marked points is less than 0.032 for a distance of 4 km upwind and 0.8 km downwind
- the height of the rotor relative to the lowest point within a distance of 4 km upwind is at least three times greater than the largest existing level difference *hC*.

Relating to presence of obstacles such as buildings, trees or terrain features, it causes adverse effects that are generally a decrease in wind speed and increased turbulence.

2.4.2.6 Roughness

Moreover from differences in elevation in the terrain, the topographical environment for a wind turbine is characterised by the roughness "of the earth's surface and by the presence of obstacles". Roughness has to do with the surface characteristics distribution primarily by the type of vegetation (forests, meadows etc.) or by the differences caused by land and water (Hau, 2006). According to the author Hau, while roughness determines the characteristics of the wind regime in a larger area, obstacles only have a limited local significance. Buildings, trees or groups of trees create turbulences which can have highly undesirable consequences for the operation and lifetime of a wind turbine.

To explain the above, by his own words "*The airflow on the lee-side of such an obstacle is separated to approximately twice the obstacle's height and is more or less turbulent (separation bubble). On the down-wind side the disturbed air flow extends to a distance of up to twenty times the height of the obstacle. If a negative influence on the wind turbine is to be avoided, the rotor should be placed at three times the height of the obstacle and sufficiently far away down-wind".*

The variation of velocity with respect to the height depends essentially on the roughness of the terrain. Smooth surfaces such as water surfaces, flat terrain with no trees or snow-covered plains, produce a smooth variation, unlike the large roughness surfaces, such as urban/semiurban buildings, irregular surfaces (not plain) or wooded terrains. Therefore, for better utilization of wind energy, interest the presence of smooth and clear areas (NREL 2004).

2.4.2.7 Density of air

In addition, the power depends linearly on the density of air; as the air is heavier, more energy receives the turbine. Keep in mind that the density of air varies with temperature and altitude, but also with humidity and presure. Hot air is less dense than cold, so any turbine will produce less energy during the summer, with the same wind speed during the winter. Also, at equal temperature, a place situated at an height close to sea level will present a power density greater than another located at higher altitude, due to the fact that air density decreases with height (Ciemat, 2008).

2.4.2.8 Rotor diameter

Power to obtain is directly related to power ouput, but also is a variable parameter of a wind turbine. Hau (2006), states that the real task is to achieve a technical and economic optimum performance for a given wind turbine size. *"At best, the rest of the wind turbine with the smaller rotor had not been exploited to its full economic potential, at worst the turbine with the larger rotor will be overloaded, at the cost of reliability and operating life".* That means, that the rotor diameter influences aerodynamically optimum rotor speed and that the energy yield increases proportionally to the rotor swept area. Figure 2.4-2 shows optimum rotor speed for different rotor diameters.

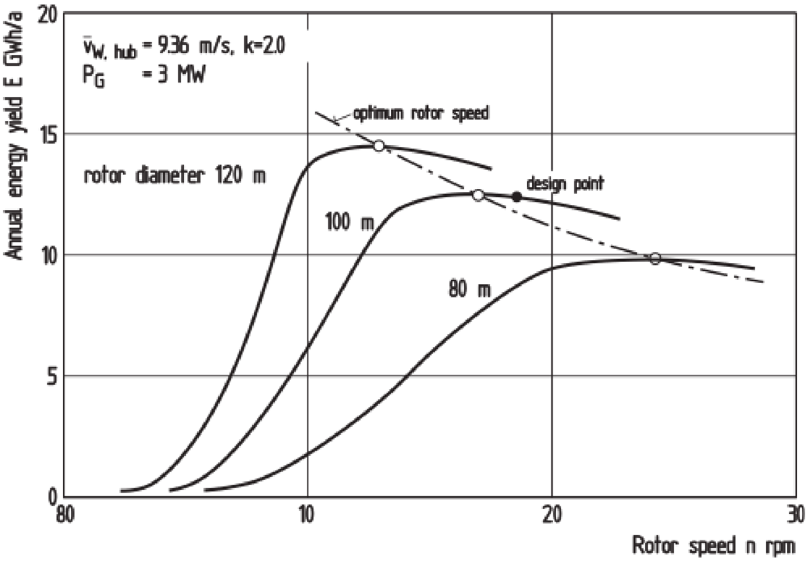


Figure 2.4-2 Optimum rotor speed for different rotor diameters

2.5 The Weibull distribution for the evaluation of wind resource

To calculate the wind potential of a place is necessary to take into account the wind speed and direction, coupled with other factors such as the topography of the site.

The frequency distribution of wind speed characterized the wind in a given place in two ways. First, the frequency distribution determines how often is a certain wind speed at that place and second, it identifies the range of wind speeds observed at that position. The distribution of wind speed is important because sites with identical average wind speeds but different distributions can result in a substantially different available wind resource (NREL, 2004).

Therefore the frequency distribution of wind speed in many areas can be approximated closely by the Weibull distribution function, defined as:

$$f(V) = (k / c)(V / c)^{k-1} \exp(-V / c)^{k}$$

where:

- f(v) = the probability density function of Weibull, the probability of find a wind speed V (m / s)
- c = the Weibull scale factor, which typically relates to the average wind speed through the form factor expressed in m / s;
- k = Weibull shape factor, which describes the distribution of wind speeds.

The wind resource at a site can be described roughly by the average wind speed, but the power density available in the wind provides a more accurate indication of the wind energy potential of a site. The density of the wind power available expresses a wind energy average over a square meter (W/m^2). The power density is proportional to the sum of the cube of the instantaneous velocity (or short-term average) of wind and density of the wind. Due to the cubic term, two sites with the same average wind speed but with different distributions may have very different values of power density. (NREL, 2004). The power density available in the wind, in units of W/m^2, is calculated using the following equation:

$$\boldsymbol{WPD} = \frac{1}{2n}\sum_{i=1}^{n} \rho \cdot v_i^{3}$$

where:

- WPD = the wind power density in W/m^2;
- n = number of records in the used interval for the average;
- **ρ** = the wind density (kg/m^3) at a particular time of observation;
- v^3 = the cube of wind speed (m/s) at the same time of observation.

This is the theoretical basis for the calculation of wind power, but this formula should not be applied when have a large data sets; it is only applicable to point data (specific date and time data).

Also, variations in the density due to different conditions of pressure and temperature can be considered through other calculation.

2.5.1 The Bet’z Law

Betz 'law states that it can only convert less than 16/27 (59%) of the kinetic energy into mechanical energy using a wind turbine (WIDA, 2003). Wind turbines extract energy by slowing down the wind. That is, for a wind turbine to be 100% efficient it would need to stop 100% of the wind, taking into account that then then the rotor would have to be a solid disk and it would not turn and no kinetic energy would be converted. On the other extreme, if having a wind turbine with just one rotor blade, most of the wind passing through the area swept by the turbine blade would miss the blade completely and so the kinetic energy would be kept by the wind (REUK, 2012). This is represented in Figure 2.5-1.

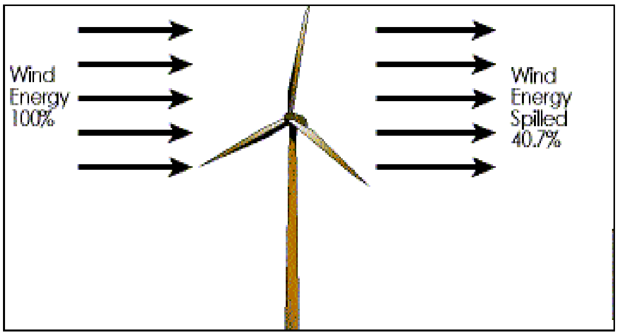


Figure 2.5-1 Betz Law (REUK, 2012)

This law was first formulated by the German physicist Albert Betz in 1919. His book "Wind-Energie", published in 1926, provides much of the knowledge that at that time was on wind energy and wind turbines.

It is still a sharp general statement that can be applied to any wind turbine with a rotor disc shaped.

2.6 Wind Turbines

The main parts of a wind turbine are the blades, the nacelle, the gearbox, the generator and the tower. Figure 2.6-1 shows the parts of a wind turbine. The blades capture the wind's energy, spinning a generator in the nacelle. The tower contains the electrical conduits, supports the nacelle, and provides access to the nacelle for maintenance. The base, made of concrete and steel, supports the whole structure. According to ECW (2012), the parts of the wind turbines can be described as follows:

- Designed like airplane wings, modern wind turbine blades use lift to capture the wind's energy. Because of the blade's special shape, the wind creates a pocket of pressure as it passes behind the blade. This pressure pulls the blade, causing the turbine to rotate. This modern blade design captures the wind's energy much more efficiently than old farm windmills, which use drag, the force of the wind pushing against the blades. The blades spin at a slow rate of about 20 revolutions per minute (RPM), although the speed at the blade tip can be over 150 miles per hour.
- The rotor designed aerodynamically to capture the maximum surface area of wind in order to spin the most ergonomically. The blades are lightweight, durable and corrosion-resistant material. The best materials are composites of fiberglass and reinforced plastic.
- The nacelle houses a generator and gearbox. The spinning blades are attached to the generator through a series of gears. The gears increase the rotational speed of the blades to the generator speed of over 1,500 RPM. As the generator spins, electricity is produced. Generators can be either variable or fixed speed. Variable speed generators produce electricity at a varying frequency, which must be corrected to 60 cycles per second before it is fed onto the grid. Fixed speed generators don't need to be corrected, but aren't as able to take advantage of fluctuations in wind speed.
- The tower is one of the most crucial parts of a wind turbine for increasing power production and cost efficiency. The U.S Department of Energy found that increasing the height of a 10 kW wind turbine from 18 meters to 30 meters resulted in a 25% increase in power production.

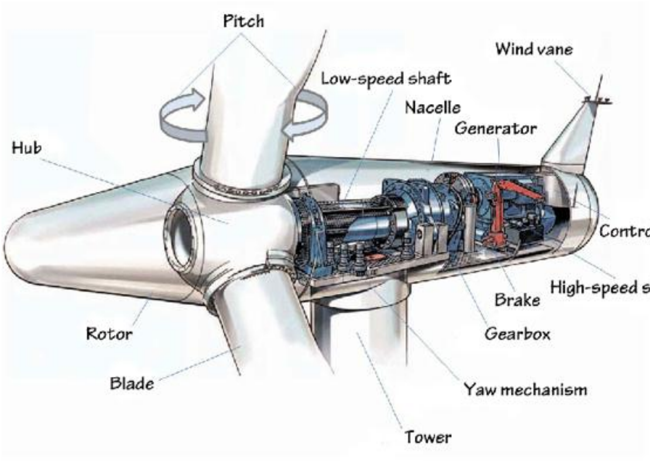


Figure 2.6-1 Major wind turbine parts (Duke University, 2012)

2.7 Environmental Impact

Wind turbines do not produce any air emmisions or require any fuel transport that can harn the environment. A wind tuebine pays back the energy that has been used o manufacture in three or nine months, depending of the wind resources in a site, the size of a turbine and the method of calculation. Adding to this, the turbine can be dismantled without leaving any lasting traces behind, and most of the material can be recycled (Wizelius, 2007).

From the environmental point of view, wind power is the best option; it has a positive impact on the global and the regional environment. The riks associated with climate change, acidification and euthophication and their impacts on agriculture, forests, lakes, landscape and human health decrease with more electricity being generated by wind.

Wind turbines can cause impacts of noise, shadow flicker, and changing views of landscapes, flora and fauna and cultural heritage. But a positive impact is that emissions from the power system are reduced. Table 2.7-1 shows a comparison between the conventional ways to produce energy and their respective impacts on environment.

Table 2.7-1 Environment impact from different energy sources (Wizelius, 2007)

Energy source	**Raw product**	**Emission**	**Other impacts**
Combustion	Coal, oil, gas	CO_2, NO_x, SO_x, VOC, ash	Oil explotation, mines, transport
Combustion	Biomass	NO_x, SO_x, VOC, ashes	Forestry, transport
Hydropower	Streaming water	None	Exploitation of land and watersheds
Wind power	Wind	None	Land use, noise
Solar heating, solar cells	Solar radiation	None	Land use

CO_2= Carbon dioxide; NO_x=Nitrogen oxides, SO_x=Sulfir oxides; VOC=volatile organic compounds

The impacts on the environment can be local, regional or global. The case of combustion is a serious problem; the extraction of fuel from mines and oil and gas wells causes further emmisions. The transport of the fuel from source to the power plants requires energy and is yet another source of emmisions.

The case of wind power impacts depends on the dimmensions of the Project, and also the perspective of the people as they have different opinions about visual impact on landscape and has to do also with the distance between the turbines and the nearest community. Figure 2.7-1 exemplifies the visual impac of a wind turbine.

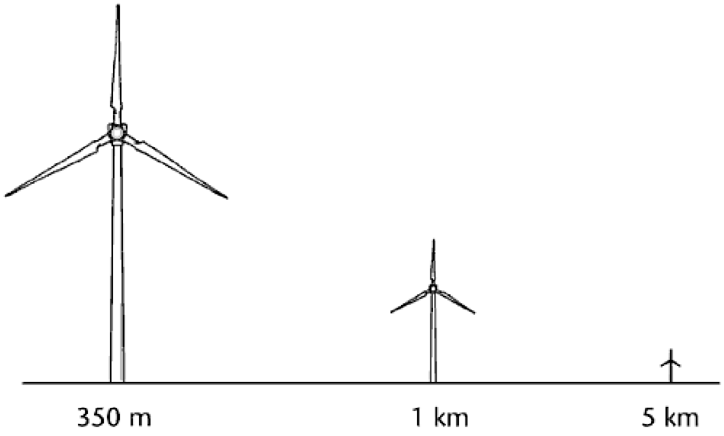


Figure 2.7-1 Visual impact of a wind turbine

The visual impact decreases with the distance. A limit for when the visual impact can be considered negligible can be set: a common rule is that turbines dominate the landscape within a distance of ten times the turbine hub height, in other words, within a circle of 600m radious for a turbine with a 60m tower, states Wizelius (2007).

In the case of the noise, according to USAID (2009), particulary in Mexico has identified flora and fauna impacts, specific on two vulnerable groups: Birds and bats. Figure 2.7-2 shows these areas for bird conservation in the country, with red indicating the state of SLP, where it can be seen that there is two on the Northeast side, AICA number 80 and 81, called "El Manantial" and "Sierra Catorce" respectively. This indicates that in the case of planning a wind project in the surrounding area, should be given special attention and study its impact as a conservative area of birds.

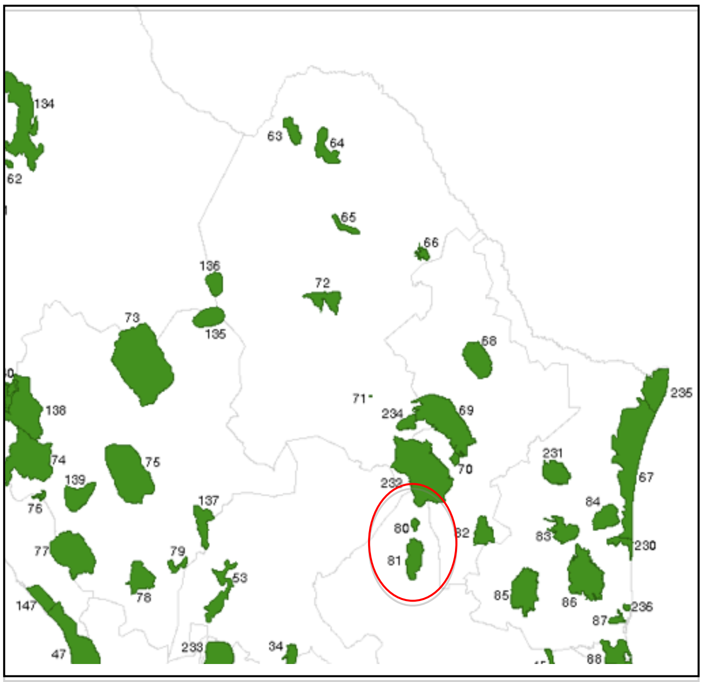


Figure 2.7-2 Areas of importance for the Conservation of Birds in Mexico (AICAS) (Conabio, 2002)

The topic is highly debatable among different members of the scientific community, by taking almost negligible for some, arguing that at least some types of birds, get used to the turbines and change their routes, while for other groups this impact is highly alarming. Citing USAID (2009) records even mention the collision of 0.04 to 0.09 birds per turbine each day, giving an average of 23 birds per machine per year and about 500 birds in the lifetime of the wind turbines. If there is poor visibility or weather conditions are not favorable, accidents increase.

It requires at least two years of bird monitoring to study its behavior and determine seasons and times when its incidence is higher for, ideally, turn off the turbines during these periods of time and avoid as much as possible, the loss of birds.

The world's best wind projects already have radar system and early warning to avoid the collision; however, data indicate that costs to purchase are similar to a life insurance for birds of about US$70 per bird, costs which are not in all projects willing to contemplate.

CHAPTER III METHODOLOGY

3.1 Introduction

The present research is projected as a quantitatively way as it is looking to locate by wind potential values and possible uses in the Highlands region of the state of San Luis Potosi. Its timing makes a synchronous design because it is not looking for comparisons between different periods, so they have not been conducted studies or trials of this type before. Thus, the methodological design fits the needs of the problem to be investigated, which responds the research question of where and how much wind capacity would be possible in this region.

The characterization of regions in the world with wind power potential has been generally accomplished through techniques implemented by descriptive statistics. The measures of central tendency and dispersion, are complemented by probability models (usually Normal or Weibull) to generate knowledge of wind behavior in the study area (Cardenas et al, 2008). For the main objective that is to evaluate wind potential in a mostly plane region in SLP, it was used an specialized software tool, with a studen’s lisence: WasP 10. Then complemented with extrapolation calculations (at different heights) using Exel to finally calculate wind power density.

With a view to design a quantitative research it was necessary to determine the fundamental elements for wind resource assessment, which are reflected in weather conditions and topographical features that together constitute the wind potential to be estimated. This conditions are wind speed and direction during a historical period of time, in this case during 2008 to 2010 data provided by SMN. With regard to topography and based in satellital images and Hellman coefficient tables, it was performed the vertical extrapolation (wind velocity at different heights).

The second stage is to process the information into the computational tool, in order to obtain wind roses (diagram), Weibull parameters, wind speed distribution and wind potential from each meteorological station data, located in San Luis Potosi, Matehuala and Zacatecas.

It was possible to asume behavior of wind in the region as wind roses provide the average intensity of the wind in various sectors represented by a circle which divides the horizon within a diagram, and so, to estimate magnitud of power that can be harnessed by the wind resource.

Afterwards, on Chap. V there is an approximation of the existing wind turbine market in small denominations in order to purpose a type of wind energy supply in rural areas of the Highlands region of San Luis Potosi, so that the identified potential can be used by the residents of these areas.

Before describing the methodology, in this seccion the characterization of the area of interest is described: location, orography, climate and vegetation. Then, it is described every steep of the methodology associated with the particular objectives of the research: data collecting, data processing in WasP computational tool and power density calculations, and final discussion about rural oportunities for wind potential.

3.2 Geographical features of San Luis Potosi and the study area

3.2.1 Location

According to INAFED (2005), the state of San Luis Potosi is located in the central highlands of Mexico. Represents 3.1% of the surface and borders to the north with Zacatecas, Nuevo Leon and Tamaulipas, on the east with Tamaulipas and Veracruz and south to Hidalgo, Queretaro de Arteaga and Guanajuato and Zacatecas to the west. Extreme geographical coordinates are: North 24° 29', South 21º 10' -north latitude-, east 98° 20' and west 102° 18' -west longitude- (INEGI, 2011). Figure 3.2-1 shows the location of the Highlands region of the state, the study area.

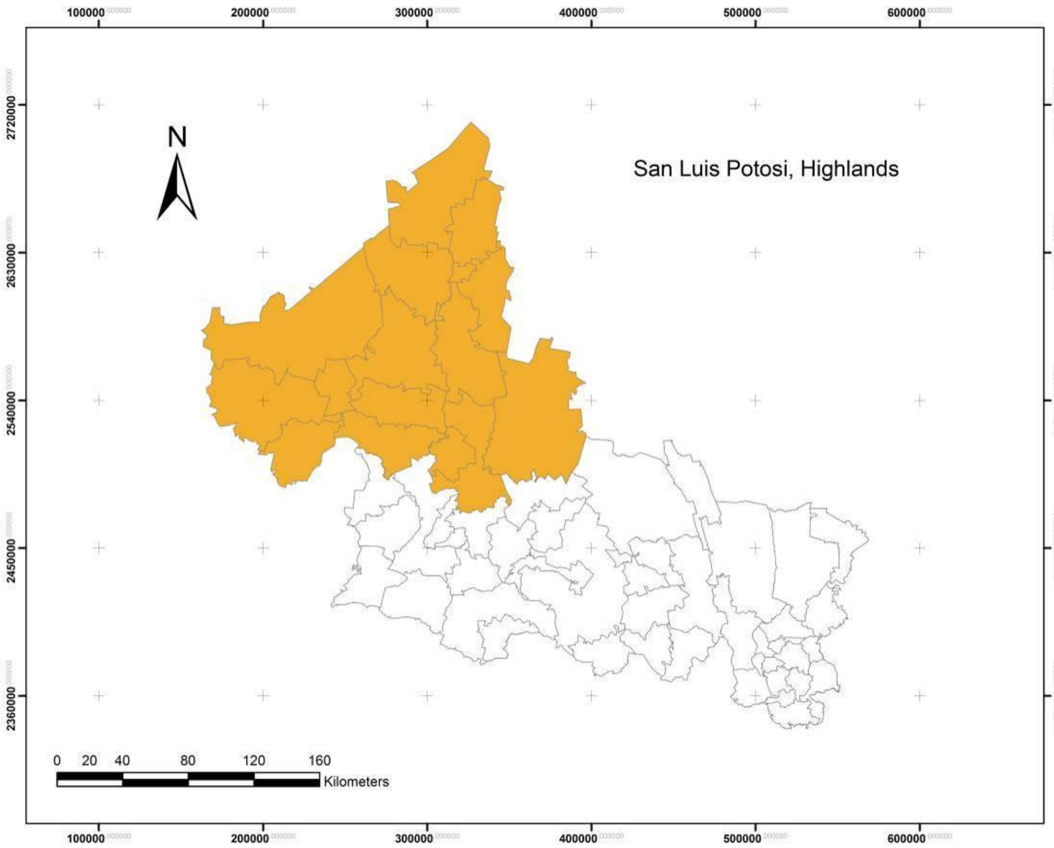


Figure 3.2-1 Area of study: Highlands region of SLP, Mexico (Lara, 2012)

The state has a diverse topography because in the eastern part of the northeast to the southeast, crosses the Sierra Madre Oriental and extensions of the Sierra Gorda of Guanajuato cross it from south to north. However, the plateau region, has the least elevation, being mostly plain (represented in yellow in Figure 3.2-2). Figure 3.2-2 shows a relief map of the state.

The plateau surface is 29.100 km^2 and its main elevations are: Sierra de Charcas, Sierra Guadalcazar, Sierra of Coro and Ypoa, Sierra of San Pedro Naola, Sierra of Peñon Blanco, Sierra Ahualulco, being the highest the Sierra of Catorce (3110 masl), Sierra Coronado (2810 masl), and Sierra of San Miguelito (2630 masl).

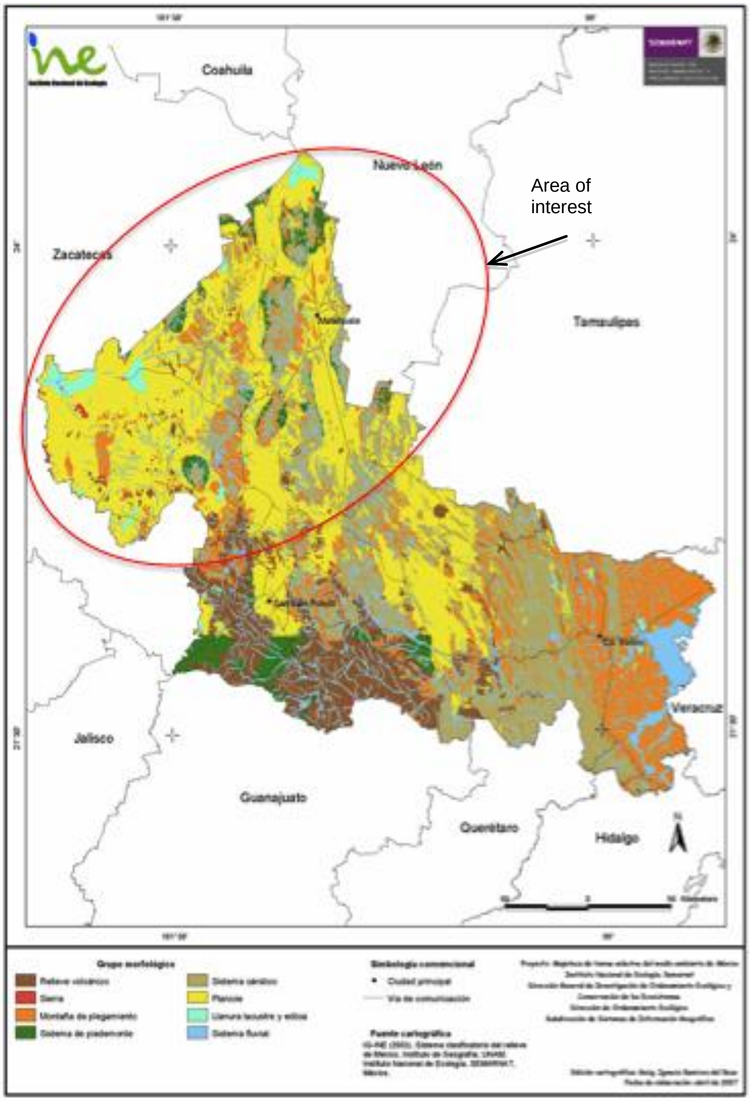


Figure 3.2-2 Classification of the relief of SLP (INE/SEMARNAT, 2007)

3.2.2 Climate

Because of the topography that presents the state, weather conditions differ markedly in the territory resulting in a variety of climates. The main are those dry –arid and semi arid- (about 74%), then the tropical wet and dry climates (about 24.41%) and in a minnor proportion the temperate/mesothermal climates are presented (INEGI, 2010). Specifically in the Highlands region, climate is predominantly dry semi-warm (PDU, 2000).

3.2.3 Vegetation

In the state of SLP there is a diversity of vegetation that can be classified into three main types: scrub, grassland and especially in the eastern part of state agriculture. With regard to the SLP-highlands and according to the physiographic division of the INEGI (2011), are located the subprovinces of the "Plains and Mountains of San Luis Potosi-Zacatecas"(SPMSZ), "Subprovince of the Mountains and Mountain Ranges of Aldama and Rio Grande" (SMAR), the "Subprovince of Transverse Ranges" (STR) and the "Subprovince of the Mountains and Western Plains" (SMWP).

In the first one (SPMSZ) over 60% of the vegetation is microphyll desert scrub, while in the second subprovince (SMAR) its the same with approximately 50% of dominance of the area, followed by rosette scrub and natural grassland. The third of the subprovinces (STR), in the case of SLP corresponds to a very small area that is covered mostly by typical scrub of arid zones, rosette and microphyll scrub. Finally, in the SMWP subprovince microphyll desert scrub dominates with physiognomy of unarmed (boned).

With regard to agriculture, although it is a smaller area, is one of the most important activities of some of the municipalities in the highlands, practiced this, both irrigated and rainfed. In the northeastern part of the SMWP subprovince, it has a large area dedicated to agriculture which is mainly grown in alfalfa, onion, chile, cabbage, tomato, lettuce, corn, and oranges. Rainfed agriculture is done in parts of the descents, hills, plains and mountains, deep or shallow soils. The crops are oats, achicalada, peanuts, pumpkin, barley, beans, chickpeas, corn and wheat. Likewise, in the SPMSZ subprovince, to the southwest part, agriculture is planted with zempoaxochitl, lettuce, carrots, cabbage, cucumber, zucchini and sunflower. Figure 3.3-7 shos ground uses and vegetation of the State.

3.3 Methodology description

3.3.1 Data collecting

By estatistical and institutional sources (SMN and CONAGUA) historical data were collected from meteorological stations that by its location, corresponds to the nearest of the area of interest. This meteorological stations correspond to two EMAS (in Matehuala and Zacatecas located) and one ESIME (in San Luis Potosi city). Location from the stations is shown in Figure 3.3-1. Figure 3.3-3 shows Photographs of them.

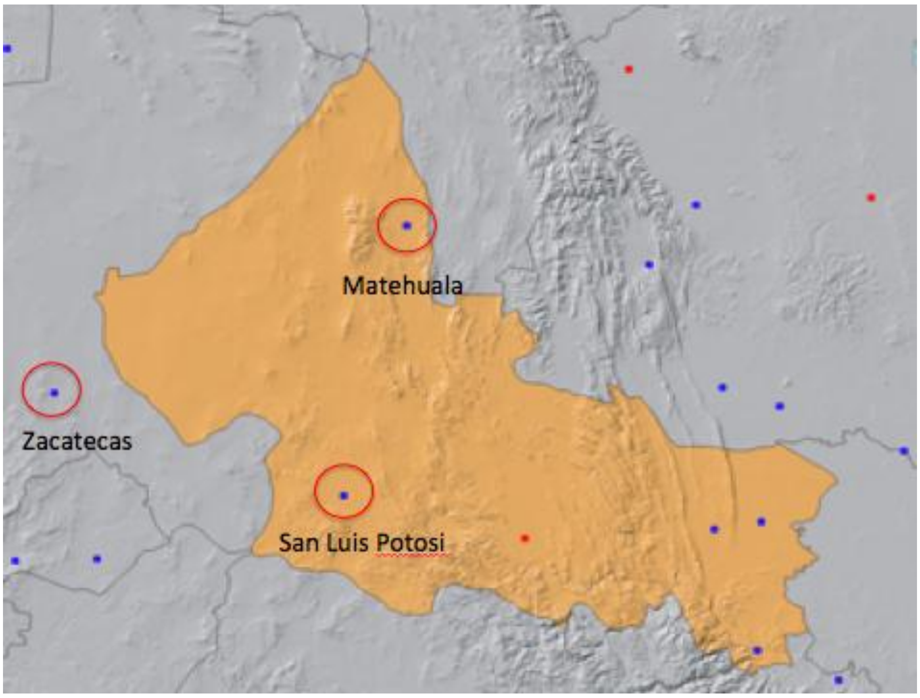


Figure 3.3-1 Location of meteorological stations (Conagua/SMN, 2011)

It should be mentioned that to have more data, given the location of the existing meteorological stations nearest the study area, it was looked for agroclimatic stations administered by INIFAP. Unfortunately, these stations recently installed, do not have sufficient historical data on wind and the institute only provides average wind speed (daily) information from the stations: Banderillas (since 2009), Buenavista (data from April 2011), La Dulce (since 2008), Yoliatl (since 2008) and Charcas (only data from 2012). Figure 3.3-2 shows location of the agroclimatic stations within San Luis Potosi. Because of the location were finally selected for reference Yoliatl and Charcas agroclimatic stations as it was necessary more points of winds speed measures.

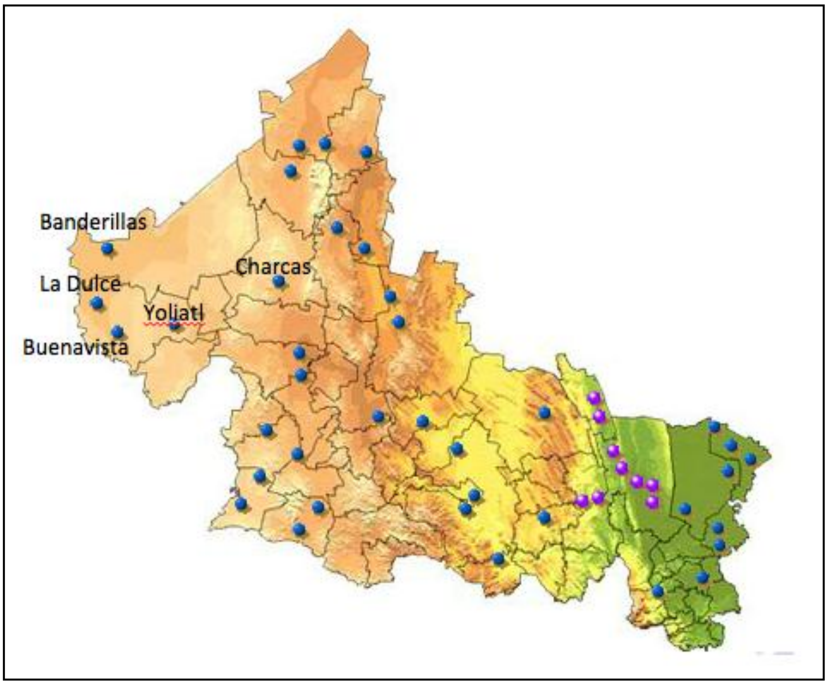


Figure 3.3-2 Location of Agroclimatic meteorological stations (INIFAP, 2012)

Table 3.3-1 Geographical location of state-owned aglo-climatic and meteorological stations

Meteorological / Agroclimatic Station	**Latitude**	**Longitude**	**Altitude (m)**
San Luis Potosi	22°10'33	100°59'01	1870
Matehuala	23°38'24"	100°39'27"	1627
Zacatecas	22°44'48"	102°30'22"	2234
Charcas	23º06’58”	101º06’11.9”	1995
Yoliatl	22º54’09”	101º41’11.47”	2068

Sources: SMN, CONAGUA and INIFAP, 2012

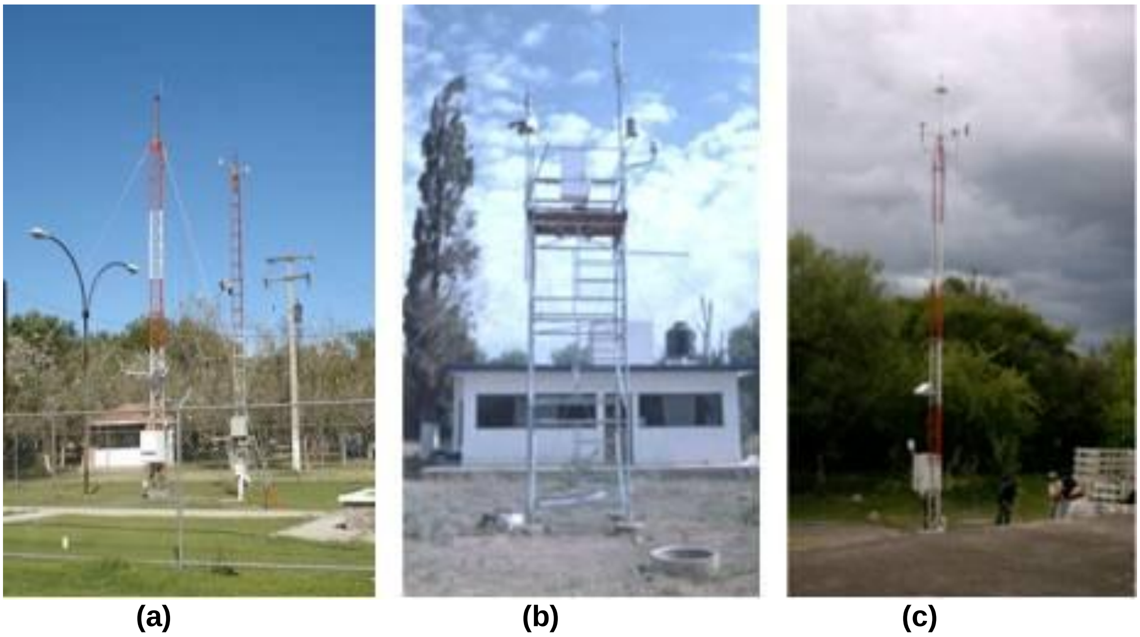

(a) **(b)** **(c)**

Figure 3.3-3 Meteorological Stations a) San Luis Potosi b) Zacatecas c) Matehuala

The selected data were those from 2008 to 2010 for Matehuala and Zacatecas and 2008 and 2009 for station of San Luis Potosi, as they were mostly available and complete by this periods.

According to Conagua, the station of San Luis Potosi (ESIME) is a set of devices that perform electrical measurements of meteorological variables automatically. It generates a database and a message summary every three hours. Is located within an observatory and the cross sectional area of this kind of stations is approximately 5 km radius, on flat ground, except in mountainous terrain. A photograph of the wind sensor is shown in Figure 3.3-4

Figure 3.3-4 Wind speed and direction sensor in the ESIME of SLP

In the case of the stations of Matehuala and Zacatecas, It corresponds to a set of electrical and mechanical devices that perform measurements of meteorological variables automatically, especially in numerical form.

This type of automatic station, consists of a group of sensors that record and transmit weather information automatically from sites where they are strategically placed. Its main function is the collection and monitoring of certain meteorological variables to generate files of 10 minutes average of all variables, being this information via satellite sent in 1 to 3 hours per station. Its measurents also consider approximately 5 km of radius on flat ground, except in mountainous terrain (Conagua, 2012).

This kind of meteorological stations perform the winds speed and direction measurements at 10 m above ground.

The state-owned aglo-climatic stations are provided with sensors for recording wind speed and direction at 2 meters above ground level, among other measurements. Data from all stations of the network are sent every 15 minutes to the National Laboratory for Modeling and Remote Sensing INIFAP, located in the Experimental Hall, in Aguascalientes State, where information is processed for distribution in the INIFAP Internet portal (INIFAP, 2012). Available information from the website regarding wind speed and direction is only dialy average.

Topographical data were obtained from the INEGI charts (orography, topography, contour lines) as well as Google satellite images. Figure 13 shows orography of the state, Figure 3.3-5 Orography of SLP, Figure 3.3-6 Contour lines, and Figure 3.3-7 ground uses as the basis for the evaluation of wind resources.

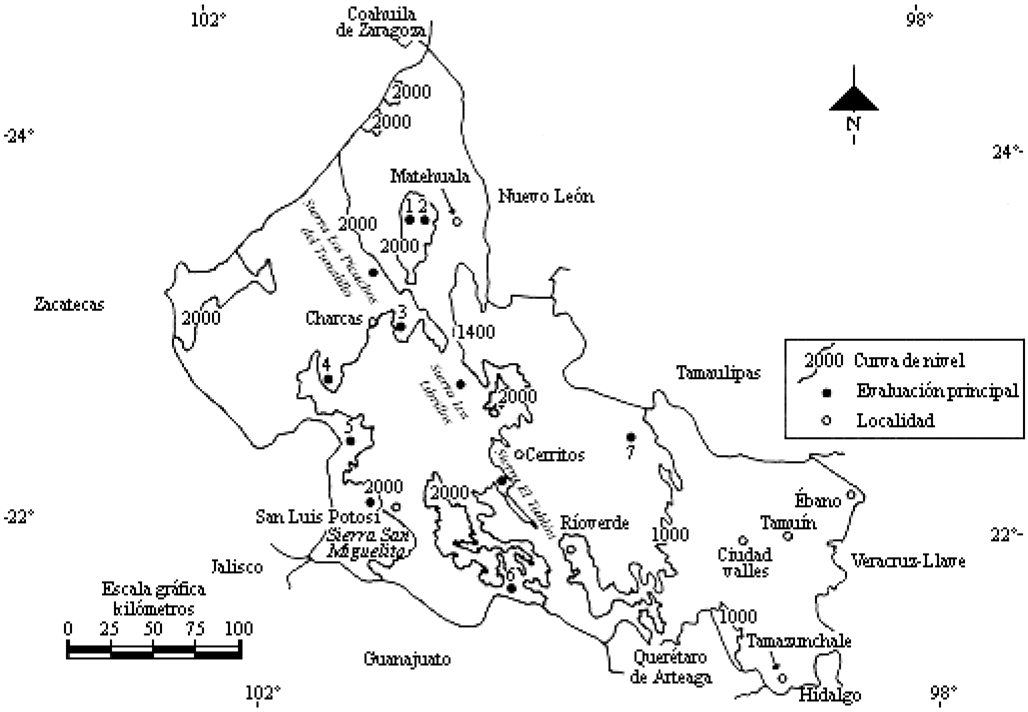


Figure 3.3-5 Ororaphy of San Luis Potosi (INEGI, 2011)

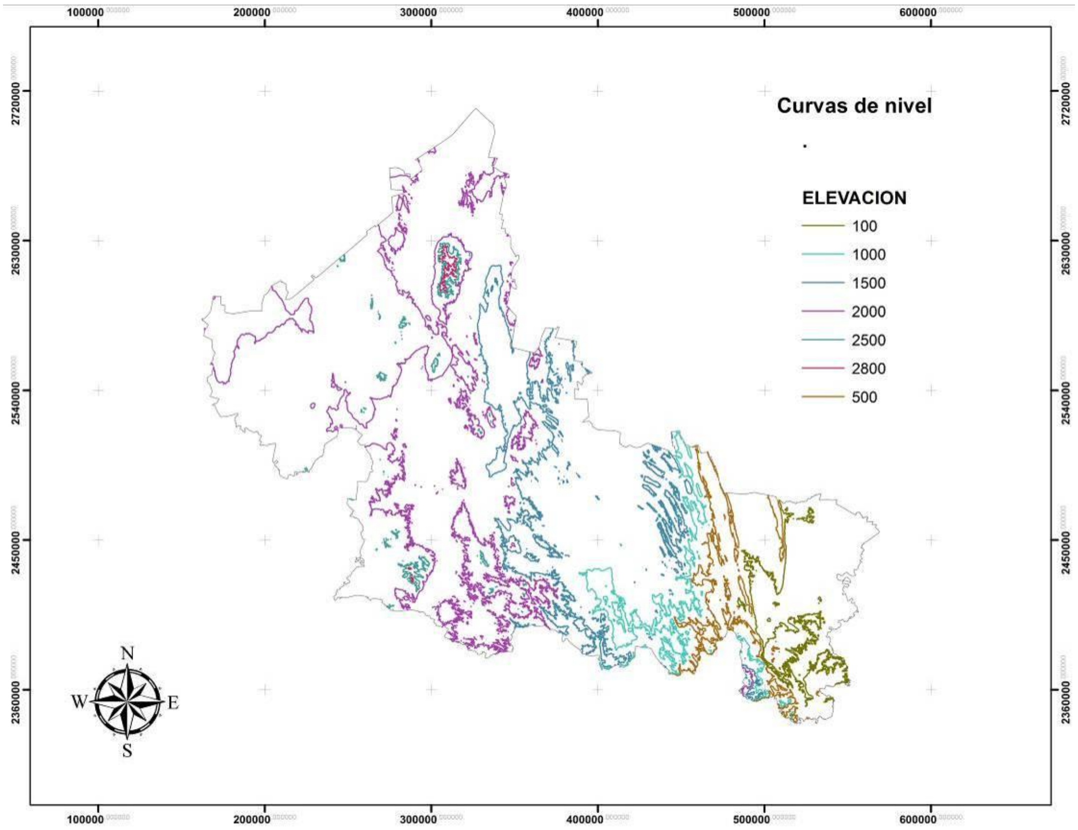
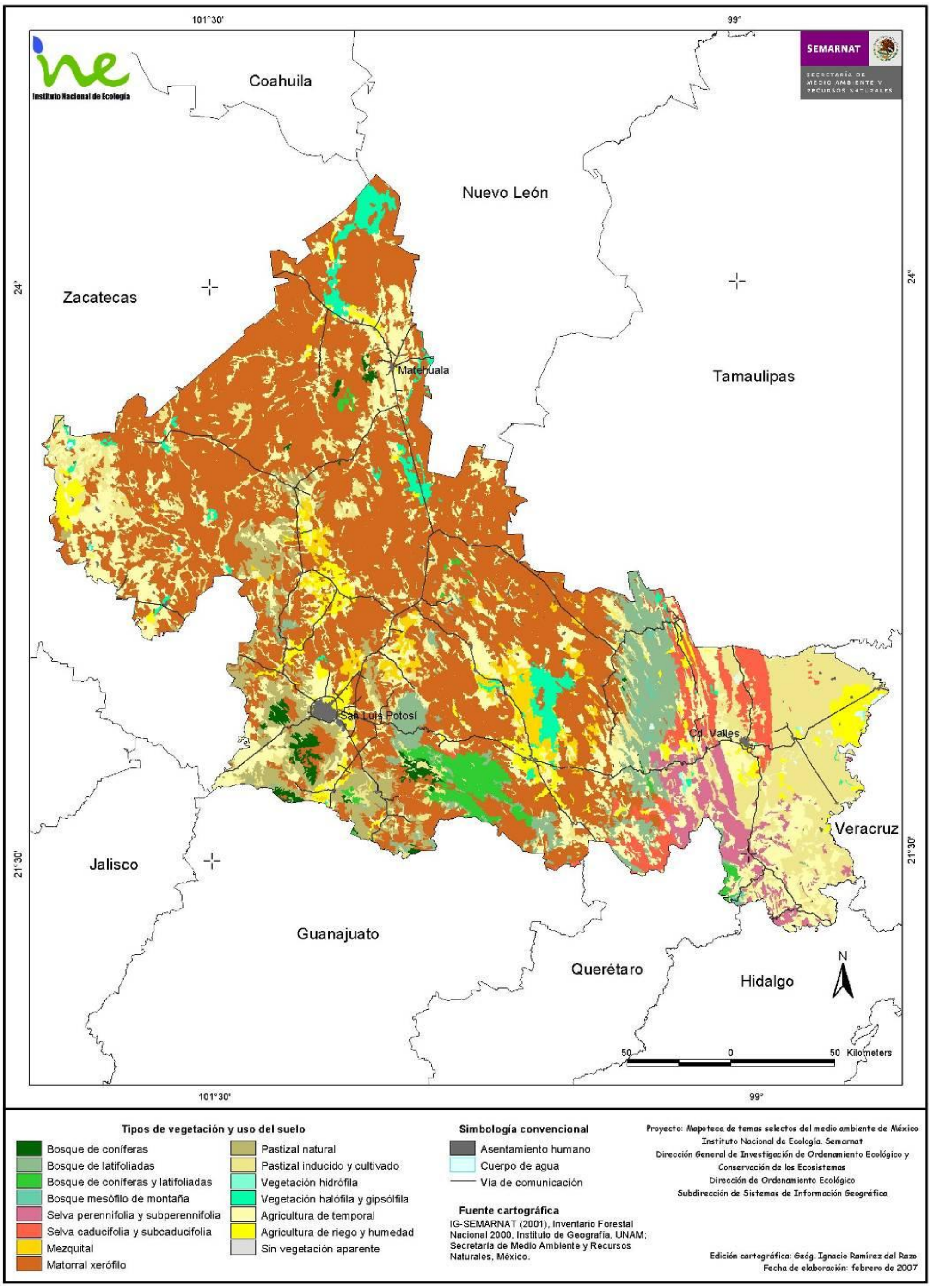


Figure 3.3-6 Countour lines, SLP (Lara, 2012)



Source: CGSNEGI Carta topográfica 1:1 000 000

CGSNEGI Carta topográfica 1: 50 000

Figure 3.3-7 Ground uses and Vegetation in SLP (INE, 2007)

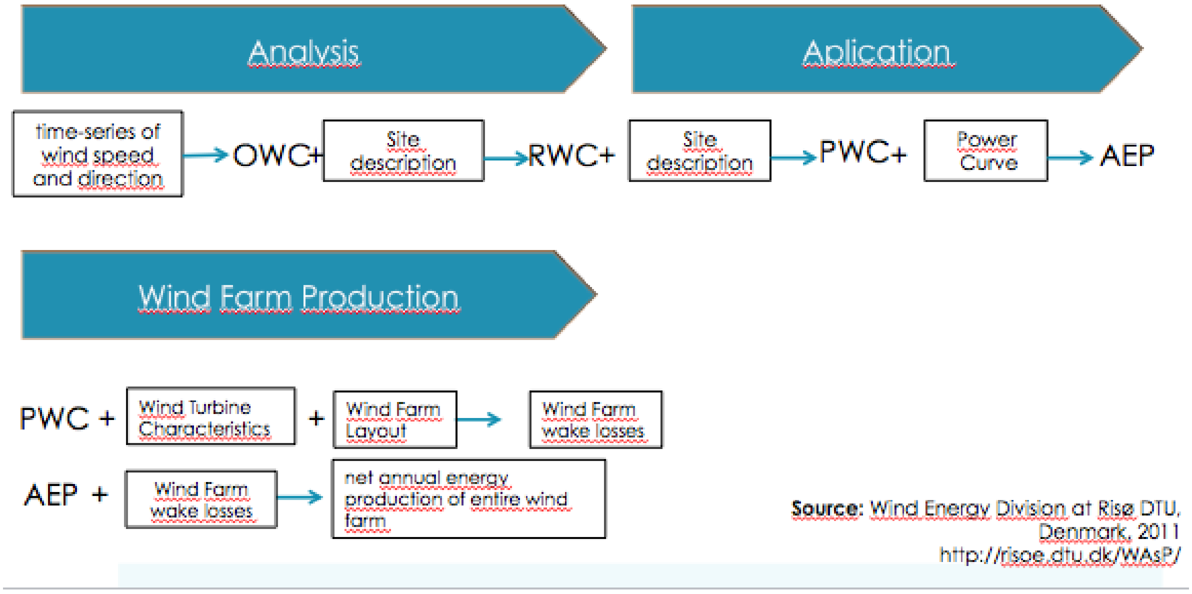
The part of the highlands is mostly at 2000 m and as part of the Mexican plateau, is plain in large extensions of land, presenting two main ground uses, desert scrub and induced pasture.

3.3.2 Data processing

As indicated, historical data of wind speed an direction were introduced into the software in order to obtain the wind rose and Weibull parameters for every meteorological station. Height of measure, as well as referenced location are also data input for this steep.

3.3.2.1 WasP 10

WAsP is a PC-program for the vertical and horizontal extrapolation of wind climate statistics. It contains several physical models to describe the wind flow over different terrains and close to sheltering obstacles. WAsP is an implementation of the so-called wind atlas methodology and consists of three stages. Analysis, aplication and calculatios of a wind farm, which may be summarized in the Figure 3.3-8. Due to reasons of license restrictions and scope of the present work, WasP was used to perform the analysis stage to obtain Observed Wind Climate (OWC). Nevertheless, the software is useful to study very big areas to design large Wind Farms as soon as having enough historical information (at least two years, 3 years is recommendable).



Source: Wind Energy Division at Risø DTU, Denmark, 2011
http://risoe.dtu.dk/WAsP/

Figure 3.3-8 The process of WasP

According to the Figure 3.3-8 :

- OWC: Observed wind climate
- RWC: Regional Wind Climate (wind atlas data sets)
- PWC: Predicted Wind Climate
- AEP: Annual Energy Production

The method employed by WAsP is called the “Wind Atlas Methodology” as mentioned above. Long-term wind speeds and directions from a reference site, usually a meteorological station, are used to create an observed wind climate (OWC) for the site (NUST). WAsP extrapolates the wind data in the OWC into a Weibull probability distribution and removes the effects of local obstacles, topography and terrain roughness, to form a geostrophic wind climate (GWC) also known as the regional wind atlas of the area, finally to proceed to calculate energy production. The statistical summary consists of the wind direction distribution (wind rose) and the sector-wise wind speed distributions; these distributions constitute the meteorological input to WAsP.

According to the Technical University of Denmark (DTU, 2012), the central base in the wind transformation model of WAsP or the so-called “Wind Atlas Methodology”, is the concept of a Regional or *Generalized Wind Climate*, or Wind Atlas. The concept of Generalized Wind Climate is defined as the “*hypothetical wind climate for an ideal, featureless and completely flat terrain with a uniform surface roughness, assuming the same overall atmospheric conditions as those of the measuring position”*.

The concept of the Regional Wind Climate links the wind data from a measuring mast to the predicted wind climate and wind resources at locations of interest, typically a candidate site for a wind turbine or a wind farm (DTU, 2012). This is represented in Figure 3.3-9.

In this model, to deduce the *Generalized Wind Climate* from measured wind in actual terrain the WAsP flow model is used reversely, to *remove* the local terrain effects, while to deduce wind climate at a location of interest from the *Generalized Wind Climate*, the WAsP flow model is used to *introduce* the effect of terrain features.

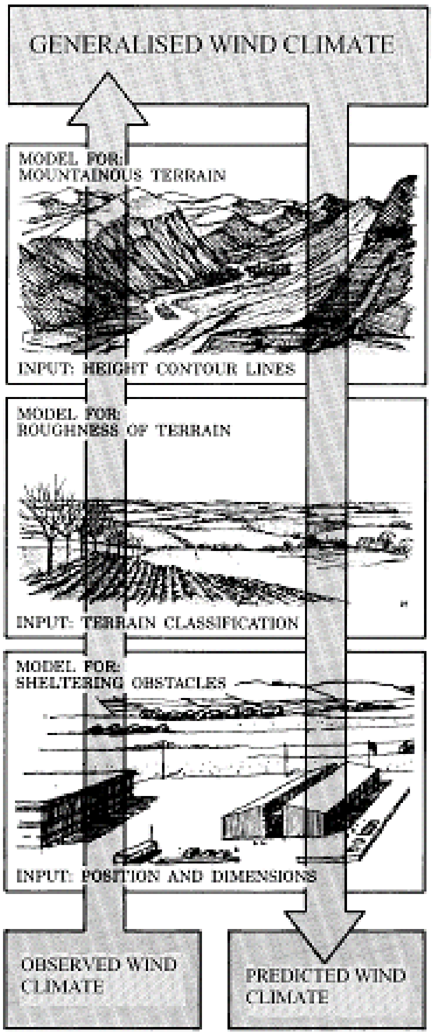


Figure 3.3-9 Scheme of Wind Atlas Methodology of WasP

3.3.2.2 Extrapolation

The ground surface substantially interferes in the wind. The roughness of the ground surface produces turbulence in the boundary layer wind. The wind velocity varies in the horizontal and the vertical direction. Vertical extrapolation means the variation of the wind speed in the vertical plane due to the friction of the air stream with the ground surface, and the horizontally extrapolation takes into account changes occurring in the wind speed in the movement horizontally on the ground surface. These changes have a significant influence on the type of soil, changes in surface roughness and obstacles present (Conrado et al, 2003).

Due to the data that usually count with from weather stations that are not always in the place where is wanted to implement a project, it has historically resorted to use empirical values that correlate the type of terrain where the station is installed and which speed can be calculated at different heights by applying formulas. Conrado (2003) ensures that as a general rule the weather station should be within 30-120 km of the selected point to install the machine. The correlation is more accurate the smaller the distance between the proposed site and the weather station. The proper distance to apply any correlation depends on the surfaces of the land on which the correlation is to be applied, requiring to be shorter while greater the difference between the surface roughness of both sites, and vice versa.

There are several theoretical expressions used to determine the wind speed profile. One way to calculate the variation of the wind velocity with regard to the height "z" is given by the equation (Conrado, 2003 and Piralla, 2001):

$$v(z) = \frac{v_f}{K}\left[\ln\frac{z}{z_0} - \xi\left(\frac{z}{L}\right)\right]$$

where *z* is the height, *Vf* is the friction velocity, *K* is the *von Karman* constant (usually assumed to be 0.4). z_0 is the length of the roughness of the terrain, and *L* a scale factor that is called the length of Monin Obukov (Bañuelos *et al*, 2008).

The function ξ(z / L) is determined by the net solar radiation in the site. This equation applies to short times (e.g. one minute) and not for months or annual average speed values (Bañuelos, *et al*, 2008).

However, the most common the expressions for calculating wind velocity at different heights and simpler one is that known as *"Hellmann Exponential Law"* which relates the two heights speeds and is expressed in the equation:

$$\frac{v}{v_0} = \left(\frac{H}{H_0}\right)^{\alpha}$$

where v is the velocity to height H; the speed v_0 to the height H_0 (often referred to a height of 10 m) and α is the coefficient of friction or *"Hellman exponent".* This ratio depends on the type of terrain on which wind speed is measured, often taken as a value of 1/7 for open land. The Table 3.3-2 shows values for α at different terrain (Piralla, 2001)

Table 3.3-2 Parameters that define the variation of wind speed with height

Type of terrain	α
Center cities with tall buildings concentration (more than half of the buildings are 21 m or more)	0.33
Urban and suburban areas, wooded areas, open fields with irregular topography	0.22
Open field with flat terrain	0.14
Seascapes and headlands	0.10

Piralla, 2001

The Highlands region of SLP present mostly two kind of ground uses: desert scrub and induced pasture, which infers no large variations in terrain (it can be seen in maps presented in the previous section). However, meteorological stations of Matehuala and Zacatecas are located in small towns while the one of San Luis Potosi is located in the capital city. This characteristics were considered to use the α coefficient of 0.22 and 0.33 respectively. Figure 3.3-10 shows the satellite image of all the stations and Figure 3.3-11 to 3.3-15 shows a zoom of each, to show why was determined every value of α to use.

By way of clarification, this formula of Hellman was applied because of data that were available. Detailed studies perform their own estimates about roughness coefficients (trial and error methods) with respect to a specific site so that approximate coefficients are obtained, which takes time.

Experience shows that simplified calculations can be used to obtain an acceptable approximation of a vertical wind profile. It reiterates that the obtained in this step is an approximation and not an exact value in terms of roughness.

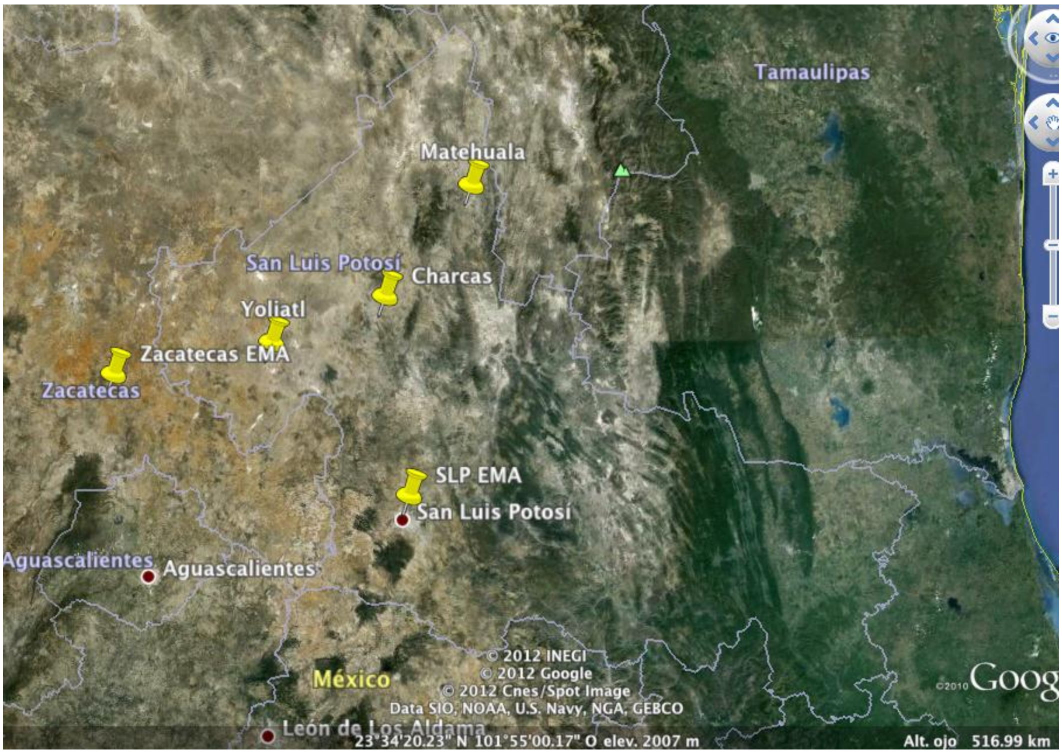


Figure 3.3-10 Location of meteorological stations.

Both images sources: Satellital image (Google Earth, 2012)

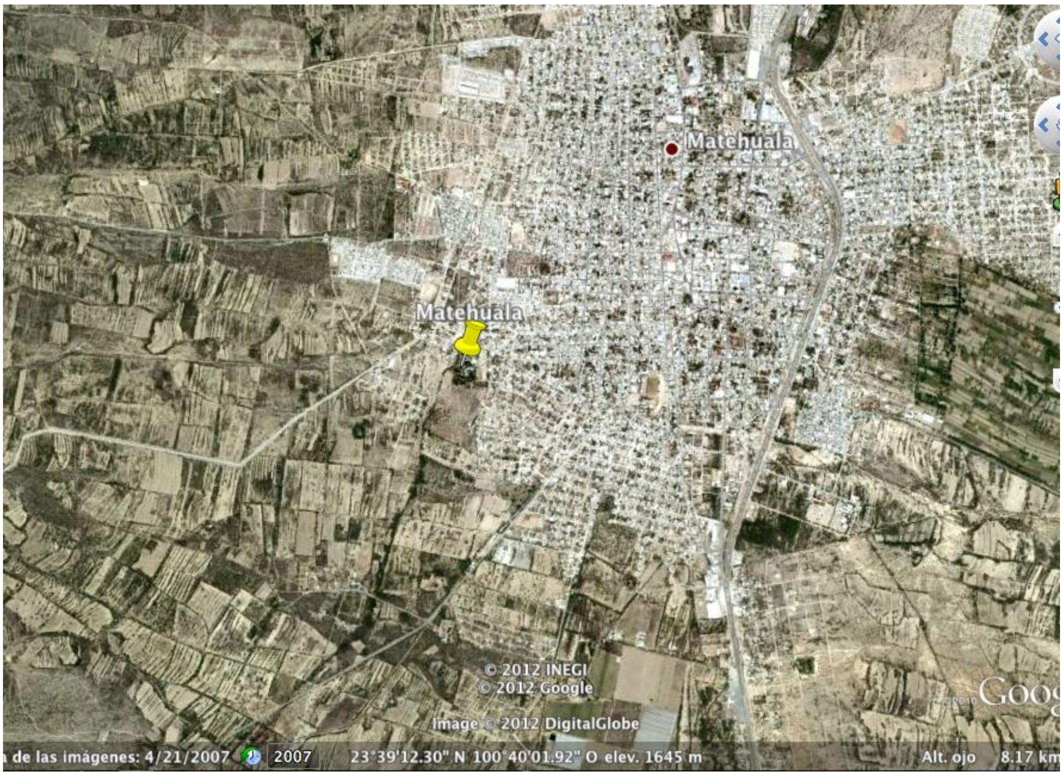


Figure 3.3-11 Matehuala station image. Suburban area with open fields with irregular topography

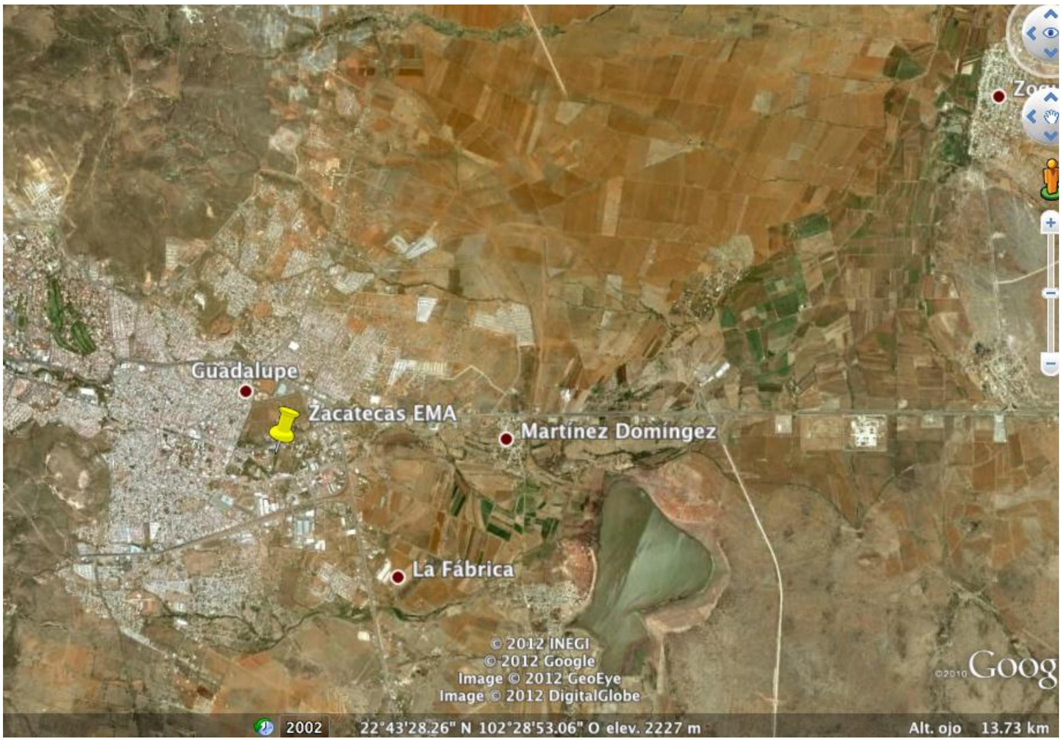


Figure 3.3-12 Zacatecas image. Suburban area with open fields with irregular topography

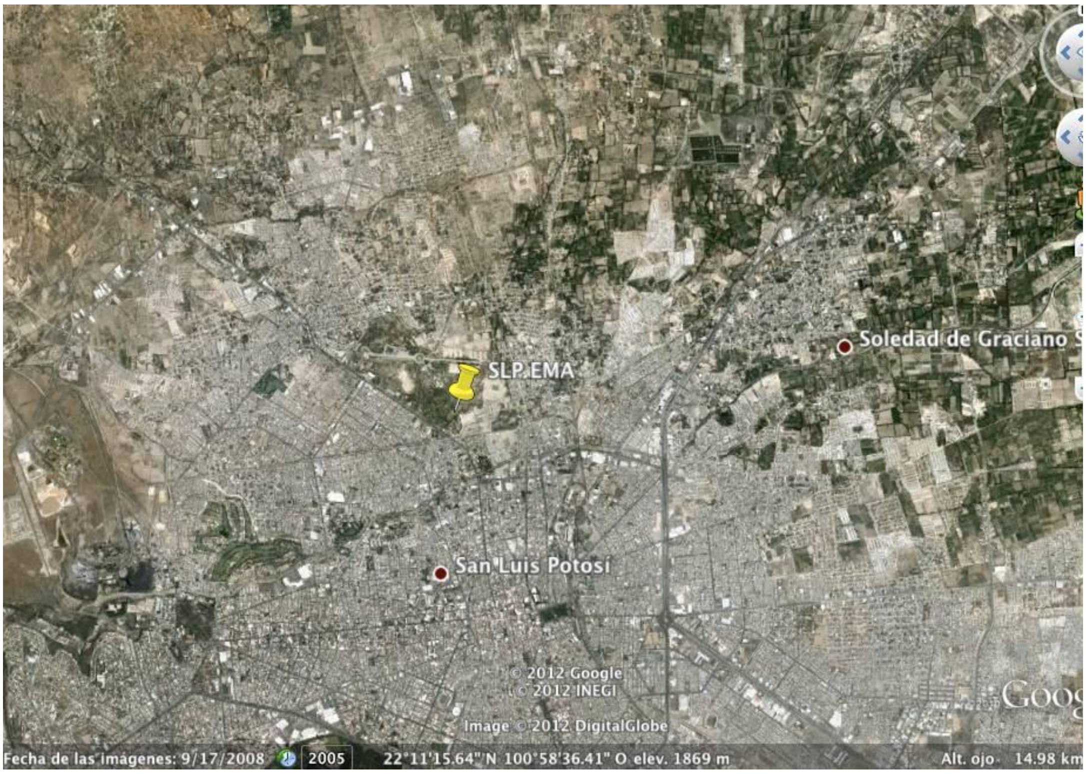


Figure 3.3-13 SLP image. City with tall biuldings

Figure 3.3-14 Charcas image. Open field with flat terrain.

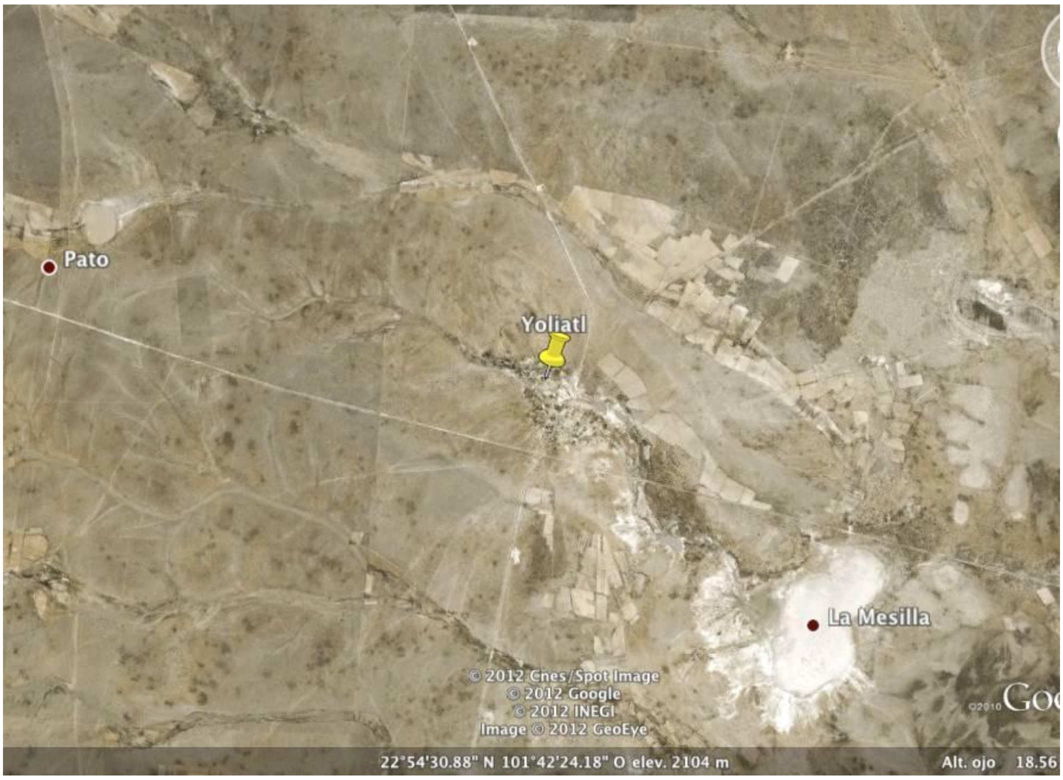
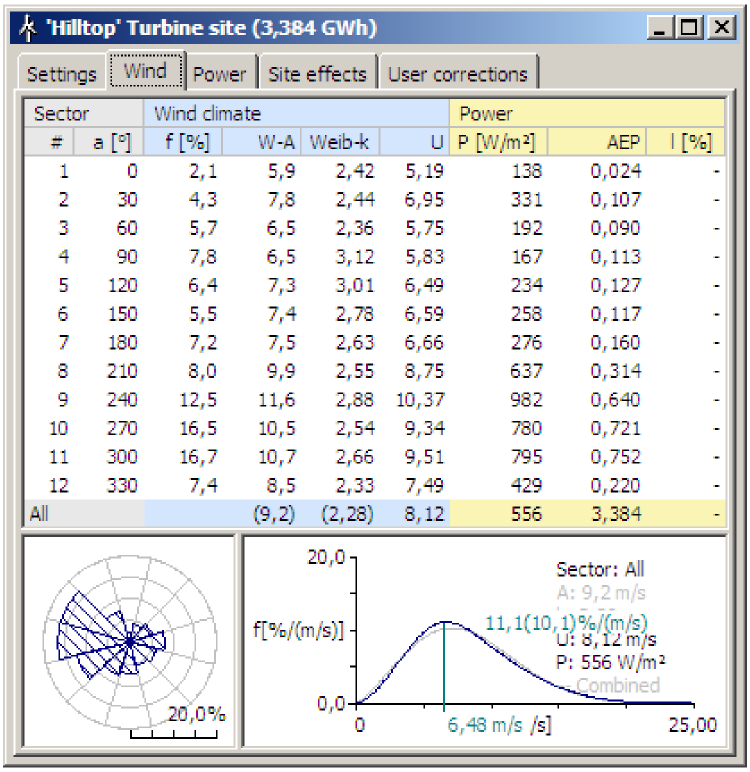


Figure 3.3-15 Yoliatl image. Open field with flat terrain

The formula of Hellman was applied in order to obtain a wind profile at 20 and 50 m and finally to obtain the respective wind frequency distributions and potential at that heights by WasP.

3.3.2.3 Power density

The total energy content of the mean wind is calculated by WAsP. Furthermore, an estimate of the mean annual energy production (AEP) of a wind turbine can be obtained by providing WAsP with the power curve of the wind turbine in question as shown in Figure below.



'Hilltop' Turbine site (3,384 GWh)

Sector		Wind climate				Power		
#	a [°]	f [%]	W-A	Weib-k	U	P [W/m²]	AEP	I [%]
1	0	2,1	5,9	2,42	5,19	138	0,024	-
2	30	4,3	7,8	2,44	6,95	331	0,107	-
3	60	5,7	6,5	2,36	5,75	192	0,090	-
4	90	7,8	6,5	3,12	5,83	167	0,113	-
5	120	6,4	7,3	3,01	6,49	234	0,127	-
6	150	5,5	7,4	2,78	6,59	258	0,117	-
7	180	7,2	7,5	2,63	6,66	276	0,160	-
8	210	8,0	9,9	2,55	8,75	637	0,314	-
9	240	12,5	11,6	2,88	10,37	982	0,640	-
10	270	16,5	10,5	2,54	9,34	780	0,721	-
11	300	16,7	10,7	2,66	9,51	795	0,752	-
12	330	7,4	8,5	2,33	7,49	429	0,220	-
All			(9,2)	(2,28)	8,12	556	3,384	-

Figure 3.3-16 Power density calculations by WasP. Example of a 1 MW-turbine

It is neccesary to specify a minimum threshold of wind power to be used in rural areas. For the present work, it is based on the suggested by NREL (2001), cited in several Eolic Manuals as stated in Table 3.3-3.

Table 3.3-3 Wind classes at 30 m height

Class	**Potential use of the Resource**		**Wind at 30m height**	
	Electric market	**Isolated Applications**	**Wind power density (W/m^2)**	**Wind speed (m/s)***
1	Marginal	Moderate	100-200	4.9-6.1
2	Moderate	Good	200-300	6.1-7.0
3	Good	Excelent	300-400	7.0-7.7
4	Excelent	Excelent	400-600	7.7-8.9
5	Excelent	Excelent	600-800	8.9-9.8
6	Excelent	Excelent	800-1000	9.8-10.5

NREL, 2001

* It means that the wind speed has been estimated by assuming a Weibull distribution of wind speeds with a shape factor (K) of 3.0 and standard air density at sea level. Variations from these values can be estimated up to 20%, depending on the distribution of the wind velocity (or Weibull K value) and elevation above sea level

3.3.2.4 Alternatives of rural applications

In response to needs of the state, manifested in the Municipal Development Plan of each municipality, the Highlands region has medium to high marginal level. The region of the state is divided in 14 municipalities that are according to its location:

Highlans-East: Catorce, Cedral, Gudalcázar, matehuala, Vanegas, Villa de Guadalupe, Villa de la Paz.

Highlands-West: Salinas, Santo Domingo, Villa de Ramos

Central-Highlands: Charcas, Moctezuma, Venado, Villa de Arista.

Several communities in the region are highly marginalized. To discuss about alternatives for rural use, methodology is based in literature about small-scale wind turbines, autonomous systems, the performed activities and needs of the communities and how the identified wind potential could be helpful. Chapter V present the research about low denomination technologies according to the identified. Discussion of altermatives will involve as possible technical, environmental and social aspects.

CHAPTER IV ESTIMATION OF WIND POTENTIAL

4.1 Introduction

In this Chapter wind potential in the Highlands region of SLP is conduced by using the tool “Wind Climate Analysis” from WasP (DTU, 2012) for wind roses and wind frequency (Weibull parameters) to estimate wind potential (W/m^2) in each meteorological station.

After analyzing wind behavior through the time at 10m of height measured in the stations, wind velocities were extrapolated at 20 and 50m. It were selected that heights due to the fact that, from the first steep (wind climate analysis at 10m) were deduced that wind potential is not high as will be describe in the following paragraphs.

At 20 and 50m of height, evaluation is useful also for investment decissions. At 20 m people in rural areas is able to confer specific uses to wind if possible, as has been demostrated in some developing countries while at 50m or more medium to large-scale projects can be implemented for large energy demands as can be residential or industrial electrification.

For the people who live in that region of the country –part of central Mexico- largely dedicated to agriculture and livestock activities, whom have no perspective to stablish necessarily very large wind farms but uses as water pumping which do not need quite a large potential, wind evaluation is useful. Nevertheless could be useful also for interested companies, as calculations give the general scenario of wind behavior in the surrounding area.

With no preliminary exploration of wind resource, eolic projects can not be implemented as the intermitent nature of the wind do not allow to guarantee it existance. Added to this, the particular behavior of wind has to be quite carefully studied as although the site present specific weather features, this resource is highly vulnerable being important not to overestimate the energy production that can be expected in that place.

In the other hand, must select from among a world of wind turbines, that one to represent the best opportunity of exploitation without implying not to work for not having the minimum speed required for startup or otherwise, even can reach to damage from exceed it.

As can be seen, the wind resource is a particular case of study to evaluate since it depends on having adequate historical data of wind, or where appropriate, a useful tool for predicting. All the above associated with a high cost to pay if evaluation is not well performed.

Relating to the present evaluation, extrapolations were performed by using Exel taking into account parameters that has to do with the roughness of the terrain. Then, data were analized also in the WasP. Results are presented and summarized in tables by month and year.

As wind potential resulted not so high, Chapter V present a comparison between different small-scale wind turbines as well as the description of technologies that could be used according to the activities and the lack of electricity they have in certain rural communities.

WasP is a very complete tool for determination of wind potential extrapolating vertical and horizontal data (heights and terrain) and then to give a certain approximation to wind behavior on an specific site to design wind farms and calculate its producction. In the present, it was performed only the climate analysis due to historical avaliable data as well as some restrictions of the license used.

Nevertheless, the scope of the present allows to state certain conclusions about wind potential in the surrounding of the area of interest, according to data provided by SMN.

4.2 Wind climate analysis by meterological station at 10, 20 and 50 m of height

"Wind Climate Analysis " tool by WasP was used to generate wind roses by month and year. It generates also the wind frequency distribution applying statistical of Weibull (described in Chapter II).

It is important to mention that some data provided by SMN-CONAGUA was incomplete for briefs periods of time, being eliminated not to affect calculations. That lack of data responds to the operation and maintenance actions of the stations. In the specific cases where data were incomplete for entire months, it is specified in the results.

4.2.1 Matehuala

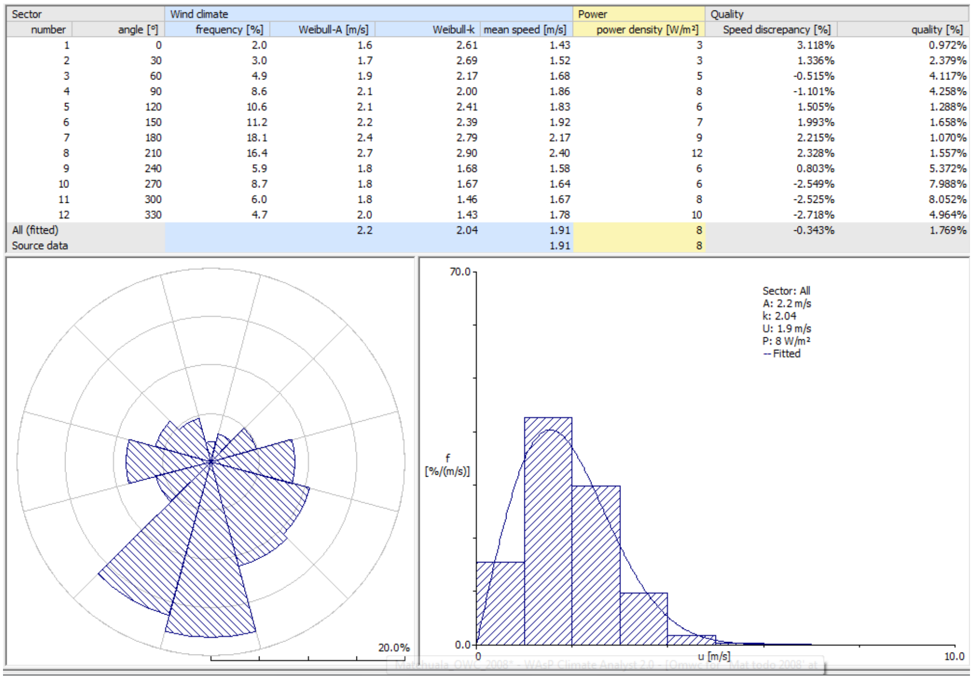
Data from 2008 to 2010 were analized for this meteorological station. It was found that at the North part of the Highlands region where is located Matehuala, potential is poor according to Table 3.3-3 presented in Chatper III. Table 4.2-1 summarizes wind potential at 10, 20 and 50 m, after analyzing by WasP.

Table 4.2-1 Wind power density in Matehuala (W/m^2)

H(m)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dic	Annual
10	8.50	10.00	10.00	9.50	10.00	9.50	8.50	7.05	4.00	5.00	5.00	7.00	8.00
20	13.50	16.00	15.00	16.00	15.50	15.00	13.00	12.00	7.00	7.50	8.00	10.50	12.50
50	24.50	28.50	28.00	29.50	27.50	28.00	23.50	21.50	12.00	14.00	14.50	20.00	22.50

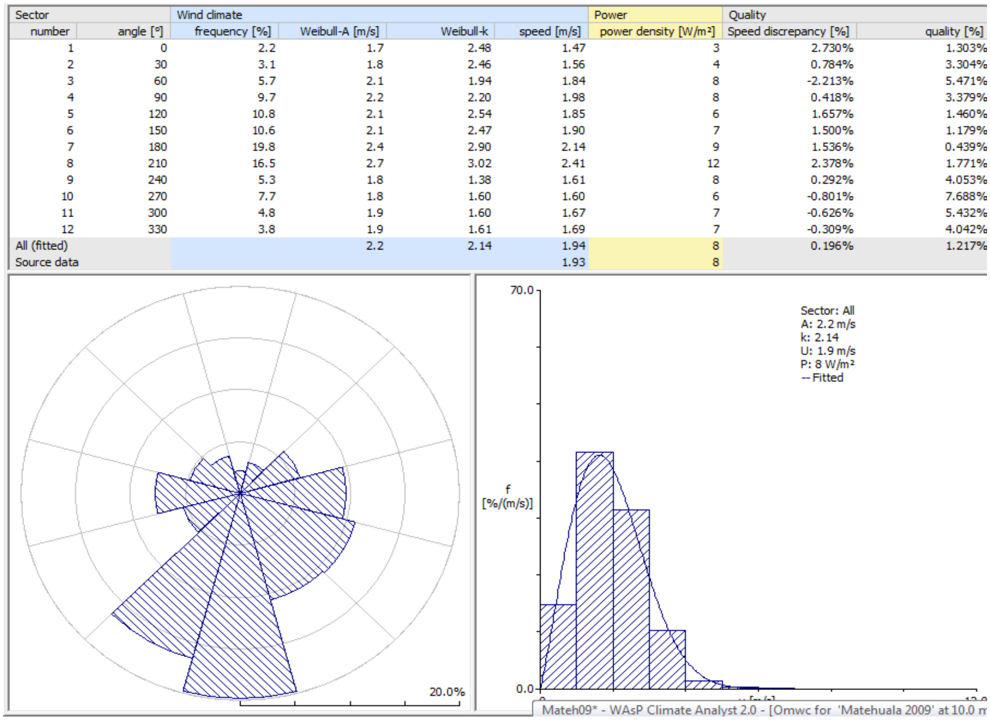
Average values 2008-2010

An annual frequency distribution of winds of the site shows the possibility to find minimum certain wind speed during a year at an specific height. Figures 4.2-1 to 4.2-6. represents annual distribution of wind during 2008 and 2009 at 10, 20 at 50 m as 20 and 50 m were extrapolated.



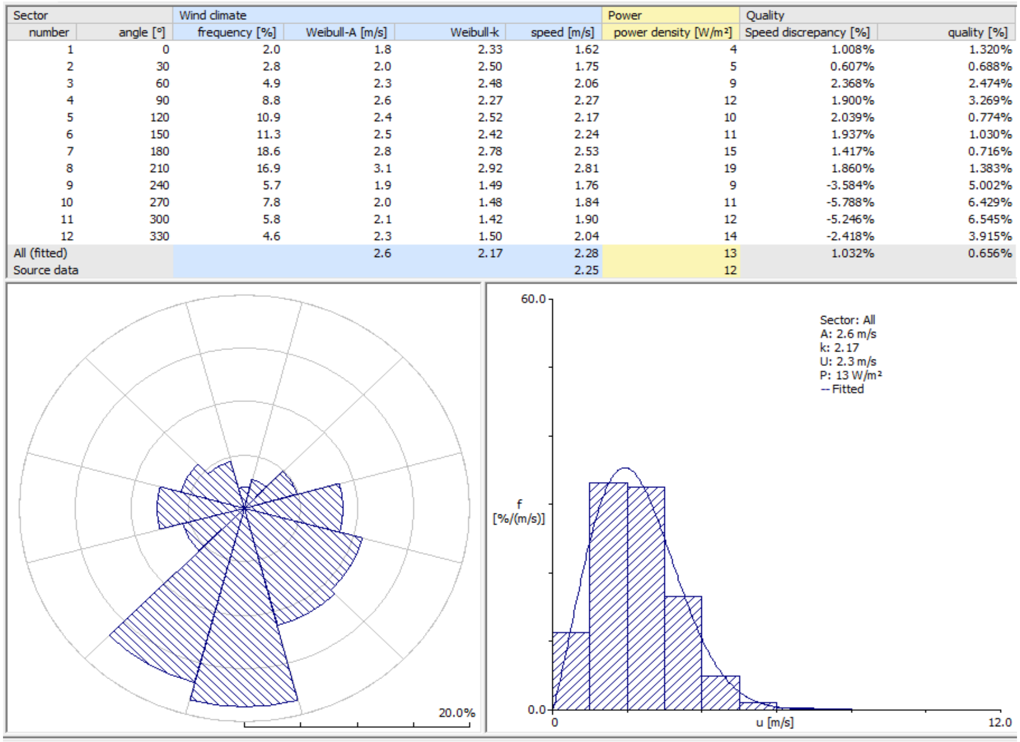
Sector		Wind climate				Power	Quality	
number	angle [°]	frequency [%]	Weibull-A [m/s]	Weibull-k	mean speed [m/s]	power density [W/m²]	Speed discrepancy [%]	quality [%]
1	0	2.0	1.6	2.61	1.43	3	3.118%	0.972%
2	30	3.0	1.7	2.69	1.52	3	1.336%	2.379%
3	60	4.9	1.9	2.17	1.68	5	-0.515%	4.117%
4	90	8.6	2.1	2.00	1.86	8	-1.101%	4.258%
5	120	10.6	2.1	2.41	1.83	6	1.505%	1.288%
6	150	11.2	2.2	2.39	1.92	7	1.993%	1.658%
7	180	18.1	2.4	2.79	2.17	9	2.215%	1.070%
8	210	16.4	2.7	2.90	2.40	12	2.328%	1.557%
9	240	5.9	1.8	1.68	1.58	6	0.803%	5.372%
10	270	8.7	1.8	1.67	1.64	6	-2.549%	7.988%
11	300	6.0	1.8	1.46	1.67	8	-2.525%	8.052%
12	330	4.7	2.0	1.43	1.78	10	-2.718%	4.964%
All (fitted)			2.2	2.04	1.91	8	-0.343%	1.769%
Source data					1.91	8		

Figure 4.2-1. Wind rose and Weibull distribution for Matehuala station in 2008 at 10 m



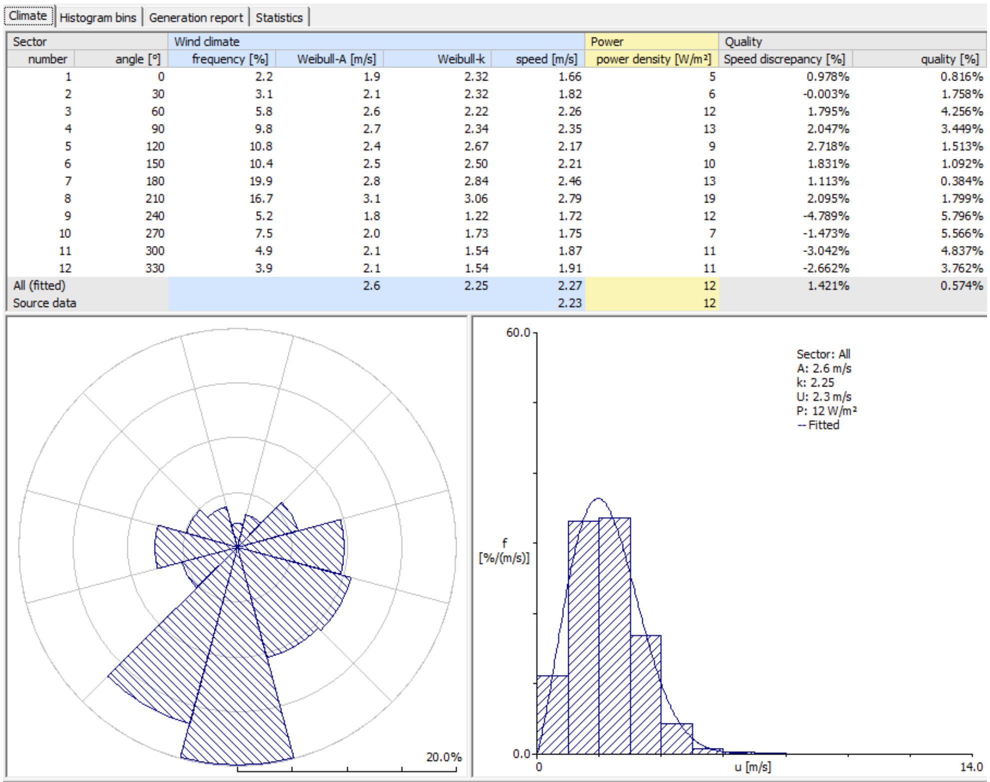
Sector		Wind climate				Power	Quality	
number	angle [°]	frequency [%]	Weibull-A [m/s]	Weibull-k	speed [m/s]	power density [W/m²]	Speed discrepancy [%]	quality [%]
1	0	2.2	1.7	2.48	1.47	3	2.730%	1.303%
2	30	3.1	1.8	2.46	1.56	4	0.784%	3.304%
3	60	5.7	2.1	1.94	1.84	8	-2.213%	5.471%
4	90	9.7	2.2	2.20	1.98	8	0.418%	3.379%
5	120	10.8	2.1	2.54	1.85	6	1.657%	1.460%
6	150	10.6	2.1	2.47	1.90	7	1.500%	1.179%
7	180	19.8	2.4	2.90	2.14	9	1.536%	0.439%
8	210	16.5	2.7	3.02	2.41	12	2.378%	1.771%
9	240	5.3	1.8	1.38	1.61	8	0.292%	4.053%
10	270	7.7	1.8	1.60	1.60	6	-0.801%	7.688%
11	300	4.8	1.9	1.60	1.67	7	-0.626%	5.432%
12	330	3.8	1.9	1.61	1.69	7	-0.309%	4.042%
All (fitted)			2.2	2.14	1.94	8	0.196%	1.217%
Source data					1.93	8		

Figure 4.2-2 . Wind rose and Weibull distribution for Matehuala station in 2009 at 10 m



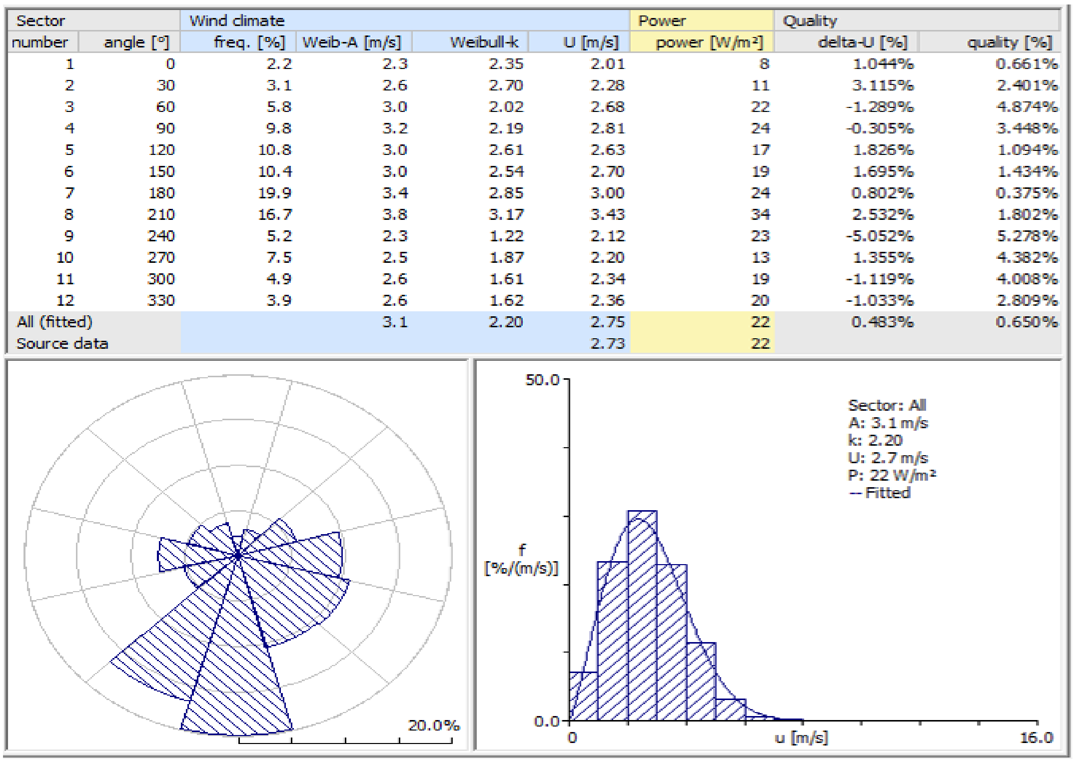
Sector		Wind climate				Power	Quality	
number	angle [°]	frequency [%]	Weibull-A [m/s]	Weibull-k	speed [m/s]	power density [W/m²]	Speed discrepancy [%]	quality [%]
1	0	2.0	1.8	2.33	1.62	4	1.008%	1.320%
2	30	2.8	2.0	2.50	1.75	5	0.607%	0.688%
3	60	4.9	2.3	2.48	2.06	9	2.368%	2.474%
4	90	8.8	2.6	2.27	2.27	12	1.900%	3.269%
5	120	10.9	2.4	2.52	2.17	10	2.039%	0.774%
6	150	11.3	2.5	2.42	2.24	11	1.937%	1.030%
7	180	18.6	2.8	2.78	2.53	15	1.417%	0.716%
8	210	16.9	3.1	2.92	2.81	19	1.860%	1.383%
9	240	5.7	1.9	1.49	1.76	9	-3.584%	5.002%
10	270	7.8	2.0	1.48	1.84	11	-5.788%	6.429%
11	300	5.8	2.1	1.42	1.90	12	-5.246%	6.545%
12	330	4.6	2.3	1.50	2.04	14	-2.418%	3.915%
All (fitted)			2.6	2.17	2.28	13	1.032%	0.656%
Source data					2.25	12		

Figure 4.2-3. Wind rose and Weibull distribution for Matehuala station in 2008 at 20 m



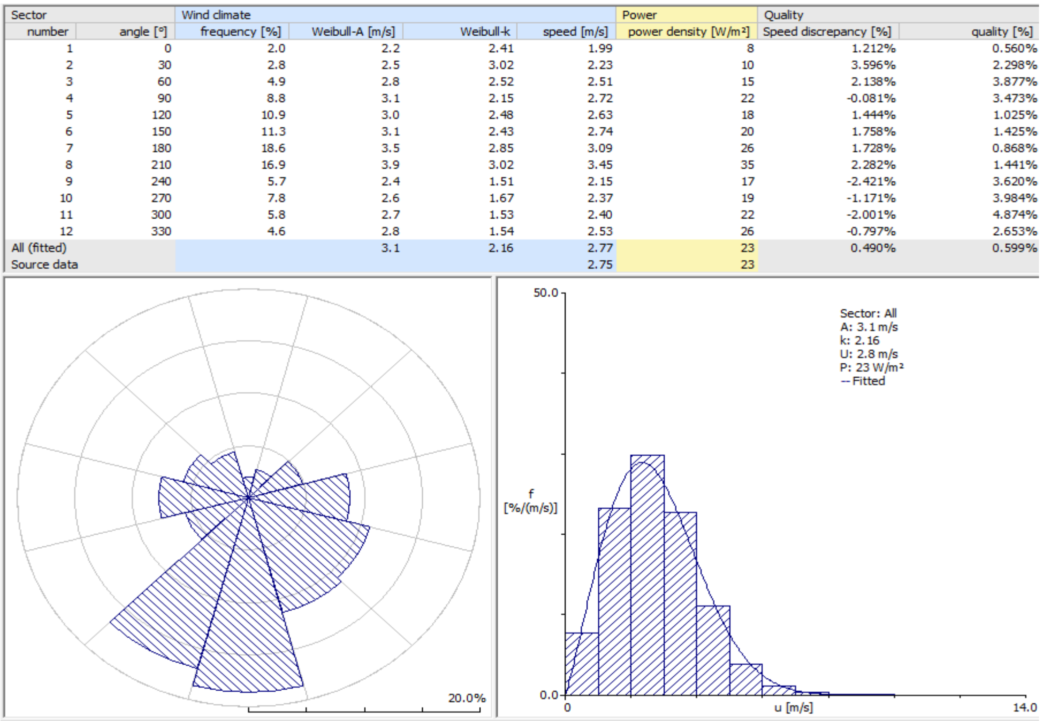
Sector		Wind climate				Power	Quality	
number	angle [°]	frequency [%]	Weibull-A [m/s]	Weibull-k	speed [m/s]	power density [W/m²]	Speed discrepancy [%]	quality [%]
1	0	2.2	1.9	2.32	1.66	5	0.978%	0.816%
2	30	3.1	2.1	2.32	1.82	6	-0.003%	1.758%
3	60	5.8	2.6	2.22	2.26	12	1.795%	4.256%
4	90	9.8	2.7	2.34	2.35	13	2.047%	3.449%
5	120	10.8	2.4	2.67	2.17	9	2.718%	1.513%
6	150	10.4	2.5	2.50	2.21	10	1.831%	1.092%
7	180	19.9	2.8	2.84	2.46	13	1.113%	0.384%
8	210	16.7	3.1	3.06	2.79	19	2.095%	1.799%
9	240	5.2	1.8	1.22	1.72	12	-4.789%	5.796%
10	270	7.5	2.0	1.73	1.75	7	-1.473%	5.566%
11	300	4.9	2.1	1.54	1.87	11	-3.042%	4.837%
12	330	3.9	2.1	1.54	1.91	11	-2.662%	3.762%
All (fitted)			2.6	2.25	2.27	12	1.421%	0.574%
Source data					2.23	12		

Figure 4.2-4. Wind rose and Weibull distribution for Matehuala station in 2009 at 20 m



Sector		Wind climate				Power	Quality	
number	angle [°]	freq. [%]	Weib-A [m/s]	Weibull-k	U [m/s]	power [W/m²]	delta-U [%]	quality [%]
1	0	2.2	2.3	2.35	2.01	8	1.044%	0.661%
2	30	3.1	2.6	2.70	2.28	11	3.115%	2.401%
3	60	5.8	3.0	2.02	2.68	22	-1.289%	4.874%
4	90	9.8	3.2	2.19	2.81	24	-0.305%	3.448%
5	120	10.8	3.0	2.61	2.63	17	1.826%	1.094%
6	150	10.4	3.0	2.54	2.70	19	1.695%	1.434%
7	180	19.9	3.4	2.85	3.00	24	0.802%	0.375%
8	210	16.7	3.8	3.17	3.43	34	2.532%	1.802%
9	240	5.2	2.3	1.22	2.12	23	-5.052%	5.278%
10	270	7.5	2.5	1.87	2.20	13	1.355%	4.382%
11	300	4.9	2.6	1.61	2.34	19	-1.119%	4.008%
12	330	3.9	2.6	1.62	2.36	20	-1.033%	2.809%
All (fitted)			3.1	2.20	2.75	22	0.483%	0.650%
Source data					2.73	22		

Figure 4.2-5. Wind rose and Weibull distribution for Matehuala station in 2008 at 50 m



Sector		Wind climate				Power	Quality	
number	angle [°]	frequency [%]	Weibull-A [m/s]	Weibull-k	speed [m/s]	power density [W/m²]	Speed discrepancy [%]	quality [%]
1	0	2.0	2.2	2.41	1.99	8	1.212%	0.560%
2	30	2.8	2.5	3.02	2.23	10	3.596%	2.298%
3	60	4.9	2.8	2.52	2.51	15	2.138%	3.877%
4	90	8.8	3.1	2.15	2.72	22	-0.081%	3.473%
5	120	10.9	3.0	2.48	2.63	18	1.444%	1.025%
6	150	11.3	3.1	2.43	2.74	20	1.758%	1.425%
7	180	18.6	3.5	2.85	3.09	26	1.728%	0.868%
8	210	16.9	3.9	3.02	3.45	35	2.282%	1.441%
9	240	5.7	2.4	1.51	2.15	17	-2.421%	3.620%
10	270	7.8	2.6	1.67	2.37	19	-1.171%	3.984%
11	300	5.8	2.7	1.53	2.40	22	-2.001%	4.874%
12	330	4.6	2.8	1.54	2.53	26	-0.797%	2.653%
All (fitted)			3.1	2.16	2.77	23	0.490%	0.599%
Source data					2.75	23		

Figure 4.2-6 Wind rose and Weibull distribution for Matehuala station in 2009 at 50 m

Wind roses for Matehuala station show that most of the time wind flows towards South-Southwest direction represented between the seventh and eighth sectors of the rose diagram with values close to 20 and 15% respectively in all the cases. For 10 m of height velocities with major possibility to ocurr are 2 m/s while, for 20 m 2.5 m/s and for 50 m there exist almost 20% to find wind speed of arround 3 m/s. However, this wind speeds only ocurr close to 20% of the time, according to Wind Climate Analysis (WasP) as mentioned.

In the Annex A. can be consulted Weibull parameters and wind roses for every month during the analyzed period of time for the Matehuala meteorological station.

4.2.2 Zacatecas

This meteorological station in fact is located out of the state of San Luis Potosi, but the lack of measurements at other points within the Highlands, led to the collection of available data with historical records, being the Zacatecas station chosen as the closest and proper for the objective. It is less than 50 km in a straight line to the southwest corner of the plateau. It is noteworthy that remains plain to about 2000 m altitude as the Highlands region of SLP.

After calculations of wind speeds at 20 and 50 m, Wind Climate Analysis was performed including 10m (the records data height). Table 4.2-2 summarizes wind power density trhough years 2008, 2009 and 2010 related to wind speeds at those different heights.

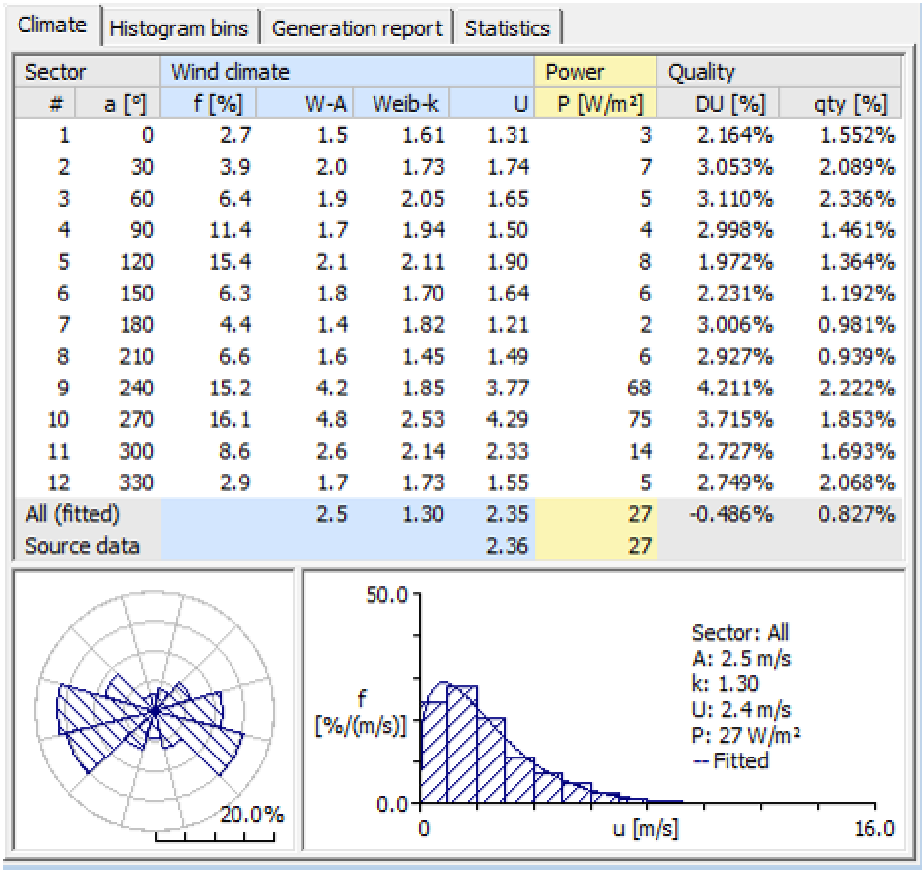
It should be mentioned that for data of this station, months of March and December of 2008 as well as August of 2010 were incomplete, so they were remove as considered insufficient to make a reliable estimation.

Table 4-2 Wind power density in Zacatecas (W/m^2).

H(m)	Jan	Feb	**Mar**	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	**Dic**	*Annual
10	43.33	48.67	**62.99**	48.00	22.67	5.33	6.00	**3.50**	3.00	8.33	22.33	**51.50**	26.00
20	67.67	76.67	**97.67**	75.67	36.00	9.33	9.67	**5.50**	4.33	13.00	35.33	**81.50**	46.67
50	124.67	139.67	**157.00**	125.67	48.67	16.33	18.00	**10.00**	8.00	23.67	64.33	**150.00**	86.67

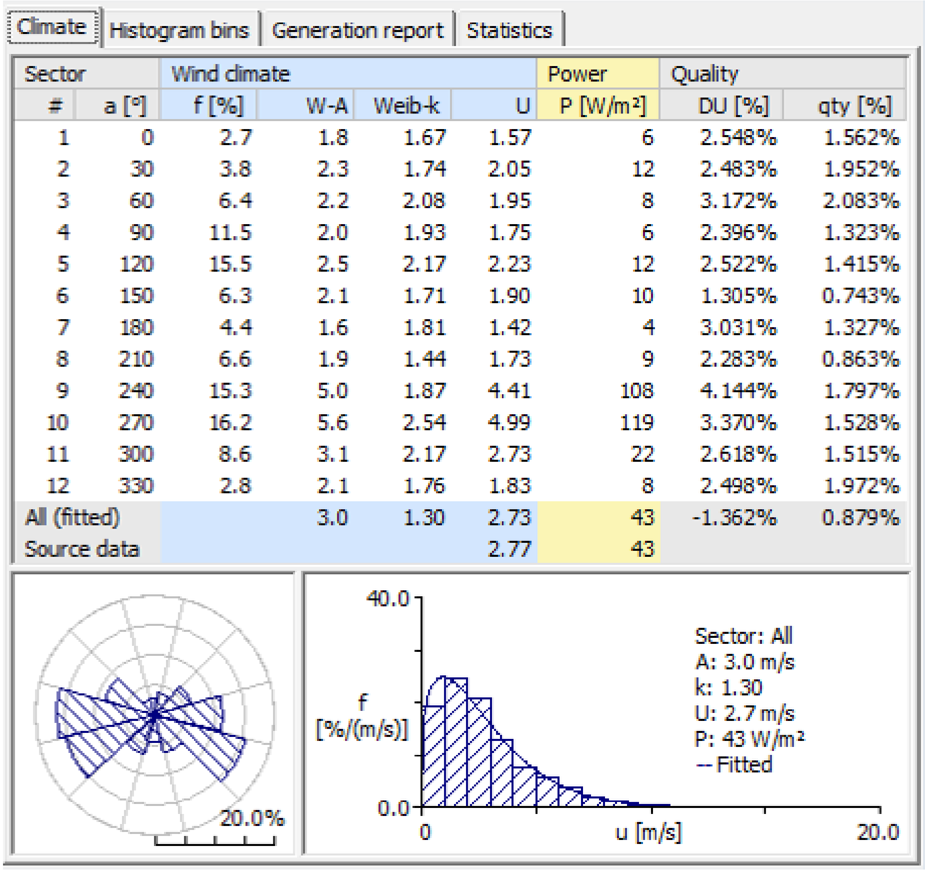
*Average values 2008, 2009 and 2010

Wind tendency is represented in next wind roses with its respective calculation of wind frequency distribution and annual wind power for 10, 20 and 50 m in height.



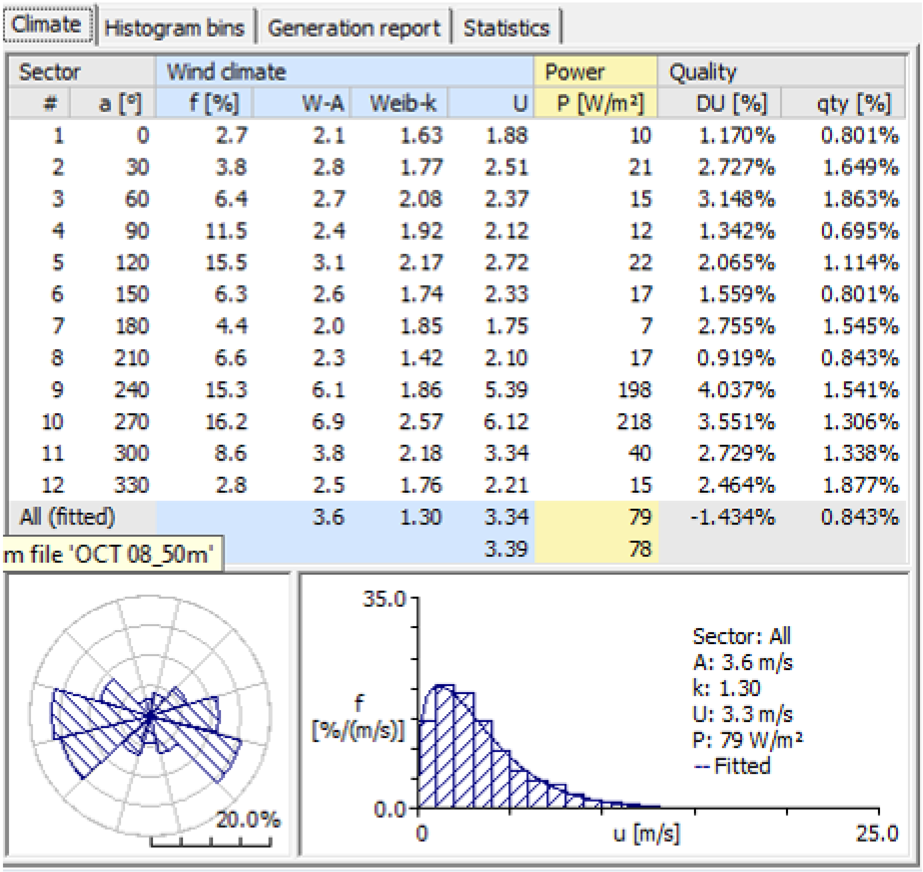
Sector		Wind climate				Power	Quality	
#	a [°]	f [%]	W-A	Weib-k	U	P [W/m²]	DU [%]	qty [%]
1	0	2.7	1.5	1.61	1.31	3	2.164%	1.552%
2	30	3.9	2.0	1.73	1.74	7	3.053%	2.089%
3	60	6.4	1.9	2.05	1.65	5	3.110%	2.336%
4	90	11.4	1.7	1.94	1.50	4	2.998%	1.461%
5	120	15.4	2.1	2.11	1.90	8	1.972%	1.364%
6	150	6.3	1.8	1.70	1.64	6	2.231%	1.192%
7	180	4.4	1.4	1.82	1.21	2	3.006%	0.981%
8	210	6.6	1.6	1.45	1.49	6	2.927%	0.939%
9	240	15.2	4.2	1.85	3.77	68	4.211%	2.222%
10	270	16.1	4.8	2.53	4.29	75	3.715%	1.853%
11	300	8.6	2.6	2.14	2.33	14	2.727%	1.693%
12	330	2.9	1.7	1.73	1.55	5	2.749%	2.068%
All (fitted)			2.5	1.30	2.35	27	-0.486%	0.827%
Source data					2.36	27		

Figure 4.2-7 Wind rose and Weibull distribution for Zacatecas station in 2008 at 10 m



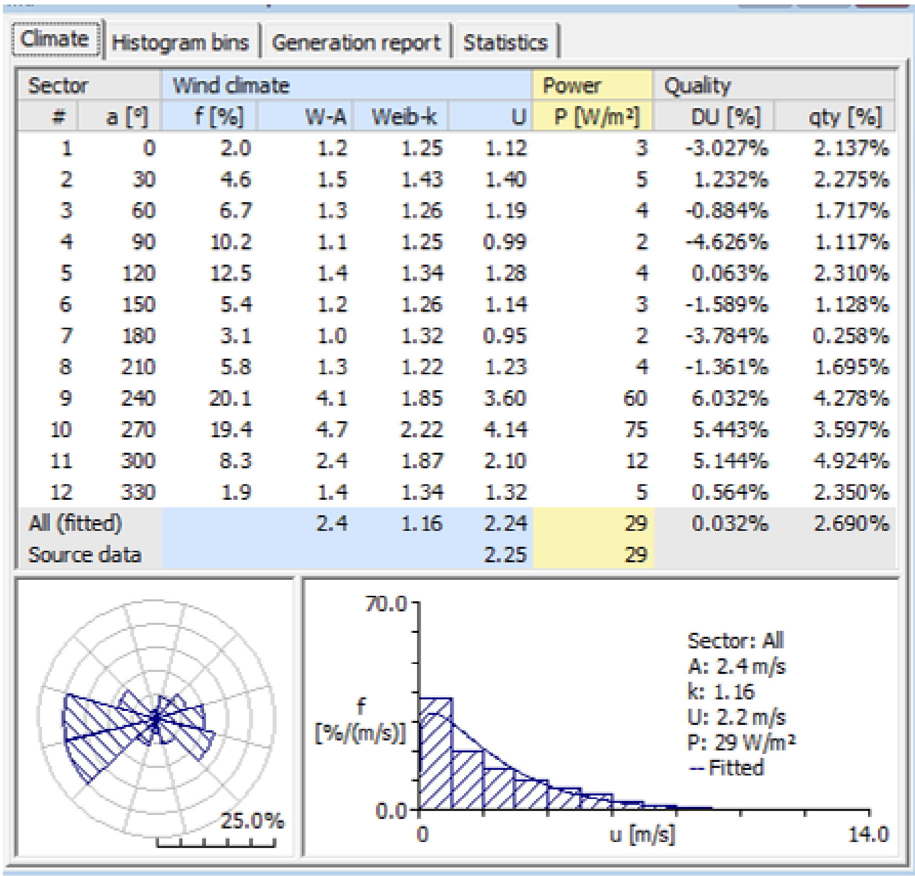
Sector		Wind climate				Power	Quality	
#	a [°]	f [%]	W-A	Weib-k	U	P [W/m²]	DU [%]	qty [%]
1	0	2.7	1.8	1.67	1.57	6	2.548%	1.562%
2	30	3.8	2.3	1.74	2.05	12	2.483%	1.952%
3	60	6.4	2.2	2.08	1.95	8	3.172%	2.083%
4	90	11.5	2.0	1.93	1.75	6	2.396%	1.323%
5	120	15.5	2.5	2.17	2.23	12	2.522%	1.415%
6	150	6.3	2.1	1.71	1.90	10	1.305%	0.743%
7	180	4.4	1.6	1.81	1.42	4	3.031%	1.327%
8	210	6.6	1.9	1.44	1.73	9	2.283%	0.863%
9	240	15.3	5.0	1.87	4.41	108	4.144%	1.797%
10	270	16.2	5.6	2.54	4.99	119	3.370%	1.528%
11	300	8.6	3.1	2.17	2.73	22	2.618%	1.515%
12	330	2.8	2.1	1.76	1.83	8	2.498%	1.972%
All (fitted)			3.0	1.30	2.73	43	-1.362%	0.879%
Source data					2.77	43		

Figure 4.2-8 Wind rose and Weibull distribution for Zacatecas station in 2008 at 20 m



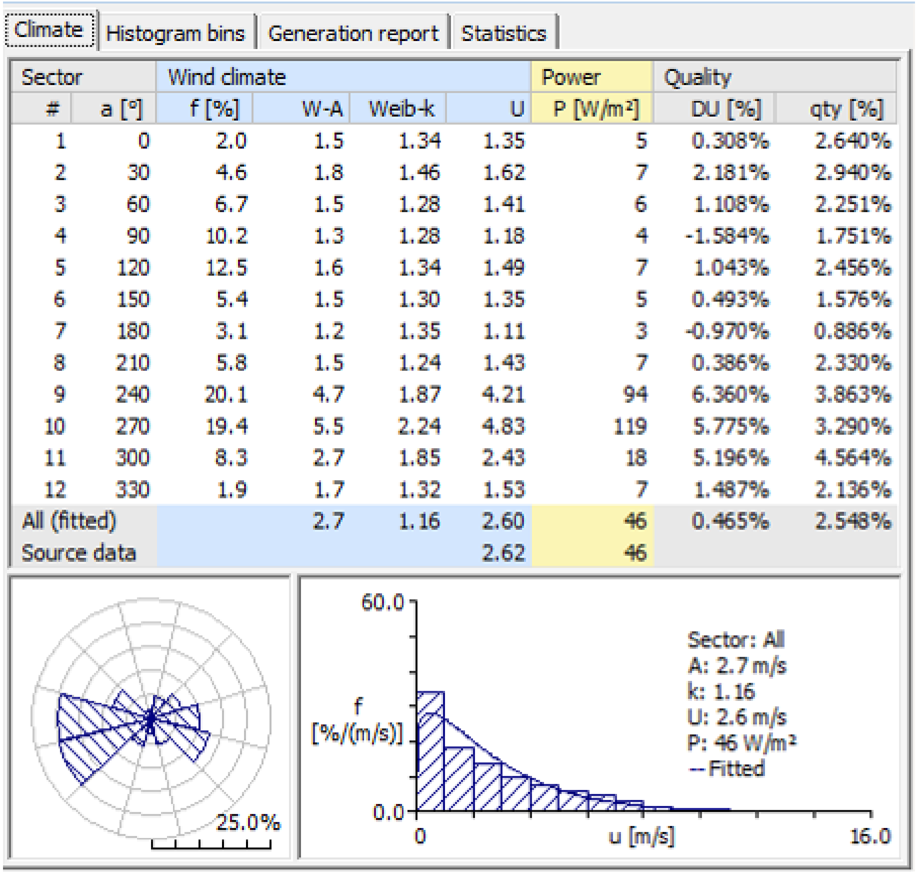
Sector		Wind climate				Power	Quality	
#	a [°]	f [%]	W-A	Weib-k	U	P [W/m²]	DU [%]	qty [%]
1	0	2.7	2.1	1.63	1.88	10	1.170%	0.801%
2	30	3.8	2.8	1.77	2.51	21	2.727%	1.649%
3	60	6.4	2.7	2.08	2.37	15	3.148%	1.863%
4	90	11.5	2.4	1.92	2.12	12	1.342%	0.695%
5	120	15.5	3.1	2.17	2.72	22	2.065%	1.114%
6	150	6.3	2.6	1.74	2.33	17	1.559%	0.801%
7	180	4.4	2.0	1.85	1.75	7	2.755%	1.545%
8	210	6.6	2.3	1.42	2.10	17	0.919%	0.843%
9	240	15.3	6.1	1.86	5.39	198	4.037%	1.541%
10	270	16.2	6.9	2.57	6.12	218	3.551%	1.306%
11	300	8.6	3.8	2.18	3.34	40	2.729%	1.338%
12	330	2.8	2.5	1.76	2.21	15	2.464%	1.877%
All (fitted)			3.6	1.30	3.34	79	-1.434%	0.843%
m file 'OCT 08_50m'					3.39	78		

Figure 4.2-9 Wind rose and Weibull distribution for Zacatecas station in 2008 at 50 m



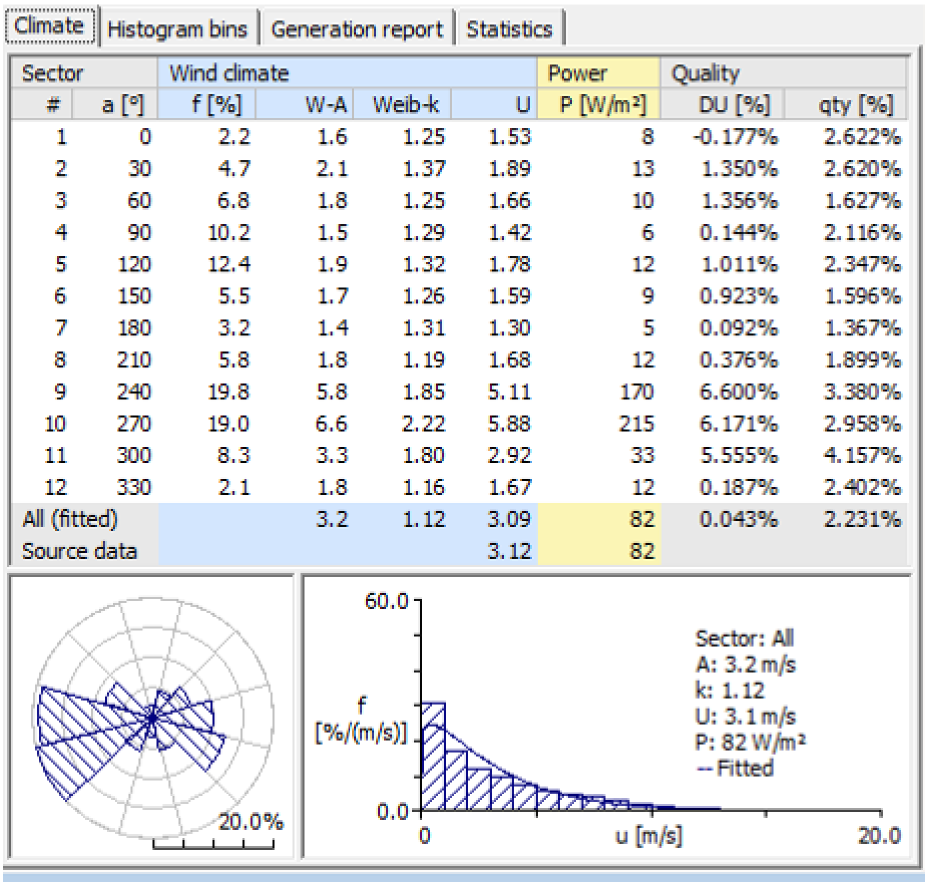
Sector		Wind climate				Power	Quality	
#	a [°]	f [%]	W-A	Weib-k	U	P [W/m²]	DU [%]	qty [%]
1	0	2.0	1.2	1.25	1.12	3	-3.027%	2.137%
2	30	4.6	1.5	1.43	1.40	5	1.232%	2.275%
3	60	6.7	1.3	1.26	1.19	4	-0.884%	1.717%
4	90	10.2	1.1	1.25	0.99	2	-4.626%	1.117%
5	120	12.5	1.4	1.34	1.28	4	0.063%	2.310%
6	150	5.4	1.2	1.26	1.14	3	-1.589%	1.128%
7	180	3.1	1.0	1.32	0.95	2	-3.784%	0.258%
8	210	5.8	1.3	1.22	1.23	4	-1.361%	1.695%
9	240	20.1	4.1	1.85	3.60	60	6.032%	4.278%
10	270	19.4	4.7	2.22	4.14	75	5.443%	3.597%
11	300	8.3	2.4	1.87	2.10	12	5.144%	4.924%
12	330	1.9	1.4	1.34	1.32	5	0.564%	2.350%
All (fitted)			2.4	1.16	2.24	29	0.032%	2.690%
Source data					2.25	29		

Figure 4.2-10 Wind rose and Weibull distribution for Zacatecas station in 2009 at 10 m



Sector		Wind climate				Power	Quality	
#	a [°]	f [%]	W-A	Weib-k	U	P [W/m²]	DU [%]	qty [%]
1	0	2.0	1.5	1.34	1.35	5	0.308%	2.640%
2	30	4.6	1.8	1.46	1.62	7	2.181%	2.940%
3	60	6.7	1.5	1.28	1.41	6	1.108%	2.251%
4	90	10.2	1.3	1.28	1.18	4	-1.584%	1.751%
5	120	12.5	1.6	1.34	1.49	7	1.043%	2.456%
6	150	5.4	1.5	1.30	1.35	5	0.493%	1.576%
7	180	3.1	1.2	1.35	1.11	3	-0.970%	0.886%
8	210	5.8	1.5	1.24	1.43	7	0.386%	2.330%
9	240	20.1	4.7	1.87	4.21	94	6.360%	3.863%
10	270	19.4	5.5	2.24	4.83	119	5.775%	3.290%
11	300	8.3	2.7	1.85	2.43	18	5.196%	4.564%
12	330	1.9	1.7	1.32	1.53	7	1.487%	2.136%
All (fitted)			2.7	1.16	2.60	46	0.465%	2.548%
Source data					2.62	46		

Figure 4.2-11 Wind rose and Weibull distribution for Zacatecas station in 2009 at 20 m



Sector		Wind climate				Power	Quality	
#	a [°]	f [%]	W-A	Weib-k	U	P [W/m²]	DU [%]	qty [%]
1	0	2.2	1.6	1.25	1.53	8	-0.177%	2.622%
2	30	4.7	2.1	1.37	1.89	13	1.350%	2.620%
3	60	6.8	1.8	1.25	1.66	10	1.356%	1.627%
4	90	10.2	1.5	1.29	1.42	6	0.144%	2.116%
5	120	12.4	1.9	1.32	1.78	12	1.011%	2.347%
6	150	5.5	1.7	1.26	1.59	9	0.923%	1.596%
7	180	3.2	1.4	1.31	1.30	5	0.092%	1.367%
8	210	5.8	1.8	1.19	1.68	12	0.376%	1.899%
9	240	19.8	5.8	1.85	5.11	170	6.600%	3.380%
10	270	19.0	6.6	2.22	5.88	215	6.171%	2.958%
11	300	8.3	3.3	1.80	2.92	33	5.555%	4.157%
12	330	2.1	1.8	1.16	1.67	12	0.187%	2.402%
All (fitted)			3.2	1.12	3.09	82	0.043%	2.231%
Source data					3.12	82		

Figure 4.2-12 Wind rose and Weibull distribution for Zacatecas station in 2009 at 50 m

In 2009 and 2010 winds in this region are most often addressed to the West. However, 2008 seems to be a different year with winds also addressed to the West but mostly East. It is possible that this may occur meteorologically, as exists an air stream in the zone (Isotachs of 130 km/h) (Pirella, 2001). If weather is consulted by month of that year (Appendix) it shows that this behavior arose in the second half of the year between June and October.

As mentioned, this phenomenon can also be explained based on the velocity map of Mexico (Wind Regionalization of the Mexican Republic by the book of Civil Works of the Federal Electricity Commission, 1993) which clearly shows the existence of a wind Isotach (10 m high) of a speed of 130 km / h (36m / s) just around the Southwestern highlands of SLP in the part where borders the state of Zacatecas (Pirella, 2001). A wind regionalization map is shown in Figure 4.2-13.

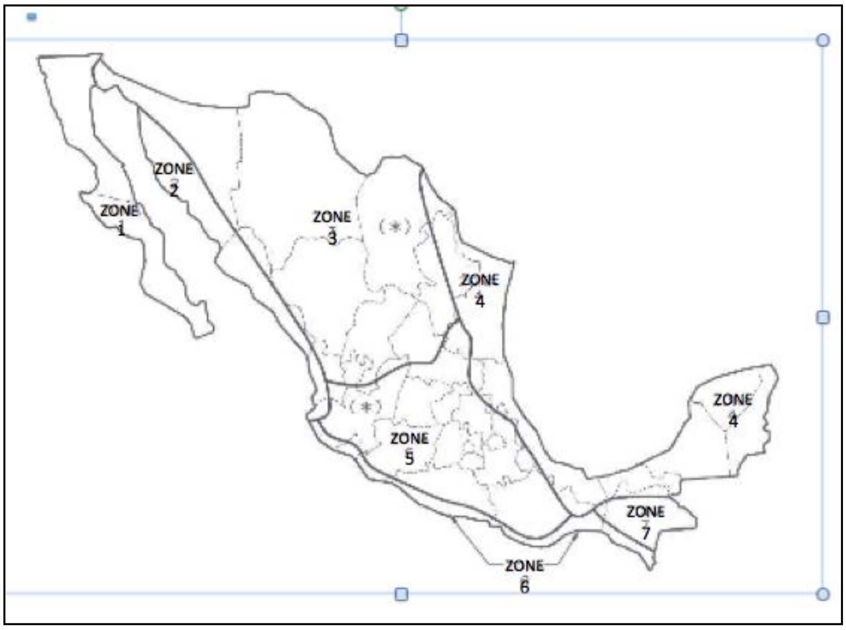


Figure 4.2-13 Wind regionalization map of the Mexican Republic (CFE, 1993)

According to Figure 4.2.13:

Zone 1: 160 km/h

Zone 2: 160 km/h

Zone 3: 130 km/h

Zone 4: 160 km/h

Zone 5: 120 km/h

Zone 6: 160 km/h

Zone 7: 110 km/h

Winds that can be around 3 m/s at 10m according to data provided by SMN-Conagua, can reach almost 5 m/s at 50 m of height. During the year, diagrams shows also that from December to April winds are blowing much more stronger than the rest of the months (2008 and 2009).

In fact, region of Zacatecas is known by its strong winds that confers appreciable eolic potential to the State, recently studied potential that has increased the interest of the companies and the government, but has not yet determined the construction of large wind farms like the one installed in the state of Oaxaca.

INE (2012) states that Zacatecas has prevailing southwesterly winds in winter and spring, easterly winds in summer, and east-northeast winds in autumn. It is quite similar to the obtained by WasP.

4.2.3 San Luis Potosi

The meteorological station of SLP has the characteristic that is located whithin the city. This condition was considered when making the extrapolation at 20 and 50m as described in Chapter III.

SMN provided data from January 2008 until September 2009. So the station is with less available data as exposed by SMN. However, this ammount of data is valid for a preliminary analysis and estimating at the short and medium term as stated by AAEE (2011).

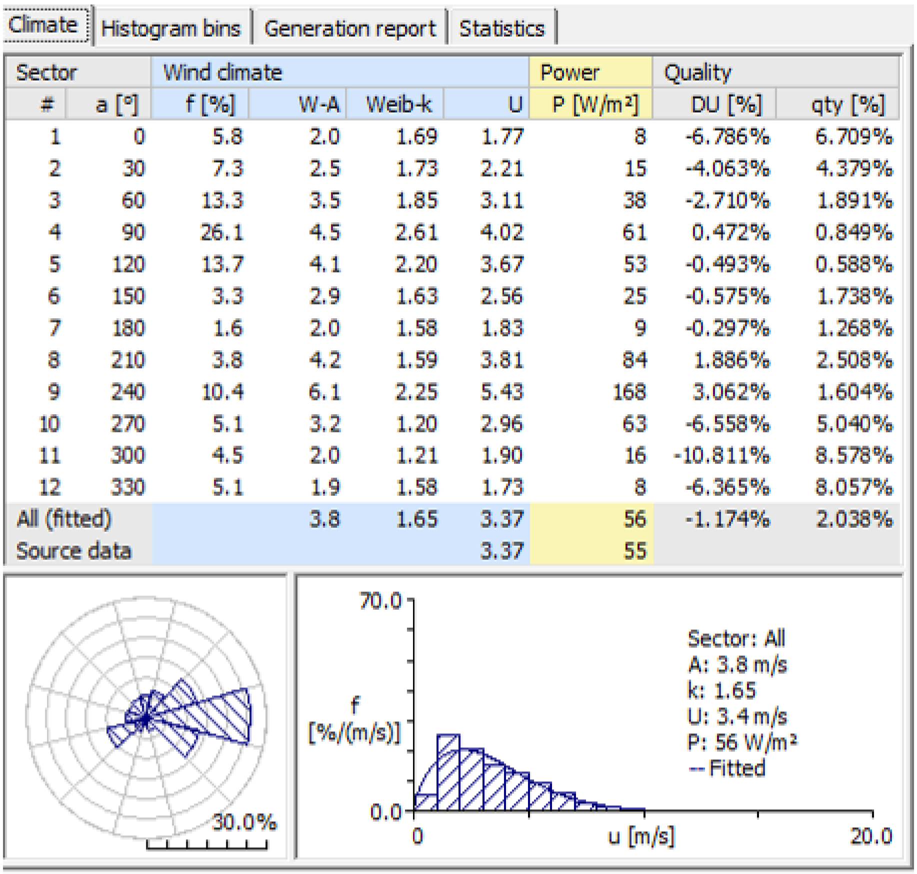
This station was chosen also as there are not the enough stations within the Highlands region of SLP. The causes of the lack of availability of data are unknown but associated with failures in its operation and recording, as can be technical failures.

Average values related to wind power density between 2008-2009 by month are shown in Table 4.2-3.

Table 4-3 Wind power density in SLP station (W/m^2).

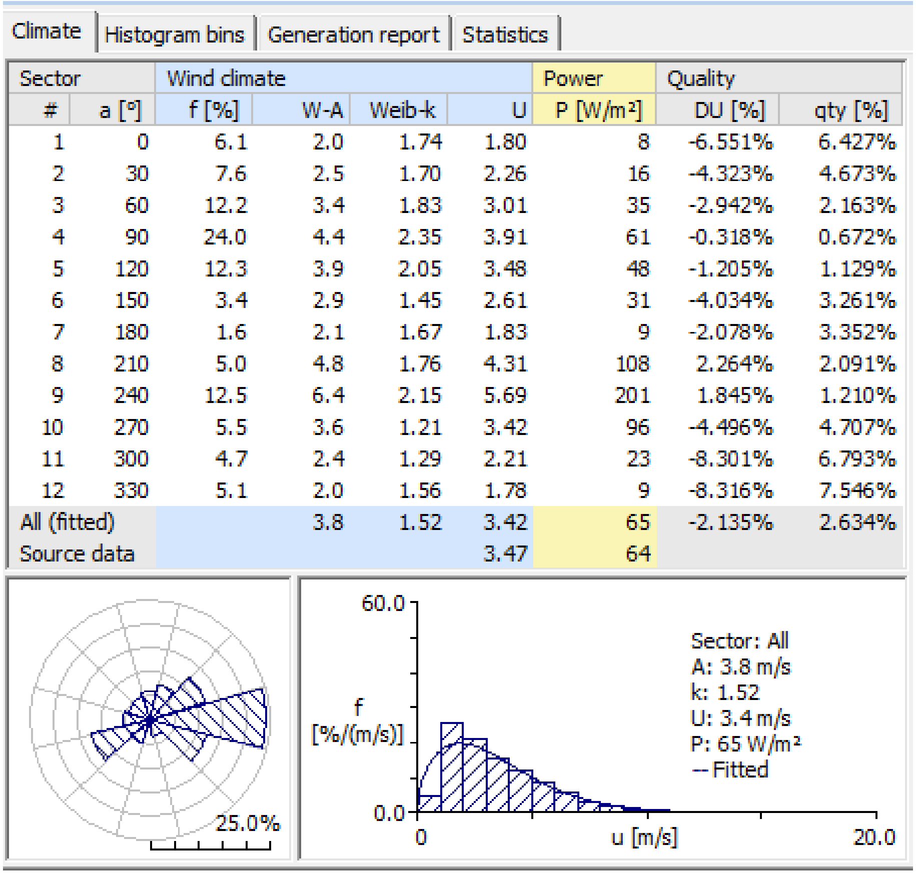
H(m)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dic	Annual
10	54.50	67.50	115.00	91.00	54.00	50.00	50.00	48.50	26.05	30.00	52.00	50.00	60.50
20	108.50	135.50	229.00	182.00	107.00	100.00	99.00	95.50	52.00	60.00	104.00	100.00	118.50
50	265.00	330.50	564.00	447.50	261.00	244.00	240.00	172.00	126.00	145.00	254.00	244.00	287.50

The incidence of wind during this period is shown in the following diagrams accompanied by their respective frequency distribution. See Figures 4.2.14 – 19.



Sector		Wind climate				Power	Quality	
#	a [°]	f [%]	W-A	Weib-k	U	P [W/m²]	DU [%]	qty [%]
1	0	5.8	2.0	1.69	1.77	8	-6.786%	6.709%
2	30	7.3	2.5	1.73	2.21	15	-4.063%	4.379%
3	60	13.3	3.5	1.85	3.11	38	-2.710%	1.891%
4	90	26.1	4.5	2.61	4.02	61	0.472%	0.849%
5	120	13.7	4.1	2.20	3.67	53	-0.493%	0.588%
6	150	3.3	2.9	1.63	2.56	25	-0.575%	1.738%
7	180	1.6	2.0	1.58	1.83	9	-0.297%	1.268%
8	210	3.8	4.2	1.59	3.81	84	1.886%	2.508%
9	240	10.4	6.1	2.25	5.43	168	3.062%	1.604%
10	270	5.1	3.2	1.20	2.96	63	-6.558%	5.040%
11	300	4.5	2.0	1.21	1.90	16	-10.811%	8.578%
12	330	5.1	1.9	1.58	1.73	8	-6.365%	8.057%
All (fitted)			3.8	1.65	3.37	56	-1.174%	2.038%
Source data					3.37	55		

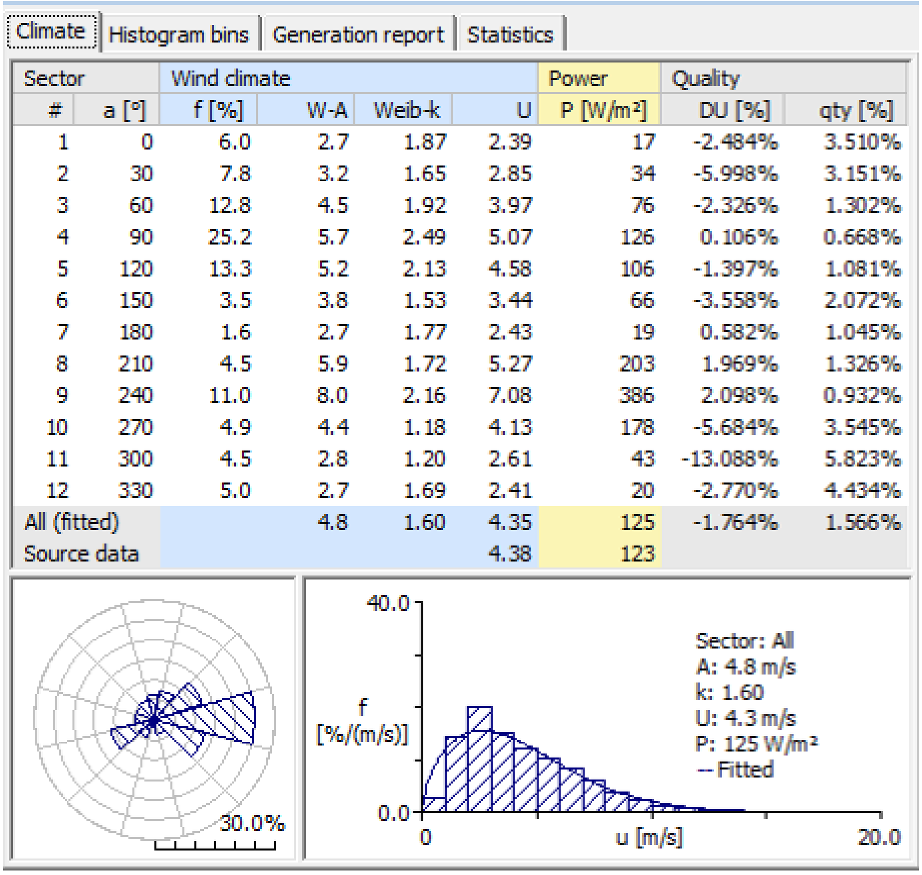
Figure 4.2-14 Wind rose and Weibull distribution for SLP station in 2008 at 10 m



Sector		Wind climate				Power	Quality	
#	a [°]	f [%]	W-A	Weib-k	U	P [W/m²]	DU [%]	qty [%]
1	0	6.1	2.0	1.74	1.80	8	-6.551%	6.427%
2	30	7.6	2.5	1.70	2.26	16	-4.323%	4.673%
3	60	12.2	3.4	1.83	3.01	35	-2.942%	2.163%
4	90	24.0	4.4	2.35	3.91	61	-0.318%	0.672%
5	120	12.3	3.9	2.05	3.48	48	-1.205%	1.129%
6	150	3.4	2.9	1.45	2.61	31	-4.034%	3.261%
7	180	1.6	2.1	1.67	1.83	9	-2.078%	3.352%
8	210	5.0	4.8	1.76	4.31	108	2.264%	2.091%
9	240	12.5	6.4	2.15	5.69	201	1.845%	1.210%
10	270	5.5	3.6	1.21	3.42	96	-4.496%	4.707%
11	300	4.7	2.4	1.29	2.21	23	-8.301%	6.793%
12	330	5.1	2.0	1.56	1.78	9	-8.316%	7.546%
All (fitted)			3.8	1.52	3.42	65	-2.135%	2.634%
Source data					3.47	64		

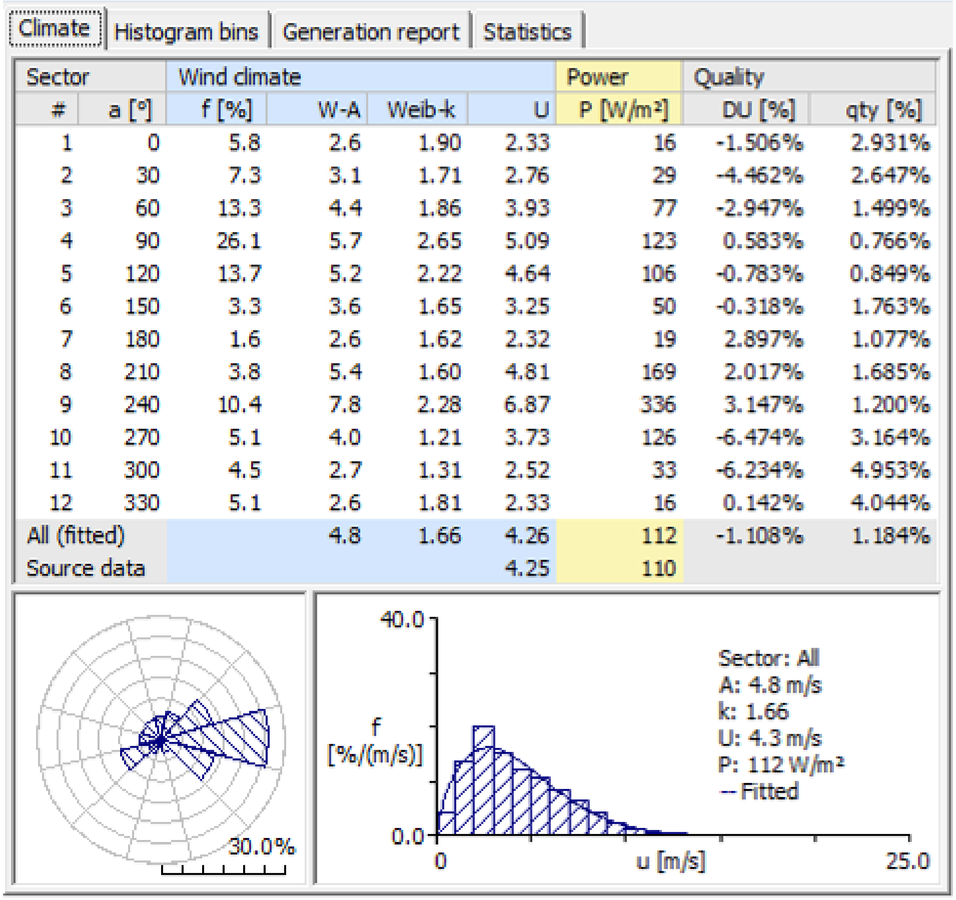
Sector: All
A: 3.8 m/s
k: 1.52
U: 3.4 m/s
P: 65 W/m²
-- Fitted

Figure 4.2-15 Wind rose and Weibull distribution for SLP station in 2009 at 10 m



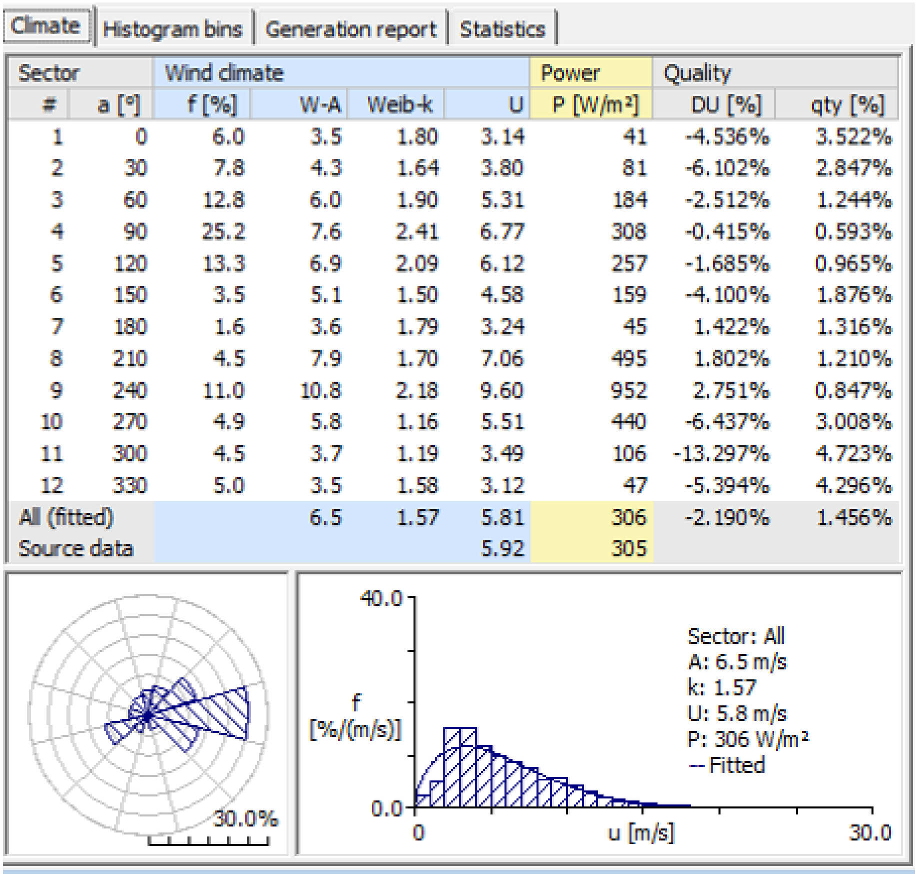
Sector		Wind climate				Power	Quality	
#	a [°]	f [%]	W-A	Weib-k	U	P [W/m²]	DU [%]	qty [%]
1	0	6.0	2.7	1.87	2.39	17	-2.484%	3.510%
2	30	7.8	3.2	1.65	2.85	34	-5.998%	3.151%
3	60	12.8	4.5	1.92	3.97	76	-2.326%	1.302%
4	90	25.2	5.7	2.49	5.07	126	0.106%	0.668%
5	120	13.3	5.2	2.13	4.58	106	-1.397%	1.081%
6	150	3.5	3.8	1.53	3.44	66	-3.558%	2.072%
7	180	1.6	2.7	1.77	2.43	19	0.582%	1.045%
8	210	4.5	5.9	1.72	5.27	203	1.969%	1.326%
9	240	11.0	8.0	2.16	7.08	386	2.098%	0.932%
10	270	4.9	4.4	1.18	4.13	178	-5.684%	3.545%
11	300	4.5	2.8	1.20	2.61	43	-13.088%	5.823%
12	330	5.0	2.7	1.69	2.41	20	-2.770%	4.434%
All (fitted)			4.8	1.60	4.35	125	-1.764%	1.566%
Source data					4.38	123		

Figure 4.2-16 Wind rose and Weibull distribution for SLP station in 2008 at 20 m



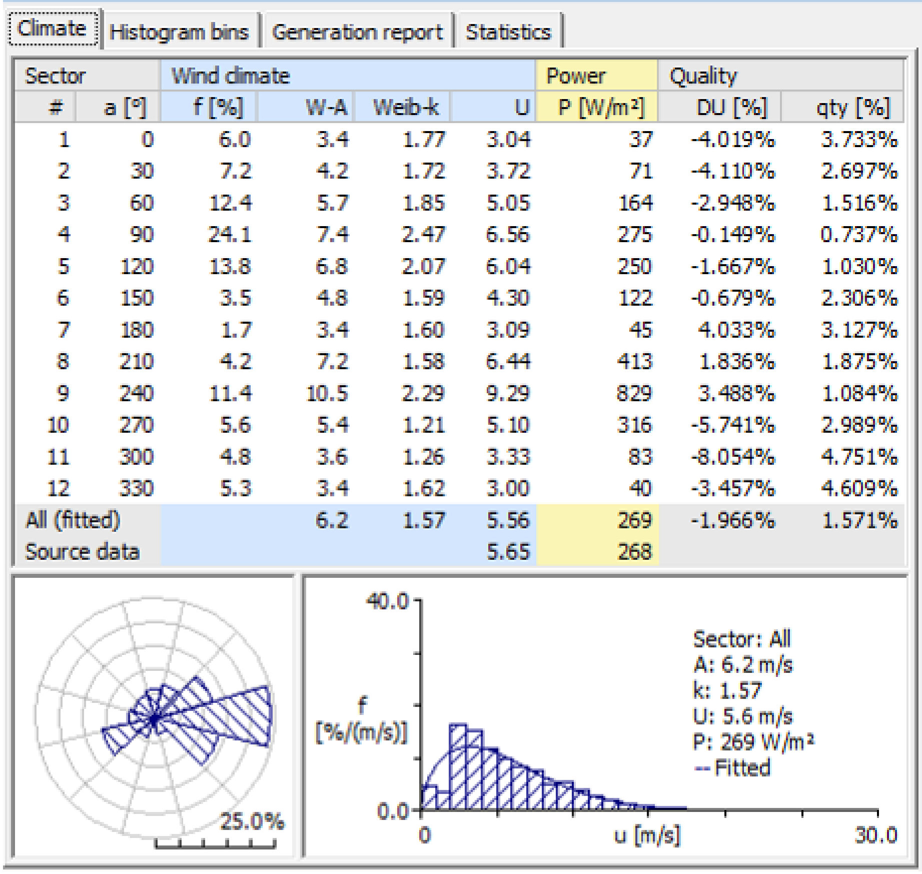
Sector		Wind climate				Power	Quality	
#	a [°]	f [%]	W-A	Weib-k	U	P [W/m²]	DU [%]	qty [%]
1	0	5.8	2.6	1.90	2.33	16	-1.506%	2.931%
2	30	7.3	3.1	1.71	2.76	29	-4.462%	2.647%
3	60	13.3	4.4	1.86	3.93	77	-2.947%	1.499%
4	90	26.1	5.7	2.65	5.09	123	0.583%	0.766%
5	120	13.7	5.2	2.22	4.64	106	-0.783%	0.849%
6	150	3.3	3.6	1.65	3.25	50	-0.318%	1.763%
7	180	1.6	2.6	1.62	2.32	19	2.897%	1.077%
8	210	3.8	5.4	1.60	4.81	169	2.017%	1.685%
9	240	10.4	7.8	2.28	6.87	336	3.147%	1.200%
10	270	5.1	4.0	1.21	3.73	126	-6.474%	3.164%
11	300	4.5	2.7	1.31	2.52	33	-6.234%	4.953%
12	330	5.1	2.6	1.81	2.33	16	0.142%	4.044%
All (fitted)			4.8	1.66	4.26	112	-1.108%	1.184%
Source data					4.25	110		

Figure 4.2-17 Wind rose and Weibull distribution for SLP station in 2009 at 20 m



Sector		Wind climate				Power	Quality	
#	a [°]	f [%]	W-A	Weib-k	U	P [W/m²]	DU [%]	qty [%]
1	0	6.0	3.5	1.80	3.14	41	-4.536%	3.522%
2	30	7.8	4.3	1.64	3.80	81	-6.102%	2.847%
3	60	12.8	6.0	1.90	5.31	184	-2.512%	1.244%
4	90	25.2	7.6	2.41	6.77	308	-0.415%	0.593%
5	120	13.3	6.9	2.09	6.12	257	-1.685%	0.965%
6	150	3.5	5.1	1.50	4.58	159	-4.100%	1.876%
7	180	1.6	3.6	1.79	3.24	45	1.422%	1.316%
8	210	4.5	7.9	1.70	7.06	495	1.802%	1.210%
9	240	11.0	10.8	2.18	9.60	952	2.751%	0.847%
10	270	4.9	5.8	1.16	5.51	440	-6.437%	3.008%
11	300	4.5	3.7	1.19	3.49	106	-13.297%	4.723%
12	330	5.0	3.5	1.58	3.12	47	-5.394%	4.296%
All (fitted)			6.5	1.57	5.81	306	-2.190%	1.456%
Source data					5.92	305		

Figure 4.2-18 Wind rose and Weibull distribution for SLP station in 2008 at 50 m



Sector		Wind climate				Power	Quality	
#	a [°]	f [%]	W-A	Weib-k	U	P [W/m²]	DU [%]	qty [%]
1	0	6.0	3.4	1.77	3.04	37	-4.019%	3.733%
2	30	7.2	4.2	1.72	3.72	71	-4.110%	2.697%
3	60	12.4	5.7	1.85	5.05	164	-2.948%	1.516%
4	90	24.1	7.4	2.47	6.56	275	-0.149%	0.737%
5	120	13.8	6.8	2.07	6.04	250	-1.667%	1.030%
6	150	3.5	4.8	1.59	4.30	122	-0.679%	2.306%
7	180	1.7	3.4	1.60	3.09	45	4.033%	3.127%
8	210	4.2	7.2	1.58	6.44	413	1.836%	1.875%
9	240	11.4	10.5	2.29	9.29	829	3.488%	1.084%
10	270	5.6	5.4	1.21	5.10	316	-5.741%	2.989%
11	300	4.8	3.6	1.26	3.33	83	-8.054%	4.751%
12	330	5.3	3.4	1.62	3.00	40	-3.457%	4.609%
All (fitted)			6.2	1.57	5.56	269	-1.966%	1.571%
Source data					5.65	268		

Figure 4.2-19 Wind rose and Weibull distribution for SLP station in 2009 at 50 m

Most frequent wind speed at 10 m high is between 3-3.5 m/s, while at 20 m around 5 m/s and at 50 m it increases until 6-6.5 m/s. Prevailing direction is East direction according to the annual wind roses in both years.

4.2.4 Agroclimatic stations used as reference

Two meteorological stations were taken as reference due to the lack of data inside the Highlands. Charcas and Yolíatl agloclimatc stations were chosen, the first one because of its location (the only one in the middle of the Highlands), and the second one, located in the Southwest part of the highlands.

As mentioned in the methodology, reiterate that such stations obey to other aims (related to agriculture sector, e.g. to predict pests and climatic parameters at just 2 m above ground level) and just provided average values of wind speed by day and not every 10 minutes as the conventional meteorological stations. Those stations are from recently operation. Vertical extrapolations was performed also to estimate potential at 10, 20 and 50m.

1. Charcas

Charcas just started to operate on May 2011, reason why estimation was made only for a year. However, it was chosen as is the only one in the middle of the area of interest and to corroborate the tendency of the winds in the area.

The wind frequency distribution was made by a conventional way as data are not sufficient to the WasP. That means to divide wind speeds in different intervals and count their incidence each.

Wind speed throughout the year (05/11-05/2012) at 10, 20 and 50 m is shown in Figure 4.2-20 Frequency of wind speed in that period is shown in Figure 4.2-21.

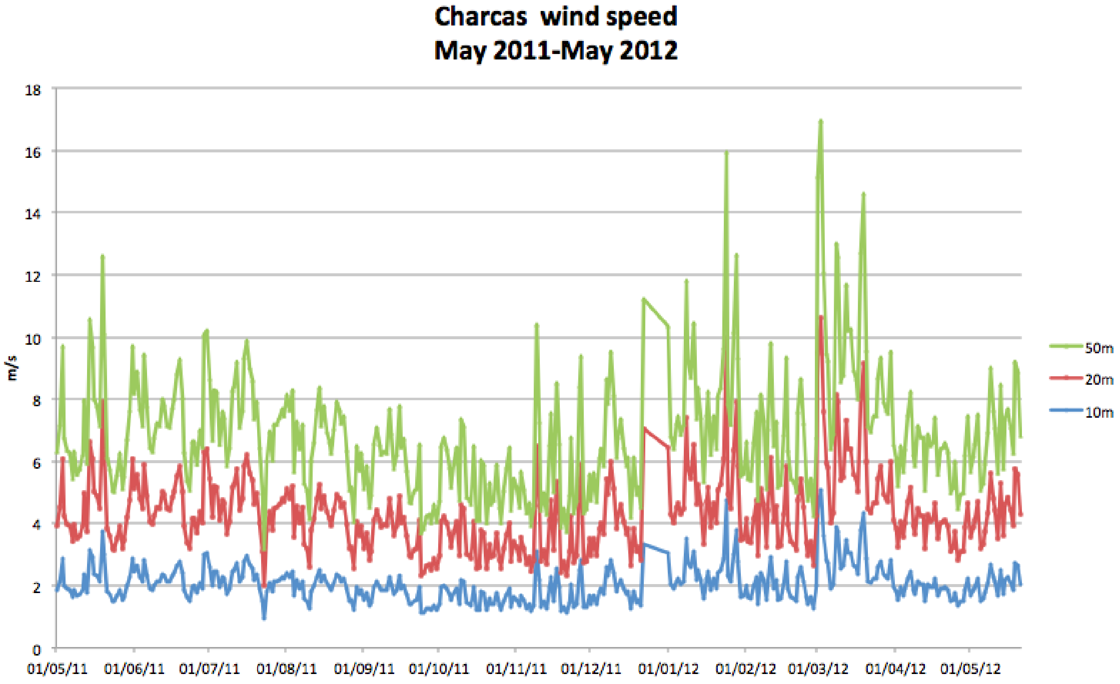


Figure 4.2-20 Wind speed in a year (05/11-05/12), Charcas

Wind velocity does not vary radically throughout the year. But according to data provided by INIFAP (2012), on May, June and July there are a bit larger speeds than the subsequent months decreasing until November. Winds increase gradually in

December finding highest wind speeds over February and April. In other words, winter and spring present stronger winds than those on summer and autumn.

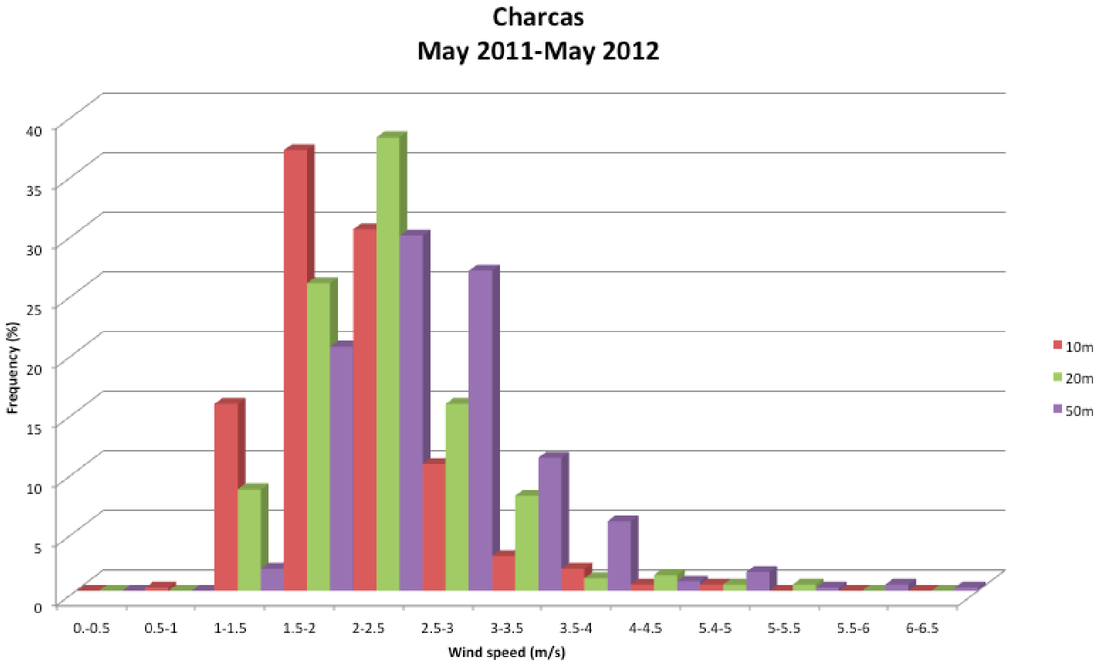


Figure 4.2-21 Wind speed frequency in Charcas (05/11-05/12) at 10, 20 and 50 m.

At 10 m the most frequent wind speed is within interval of 1.5-2 m/s, while for 20 m and 50m is 2-2.5 m/s above ground level. For this interval it can be expected a wind potential between 5 and 10 W/m^2 based on the formula of wind power density (Chapter II). That means poor wind potential even for low denomination tecnologies which require between 50-200 W/m^2 (NREL, 2001).

As wind power is function of the cube of wind speed, it confers much more power with a short increase of the velocity; however, in this case that class of prevailing wind around 2-2.5 m/s, does not gives enough potential.

2. Yoliatl

In the case of Yoliatl agroclimatic station, situated at the Southwest side of the State, INIFAP website counts with data from 2008 (dialy wind speed average and direction). From 2008 to 2010, wind frequency distribution at 10, 20 and 50 m is shown in Figure 4.2-22. Wind speed in a year is shown in Figure 4.2-23.

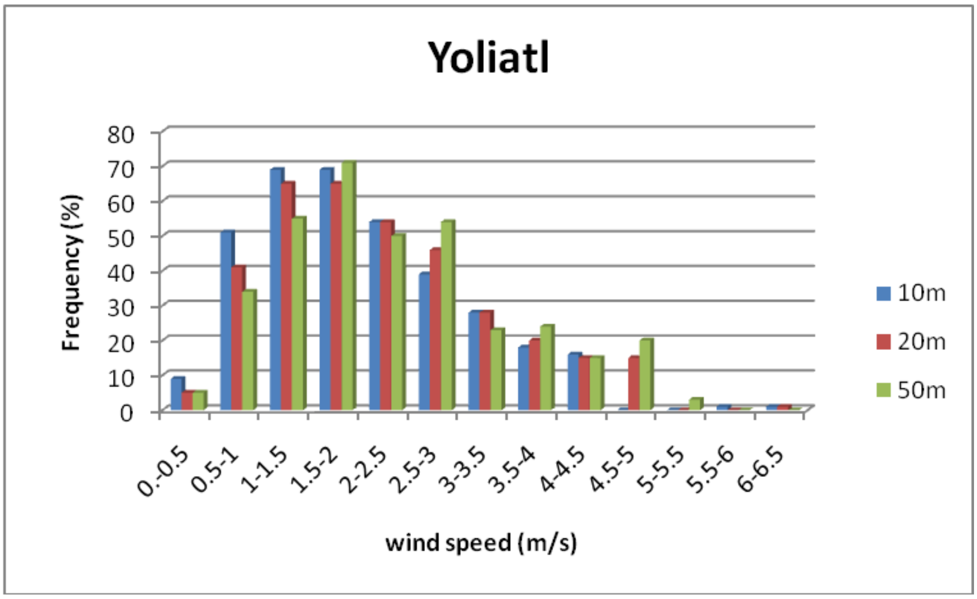


Figure 4.2-22 Wind frequency distribution of Yoliatl (2008-2010)

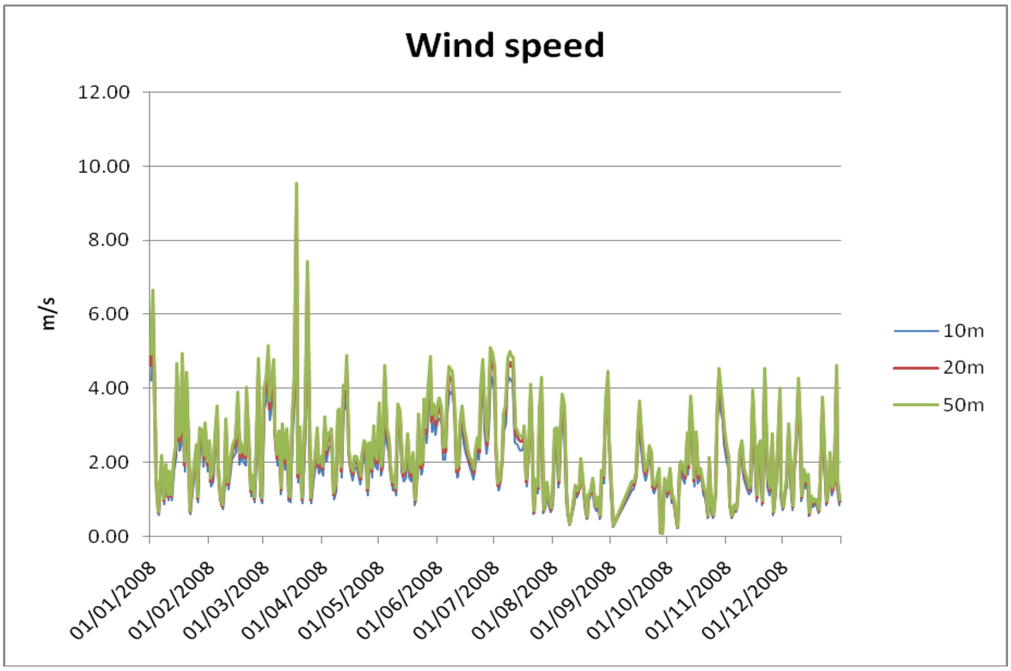


Figure 4.2-23 Wind speed in a year. Yoliatl.

Between 1 and 2.5 m/s, Yoliatl presents most of its winds, for every evaluated high. It is related to its roughness, as is mostly plain and wind speed increase is small. In other words, as there is not much obtruction, wind speeds even at 10 m are similar to those at 50 m. Nevertheless, wind power density to obtain with that amount of wind – and that does not varies significant during the year- may be in the range of 5-10

W/m^2 when wind blows at 2.5 m/s (average value of wind speed is 2.02, 2.23 and 2.36 m/s at 10, 20 and 50 m respectively).

That amount of power is still very low even at 50 m, reason why, according to data used by INIFAP, is considered as poor potential.

4.3 Results summary

In this section, results will be summarized and analyzed by:

a) Wind speed graphics to show monthly wind variability by each station;
b) Wind density power. Comparison among the main and reference stations.
c) Summary about wind direction
d) Stablishment of wind class at each station (marginal, moderate or good) according to stated in Table 3.3-3 (Chapter III-Methodology).

4.3.1 Wind speed variations related to height

Figures 4.3-1-3 shows the behavior of wind in velocity, average values through the contemplated periods of time for every station.

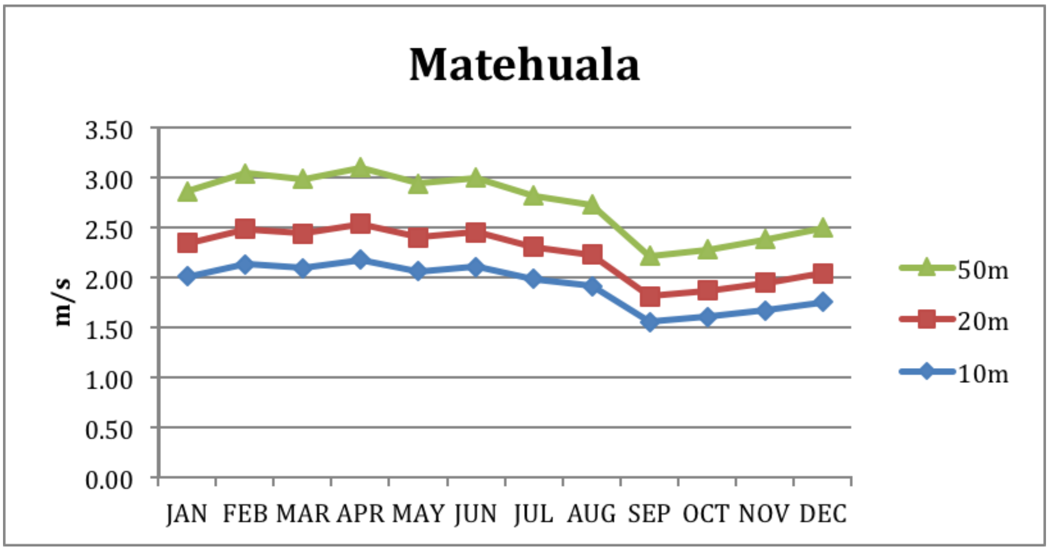


Figure 4.3-1 Monthly variations of wind speed measured in Matehuala station at 10, 20, and 50 m.

Winter and spring are the seasons with major wind speeds. Months of summer wind speed decreases gradually to finally increase during autumn season. Throughout three years of evaluation, behavior of the wind was the same for every month. Even increase in speed is around 1 m/s between 10 and 50 m, power that can be extracted is much more as function of the cube of wind velocity. Increasing of wind velocity with height corresponds to a typical wind profile.

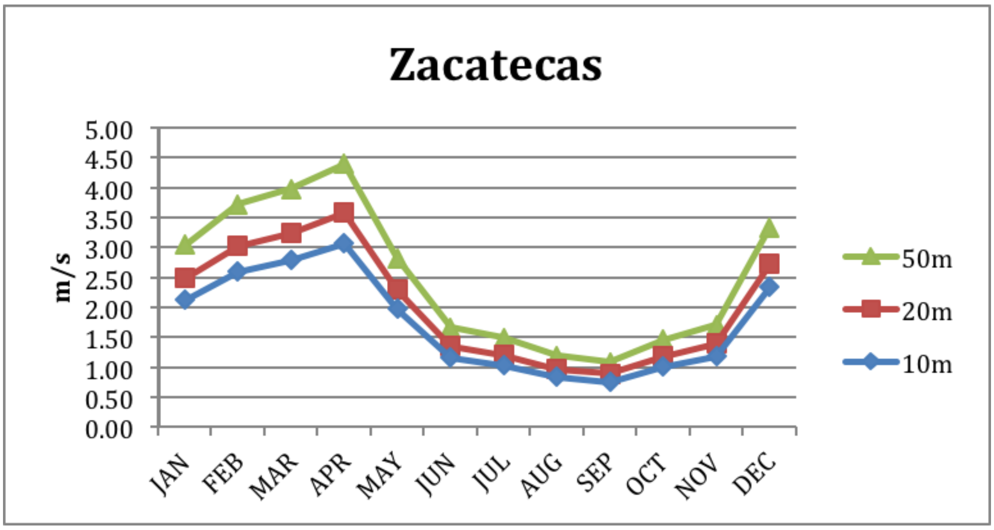


Figure 4.3-2 Monthly variations of wind speed measured in Zacatecas station at 10, 20, and 50 m.

The case of Zacatecas is stronger winds during winter, but then they decrease from March to November. Most part of the year wind speed is less than 2 m/s for all heights. Nevertheless, winter is quite a powerfull season reaching winds between 3-4 m/s at 20 and 50 m.

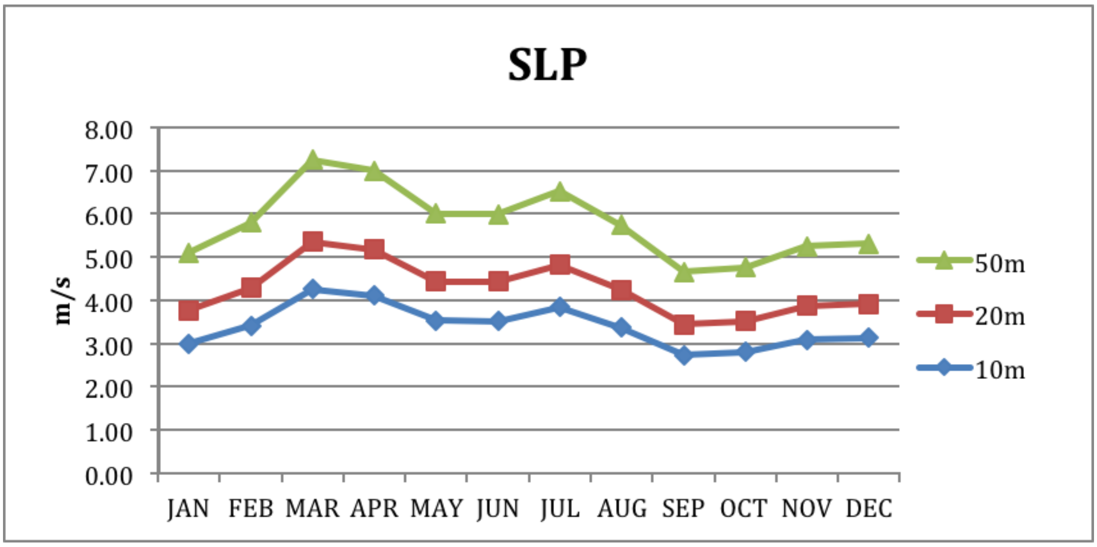


Figure 4.3-3 Monthly variations of wind speed measured in SLP station at 10, 20, and 50 m.

SLP presents more variations related to wind during the year, being March and April the months with higher wind speeds that can reach 4 m/s at just 10 m high.

Being exponential the power with respect to the wind velocity, it can be found good potential at 50 m high (more than 100 W/m^2) that actually can be useful for low demands of electricity.

4.3.2 Wind power density

Wind power density (WPD) is the power that can be extracted per area unit related to an specific wind resource in certain location and meteorological conditions. Wind power density is in function of the cube of wind velocity. That means that low increase in velocity of wind, can generate quite a large increase in wind power. Nevertheless, wind frequency distribution determines the prevailing wind speed (the most frequent interval of wind speed), and thus, the minimum power density. That is why two locations with the same wind speed average could have quite a different wind potential.

Figures 4.3-4 -6 shows the WPD calculated for every meteorological station, at 10, 20 and 50m.

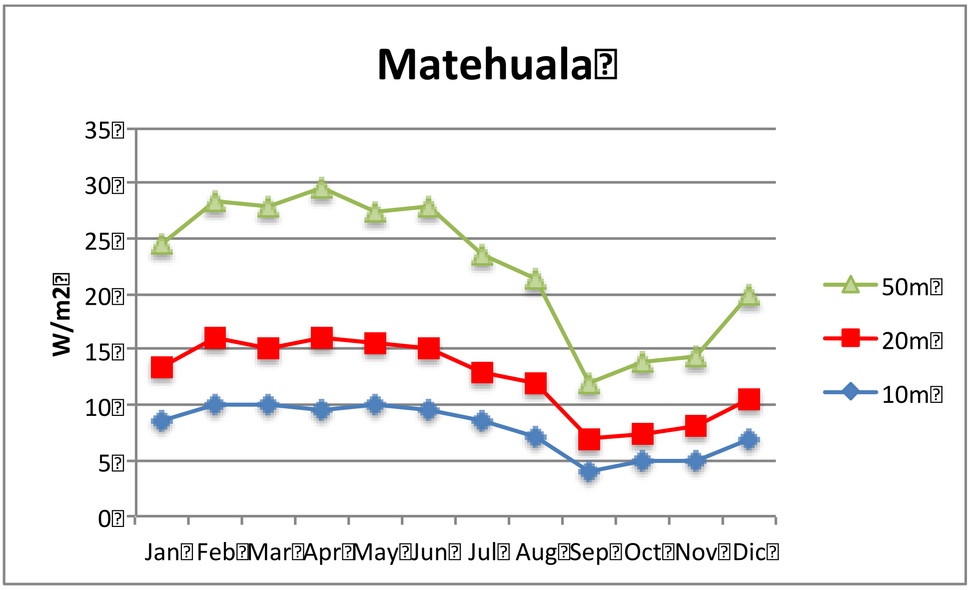


Figure 4.3-4 WPD in Matehuala station at 10, 20 and 50 m

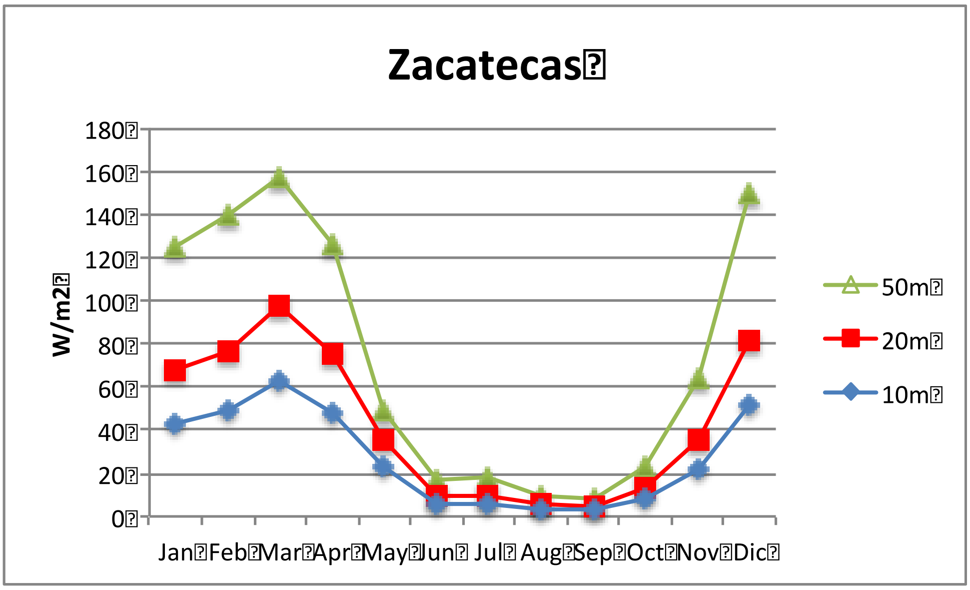


Figure 4.3-5. WPD in Zacatecas station at 10, 20 and 50 m

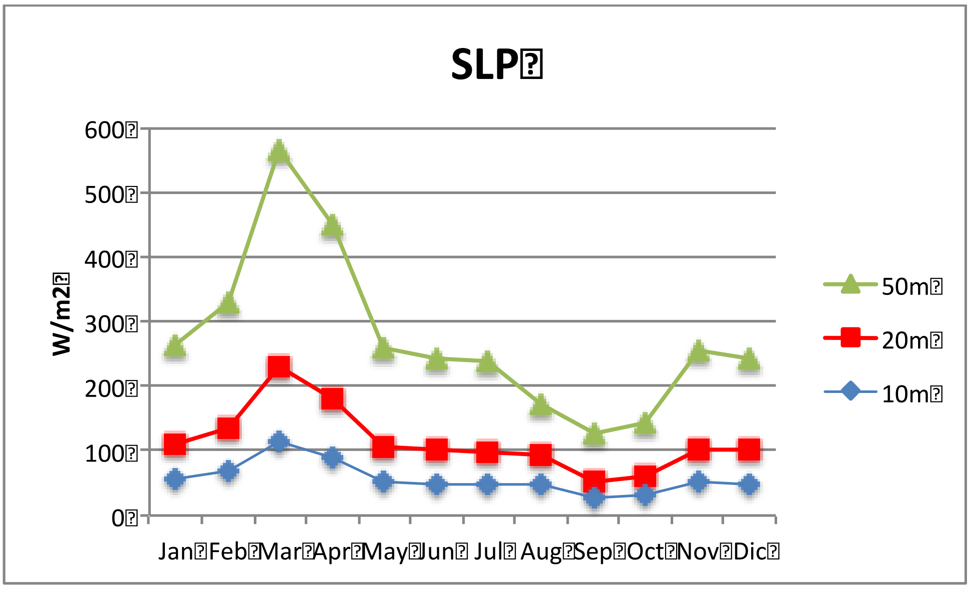


Figure 4.3-6. WPD in SLP station at 10, 20 and 50 m

It can be seen that for Matehuala meteorological station, even at 50 m high, WPD does not exceeds 30 W/m^2, only by the month of April, being autumn the worst period to harvest wind power. For this reason Matehuala surroundings are considered as a "poor wind potential" zone.

In the case of Zacatecas wind power seems to be "moderate" for certain rural uses as water pumping but only by winter season, reaching almost 160 W/m^2 in December and 120 in April, beginning to decrease the rest of the year.

Finally, according to data provided by SMN and the analysis performed by WAsP, in SLP it was estimated until more than 500 W/m^2 in March, but, as indicated the Figure 4.3-6, it can be assumed a windy month during 2008, that could be cause of other meteorological phenomena in the center of the country, or even an error in the record, since it is an abrupt spike in the data. If dismiss it as an abrupt value, and taking into account that by analyzing the source data in the following year compared with wind speeds, it did not reflect a similar peak, it can be asummed still a power between 300 and 400 W/m^2 in February-April period being minnor than 200 W/m^2 from July to October. It is, in SLP it can be found "moderate" for some specific uses, wind potential at 50 m high in the Winter and Spring seasons mostly. At 20 m high it can hardly exceed 100-150 W/m^2 while at 10m is considered a negligible potential.

Under this scheme, Betz Law (described in Chap. II) must still be considered indicating that this calculated potential, is only about 59% that it can really be profitable. Applying this criteria, the removable wind potential for SLP at 50 m (annual average value of 287.50 W/m^2 according to Table 4.2-3) would be around 169.625 W/m^2.

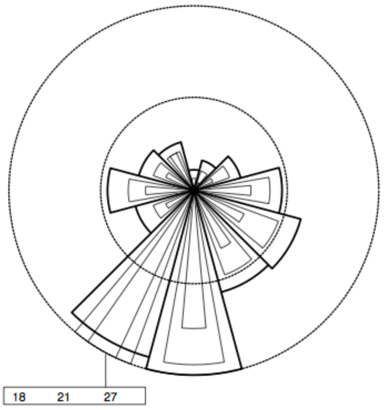
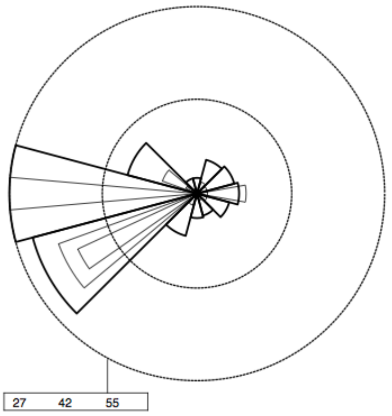
In the case of Zacatecas, it results to be enough just for specific and isolated small-scale applications as can be water pumping but only on certain months of the year. Nonetheless, after applying the Betz Law, which states the difference between wind potential and exploitable potential, the second one equivalent to approximately 59%, it becomes practically negligible. For this reason, Chapter V about rural uses for wind potential will be only applied to SLP case.

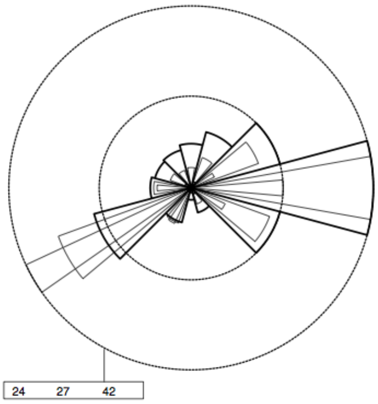
In the other side, annual energy production is directly associated with rotor diameter of wind turbine. For this reason, it would be considered small-scale wind turbines associated with prevailing wind speeds in the SLP region.

4.3.3 Wind direction

Table 4.3-1 Summarizes the prevailing winds present in each evaluated station.

Table 4.3-1 Prevailing wind direction in Matehuala, Zacatecas and SLP meteorological stations

Site	Wind direction tendency	Anual wind direction
Matehuala	As regards Matehuala, winds are characterized by presenting mostly West-Southwest direction during the year. From November to March winds ocurr mostly directed Southward while from April start taking skightly a West direction also. This behavior is slightly variable throught the months as can be consulted in the Appendix A.	
Zacatecas	In the case of this station, the years of 2009 and 2010 present mostly addressed to West and Southwest winds. While the year of 2008 present more distributed winds being East as well as West addressed winds the most frequent. From June to September is usual to prevail East-Southeast winds.	

Site	Wind direction tendency	Anual wind direction
SLP	Near of the SLP city, wind blows mostly to East direction, but from November to March it is presented West and Southwest winds as well. To more detailed information about, monthly variations can be consulted in the Appendix.	

Meteorological fingerprints generated by WasP

4.3.4 Wind class

Complementing wind class clasification -shown in Chapter III-also proposed by NREL, Table 4.3-2 presents classes of wind power density at 10 and 50 m.

Table 4.3-2. Wind power density classes at 10 and 50 m (NREL, 2001).

Wind power class	10m		50m	
	Wind power density (W/m^2)	Wind speed (m/s)	Wind power density (W/m^2)	Wind speed (m/s)
1	0-99	>4.4	0-199	>5.6
2	100-149	4.4	200-299	5.6
3	150-199	5.1	300-399	6.4
4	200-249	5.6	400-499	7
5	250-299	6	500-599	7.5
6	300-399	6.4	600-799	8
7	400-999	7	800-1999	8.8
	>1000	9.4	>2000	11.9

The performed estimation is inside values in grey

According to this:

Table 4.3-3 Wind class of the evaluated stations

Station	Wind power density (10m)	Wind power class	Wind power density (50m)	Wind power class
Matehuala	8.00	1	22.50	1
Zacatecas	26.00	1	86.67	1
SLP	60.50	1	287.50	2
Charcas	>5	1	>10	1
Yoliatl	>5	1	10	1

As mentioned before, the cases of Matehuala and Zacatecas count with poor wind potential. Thus, Chap. V base its discussion of alternative in rural uses at small-scale technologies exemplifying the case of SLP at 50 m.

CHAPTER V. ALTERNATIVES FOR RURAL USE

5.1 Introduction

The extension of the power grid is the most common strategy to provide access to the electricity service, being unfeasible when it comes to reach remote areas, that are inaccessible and low density populated. This is why, autonomous and decentralized systems, based in renewables, represent a good alternative, being eolic as well as photovoltaics one of the technically possible options whenever the resource exists at exploitable dimensions (Lega, 2010).

According to power density obtained in Chapter IV, estimated wind potential is negiglible to the north side of the Highlands region of SLP (Matehuala station), poor in Zacatecas station, and moderate for small-scale technologies at SLP station. Yoliatl and Charcas used as reference stations resulted poor in wind potential.

Table 5.1-1 WPD summary (W/m^2)

Station	10m (W/m^2)	20m (W/m^2)	50m (W/m^2)	Wind potential classification
Matehuala	8	12.50	22.50	Negligible
Zacatecas	26.00	46.67	86.67	Poor
SLP	60.50	118.50	287.50	Moderate at 50 m

Under this scenario, "specific" or "marginal use" refers to as those useful for applications that do not require a high potential as pumping water or autonomous electrification, subject that will be developed in the subsequent paragraphs.

SLP is a state with high levels of marginalization, especially in the Highlands region; however, as better wind potential resulted in SLP station located in the capital city, it should be mentioned that some of the municipalities around are highly characterized by poverty as Aquismon and Moctezuma municipalities, which present high levels of marginalization, among others with medium level of marginalization as Villa de Reyes, Villa de Arriaga and Zaragoza (INEGI, 2010).

5.2 Rural applications for wind power

In rural areas the most common applications of wind energy in agriculture focus to water pumping, electric fences, refrigerators and freezers, as well as drying of some agricultural products. According to Gonzalez-Avila (2006) in agricultural regions, electricity is used for pumping water to areas suffering drought or troughs for cattle, and is also used in food preservation or material related to livestock.

The research of Gonzalez-Avila highlights the public lighting as one of the main uses, followed by others as the use of radio and television. Another important use resides in nixtamal mills, making it easier for women making "tortillas" or other food.

Although in Mexico there is little experience in wind resource exploration as well as in the implementation of such projects, the most notable example of rural electrification by wind power is that developed in La Ventosa, Oaxaca, where the production of medium-power wind energy has combined electricity production with planting, harvesting and livestock, so using more technology raises the standard of living of marginalized populations in one of the poorest states of the country (Gonzalez et al, 2006).

Since it is intended that the estimated wind energy can be harnessed in marginalized areas, the following equipment seems to be typical (UPME, 2003):

a) Individual eolic equipment on farms and rural areas. Also known as autonomous systems. This use consists of individual systems with power ratings from 10 KW to 100 KW. Such equipment is designed to operate in parallel with the grid or to operate independently of it. Its application may include uses such as providing hot water (collectors are cheaper for this purpose), cooling, irrigation and / or delivery of electricity to conventional charges.

b) Power supply equipment with storage: These systems typically have a lower nominal power up to a few kilowatts. These devices are designed for a modest supply of energy (radio transmitters, electric fences, relay stations, lighting). These systems are supplied with battery banks, and have been widely used since the 20s worldwide. The latest developments of these devices include sealed batteries, electronic controllers and in some cases inverters.

Final production depends mainly of the presence of the resource, but also in the size of the rotor. Table 5.2-1 shows the approximate monthly production for various sizes of generators in locations with different wind speeds.

Table 5.2-1. Approximate monthly energy production (kWh) for various sizes of wind turbines in several different locations

Rotor diameter	**Wind velocity (m/s)**			
(m)	**3**	**4**	**5**	**6**
1	2	6	10	20
2	10	25	50	70
3	20	60	100	160
4	40	100	200	280
5	60	160	300	430

UPM, 2003

5.3 Small-scale wind power

Despite the intermittent nature of wind, harnessing the energy extracted from this can be done on a smaller scale, and in fact, this small-scale use has its own important advantages over large-scale wind.

The most important feature of the smaller scale wind energy is that it is capable of supplying electricity in isolated and remote sites from the mains, becoming possible, as occurs in the place where the renewable source is, the reduction of losses.

Technically, does not require feasibility studies with high precission by presenting moderate winds, coupled with the fact that the installation of small equipment is simple, which makes technology accessible to many users. In the environmental aspect, the visual impact is far less than is generated by large wind farms, may be barely noticeable by the inhabitants of the communities.

The smaller or "micro", <1 kW wind turbines, are used in a variety of applications such as charging batteries for boats, communication systems, mountain refuges, etc. The turbines from 1 to 10 kW are typically used on farms to pump water (where wells are deeper), power for isolated houses, and so on. The turbines for residential applications may be in the range of 400 W to 100 kW, depending on the amount of electricity to generate. For example, a 1.5 kW turbine could cover the needs in a home that consumes about 300 kWh per month on a site with a wind speed of 6.26 m/s (CIEMAT, 2008).

In fact technology in small denominations from 1 to 20 kW for rural uses has not changed much over the years, states the IIE (2005). Usually works as a hybrid system combining wind power with photovoltaics. Typically, these systems are not interconnected to the grid and use batteries to store the electricity produced requiring like any other machine an adequate maintenance.

Table 5.3-1 shows examples of typical applications where small-wind turbines can be used, not only as rural applications but also at commercial and residential sector whenever do not exceed a limit of energy demand, for around 300 kW.

Table 5.3-1 Typical applications for small-wind turbines

	Small Wind Turbine Category		
	Battery Charging & Light Seasonal Loads	**Residential & Heavy Seasonal Loads**	**Commercial, Institutional, Farms, and Remote Communities**
Typical Power Rating	0-1000 W (0-1 kW)	1-30 kW	30-300 kW
Typical Grid Connectivity	Mostly off-grid, some on-grid*	Mostly On-grid*, Some Off-grid	On-grid*, Isolated-grid, or Off-grid
Typical Applications	Mobile uses (sailboats, recreational vehicles, etc.) Seasonal applications (small cottages, hunting lodges, etc.) Rural & 'urban perimeter' residential homes (small loads) Specialty power sources (radar and telecomm devices, measurement instruments, cathodic protection,	Off-grid rural houses with large lot sizes (usually >1 acre) On-grid rural houses with large lot sizes (usually >1 acre) where DC appliances are driven by wind turbine/batteries *or* where some electricity is stored on the grid through Net Metering Larger cottages or hunting lodges with significant share of electricity from wind	On-grid or isolated-grid large farms Off-grid small farms where small wind complements a diesel generator set and/or solar photovoltaics On- or off-grid commercial or institutional buildings Isolated-grid communities where wind is complemented by diesel generators and/or other sources

	remote weather stations, etc.) Commercial parks & camps Electric fencing		

Canwea, 2012

The European experience has been successful in implementing such systems, associated with the financial solvency in which maintenance is not an obstacle. Unlike this, in Mexico the few small-scale projects that exist have failed by not having capital to maintainance since, despite being driven by social programs, have left this task to the communities themselves. Although there are two projects in Baja California that have been successful (San Juanico and Isla Santa Margarita) due to the fact that CFE has supported them with these tasks (IIE, 2005). Therefore it is considered that these types of projects in rural areas are facing greater challenges in developing countries.

No one has established a threshold for considering wind power small-scale systems, but often allude to power installations under 100 kW, and the overall yields of these facilities are usually between 0.3 and 0.6, ie below the industrial size (Cuenca, 2009).

There are very low power turbines, below 10 kW power, traditionally used for water pumping (windpumps multiblade) and mini-wind turbines for electricity production (usually forming wind-photovoltaic mixed clusters in remote homes). The majority of micro-generators are horizontal axis, upwind (wind blades located first and then the tower), also usually of zero conicity.

As regards the installation, different configurations of wind turbines exist: one-blade, two-bladed, three-bladed, multiblade. Increasing the number of blades decreases the rotational speed and increases the yield, leading to the turbines to be more expensive. For this reason, the market has focused on two bladed and three-bladed rotors, this one being the most common configuration since the generator operates more uniformly, and therefore its duration is greater. In addition, the energy produced is slightly higher, with a consequent increase in performance and also visually less aggressive as they have a more symmetrical configuration and a lower rotation speed (Cuenca, 2009). In Table 5.3-2 can appreciate the technical characteristics of small commercial wind turbines with outputs ranging from 50 to 6,000 W. For each model presented in this table, it can be seen the nominal voltage, but can be delivered to the various output voltages indicated.

Table 5.3-2. Small commercial wind turbines (Enercon GmbH)

Model	Nom. Vol.	Output		Diameter (m)	Number of Blades
		Watts	Volts		
W50	18	50 DC	06/12/24	0.45	2
W250	18	250 DC	12/24	0.66	2
W V05	9	600 DC	25/36	2.5	2
W V15G	10	1200 DC	25/36/48/65/110	3	2
W V15W	10	1200 AC	110,1Phase (30-70 Hz)	3	2
W V25G	11	2200 DC	35/48/65/110	3.6	2
W V 25D	11	200 AC	110, 3 Phase (40,70 Hz)	3.6	3
W V35G	11	4000 DC	48/65/110	4.4	3
W V35D	10	3500 AC	110/220, 3 Phase (30-60 Hz)	4.4	3
W VG50G	12	5/6000 DC	65/110	5	3
W VG50D	10	5000 AC	110/220, 3 Phase	5	3

Ministry of Energy and Mines of Peru, 2004

It should be considered that small systems generally use lead acid batteries. Some use alkaline batteries that are more expensive but require less maintenance and have better storage characteristics.

In general, the best batteries for wind turbines are deep cycle type, which are designed to allow up to 300 downloads, followed by full loads in their life cycle.

The storage capacity depends not only to select the size and characteristics of the generator, but longer quiet period in which the power supply have to be maintained. In practice the batteries are suitable in the range of 130 to 450 Ah (Ministry of Energy and Mines of Peru, 2004).

5.3.1 Pumping Water

One of the most ancient applications of wind power is pumping water which regard its mechanism -driven piston pump- has become the second symbol for the utilisation of wind energy, next to the European windmill (Hau, 2006). This technology is particularly well-suited to areas with moderate wind speeds and for the pumping of small amounts of water from a great depth, primarily for providing drinking water.

Regarding irrigation and specially in developing countries, where agriculture plays an important role where managing large amount of water is required, wind turbines have demonstrated its capacity for driving electrical water pumps even though this technology is far more complicated, as Hau stated (2006), sometimes has to be installed in a combined system with a diesel generator, for safety reasons.

In principle, the wind turbine can operate in combination with a piston pump or a centrifugal pump. While piston pumps have a high efficiency of approximately 80 to 90 %, even at reduced rotational speeds, that from a centrifugal pumps is lower, approximately 50 to 75 %, and it drops rapidly with decreasing speed. The pumping characteristics and thus power consumption relative to speed also differ greatly. According to Hau (2006) piston pumps raise a volume flow which is proportional to the rotational speed and almost independent of the delivery head, i. e. the depth of the well. Moreover, a certain delivery head requires a minimum rotational speed.

The author compares the operating characteristics of the two types of pumps with the power characteristic of a high-speed wind turbine shows and states that "*the operating characteristics of the water pump can be matched more easily to the power characteristics of a wind rotor if it is a centrifugal pump"* (as can be seen in Figure 5.3-1). The reason is that the characteristics of the two fluid flow machines, wind rotor and centrifugal pump, are a better match. Taking into account that the electrical transmission of power from wind turbine to water pump involves a twofold energy conversion, with corresponding losses of altogether about 30 %, this loss is more than compensated for in many cases by the optimal siting of the wind turbine.

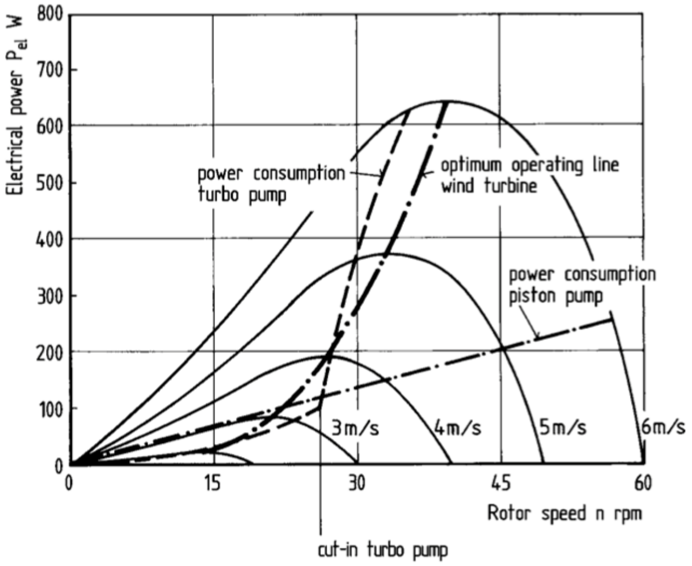


Figure 5.3-1 Power consumption of a piston pump and a centrifugal pump compared to the optimal power characteristics of a wind turbine (Hau, 2006)

Figure 5.3-2 shows a modern concept of a wind/pump system. It corresponds to an Aeroman wind turbine, equipped with a synchronous generator of 14kVA and supplies the two submerged electric pumps in the well via a three-phase low-voltage line. Depending on the wind power offer, the electric control system switches on one or both pumps and thus roughly adapts pump power consumption to the available wind power. The pumps operate at the frequency dictated by the wind turbine's synchronous generator. This frequency varies between 40 and 50 Hz., with the power consumption of the pumps ranging from 59 to 100 % of the rated power.

The pumping capacity of the described wind pump system depends directly on the wind regime and the delivery head. To exemplify this, for a site with a mean annual wind speed of 5.5 m/s and a delivery head of 50 m, the water volume pumped annually amounts to approximately 130 000 m^3. As soon as the investment costs, which are still too high at present, can be lowered via higher production numbers, wind-driven water pumps of this or similar concepts are projected to have very good chances of being used widely in developing countries (Hau, 2006).

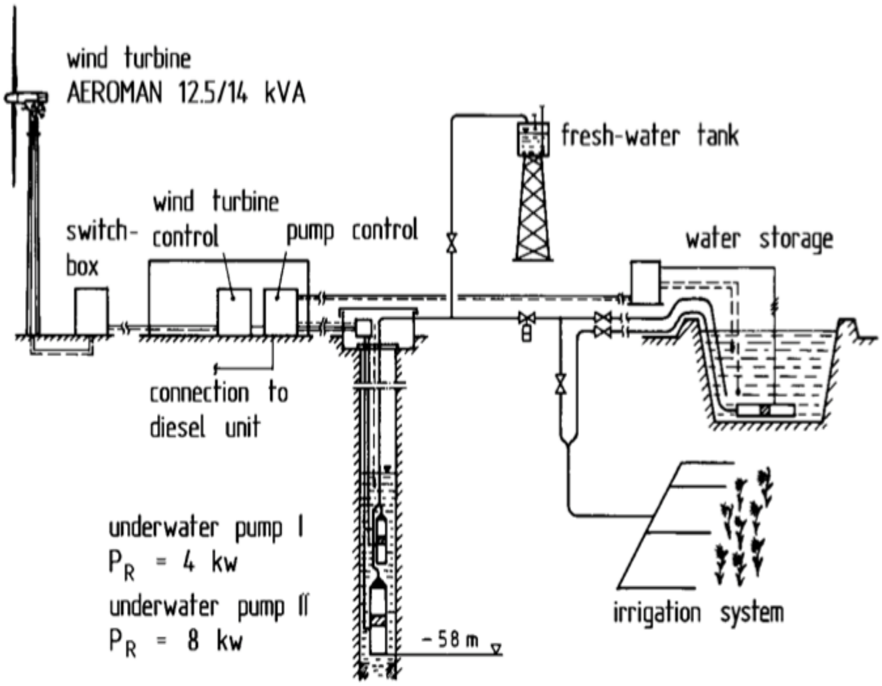


Figure 5.3-2 Wind supported irrigation system with an Aeroman wind turbine and two underwater electric well (Hau, 2006).

5.3.2 Hybrid systems

Given the intermittency of wind, it is usual for small wind systems to be accompanied by photovoltaic panels as part of small hybrid systems, through the combination of the energy of the sun and wind, to guarantee the power supply. These systems, quite reliable, include a battery that stores excess energy until there is no wind or sun. Diesel generator plays an important role in this type of systems, as they confer security to the supply.

The technology resides in a combination of advanced small wind turbines with microprocessor-controlled solar tracking technology, which together delivers more consistent energy and represents a new chapter in small-scale, on-site power generation.

In fact, generally, hybrid power systems are considered to supply loads in the size of several watts up to several megawatts. They usually supply island networks that are not connected to an integrated grid covering countries or even continents, but represent small grids with a limited number of consumers. Due to the resulting fluctuating consumption pattern, several specific features are required concerning the electricity supplying (Peterschmidt, 2012). Figure 5.3-3 shows a real hybrid power system in Sagar.

Figure 5.3-3 Hybrid Power System on Sagar Island, India, including a small-scale wind turbine and PV

In some places this type of technology is necessary, due to the fact that the fluctuations of weather avoid to have a minimum continuous power. Also taking into account the daily variability of both, solar and wind resources, having more solar radiation in the morning but towards evening, stronger winds are plevalent, ensuring energy production the whole time. This is very useful when prevail only moderate winds at specific times, which alone itself this resource is incapable of guaranteeing the continuous production of energy.

Example of this kind of system is one developed by Southwest Windpower’s company, named Skystream Hybrid 6, which uses a Skystream 3.7 wind generator, six solar panels and a GPS-controlled tracking mechanism that rotates the panels to capture the best available sunlight. The tracking mechanism delivers up to 35 percent more energy than fixed panels on a rooftop, according to the companies. The solar panels and tracker are mounted on the wind turbine’s tower, which minimizes the system’s visual impact and reduces the costs compared with separate systems. State and local incentives for solar and wind systems can reduce the overall costs significantly in many locations (Leveske, 2011). Depending to weather conditions, wind turbines and solar panels produce energy in a combined system. Table 5.3-3 shows specifications of this product (Skystream 3.7 and Solar panels by Southweast

Windpower Co.) and Figure 5.3-4 exemplifies production of energy in different places.

Table 5.3-3 Skystream 3.7 and Solar panels specifications

Wind Turbine		**Solar Panel Specifications**	
AWEA Rated Annual Energy	3,420 kWh*	Solar Panels	235 W PV panels
Rated Power	2.1 kW at 11 m/s	Rated Capacity	1.41 kW (Skystream Hybrid 6™) or 470 W (Skystream Hybrid 2™)
Nominal Power	2.4 kW at 13 m/s	Size, tracking module	44" (112 cm) h x 24.1" (61 cm) diameter
Energy Monitoring	Skyview™ wireless communication & monitoring system	Weight, tracking module	125 lb (57 kg)
Weight	170 lb (77 kg)	Mount	High strength steel
Rotor Diameter	12 ft (3.72 m) Swept Area: 115.7 ft² (10.87 m²)	Operating Environment	All weather
Type	Downwind rotor with stall-regulation control	Temperature operating range	-6 F to 149 F (-21C to +65C)
Direction of Rotation	Clockwise looking upwind	Controller power consumption	0.982 Wh/day typical consumption Sleeping Mode: 0.018 Wh/day Active Mode: 0.964 Wh/day
Blade Material	Fiberglass reinforced composite	Grid Feeding	Microinverters (included)
Number of Blades	3	Sun Tracking	Microprocessor-based true position sun tracking. GPS enabled for automatic initialization. No batteries.
Rotor Speed	50-330 rpm	Sun Tracking Range	Horizon to horizon
Tip Speed	213 ft/sec. (66 m/s)	User Monitoring	Enphase Envoy monitoring system
Alternator	Slotless permanent magnet brushless	Survival Wind Speed	90 mph (40 m/s)
Yaw Control	Passive	Warranty	5 year limited warranty
Grid Feeding	Southwest Windpower inverter 120/240 VAC 50-60 Hz	Tower Mounting	Southwest Windpower 45-19 HD towers for new systems; retrofit options are available for some existing Skystream 3.7 installations.3
Braking System	Electronic stall regulation with redundant relay switch control	---------	---------
Cut-in Wind Speed (power production starts)	6.7 mph (3.0 m/s)	---------	---------

User Control	Wireless 2-way interface remote system	---------	---------
Survival Wind Speed	140 mph (63 m/s)	---------	---------

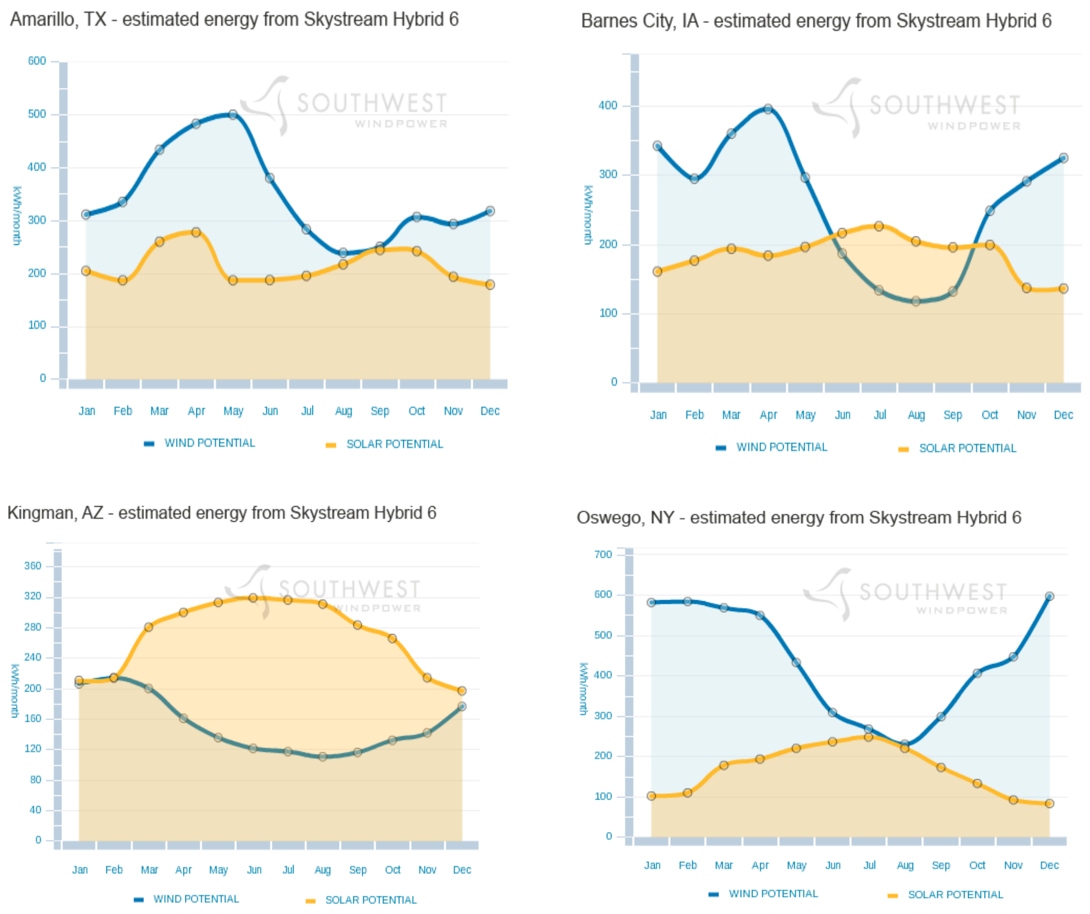


Figure 5.3-4 Wind power generated by Skytream Hybrid 6 in different sites

5.3.3 Rural electrification

Rural electrification with wind power depends absolutely on specific wind resource as seen in the previous chapters. This application of wind power has been widely extended in the recent years as its efficiency has been proved in isolated communities worldwide, especially in developing countries.

According to experience, under optimal conditions of wind, as well as the support of the government, most wind electrification projects consist of the installation of only one turbine, being in most of them the wind turbine which supplies electricity to the residents of the community through battery charging services. There is one experience in Kenya in which one community turbine supplies electricity through a microgrid. In fact, very few projects have used more than one turbine (Ferrer *et al*, 2010).

Taking advantage of its large wind potential, an exception to this has been in Argentina, where an important institutional effort has been carried out for developing rural electrification projects in Chubut (Ferrer *et al*, 2010). In the flat plains of Patagonia, a number of individual systems for rural households have been installed, and some rural village schools were also electrified with a few wind turbines. Figure 5.3-4 shows an example of electrification by an small wind turbine for a house.

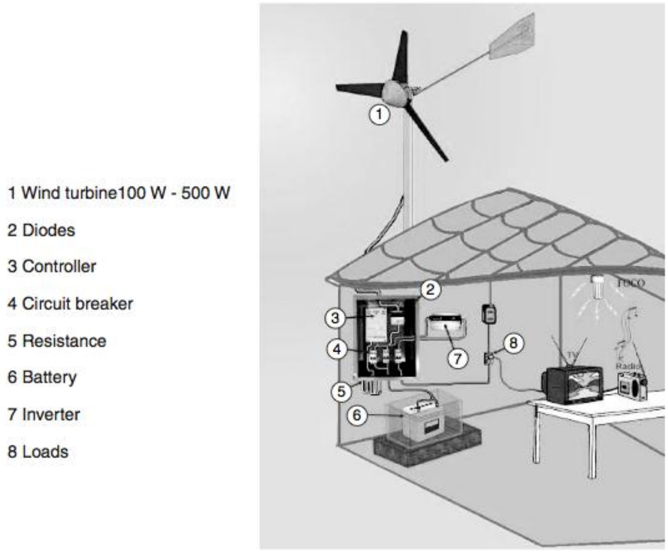


Figure 5.3-4 Small wind power for rural electrification (Ferrer *et al*, 2010)

5.4 Production and costs

A wind turbine has the following characteristic parameters necessary to estimate energy production with a certain wind speed.

- Starting speed: Wind speed [m/s] from which the turbine begins to generate.

- Maximum power: Maximum power [W] at which the turbine can get to work. Cutting speed: Maximum wind speed [m/s] from which the turbine stops generating.
- Voltage: Voltage [V] at which the turbine generates electricity.
- Power curve: indicates the power generated by a wind turbine based on wind speed in standard conditions (25° C and 0 m). With the power curve, one can determine the energy generated ideally, which is a good approximation to reality in low power systems.

Wind turbines are obstacles to the wind, creating turmoil in its trajectory, which may affect the performance of other turbines nearby. Therefore it is recommended to be a minimum separation between these devices as well as to limit the number installed on one point.

At this regard, to minimize mutual interference, the rotors must be located at a certain minimum distance from each other. This is mainly dependent on the system size and the prevailing wind direction. On most horizontal windturbine farms, a spacing of about 6-10 times the rotor diameter is often upheld. However, for large wind farms distances of about 15 rotor diameters should be more economically optimal, taking into account typical wind turbine and land costs. This conclusion has been reached by research (Mayers *et al*, 2011- Belgium University), based on computer simulations that take into account the detailed interactions among wind turbines (wakes) as well as with the entire turbulent atmospheric boundary layer. Moreover, recent research by John Dabiri of Caltech (cited by Mayers, 2011) suggests that vertical wind turbines may be placed much more closely together so long as an alternating pattern of rotation is created allowing blades of neighboring turbines to move in the same direction as they approach one another (Mayers *et al*, 2011).

Such facilities also has a wind controller, whose two main functions are to protect the battery against overload and discharge and pass alternating current generated by the wind turbine to DC with which energy is stored in batteries. The main feature of these components is the maximum power [W] which can bear. This product is obtained from the maximum intensity [A] for voltage [V]. Being power electronics, the losses are negligible. Table 5.4-1 present a comparison in terms of energy production between different small wind turbines at different wind speeds.

Table 5.4-1 Comparison of Annual Energy Production by different small wind turbines

Model	Rated power (KW)	Swept area (m2)	Rotor radius (m)	AEP (hub height wind speed)		
				5 m/s	6 m/s	7 m/s
CF20	20	135	6.55	N/A	N/A	N/A
Gaia-Wind 133-11kW	11	133	6.5	27,502	37,959	46,527
CF15	15	92	5.4	N/A	N/A	N/A
Westwind 20kW	20	82	5.2	N/A	N/A	N/A
Evoco 10	9.55	74	4.85	21,706	31,166	39,542
Aircon 10s	9.8	45	3.8	17,488	26,714	35,500
Xzeres 442SR	10	41	3.6	16,000	25,000	33,500
Bergey Excel 1o	10	38	3.5	13,842	22,300	31,342

Gaia, 2012

Table 5.4-2 Comparison between different wind turbines

WT	Model	Power (kW)	Hub height (m)	Rotor diameter (m)	Generator	Speed (m/s) starting / nominal
ECOTECNIA	E44	640	37	44	Asynchronous	4 / 13
ENERCON	E44	600	46	44	Synchronous	2 / 12,5
GAMESA EOLICA	G47	660	40	47	Asynchronous	4 / 12,5
MADE	AE46	660	45	46	Asynchronous	4 / 15
NEG-MICON	NM48	750	45	48	Asynchronous	4 / 14
MADE	AE52	800	45	52	Synchronous	3,5 / 12
GAMESA EOLICA	G52	850	45	52	Asynchronous	4 / 15

Canary Islands Technological Institute, 2004

Regarding to costs, in the case of an isolated and wind power project, it can vary considerably depending on several factors, among which stand out the electrical capacity installed in kW, including batteries, the use of an inverter and installation aspects. Table 5.4-3 summarizes the costs of small wind turbines respecting its use, electrification or water pumping.

Table 5.4-3 General costs of a small-scale wind project

Use	**WT Price (US $ /kW)**	**Total price (US $ /kW)**	**Other**
Electrification	US$1.500 - US$3.000 (approx. 25% of the total)	US$2.000 to US$4.000 (including batteries, inversor, tower, installation)	Operation and Maintence costs (3-5% of the cost) Replacement of components (usually batteries)
Water pumping	Mechanical system: US$2.500 - US$10.000 Electrical system: US$8.000 – US$25.000	Mechanical system do not need much more equipment. Easy installation. Costs depends in capacity of pumping water (l / s)	Maintenance and Replacement costs are low for mechanical system.

Bun-Ca, 2002

5.5 Mexican regulatory scheme

By the experience of the implementation of small wind turbines in isolated areas around the world, it is known nowadays that a common challenge in isolated electrification systems is guaranteeing the long-term sustainability of the projects by insuring sufficient maintenance and access to replacement parts (Ferrer *et al*, 2010).

Moreover, the regulation in Mexico in this area is still incipient and not very similar to that of other countries. Both in Europe and in the United States (holding major wind energy markets), there are rules that promote incentives for those markets, such as national goals in installed wind power, obligations imposed on electricity companies to purchase certain quantity of electricity from that resource, special rates that companies or governments have to pay for each unit of electricity kWh produced with wind into the grid, and a set of tax incentives and other types. Most of these mechanisms are not applicable in Mexico in the present regulatory environment, making necessary to develop alternative mechanisms.

The legal framework governing the electricity industry in Mexico, contained in the Law of Public Service Electric, in 1993 modified to make explicit the prohibition of the production of electricity for sale to others, as only the CFE can perform this activity (only CFE has the competence to offer power supply); however, this prohibition does not applies to exporters as they can produce electricity in national terrotory and sell it across the border (Huacuz, 2010).

In the self-generation mode, the Law allows individuals and companies to produce electricity for their own consumption, but in practice they have developed schemes where one or more electricity consumers associate as investors and technologists to create companies for electric self-sufficiency, being this, the way that more wind projects have born as independent production. The generation of electricity for sale is a practice reserved only for the CFE, but still not generates the necessary costs to make it competitive with other conventional alternatives.

Although this scheme, the Energy Regulatory Commission (CRE) has issued rules to the imposition of provide premiums and direct economic incentives, that have motivate the development of projects that are in the portfolio. The main motivation of self-sufficiency is the ability to generate their own electricity at lower costs than electricity prices. However, given the intermittent nature of wind and daily and seasonal patterns that characterize this resource, electricity production periods, not always coincide with those of the highest rates (as in the northern border states that have severe weather -warm and cold-, which must be mitigated with technology), so the incentive to use the wind as an energy source, can be lost (Huacuz, 2010). Take into account the savings regarding fuel, when grid connected systems; transportation has been a decisive factor to renewables transition.

What has emerged in this scenario, is the establishment of contracts for interconnection of renewable energy, which offers the option of using the national electric network, not only as a holder, for when the electricity for self-sufficiency is produced and consumed at different point, but also as storage, which means to deliver to CFE surplus electricity when possible, so as to have it back, all under a scheme of established rules.

Other incentive mechanisms include lower costs for the transport of electricity generation to the point of consumption, as well as support services when there is no enough wind. It also include tax incentives for environmental motivation such as 100% of depreciation and exemption of import duties for technology friendly to the environment.

5.5.1 Barriers

A lack of appreciation of other benefits that renewable energy can provide, such as greater price stability and better security generation in energy supply, coupled with the goal of CFE to expand natural gas generation, has led to a minimum development of alternative non-hydraulic sources. In the case of wind energy, a class I potential of about 10,000 MW estimated in Mexico, CFE only plans to develop 500 MW (5%) between 2008 and 2017 (USAID, 2009).

In the case of self-supply mode, a potential barrier to the development of wind energy is the charge for transmission service, as eventually the CFE is responsible for calculating transmission charges, although the CRE was who published the methodology of calculation. This makes difficult the processes of transparency, giving to the CFE major control over the market.

Thus, the main reasons that explain the slow development of wind power in Mexico are the lack of government incentives to encourage the use of renewable energies, as well as the absence of a clear regulatory framework to allow greater private sector participation in development of wind farms.

Although in some specific sites, it has shown an increased interest in developing eolo-electric, both municipalities and states face challenges such as (USAID, 2009):

- Lack of studies that demonstrate the feasibility of the project
- Lack of government investment for project development
- Null definition of regulatory and institutional frameworks for a municipality to develop a project of this type (federal, state and municipal)
- Lack of subsidies
- High costs of interconnection and transmission of electric power
- Social barriers
- Environmental problems

The state and local governments have economic pressures that force them to reduce their costs and therefore to seek energy saving options, mainly in street lighting and water pumping, as only the latter demand is estimated between 5-12 MW (USAID, 2009).

Moreover, the opportunities that exist to develop such projects in municipalities are that the expenditures that make municipal government for electricity concept are increasingly low and, moreover, that the administration can get extra income for carbon bonuses concept, although for this one is probably no longer time to the life of the program. Meanwhile, the company revenue is from the "sale" of electricity directly to the municipality which, coupled with the reduction of GHG, would make the project profitable.

The municipal utilities that can be used in wind power are public buildings (administrative, hospitals, schools, libraries, sports, etc.), street lighting, pumping of water and wastewater and water treatment plants, mainly.

However, municipalities must overcome several barriers (legal, administrative, social, environmental) to implement these projects. For this, there are two patterns of participation.

The first scheme, known as Model of Collaboration Agreement is defined in three parts: 1. The owner of the land where the wind system would be installed; 2.The municipality that would be the largest consumer of electricity produced and 3. the project developer counterpart, including the installation company with their investors. The scheme is to perform a contract which is the collaboration model and each part would participate: The owner of the land leasing it, the municipality acquiring the cheapest electricity and the developer selling energy and carbon credits.

The benefits would be easily to get through a direct assignment of the project, thus avoiding the tendering process. However, the negative point is that due to changes in municipal public administration possibly new administration unknown some contract.

The second model proposed is the creation of an municipal enterprise, ie, a public agency that belongs to the municipal government, with autonomy. The advantage of this scheme is that it is not affected by the renovation of the municipal administration, ensuring the continuity of the project and providing certainty to developers to form a partnership with a permanent institution.

5.6 Application in the surrounding SLP

To implement water pumping by wind power in SLP, first of all must be taken into account the number of liters of water to be pumped either to provide drinking water to a community, or for irrigation or for livestock. This involves a detailed study for a specific objective, determining the specific location where such use would be implemented.

Exist guides to calculate water demand for human water consumption or water for livestock activities. For example, it can be mentioned the UPME (2003), which states that in terms of the amount of clean water required for human consumption, it is estimated that the minimum daily intake per person may vary between 20 and 40 liters per day in some latinamerican countries in rural areas. Take into account that in developed countries this consumption can increase until 100 liters per day (European countries- UK Environment Agency, 2008-) or even until 500 liters per day (in USA) (United Nations Development Program 2006). Even in Mexico, average consumption is more than 300 liters per person, but in rural areas consupmtion as well as availability is quite less. With respect to water supply for animals that daily consumption varies between 20 and 40 liters per head for horses and cattle, reaching 100 liters for cows and, for sheep, goats and pigs can be between 1 and 10 liters per day.

With respect to the calculation of water demand for irrigation, it depends on the size and type of crop, taking into account the levels of evapotranspiration in place. These amounts of water are generally required daily irrigation contained in handbooks.

However, for this particular case, should be noted that it takes at least 3 m / s of wind speed in order to perform this type of use. The IDEA (2006) states that, for example, a multiblade mill of 5 m in diameter, particularly suitable for capturing average flows at 7.5 m/s, is capable of powering 8,000 liters of water per hour from a depth of 50 meters . Such mills are designed to operate efficiently at speeds between 3 and 7.5 m/s. So, according to data from previous chapter, this condition holds for Zacatecas station at a height greater than 20 m and only in the months from February to April. While in the case of SLP this condition is met from 10 meters high (data provided by SMN).

Regarding electrification, a looking for the small-wind turbine market led to compare different wind turbines that could response to available wind in the area –Table 5.6-1-.

Table 5.6-1 Small-wind turbines in the market. Aeolos Co. 2012

Specifications	**Eolos-H 500w Wind Turbine**	**Aeolos WT 1kw**	**Aeolos Wind Turbine 10kw**	**Aeolos WT 30kw**	**Aeolos Wind Turbine 50kw**
Rated Power	500w	1 kw	10 kw	30 kw	50 kw
Maximum Output Power	600w	1.2 kw	13 kw	35 kw	54 kw
Output Voltage	24 V	48 V	--	--	--
Blade Quantity	3 Glass Fiber Blades	3 Glass Fiber	3 Glass Fiber	3 Glass Fiber	3 Glass Fiber

Specifications	**Eolos-H 500w Wind Turbine**	**Aeolos WT 1kw**	**Aeolos Wind Turbine 10kw**	**Aeolos WT 30kw**	**Aeolos Wind Turbine 50kw**
		Blades	Blades	Blades	Blades
sRotor Blade Diameter	2.7m (8.9ft)	3.2 m (10.5 ft)	8 m (26.2 ft)	12.5 m (41.0 ft)	18.0 m (59.1 ft)
Start-up Wind Speed	2.5 m/s (5.6 mph)	2.5 m/s (5.6 mph)	3.0 m/s (6.7 mph)	3.0 m/s (6.7 mph)	3.0 m/s (6.7 mph)
Rated Wind Speed	12 m/s (26.8 mph)	12 m/s (26.8 mph)	10 m/s (22.3 mph)	10 m/s (22.3 mph)	10 m/s (22.3 mph)
Survival Wind Speed	45 m/s (100.7 mph)	45 m/s (100.7 mph)	45 m/s (100.7 mph)	50 m/s (111.5 mph)	50 m/s (111.5 mph)
Generator	Three Phase Permanent Magnetic Generator	Three Phase Permanent Magnetic Generator	Direct-Drive Permanent Magnet Generator	Direct-Drive Permanent Magnet Generator	Direct-Drive Permanent Magnet Generator
Generator Efficiency	>0.96	>0.96	---	-----	---
Turbine Weight	28kg (61.7lbs)	60 kg (132.3 lbs)	420 kg (925.9 lbs)	1380 kg (3042.3 lbs)	3120 kg (6878.3 lbs)
Noise	25 db(A) @ 5m/s	30 db(A) @ 5m/s	45 db(A) @ 5m/s	55 db(A) @ 7m/s	58.5 db(A) @ 7m/s
Temperature Range	-20°C to +50°C	-20°C to +50°C	-20°C to +50°C	-20°C to +50°C	-20°C to +50°C
Design Lifetime	20 Years	20 Years	20 Years	20 Years	20 Years
Warranty	Standard 5 Years	Standard 5 Years	Standard 5 Years	Standard 5 Years	Standard 5 Years

All these turbines are useful for small demands, as can be autonomous electrification and in SLP there exists enough wind speed for starting to operate; however, it is necessary when implementing a project to look for the power curve of each turbine to know the especific energy production to have in a certain site with its regarding wind speed average.

For SLP it was determined to have 3 m/s at 10 m of height, between 3.5 and 4.5 m/s at 20 m and at least 5 m/s at 50m. For example, if taking a 600 W rated power small-wind turbine as can be the Model 600 of Bornay Company, 2.5 m/s are needed for starting to work and we have the next power curve as can be seen in Figure 5.6-2.

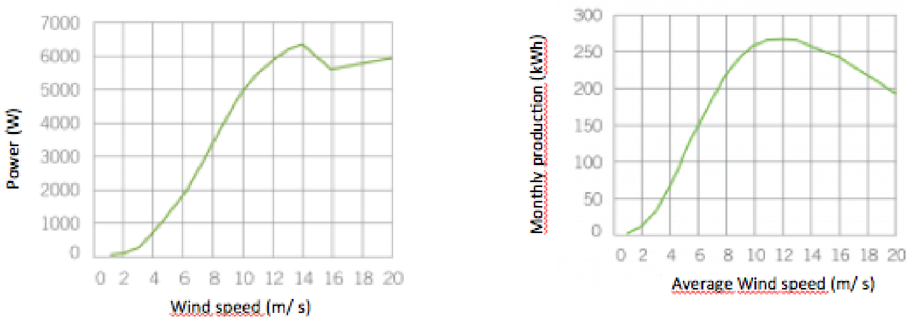


Figure 5.6-2 Power curve and monthly production of a Borney 600 WT

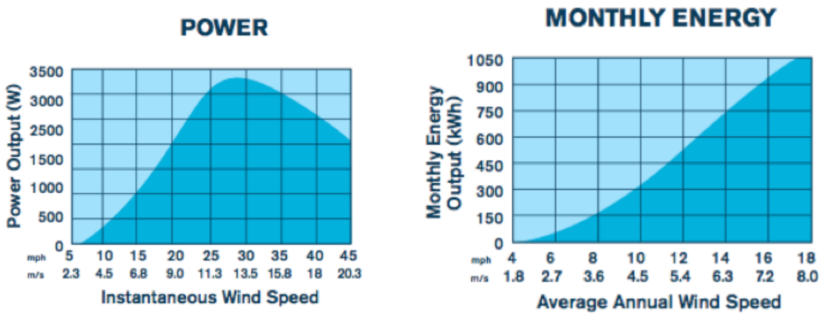
At 20 m hight this turbine could generate approximately 80 kWh, enough to provide electricity in a typical rural home where is common to have just a few devices, typically only TV or radio, and one or two lamps. In the case of having a fredge of 240 W for example, 57.50 kWh monthly are estimated (Ministry of Energy and Mines of Peru, 2004). Table 5.6-2 shows typical consumptions associated with rural homes.

Table 5.6-2 Estimated monthly consumption of such devices in a rural home

Devices	Monthly kWh
Water heater 45 kw	323
Oven cooking 12 kw	100
Radio 50 W	4.5
Fridge STD 12'3 295 W	71
TV B/W 70 W	8.4
Ventilator 85 W	27
Lamps 20 W	15

MEMP, 2004

Another example comes from the turbine Whisper 500, that can produce enough energy to power an entire home, even in urban places. Assuming a 12 mph (5.4 m/s) wind, a Whisper 500 will produce as much as 500 kWh per month. Power curve from this WT shows in Figure 5.6-3.



Southwest Windpower, 2012

www.windenergy.com

Figure 5.6-3 Whisper 500 Power curve and monthly production

The above are just examples of the market at small wind turbines. To implement a project of this scale, must necessarily know the energy requirements to meet, either for consumption or to perform activities relating to agriculture or livestock, or in the case of electrification, if a centralized or decentralized system is required.

The above involves focusing on the analysis of a specific project that is not in the scope of the present thesis work; however, this has served to identify that exploitable potential exists at this scale and requires substantial depth analysis of financial mechanisms under which these small projects can become a reality for low-income people who do not enjoy all public basic services or they are not sufficient to meet all their demands.

Certainly it can be argued that the study of the turbines on the market can be as wide as required as exists a large market like the one we have today. However, like any project, the wind projects involving rural purposes depend mostly of the times on a considerably limited budget which define the type of turbine to be installed. That is, although there is a wide range of highly efficient small wind turbines that operate with low intensity of winds, they have a high economic cost implied to be covered at the beginning of the project, but a long-term vision is going to take the best decision concerning the savings will represent in the future, according to current electricity tariffs, as long as system transcends into a suitable regulatory scheme for consumers.

5.7 Associated costs and Financial schemes

Approximately 75% of the total cost of energy for a wind turbine is related to upfront costs such as the cost of the turbine, foundation, electrical equipment, grid-connection and so on. Fluctuating fuel costs have no impact on power generation costs. Thus a wind turbine is capital-intensive compared to conventional fossil fuel fired technologies such as a natural gas power plant, where as much as 40-70% of costs are related to fuel and O&M (BWEA, 2012).

According to this institution, there are two main influences which affect the cost of electricity generated from the wind, and therefore its final price:

- technical factors, such as wind speed and the nature of the turbines
- the financial perspective of those that commission the projects, e.g. what rate of return is required on the capital, and the length of time over which the capital is repaid.

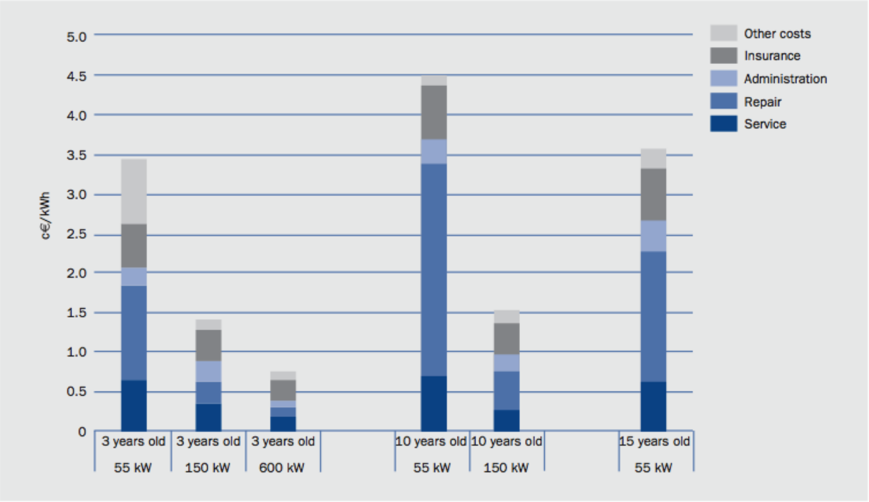
5.7.1 Price of a Wind turbine, O&M and land rent

The price of a wind turbine is a function to their swept rotor surface area and generally speaking in proportion to roughly the square root of their hub height. The size of the generator of a wind turbine plays a fairly minor role in the pricing of a wind turbine, even though the rated power of the generator tends to be fairly proportional to the swept rotor area.

The reason for this is that for a given rotor geometry and a given tip speed ratio, the annual energy yield from a wind turbine in a given wind climate is largely proportional to the rotor area. In relation to tower heights, the production increases with the hub height roughly in proportion to the square root of the hub height (depending on the roughness of the surrounding terrain) (BWEA, 2012).

In the case of small wind turbines, they remain much more expensive per kW installed than large ones, especially if the prime function is to produce grid quality electricity. This is partly because towers need to be higher in proportion to diameter in order to clear obstacles to wind flow and escape the worst conditions of turbulence and wind shear near the surface of the earth. But it is primarily because controls, electrical connection to grid and maintenance are a much higher proportion of the capital value of the system in small turbines than in larger ones, when requieres grid conexion.

O&M costs are considered by the experience of the wind turbines industry as very low in comparison to conventional energy production. However, estimates of O&M costs are still uncertain, especially around the end of a turbine's lifetime. According to information of DWIA (2008), based on experiences in Germany, Spain, the UK and Denmark, O&M costs are generally estimated to be around 1.2 to 1.5 eurocents (c€) per kWh of wind power produced over the total lifetime of a turbine. Spanish data indicates that less than 60% of this amount goes strictly to the O&M of the turbine and installations, with the rest equally distributed between labour costs and spare parts. The remaining 40% is split equally between insurance, land rental and overheads. Figure 5.7-1 shows O&M costs evaluation between different turbines in function of its lifetime as well as its capacity.



Source: Jensen et al. (2002)

Figure 5.7-1 O&M costs for selected types and ages turbines (c€/kWh)(EWEA, 2009)

As can be seen in Figure 5.7-1 the costs of O&M of a wind turbine are quite minnor as its capacity increase despite its lifetime; as Figure shows even at 3 years old wind turbine or a 15 years old one, cost of O&M is major at less capacity.

With regard the land rent, a wind project has to include in the costs, the compensation to use the required land to install the wind power facility. Generally, this costs are quite small taking into account the fact that wind projects use only 1-2% of the space for the installation of turbines, transformers and access roads.

This costs may be include in the O&M of a wind farm or capitalised as an up front payment once and for all to the landowner. The EWEA states that If the amount paid to a landowner for locating a wind turbine on his terrain exceeds the value of the agricultural land (and the inconvenience of having to take account of the turbines and roads when farming the land), then economists refer to the excess payment as land rent.

Land rent is not considered a cost in socioeconomic terms, but is considered a transfer of income, that is to say a redistribution of profits, since the rent can only be earned if the profits on that particular terrain exceed the normal profits required by an investor to undertake a project (EWEA, 2009).

5.7.2 Financial schemes

According to Wizeluis (2007) after analizing European expirience, incentives to promote wind power, can be classified in three categories:

1. Green marketing: voluntary systems where market determines the price and quantity of renewable energy;
2. Fixed prices: systems where government dictates the electricity prices paid to the producer and lets the market determine the quantity, and
3. Quotas: systems where the government dictates the quantity of renewable electricity and leaves it to the market to determine the price.

Experience has demonstrated that the first one is quite inefficient as do not exist a general regulation and thus, do not apply under similar conditions. Systems with fixed prices or quotas are regulated by law, and are thus compulsory and more efficient. For those systems there are several types of support schemes:

1. investment subsidies;
2. fixed feed-in tariffs;
3. fixed premium systems;
4. tendering systems, and

5. tradable green certificate systems

In the case of “investment in subsidies”, the advantage is that is a simple system and that the subsidies are paid up front (as Denmark and Germany have proved before). The support cannot be reduced or withdrawn during the lifetime of the Project and this gives security to investor. The drawback is that is does not differentiate good projects from bad. Investment subsidies have nowadays only working at regional level in Spain.

In the case of fixed feed-in tariffs, the price paid for wind-generated electric power is fixed, either to a specific value or in relation to the consumer price. The price can be fixed for the lifetime of the turbine or until a specified target is reached. The system guarantees that all the investors will always get their money back. This kind of scheme has also been successfully prove in Denmark, Germany and Spain.

The fixed premiums has been used in combination with other promotion strategies. The premiums, in Sweden called environment bonuses, reward operators for health and environment costs avoided by wind power. In practice, the value of the premium is set in relation to the power price to make wind power competitive.

The tendering systems have been used in the UK, the NFFO (Non-Fossil Fuel Obligation) system. This hasn’t work very well, however, since many of the projects that won the tenders were never built, and has now been replaces by a green certificate system. Tendering is still used for offshore development in Denmark and UK.

Finally, the certificates have been introduced in the recent years in countries like, Italy (2002), UK (2002), Belgium (2002) and Sweden (2003). Producers get certifcates based on the produced power during a year; these certificates can be treated on a certificate market where the price is set a supply and demand.

CHAPTER VI CONCLUSIONS

Applying climate analysis of wind frequency distribution (Weibull dist.) by WASP tool for Matehuala, Zacatecas, and SLP meteorological stations, so as to Yolíatl and Charcas agroclimatic stations, found only a moderate potential for rural uses in SLP station, resulting 60.50 W/m^2 at 10 m, 118.50 at 20m and 287.50 at 50m. Zacatecas side may be considered moderate, but only at 50 m.

However it should be noted that this estimate was based on data provided by SMN, data that were incomplete for some periods of time. Therefore, from the foregoing, it is necessary to count with the adequate data and as complete as possible, as this will also ensure closer estimation.

Being all these data obtained from a sample over a period of time, the results are estimates and as such have a number of associated uncertainties, these uncertainties are due to imprecisions in the measuring instruments, the representativeness of the site measure, vertical profile of velocities, period and data availability, among others.

One of the most important findings is the need of more meteorological information in Mexico, as there are not enough weather stations that record the necessary data in remote areas such as in the Highlands region of San Luis Potosi, so stations had to be the closer and not necessarily within the area of interest. It became evident this lack of data at being analyzed, reason why it is recommended at the same time to take the necessary steps to improve its quality and ensure the registration of all of them every ten minutes as expected. It was identified the lack of wind speed data; however not in all cases involved the lack of other meteorological information such as humidity, solar radiation, etc., which means that SMN have to solve the currently faults present in anemometers and/or in registration systems.

From the above emerges the need for field verification of cabinet work, wherever possible this verification may "reduce" the range of error in the estimate at ensure that wind speeds behave is as on the record, since the entire estimate is based on it.

As mentioned, the best practice is to make the estimation of wind potential counting with as much data as possible. However, the potential for rural uses identified in SLP was as the estimated in 1995 by the NREL, being Mexico a country with long lags on poverty in which to find this potential is valuable by rectifying this potential with mostly current and accurate data, fact that can become part of a development strategy for those isolated communities.

It was also confirmed the existence of potential in the area of the SLP municipalty according to preliminary map of solar and wind resource in Mexico recently available for public consultation on the SENER website. However, towards Charcas, area located in approximately the middle of the highlands region, where was expected to identify more potential; contrary to this, it was found negligible potential, even at higher heights.

It is noteworthy that the estimated wind energy potential using a computational tool called WASP, being this software one of the most demanded in the market for this purpose, was carried out by a student license with their own limitations, which together with the lack of some data, restricted the complete modeling of wind in the area (horizontal extrapolation). Nonetheless, it was performed the wind climate analysis (2 or 3 years by analized station) at 10, 20 and 50 m of height, taking into account prevailing roughness parameters of the terrain.

This work was useful for the specific information that was generated through it, since in Mexico energy production through renewable sources is not deeply explored despite having renewable resources, interest has been only manifested to study and exploit those areas where the incidence of strong winds is evident most of the year, and not towards the interior of country, where may winds are quite minor, but can generate useful potential for medium or low level.

In the case of wind power, quite different is the creation of large wind farms for which must be available wind speeds of at least 7 m/s, in comparison with the use of wind energy even at 3 m/s, which takes far less economic resources but huge profits to benefit people at the rural level. However, given the intermittent nature of the wind resource, it is essential to ensure the incidence of winds and periods when this is greater, to ensure a minimum of energy production (highly related also to rotor diameter) and to adapt to the needs, whether for water pumping to human drinking, for cattle troughs or irrigation in agriculture activities, depending on the liters to be pumped as well as the depth of the wells, or in other cases, for electrification of houses, fences and street lighting just to mention the most common uses at low scale.

Despite the unfortunate economic situation and standard of living faced by people living in rural areas as in the case of many communities of SLP, is important to promote renewable energy because of its large benefits over oil depletion and critical stage of current climate change. Renewable sources such as solar radiation and wind should be exploited by being a renewable, clean and free, and also on the environmental side, by being low-impact technologies with regard to the low cost that represent at mid and long term respecting to conventional energies.

Main costs are highly dependant on the wind turbine and equipment, being wind turbines size and capacity related to the energy demand, which define the larger cost. Adding to this, rotor diameter and prevailing wind speed in a site, are factors that define annual energy production and necessary storage, both also implied in the equipment costs. O&M costs are very small compared with other conventional types of energy production. Land rent is a necessary cost but its magnitud is related to the kind of terrain, its use, the owner and the regulations in the place.

Recognition of renewable sources as clean energy producers and at much lower costs, left implicit the increase of standard of living of those who use them, which for rural communities represent a potential benefit of development, both economic and social, as these projects also create jobs. However, when a eolic project is contemplated, it has also to be taken into account all the social aspects involved, as can be places with high cultural or religious value.

As for environmental impacts are concerned, wind energy has presented a substantial development through their advances as a low-impact technology, such as improved building materials as well as the efficiencies of the turbines, noise abatement and its implementation in harmony with the landscape, which has been placing the technology as less impact and more environmentally friendly among all renewables.

For these reasons and because of the privileged geographical location of Mexico, its exploration and development should be boosted, both in large and small-scale, for which is required in the first instance an adequate regulatory framework that benefits the implementation of these technologies and to support small producers.

In this regard, the challenges faced by states and municipalities to develop projects generating electricity by harnessing wind power are many, among which be can mentioned: 1) the lack of studies which demonstrate the feasibility, 2) the lack of support by government to invest even in places where it has identified the potential, 3) no definition of institutional regulatory frameworks for a municipality to develop a project of this type (federal, state and municipal levels), and 4) lack of subsidies, since in the country have high interconnection and power electricity transmission costs.

A new regulatory framework should supose the inclusion of issues such as the reactivation of the metal-working industry, creating jobs and boosting specialized services in wind power, not being minnor the subject of politics, as it is widely involved in the lack of development of renewables. It is certain that to date aspects of land holdings, and the lack of clear regulations about (electricity generation permits, leases and land possession, mainly) imply that only a few will benefit from these technologies; meanwhile, all levels of government have declined to grant certainty about it.

Until now there has only been interest in making large wind sites that guarantee a fair amount of MW of annual production, useful for industrial and commercial sectors, ignoring the advantages of small-scale wind power, which can benefit farmers causing a very low impact with regard to the large wind, as proven in various European locations.

From the regulatory side, it has to be mentioned that in 2008 was created the Law for the Use of Renewable Energy and Energy Transition Financing, that despite missing several important aspects to regulate, another ones as the promotion of the research as well as certain environmental and economic benefits among other are considered. However, it leaves many outstanding issues as the financing process to encourage research, and the creation of companies dedicated to the field of renewables. Nevertheless it is expected that in the short term this Act becomes the basis for development and implementation of such projects to be impulse of social and economic development as dictated by experience from other countries.

Although it has long and successful experience in wind projects in European countries that have demonstrated the range and scale of applications of this type of energy production, experience of other developing countries that use it mostly for rural applications with natural, technical and financial resources on which them counts with, they provide important contributions about how to implement a wind power with few resources and using simplified methods of wind estimates as small-scale potential studies are unfeasible to perform in comparison to those conventionally carried out when implementing a large project.

The above bring us back to the times when wind energy was obtained with sampler and austere instruments than current; however, it remind us how benefited was the society with this type of technologies that did not require quite a high costs and rethink the fact to be highly dependant of what market sells, when exist applications that need less resources and grant large benefits to particular society groups.

These benefits of small-scale energy production have been dismissed because they do not imply a considerable economic gain for a company. However, from the perspective of social development, these projects have a high positive impact which resides in increasing the standard of living for a low cost for the consumer.

Finally, this thesis has contributed as far as possible, to generate certain information about the wind potential in a specific area through a specific computational tool, that despite of the inherent contingencies that arose in its realization, it have served to recommend actions for future work to be taken into account to reduce the uncertainty of the results in the study of a wind project purposes, as the wind resource is a highly variable, reason why should be studied in detail.

It also intends to conduct interest towards the development of rural wind energy purposes, in one of the poorest states in Mexico, being this a preliminary analysis which assumes the existence of the resource technically feasible near the municipality of San Luis Potosi that can be useful for pumping water or electrification.

REFERENCES

Almonacid B., Nahuelhual M., 2009. **Estimación del potencial eólico y costos de produccion de energia eolica en la costa de Valdivia, sur de Chile.** Instituto de Economía Agraria, Universidad Austral de Chile.

Andersen, 1997. [RISOE, 1997] Review of Historical and Modern Utilization of Wind Power. Available in: http://www.risoe.dtu.dk/rispubl/VEA/Review_Historical_Modern_Utilization_Wind_Power.pdf

Argentine Wind Energy Association, 2008. **Gestión de variables meteorológicas y mapeo eólico.** Faiella L., Gesino A. Área de Investigación y Desarrollo.

Bañuelos F., Angeles C., Serrano J. Y Munciño D., 2008. **Análisis y Validación de la Metodología usada para la obtención de perfiles de velocidad de viento**. Universidad Nacional Autónoma de México.

BWEA, 2012. **The economics of wind energy**. British Wind Energy Association. Renewable UK. Available in: www.bwea.com

Canarias Islands Tecnological Institute, 2004. Aquamac Project. **Guía para la realización de estudios de viabilidad técnico-económica de las instalaciones de aprovechamiento de la enegía eólica en los ciclos de agua.**

Canwea 2012. **Small Wind Energy**. Typical Appications. Canadian Wind Energy Association.

Cárdenas E., Rivera W., 2008. **Análisis estadístico de Mediciones de la velocidad del viento utilzando la técnica de valores desviados.**

CFE, 1993. **Wind regionalization map of the Mexican Republic**. Civil Works Manual.

CFE, 2006. **Parque Eólico en el Itsmo de Tehuantepec**. Comisión Federal de Electricidad. Available in www.conae.gob.mx

CIEMAT, 2008. Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas-**Aerogeneradores de potencia inferior a 100 kw**. Cuesta M., et. al. Gobierno de España. Pp. 3-8.

CNA/SMN, 2011. Comisión Nacional del Agua / Servicio Meteorológico Nacional. **Estaciones Meteorológicas Automáticas y Estaciones Sinópticas Meteorológicas.** Available in: http://smn.cna.gob.mx/

CONAPO, 2005. Consejo Nacional de Población. **Índices de marginación**. Anexo B. Índice de marginación nacional e índice de marginación por estado.

Conrado, 2006. **Método simplificado para la determinación del potencial eólico cuando se desean instalar pequeñas máquinas eólicas.** Centro de Estudio de Tecnologías Energéticas Renovables (CETER). Ciudad de la Habana, Cuba.

D'Ambrosio M. and Medaglia M., 2010. **Vertical Axis Wind Turbines: History, Technology and Applications.**

DTU, 2012. Technical University of Denmark. **The Wind Atlas Analysis and Application Program.** Available in: http://www.wasp.dk/?sc_lang=en

ECW, 2012. **Parts of a Wind Turbine**. Energy Center of Winsconsin.

Environment Agency, 2008. Water environment. **International comparisons of domestic per capita consumption**. UK. Available in: http//publications.environment-agency.gov.uk
P. 16-18.

EWEA, 2009. **The economics of wind energy**. A report by the EWEA. The European Wind Energy Association. P. 37, 73-87.

Ferrer-Martí L., Garwood A., Chiroque J., Escobar R., Coello J. Y Castro M. 2010. **A community small-scale wind generator project in Perú**. MultiScience Publishing Company. Vol. 34. No. 3. UK. Available in:
tp://www.greenempowerment.org/attachments/rnXHY_CommunitySmall-ScaleWindGenerationinPeru.pdf

Gaia, 2012. Wind turbines. Gaia-Wind Manufacturer. Available in www.gaia-wind.com.

García P., Silván F., Zapico P. 2005. **Evaluación de recursos eólicos con WasP**. Técnica Industrial No. 256.

GWEC, 2010. Global Wind Energy Council. **Global Wind Report. Annual market update 2010**. Pp. 11-14.

Gónzalez-Ávila, Beltrán-Morales, Troyo-Dieguez, *et al*. **Potencial de aprovechamiento de la energía eólica para la generación de energía eléctrica en zonas rurales de México.** *INCI*. [online]. abr. 2006, vol.31, no.4 [citado 30 Diciembre 2010], p.240-245. Available in:

<http://www.scielo.org.ve/scielo.php?script=sci_arttext&pid=S0378-18442006000400002&lng=es&nrm=iso>. ISSN 0378-1844.

Hau, 2006. Wind Turbines. Fundamentals, Technologies, Applications, Economics. 2nd Ed. P. 4, 451-470, 509, 572.

Hazcuz J. 2010. **Energía Eólica en México ¿Y para México?.** Ciencia y Desarrollo.

IAE, 2003. Instituto Argentino de la Energía “General Mosconi”. Energía Eólica.

IDEA, 2006. Manual Eólico. España. Bombeo de agua. P. 61.

IEE, 2005. **Prospectiva de la Tecnología de Generación Eoloeléctrica**. Available in: http://www.renovables.gob.mx/renovables/portal/Default.aspx?id=1651

INAFAP, 2012. Instituto Nacional de Investigaciones Forestales, Agrícolas y Pecuarias. **Red Nacional de Estaciones Agroclimáticas**. Sagarpa. Available in: http://clima.inifap.gob.mx/redclima/default.aspx

INAFED, 2005. Instituto Nacional para el Federalismo y el Desarrollo Municipal. **Medio Físico de San Luis Potosí**. Gobierno del Estado de San Luis Potosí.

INE, 2012. **El cambio climático en México**. Información por estado y sector. Available in: www2.ine.gob.mx/cclimatico/edo_sector/estados/zacatecas.html

INEGI, 20011. Instituto Nacional de Estadística y Geografía. **Aspectos geográficos de San Luis Potosí**. Available in: http://mapserver.inegi.gob.mx/geografia/espanol/estados/slp/ubic_geo.cfm?c=1203&e=24&CFID=2038646&CFTOKEN=46590557

IIE / SENER, 2010. Instituto de Investigaciones Eléctricas / Secretaría de Energía. **Potencial eólico y solar en México.** 2010. Available in: http://www.sener.gob.mx/#

Instituto de las Américas, 2010. **Potencial éolico de México**. Mesa redonda sobre energía en México. Available in: http://www.iamericas.org/presentations/energy/Mexico_2010/Carlos_Arriola.pdf

Lega B. 2010. **Modelo para el diseño de proyectos de electrificación rural en consideraciones técnicas y sociales**. Universitàt Politècnica de Catalunya.

Leveske, 2011. **Wind Solar Hybrid System**. American Wind Energy Association. Available in: www.awea.org.

Meteosim SL, 2005. **Estudio del recurso eólico de Cantabria con Mesomap**. Principal author: Vidal J. Dirección General de Industria.

Meteosim True Wind SL, 2008. **Nuevo atlas eólico de alta resolución del estado de Jalisco.** Vidal J., Aymami J., Barcelona.

Meyers J. and Meneveau C., 2011. **Optimal turbine spacing in fully developing wind farm boundary layers**. Wind energy. Vol. 15. Issue 2. P. 305-317.

Ministry of Energy and Mines of Peru, 2004. U**sos de la Energía Eólica para generar energía en bajas potencias**. P. 8, 18, 19.

NREL, 1995. National Renewable Energy Laboratory. **Mexico Wind Resource Assessment Project**. Schwartz and Elliott.

NREL, 2004. National Renewable Energy Laboratory. **Atlas de Recursos Eólicos del Estado de Oaxaca**. D. Elliot. Pp. 7-18.

Núñez, et. al, 2011. **Estimación de Potencial Eólico en Tres Regiones del Estado de Zacatecas, México.** Unidad Académica de Ingeniería Eléctrica, Universidad Autónoma de Zacatecas. Instituto de Investigaciones Eléctricas.

Nyzar J., 2010. **Performance analisys of wind reosurce assessment software in different wind sites in Mexico and Brazil.** Universidad Autónoma de San Luis Potosí / Cologne University of Applied Sciences.

OLADE, 1983. Organización Latinoamericana de Energía. **Atlas Eólico Preliminar de America Latina y el Caribe**. Programa Regional de Energía.

PDU, 2000. **Plan de Desarrollo Urbano de San Luis Potosí, 2000-2020**. Secretaría de Desarrollo Urbano, Comunicaciones y obras públicas. Gobierno del Estado de San Luis Potosi. Secretaría de Desarrollo Social. Universidad Autónoma de San Luis Potosí.

Peterschmidt N., 2012. **Hybrid Power Systems. An Introduction**. WWEA Hybrid System Working Group Inensus GmbH. Germany. Available in: http://www.wwindea.org/

Piralla 2001. **Diseño Estructural**. 2nd Ed. Limusa. Cap. Efectos del Viento. P. 207-217. México.

REUK, 2012. Renevable Energy United Kingdom. **Betz Limit**. Available in http://www.reuk.co.uk/

TWC, 2012. **The Wind Coalition**. History of Wind Energy. Departament of Energy. Available in: http://www.windcoalition.org/wind-energy/history

USAID 2009a. United States Agency International Development. **Análisis Comparativo del Marco Eléctrico Legal y Regulatorio de EE. UU. y México para la Promoción de la Energía Eólica.**

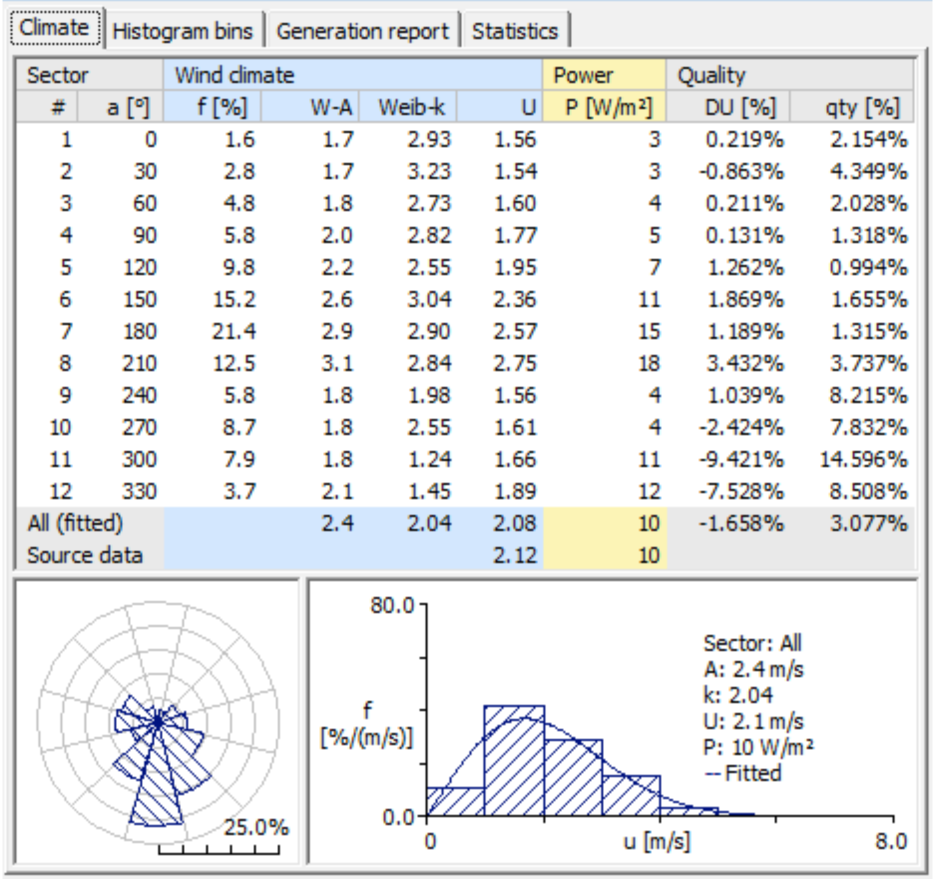
USAID, 2009b. United States Agency International Development. **Elementos para la Promoción de la Energía Eólica en México.** Available in: www.amdee.org/LiteratureRetrieve.aspx?ID=44031

Wind Energy Division at Risø DTU, Denmark, 2011. Available in: http://risoe.dtu.dk/WAsP/

Wizelius Y., 2007. **Developing wind power projects**. Theory and Practice. UK. P. 139-145, 165.

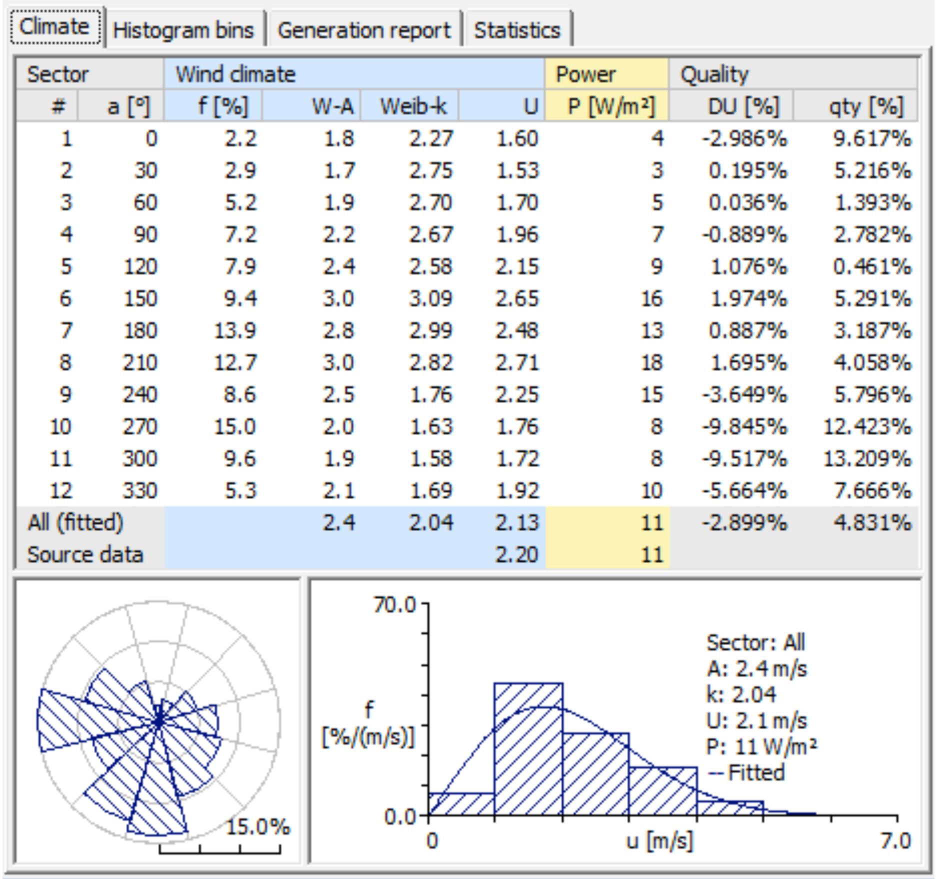
WWEA, 2011. Asociación Mundial de Energía Eólica. **Reporte Anual de la Energía Eólica en el Mundo 2010.** Available in: http://www.wwindea.org/home/images/stories/pdfs/worldwindenergyreport2010_e.pdf

Matehuala. January 2008. 10m



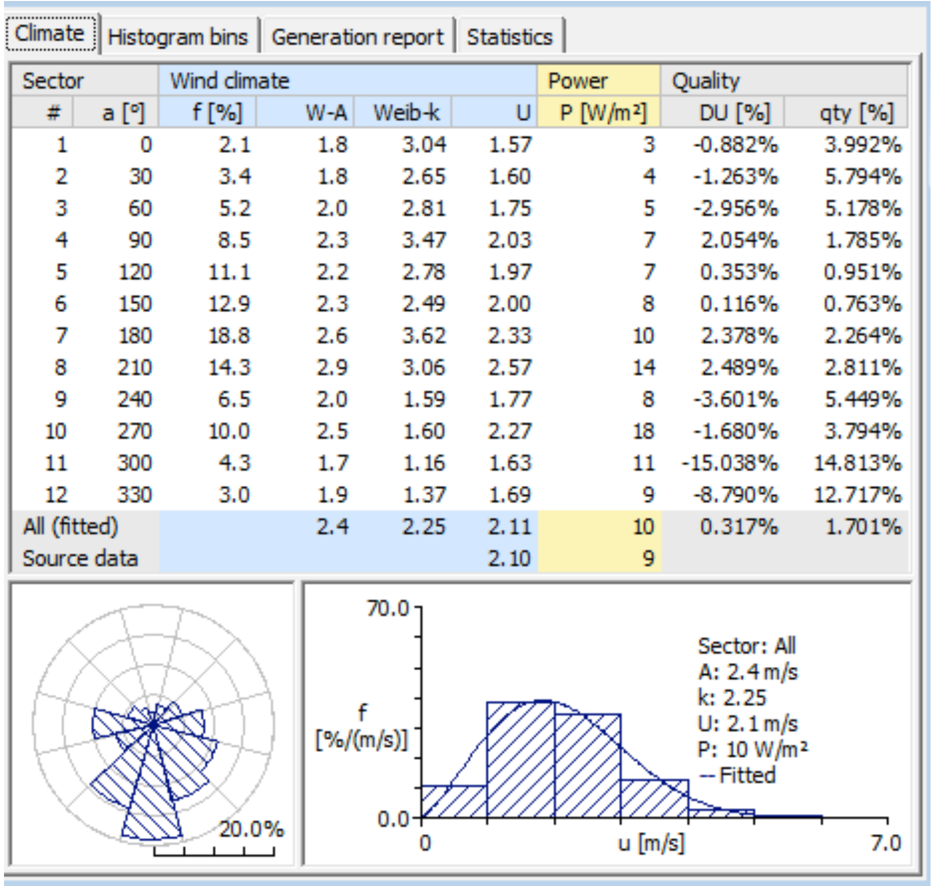
Sector		Wind climate				Power	Quality	
#	a [°]	f [%]	W-A	Weib-k	U	P [W/m²]	DU [%]	qty [%]
1	0	1.6	1.7	2.93	1.56	3	0.219%	2.154%
2	30	2.8	1.7	3.23	1.54	3	-0.863%	4.349%
3	60	4.8	1.8	2.73	1.60	4	0.211%	2.028%
4	90	5.8	2.0	2.82	1.77	5	0.131%	1.318%
5	120	9.8	2.2	2.55	1.95	7	1.262%	0.994%
6	150	15.2	2.6	3.04	2.36	11	1.869%	1.655%
7	180	21.4	2.9	2.90	2.57	15	1.189%	1.315%
8	210	12.5	3.1	2.84	2.75	18	3.432%	3.737%
9	240	5.8	1.8	1.98	1.56	4	1.039%	8.215%
10	270	8.7	1.8	2.55	1.61	4	-2.424%	7.832%
11	300	7.9	1.8	1.24	1.66	11	-9.421%	14.596%
12	330	3.7	2.1	1.45	1.89	12	-7.528%	8.508%
All (fitted)			2.4	2.04	2.08	10	-1.658%	3.077%
Source data					2.12	10		

Matehuala. February 2008. 10m



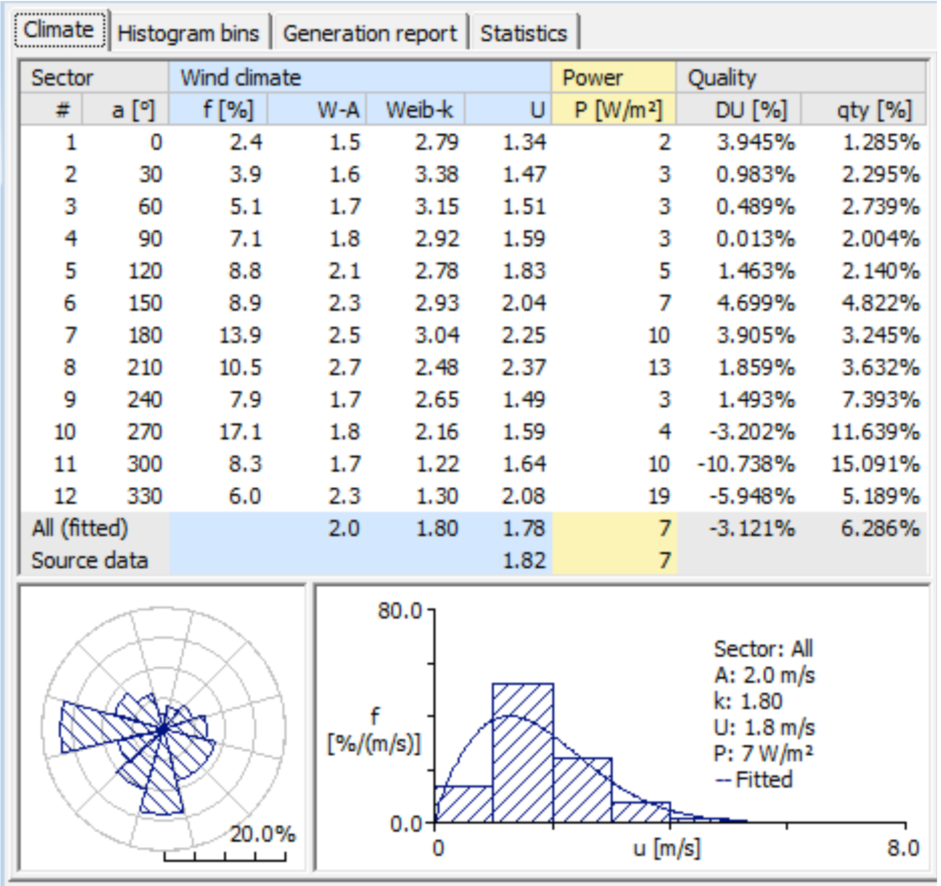
Sector		Wind climate				Power	Quality	
#	a [°]	f [%]	W-A	Weib-k	U	P [W/m²]	DU [%]	qty [%]
1	0	2.2	1.8	2.27	1.60	4	-2.986%	9.617%
2	30	2.9	1.7	2.75	1.53	3	0.195%	5.216%
3	60	5.2	1.9	2.70	1.70	5	0.036%	1.393%
4	90	7.2	2.2	2.67	1.96	7	-0.889%	2.782%
5	120	7.9	2.4	2.58	2.15	9	1.076%	0.461%
6	150	9.4	3.0	3.09	2.65	16	1.974%	5.291%
7	180	13.9	2.8	2.99	2.48	13	0.887%	3.187%
8	210	12.7	3.0	2.82	2.71	18	1.695%	4.058%
9	240	8.6	2.5	1.76	2.25	15	-3.649%	5.796%
10	270	15.0	2.0	1.63	1.76	8	-9.845%	12.423%
11	300	9.6	1.9	1.58	1.72	8	-9.517%	13.209%
12	330	5.3	2.1	1.69	1.92	10	-5.664%	7.666%
All (fitted)			2.4	2.04	2.13	11	-2.899%	4.831%
Source data					2.20	11		

Matehuala. March 2008. 10m



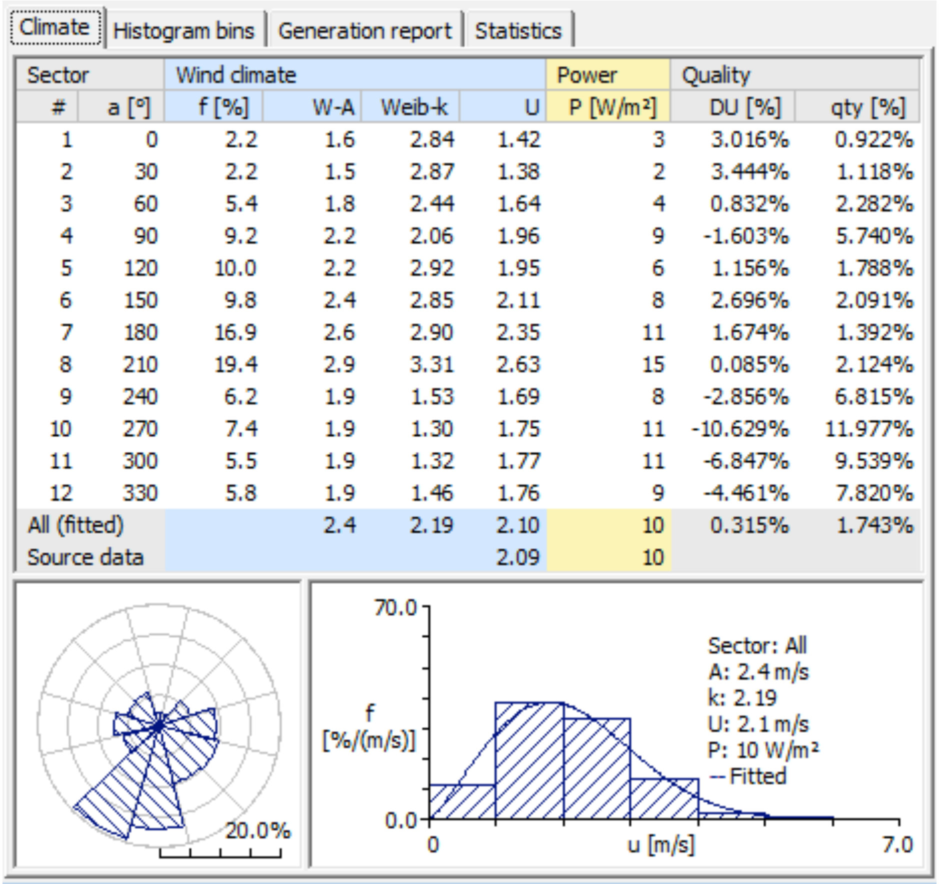
Sector		Wind climate				Power	Quality	
#	a [°]	f [%]	W-A	Weib-k	U	P [W/m²]	DU [%]	qty [%]
1	0	2.1	1.8	3.04	1.57	3	-0.882%	3.992%
2	30	3.4	1.8	2.65	1.60	4	-1.263%	5.794%
3	60	5.2	2.0	2.81	1.75	5	-2.956%	5.178%
4	90	8.5	2.3	3.47	2.03	7	2.054%	1.785%
5	120	11.1	2.2	2.78	1.97	7	0.353%	0.951%
6	150	12.9	2.3	2.49	2.00	8	0.116%	0.763%
7	180	18.8	2.6	3.62	2.33	10	2.378%	2.264%
8	210	14.3	2.9	3.06	2.57	14	2.489%	2.811%
9	240	6.5	2.0	1.59	1.77	8	-3.601%	5.449%
10	270	10.0	2.5	1.60	2.27	18	-1.680%	3.794%
11	300	4.3	1.7	1.16	1.63	11	-15.038%	14.813%
12	330	3.0	1.9	1.37	1.69	9	-8.790%	12.717%
All (fitted)			2.4	2.25	2.11	10	0.317%	1.701%
Source data					2.10	9		

Matehuala. April 2008. 10m



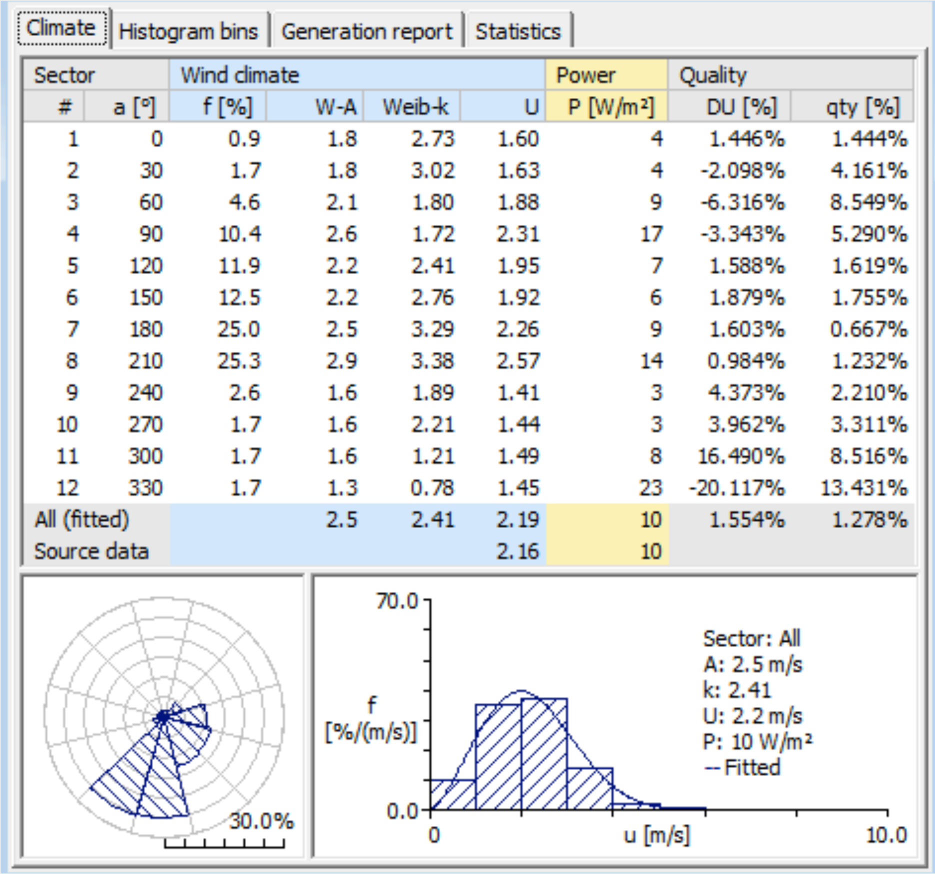
Sector		Wind climate				Power	Quality	
#	a [°]	f [%]	W-A	Weib-k	U	P [W/m²]	DU [%]	qty [%]
1	0	2.4	1.5	2.79	1.34	2	3.945%	1.285%
2	30	3.9	1.6	3.38	1.47	3	0.983%	2.295%
3	60	5.1	1.7	3.15	1.51	3	0.489%	2.739%
4	90	7.1	1.8	2.92	1.59	3	0.013%	2.004%
5	120	8.8	2.1	2.78	1.83	5	1.463%	2.140%
6	150	8.9	2.3	2.93	2.04	7	4.699%	4.822%
7	180	13.9	2.5	3.04	2.25	10	3.905%	3.245%
8	210	10.5	2.7	2.48	2.37	13	1.859%	3.632%
9	240	7.9	1.7	2.65	1.49	3	1.493%	7.393%
10	270	17.1	1.8	2.16	1.59	4	-3.202%	11.639%
11	300	8.3	1.7	1.22	1.64	10	-10.738%	15.091%
12	330	6.0	2.3	1.30	2.08	19	-5.948%	5.189%
All (fitted)			2.0	1.80	1.78	7	-3.121%	6.286%
Source data					1.82	7		

Matehuala. May 2008. 10m



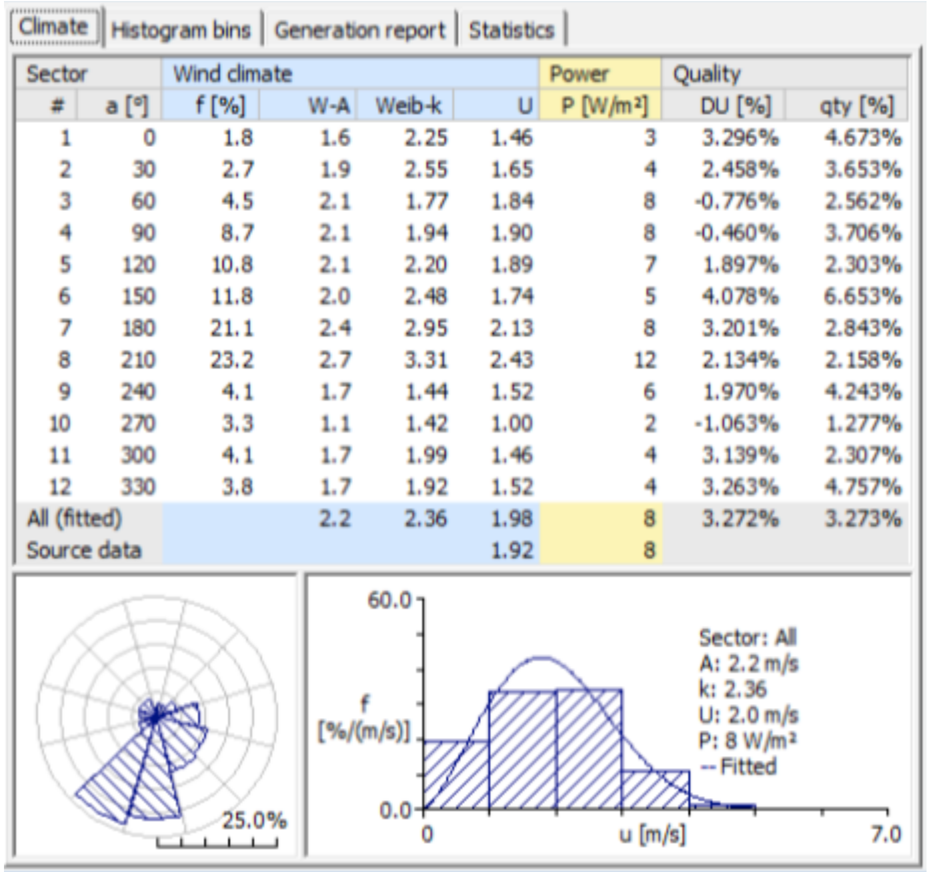
Sector		Wind climate				Power	Quality	
#	a [°]	f [%]	W-A	Weib-k	U	P [W/m²]	DU [%]	qty [%]
1	0	2.2	1.6	2.84	1.42	3	3.016%	0.922%
2	30	2.2	1.5	2.87	1.38	2	3.444%	1.118%
3	60	5.4	1.8	2.44	1.64	4	0.832%	2.282%
4	90	9.2	2.2	2.06	1.96	9	-1.603%	5.740%
5	120	10.0	2.2	2.92	1.95	6	1.156%	1.788%
6	150	9.8	2.4	2.85	2.11	8	2.696%	2.091%
7	180	16.9	2.6	2.90	2.35	11	1.674%	1.392%
8	210	19.4	2.9	3.31	2.63	15	0.085%	2.124%
9	240	6.2	1.9	1.53	1.69	8	-2.856%	6.815%
10	270	7.4	1.9	1.30	1.75	11	-10.629%	11.977%
11	300	5.5	1.9	1.32	1.77	11	-6.847%	9.539%
12	330	5.8	1.9	1.46	1.76	9	-4.461%	7.820%
All (fitted)			2.4	2.19	2.10	10	0.315%	1.743%
Source data					2.09	10		

Matehuala. June 2008. 10m



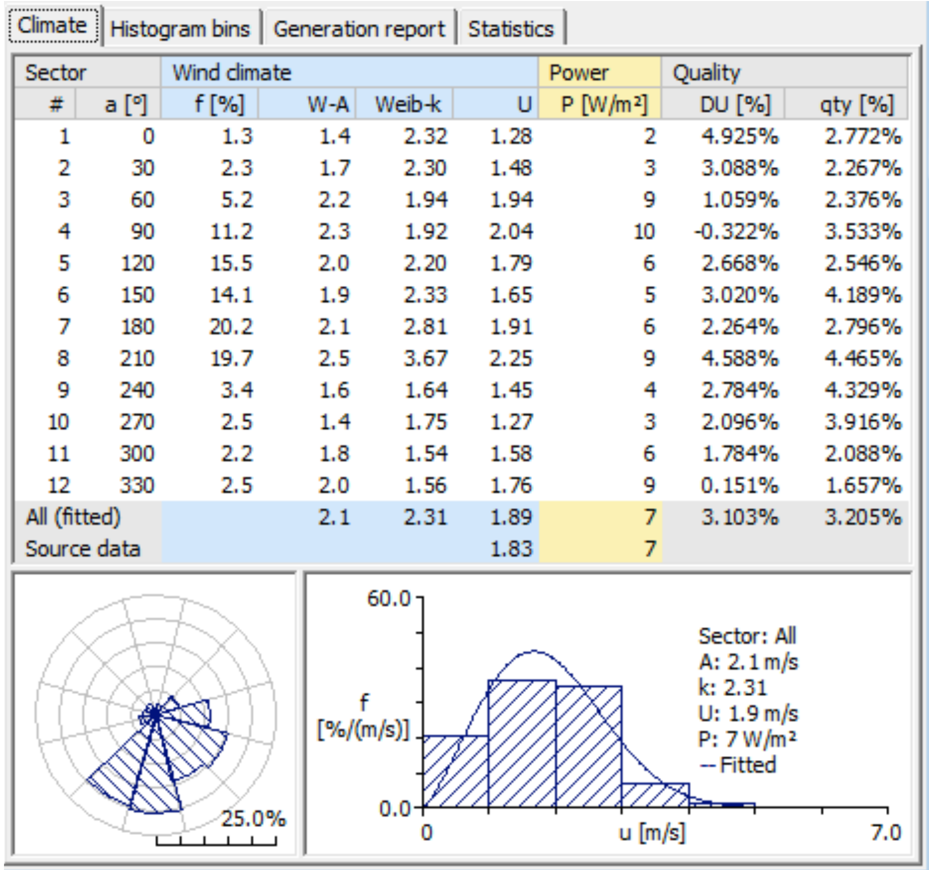
Sector		Wind climate				Power	Quality	
#	a [°]	f [%]	W-A	Weib-k	U	P [W/m²]	DU [%]	qty [%]
1	0	0.9	1.8	2.73	1.60	4	1.446%	1.444%
2	30	1.7	1.8	3.02	1.63	4	-2.098%	4.161%
3	60	4.6	2.1	1.80	1.88	9	-6.316%	8.549%
4	90	10.4	2.6	1.72	2.31	17	-3.343%	5.290%
5	120	11.9	2.2	2.41	1.95	7	1.588%	1.619%
6	150	12.5	2.2	2.76	1.92	6	1.879%	1.755%
7	180	25.0	2.5	3.29	2.26	9	1.603%	0.667%
8	210	25.3	2.9	3.38	2.57	14	0.984%	1.232%
9	240	2.6	1.6	1.89	1.41	3	4.373%	2.210%
10	270	1.7	1.6	2.21	1.44	3	3.962%	3.311%
11	300	1.7	1.6	1.21	1.49	8	16.490%	8.516%
12	330	1.7	1.3	0.78	1.45	23	-20.117%	13.431%
All (fitted)			2.5	2.41	2.19	10	1.554%	1.278%
Source data					2.16	10		

Matehuala. July 2008. 10m



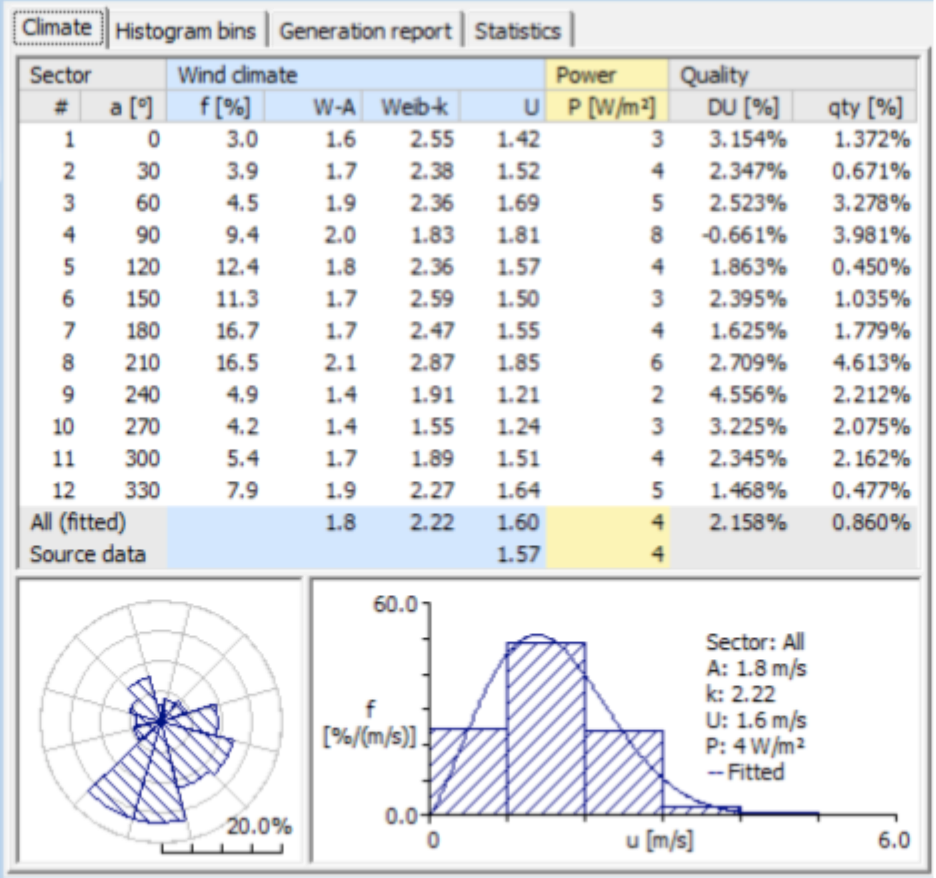
Sector		Wind climate				Power	Quality	
#	a [°]	f [%]	W-A	Weib-k	U	P [W/m²]	DU [%]	qty [%]
1	0	1.8	1.6	2.25	1.46	3	3.296%	4.673%
2	30	2.7	1.9	2.55	1.65	4	2.458%	3.653%
3	60	4.5	2.1	1.77	1.84	8	-0.776%	2.562%
4	90	8.7	2.1	1.94	1.90	8	-0.460%	3.706%
5	120	10.8	2.1	2.20	1.89	7	1.897%	2.303%
6	150	11.8	2.0	2.48	1.74	5	4.078%	6.653%
7	180	21.1	2.4	2.95	2.13	8	3.201%	2.843%
8	210	23.2	2.7	3.31	2.43	12	2.134%	2.158%
9	240	4.1	1.7	1.44	1.52	6	1.970%	4.243%
10	270	3.3	1.1	1.42	1.00	2	-1.063%	1.277%
11	300	4.1	1.7	1.99	1.46	4	3.139%	2.307%
12	330	3.8	1.7	1.92	1.52	4	3.263%	4.757%
All (fitted)			2.2	2.36	1.98	8	3.272%	3.273%
Source data					1.92	8		

Matehuala. August 2008. 10m



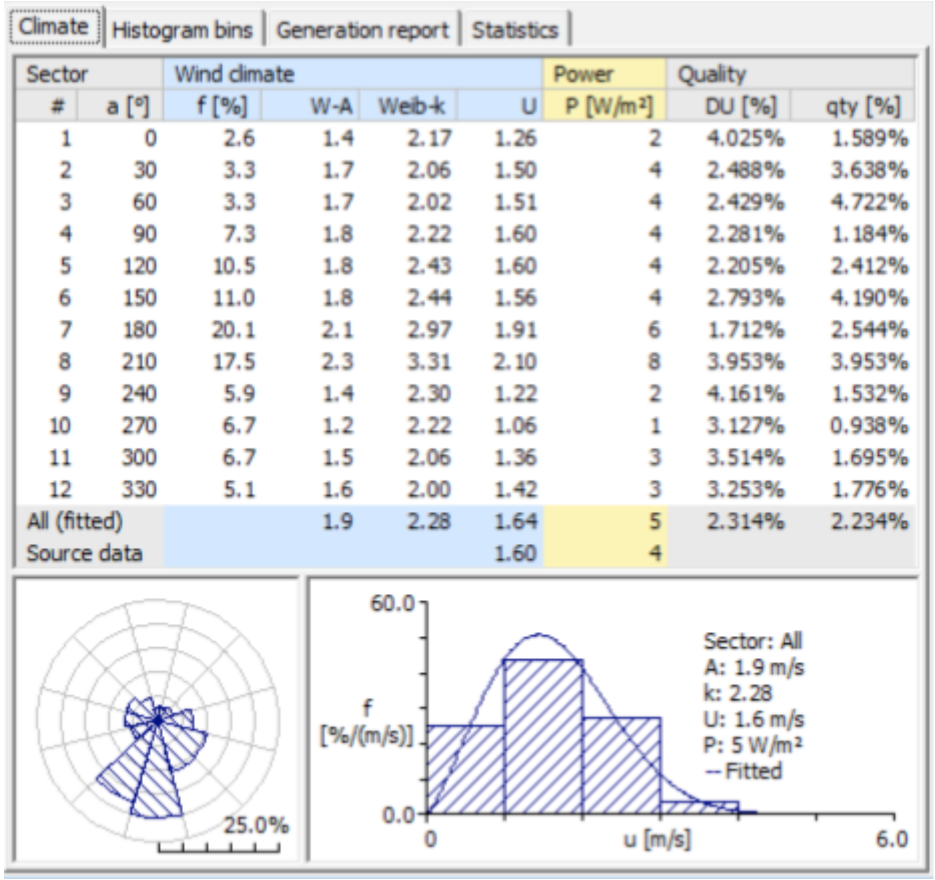
Sector		Wind climate				Power	Quality	
#	a [°]	f [%]	W-A	Weib-k	U	P [W/m²]	DU [%]	qty [%]
1	0	1.3	1.4	2.32	1.28	2	4.925%	2.772%
2	30	2.3	1.7	2.30	1.48	3	3.088%	2.267%
3	60	5.2	2.2	1.94	1.94	9	1.059%	2.376%
4	90	11.2	2.3	1.92	2.04	10	-0.322%	3.533%
5	120	15.5	2.0	2.20	1.79	6	2.668%	2.546%
6	150	14.1	1.9	2.33	1.65	5	3.020%	4.189%
7	180	20.2	2.1	2.81	1.91	6	2.264%	2.796%
8	210	19.7	2.5	3.67	2.25	9	4.588%	4.465%
9	240	3.4	1.6	1.64	1.45	4	2.784%	4.329%
10	270	2.5	1.4	1.75	1.27	3	2.096%	3.916%
11	300	2.2	1.8	1.54	1.58	6	1.784%	2.088%
12	330	2.5	2.0	1.56	1.76	9	0.151%	1.657%
All (fitted)			2.1	2.31	1.89	7	3.103%	3.205%
Source data					1.83	7		

Matehuala. September 2008. 10m



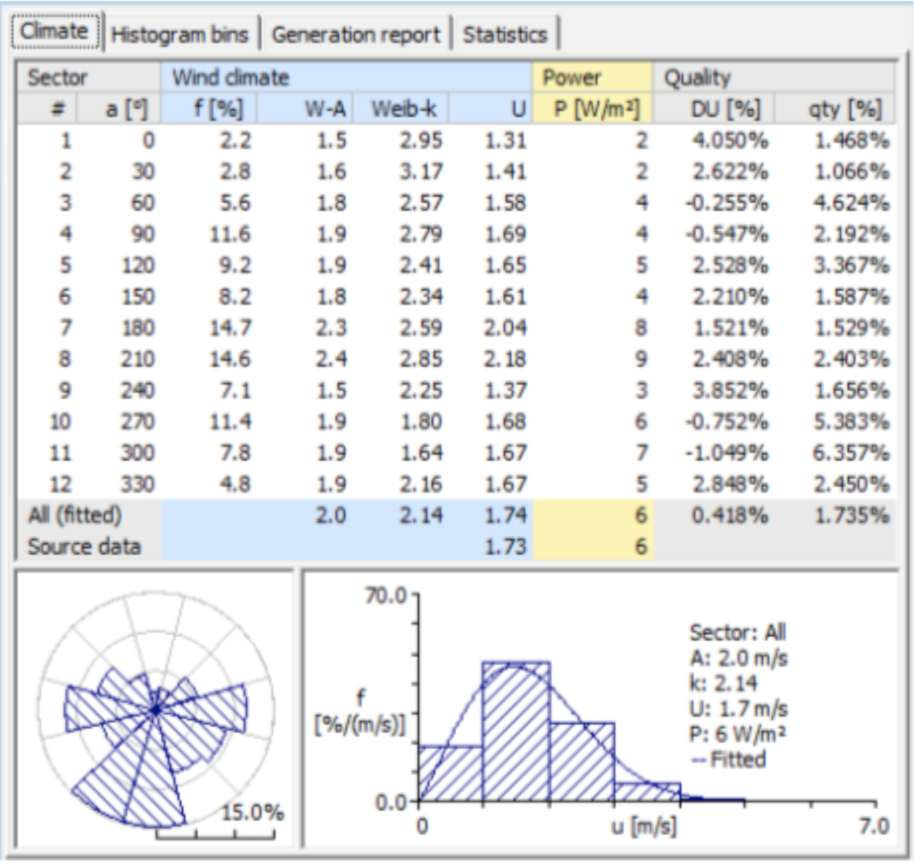
Sector		Wind climate				Power	Quality	
#	a [°]	f [%]	W-A	Weib-k	U	P [W/m²]	DU [%]	qty [%]
1	0	3.0	1.6	2.55	1.42	3	3.154%	1.372%
2	30	3.9	1.7	2.38	1.52	4	2.347%	0.671%
3	60	4.5	1.9	2.36	1.69	5	2.523%	3.278%
4	90	9.4	2.0	1.83	1.81	8	-0.661%	3.981%
5	120	12.4	1.8	2.36	1.57	4	1.863%	0.450%
6	150	11.3	1.7	2.59	1.50	3	2.395%	1.035%
7	180	16.7	1.7	2.47	1.55	4	1.625%	1.779%
8	210	16.5	2.1	2.87	1.85	6	2.709%	4.613%
9	240	4.9	1.4	1.91	1.21	2	4.556%	2.212%
10	270	4.2	1.4	1.55	1.24	3	3.225%	2.075%
11	300	5.4	1.7	1.89	1.51	4	2.345%	2.162%
12	330	7.9	1.9	2.27	1.64	5	1.468%	0.477%
All (fitted)			1.8	2.22	1.60	4	2.158%	0.860%
Source data					1.57	4		

Matehuala. October 2008. 10m



Sector		Wind climate				Power	Quality	
#	a [°]	f [%]	W-A	Weib-k	U	P [W/m²]	DU [%]	qty [%]
1	0	2.6	1.4	2.17	1.26	2	4.025%	1.589%
2	30	3.3	1.7	2.06	1.50	4	2.488%	3.638%
3	60	3.3	1.7	2.02	1.51	4	2.429%	4.722%
4	90	7.3	1.8	2.22	1.60	4	2.281%	1.184%
5	120	10.5	1.8	2.43	1.60	4	2.205%	2.412%
6	150	11.0	1.8	2.44	1.56	4	2.793%	4.190%
7	180	20.1	2.1	2.97	1.91	6	1.712%	2.544%
8	210	17.5	2.3	3.31	2.10	8	3.953%	3.953%
9	240	5.9	1.4	2.30	1.22	2	4.161%	1.532%
10	270	6.7	1.2	2.22	1.06	1	3.127%	0.938%
11	300	6.7	1.5	2.06	1.36	3	3.514%	1.695%
12	330	5.1	1.6	2.00	1.42	3	3.253%	1.776%
All (fitted)			1.9	2.28	1.64	5	2.314%	2.234%
Source data					1.60	4		

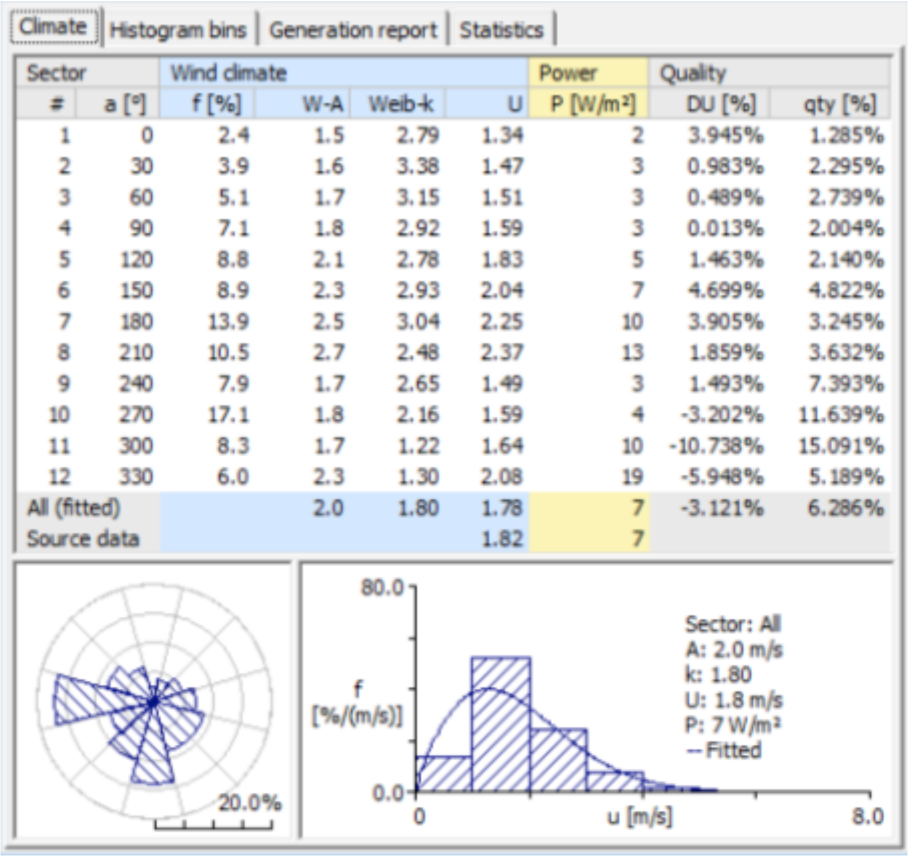
Matehuala. November 2008. 10m



Sector		Wind climate				Power	Quality	
#	a [°]	f [%]	W-A	Weib-k	U	P [W/m²]	DU [%]	qty [%]
1	0	2.2	1.5	2.95	1.31	2	4.050%	1.468%
2	30	2.8	1.6	3.17	1.41	2	2.622%	1.066%
3	60	5.6	1.8	2.57	1.58	4	-0.255%	4.624%
4	90	11.6	1.9	2.79	1.69	4	-0.547%	2.192%
5	120	9.2	1.9	2.41	1.65	5	2.528%	3.367%
6	150	8.2	1.8	2.34	1.61	4	2.210%	1.587%
7	180	14.7	2.3	2.59	2.04	8	1.521%	1.529%
8	210	14.6	2.4	2.85	2.18	9	2.408%	2.403%
9	240	7.1	1.5	2.25	1.37	3	3.852%	1.656%
10	270	11.4	1.9	1.80	1.68	6	-0.752%	5.383%
11	300	7.8	1.9	1.64	1.67	7	-1.049%	6.357%
12	330	4.8	1.9	2.16	1.67	5	2.848%	2.450%
All (fitted)			2.0	2.14	1.74	6	0.418%	1.735%
Source data					1.73	6		

Sector: All
A: 2.0 m/s
k: 2.14
U: 1.7 m/s
P: 6 W/m²
-- Fitted

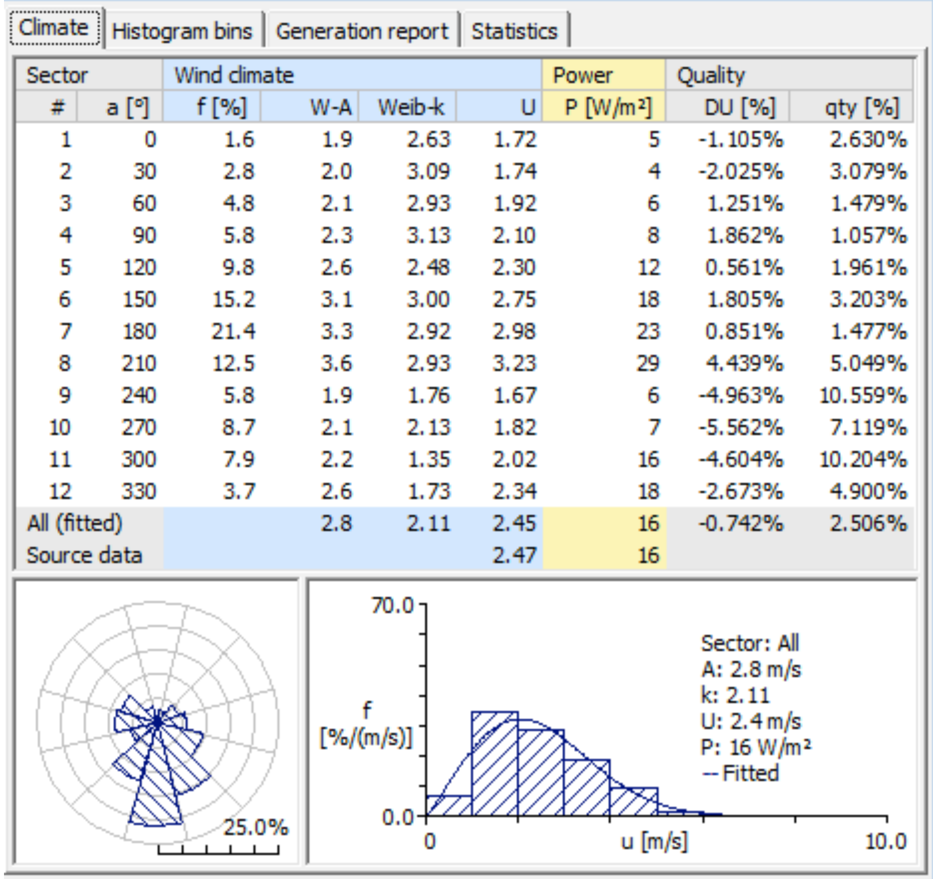
Matehuala. December 2008. 10m



Sector		Wind climate				Power	Quality	
#	a [°]	f [%]	W-A	Weib-k	U	P [W/m²]	DU [%]	qty [%]
1	0	2.4	1.5	2.79	1.34	2	3.945%	1.285%
2	30	3.9	1.6	3.38	1.47	3	0.983%	2.295%
3	60	5.1	1.7	3.15	1.51	3	0.489%	2.739%
4	90	7.1	1.8	2.92	1.59	3	0.013%	2.004%
5	120	8.8	2.1	2.78	1.83	5	1.463%	2.140%
6	150	8.9	2.3	2.93	2.04	7	4.699%	4.822%
7	180	13.9	2.5	3.04	2.25	10	3.905%	3.245%
8	210	10.5	2.7	2.48	2.37	13	1.859%	3.632%
9	240	7.9	1.7	2.65	1.49	3	1.493%	7.393%
10	270	17.1	1.8	2.16	1.59	4	-3.202%	11.639%
11	300	8.3	1.7	1.22	1.64	10	-10.738%	15.091%
12	330	6.0	2.3	1.30	2.08	19	-5.948%	5.189%
All (fitted)			2.0	1.80	1.78	7	-3.121%	6.286%
Source data					1.82	7		

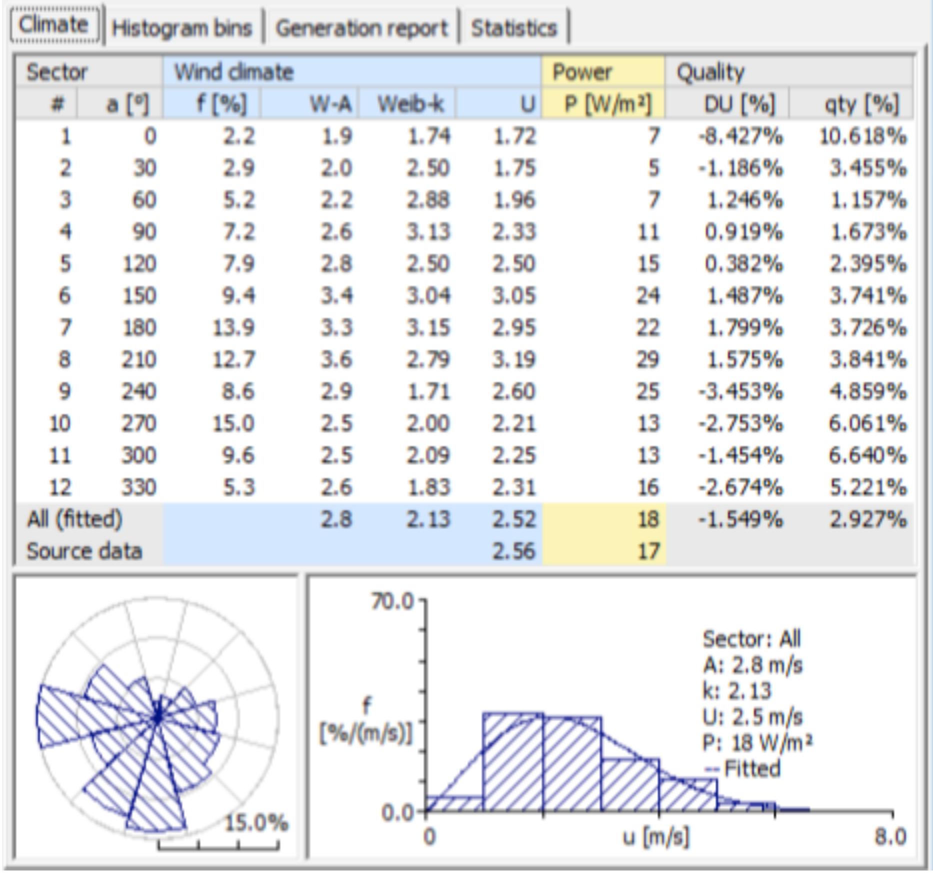
Sector: All
A: 2.0 m/s
k: 1.80
U: 1.8 m/s
P: 7 W/m²
-- Fitted

Matehuala. January 2008. 20m



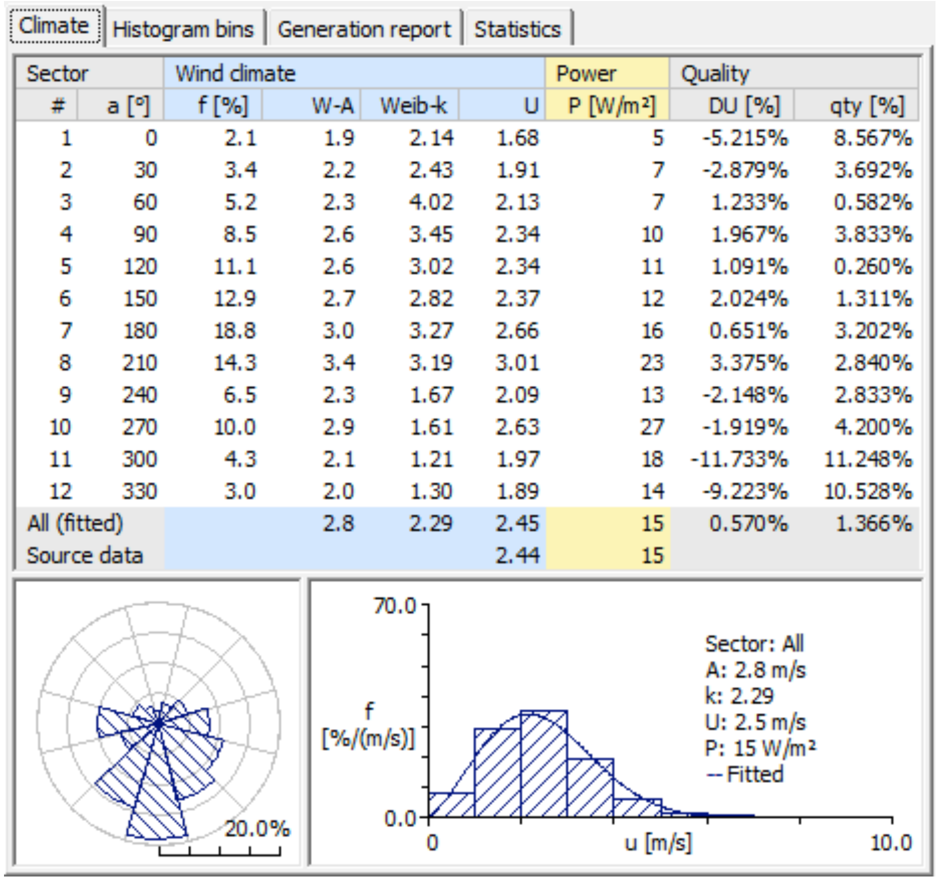
Sector		Wind climate				Power	Quality	
#	a [°]	f [%]	W-A	Weib-k	U	P [W/m²]	DU [%]	qty [%]
1	0	1.6	1.9	2.63	1.72	5	-1.105%	2.630%
2	30	2.8	2.0	3.09	1.74	4	-2.025%	3.079%
3	60	4.8	2.1	2.93	1.92	6	1.251%	1.479%
4	90	5.8	2.3	3.13	2.10	8	1.862%	1.057%
5	120	9.8	2.6	2.48	2.30	12	0.561%	1.961%
6	150	15.2	3.1	3.00	2.75	18	1.805%	3.203%
7	180	21.4	3.3	2.92	2.98	23	0.851%	1.477%
8	210	12.5	3.6	2.93	3.23	29	4.439%	5.049%
9	240	5.8	1.9	1.76	1.67	6	-4.963%	10.559%
10	270	8.7	2.1	2.13	1.82	7	-5.562%	7.119%
11	300	7.9	2.2	1.35	2.02	16	-4.604%	10.204%
12	330	3.7	2.6	1.73	2.34	18	-2.673%	4.900%
All (fitted)			2.8	2.11	2.45	16	-0.742%	2.506%
Source data					2.47	16		

Matehuala. February 2008. 20m



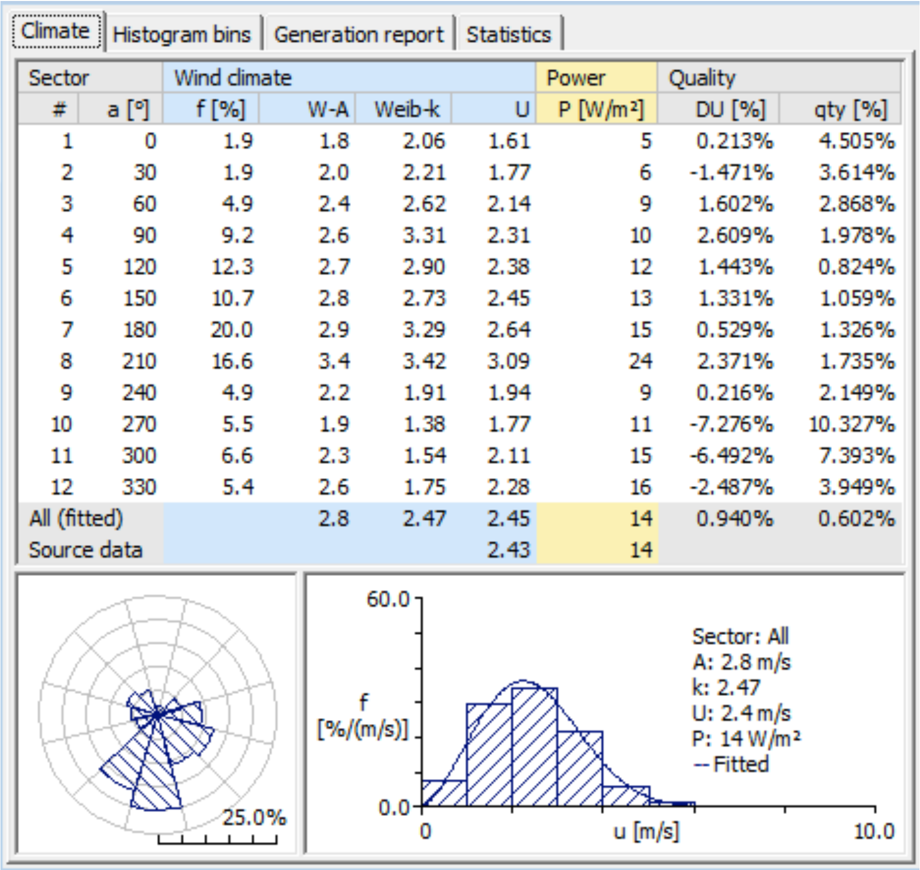
Sector		Wind climate				Power	Quality	
#	a [°]	f [%]	W-A	Weib-k	U	P [W/m²]	DU [%]	qty [%]
1	0	2.2	1.9	1.74	1.72	7	-8.427%	10.618%
2	30	2.9	2.0	2.50	1.75	5	-1.186%	3.455%
3	60	5.2	2.2	2.88	1.96	7	1.246%	1.157%
4	90	7.2	2.6	3.13	2.33	11	0.919%	1.673%
5	120	7.9	2.8	2.50	2.50	15	0.382%	2.395%
6	150	9.4	3.4	3.04	3.05	24	1.487%	3.741%
7	180	13.9	3.3	3.15	2.95	22	1.799%	3.726%
8	210	12.7	3.6	2.79	3.19	29	1.575%	3.841%
9	240	8.6	2.9	1.71	2.60	25	-3.453%	4.859%
10	270	15.0	2.5	2.00	2.21	13	-2.753%	6.061%
11	300	9.6	2.5	2.09	2.25	13	-1.454%	6.640%
12	330	5.3	2.6	1.83	2.31	16	-2.674%	5.221%
All (fitted)			2.8	2.13	2.52	18	-1.549%	2.927%
Source data					2.56	17		

Matehuala. March 2008. 20m



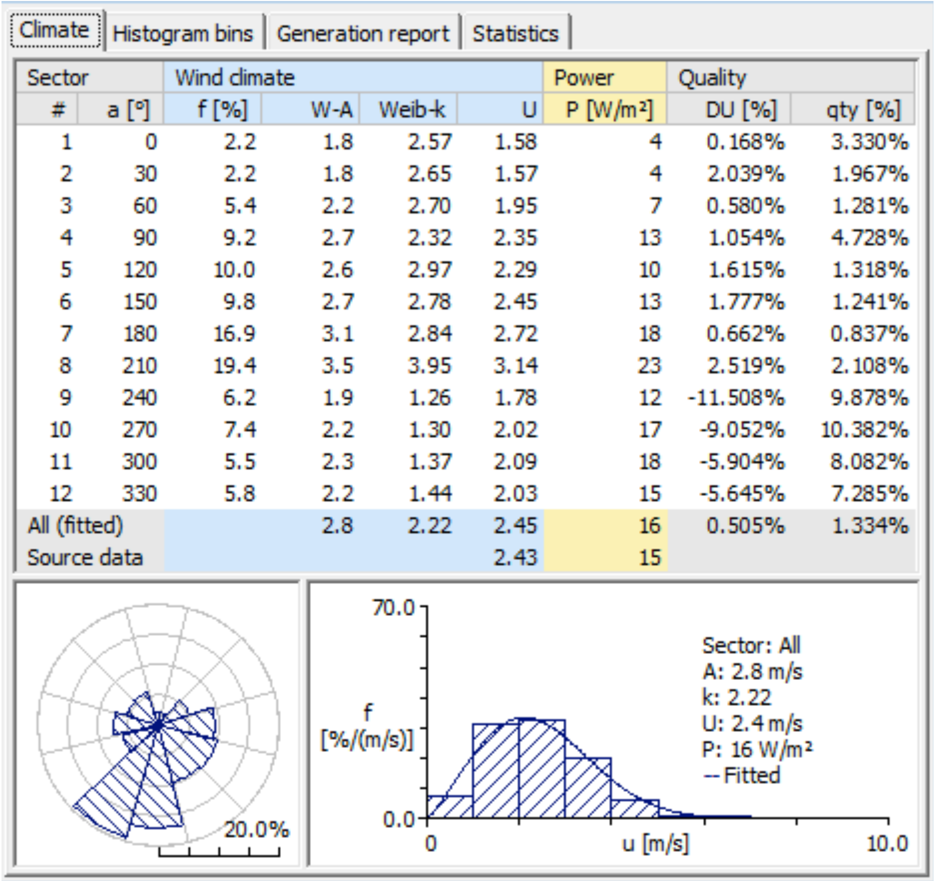
Sector		Wind climate				Power	Quality	
#	a [º]	f [%]	W-A	Weib-k	U	P [W/m²]	DU [%]	qty [%]
1	0	2.1	1.9	2.14	1.68	5	-5.215%	8.567%
2	30	3.4	2.2	2.43	1.91	7	-2.879%	3.692%
3	60	5.2	2.3	4.02	2.13	7	1.233%	0.582%
4	90	8.5	2.6	3.45	2.34	10	1.967%	3.833%
5	120	11.1	2.6	3.02	2.34	11	1.091%	0.260%
6	150	12.9	2.7	2.82	2.37	12	2.024%	1.311%
7	180	18.8	3.0	3.27	2.66	16	0.651%	3.202%
8	210	14.3	3.4	3.19	3.01	23	3.375%	2.840%
9	240	6.5	2.3	1.67	2.09	13	-2.148%	2.833%
10	270	10.0	2.9	1.61	2.63	27	-1.919%	4.200%
11	300	4.3	2.1	1.21	1.97	18	-11.733%	11.248%
12	330	3.0	2.0	1.30	1.89	14	-9.223%	10.528%
All (fitted)			2.8	2.29	2.45	15	0.570%	1.366%
Source data					2.44	15		

Matehuala. April 2008. 20m



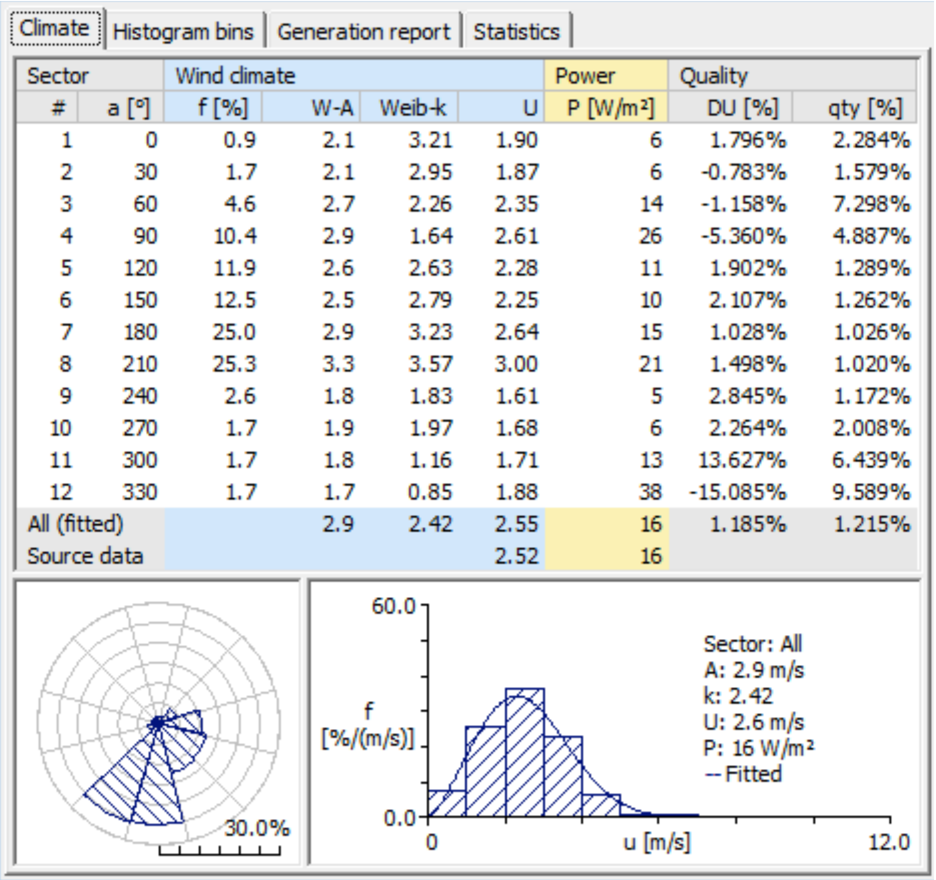
Sector		Wind climate				Power	Quality	
#	a [º]	f [%]	W-A	Weib-k	U	P [W/m²]	DU [%]	qty [%]
1	0	1.9	1.8	2.06	1.61	5	0.213%	4.505%
2	30	1.9	2.0	2.21	1.77	6	-1.471%	3.614%
3	60	4.9	2.4	2.62	2.14	9	1.602%	2.868%
4	90	9.2	2.6	3.31	2.31	10	2.609%	1.978%
5	120	12.3	2.7	2.90	2.38	12	1.443%	0.824%
6	150	10.7	2.8	2.73	2.45	13	1.331%	1.059%
7	180	20.0	2.9	3.29	2.64	15	0.529%	1.326%
8	210	16.6	3.4	3.42	3.09	24	2.371%	1.735%
9	240	4.9	2.2	1.91	1.94	9	0.216%	2.149%
10	270	5.5	1.9	1.38	1.77	11	-7.276%	10.327%
11	300	6.6	2.3	1.54	2.11	15	-6.492%	7.393%
12	330	5.4	2.6	1.75	2.28	16	-2.487%	3.949%
All (fitted)			2.8	2.47	2.45	14	0.940%	0.602%
Source data					2.43	14		

Matehuala. May 2008. 20m



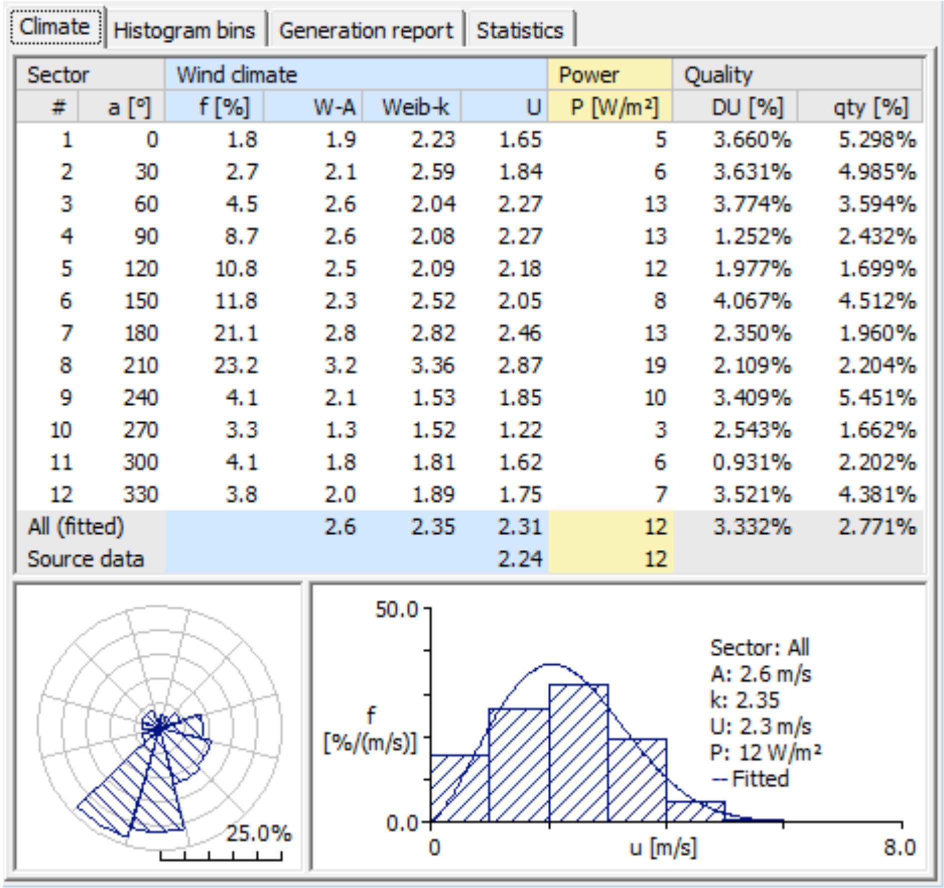
Sector		Wind climate				Power	Quality	
#	a [°]	f [%]	W-A	Weib-k	U	P [W/m²]	DU [%]	qty [%]
1	0	2.2	1.8	2.57	1.58	4	0.168%	3.330%
2	30	2.2	1.8	2.65	1.57	4	2.039%	1.967%
3	60	5.4	2.2	2.70	1.95	7	0.580%	1.281%
4	90	9.2	2.7	2.32	2.35	13	1.054%	4.728%
5	120	10.0	2.6	2.97	2.29	10	1.615%	1.318%
6	150	9.8	2.7	2.78	2.45	13	1.777%	1.241%
7	180	16.9	3.1	2.84	2.72	18	0.662%	0.837%
8	210	19.4	3.5	3.95	3.14	23	2.519%	2.108%
9	240	6.2	1.9	1.26	1.78	12	-11.508%	9.878%
10	270	7.4	2.2	1.30	2.02	17	-9.052%	10.382%
11	300	5.5	2.3	1.37	2.09	18	-5.904%	8.082%
12	330	5.8	2.2	1.44	2.03	15	-5.645%	7.285%
All (fitted)			2.8	2.22	2.45	16	0.505%	1.334%
Source data					2.43	15		

Matehuala. June 2008. 20m



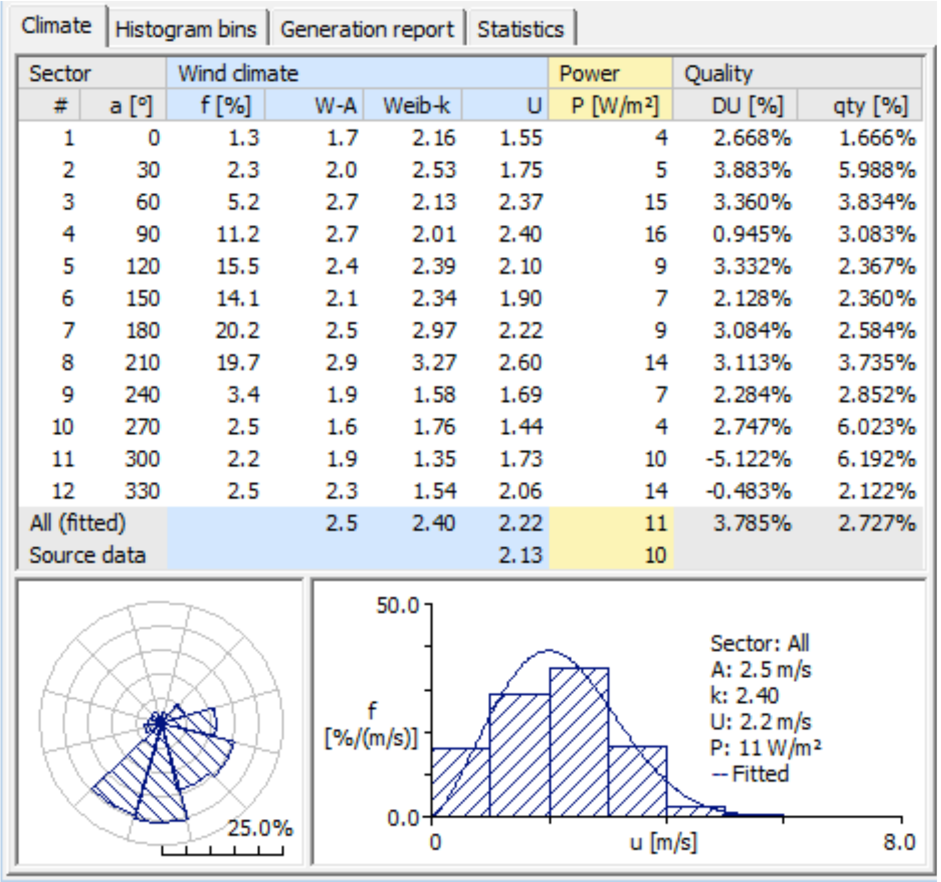
Sector		Wind climate				Power	Quality	
#	a [°]	f [%]	W-A	Weib-k	U	P [W/m²]	DU [%]	qty [%]
1	0	0.9	2.1	3.21	1.90	6	1.796%	2.284%
2	30	1.7	2.1	2.95	1.87	6	-0.783%	1.579%
3	60	4.6	2.7	2.26	2.35	14	-1.158%	7.298%
4	90	10.4	2.9	1.64	2.61	26	-5.360%	4.887%
5	120	11.9	2.6	2.63	2.28	11	1.902%	1.289%
6	150	12.5	2.5	2.79	2.25	10	2.107%	1.262%
7	180	25.0	2.9	3.23	2.64	15	1.028%	1.026%
8	210	25.3	3.3	3.57	3.00	21	1.498%	1.020%
9	240	2.6	1.8	1.83	1.61	5	2.845%	1.172%
10	270	1.7	1.9	1.97	1.68	6	2.264%	2.008%
11	300	1.7	1.8	1.16	1.71	13	13.627%	6.439%
12	330	1.7	1.7	0.85	1.88	38	-15.085%	9.589%
All (fitted)			2.9	2.42	2.55	16	1.185%	1.215%
Source data					2.52	16		

Matehuala. July 2008. 20m



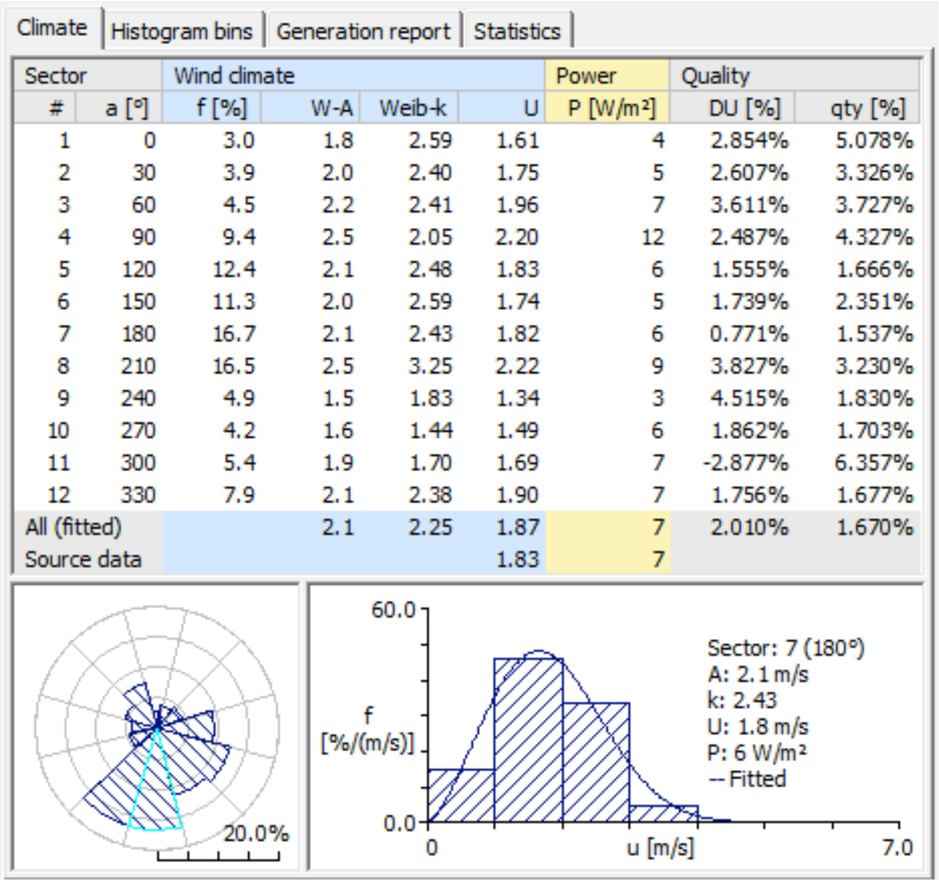
Sector		Wind climate				Power	Quality	
#	a [°]	f [%]	W-A	Weib-k	U	P [W/m²]	DU [%]	qty [%]
1	0	1.8	1.9	2.23	1.65	5	3.660%	5.298%
2	30	2.7	2.1	2.59	1.84	6	3.631%	4.985%
3	60	4.5	2.6	2.04	2.27	13	3.774%	3.594%
4	90	8.7	2.6	2.08	2.27	13	1.252%	2.432%
5	120	10.8	2.5	2.09	2.18	12	1.977%	1.699%
6	150	11.8	2.3	2.52	2.05	8	4.067%	4.512%
7	180	21.1	2.8	2.82	2.46	13	2.350%	1.960%
8	210	23.2	3.2	3.36	2.87	19	2.109%	2.204%
9	240	4.1	2.1	1.53	1.85	10	3.409%	5.451%
10	270	3.3	1.3	1.52	1.22	3	2.543%	1.662%
11	300	4.1	1.8	1.81	1.62	6	0.931%	2.202%
12	330	3.8	2.0	1.89	1.75	7	3.521%	4.381%
All (fitted)			2.6	2.35	2.31	12	3.332%	2.771%
Source data					2.24	12		

Matehuala. August 2008. 20m



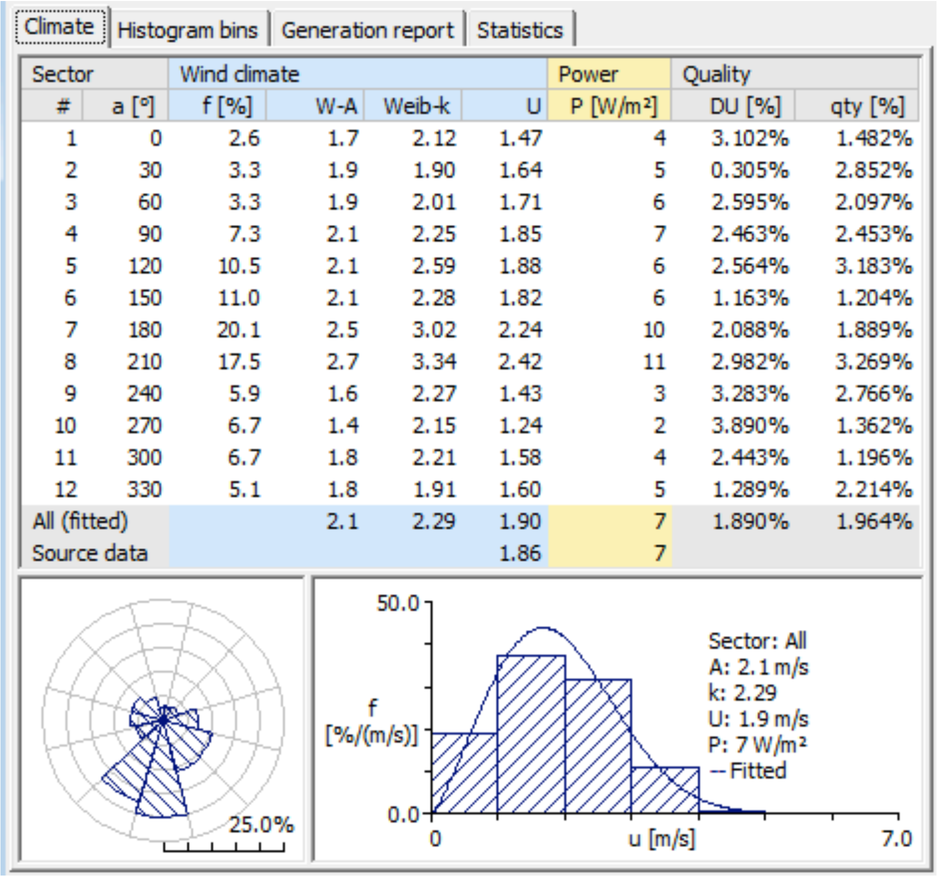
Sector		Wind climate				Power	Quality	
#	a [°]	f [%]	W-A	Weib-k	U	P [W/m²]	DU [%]	qty [%]
1	0	1.3	1.7	2.16	1.55	4	2.668%	1.666%
2	30	2.3	2.0	2.53	1.75	5	3.883%	5.988%
3	60	5.2	2.7	2.13	2.37	15	3.360%	3.834%
4	90	11.2	2.7	2.01	2.40	16	0.945%	3.083%
5	120	15.5	2.4	2.39	2.10	9	3.332%	2.367%
6	150	14.1	2.1	2.34	1.90	7	2.128%	2.360%
7	180	20.2	2.5	2.97	2.22	9	3.084%	2.584%
8	210	19.7	2.9	3.27	2.60	14	3.113%	3.735%
9	240	3.4	1.9	1.58	1.69	7	2.284%	2.852%
10	270	2.5	1.6	1.76	1.44	4	2.747%	6.023%
11	300	2.2	1.9	1.35	1.73	10	-5.122%	6.192%
12	330	2.5	2.3	1.54	2.06	14	-0.483%	2.122%
All (fitted)			2.5	2.40	2.22	11	3.785%	2.727%
Source data					2.13	10		

Matehuala. September 2008. 20m



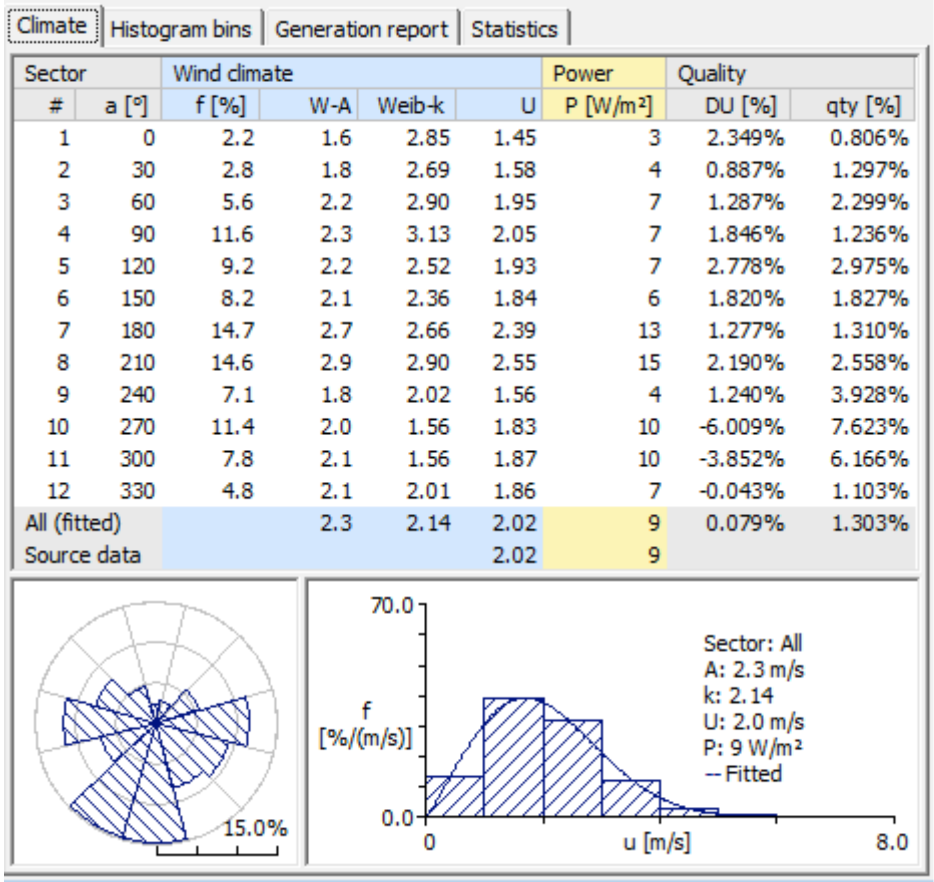
Sector		Wind climate				Power	Quality	
#	a [°]	f [%]	W-A	Weib-k	U	P [W/m²]	DU [%]	qty [%]
1	0	3.0	1.8	2.59	1.61	4	2.854%	5.078%
2	30	3.9	2.0	2.40	1.75	5	2.607%	3.326%
3	60	4.5	2.2	2.41	1.96	7	3.611%	3.727%
4	90	9.4	2.5	2.05	2.20	12	2.487%	4.327%
5	120	12.4	2.1	2.48	1.83	6	1.555%	1.666%
6	150	11.3	2.0	2.59	1.74	5	1.739%	2.351%
7	180	16.7	2.1	2.43	1.82	6	0.771%	1.537%
8	210	16.5	2.5	3.25	2.22	9	3.827%	3.230%
9	240	4.9	1.5	1.83	1.34	3	4.515%	1.830%
10	270	4.2	1.6	1.44	1.49	6	1.862%	1.703%
11	300	5.4	1.9	1.70	1.69	7	-2.877%	6.357%
12	330	7.9	2.1	2.38	1.90	7	1.756%	1.677%
All (fitted)			2.1	2.25	1.87	7	2.010%	1.670%
Source data					1.83	7		

Matehuala. October 2008. 20m



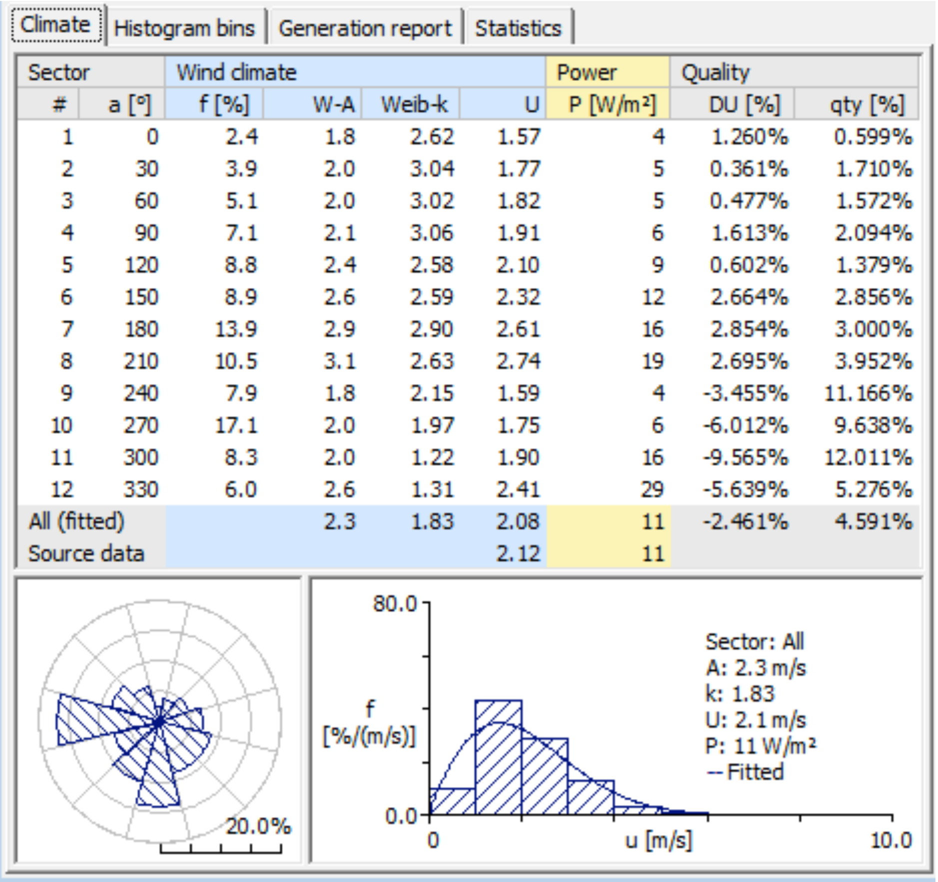
Sector		Wind climate				Power	Quality	
#	a [°]	f [%]	W-A	Weib-k	U	P [W/m²]	DU [%]	qty [%]
1	0	2.6	1.7	2.12	1.47	4	3.102%	1.482%
2	30	3.3	1.9	1.90	1.64	5	0.305%	2.852%
3	60	3.3	1.9	2.01	1.71	6	2.595%	2.097%
4	90	7.3	2.1	2.25	1.85	7	2.463%	2.453%
5	120	10.5	2.1	2.59	1.88	6	2.564%	3.183%
6	150	11.0	2.1	2.28	1.82	6	1.163%	1.204%
7	180	20.1	2.5	3.02	2.24	10	2.088%	1.889%
8	210	17.5	2.7	3.34	2.42	11	2.982%	3.269%
9	240	5.9	1.6	2.27	1.43	3	3.283%	2.766%
10	270	6.7	1.4	2.15	1.24	2	3.890%	1.362%
11	300	6.7	1.8	2.21	1.58	4	2.443%	1.196%
12	330	5.1	1.8	1.91	1.60	5	1.289%	2.214%
All (fitted)			2.1	2.29	1.90	7	1.890%	1.964%
Source data					1.86	7		

Matehuala. November 2008. 20m



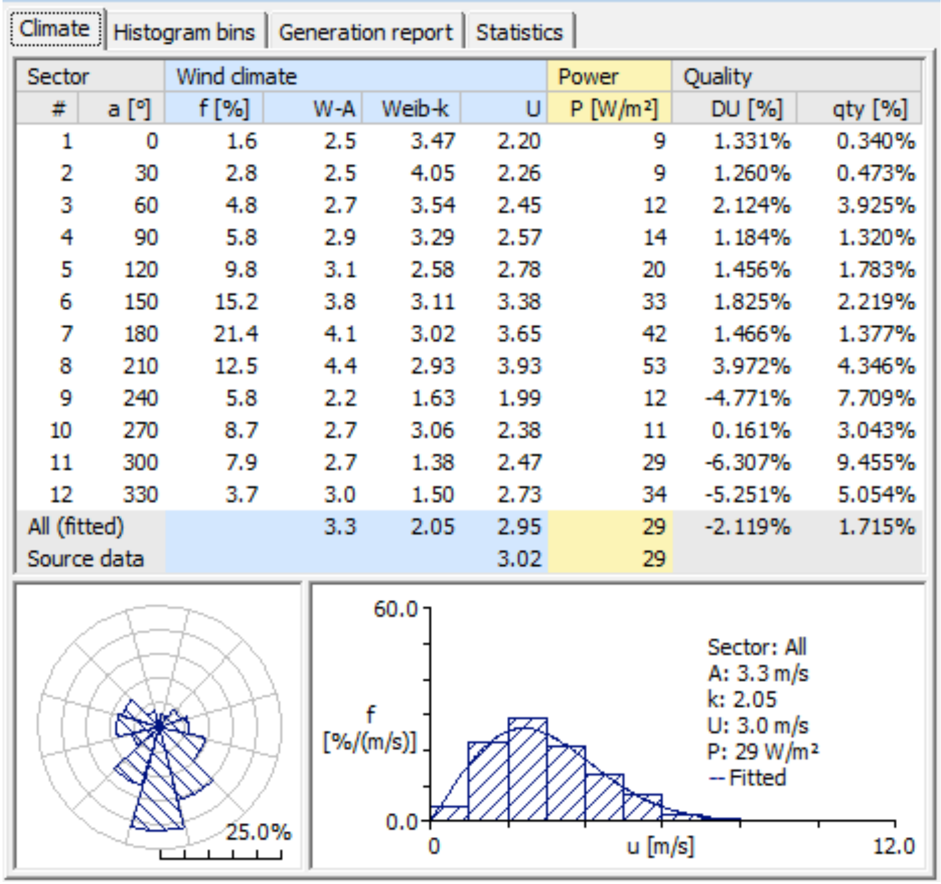
Sector		Wind climate				Power	Quality	
#	a [°]	f [%]	W-A	Weib-k	U	P [W/m²]	DU [%]	qty [%]
1	0	2.2	1.6	2.85	1.45	3	2.349%	0.806%
2	30	2.8	1.8	2.69	1.58	4	0.887%	1.297%
3	60	5.6	2.2	2.90	1.95	7	1.287%	2.299%
4	90	11.6	2.3	3.13	2.05	7	1.846%	1.236%
5	120	9.2	2.2	2.52	1.93	7	2.778%	2.975%
6	150	8.2	2.1	2.36	1.84	6	1.820%	1.827%
7	180	14.7	2.7	2.66	2.39	13	1.277%	1.310%
8	210	14.6	2.9	2.90	2.55	15	2.190%	2.558%
9	240	7.1	1.8	2.02	1.56	4	1.240%	3.928%
10	270	11.4	2.0	1.56	1.83	10	-6.009%	7.623%
11	300	7.8	2.1	1.56	1.87	10	-3.852%	6.166%
12	330	4.8	2.1	2.01	1.86	7	-0.043%	1.103%
All (fitted)			2.3	2.14	2.02	9	0.079%	1.303%
Source data					2.02	9		

Matehuala. December 2008. 20m



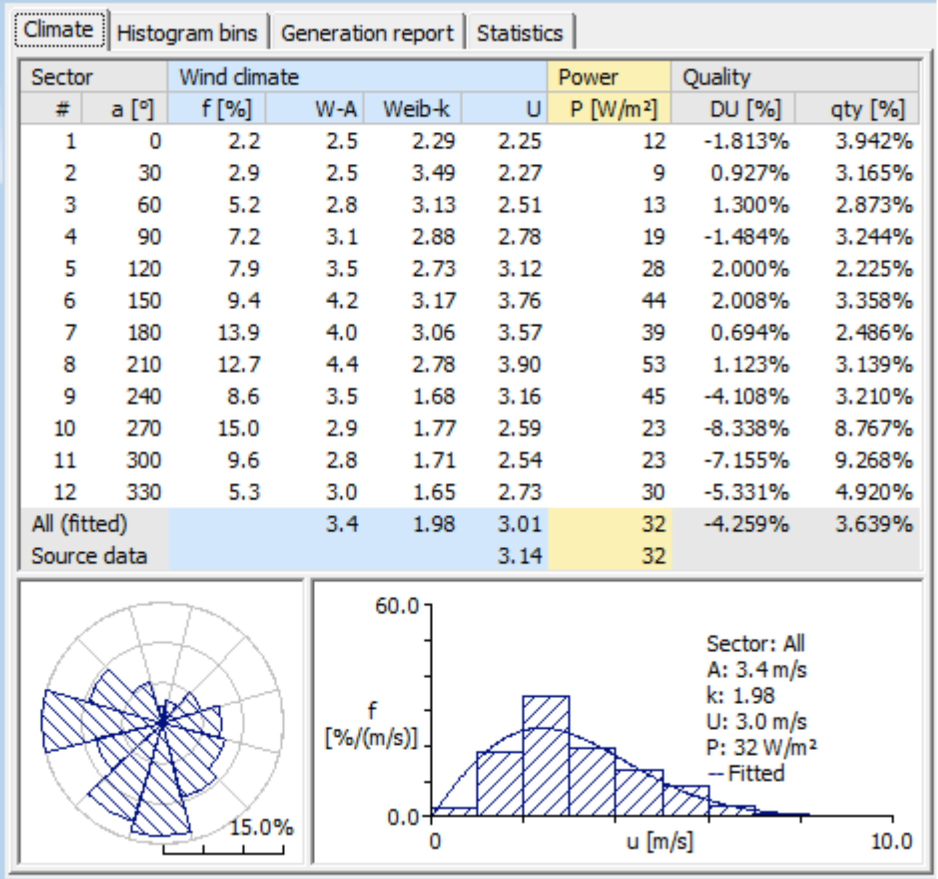
Sector		Wind climate				Power	Quality	
#	a [°]	f [%]	W-A	Weib-k	U	P [W/m²]	DU [%]	qty [%]
1	0	2.4	1.8	2.62	1.57	4	1.260%	0.599%
2	30	3.9	2.0	3.04	1.77	5	0.361%	1.710%
3	60	5.1	2.0	3.02	1.82	5	0.477%	1.572%
4	90	7.1	2.1	3.06	1.91	6	1.613%	2.094%
5	120	8.8	2.4	2.58	2.10	9	0.602%	1.379%
6	150	8.9	2.6	2.59	2.32	12	2.664%	2.856%
7	180	13.9	2.9	2.90	2.61	16	2.854%	3.000%
8	210	10.5	3.1	2.63	2.74	19	2.695%	3.952%
9	240	7.9	1.8	2.15	1.59	4	-3.455%	11.166%
10	270	17.1	2.0	1.97	1.75	6	-6.012%	9.638%
11	300	8.3	2.0	1.22	1.90	16	-9.565%	12.011%
12	330	6.0	2.6	1.31	2.41	29	-5.639%	5.276%
All (fitted)			2.3	1.83	2.08	11	-2.461%	4.591%
Source data					2.12	11		

Matehuala. January 2008. 50m



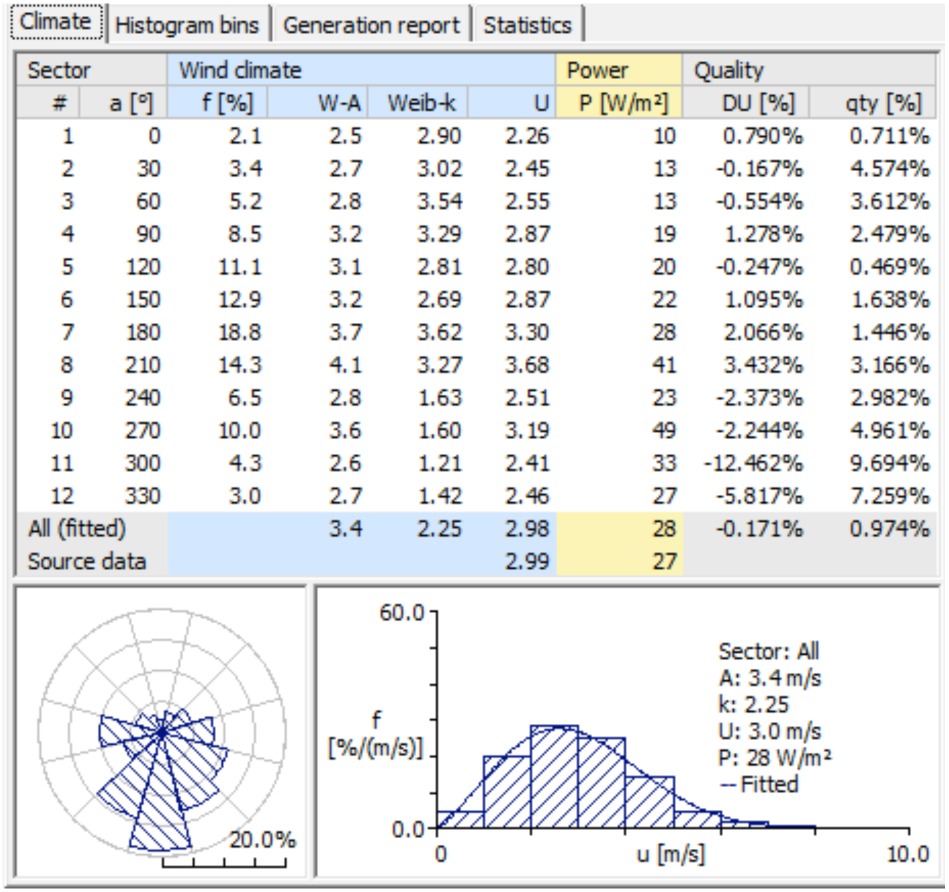
Sector		Wind climate				Power	Quality	
#	a [°]	f [%]	W-A	Weib-k	U	P [W/m^2]	DU [%]	qty [%]
1	0	1.6	2.5	3.47	2.20	9	1.331%	0.340%
2	30	2.8	2.5	4.05	2.26	9	1.260%	0.473%
3	60	4.8	2.7	3.54	2.45	12	2.124%	3.925%
4	90	5.8	2.9	3.29	2.57	14	1.184%	1.320%
5	120	9.8	3.1	2.58	2.78	20	1.456%	1.783%
6	150	15.2	3.8	3.11	3.38	33	1.825%	2.219%
7	180	21.4	4.1	3.02	3.65	42	1.466%	1.377%
8	210	12.5	4.4	2.93	3.93	53	3.972%	4.346%
9	240	5.8	2.2	1.63	1.99	12	-4.771%	7.709%
10	270	8.7	2.7	3.06	2.38	11	0.161%	3.043%
11	300	7.9	2.7	1.38	2.47	29	-6.307%	9.455%
12	330	3.7	3.0	1.50	2.73	34	-5.251%	5.054%
All (fitted)			3.3	2.05	2.95	29	-2.119%	1.715%
Source data					3.02	29		

Matehuala. February 2008. 50m



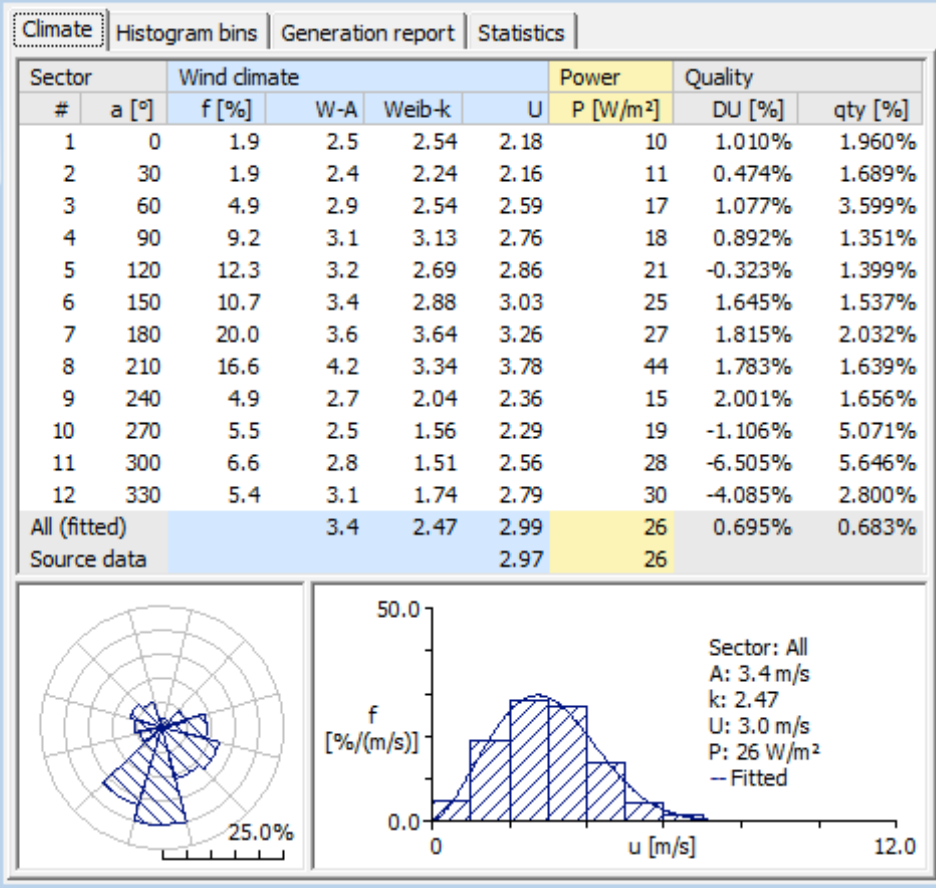
Sector		Wind climate				Power	Quality	
#	a [°]	f [%]	W-A	Weib-k	U	P [W/m^2]	DU [%]	qty [%]
1	0	2.2	2.5	2.29	2.25	12	-1.813%	3.942%
2	30	2.9	2.5	3.49	2.27	9	0.927%	3.165%
3	60	5.2	2.8	3.13	2.51	13	1.300%	2.873%
4	90	7.2	3.1	2.88	2.78	19	-1.484%	3.244%
5	120	7.9	3.5	2.73	3.12	28	2.000%	2.225%
6	150	9.4	4.2	3.17	3.76	44	2.008%	3.358%
7	180	13.9	4.0	3.06	3.57	39	0.694%	2.486%
8	210	12.7	4.4	2.78	3.90	53	1.123%	3.139%
9	240	8.6	3.5	1.68	3.16	45	-4.108%	3.210%
10	270	15.0	2.9	1.77	2.59	23	-8.338%	8.767%
11	300	9.6	2.8	1.71	2.54	23	-7.155%	9.268%
12	330	5.3	3.0	1.65	2.73	30	-5.331%	4.920%
All (fitted)			3.4	1.98	3.01	32	-4.259%	3.639%
Source data					3.14	32		

Matehuala. March 2008. 50m



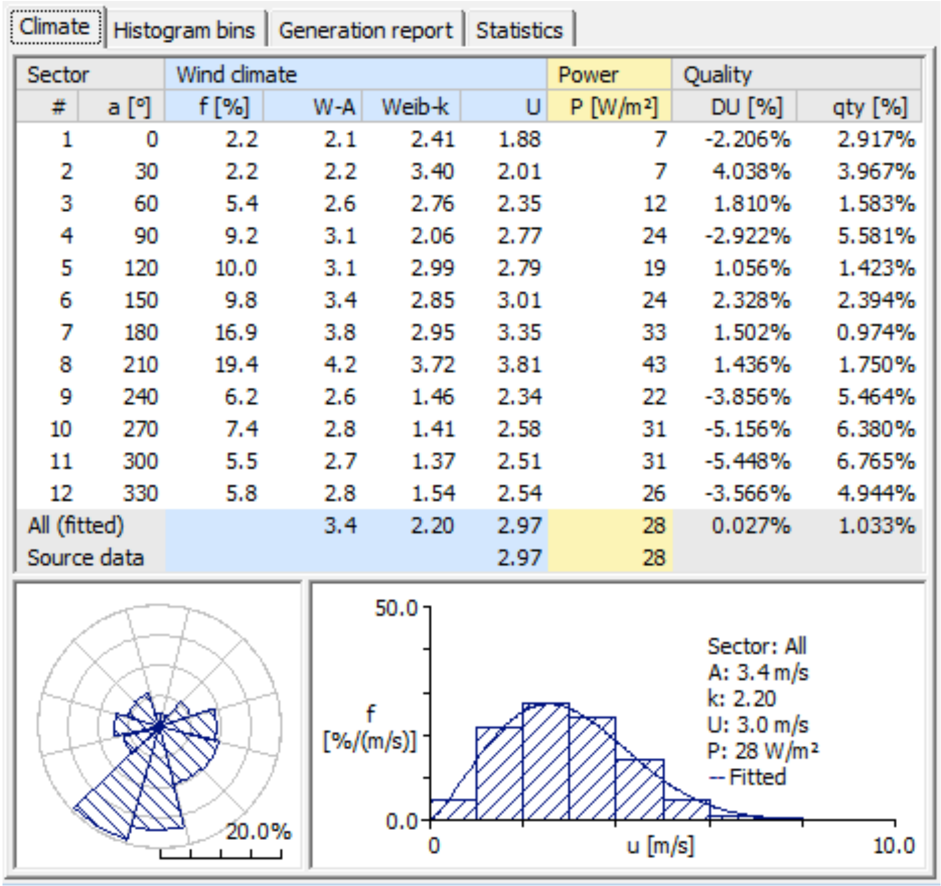
Sector		Wind climate				Power	Quality	
#	a [°]	f [%]	W-A	Weib-k	U	P [W/m²]	DU [%]	qty [%]
1	0	2.1	2.5	2.90	2.26	10	0.790%	0.711%
2	30	3.4	2.7	3.02	2.45	13	-0.167%	4.574%
3	60	5.2	2.8	3.54	2.55	13	-0.554%	3.612%
4	90	8.5	3.2	3.29	2.87	19	1.278%	2.479%
5	120	11.1	3.1	2.81	2.80	20	-0.247%	0.469%
6	150	12.9	3.2	2.69	2.87	22	1.095%	1.638%
7	180	18.8	3.7	3.62	3.30	28	2.066%	1.446%
8	210	14.3	4.1	3.27	3.68	41	3.432%	3.166%
9	240	6.5	2.8	1.63	2.51	23	-2.373%	2.982%
10	270	10.0	3.6	1.60	3.19	49	-2.244%	4.961%
11	300	4.3	2.6	1.21	2.41	33	-12.462%	9.694%
12	330	3.0	2.7	1.42	2.46	27	-5.817%	7.259%
All (fitted)			3.4	2.25	2.98	28	-0.171%	0.974%
Source data					2.99	27		

Matehuala. April 2008. 50m



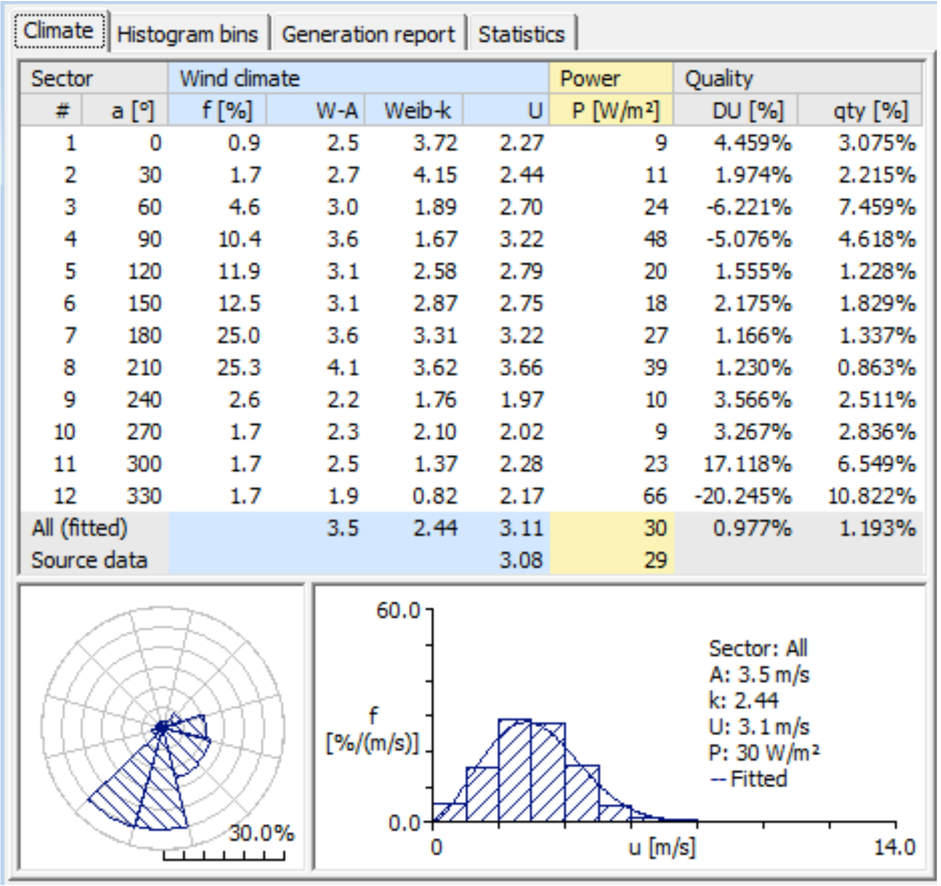
Sector		Wind climate				Power	Quality	
#	a [°]	f [%]	W-A	Weib-k	U	P [W/m²]	DU [%]	qty [%]
1	0	1.9	2.5	2.54	2.18	10	1.010%	1.960%
2	30	1.9	2.4	2.24	2.16	11	0.474%	1.689%
3	60	4.9	2.9	2.54	2.59	17	1.077%	3.599%
4	90	9.2	3.1	3.13	2.76	18	0.892%	1.351%
5	120	12.3	3.2	2.69	2.86	21	-0.323%	1.399%
6	150	10.7	3.4	2.88	3.03	25	1.645%	1.537%
7	180	20.0	3.6	3.64	3.26	27	1.815%	2.032%
8	210	16.6	4.2	3.34	3.78	44	1.783%	1.639%
9	240	4.9	2.7	2.04	2.36	15	2.001%	1.656%
10	270	5.5	2.5	1.56	2.29	19	-1.106%	5.071%
11	300	6.6	2.8	1.51	2.56	28	-6.505%	5.646%
12	330	5.4	3.1	1.74	2.79	30	-4.085%	2.800%
All (fitted)			3.4	2.47	2.99	26	0.695%	0.683%
Source data					2.97	26		

Matehuala. May 2008. 50m



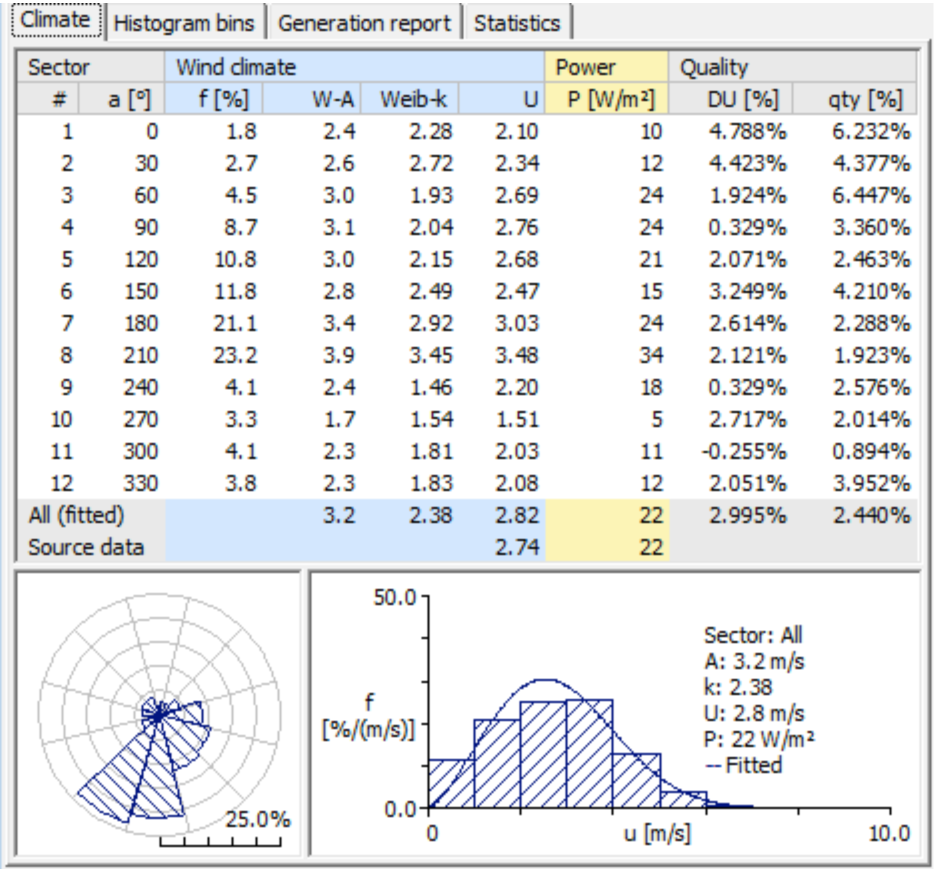
Sector		Wind climate				Power	Quality	
#	a [°]	f [%]	W-A	Weib-k	U	P [W/m²]	DU [%]	qty [%]
1	0	2.2	2.1	2.41	1.88	7	-2.206%	2.917%
2	30	2.2	2.2	3.40	2.01	7	4.038%	3.967%
3	60	5.4	2.6	2.76	2.35	12	1.810%	1.583%
4	90	9.2	3.1	2.06	2.77	24	-2.922%	5.581%
5	120	10.0	3.1	2.99	2.79	19	1.056%	1.423%
6	150	9.8	3.4	2.85	3.01	24	2.328%	2.394%
7	180	16.9	3.8	2.95	3.35	33	1.502%	0.974%
8	210	19.4	4.2	3.72	3.81	43	1.436%	1.750%
9	240	6.2	2.6	1.46	2.34	22	-3.856%	5.464%
10	270	7.4	2.8	1.41	2.58	31	-5.156%	6.380%
11	300	5.5	2.7	1.37	2.51	31	-5.448%	6.765%
12	330	5.8	2.8	1.54	2.54	26	-3.566%	4.944%
All (fitted)			3.4	2.20	2.97	28	0.027%	1.033%
Source data					2.97	28		

Matehuala. June 2008. 50m



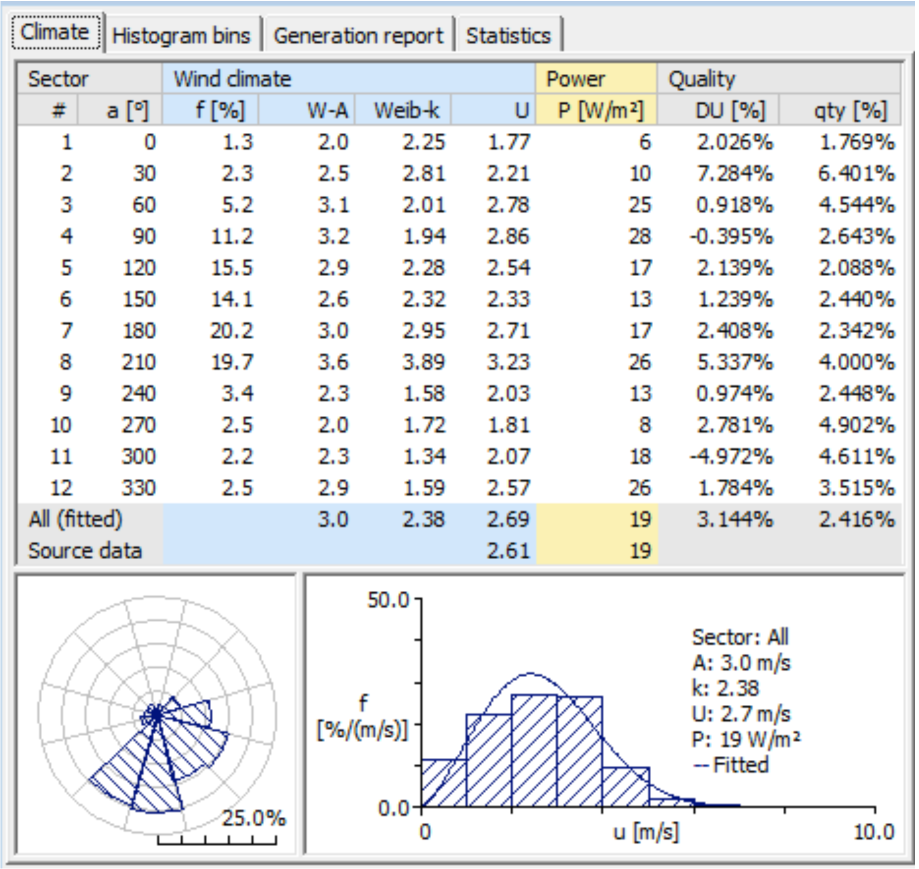
Sector		Wind climate				Power	Quality	
#	a [°]	f [%]	W-A	Weib-k	U	P [W/m²]	DU [%]	qty [%]
1	0	0.9	2.5	3.72	2.27	9	4.459%	3.075%
2	30	1.7	2.7	4.15	2.44	11	1.974%	2.215%
3	60	4.6	3.0	1.89	2.70	24	-6.221%	7.459%
4	90	10.4	3.6	1.67	3.22	48	-5.076%	4.618%
5	120	11.9	3.1	2.58	2.79	20	1.555%	1.228%
6	150	12.5	3.1	2.87	2.75	18	2.175%	1.829%
7	180	25.0	3.6	3.31	3.22	27	1.166%	1.337%
8	210	25.3	4.1	3.62	3.66	39	1.230%	0.863%
9	240	2.6	2.2	1.76	1.97	10	3.566%	2.511%
10	270	1.7	2.3	2.10	2.02	9	3.267%	2.836%
11	300	1.7	2.5	1.37	2.28	23	17.118%	6.549%
12	330	1.7	1.9	0.82	2.17	66	-20.245%	10.822%
All (fitted)			3.5	2.44	3.11	30	0.977%	1.193%
Source data					3.08	29		

Matehuala. July 2008. 50m



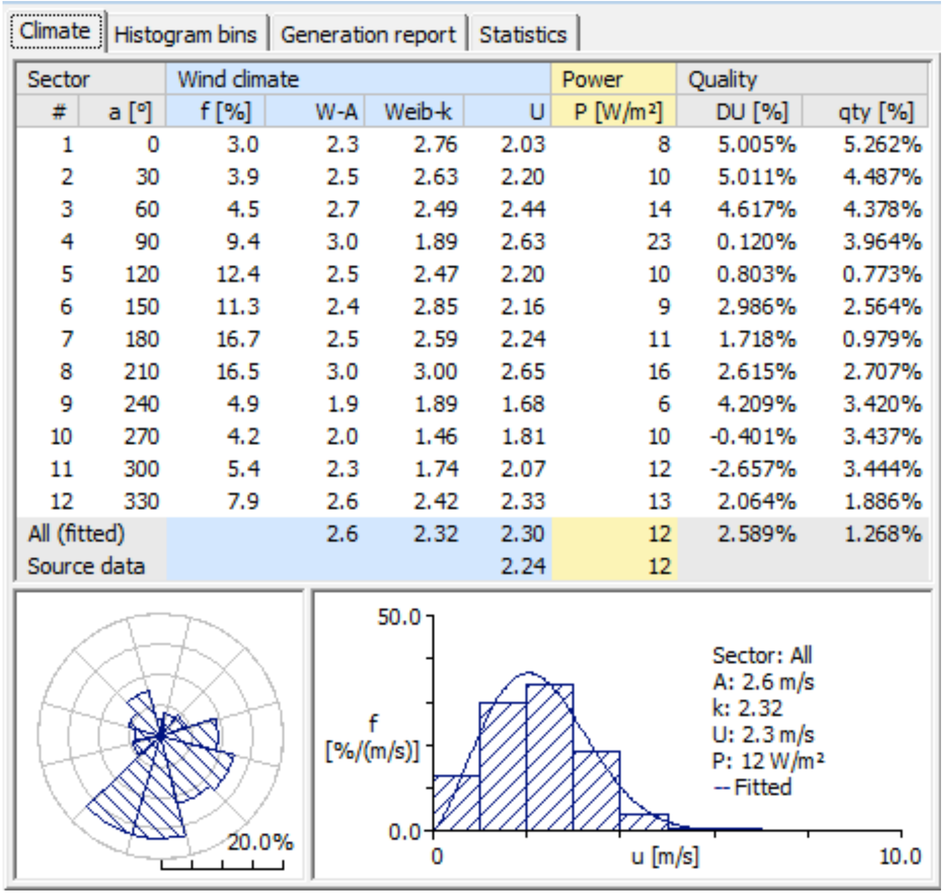
Sector		Wind climate				Power	Quality	
#	a [°]	f [%]	W-A	Weib-k	U	P [W/m²]	DU [%]	qty [%]
1	0	1.8	2.4	2.28	2.10	10	4.788%	6.232%
2	30	2.7	2.6	2.72	2.34	12	4.423%	4.377%
3	60	4.5	3.0	1.93	2.69	24	1.924%	6.447%
4	90	8.7	3.1	2.04	2.76	24	0.329%	3.360%
5	120	10.8	3.0	2.15	2.68	21	2.071%	2.463%
6	150	11.8	2.8	2.49	2.47	15	3.249%	4.210%
7	180	21.1	3.4	2.92	3.03	24	2.614%	2.288%
8	210	23.2	3.9	3.45	3.48	34	2.121%	1.923%
9	240	4.1	2.4	1.46	2.20	18	0.329%	2.576%
10	270	3.3	1.7	1.54	1.51	5	2.717%	2.014%
11	300	4.1	2.3	1.81	2.03	11	-0.255%	0.894%
12	330	3.8	2.3	1.83	2.08	12	2.051%	3.952%
All (fitted)			3.2	2.38	2.82	22	2.995%	2.440%
Source data					2.74	22		

Matehuala. August 2008. 50m



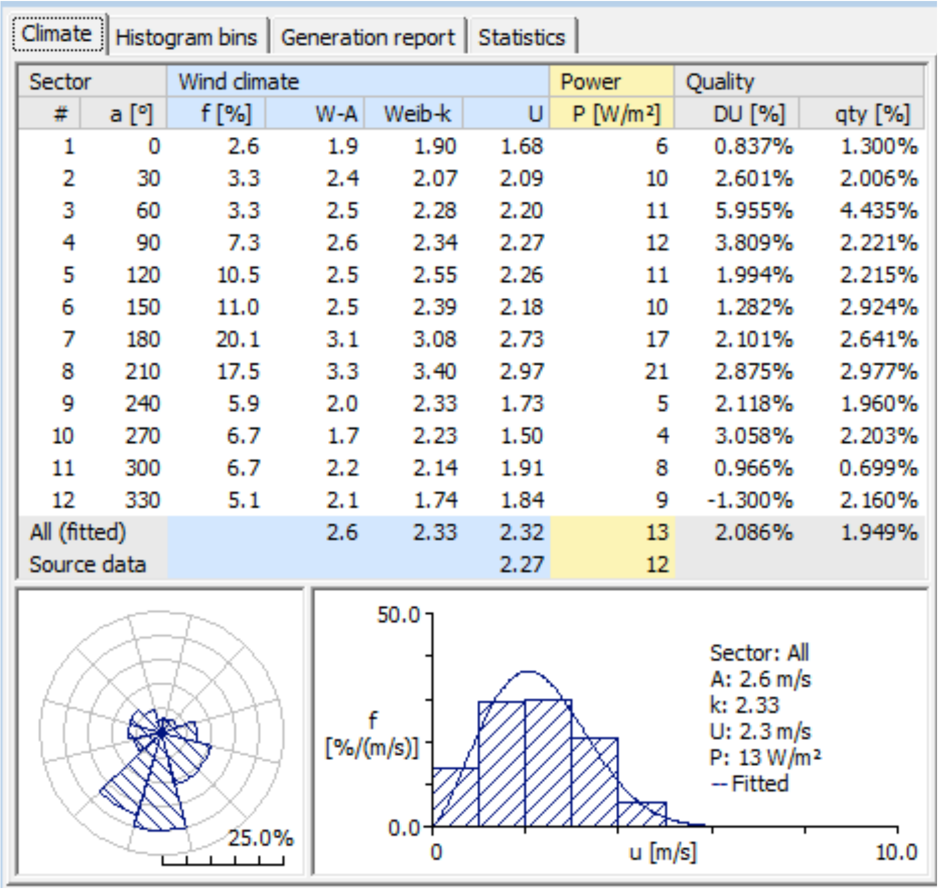
Sector		Wind climate				Power	Quality	
#	a [°]	f [%]	W-A	Weib-k	U	P [W/m²]	DU [%]	qty [%]
1	0	1.3	2.0	2.25	1.77	6	2.026%	1.769%
2	30	2.3	2.5	2.81	2.21	10	7.284%	6.401%
3	60	5.2	3.1	2.01	2.78	25	0.918%	4.544%
4	90	11.2	3.2	1.94	2.86	28	-0.395%	2.643%
5	120	15.5	2.9	2.28	2.54	17	2.139%	2.088%
6	150	14.1	2.6	2.32	2.33	13	1.239%	2.440%
7	180	20.2	3.0	2.95	2.71	17	2.408%	2.342%
8	210	19.7	3.6	3.89	3.23	26	5.337%	4.000%
9	240	3.4	2.3	1.58	2.03	13	0.974%	2.448%
10	270	2.5	2.0	1.72	1.81	8	2.781%	4.902%
11	300	2.2	2.3	1.34	2.07	18	-4.972%	4.611%
12	330	2.5	2.9	1.59	2.57	26	1.784%	3.515%
All (fitted)			3.0	2.38	2.69	19	3.144%	2.416%
Source data					2.61	19		

Matehuala. September 2008. 50m



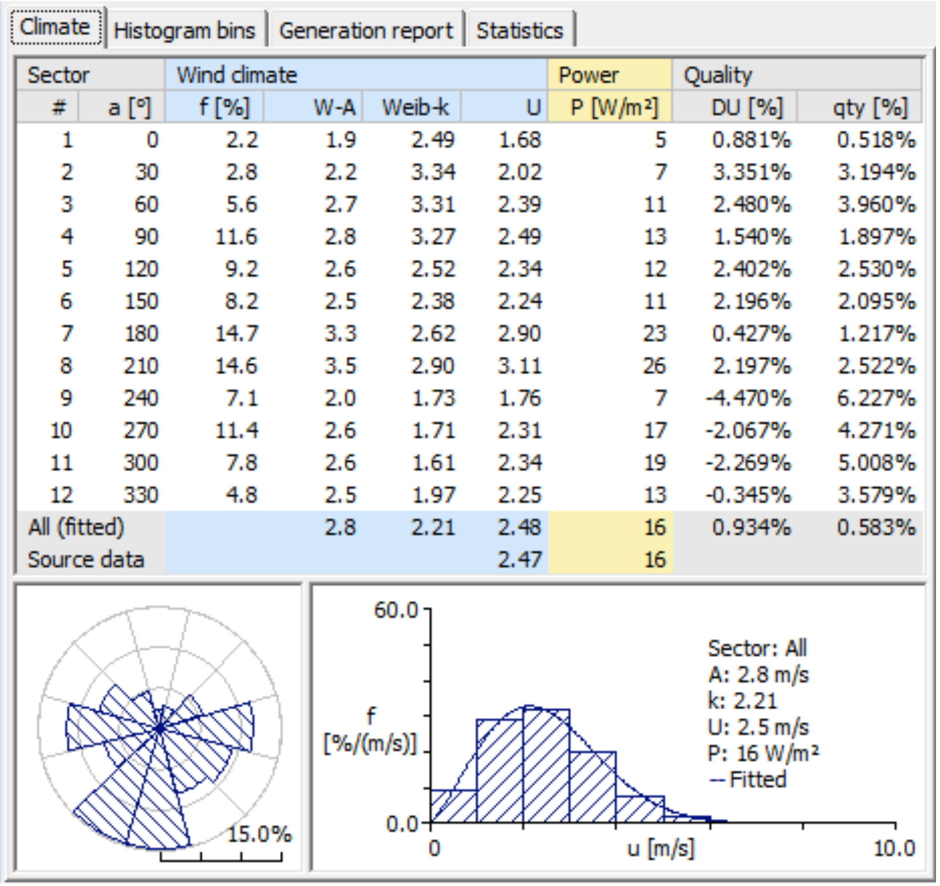
Sector		Wind climate				Power	Quality	
#	a [°]	f [%]	W-A	Weib-k	U	P [W/m²]	DU [%]	qty [%]
1	0	3.0	2.3	2.76	2.03	8	5.005%	5.262%
2	30	3.9	2.5	2.63	2.20	10	5.011%	4.487%
3	60	4.5	2.7	2.49	2.44	14	4.617%	4.378%
4	90	9.4	3.0	1.89	2.63	23	0.120%	3.964%
5	120	12.4	2.5	2.47	2.20	10	0.803%	0.773%
6	150	11.3	2.4	2.85	2.16	9	2.986%	2.564%
7	180	16.7	2.5	2.59	2.24	11	1.718%	0.979%
8	210	16.5	3.0	3.00	2.65	16	2.615%	2.707%
9	240	4.9	1.9	1.89	1.68	6	4.209%	3.420%
10	270	4.2	2.0	1.46	1.81	10	-0.401%	3.437%
11	300	5.4	2.3	1.74	2.07	12	-2.657%	3.444%
12	330	7.9	2.6	2.42	2.33	13	2.064%	1.886%
All (fitted)			2.6	2.32	2.30	12	2.589%	1.268%
Source data					2.24	12		

Matehuala. October 2008. 50m



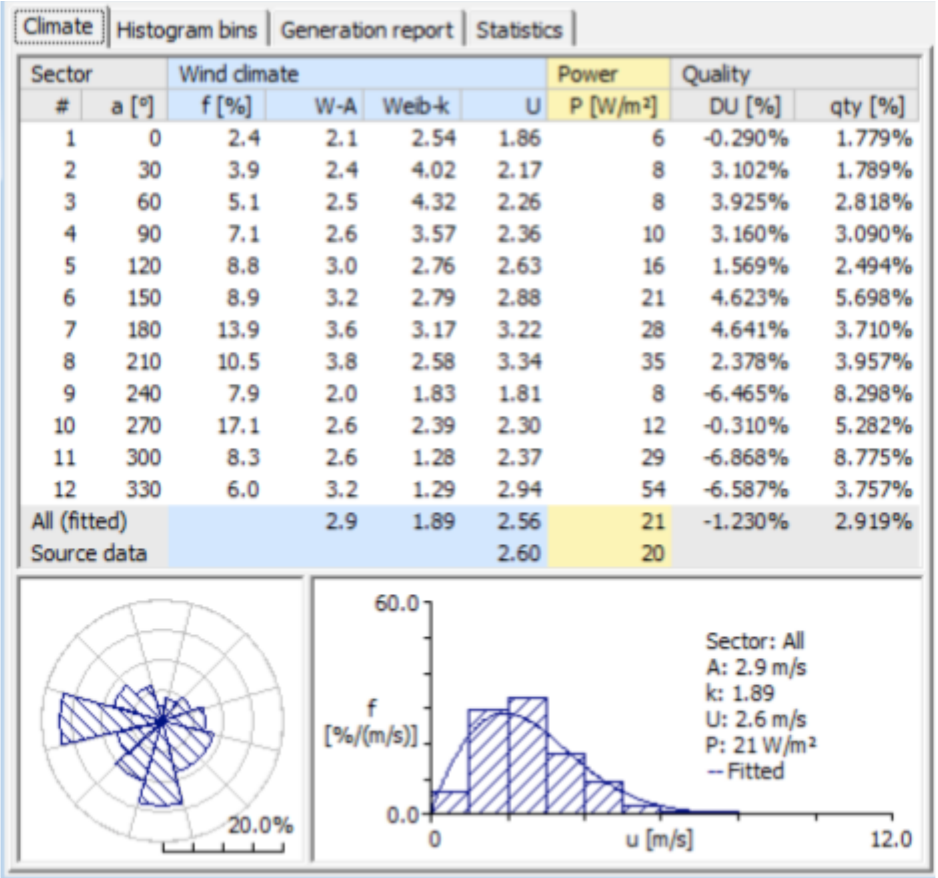
Sector		Wind climate				Power	Quality	
#	a [°]	f [%]	W-A	Weib-k	U	P [W/m²]	DU [%]	qty [%]
1	0	2.6	1.9	1.90	1.68	6	0.837%	1.300%
2	30	3.3	2.4	2.07	2.09	10	2.601%	2.006%
3	60	3.3	2.5	2.28	2.20	11	5.955%	4.435%
4	90	7.3	2.6	2.34	2.27	12	3.809%	2.221%
5	120	10.5	2.5	2.55	2.26	11	1.994%	2.215%
6	150	11.0	2.5	2.39	2.18	10	1.282%	2.924%
7	180	20.1	3.1	3.08	2.73	17	2.101%	2.641%
8	210	17.5	3.3	3.40	2.97	21	2.875%	2.977%
9	240	5.9	2.0	2.33	1.73	5	2.118%	1.960%
10	270	6.7	1.7	2.23	1.50	4	3.058%	2.203%
11	300	6.7	2.2	2.14	1.91	8	0.966%	0.699%
12	330	5.1	2.1	1.74	1.84	9	-1.300%	2.160%
All (fitted)			2.6	2.33	2.32	13	2.086%	1.949%
Source data					2.27	12		

Matehuala. November 2008. 50m



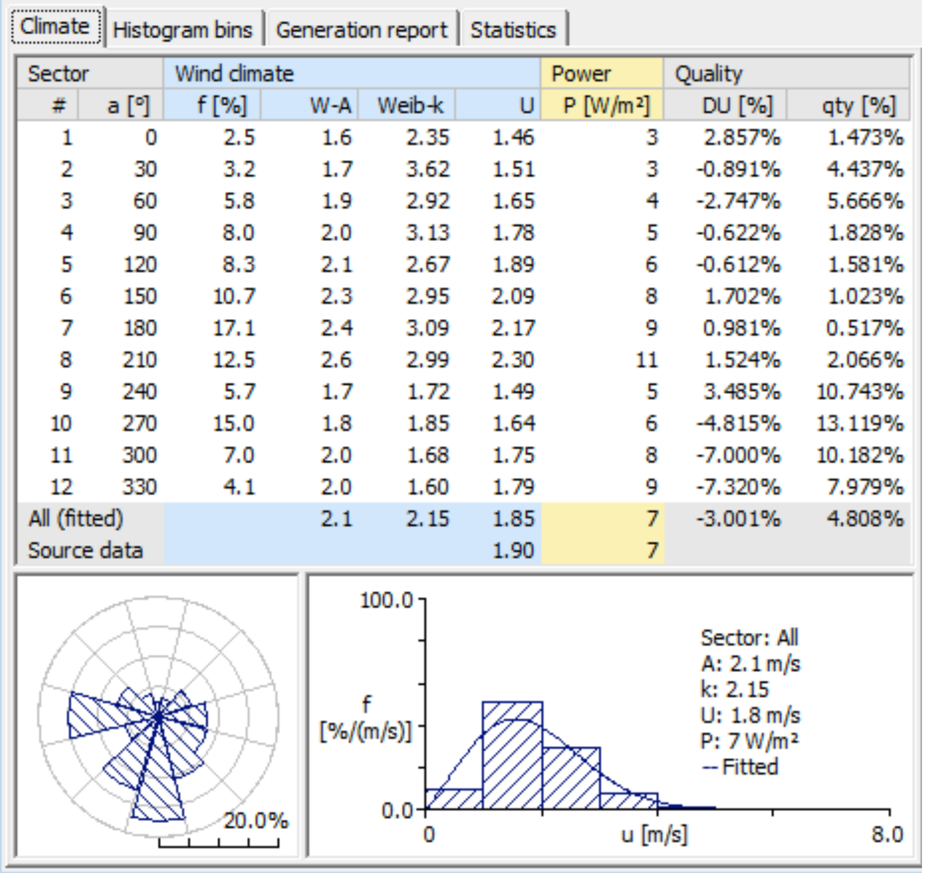
Sector		Wind climate				Power	Quality	
#	a [°]	f [%]	W-A	Weib-k	U	P [W/m²]	DU [%]	qty [%]
1	0	2.2	1.9	2.49	1.68	5	0.881%	0.518%
2	30	2.8	2.2	3.34	2.02	7	3.351%	3.194%
3	60	5.6	2.7	3.31	2.39	11	2.480%	3.960%
4	90	11.6	2.8	3.27	2.49	13	1.540%	1.897%
5	120	9.2	2.6	2.52	2.34	12	2.402%	2.530%
6	150	8.2	2.5	2.38	2.24	11	2.196%	2.095%
7	180	14.7	3.3	2.62	2.90	23	0.427%	1.217%
8	210	14.6	3.5	2.90	3.11	26	2.197%	2.522%
9	240	7.1	2.0	1.73	1.76	7	-4.470%	6.227%
10	270	11.4	2.6	1.71	2.31	17	-2.067%	4.271%
11	300	7.8	2.6	1.61	2.34	19	-2.269%	5.008%
12	330	4.8	2.5	1.97	2.25	13	-0.345%	3.579%
All (fitted)			2.8	2.21	2.48	16	0.934%	0.583%
Source data					2.47	16		

Matehuala. December 2008. 50m



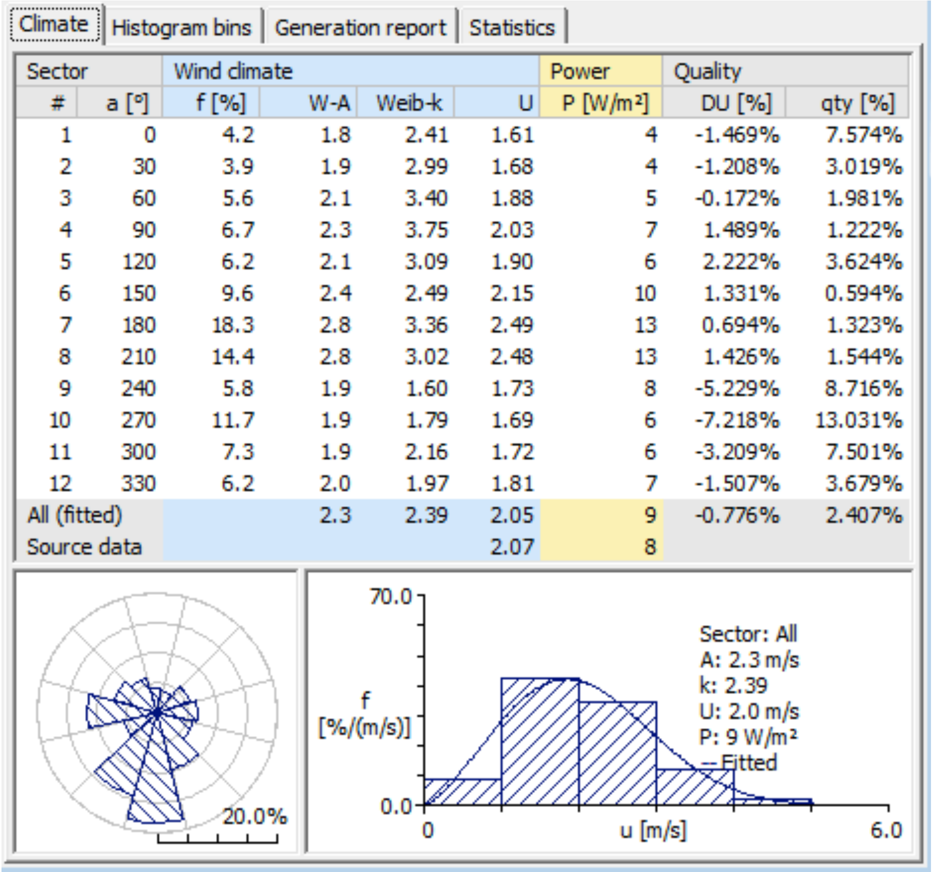
Sector		Wind climate				Power	Quality	
#	a [°]	f [%]	W-A	Weib-k	U	P [W/m²]	DU [%]	qty [%]
1	0	2.4	2.1	2.54	1.86	6	-0.290%	1.779%
2	30	3.9	2.4	4.02	2.17	8	3.102%	1.789%
3	60	5.1	2.5	4.32	2.26	8	3.925%	2.818%
4	90	7.1	2.6	3.57	2.36	10	3.160%	3.090%
5	120	8.8	3.0	2.76	2.63	16	1.569%	2.494%
6	150	8.9	3.2	2.79	2.88	21	4.623%	5.698%
7	180	13.9	3.6	3.17	3.22	28	4.641%	3.710%
8	210	10.5	3.8	2.58	3.34	35	2.378%	3.957%
9	240	7.9	2.0	1.83	1.81	8	-6.465%	8.298%
10	270	17.1	2.6	2.39	2.30	12	-0.310%	5.282%
11	300	8.3	2.6	1.28	2.37	29	-6.868%	8.775%
12	330	6.0	3.2	1.29	2.94	54	-6.587%	3.757%
All (fitted)			2.9	1.89	2.56	21	-1.230%	2.919%
Source data					2.60	20		

Matehuala. January 2009. 10m



Sector		Wind climate				Power	Quality	
#	a [°]	f [%]	W-A	Weib-k	U	P [W/m²]	DU [%]	qty [%]
1	0	2.5	1.6	2.35	1.46	3	2.857%	1.473%
2	30	3.2	1.7	3.62	1.51	3	-0.891%	4.437%
3	60	5.8	1.9	2.92	1.65	4	-2.747%	5.666%
4	90	8.0	2.0	3.13	1.78	5	-0.622%	1.828%
5	120	8.3	2.1	2.67	1.89	6	-0.612%	1.581%
6	150	10.7	2.3	2.95	2.09	8	1.702%	1.023%
7	180	17.1	2.4	3.09	2.17	9	0.981%	0.517%
8	210	12.5	2.6	2.99	2.30	11	1.524%	2.066%
9	240	5.7	1.7	1.72	1.49	5	3.485%	10.743%
10	270	15.0	1.8	1.85	1.64	6	-4.815%	13.119%
11	300	7.0	2.0	1.68	1.75	8	-7.000%	10.182%
12	330	4.1	2.0	1.60	1.79	9	-7.320%	7.979%
All (fitted)			2.1	2.15	1.85	7	-3.001%	4.808%
Source data					1.90	7		

Matehuala. February 2009. 10m

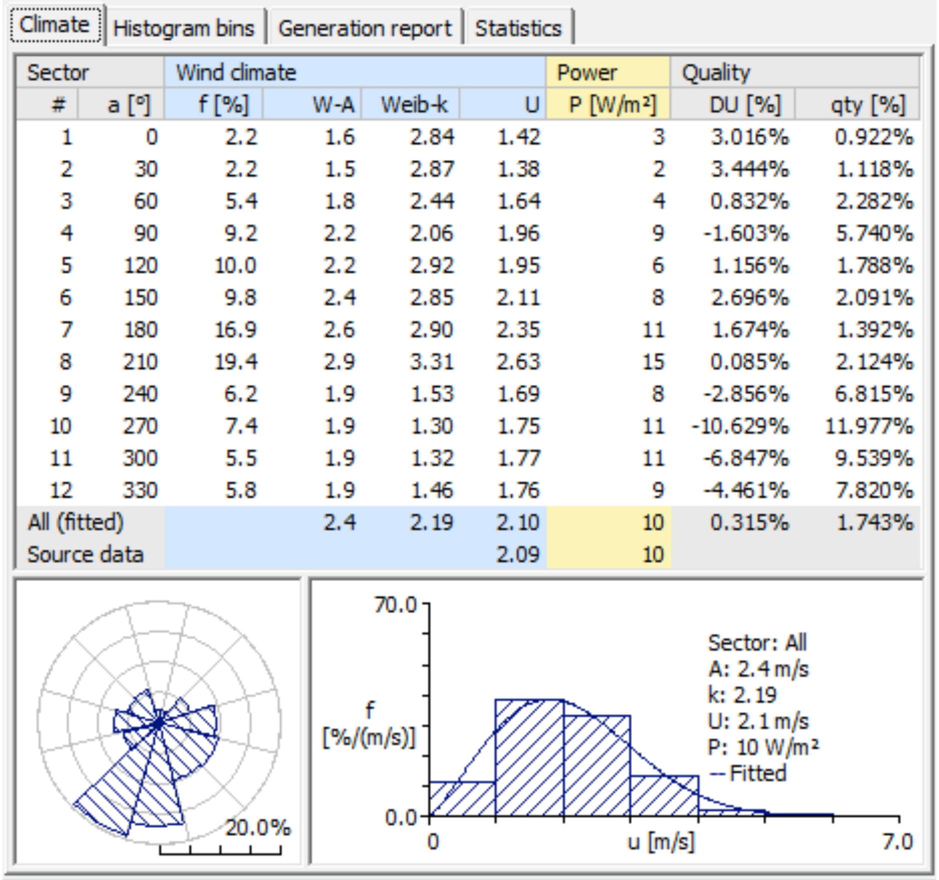


Sector		Wind climate				Power	Quality	
#	a [°]	f [%]	W-A	Weib-k	U	P [W/m²]	DU [%]	qty [%]
1	0	4.2	1.8	2.41	1.61	4	-1.469%	7.574%
2	30	3.9	1.9	2.99	1.68	4	-1.208%	3.019%
3	60	5.6	2.1	3.40	1.88	5	-0.172%	1.981%
4	90	6.7	2.3	3.75	2.03	7	1.489%	1.222%
5	120	6.2	2.1	3.09	1.90	6	2.222%	3.624%
6	150	9.6	2.4	2.49	2.15	10	1.331%	0.594%
7	180	18.3	2.8	3.36	2.49	13	0.694%	1.323%
8	210	14.4	2.8	3.02	2.48	13	1.426%	1.544%
9	240	5.8	1.9	1.60	1.73	8	-5.229%	8.716%
10	270	11.7	1.9	1.79	1.69	6	-7.218%	13.031%
11	300	7.3	1.9	2.16	1.72	6	-3.209%	7.501%
12	330	6.2	2.0	1.97	1.81	7	-1.507%	3.679%
All (fitted)			2.3	2.39	2.05	9	-0.776%	2.407%
Source data					2.07	8		

Matehuala. March 2009. 10m

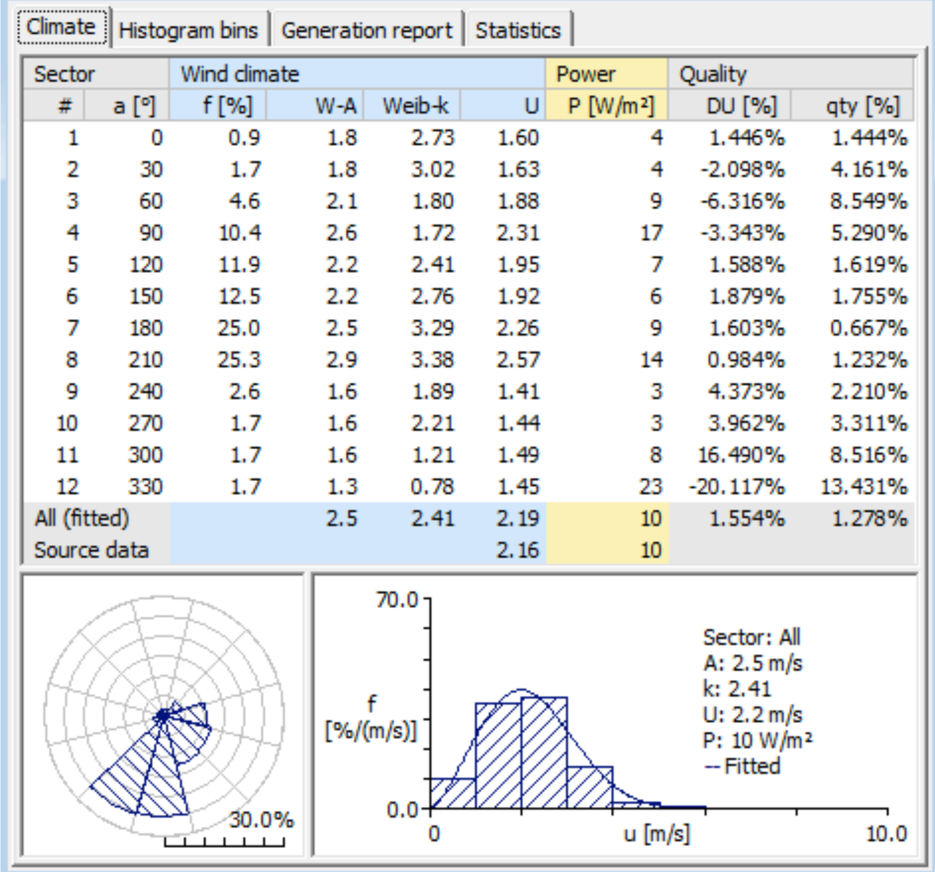
Matehuala. April 2009. 10m

Matehuala. May 2008. 10m



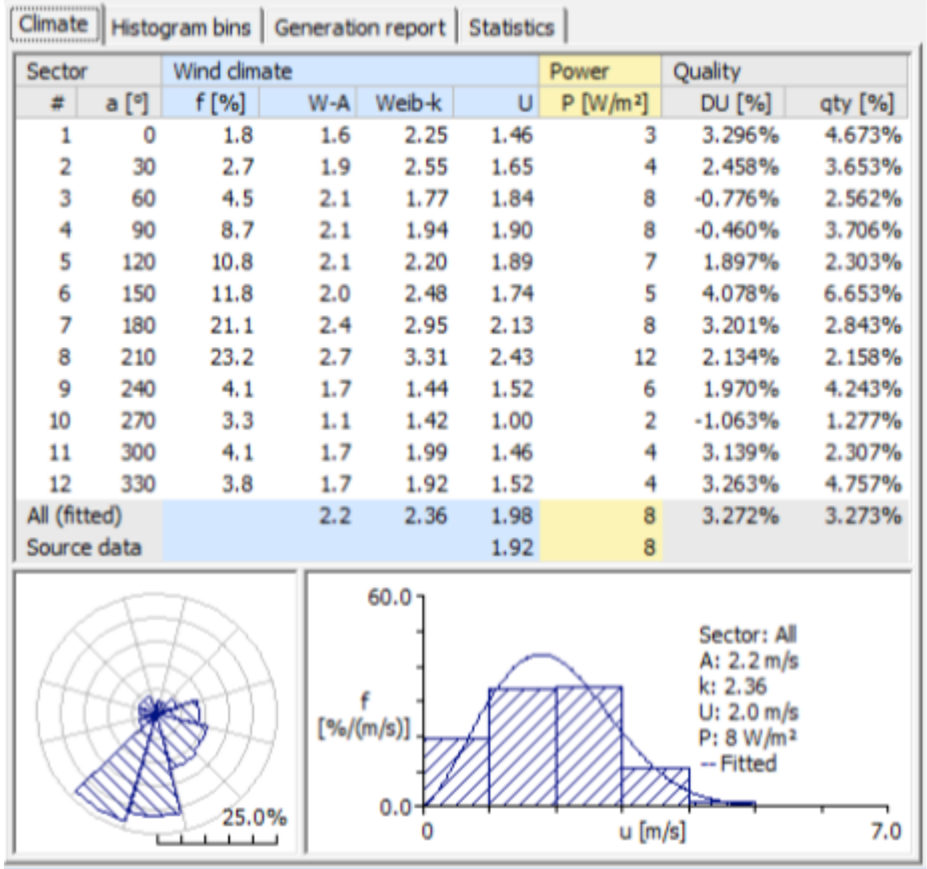
Sector		Wind climate				Power	Quality	
#	a [°]	f [%]	W-A	Weib-k	U	P [W/m²]	DU [%]	qty [%]
1	0	2.2	1.6	2.84	1.42	3	3.016%	0.922%
2	30	2.2	1.5	2.87	1.38	2	3.444%	1.118%
3	60	5.4	1.8	2.44	1.64	4	0.832%	2.282%
4	90	9.2	2.2	2.06	1.96	9	-1.603%	5.740%
5	120	10.0	2.2	2.92	1.95	6	1.156%	1.788%
6	150	9.8	2.4	2.85	2.11	8	2.696%	2.091%
7	180	16.9	2.6	2.90	2.35	11	1.674%	1.392%
8	210	19.4	2.9	3.31	2.63	15	0.085%	2.124%
9	240	6.2	1.9	1.53	1.69	8	-2.856%	6.815%
10	270	7.4	1.9	1.30	1.75	11	-10.629%	11.977%
11	300	5.5	1.9	1.32	1.77	11	-6.847%	9.539%
12	330	5.8	1.9	1.46	1.76	9	-4.461%	7.820%
All (fitted)			2.4	2.19	2.10	10	0.315%	1.743%
Source data					2.09	10		

Matehuala. June 2008. 10m



Sector		Wind climate				Power	Quality	
#	a [°]	f [%]	W-A	Weib-k	U	P [W/m²]	DU [%]	qty [%]
1	0	0.9	1.8	2.73	1.60	4	1.446%	1.444%
2	30	1.7	1.8	3.02	1.63	4	-2.098%	4.161%
3	60	4.6	2.1	1.80	1.88	9	-6.316%	8.549%
4	90	10.4	2.6	1.72	2.31	17	-3.343%	5.290%
5	120	11.9	2.2	2.41	1.95	7	1.588%	1.619%
6	150	12.5	2.2	2.76	1.92	6	1.879%	1.755%
7	180	25.0	2.5	3.29	2.26	9	1.603%	0.667%
8	210	25.3	2.9	3.38	2.57	14	0.984%	1.232%
9	240	2.6	1.6	1.89	1.41	3	4.373%	2.210%
10	270	1.7	1.6	2.21	1.44	3	3.962%	3.311%
11	300	1.7	1.6	1.21	1.49	8	16.490%	8.516%
12	330	1.7	1.3	0.78	1.45	23	-20.117%	13.431%
All (fitted)			2.5	2.41	2.19	10	1.554%	1.278%
Source data					2.16	10		

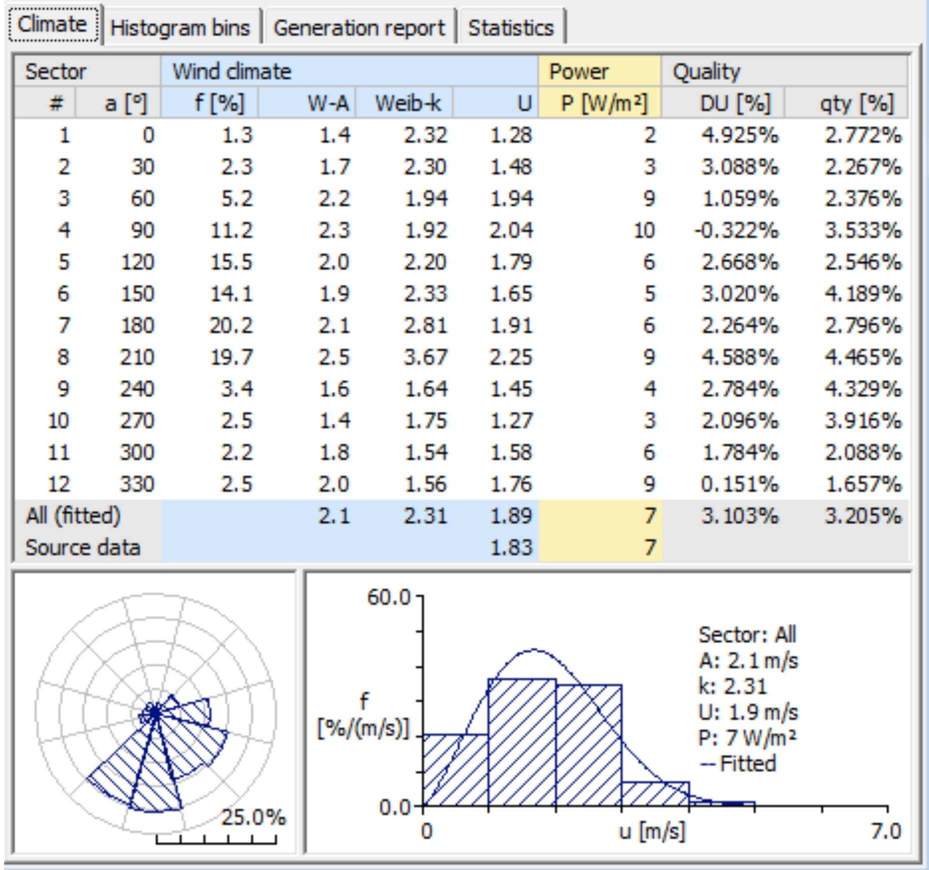
Matehuala. July 2008. 10m



Sector		Wind climate				Power	Quality	
#	a [°]	f [%]	W-A	Weib-k	U	P [W/m²]	DU [%]	qty [%]
1	0	1.8	1.6	2.25	1.46	3	3.296%	4.673%
2	30	2.7	1.9	2.55	1.65	4	2.458%	3.653%
3	60	4.5	2.1	1.77	1.84	8	-0.776%	2.562%
4	90	8.7	2.1	1.94	1.90	8	-0.460%	3.706%
5	120	10.8	2.1	2.20	1.89	7	1.897%	2.303%
6	150	11.8	2.0	2.48	1.74	5	4.078%	6.653%
7	180	21.1	2.4	2.95	2.13	8	3.201%	2.843%
8	210	23.2	2.7	3.31	2.43	12	2.134%	2.158%
9	240	4.1	1.7	1.44	1.52	6	1.970%	4.243%
10	270	3.3	1.1	1.42	1.00	2	-1.063%	1.277%
11	300	4.1	1.7	1.99	1.46	4	3.139%	2.307%
12	330	3.8	1.7	1.92	1.52	4	3.263%	4.757%
All (fitted)			2.2	2.36	1.98	8	3.272%	3.273%
Source data					1.92	8		

Sector: All
A: 2.2 m/s
k: 2.36
U: 2.0 m/s
P: 8 W/m²

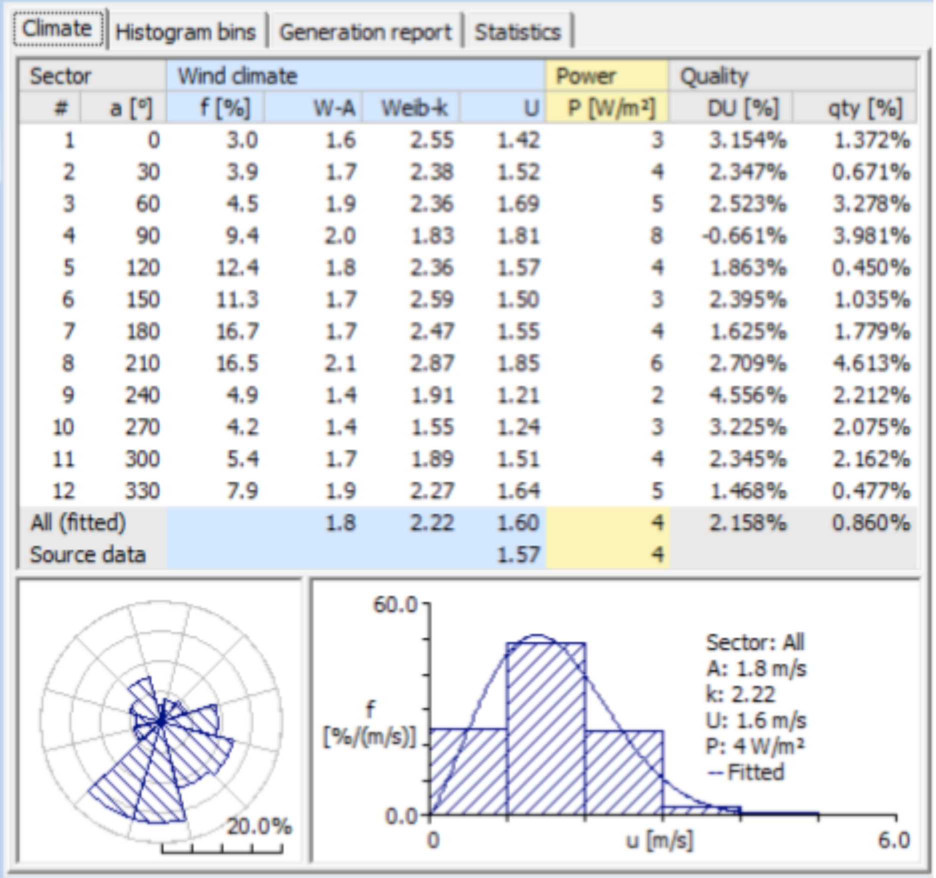
Matehuala. August 2008. 10m



Sector		Wind climate				Power	Quality	
#	a [°]	f [%]	W-A	Weib-k	U	P [W/m²]	DU [%]	qty [%]
1	0	1.3	1.4	2.32	1.28	2	4.925%	2.772%
2	30	2.3	1.7	2.30	1.48	3	3.088%	2.267%
3	60	5.2	2.2	1.94	1.94	9	1.059%	2.376%
4	90	11.2	2.3	1.92	2.04	10	-0.322%	3.533%
5	120	15.5	2.0	2.20	1.79	6	2.668%	2.546%
6	150	14.1	1.9	2.33	1.65	5	3.020%	4.189%
7	180	20.2	2.1	2.81	1.91	6	2.264%	2.796%
8	210	19.7	2.5	3.67	2.25	9	4.588%	4.465%
9	240	3.4	1.6	1.64	1.45	4	2.784%	4.329%
10	270	2.5	1.4	1.75	1.27	3	2.096%	3.916%
11	300	2.2	1.8	1.54	1.58	6	1.784%	2.088%
12	330	2.5	2.0	1.56	1.76	9	0.151%	1.657%
All (fitted)			2.1	2.31	1.89	7	3.103%	3.205%
Source data					1.83	7		

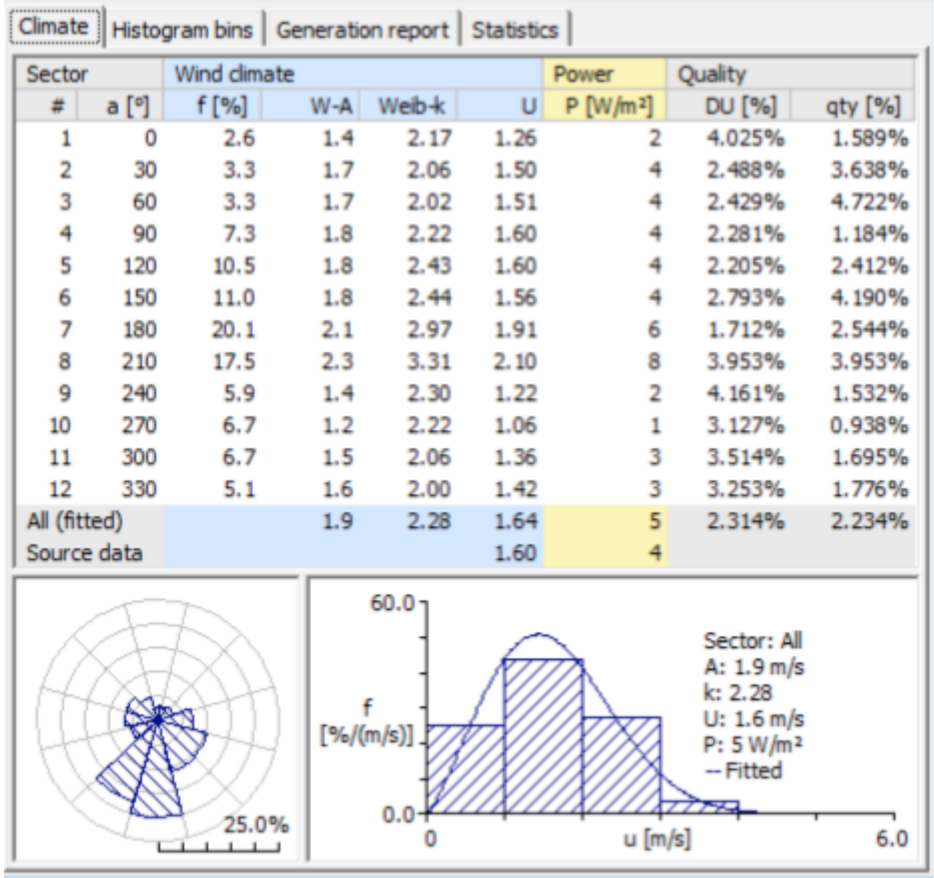
Sector: All
A: 2.1 m/s
k: 2.31
U: 1.9 m/s
P: 7 W/m²

Matehuala. September 2008. 10m



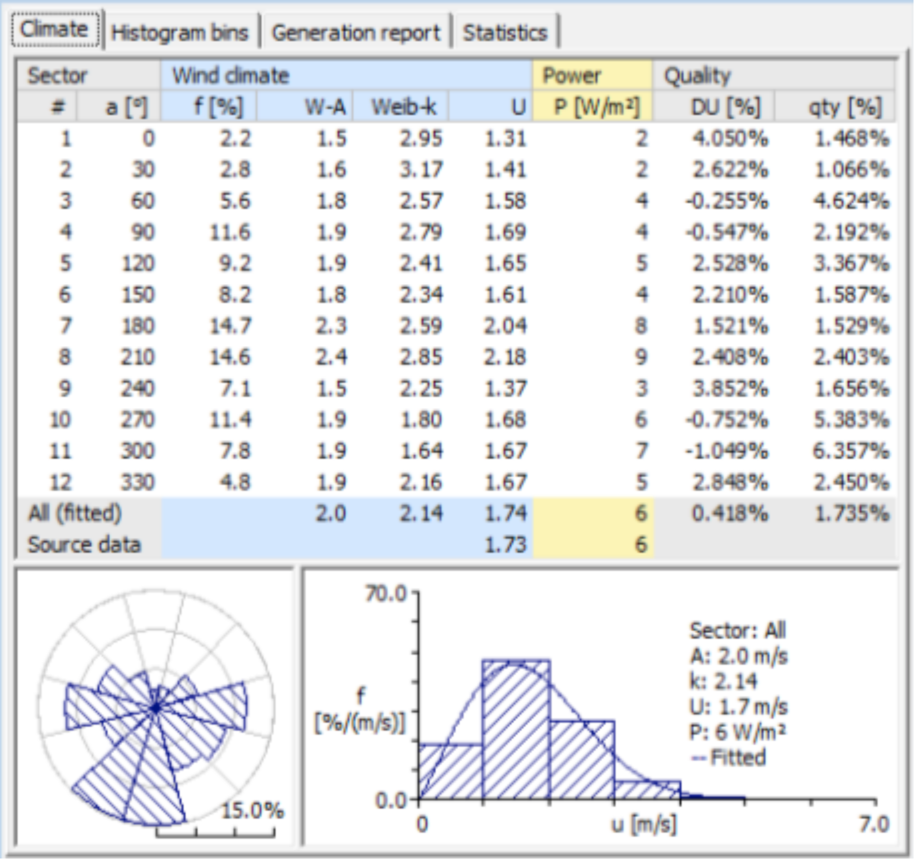
Sector		Wind climate				Power	Quality	
#	a [°]	f [%]	W-A	Weib-k	U	P [W/m²]	DU [%]	qty [%]
1	0	3.0	1.6	2.55	1.42	3	3.154%	1.372%
2	30	3.9	1.7	2.38	1.52	4	2.347%	0.671%
3	60	4.5	1.9	2.36	1.69	5	2.523%	3.278%
4	90	9.4	2.0	1.83	1.81	8	-0.661%	3.981%
5	120	12.4	1.8	2.36	1.57	4	1.863%	0.450%
6	150	11.3	1.7	2.59	1.50	3	2.395%	1.035%
7	180	16.7	1.7	2.47	1.55	4	1.625%	1.779%
8	210	16.5	2.1	2.87	1.85	6	2.709%	4.613%
9	240	4.9	1.4	1.91	1.21	2	4.556%	2.212%
10	270	4.2	1.4	1.55	1.24	3	3.225%	2.075%
11	300	5.4	1.7	1.89	1.51	4	2.345%	2.162%
12	330	7.9	1.9	2.27	1.64	5	1.468%	0.477%
All (fitted)			1.8	2.22	1.60	4	2.158%	0.860%
Source data					1.57	4		

Matehuala. October 2008. 10m



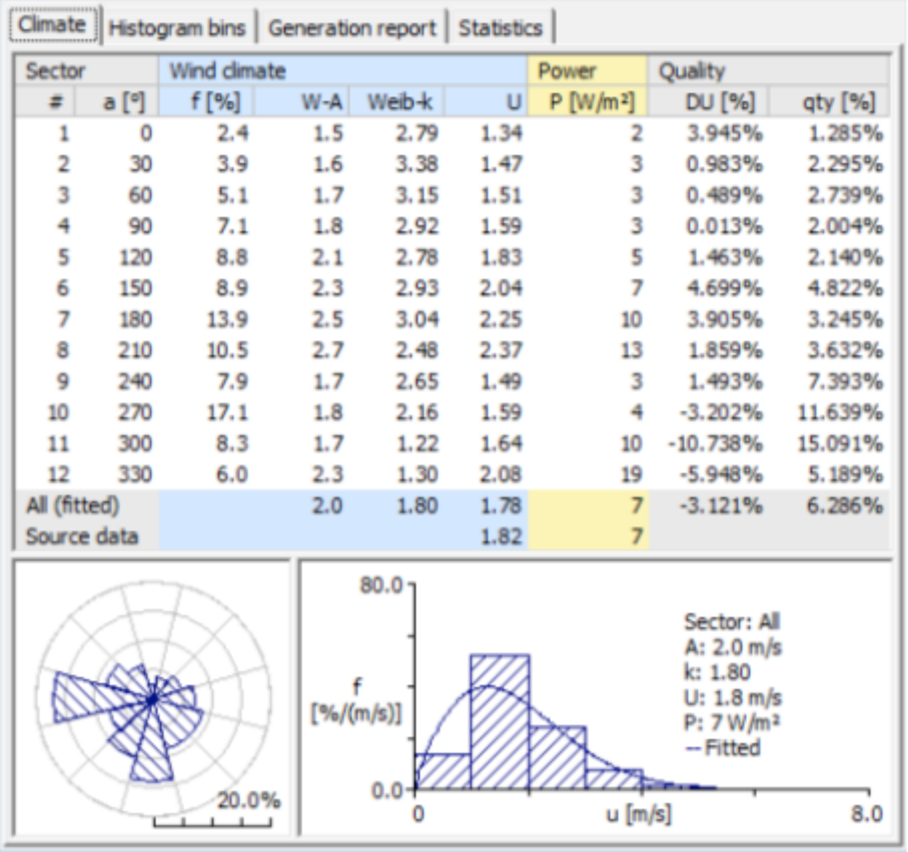
Sector		Wind climate				Power	Quality	
#	a [°]	f [%]	W-A	Weib-k	U	P [W/m²]	DU [%]	qty [%]
1	0	2.6	1.4	2.17	1.26	2	4.025%	1.589%
2	30	3.3	1.7	2.06	1.50	4	2.488%	3.638%
3	60	3.3	1.7	2.02	1.51	4	2.429%	4.722%
4	90	7.3	1.8	2.22	1.60	4	2.281%	1.184%
5	120	10.5	1.8	2.43	1.60	4	2.205%	2.412%
6	150	11.0	1.8	2.44	1.56	4	2.793%	4.190%
7	180	20.1	2.1	2.97	1.91	6	1.712%	2.544%
8	210	17.5	2.3	3.31	2.10	8	3.953%	3.953%
9	240	5.9	1.4	2.30	1.22	2	4.161%	1.532%
10	270	6.7	1.2	2.22	1.06	1	3.127%	0.938%
11	300	6.7	1.5	2.06	1.36	3	3.514%	1.695%
12	330	5.1	1.6	2.00	1.42	3	3.253%	1.776%
All (fitted)			1.9	2.28	1.64	5	2.314%	2.234%
Source data					1.60	4		

Matehuala. November 2008. 10m



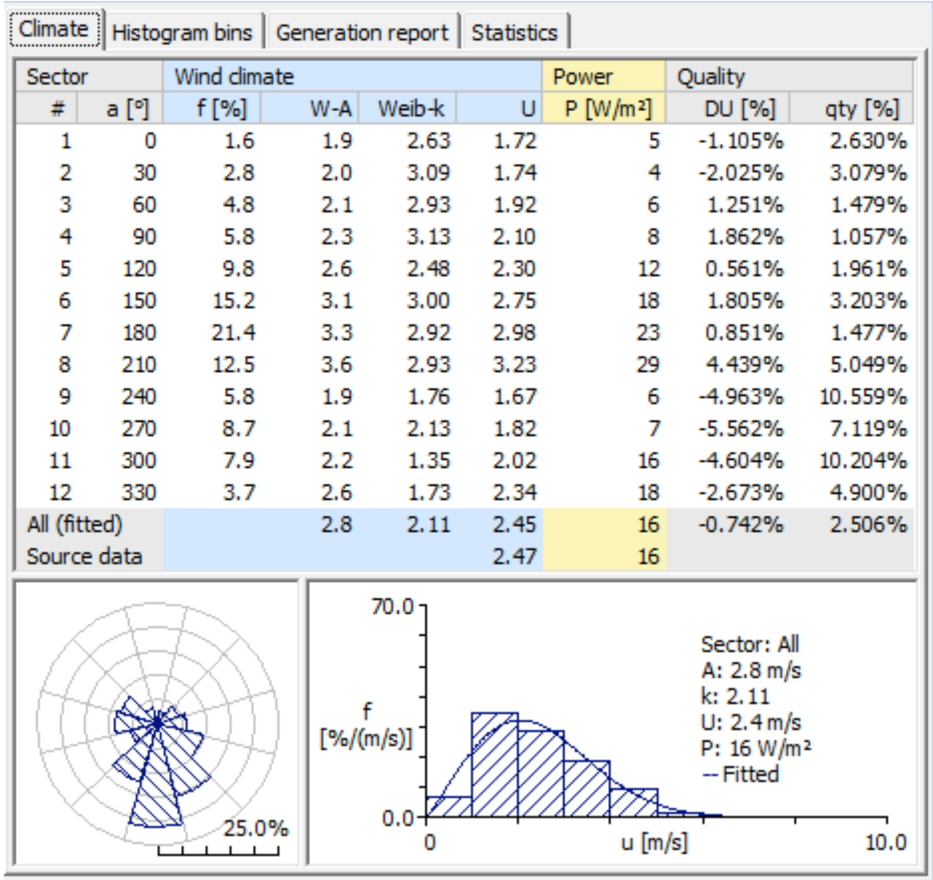
Sector		Wind climate				Power	Quality	
#	a [°]	f [%]	W-A	Weib-k	U	P [W/m²]	DU [%]	qty [%]
1	0	2.2	1.5	2.95	1.31	2	4.050%	1.468%
2	30	2.8	1.6	3.17	1.41	2	2.622%	1.066%
3	60	5.6	1.8	2.57	1.58	4	-0.255%	4.624%
4	90	11.6	1.9	2.79	1.69	4	-0.547%	2.192%
5	120	9.2	1.9	2.41	1.65	5	2.528%	3.367%
6	150	8.2	1.8	2.34	1.61	4	2.210%	1.587%
7	180	14.7	2.3	2.59	2.04	8	1.521%	1.529%
8	210	14.6	2.4	2.85	2.18	9	2.408%	2.403%
9	240	7.1	1.5	2.25	1.37	3	3.852%	1.656%
10	270	11.4	1.9	1.80	1.68	6	-0.752%	5.383%
11	300	7.8	1.9	1.64	1.67	7	-1.049%	6.357%
12	330	4.8	1.9	2.16	1.67	5	2.848%	2.450%
All (fitted)			2.0	2.14	1.74	6	0.418%	1.735%
Source data					1.73	6		

Matehuala. December 2008. 10m



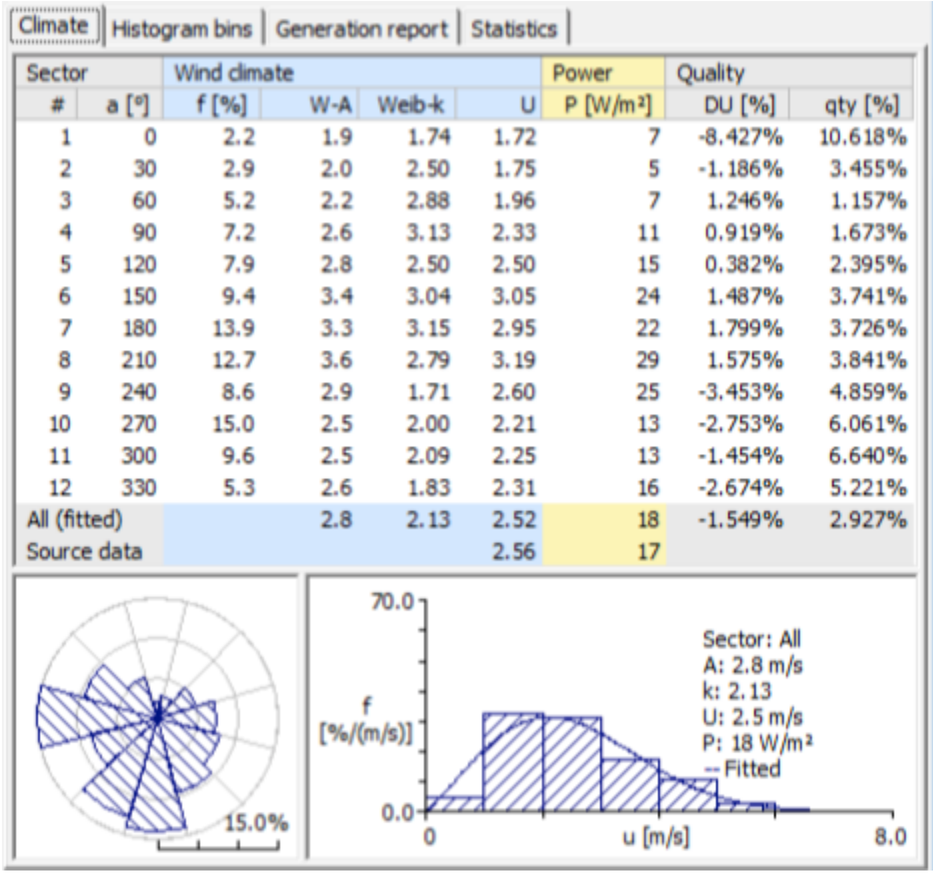
Sector		Wind climate				Power	Quality	
#	a [°]	f [%]	W-A	Weib-k	U	P [W/m²]	DU [%]	qty [%]
1	0	2.4	1.5	2.79	1.34	2	3.945%	1.285%
2	30	3.9	1.6	3.38	1.47	3	0.983%	2.295%
3	60	5.1	1.7	3.15	1.51	3	0.489%	2.739%
4	90	7.1	1.8	2.92	1.59	3	0.013%	2.004%
5	120	8.8	2.1	2.78	1.83	5	1.463%	2.140%
6	150	8.9	2.3	2.93	2.04	7	4.699%	4.822%
7	180	13.9	2.5	3.04	2.25	10	3.905%	3.245%
8	210	10.5	2.7	2.48	2.37	13	1.859%	3.632%
9	240	7.9	1.7	2.65	1.49	3	1.493%	7.393%
10	270	17.1	1.8	2.16	1.59	4	-3.202%	11.639%
11	300	8.3	1.7	1.22	1.64	10	-10.738%	15.091%
12	330	6.0	2.3	1.30	2.08	19	-5.948%	5.189%
All (fitted)			2.0	1.80	1.78	7	-3.121%	6.286%
Source data					1.82	7		

Matehuala. January 2008. 20m



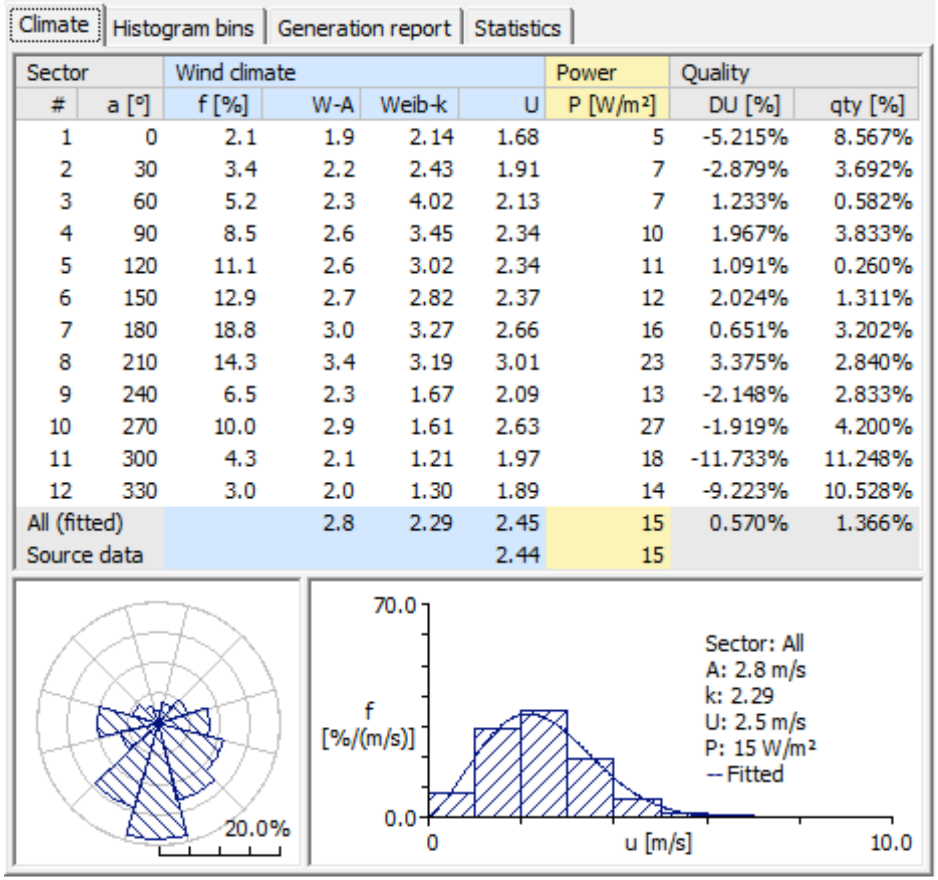
Sector		Wind climate				Power	Quality	
#	a [°]	f [%]	W-A	Weib-k	U	P [W/m²]	DU [%]	qty [%]
1	0	1.6	1.9	2.63	1.72	5	-1.105%	2.630%
2	30	2.8	2.0	3.09	1.74	4	-2.025%	3.079%
3	60	4.8	2.1	2.93	1.92	6	1.251%	1.479%
4	90	5.8	2.3	3.13	2.10	8	1.862%	1.057%
5	120	9.8	2.6	2.48	2.30	12	0.561%	1.961%
6	150	15.2	3.1	3.00	2.75	18	1.805%	3.203%
7	180	21.4	3.3	2.92	2.98	23	0.851%	1.477%
8	210	12.5	3.6	2.93	3.23	29	4.439%	5.049%
9	240	5.8	1.9	1.76	1.67	6	-4.963%	10.559%
10	270	8.7	2.1	2.13	1.82	7	-5.562%	7.119%
11	300	7.9	2.2	1.35	2.02	16	-4.604%	10.204%
12	330	3.7	2.6	1.73	2.34	18	-2.673%	4.900%
All (fitted)			2.8	2.11	2.45	16	-0.742%	2.506%
Source data					2.47	16		

Matehuala. February 2008. 20m



Sector		Wind climate				Power	Quality	
#	a [°]	f [%]	W-A	Weib-k	U	P [W/m²]	DU [%]	qty [%]
1	0	2.2	1.9	1.74	1.72	7	-8.427%	10.618%
2	30	2.9	2.0	2.50	1.75	5	-1.186%	3.455%
3	60	5.2	2.2	2.88	1.96	7	1.246%	1.157%
4	90	7.2	2.6	3.13	2.33	11	0.919%	1.673%
5	120	7.9	2.8	2.50	2.50	15	0.382%	2.395%
6	150	9.4	3.4	3.04	3.05	24	1.487%	3.741%
7	180	13.9	3.3	3.15	2.95	22	1.799%	3.726%
8	210	12.7	3.6	2.79	3.19	29	1.575%	3.841%
9	240	8.6	2.9	1.71	2.60	25	-3.453%	4.859%
10	270	15.0	2.5	2.00	2.21	13	-2.753%	6.061%
11	300	9.6	2.5	2.09	2.25	13	-1.454%	6.640%
12	330	5.3	2.6	1.83	2.31	16	-2.674%	5.221%
All (fitted)			2.8	2.13	2.52	18	-1.549%	2.927%
Source data					2.56	17		

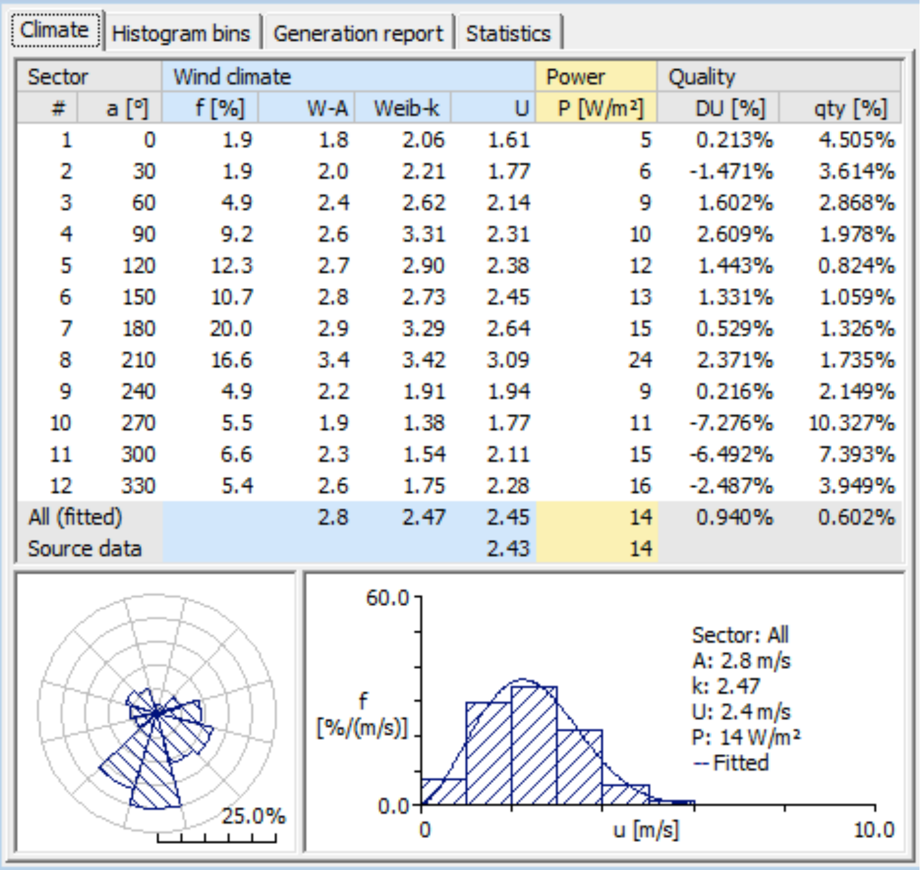
Matehuala. March 2008. 20m



Sector		Wind climate				Power	Quality	
#	a [°]	f [%]	W-A	Weib-k	U	P [W/m²]	DU [%]	qty [%]
1	0	2.1	1.9	2.14	1.68	5	-5.215%	8.567%
2	30	3.4	2.2	2.43	1.91	7	-2.879%	3.692%
3	60	5.2	2.3	4.02	2.13	7	1.233%	0.582%
4	90	8.5	2.6	3.45	2.34	10	1.967%	3.833%
5	120	11.1	2.6	3.02	2.34	11	1.091%	0.260%
6	150	12.9	2.7	2.82	2.37	12	2.024%	1.311%
7	180	18.8	3.0	3.27	2.66	16	0.651%	3.202%
8	210	14.3	3.4	3.19	3.01	23	3.375%	2.840%
9	240	6.5	2.3	1.67	2.09	13	-2.148%	2.833%
10	270	10.0	2.9	1.61	2.63	27	-1.919%	4.200%
11	300	4.3	2.1	1.21	1.97	18	-11.733%	11.248%
12	330	3.0	2.0	1.30	1.89	14	-9.223%	10.528%
All (fitted)			2.8	2.29	2.45	15	0.570%	1.366%
Source data					2.44	15		

Sector: All
A: 2.8 m/s
k: 2.29
U: 2.5 m/s
P: 15 W/m²
-- Fitted

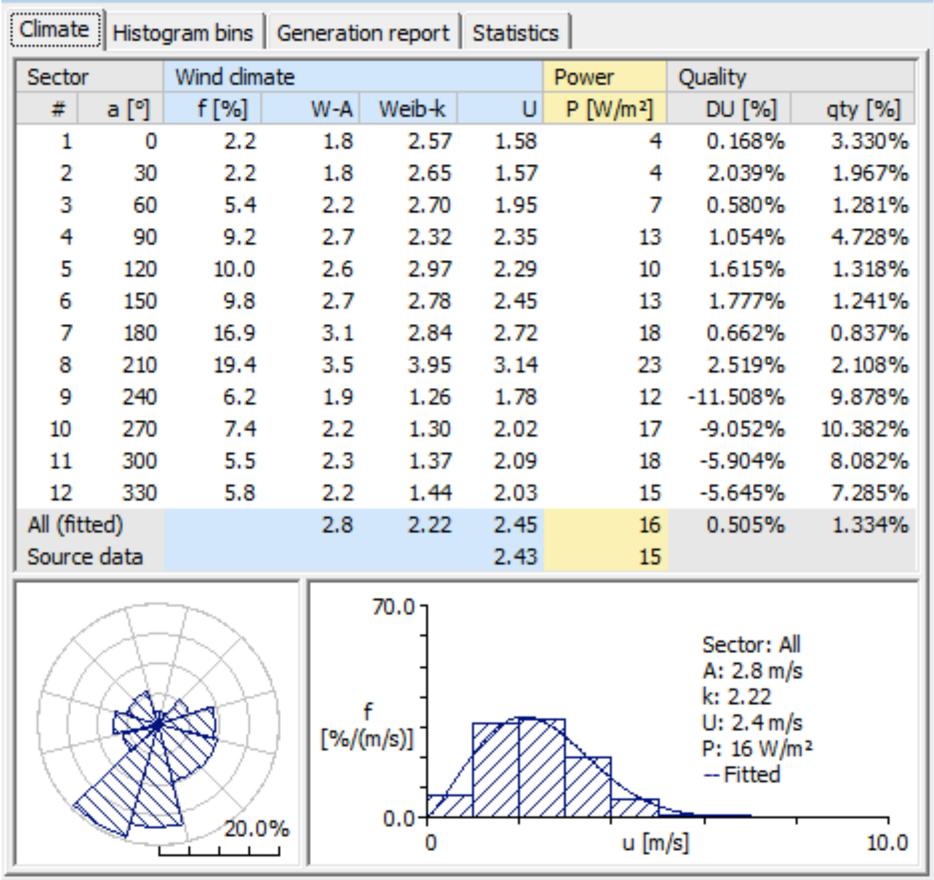
Matehuala. April 2008. 20m



Sector		Wind climate				Power	Quality	
#	a [°]	f [%]	W-A	Weib-k	U	P [W/m²]	DU [%]	qty [%]
1	0	1.9	1.8	2.06	1.61	5	0.213%	4.505%
2	30	1.9	2.0	2.21	1.77	6	-1.471%	3.614%
3	60	4.9	2.4	2.62	2.14	9	1.602%	2.868%
4	90	9.2	2.6	3.31	2.31	10	2.609%	1.978%
5	120	12.3	2.7	2.90	2.38	12	1.443%	0.824%
6	150	10.7	2.8	2.73	2.45	13	1.331%	1.059%
7	180	20.0	2.9	3.29	2.64	15	0.529%	1.326%
8	210	16.6	3.4	3.42	3.09	24	2.371%	1.735%
9	240	4.9	2.2	1.91	1.94	9	0.216%	2.149%
10	270	5.5	1.9	1.38	1.77	11	-7.276%	10.327%
11	300	6.6	2.3	1.54	2.11	15	-6.492%	7.393%
12	330	5.4	2.6	1.75	2.28	16	-2.487%	3.949%
All (fitted)			2.8	2.47	2.45	14	0.940%	0.602%
Source data					2.43	14		

Sector: All
A: 2.8 m/s
k: 2.47
U: 2.4 m/s
P: 14 W/m²
-- Fitted

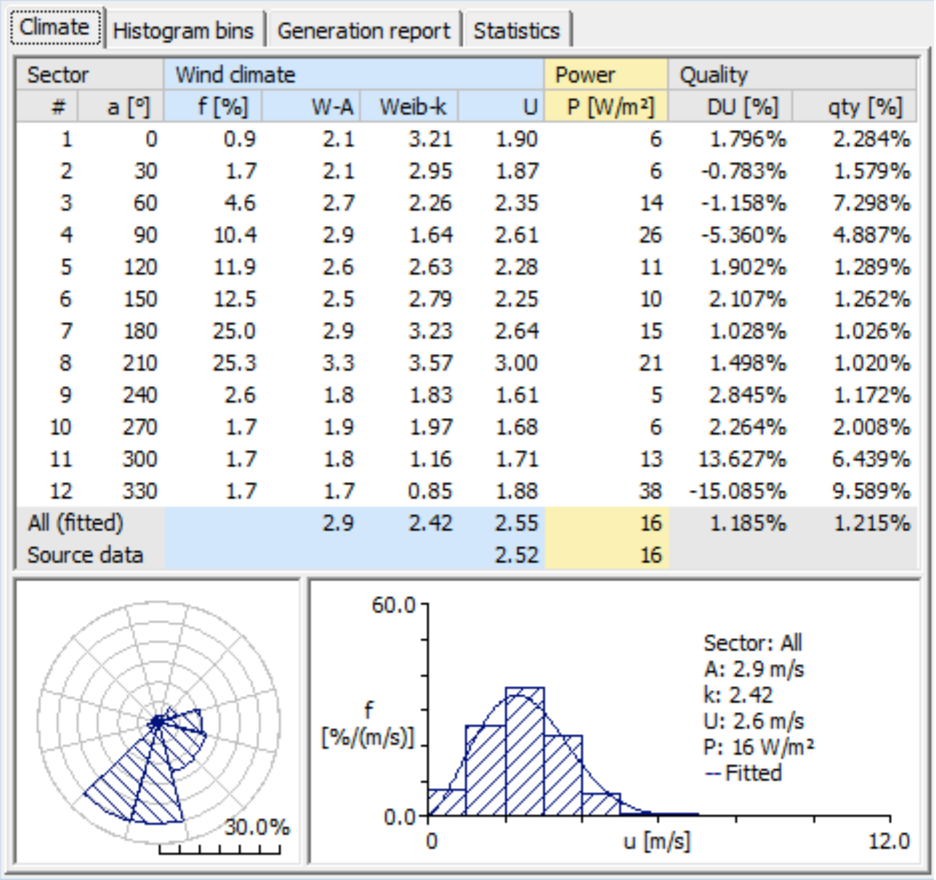
Matehuala. May 2008. 20m



Sector		Wind climate				Power	Quality	
#	a [°]	f [%]	W-A	Weib-k	U	P [W/m²]	DU [%]	qty [%]
1	0	2.2	1.8	2.57	1.58	4	0.168%	3.330%
2	30	2.2	1.8	2.65	1.57	4	2.039%	1.967%
3	60	5.4	2.2	2.70	1.95	7	0.580%	1.281%
4	90	9.2	2.7	2.32	2.35	13	1.054%	4.728%
5	120	10.0	2.6	2.97	2.29	10	1.615%	1.318%
6	150	9.8	2.7	2.78	2.45	13	1.777%	1.241%
7	180	16.9	3.1	2.84	2.72	18	0.662%	0.837%
8	210	19.4	3.5	3.95	3.14	23	2.519%	2.108%
9	240	6.2	1.9	1.26	1.78	12	-11.508%	9.878%
10	270	7.4	2.2	1.30	2.02	17	-9.052%	10.382%
11	300	5.5	2.3	1.37	2.09	18	-5.904%	8.082%
12	330	5.8	2.2	1.44	2.03	15	-5.645%	7.285%
All (fitted)			2.8	2.22	2.45	16	0.505%	1.334%
Source data					2.43	15		

Sector: All
A: 2.8 m/s
k: 2.22
U: 2.4 m/s
P: 16 W/m²

Matehuala. June 2008. 20m

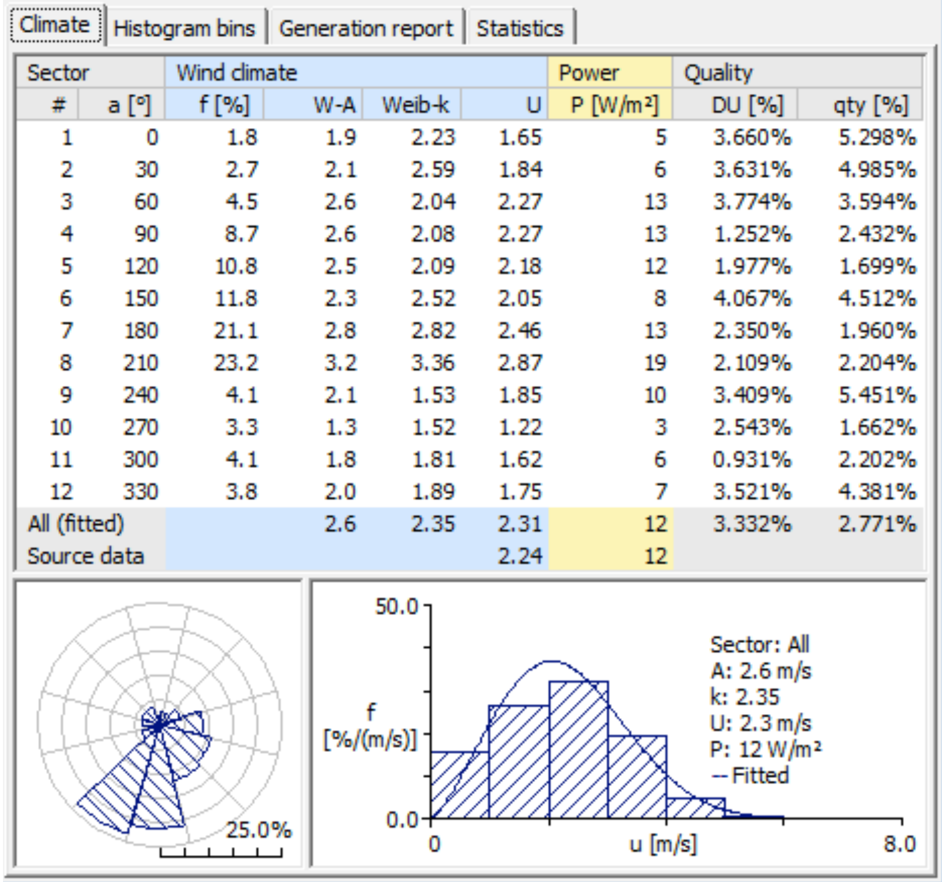


Sector		Wind climate				Power	Quality	
#	a [°]	f [%]	W-A	Weib-k	U	P [W/m²]	DU [%]	qty [%]
1	0	0.9	2.1	3.21	1.90	6	1.796%	2.284%
2	30	1.7	2.1	2.95	1.87	6	-0.783%	1.579%
3	60	4.6	2.7	2.26	2.35	14	-1.158%	7.298%
4	90	10.4	2.9	1.64	2.61	26	-5.360%	4.887%
5	120	11.9	2.6	2.63	2.28	11	1.902%	1.289%
6	150	12.5	2.5	2.79	2.25	10	2.107%	1.262%
7	180	25.0	2.9	3.23	2.64	15	1.028%	1.026%
8	210	25.3	3.3	3.57	3.00	21	1.498%	1.020%
9	240	2.6	1.8	1.83	1.61	5	2.845%	1.172%
10	270	1.7	1.9	1.97	1.68	6	2.264%	2.008%
11	300	1.7	1.8	1.16	1.71	13	13.627%	6.439%
12	330	1.7	1.7	0.85	1.88	38	-15.085%	9.589%
All (fitted)			2.9	2.42	2.55	16	1.185%	1.215%
Source data					2.52	16		

Sector: All
A: 2.9 m/s
k: 2.42
U: 2.6 m/s
P: 16 W/m²

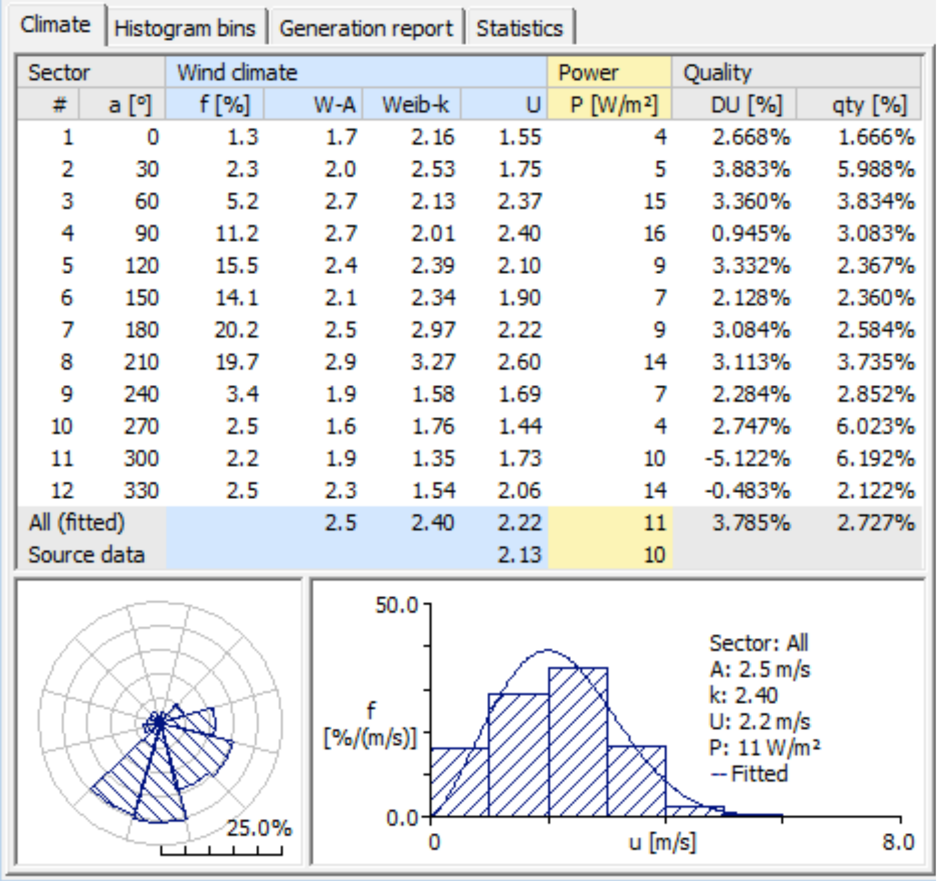
Appendix. Wind Climate Analysis

Matehuala. July 2008. 20m



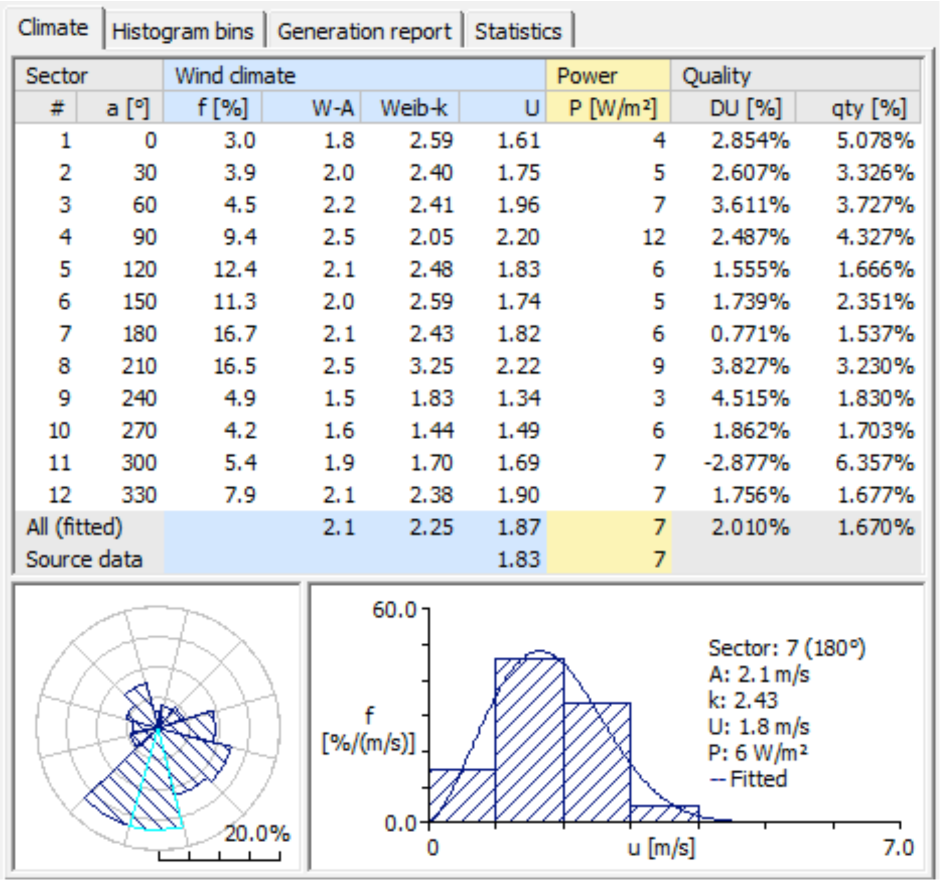
Sector		Wind climate				Power	Quality	
#	a [°]	f [%]	W-A	Weib-k	U	P [W/m²]	DU [%]	qty [%]
1	0	1.8	1.9	2.23	1.65	5	3.660%	5.298%
2	30	2.7	2.1	2.59	1.84	6	3.631%	4.985%
3	60	4.5	2.6	2.04	2.27	13	3.774%	3.594%
4	90	8.7	2.6	2.08	2.27	13	1.252%	2.432%
5	120	10.8	2.5	2.09	2.18	12	1.977%	1.699%
6	150	11.8	2.3	2.52	2.05	8	4.067%	4.512%
7	180	21.1	2.8	2.82	2.46	13	2.350%	1.960%
8	210	23.2	3.2	3.36	2.87	19	2.109%	2.204%
9	240	4.1	2.1	1.53	1.85	10	3.409%	5.451%
10	270	3.3	1.3	1.52	1.22	3	2.543%	1.662%
11	300	4.1	1.8	1.81	1.62	6	0.931%	2.202%
12	330	3.8	2.0	1.89	1.75	7	3.521%	4.381%
All (fitted)			2.6	2.35	2.31	12	3.332%	2.771%
Source data					2.24	12		

Matehuala. August 2008. 20m



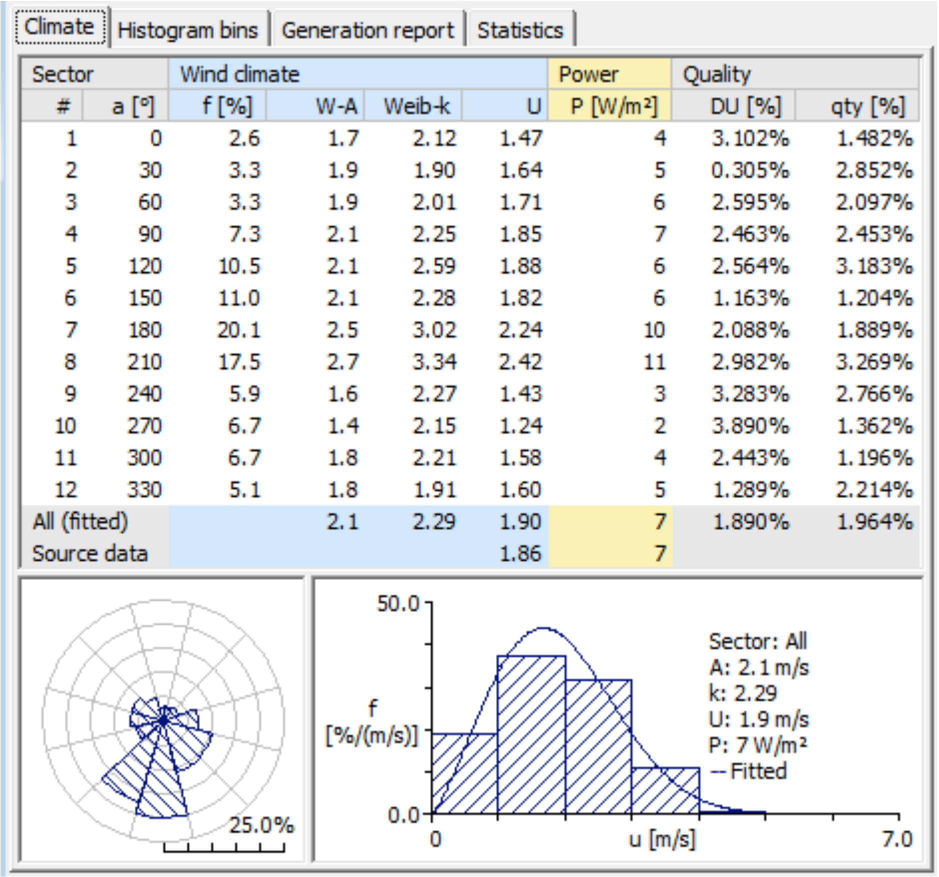
Sector		Wind climate				Power	Quality	
#	a [°]	f [%]	W-A	Weib-k	U	P [W/m²]	DU [%]	qty [%]
1	0	1.3	1.7	2.16	1.55	4	2.668%	1.666%
2	30	2.3	2.0	2.53	1.75	5	3.883%	5.988%
3	60	5.2	2.7	2.13	2.37	15	3.360%	3.834%
4	90	11.2	2.7	2.01	2.40	16	0.945%	3.083%
5	120	15.5	2.4	2.39	2.10	9	3.332%	2.367%
6	150	14.1	2.1	2.34	1.90	7	2.128%	2.360%
7	180	20.2	2.5	2.97	2.22	9	3.084%	2.584%
8	210	19.7	2.9	3.27	2.60	14	3.113%	3.735%
9	240	3.4	1.9	1.58	1.69	7	2.284%	2.852%
10	270	2.5	1.6	1.76	1.44	4	2.747%	6.023%
11	300	2.2	1.9	1.35	1.73	10	-5.122%	6.192%
12	330	2.5	2.3	1.54	2.06	14	-0.483%	2.122%
All (fitted)			2.5	2.40	2.22	11	3.785%	2.727%
Source data					2.13	10		

Matehuala. September 2008. 20m



Sector		Wind climate				Power	Quality	
#	a [°]	f [%]	W-A	Weib-k	U	P [W/m²]	DU [%]	qty [%]
1	0	3.0	1.8	2.59	1.61	4	2.854%	5.078%
2	30	3.9	2.0	2.40	1.75	5	2.607%	3.326%
3	60	4.5	2.2	2.41	1.96	7	3.611%	3.727%
4	90	9.4	2.5	2.05	2.20	12	2.487%	4.327%
5	120	12.4	2.1	2.48	1.83	6	1.555%	1.666%
6	150	11.3	2.0	2.59	1.74	5	1.739%	2.351%
7	180	16.7	2.1	2.43	1.82	6	0.771%	1.537%
8	210	16.5	2.5	3.25	2.22	9	3.827%	3.230%
9	240	4.9	1.5	1.83	1.34	3	4.515%	1.830%
10	270	4.2	1.6	1.44	1.49	6	1.862%	1.703%
11	300	5.4	1.9	1.70	1.69	7	-2.877%	6.357%
12	330	7.9	2.1	2.38	1.90	7	1.756%	1.677%
All (fitted)			2.1	2.25	1.87	7	2.010%	1.670%
Source data					1.83	7		

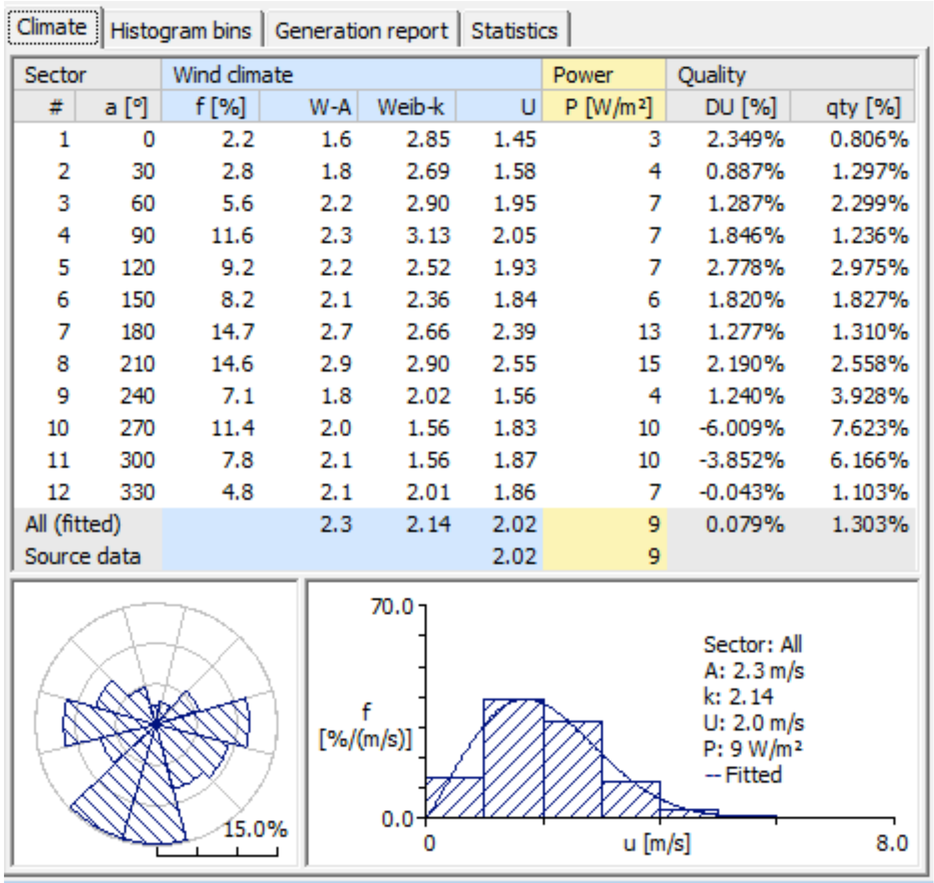
Matehuala. October 2008. 20m



Sector		Wind climate				Power	Quality	
#	a [°]	f [%]	W-A	Weib-k	U	P [W/m²]	DU [%]	qty [%]
1	0	2.6	1.7	2.12	1.47	4	3.102%	1.482%
2	30	3.3	1.9	1.90	1.64	5	0.305%	2.852%
3	60	3.3	1.9	2.01	1.71	6	2.595%	2.097%
4	90	7.3	2.1	2.25	1.85	7	2.463%	2.453%
5	120	10.5	2.1	2.59	1.88	6	2.564%	3.183%
6	150	11.0	2.1	2.28	1.82	6	1.163%	1.204%
7	180	20.1	2.5	3.02	2.24	10	2.088%	1.889%
8	210	17.5	2.7	3.34	2.42	11	2.982%	3.269%
9	240	5.9	1.6	2.27	1.43	3	3.283%	2.766%
10	270	6.7	1.4	2.15	1.24	2	3.890%	1.362%
11	300	6.7	1.8	2.21	1.58	4	2.443%	1.196%
12	330	5.1	1.8	1.91	1.60	5	1.289%	2.214%
All (fitted)			2.1	2.29	1.90	7	1.890%	1.964%
Source data					1.86	7		

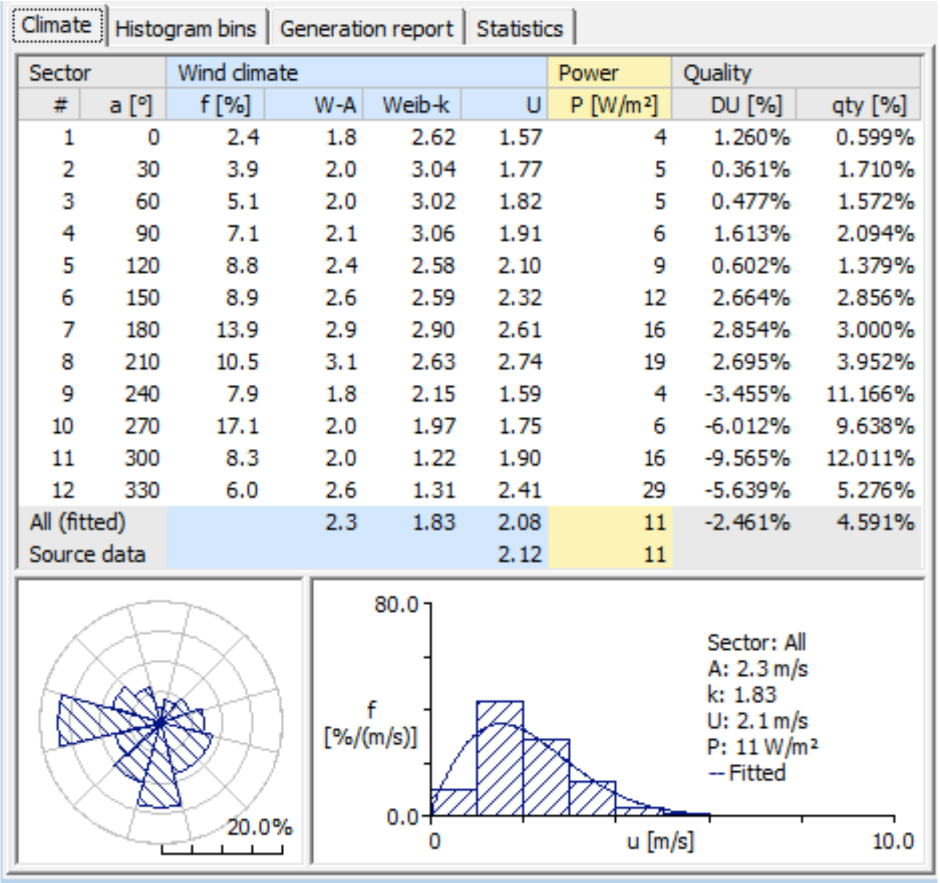
Appendix. Wind Climate Analysis

Matehuala. November 2008. 20m



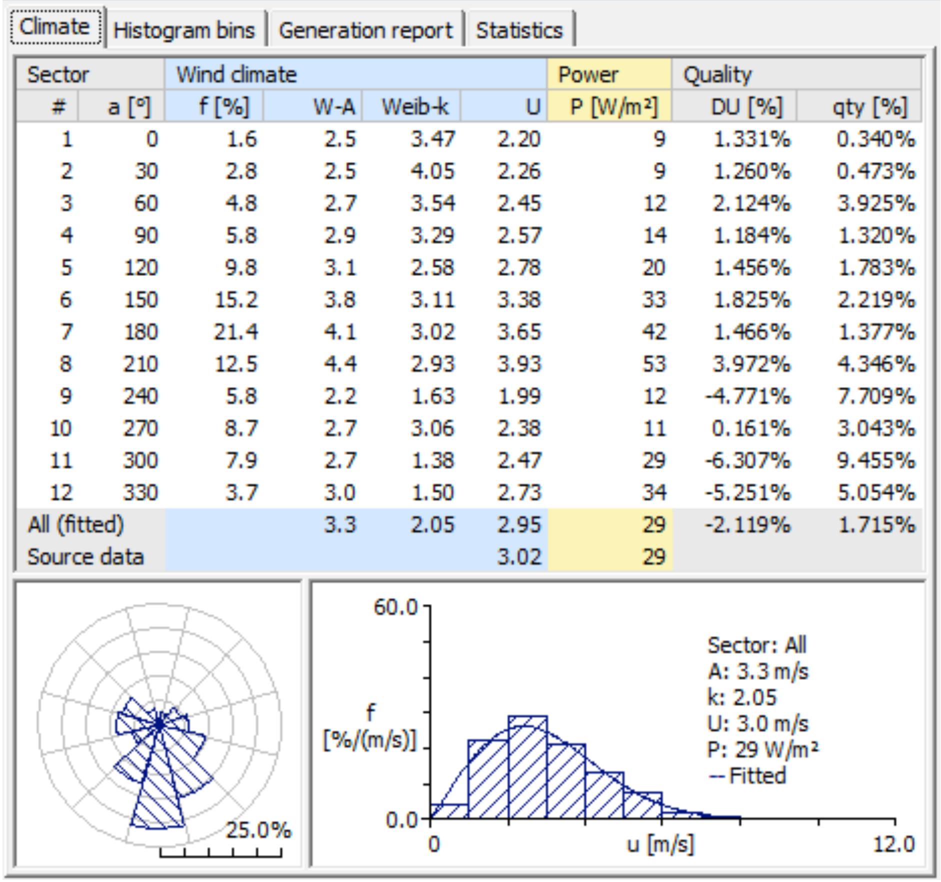
Sector		Wind climate				Power	Quality	
#	a [°]	f [%]	W-A	Weib-k	U	P [W/m²]	DU [%]	qty [%]
1	0	2.2	1.6	2.85	1.45	3	2.349%	0.806%
2	30	2.8	1.8	2.69	1.58	4	0.887%	1.297%
3	60	5.6	2.2	2.90	1.95	7	1.287%	2.299%
4	90	11.6	2.3	3.13	2.05	7	1.846%	1.236%
5	120	9.2	2.2	2.52	1.93	7	2.778%	2.975%
6	150	8.2	2.1	2.36	1.84	6	1.820%	1.827%
7	180	14.7	2.7	2.66	2.39	13	1.277%	1.310%
8	210	14.6	2.9	2.90	2.55	15	2.190%	2.558%
9	240	7.1	1.8	2.02	1.56	4	1.240%	3.928%
10	270	11.4	2.0	1.56	1.83	10	-6.009%	7.623%
11	300	7.8	2.1	1.56	1.87	10	-3.852%	6.166%
12	330	4.8	2.1	2.01	1.86	7	-0.043%	1.103%
All (fitted)			2.3	2.14	2.02	9	0.079%	1.303%
Source data					2.02	9		

Matehuala. December 2008. 20m



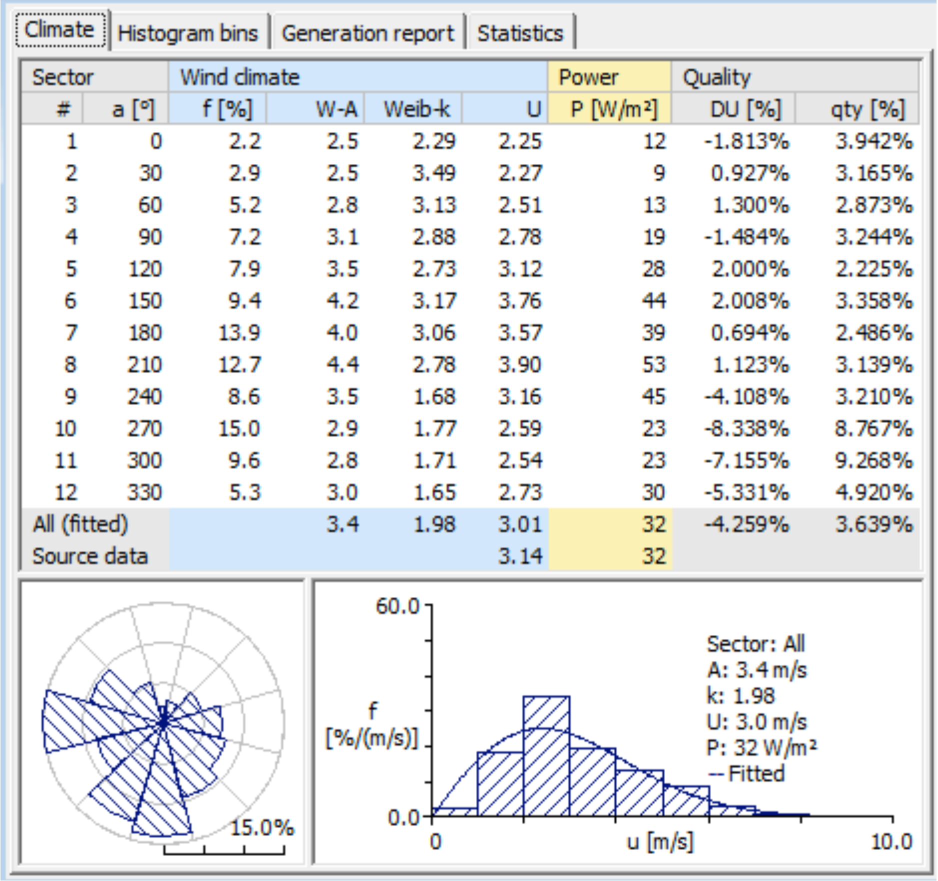
Sector		Wind climate				Power	Quality	
#	a [°]	f [%]	W-A	Weib-k	U	P [W/m²]	DU [%]	qty [%]
1	0	2.4	1.8	2.62	1.57	4	1.260%	0.599%
2	30	3.9	2.0	3.04	1.77	5	0.361%	1.710%
3	60	5.1	2.0	3.02	1.82	5	0.477%	1.572%
4	90	7.1	2.1	3.06	1.91	6	1.613%	2.094%
5	120	8.8	2.4	2.58	2.10	9	0.602%	1.379%
6	150	8.9	2.6	2.59	2.32	12	2.664%	2.856%
7	180	13.9	2.9	2.90	2.61	16	2.854%	3.000%
8	210	10.5	3.1	2.63	2.74	19	2.695%	3.952%
9	240	7.9	1.8	2.15	1.59	4	-3.455%	11.166%
10	270	17.1	2.0	1.97	1.75	6	-6.012%	9.638%
11	300	8.3	2.0	1.22	1.90	16	-9.565%	12.011%
12	330	6.0	2.6	1.31	2.41	29	-5.639%	5.276%
All (fitted)			2.3	1.83	2.08	11	-2.461%	4.591%
Source data					2.12	11		

Matehuala. January 2008. 50m



Sector		Wind climate				Power	Quality	
#	a [°]	f [%]	W-A	Weib-k	U	P [W/m²]	DU [%]	qty [%]
1	0	1.6	2.5	3.47	2.20	9	1.331%	0.340%
2	30	2.8	2.5	4.05	2.26	9	1.260%	0.473%
3	60	4.8	2.7	3.54	2.45	12	2.124%	3.925%
4	90	5.8	2.9	3.29	2.57	14	1.184%	1.320%
5	120	9.8	3.1	2.58	2.78	20	1.456%	1.783%
6	150	15.2	3.8	3.11	3.38	33	1.825%	2.219%
7	180	21.4	4.1	3.02	3.65	42	1.466%	1.377%
8	210	12.5	4.4	2.93	3.93	53	3.972%	4.346%
9	240	5.8	2.2	1.63	1.99	12	-4.771%	7.709%
10	270	8.7	2.7	3.06	2.38	11	0.161%	3.043%
11	300	7.9	2.7	1.38	2.47	29	-6.307%	9.455%
12	330	3.7	3.0	1.50	2.73	34	-5.251%	5.054%
All (fitted)			3.3	2.05	2.95	29	-2.119%	1.715%
Source data					3.02	29		

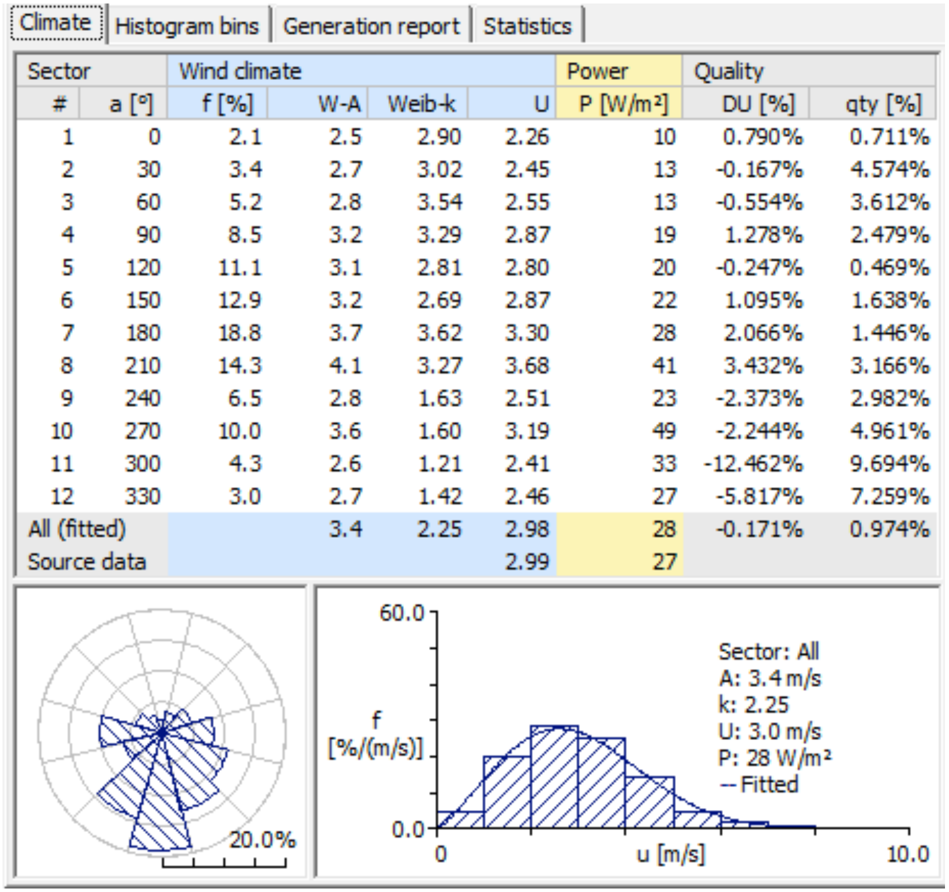
Matehuala. February 2008. 50m



Sector		Wind climate				Power	Quality	
#	a [°]	f [%]	W-A	Weib-k	U	P [W/m²]	DU [%]	qty [%]
1	0	2.2	2.5	2.29	2.25	12	-1.813%	3.942%
2	30	2.9	2.5	3.49	2.27	9	0.927%	3.165%
3	60	5.2	2.8	3.13	2.51	13	1.300%	2.873%
4	90	7.2	3.1	2.88	2.78	19	-1.484%	3.244%
5	120	7.9	3.5	2.73	3.12	28	2.000%	2.225%
6	150	9.4	4.2	3.17	3.76	44	2.008%	3.358%
7	180	13.9	4.0	3.06	3.57	39	0.694%	2.486%
8	210	12.7	4.4	2.78	3.90	53	1.123%	3.139%
9	240	8.6	3.5	1.68	3.16	45	-4.108%	3.210%
10	270	15.0	2.9	1.77	2.59	23	-8.338%	8.767%
11	300	9.6	2.8	1.71	2.54	23	-7.155%	9.268%
12	330	5.3	3.0	1.65	2.73	30	-5.331%	4.920%
All (fitted)			3.4	1.98	3.01	32	-4.259%	3.639%
Source data					3.14	32		

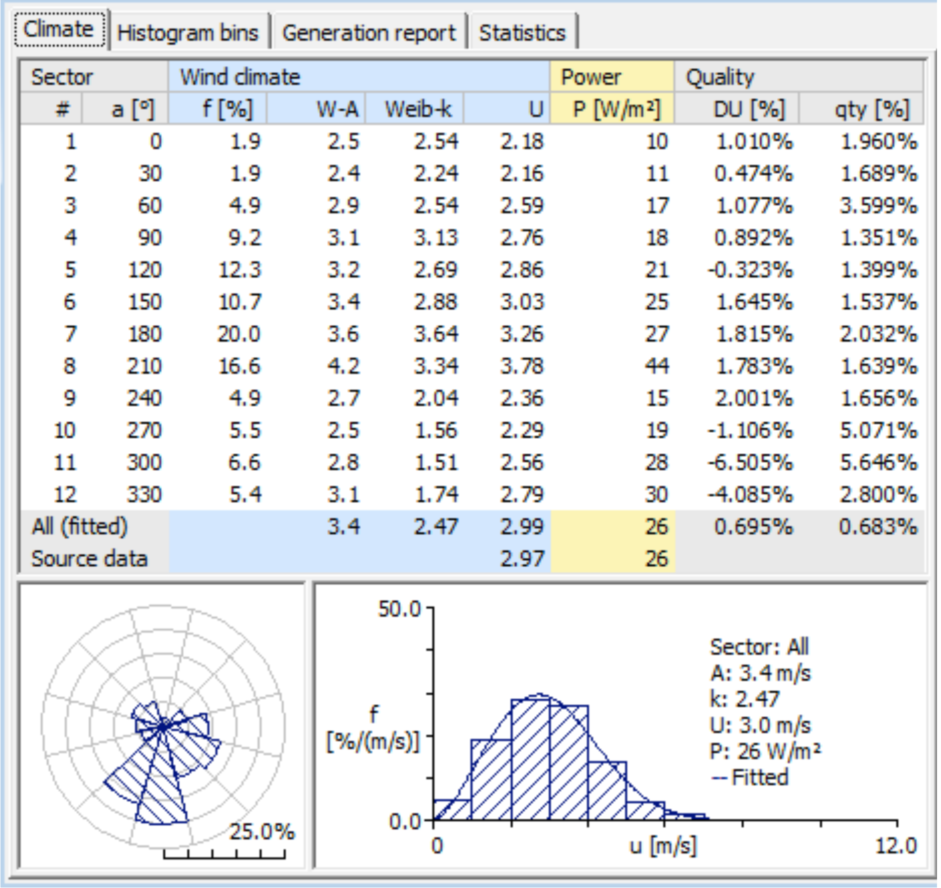
Appendix. Wind Climate Analysis

Matehuala. March 2008. 50m



Sector		Wind climate				Power	Quality	
#	a [°]	f [%]	W-A	Weib-k	U	P [W/m²]	DU [%]	qty [%]
1	0	2.1	2.5	2.90	2.26	10	0.790%	0.711%
2	30	3.4	2.7	3.02	2.45	13	-0.167%	4.574%
3	60	5.2	2.8	3.54	2.55	13	-0.554%	3.612%
4	90	8.5	3.2	3.29	2.87	19	1.278%	2.479%
5	120	11.1	3.1	2.81	2.80	20	-0.247%	0.469%
6	150	12.9	3.2	2.69	2.87	22	1.095%	1.638%
7	180	18.8	3.7	3.62	3.30	28	2.066%	1.446%
8	210	14.3	4.1	3.27	3.68	41	3.432%	3.166%
9	240	6.5	2.8	1.63	2.51	23	-2.373%	2.982%
10	270	10.0	3.6	1.60	3.19	49	-2.244%	4.961%
11	300	4.3	2.6	1.21	2.41	33	-12.462%	9.694%
12	330	3.0	2.7	1.42	2.46	27	-5.817%	7.259%
All (fitted)			3.4	2.25	2.98	28	-0.171%	0.974%
Source data					2.99	27		

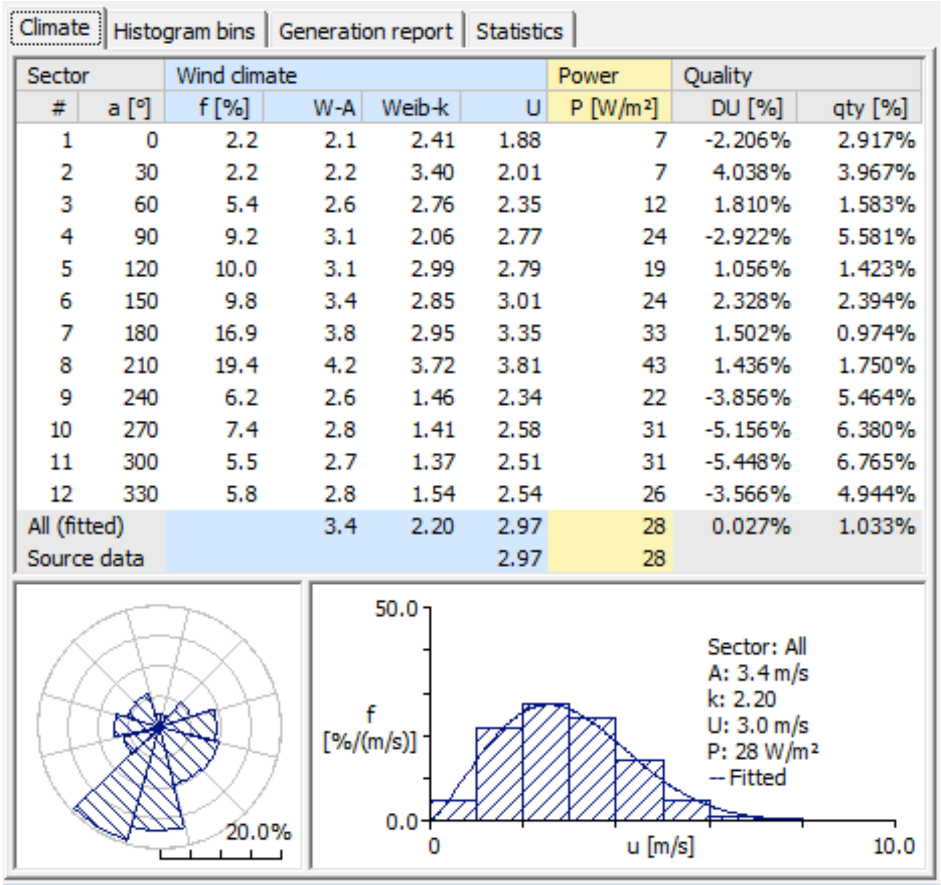
Matehuala. April 2008. 50m



Sector		Wind climate				Power	Quality	
#	a [°]	f [%]	W-A	Weib-k	U	P [W/m²]	DU [%]	qty [%]
1	0	1.9	2.5	2.54	2.18	10	1.010%	1.960%
2	30	1.9	2.4	2.24	2.16	11	0.474%	1.689%
3	60	4.9	2.9	2.54	2.59	17	1.077%	3.599%
4	90	9.2	3.1	3.13	2.76	18	0.892%	1.351%
5	120	12.3	3.2	2.69	2.86	21	-0.323%	1.399%
6	150	10.7	3.4	2.88	3.03	25	1.645%	1.537%
7	180	20.0	3.6	3.64	3.26	27	1.815%	2.032%
8	210	16.6	4.2	3.34	3.78	44	1.783%	1.639%
9	240	4.9	2.7	2.04	2.36	15	2.001%	1.656%
10	270	5.5	2.5	1.56	2.29	19	-1.106%	5.071%
11	300	6.6	2.8	1.51	2.56	28	-6.505%	5.646%
12	330	5.4	3.1	1.74	2.79	30	-4.085%	2.800%
All (fitted)			3.4	2.47	2.99	26	0.695%	0.683%
Source data					2.97	26		

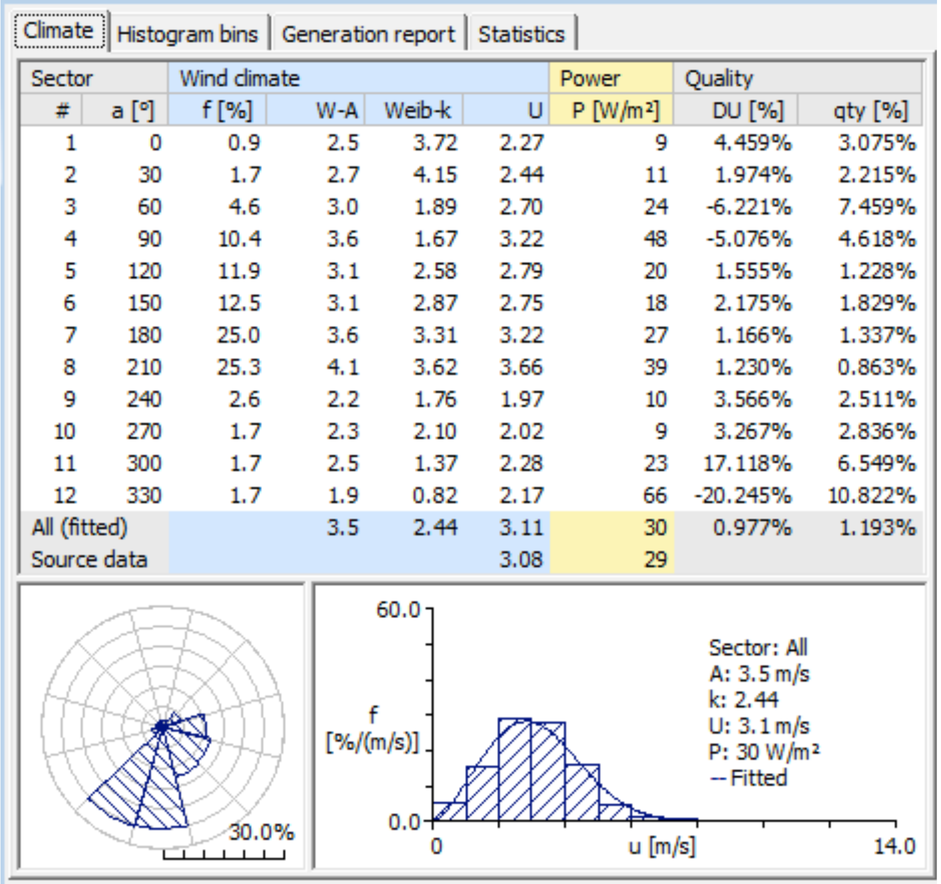
Appendix. Wind Climate Analysis

Matehuala. May 2008. 50m



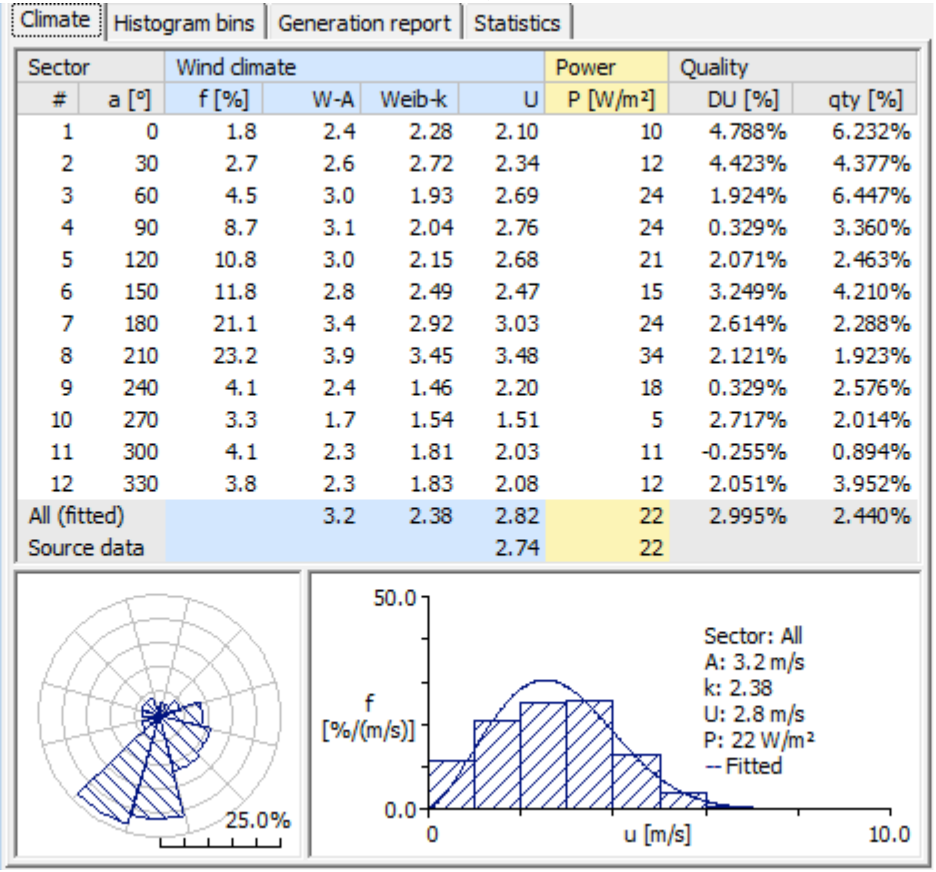
Sector		Wind climate				Power	Quality	
#	a [°]	f [%]	W-A	Weib-k	U	P [W/m²]	DU [%]	qty [%]
1	0	2.2	2.1	2.41	1.88	7	-2.206%	2.917%
2	30	2.2	2.2	3.40	2.01	7	4.038%	3.967%
3	60	5.4	2.6	2.76	2.35	12	1.810%	1.583%
4	90	9.2	3.1	2.06	2.77	24	-2.922%	5.581%
5	120	10.0	3.1	2.99	2.79	19	1.056%	1.423%
6	150	9.8	3.4	2.85	3.01	24	2.328%	2.394%
7	180	16.9	3.8	2.95	3.35	33	1.502%	0.974%
8	210	19.4	4.2	3.72	3.81	43	1.436%	1.750%
9	240	6.2	2.6	1.46	2.34	22	-3.856%	5.464%
10	270	7.4	2.8	1.41	2.58	31	-5.156%	6.380%
11	300	5.5	2.7	1.37	2.51	31	-5.448%	6.765%
12	330	5.8	2.8	1.54	2.54	26	-3.566%	4.944%
All (fitted)			3.4	2.20	2.97	28	0.027%	1.033%
Source data					2.97	28		

Matehuala. June 2008. 50m



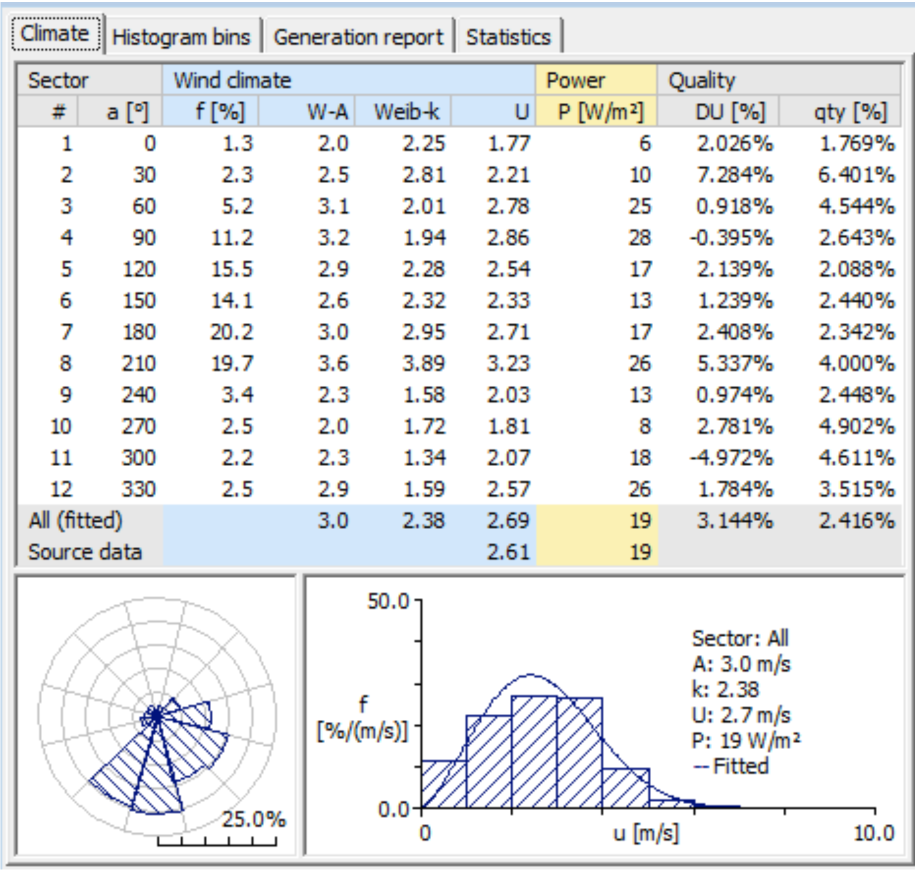
Sector		Wind climate				Power	Quality	
#	a [°]	f [%]	W-A	Weib-k	U	P [W/m²]	DU [%]	qty [%]
1	0	0.9	2.5	3.72	2.27	9	4.459%	3.075%
2	30	1.7	2.7	4.15	2.44	11	1.974%	2.215%
3	60	4.6	3.0	1.89	2.70	24	-6.221%	7.459%
4	90	10.4	3.6	1.67	3.22	48	-5.076%	4.618%
5	120	11.9	3.1	2.58	2.79	20	1.555%	1.228%
6	150	12.5	3.1	2.87	2.75	18	2.175%	1.829%
7	180	25.0	3.6	3.31	3.22	27	1.166%	1.337%
8	210	25.3	4.1	3.62	3.66	39	1.230%	0.863%
9	240	2.6	2.2	1.76	1.97	10	3.566%	2.511%
10	270	1.7	2.3	2.10	2.02	9	3.267%	2.836%
11	300	1.7	2.5	1.37	2.28	23	17.118%	6.549%
12	330	1.7	1.9	0.82	2.17	66	-20.245%	10.822%
All (fitted)			3.5	2.44	3.11	30	0.977%	1.193%
Source data					3.08	29		

Matehuala. July 2008. 50m



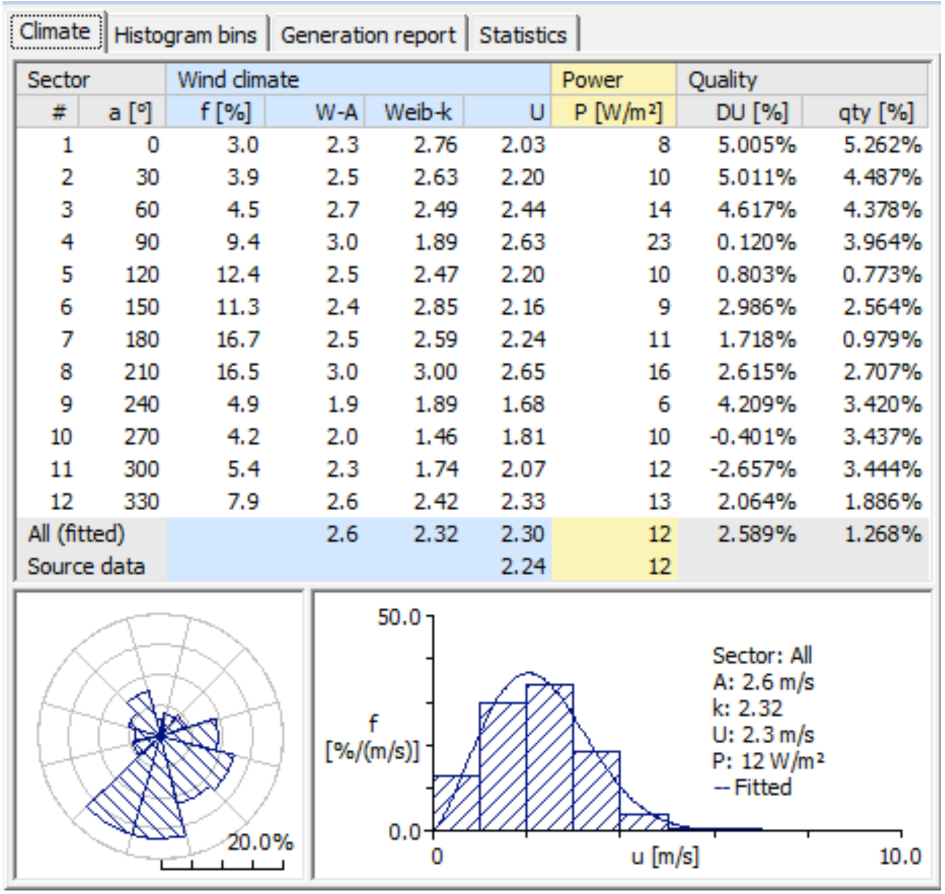
Sector		Wind climate				Power	Quality	
#	a [°]	f [%]	W-A	Weib-k	U	P [W/m²]	DU [%]	qty [%]
1	0	1.8	2.4	2.28	2.10	10	4.788%	6.232%
2	30	2.7	2.6	2.72	2.34	12	4.423%	4.377%
3	60	4.5	3.0	1.93	2.69	24	1.924%	6.447%
4	90	8.7	3.1	2.04	2.76	24	0.329%	3.360%
5	120	10.8	3.0	2.15	2.68	21	2.071%	2.463%
6	150	11.8	2.8	2.49	2.47	15	3.249%	4.210%
7	180	21.1	3.4	2.92	3.03	24	2.614%	2.288%
8	210	23.2	3.9	3.45	3.48	34	2.121%	1.923%
9	240	4.1	2.4	1.46	2.20	18	0.329%	2.576%
10	270	3.3	1.7	1.54	1.51	5	2.717%	2.014%
11	300	4.1	2.3	1.81	2.03	11	-0.255%	0.894%
12	330	3.8	2.3	1.83	2.08	12	2.051%	3.952%
All (fitted)			3.2	2.38	2.82	22	2.995%	2.440%
Source data					2.74	22		

Matehuala. August 2008. 50m



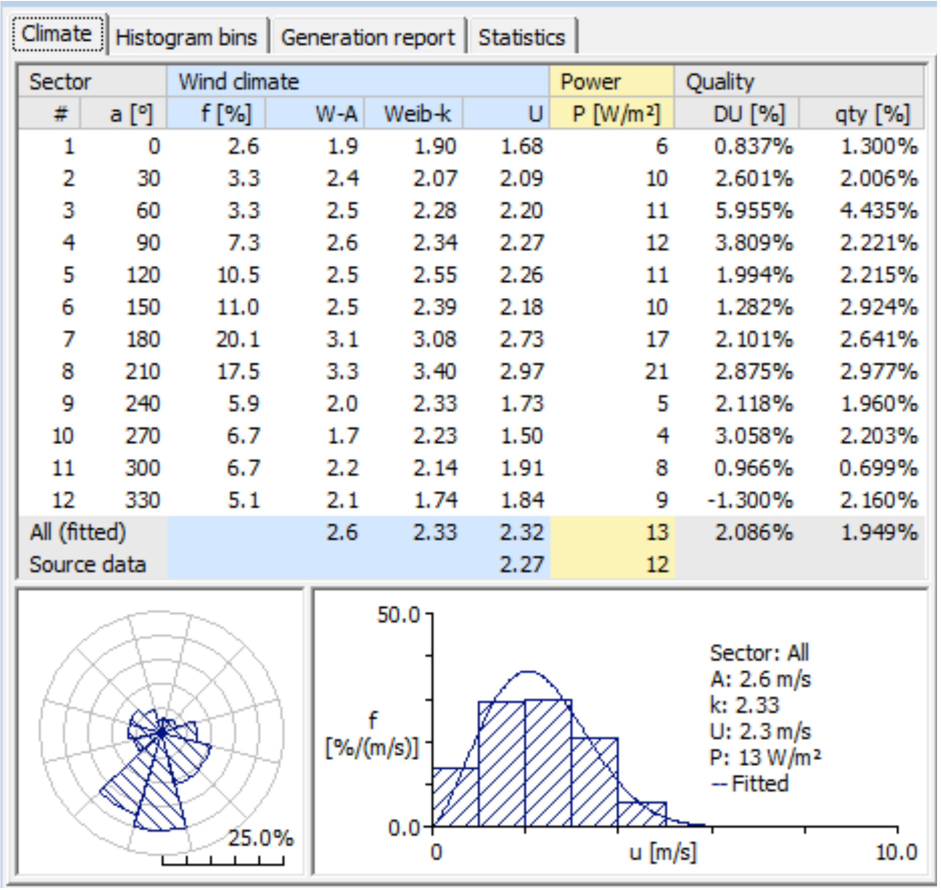
Sector		Wind climate				Power	Quality	
#	a [°]	f [%]	W-A	Weib-k	U	P [W/m²]	DU [%]	qty [%]
1	0	1.3	2.0	2.25	1.77	6	2.026%	1.769%
2	30	2.3	2.5	2.81	2.21	10	7.284%	6.401%
3	60	5.2	3.1	2.01	2.78	25	0.918%	4.544%
4	90	11.2	3.2	1.94	2.86	28	-0.395%	2.643%
5	120	15.5	2.9	2.28	2.54	17	2.139%	2.088%
6	150	14.1	2.6	2.32	2.33	13	1.239%	2.440%
7	180	20.2	3.0	2.95	2.71	17	2.408%	2.342%
8	210	19.7	3.6	3.89	3.23	26	5.337%	4.000%
9	240	3.4	2.3	1.58	2.03	13	0.974%	2.448%
10	270	2.5	2.0	1.72	1.81	8	2.781%	4.902%
11	300	2.2	2.3	1.34	2.07	18	-4.972%	4.611%
12	330	2.5	2.9	1.59	2.57	26	1.784%	3.515%
All (fitted)			3.0	2.38	2.69	19	3.144%	2.416%
Source data					2.61	19		

Matehuala. September 2008. 50m



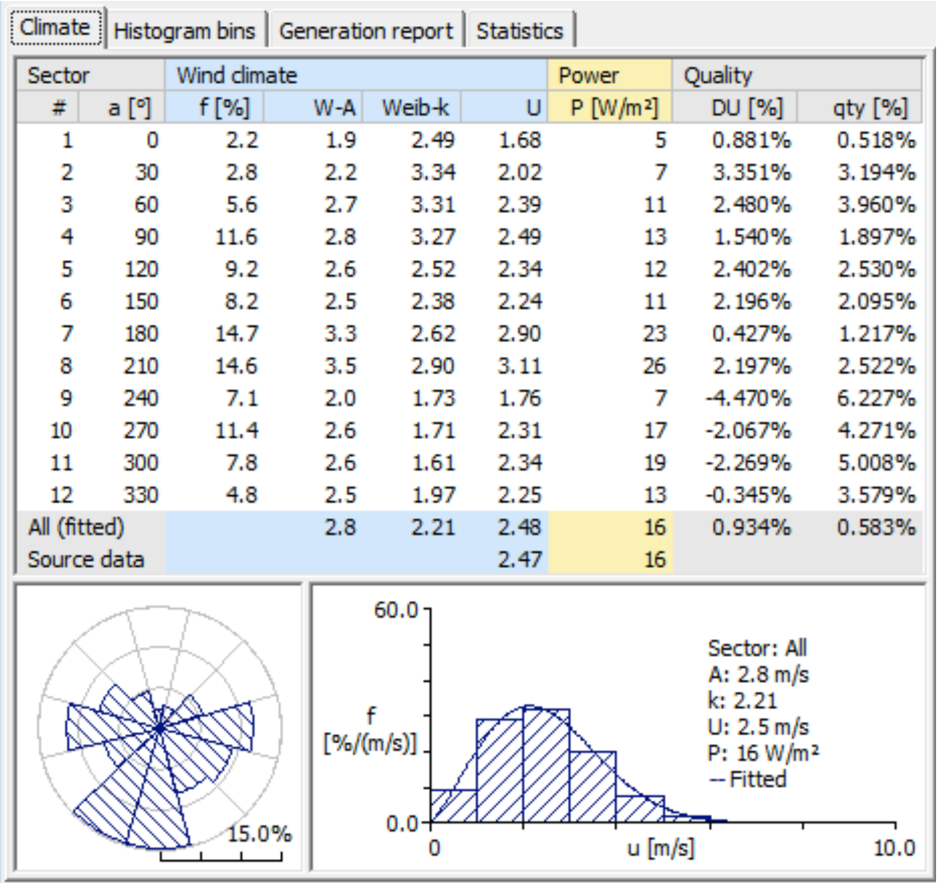
Sector		Wind climate				Power	Quality	
#	a [°]	f [%]	W-A	Weib-k	U	P [W/m²]	DU [%]	qty [%]
1	0	3.0	2.3	2.76	2.03	8	5.005%	5.262%
2	30	3.9	2.5	2.63	2.20	10	5.011%	4.487%
3	60	4.5	2.7	2.49	2.44	14	4.617%	4.378%
4	90	9.4	3.0	1.89	2.63	23	0.120%	3.964%
5	120	12.4	2.5	2.47	2.20	10	0.803%	0.773%
6	150	11.3	2.4	2.85	2.16	9	2.986%	2.564%
7	180	16.7	2.5	2.59	2.24	11	1.718%	0.979%
8	210	16.5	3.0	3.00	2.65	16	2.615%	2.707%
9	240	4.9	1.9	1.89	1.68	6	4.209%	3.420%
10	270	4.2	2.0	1.46	1.81	10	-0.401%	3.437%
11	300	5.4	2.3	1.74	2.07	12	-2.657%	3.444%
12	330	7.9	2.6	2.42	2.33	13	2.064%	1.886%
All (fitted)			2.6	2.32	2.30	12	2.589%	1.268%
Source data					2.24	12		

Matehuala. October 2008. 50m



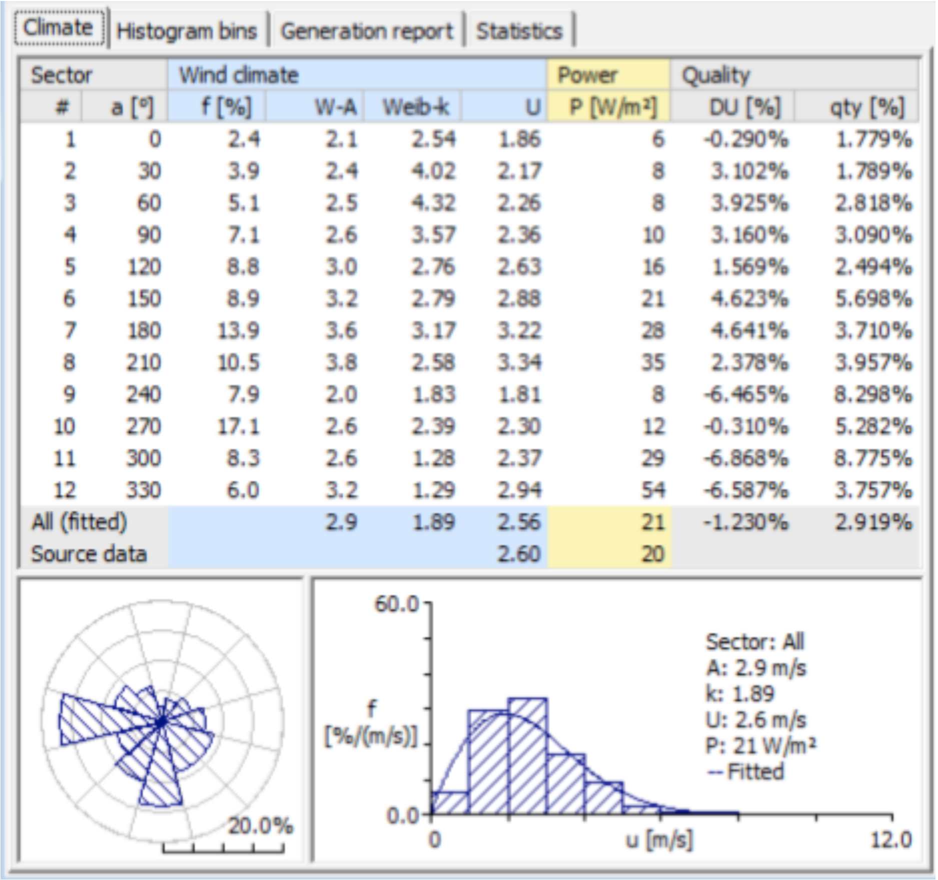
Sector		Wind climate				Power	Quality	
#	a [°]	f [%]	W-A	Weib-k	U	P [W/m²]	DU [%]	qty [%]
1	0	2.6	1.9	1.90	1.68	6	0.837%	1.300%
2	30	3.3	2.4	2.07	2.09	10	2.601%	2.006%
3	60	3.3	2.5	2.28	2.20	11	5.955%	4.435%
4	90	7.3	2.6	2.34	2.27	12	3.809%	2.221%
5	120	10.5	2.5	2.55	2.26	11	1.994%	2.215%
6	150	11.0	2.5	2.39	2.18	10	1.282%	2.924%
7	180	20.1	3.1	3.08	2.73	17	2.101%	2.641%
8	210	17.5	3.3	3.40	2.97	21	2.875%	2.977%
9	240	5.9	2.0	2.33	1.73	5	2.118%	1.960%
10	270	6.7	1.7	2.23	1.50	4	3.058%	2.203%
11	300	6.7	2.2	2.14	1.91	8	0.966%	0.699%
12	330	5.1	2.1	1.74	1.84	9	-1.300%	2.160%
All (fitted)			2.6	2.33	2.32	13	2.086%	1.949%
Source data					2.27	12		

Matehuala. November 2008. 50m



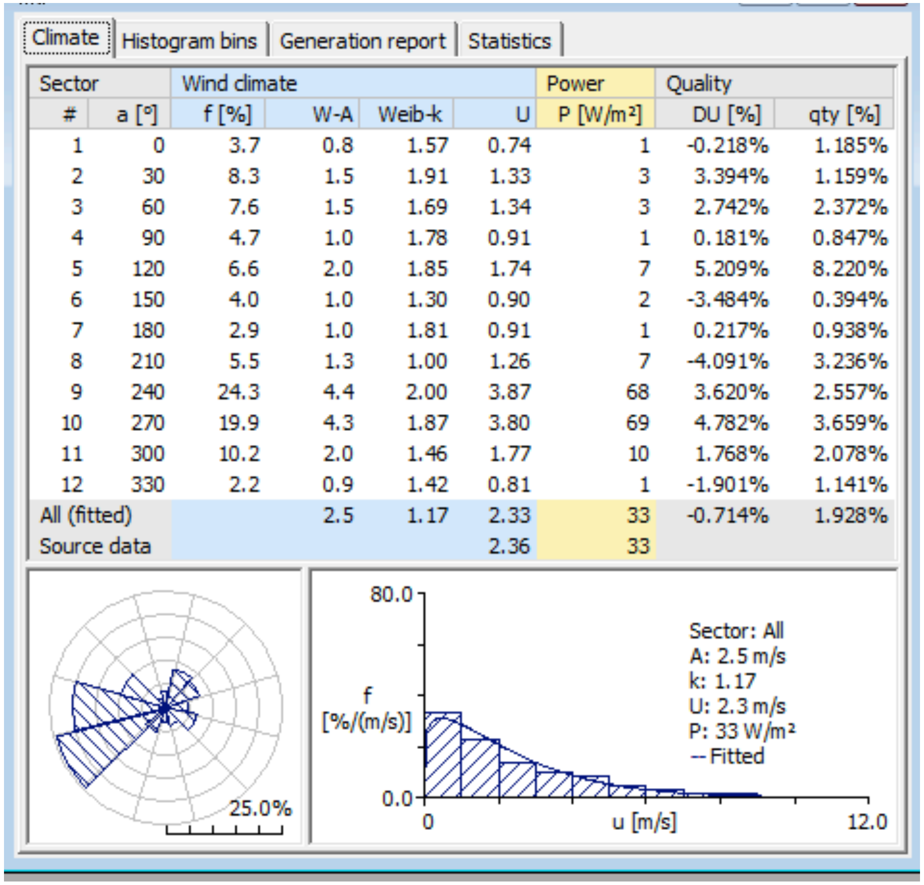
Sector		Wind climate				Power	Quality	
#	a [°]	f [%]	W-A	Weib-k	U	P [W/m²]	DU [%]	qty [%]
1	0	2.2	1.9	2.49	1.68	5	0.881%	0.518%
2	30	2.8	2.2	3.34	2.02	7	3.351%	3.194%
3	60	5.6	2.7	3.31	2.39	11	2.480%	3.960%
4	90	11.6	2.8	3.27	2.49	13	1.540%	1.897%
5	120	9.2	2.6	2.52	2.34	12	2.402%	2.530%
6	150	8.2	2.5	2.38	2.24	11	2.196%	2.095%
7	180	14.7	3.3	2.62	2.90	23	0.427%	1.217%
8	210	14.6	3.5	2.90	3.11	26	2.197%	2.522%
9	240	7.1	2.0	1.73	1.76	7	-4.470%	6.227%
10	270	11.4	2.6	1.71	2.31	17	-2.067%	4.271%
11	300	7.8	2.6	1.61	2.34	19	-2.269%	5.008%
12	330	4.8	2.5	1.97	2.25	13	-0.345%	3.579%
All (fitted)			2.8	2.21	2.48	16	0.934%	0.583%
Source data					2.47	16		

Matehuala. December 2008. 50m



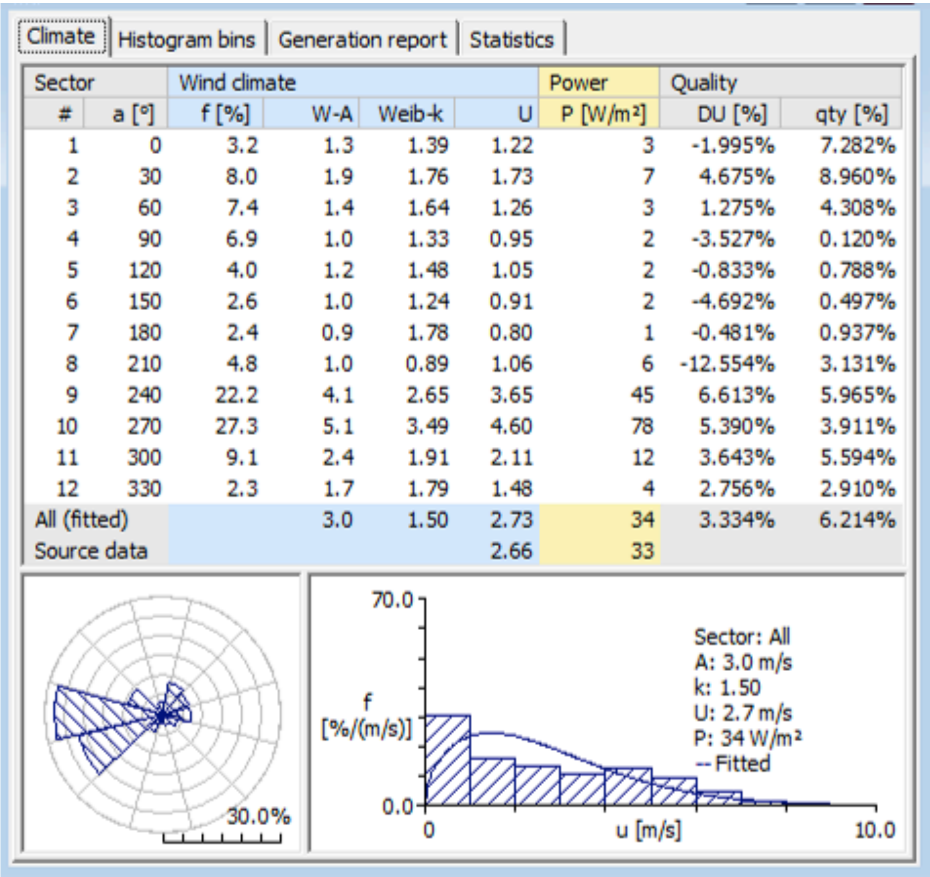
Sector		Wind climate				Power	Quality	
#	a [°]	f [%]	W-A	Weib-k	U	P [W/m²]	DU [%]	qty [%]
1	0	2.4	2.1	2.54	1.86	6	-0.290%	1.779%
2	30	3.9	2.4	4.02	2.17	8	3.102%	1.789%
3	60	5.1	2.5	4.32	2.26	8	3.925%	2.818%
4	90	7.1	2.6	3.57	2.36	10	3.160%	3.090%
5	120	8.8	3.0	2.76	2.63	16	1.569%	2.494%
6	150	8.9	3.2	2.79	2.88	21	4.623%	5.698%
7	180	13.9	3.6	3.17	3.22	28	4.641%	3.710%
8	210	10.5	3.8	2.58	3.34	35	2.378%	3.957%
9	240	7.9	2.0	1.83	1.81	8	-6.465%	8.298%
10	270	17.1	2.6	2.39	2.30	12	-0.310%	5.282%
11	300	8.3	2.6	1.28	2.37	29	-6.868%	8.775%
12	330	6.0	3.2	1.29	2.94	54	-6.587%	3.757%
All (fitted)			2.9	1.89	2.56	21	-1.230%	2.919%
Source data					2.60	20		

Zacatecas. January 2009. 10m



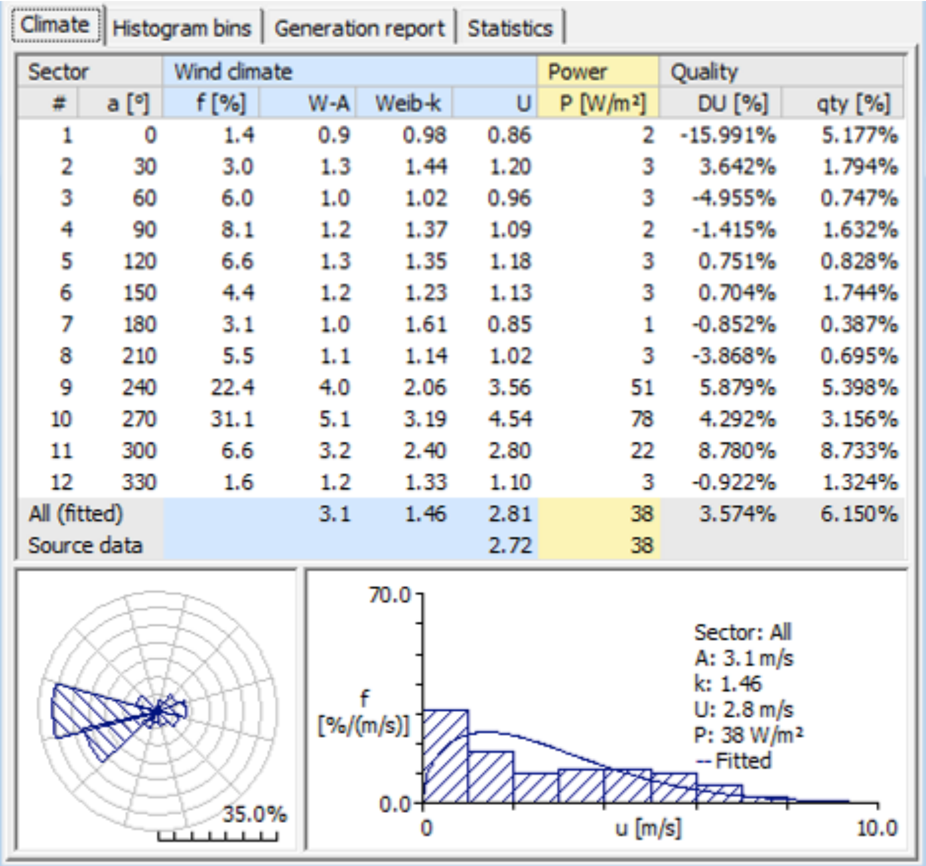
Sector		Wind climate				Power	Quality	
#	a [°]	f [%]	W-A	Weib-k	U	P [W/m²]	DU [%]	qty [%]
1	0	3.7	0.8	1.57	0.74	1	-0.218%	1.185%
2	30	8.3	1.5	1.91	1.33	3	3.394%	1.159%
3	60	7.6	1.5	1.69	1.34	3	2.742%	2.372%
4	90	4.7	1.0	1.78	0.91	1	0.181%	0.847%
5	120	6.6	2.0	1.85	1.74	7	5.209%	8.220%
6	150	4.0	1.0	1.30	0.90	2	-3.484%	0.394%
7	180	2.9	1.0	1.81	0.91	1	0.217%	0.938%
8	210	5.5	1.3	1.00	1.26	7	-4.091%	3.236%
9	240	24.3	4.4	2.00	3.87	68	3.620%	2.557%
10	270	19.9	4.3	1.87	3.80	69	4.782%	3.659%
11	300	10.2	2.0	1.46	1.77	10	1.768%	2.078%
12	330	2.2	0.9	1.42	0.81	1	-1.901%	1.141%
All (fitted)			2.5	1.17	2.33	33	-0.714%	1.928%
Source data					2.36	33		

Zacatecas. February 2009. 10m



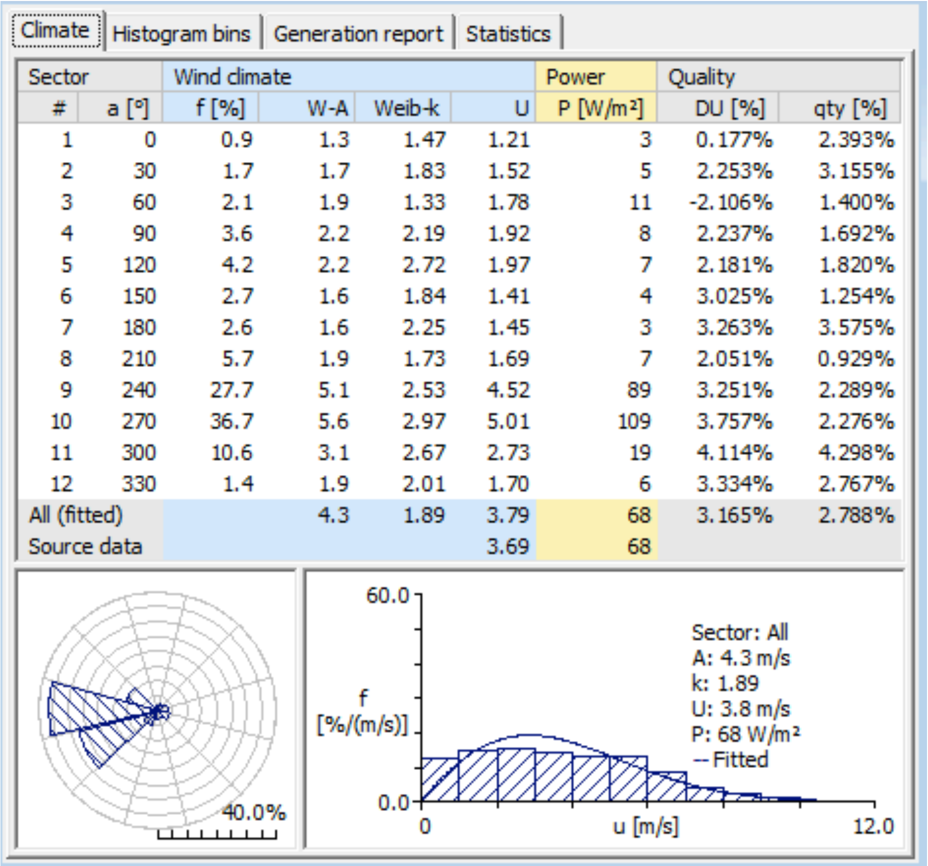
Sector		Wind climate				Power	Quality	
#	a [°]	f [%]	W-A	Weib-k	U	P [W/m²]	DU [%]	qty [%]
1	0	3.2	1.3	1.39	1.22	3	-1.995%	7.282%
2	30	8.0	1.9	1.76	1.73	7	4.675%	8.960%
3	60	7.4	1.4	1.64	1.26	3	1.275%	4.308%
4	90	6.9	1.0	1.33	0.95	2	-3.527%	0.120%
5	120	4.0	1.2	1.48	1.05	2	-0.833%	0.788%
6	150	2.6	1.0	1.24	0.91	2	-4.692%	0.497%
7	180	2.4	0.9	1.78	0.80	1	-0.481%	0.937%
8	210	4.8	1.0	0.89	1.06	6	-12.554%	3.131%
9	240	22.2	4.1	2.65	3.65	45	6.613%	5.965%
10	270	27.3	5.1	3.49	4.60	78	5.390%	3.911%
11	300	9.1	2.4	1.91	2.11	12	3.643%	5.594%
12	330	2.3	1.7	1.79	1.48	4	2.756%	2.910%
All (fitted)			3.0	1.50	2.73	34	3.334%	6.214%
Source data					2.66	33		

Zacatecas. March 2009. 10m



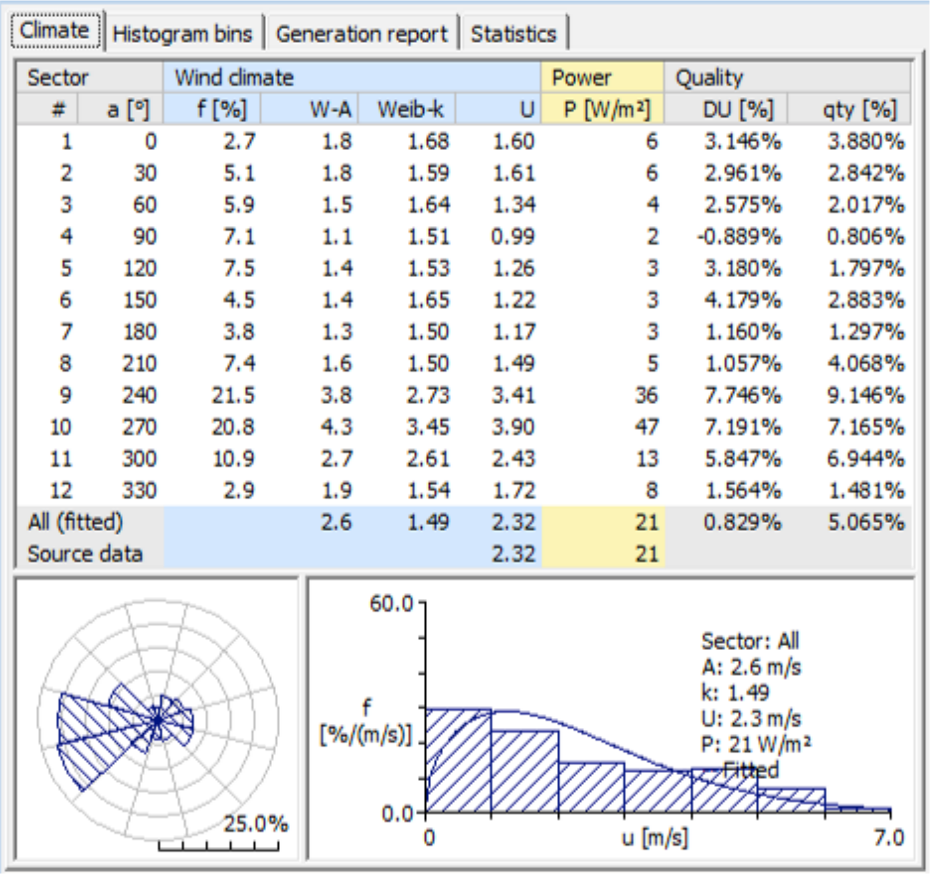
Sector		Wind climate				Power	Quality	
#	a [°]	f [%]	W-A	Weib-k	U	P [W/m²]	DU [%]	qty [%]
1	0	1.4	0.9	0.98	0.86	2	-15.991%	5.177%
2	30	3.0	1.3	1.44	1.20	3	3.642%	1.794%
3	60	6.0	1.0	1.02	0.96	3	-4.955%	0.747%
4	90	8.1	1.2	1.37	1.09	2	-1.415%	1.632%
5	120	6.6	1.3	1.35	1.18	3	0.751%	0.828%
6	150	4.4	1.2	1.23	1.13	3	0.704%	1.744%
7	180	3.1	1.0	1.61	0.85	1	-0.852%	0.387%
8	210	5.5	1.1	1.14	1.02	3	-3.868%	0.695%
9	240	22.4	4.0	2.06	3.56	51	5.879%	5.398%
10	270	31.1	5.1	3.19	4.54	78	4.292%	3.156%
11	300	6.6	3.2	2.40	2.80	22	8.780%	8.733%
12	330	1.6	1.2	1.33	1.10	3	-0.922%	1.324%
All (fitted)			3.1	1.46	2.81	38	3.574%	6.150%
Source data					2.72	38		

Zacatecas. April 2009. 10m



Sector		Wind climate				Power	Quality	
#	a [°]	f [%]	W-A	Weib-k	U	P [W/m²]	DU [%]	qty [%]
1	0	0.9	1.3	1.47	1.21	3	0.177%	2.393%
2	30	1.7	1.7	1.83	1.52	5	2.253%	3.155%
3	60	2.1	1.9	1.33	1.78	11	-2.106%	1.400%
4	90	3.6	2.2	2.19	1.92	8	2.237%	1.692%
5	120	4.2	2.2	2.72	1.97	7	2.181%	1.820%
6	150	2.7	1.6	1.84	1.41	4	3.025%	1.254%
7	180	2.6	1.6	2.25	1.45	3	3.263%	3.575%
8	210	5.7	1.9	1.73	1.69	7	2.051%	0.929%
9	240	27.7	5.1	2.53	4.52	89	3.251%	2.289%
10	270	36.7	5.6	2.97	5.01	109	3.757%	2.276%
11	300	10.6	3.1	2.67	2.73	19	4.114%	4.298%
12	330	1.4	1.9	2.01	1.70	6	3.334%	2.767%
All (fitted)			4.3	1.89	3.79	68	3.165%	2.788%
Source data					3.69	68		

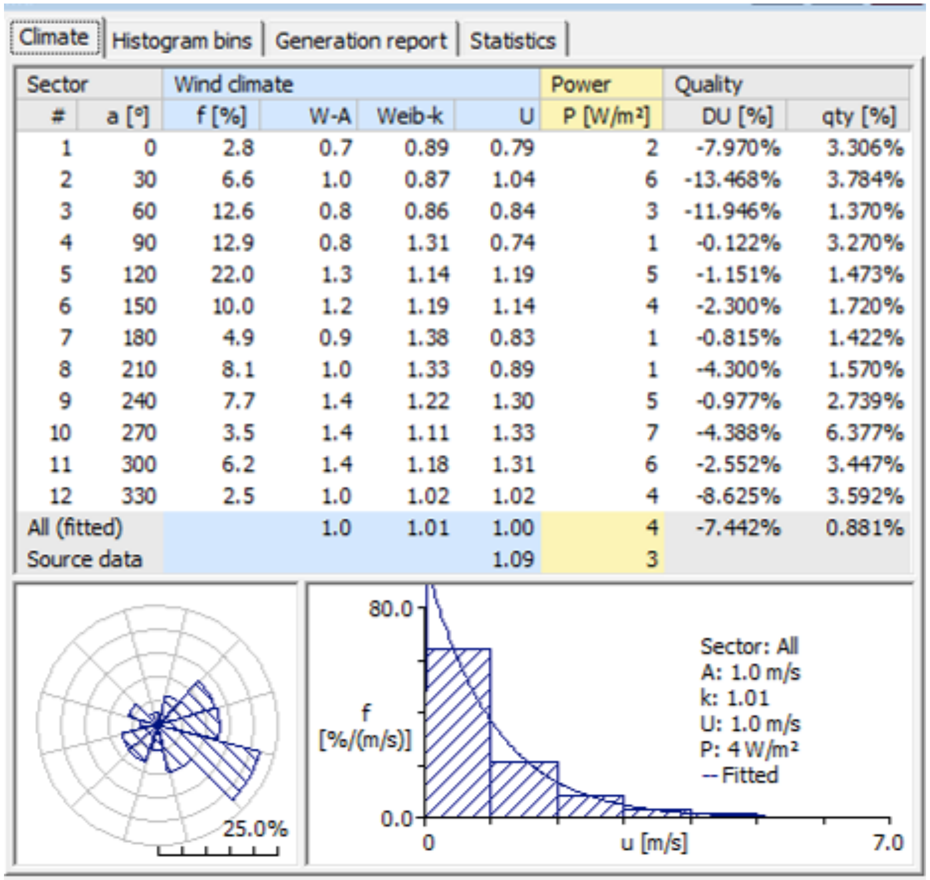
Zacatecas. May 2009. 10m



Sector		Wind climate				Power	Quality	
#	a [°]	f [%]	W-A	Weib-k	U	P [W/m²]	DU [%]	qty [%]
1	0	2.7	1.8	1.68	1.60	6	3.146%	3.880%
2	30	5.1	1.8	1.59	1.61	6	2.961%	2.842%
3	60	5.9	1.5	1.64	1.34	4	2.575%	2.017%
4	90	7.1	1.1	1.51	0.99	2	-0.889%	0.806%
5	120	7.5	1.4	1.53	1.26	3	3.180%	1.797%
6	150	4.5	1.4	1.65	1.22	3	4.179%	2.883%
7	180	3.8	1.3	1.50	1.17	3	1.160%	1.297%
8	210	7.4	1.6	1.50	1.49	5	1.057%	4.068%
9	240	21.5	3.8	2.73	3.41	36	7.746%	9.146%
10	270	20.8	4.3	3.45	3.90	47	7.191%	7.165%
11	300	10.9	2.7	2.61	2.43	13	5.847%	6.944%
12	330	2.9	1.9	1.54	1.72	8	1.564%	1.481%
All (fitted)			2.6	1.49	2.32	21	0.829%	5.065%
Source data					2.32	21		

Sector: All
A: 2.6 m/s
k: 1.49
U: 2.3 m/s
P: 21 W/m²

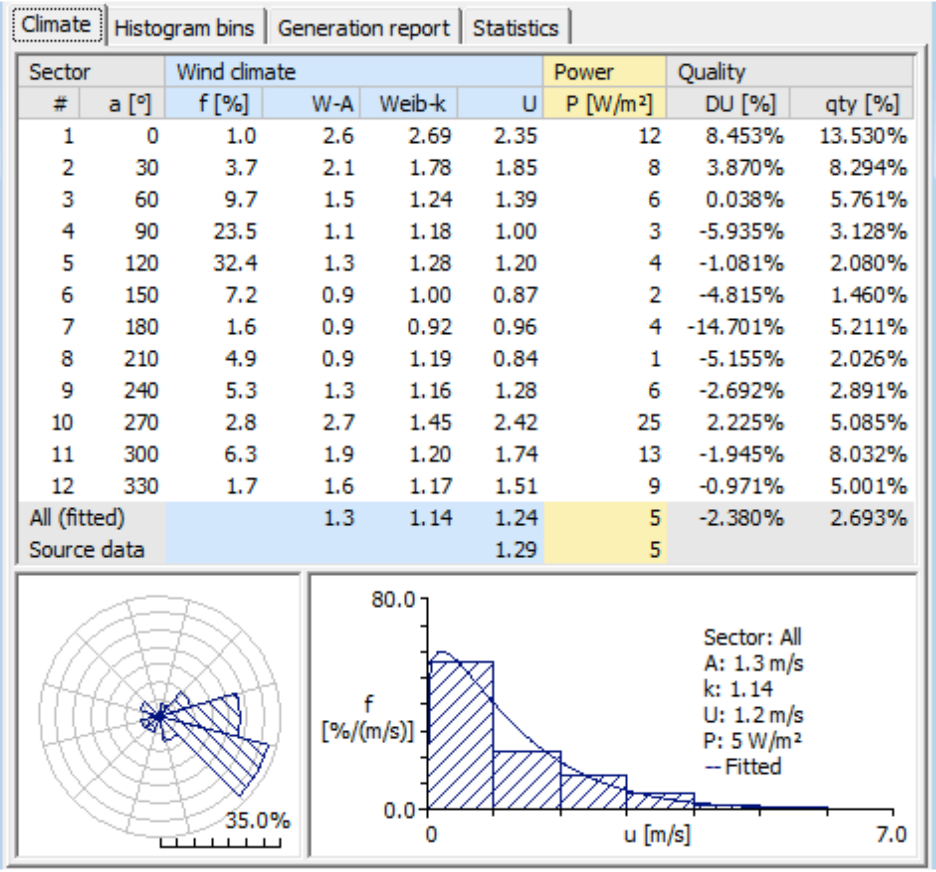
Zacatecas. June 2009. 10m



Sector		Wind climate				Power	Quality	
#	a [°]	f [%]	W-A	Weib-k	U	P [W/m²]	DU [%]	qty [%]
1	0	2.8	0.7	0.89	0.79	2	-7.970%	3.306%
2	30	6.6	1.0	0.87	1.04	6	-13.468%	3.784%
3	60	12.6	0.8	0.86	0.84	3	-11.946%	1.370%
4	90	12.9	0.8	1.31	0.74	1	-0.122%	3.270%
5	120	22.0	1.3	1.14	1.19	5	-1.151%	1.473%
6	150	10.0	1.2	1.19	1.14	4	-2.300%	1.720%
7	180	4.9	0.9	1.38	0.83	1	-0.815%	1.422%
8	210	8.1	1.0	1.33	0.89	1	-4.300%	1.570%
9	240	7.7	1.4	1.22	1.30	5	-0.977%	2.739%
10	270	3.5	1.4	1.11	1.33	7	-4.388%	6.377%
11	300	6.2	1.4	1.18	1.31	6	-2.552%	3.447%
12	330	2.5	1.0	1.02	1.02	4	-8.625%	3.592%
All (fitted)			1.0	1.01	1.00	4	-7.442%	0.881%
Source data					1.09	3		

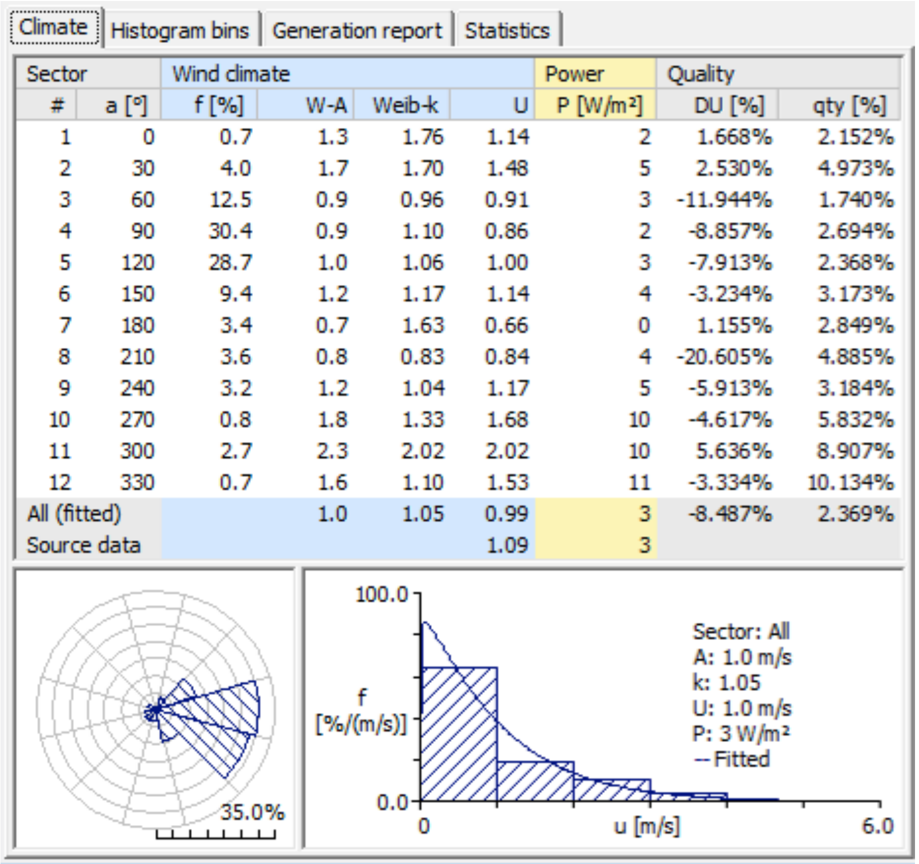
Sector: All
A: 1.0 m/s
k: 1.01
U: 1.0 m/s
P: 4 W/m²

Zacatecas. July 2009. 10m



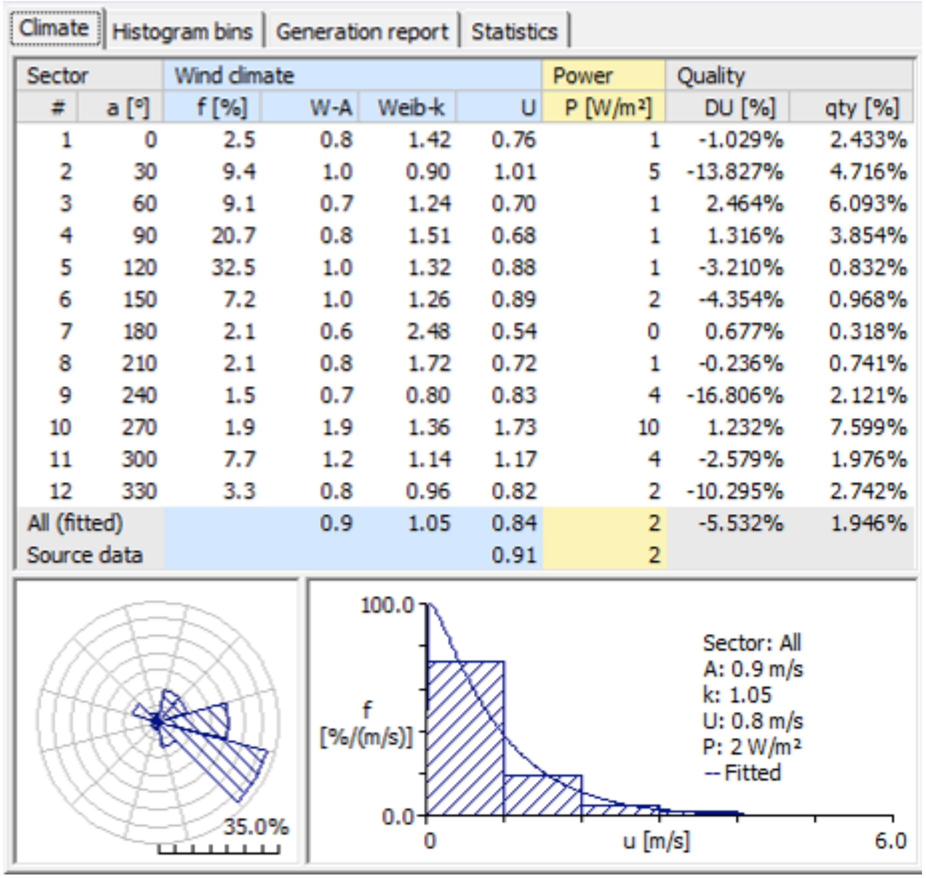
Sector		Wind climate				Power	Quality	
#	a [°]	f [%]	W-A	Weib-k	U	P [W/m²]	DU [%]	qty [%]
1	0	1.0	2.6	2.69	2.35	12	8.453%	13.530%
2	30	3.7	2.1	1.78	1.85	8	3.870%	8.294%
3	60	9.7	1.5	1.24	1.39	6	0.038%	5.761%
4	90	23.5	1.1	1.18	1.00	3	-5.935%	3.128%
5	120	32.4	1.3	1.28	1.20	4	-1.081%	2.080%
6	150	7.2	0.9	1.00	0.87	2	-4.815%	1.460%
7	180	1.6	0.9	0.92	0.96	4	-14.701%	5.211%
8	210	4.9	0.9	1.19	0.84	1	-5.155%	2.026%
9	240	5.3	1.3	1.16	1.28	6	-2.692%	2.891%
10	270	2.8	2.7	1.45	2.42	25	2.225%	5.085%
11	300	6.3	1.9	1.20	1.74	13	-1.945%	8.032%
12	330	1.7	1.6	1.17	1.51	9	-0.971%	5.001%
All (fitted)			1.3	1.14	1.24	5	-2.380%	2.693%
Source data					1.29	5		

Zacatecas. August 2009. 10m



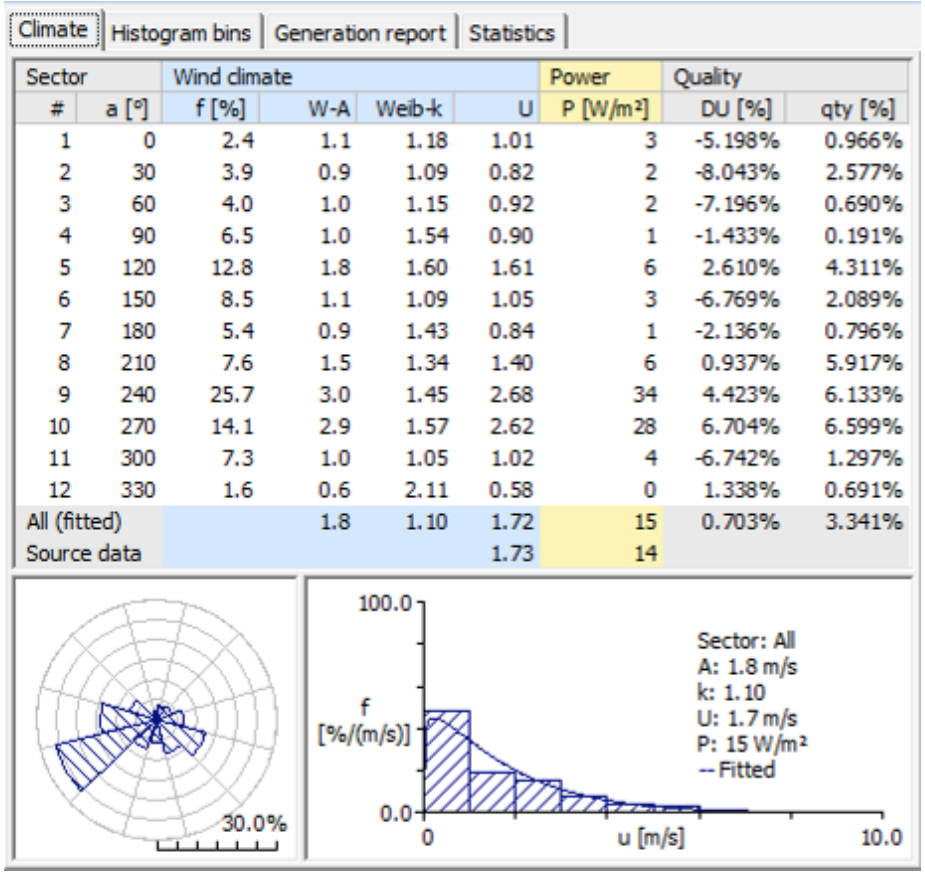
Sector		Wind climate				Power	Quality	
#	a [°]	f [%]	W-A	Weib-k	U	P [W/m²]	DU [%]	qty [%]
1	0	0.7	1.3	1.76	1.14	2	1.668%	2.152%
2	30	4.0	1.7	1.70	1.48	5	2.530%	4.973%
3	60	12.5	0.9	0.96	0.91	3	-11.944%	1.740%
4	90	30.4	0.9	1.10	0.86	2	-8.857%	2.694%
5	120	28.7	1.0	1.06	1.00	3	-7.913%	2.368%
6	150	9.4	1.2	1.17	1.14	4	-3.234%	3.173%
7	180	3.4	0.7	1.63	0.66	0	1.155%	2.849%
8	210	3.6	0.8	0.83	0.84	4	-20.605%	4.885%
9	240	3.2	1.2	1.04	1.17	5	-5.913%	3.184%
10	270	0.8	1.8	1.33	1.68	10	-4.617%	5.832%
11	300	2.7	2.3	2.02	2.02	10	5.636%	8.907%
12	330	0.7	1.6	1.10	1.53	11	-3.334%	10.134%
All (fitted)			1.0	1.05	0.99	3	-8.487%	2.369%
Source data					1.09	3		

Zacatecas. September 2009. 10m



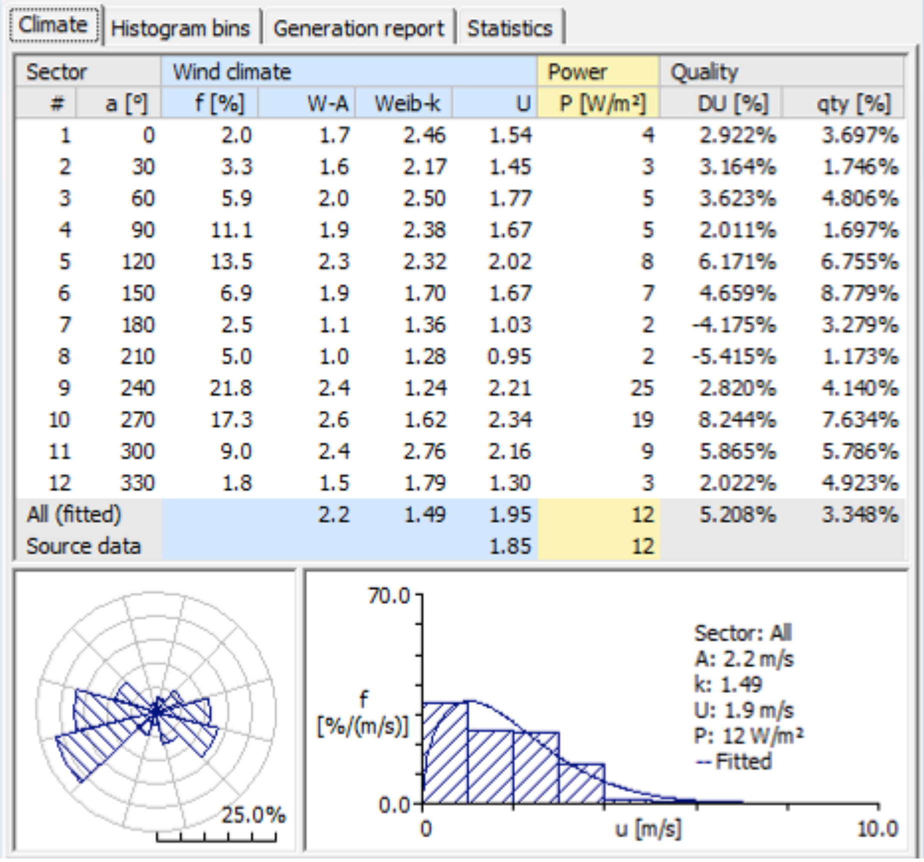
Sector		Wind climate				Power	Quality	
#	a [°]	f [%]	W-A	Weib-k	U	P [W/m²]	DU [%]	qty [%]
1	0	2.5	0.8	1.42	0.76	1	-1.029%	2.433%
2	30	9.4	1.0	0.90	1.01	5	-13.827%	4.716%
3	60	9.1	0.7	1.24	0.70	1	2.464%	6.093%
4	90	20.7	0.8	1.51	0.68	1	1.316%	3.854%
5	120	32.5	1.0	1.32	0.88	1	-3.210%	0.832%
6	150	7.2	1.0	1.26	0.89	2	-4.354%	0.968%
7	180	2.1	0.6	2.48	0.54	0	0.677%	0.318%
8	210	2.1	0.8	1.72	0.72	1	-0.236%	0.741%
9	240	1.5	0.7	0.80	0.83	4	-16.806%	2.121%
10	270	1.9	1.9	1.36	1.73	10	1.232%	7.599%
11	300	7.7	1.2	1.14	1.17	4	-2.579%	1.976%
12	330	3.3	0.8	0.96	0.82	2	-10.295%	2.742%
All (fitted)			0.9	1.05	0.84	2	-5.532%	1.946%
Source data					0.91	2		

Zacatecas. October 2009. 10m



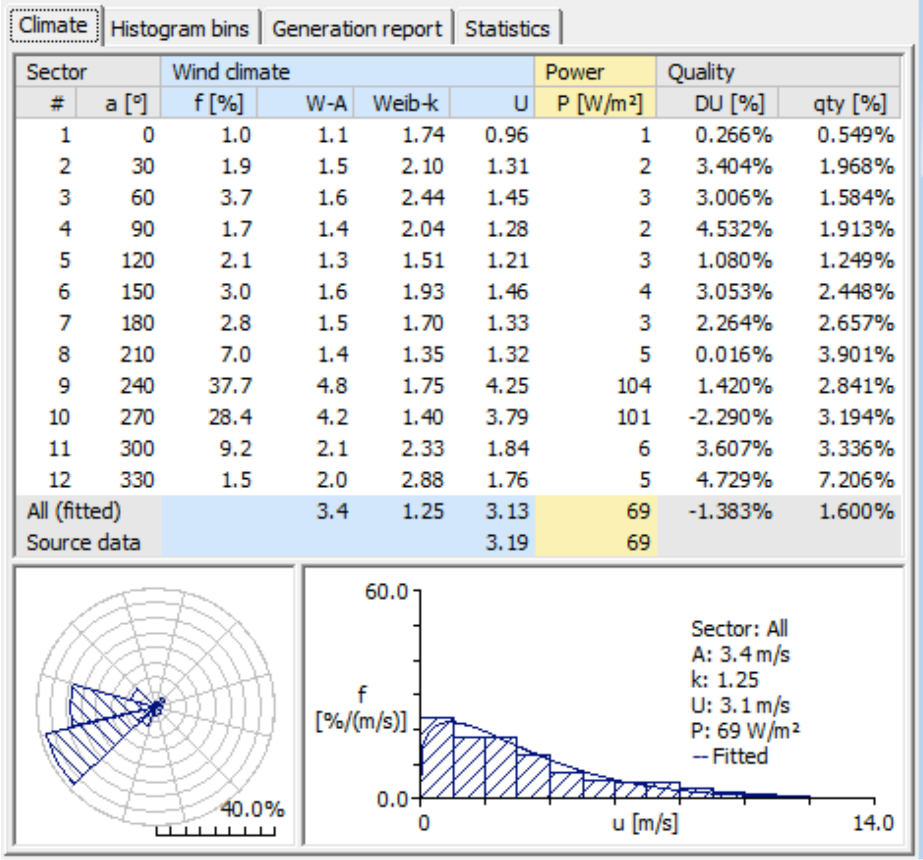
Sector		Wind climate				Power	Quality	
#	a [°]	f [%]	W-A	Weib-k	U	P [W/m²]	DU [%]	qty [%]
1	0	2.4	1.1	1.18	1.01	3	-5.198%	0.966%
2	30	3.9	0.9	1.09	0.82	2	-8.043%	2.577%
3	60	4.0	1.0	1.15	0.92	2	-7.196%	0.690%
4	90	6.5	1.0	1.54	0.90	1	-1.433%	0.191%
5	120	12.8	1.8	1.60	1.61	6	2.610%	4.311%
6	150	8.5	1.1	1.09	1.05	3	-6.769%	2.089%
7	180	5.4	0.9	1.43	0.84	1	-2.136%	0.796%
8	210	7.6	1.5	1.34	1.40	6	0.937%	5.917%
9	240	25.7	3.0	1.45	2.68	34	4.423%	6.133%
10	270	14.1	2.9	1.57	2.62	28	6.704%	6.599%
11	300	7.3	1.0	1.05	1.02	4	-6.742%	1.297%
12	330	1.6	0.6	2.11	0.58	0	1.338%	0.691%
All (fitted)			1.8	1.10	1.72	15	0.703%	3.341%
Source data					1.73	14		

Zacatecas. November 2009. 10m



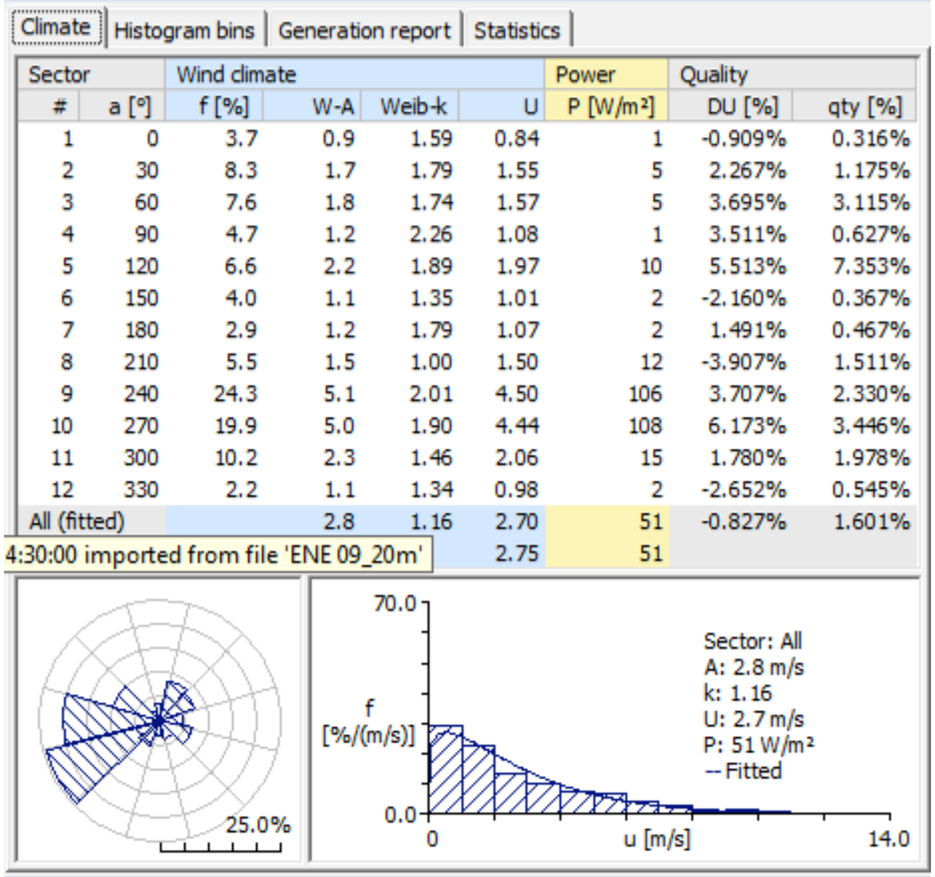
Sector		Wind climate				Power	Quality	
#	a [°]	f [%]	W-A	Weib-k	U	P [W/m²]	DU [%]	qty [%]
1	0	2.0	1.7	2.46	1.54	4	2.922%	3.697%
2	30	3.3	1.6	2.17	1.45	3	3.164%	1.746%
3	60	5.9	2.0	2.50	1.77	5	3.623%	4.806%
4	90	11.1	1.9	2.38	1.67	5	2.011%	1.697%
5	120	13.5	2.3	2.32	2.02	8	6.171%	6.755%
6	150	6.9	1.9	1.70	1.67	7	4.659%	8.779%
7	180	2.5	1.1	1.36	1.03	2	-4.175%	3.279%
8	210	5.0	1.0	1.28	0.95	2	-5.415%	1.173%
9	240	21.8	2.4	1.24	2.21	25	2.820%	4.140%
10	270	17.3	2.6	1.62	2.34	19	8.244%	7.634%
11	300	9.0	2.4	2.76	2.16	9	5.865%	5.786%
12	330	1.8	1.5	1.79	1.30	3	2.022%	4.923%
All (fitted)			2.2	1.49	1.95	12	5.208%	3.348%
Source data					1.85	12		

Zacatecas. December 2009. 10m



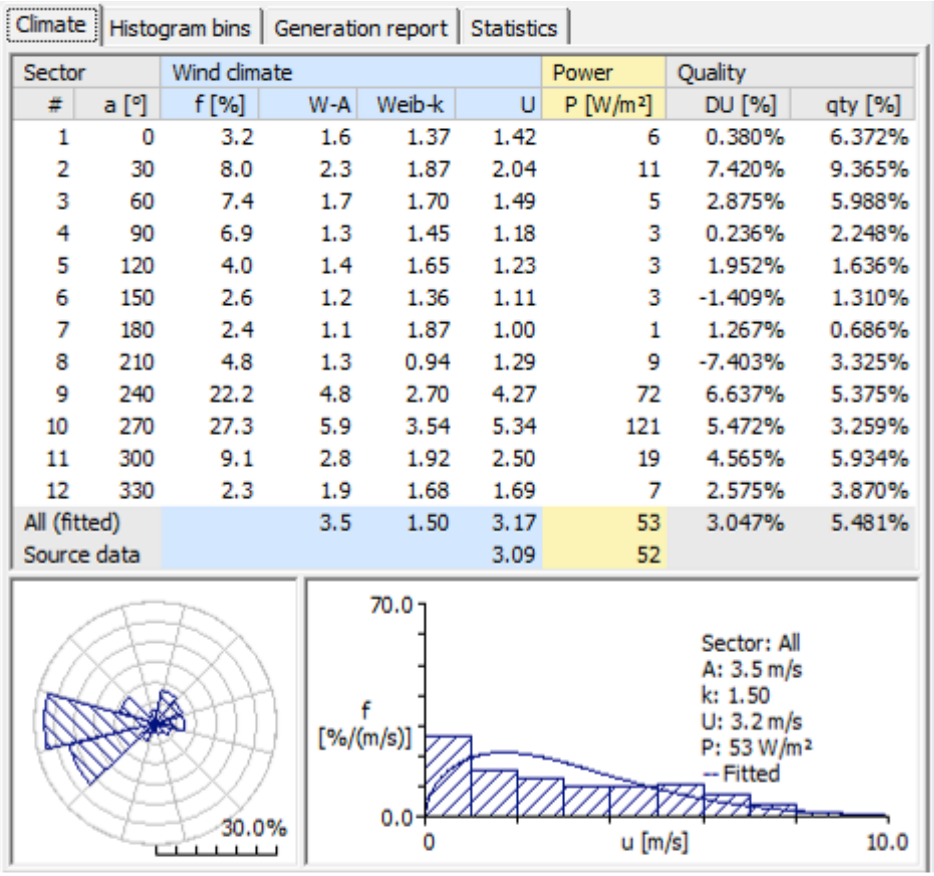
Sector		Wind climate				Power	Quality	
#	a [°]	f [%]	W-A	Weib-k	U	P [W/m²]	DU [%]	qty [%]
1	0	1.0	1.1	1.74	0.96	1	0.266%	0.549%
2	30	1.9	1.5	2.10	1.31	2	3.404%	1.968%
3	60	3.7	1.6	2.44	1.45	3	3.006%	1.584%
4	90	1.7	1.4	2.04	1.28	2	4.532%	1.913%
5	120	2.1	1.3	1.51	1.21	3	1.080%	1.249%
6	150	3.0	1.6	1.93	1.46	4	3.053%	2.448%
7	180	2.8	1.5	1.70	1.33	3	2.264%	2.657%
8	210	7.0	1.4	1.35	1.32	5	0.016%	3.901%
9	240	37.7	4.8	1.75	4.25	104	1.420%	2.841%
10	270	28.4	4.2	1.40	3.79	101	-2.290%	3.194%
11	300	9.2	2.1	2.33	1.84	6	3.607%	3.336%
12	330	1.5	2.0	2.88	1.76	5	4.729%	7.206%
All (fitted)			3.4	1.25	3.13	69	-1.383%	1.600%
Source data					3.19	69		

Zacatecas. January 2009. 20m



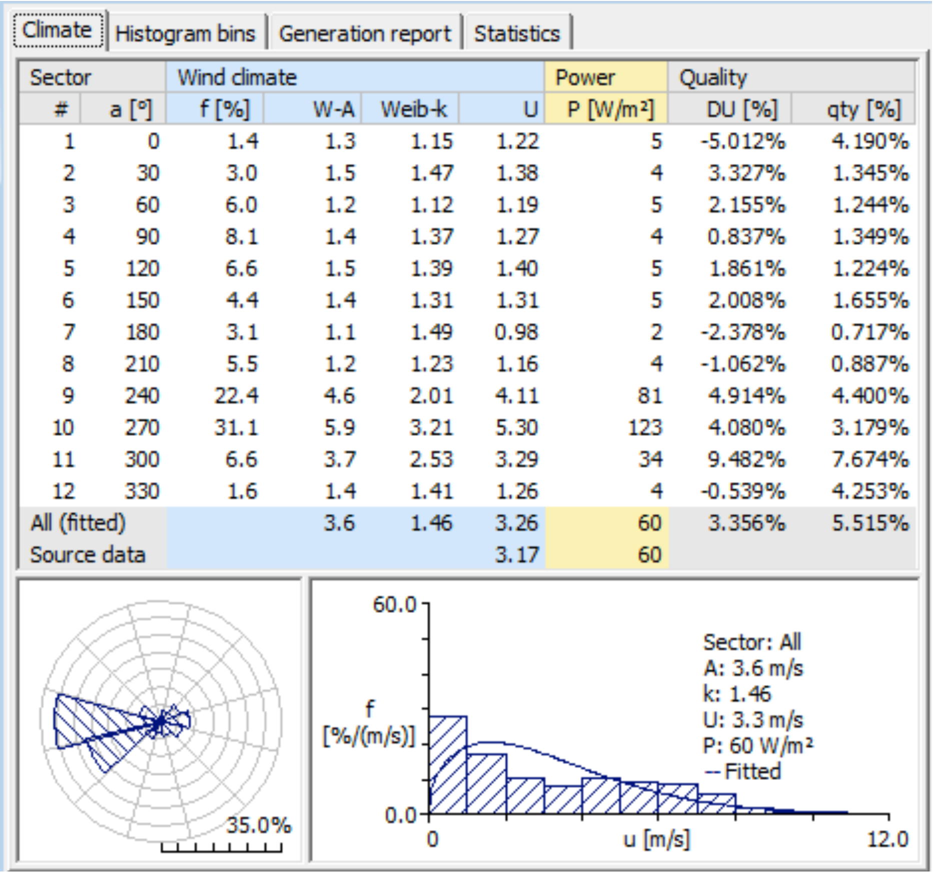
Sector		Wind climate				Power	Quality	
#	a [°]	f [%]	W-A	Weib-k	U	P [W/m²]	DU [%]	qty [%]
1	0	3.7	0.9	1.59	0.84	1	-0.909%	0.316%
2	30	8.3	1.7	1.79	1.55	5	2.267%	1.175%
3	60	7.6	1.8	1.74	1.57	5	3.695%	3.115%
4	90	4.7	1.2	2.26	1.08	1	3.511%	0.627%
5	120	6.6	2.2	1.89	1.97	10	5.513%	7.353%
6	150	4.0	1.1	1.35	1.01	2	-2.160%	0.367%
7	180	2.9	1.2	1.79	1.07	2	1.491%	0.467%
8	210	5.5	1.5	1.00	1.50	12	-3.907%	1.511%
9	240	24.3	5.1	2.01	4.50	106	3.707%	2.330%
10	270	19.9	5.0	1.90	4.44	108	6.173%	3.446%
11	300	10.2	2.3	1.46	2.06	15	1.780%	1.978%
12	330	2.2	1.1	1.34	0.98	2	-2.652%	0.545%
All (fitted)			2.8	1.16	2.70	51	-0.827%	1.601%
4:30:00 imported from file 'ENE 09_20m'					2.75	51		

Zacatecas. February 2009. 20m



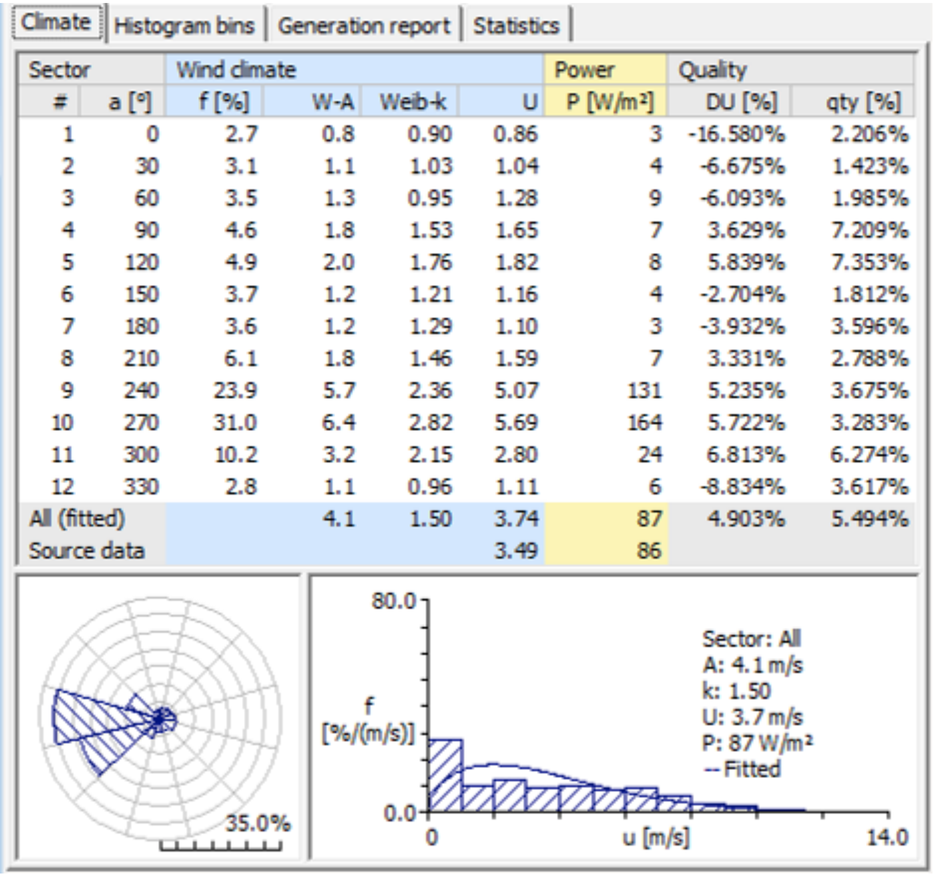
Sector		Wind climate				Power	Quality	
#	a [°]	f [%]	W-A	Weib-k	U	P [W/m²]	DU [%]	qty [%]
1	0	3.2	1.6	1.37	1.42	6	0.380%	6.372%
2	30	8.0	2.3	1.87	2.04	11	7.420%	9.365%
3	60	7.4	1.7	1.70	1.49	5	2.875%	5.988%
4	90	6.9	1.3	1.45	1.18	3	0.236%	2.248%
5	120	4.0	1.4	1.65	1.23	3	1.952%	1.636%
6	150	2.6	1.2	1.36	1.11	3	-1.409%	1.310%
7	180	2.4	1.1	1.87	1.00	1	1.267%	0.686%
8	210	4.8	1.3	0.94	1.29	9	-7.403%	3.325%
9	240	22.2	4.8	2.70	4.27	72	6.637%	5.375%
10	270	27.3	5.9	3.54	5.34	121	5.472%	3.259%
11	300	9.1	2.8	1.92	2.50	19	4.565%	5.934%
12	330	2.3	1.9	1.68	1.69	7	2.575%	3.870%
All (fitted)			3.5	1.50	3.17	53	3.047%	5.481%
Source data					3.09	52		

Zacatecas. March 2009. 20m



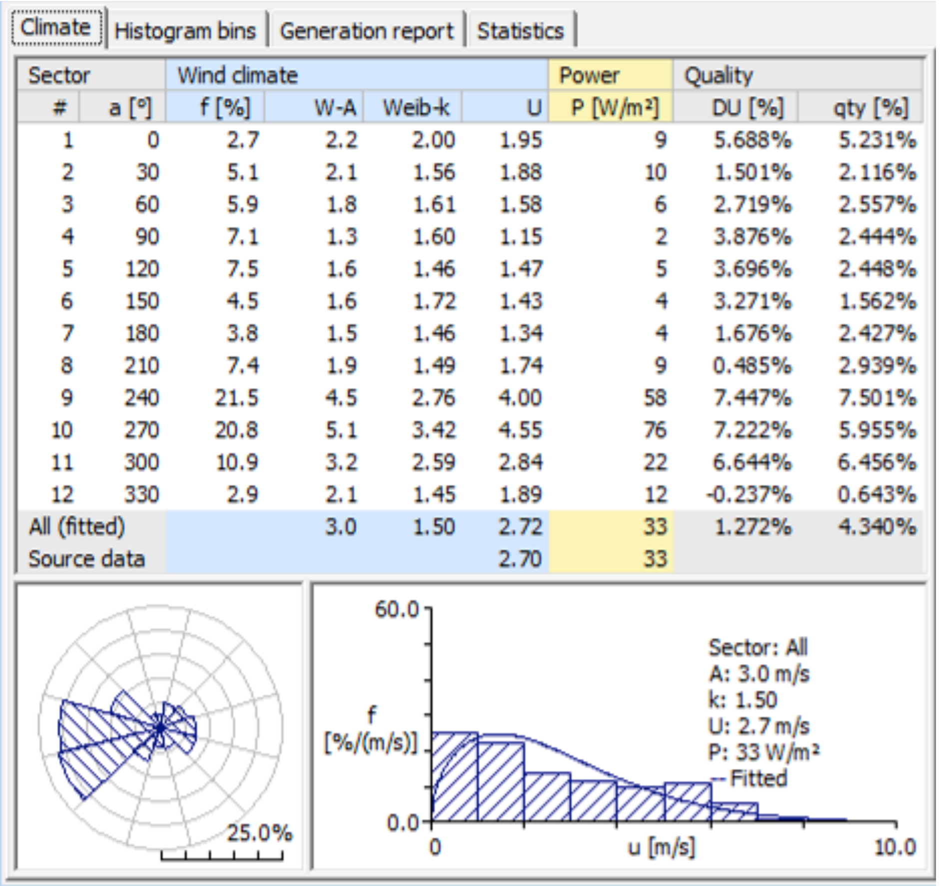
Sector		Wind climate				Power	Quality	
#	a [°]	f [%]	W-A	Weib-k	U	P [W/m²]	DU [%]	qty [%]
1	0	1.4	1.3	1.15	1.22	5	-5.012%	4.190%
2	30	3.0	1.5	1.47	1.38	4	3.327%	1.345%
3	60	6.0	1.2	1.12	1.19	5	2.155%	1.244%
4	90	8.1	1.4	1.37	1.27	4	0.837%	1.349%
5	120	6.6	1.5	1.39	1.40	5	1.861%	1.224%
6	150	4.4	1.4	1.31	1.31	5	2.008%	1.655%
7	180	3.1	1.1	1.49	0.98	2	-2.378%	0.717%
8	210	5.5	1.2	1.23	1.16	4	-1.062%	0.887%
9	240	22.4	4.6	2.01	4.11	81	4.914%	4.400%
10	270	31.1	5.9	3.21	5.30	123	4.080%	3.179%
11	300	6.6	3.7	2.53	3.29	34	9.482%	7.674%
12	330	1.6	1.4	1.41	1.26	4	-0.539%	4.253%
All (fitted)			3.6	1.46	3.26	60	3.356%	5.515%
Source data					3.17	60		

Zacatecas. April 2009. 20m



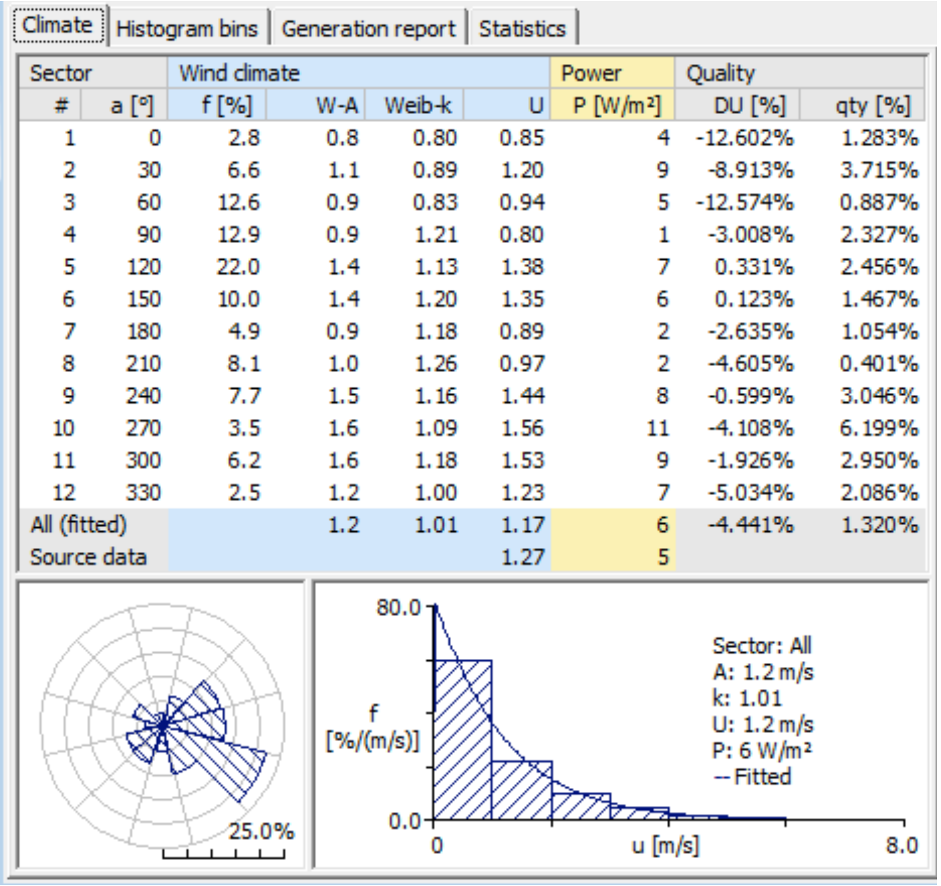
Sector		Wind climate				Power	Quality	
#	a [°]	f [%]	W-A	Weib-k	U	P [W/m²]	DU [%]	qty [%]
1	0	2.7	0.8	0.90	0.86	3	-16.580%	2.206%
2	30	3.1	1.1	1.03	1.04	4	-6.675%	1.423%
3	60	3.5	1.3	0.95	1.28	9	-6.093%	1.985%
4	90	4.6	1.8	1.53	1.65	7	3.629%	7.209%
5	120	4.9	2.0	1.76	1.82	8	5.839%	7.353%
6	150	3.7	1.2	1.21	1.16	4	-2.704%	1.812%
7	180	3.6	1.2	1.29	1.10	3	-3.932%	3.596%
8	210	6.1	1.8	1.46	1.59	7	3.331%	2.788%
9	240	23.9	5.7	2.36	5.07	131	5.235%	3.675%
10	270	31.0	6.4	2.82	5.69	164	5.722%	3.283%
11	300	10.2	3.2	2.15	2.80	24	6.813%	6.274%
12	330	2.8	1.1	0.96	1.11	6	-8.834%	3.617%
All (fitted)			4.1	1.50	3.74	87	4.903%	5.494%
Source data					3.49	86		

Zacatecas. May 2009. 20m



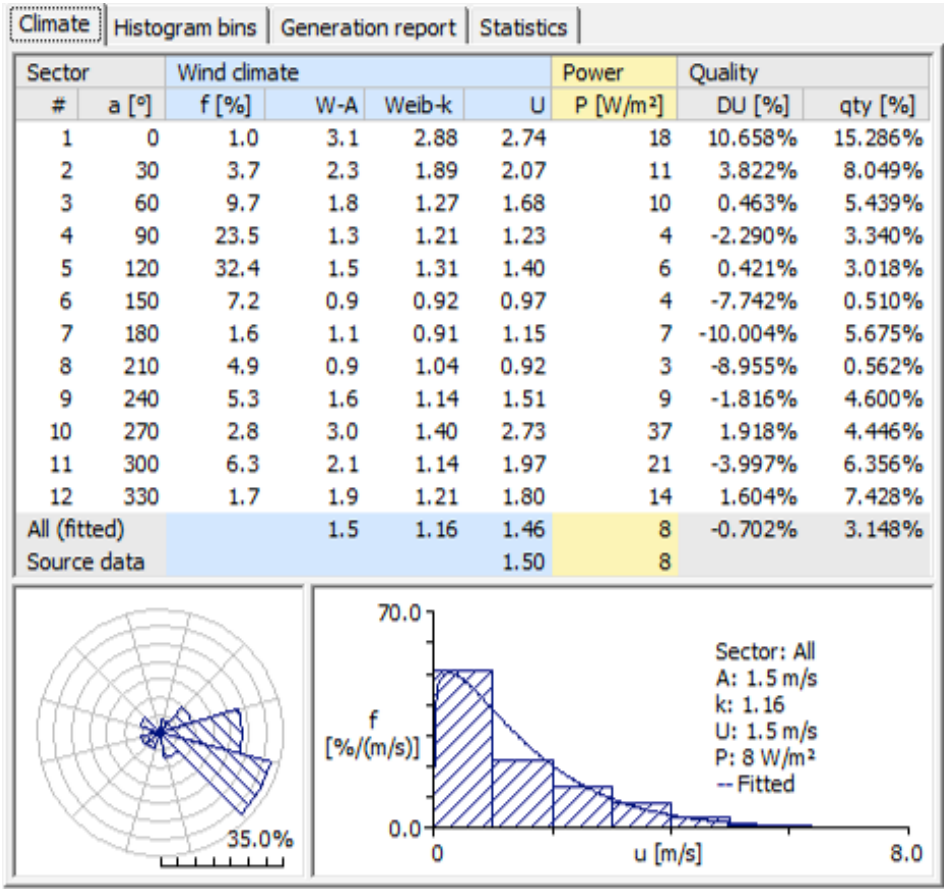
Sector		Wind climate				Power	Quality	
#	a [°]	f [%]	W-A	Weib-k	U	P [W/m²]	DU [%]	qty [%]
1	0	2.7	2.2	2.00	1.95	9	5.688%	5.231%
2	30	5.1	2.1	1.56	1.88	10	1.501%	2.116%
3	60	5.9	1.8	1.61	1.58	6	2.719%	2.557%
4	90	7.1	1.3	1.60	1.15	2	3.876%	2.444%
5	120	7.5	1.6	1.46	1.47	5	3.696%	2.448%
6	150	4.5	1.6	1.72	1.43	4	3.271%	1.562%
7	180	3.8	1.5	1.46	1.34	4	1.676%	2.427%
8	210	7.4	1.9	1.49	1.74	9	0.485%	2.939%
9	240	21.5	4.5	2.76	4.00	58	7.447%	7.501%
10	270	20.8	5.1	3.42	4.55	76	7.222%	5.955%
11	300	10.9	3.2	2.59	2.84	22	6.644%	6.456%
12	330	2.9	2.1	1.45	1.89	12	-0.237%	0.643%
All (fitted)			3.0	1.50	2.72	33	1.272%	4.340%
Source data					2.70	33		

Zacatecas. June 2009. 20m



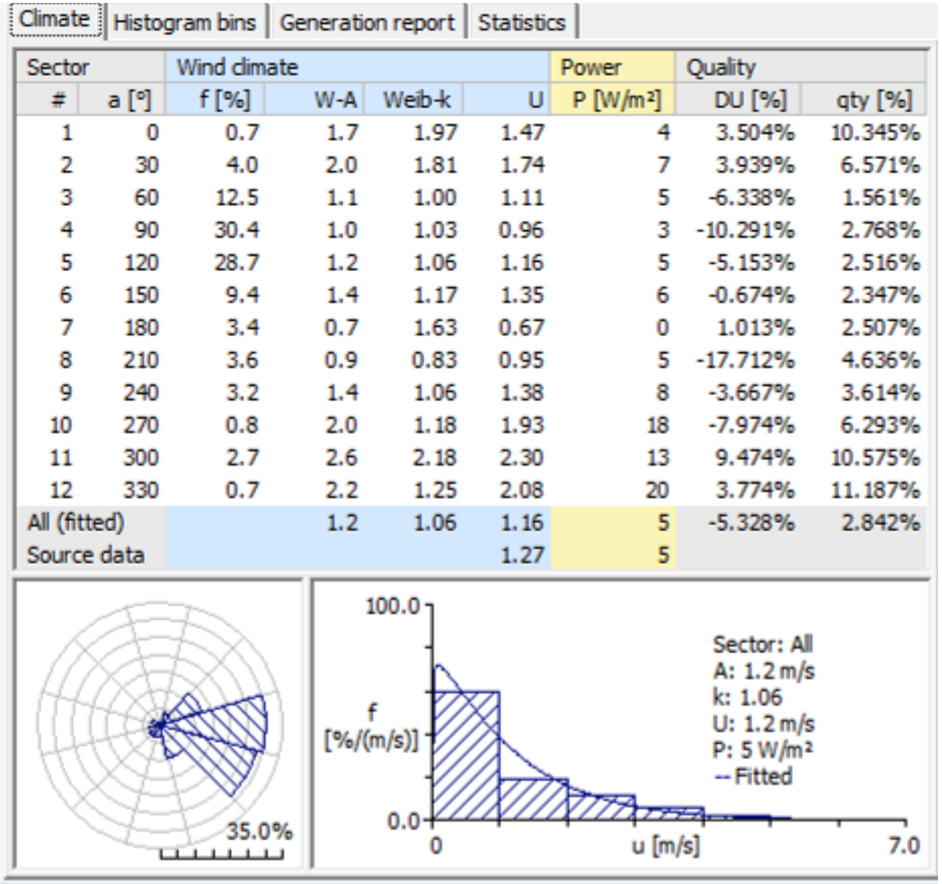
Sector		Wind climate				Power	Quality	
#	a [°]	f [%]	W-A	Weib-k	U	P [W/m²]	DU [%]	qty [%]
1	0	2.8	0.8	0.80	0.85	4	-12.602%	1.283%
2	30	6.6	1.1	0.89	1.20	9	-8.913%	3.715%
3	60	12.6	0.9	0.83	0.94	5	-12.574%	0.887%
4	90	12.9	0.9	1.21	0.80	1	-3.008%	2.327%
5	120	22.0	1.4	1.13	1.38	7	0.331%	2.456%
6	150	10.0	1.4	1.20	1.35	6	0.123%	1.467%
7	180	4.9	0.9	1.18	0.89	2	-2.635%	1.054%
8	210	8.1	1.0	1.26	0.97	2	-4.605%	0.401%
9	240	7.7	1.5	1.16	1.44	8	-0.599%	3.046%
10	270	3.5	1.6	1.09	1.56	11	-4.108%	6.199%
11	300	6.2	1.6	1.18	1.53	9	-1.926%	2.950%
12	330	2.5	1.2	1.00	1.23	7	-5.034%	2.086%
All (fitted)			1.2	1.01	1.17	6	-4.441%	1.320%
Source data					1.27	5		

Zacatecas. July 2009. 20m



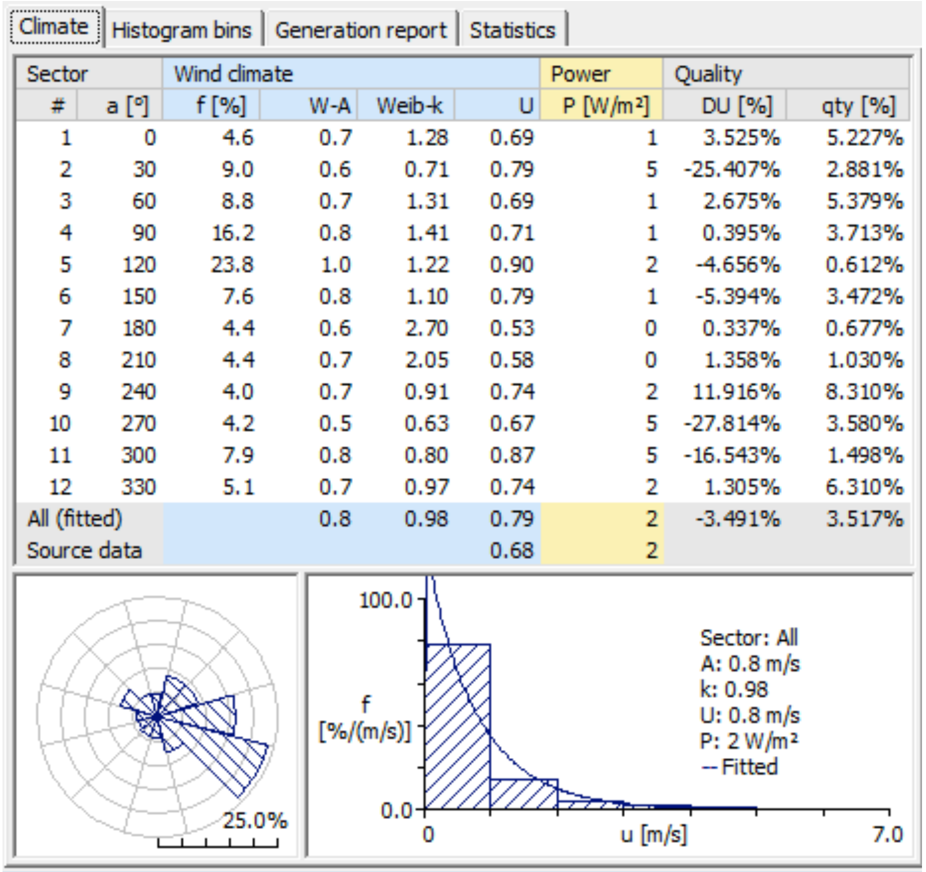
Sector		Wind climate				Power	Quality	
#	a [°]	f [%]	W-A	Weib-k	U	P [W/m²]	DU [%]	qty [%]
1	0	1.0	3.1	2.88	2.74	18	10.658%	15.286%
2	30	3.7	2.3	1.89	2.07	11	3.822%	8.049%
3	60	9.7	1.8	1.27	1.68	10	0.463%	5.439%
4	90	23.5	1.3	1.21	1.23	4	-2.290%	3.340%
5	120	32.4	1.5	1.31	1.40	6	0.421%	3.018%
6	150	7.2	0.9	0.92	0.97	4	-7.742%	0.510%
7	180	1.6	1.1	0.91	1.15	7	-10.004%	5.675%
8	210	4.9	0.9	1.04	0.92	3	-8.955%	0.562%
9	240	5.3	1.6	1.14	1.51	9	-1.816%	4.600%
10	270	2.8	3.0	1.40	2.73	37	1.918%	4.446%
11	300	6.3	2.1	1.14	1.97	21	-3.997%	6.356%
12	330	1.7	1.9	1.21	1.80	14	1.604%	7.428%
All (fitted)			1.5	1.16	1.46	8	-0.702%	3.148%
Source data					1.50	8		

Zacatecas. August 2009. 20m



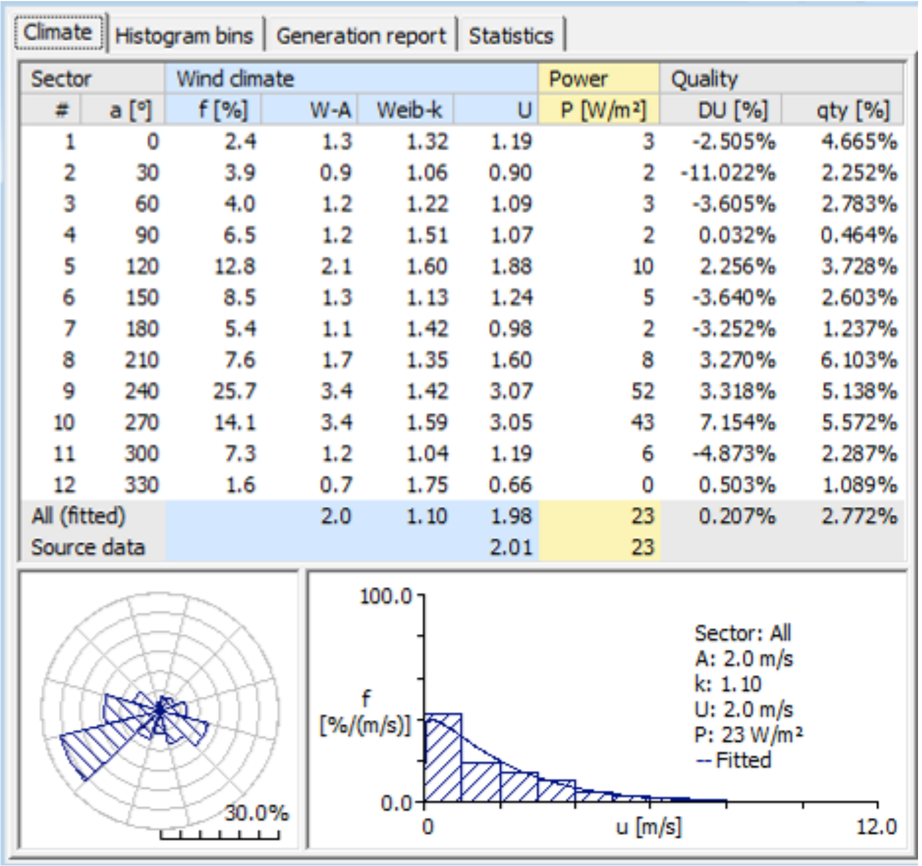
Sector		Wind climate				Power	Quality	
#	a [°]	f [%]	W-A	Weib-k	U	P [W/m²]	DU [%]	qty [%]
1	0	0.7	1.7	1.97	1.47	4	3.504%	10.345%
2	30	4.0	2.0	1.81	1.74	7	3.939%	6.571%
3	60	12.5	1.1	1.00	1.11	5	-6.338%	1.561%
4	90	30.4	1.0	1.03	0.96	3	-10.291%	2.768%
5	120	28.7	1.2	1.06	1.16	5	-5.153%	2.516%
6	150	9.4	1.4	1.17	1.35	6	-0.674%	2.347%
7	180	3.4	0.7	1.63	0.67	0	1.013%	2.507%
8	210	3.6	0.9	0.83	0.95	5	-17.712%	4.636%
9	240	3.2	1.4	1.06	1.38	8	-3.667%	3.614%
10	270	0.8	2.0	1.18	1.93	18	-7.974%	6.293%
11	300	2.7	2.6	2.18	2.30	13	9.474%	10.575%
12	330	0.7	2.2	1.25	2.08	20	3.774%	11.187%
All (fitted)			1.2	1.06	1.16	5	-5.328%	2.842%
Source data					1.27	5		

Zacatecas. September 2009. 20m



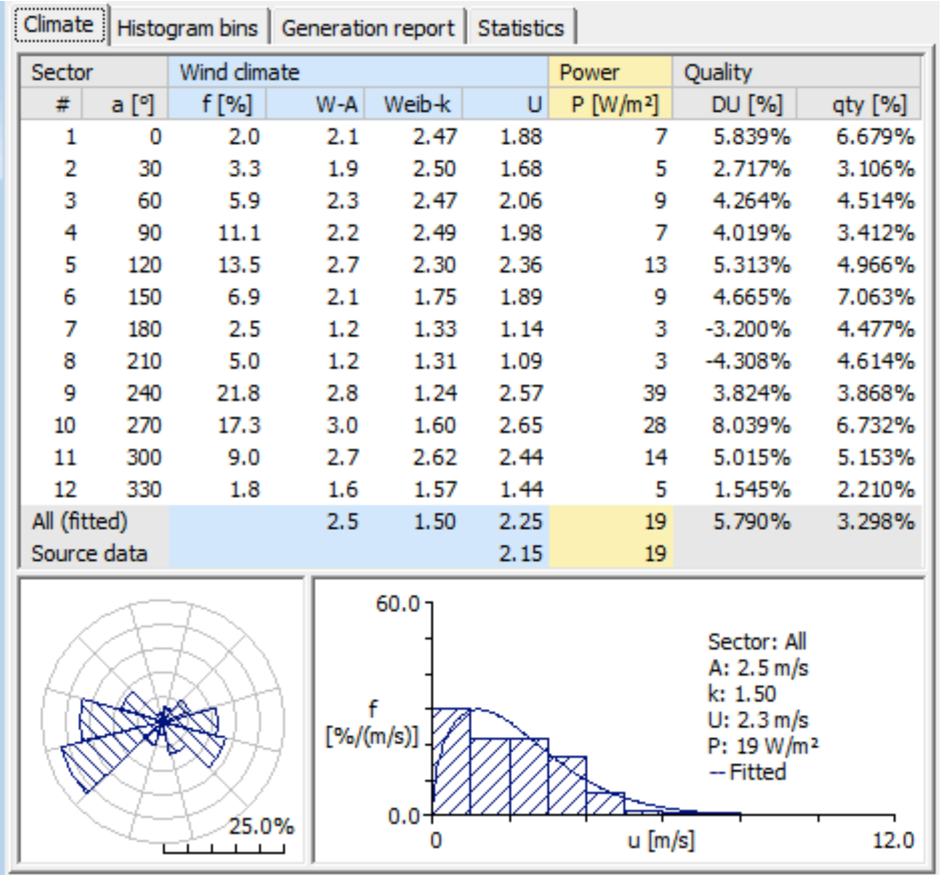
Sector		Wind climate				Power	Quality	
#	a [°]	f [%]	W-A	Weib-k	U	P [W/m²]	DU [%]	qty [%]
1	0	4.6	0.7	1.28	0.69	1	3.525%	5.227%
2	30	9.0	0.6	0.71	0.79	5	-25.407%	2.881%
3	60	8.8	0.7	1.31	0.69	1	2.675%	5.379%
4	90	16.2	0.8	1.41	0.71	1	0.395%	3.713%
5	120	23.8	1.0	1.22	0.90	2	-4.656%	0.612%
6	150	7.6	0.8	1.10	0.79	1	-5.394%	3.472%
7	180	4.4	0.6	2.70	0.53	0	0.337%	0.677%
8	210	4.4	0.7	2.05	0.58	0	1.358%	1.030%
9	240	4.0	0.7	0.91	0.74	2	11.916%	8.310%
10	270	4.2	0.5	0.63	0.67	5	-27.814%	3.580%
11	300	7.9	0.8	0.80	0.87	5	-16.543%	1.498%
12	330	5.1	0.7	0.97	0.74	2	1.305%	6.310%
All (fitted)			0.8	0.98	0.79	2	-3.491%	3.517%
Source data					0.68	2		

Zacatecas. October 2009. 20m



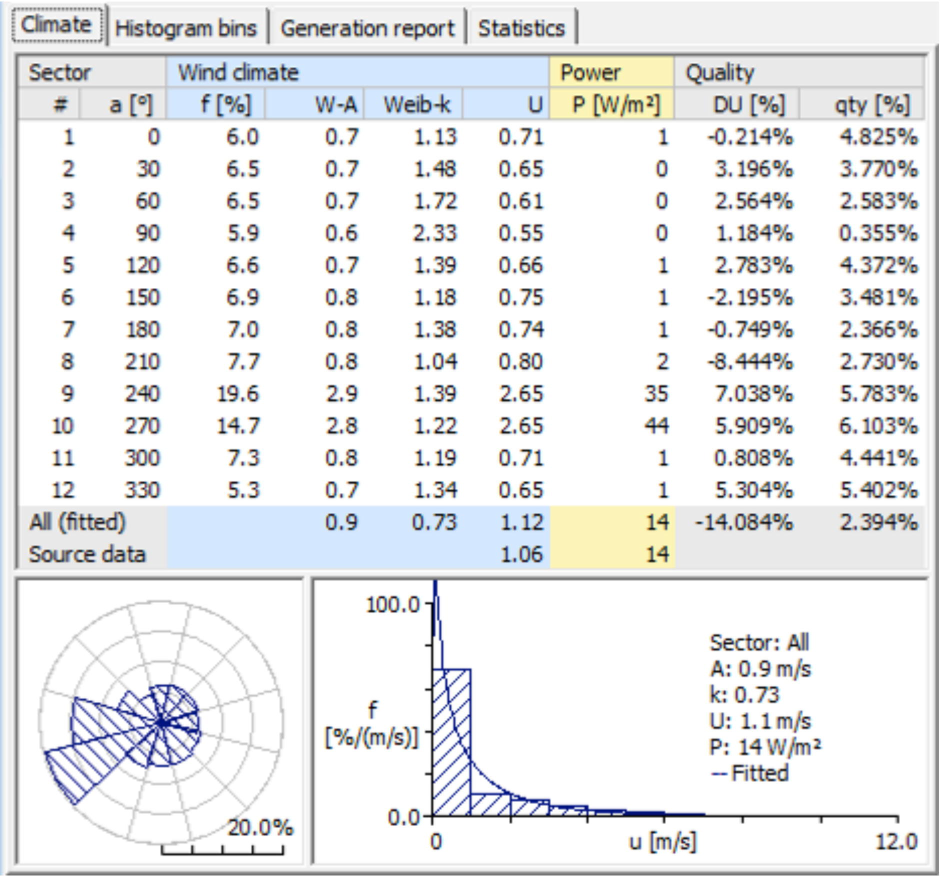
Sector		Wind climate				Power	Quality	
#	a [°]	f [%]	W-A	Weib-k	U	P [W/m²]	DU [%]	qty [%]
1	0	2.4	1.3	1.32	1.19	3	-2.505%	4.665%
2	30	3.9	0.9	1.06	0.90	2	-11.022%	2.252%
3	60	4.0	1.2	1.22	1.09	3	-3.605%	2.783%
4	90	6.5	1.2	1.51	1.07	2	0.032%	0.464%
5	120	12.8	2.1	1.60	1.88	10	2.256%	3.728%
6	150	8.5	1.3	1.13	1.24	5	-3.640%	2.603%
7	180	5.4	1.1	1.42	0.98	2	-3.252%	1.237%
8	210	7.6	1.7	1.35	1.60	8	3.270%	6.103%
9	240	25.7	3.4	1.42	3.07	52	3.318%	5.138%
10	270	14.1	3.4	1.59	3.05	43	7.154%	5.572%
11	300	7.3	1.2	1.04	1.19	6	-4.873%	2.287%
12	330	1.6	0.7	1.75	0.66	0	0.503%	1.089%
All (fitted)			2.0	1.10	1.98	23	0.207%	2.772%
Source data					2.01	23		

Zacatecas. November 2009. 20m



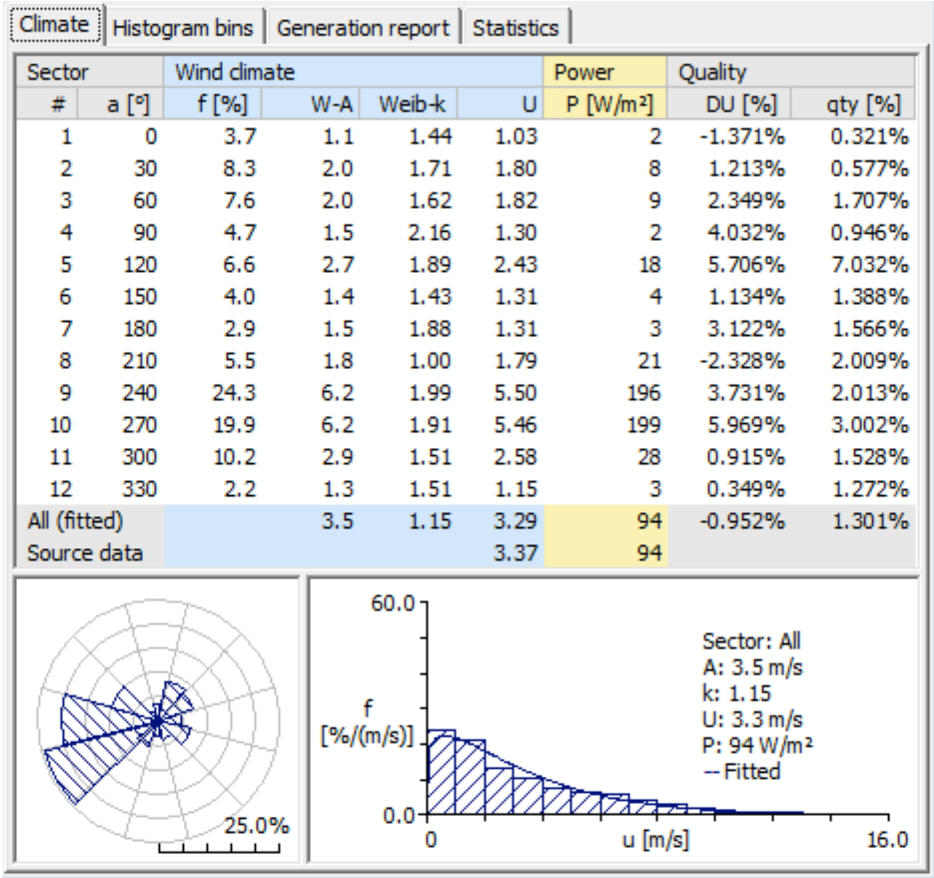
Sector		Wind climate				Power	Quality	
#	a [°]	f [%]	W-A	Weib-k	U	P [W/m²]	DU [%]	qty [%]
1	0	2.0	2.1	2.47	1.88	7	5.839%	6.679%
2	30	3.3	1.9	2.50	1.68	5	2.717%	3.106%
3	60	5.9	2.3	2.47	2.06	9	4.264%	4.514%
4	90	11.1	2.2	2.49	1.98	7	4.019%	3.412%
5	120	13.5	2.7	2.30	2.36	13	5.313%	4.966%
6	150	6.9	2.1	1.75	1.89	9	4.665%	7.063%
7	180	2.5	1.2	1.33	1.14	3	-3.200%	4.477%
8	210	5.0	1.2	1.31	1.09	3	-4.308%	4.614%
9	240	21.8	2.8	1.24	2.57	39	3.824%	3.868%
10	270	17.3	3.0	1.60	2.65	28	8.039%	6.732%
11	300	9.0	2.7	2.62	2.44	14	5.015%	5.153%
12	330	1.8	1.6	1.57	1.44	5	1.545%	2.210%
All (fitted)			2.5	1.50	2.25	19	5.790%	3.298%
Source data					2.15	19		

Zacatecas. December 2009. 20m



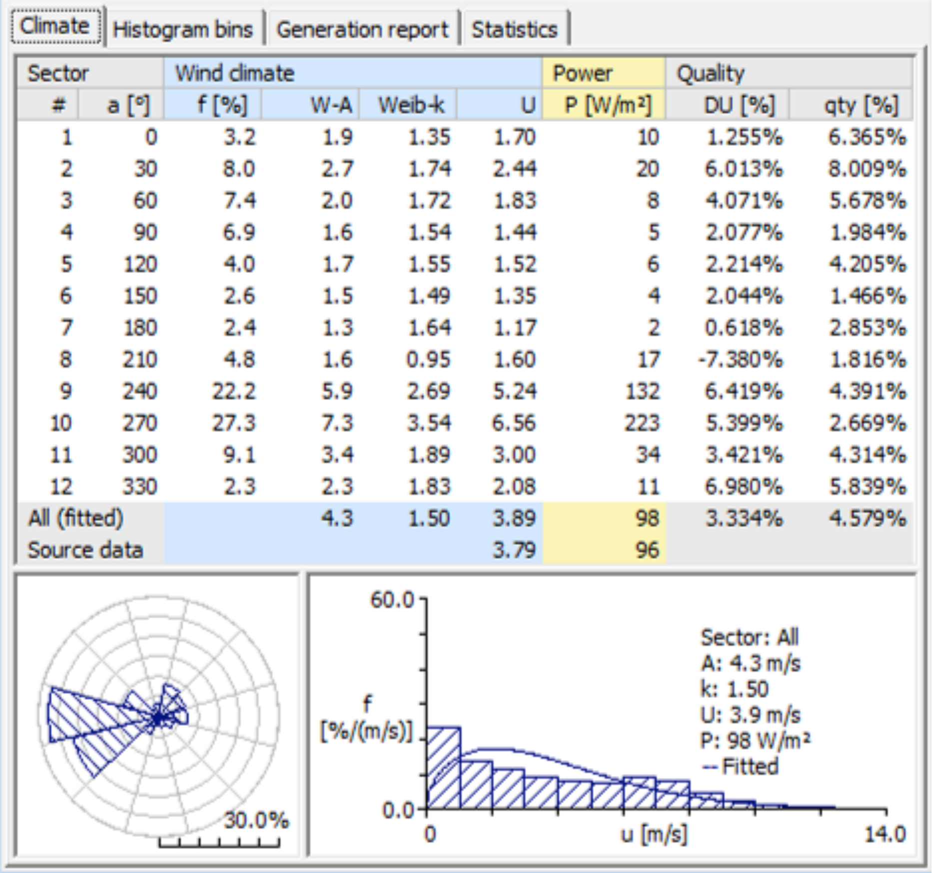
Sector		Wind climate				Power	Quality	
#	a [°]	f [%]	W-A	Weib-k	U	P [W/m²]	DU [%]	qty [%]
1	0	6.0	0.7	1.13	0.71	1	-0.214%	4.825%
2	30	6.5	0.7	1.48	0.65	0	3.196%	3.770%
3	60	6.5	0.7	1.72	0.61	0	2.564%	2.583%
4	90	5.9	0.6	2.33	0.55	0	1.184%	0.355%
5	120	6.6	0.7	1.39	0.66	1	2.783%	4.372%
6	150	6.9	0.8	1.18	0.75	1	-2.195%	3.481%
7	180	7.0	0.8	1.38	0.74	1	-0.749%	2.366%
8	210	7.7	0.8	1.04	0.80	2	-8.444%	2.730%
9	240	19.6	2.9	1.39	2.65	35	7.038%	5.783%
10	270	14.7	2.8	1.22	2.65	44	5.909%	6.103%
11	300	7.3	0.8	1.19	0.71	1	0.808%	4.441%
12	330	5.3	0.7	1.34	0.65	1	5.304%	5.402%
All (fitted)			0.9	0.73	1.12	14	-14.084%	2.394%
Source data					1.06	14		

Zacatecas. January 2009. 50m



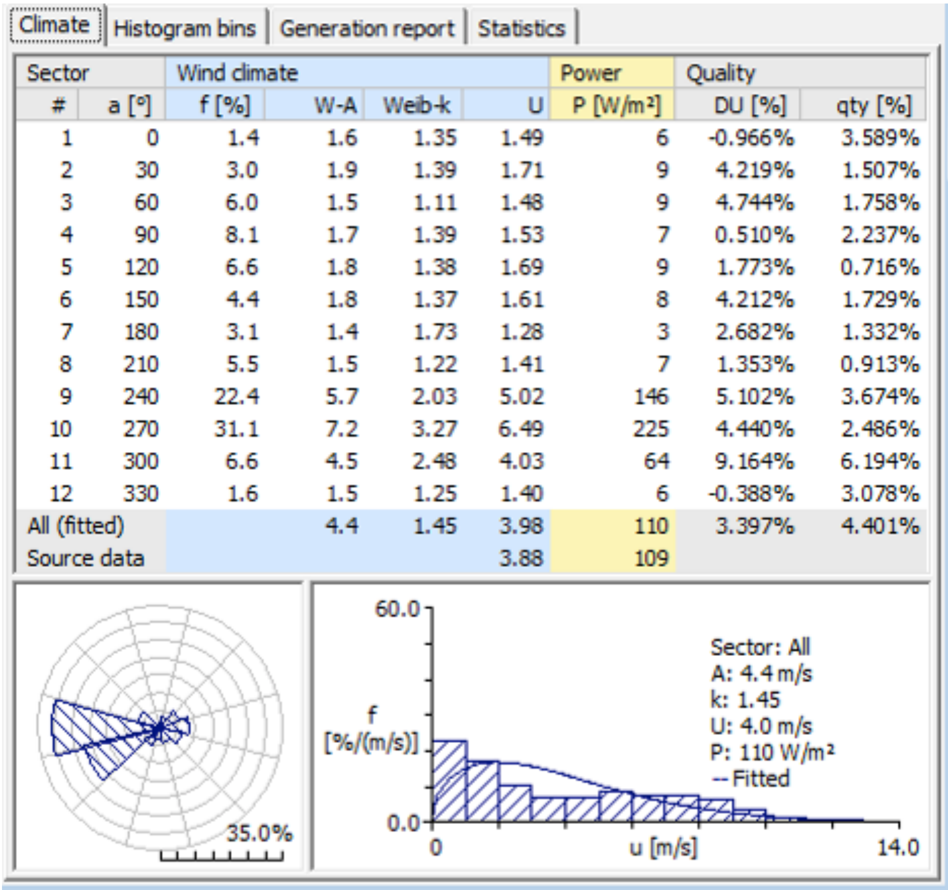
Sector		Wind climate				Power	Quality	
#	a [°]	f [%]	W-A	Weib-k	U	P [W/m²]	DU [%]	qty [%]
1	0	3.7	1.1	1.44	1.03	2	-1.371%	0.321%
2	30	8.3	2.0	1.71	1.80	8	1.213%	0.577%
3	60	7.6	2.0	1.62	1.82	9	2.349%	1.707%
4	90	4.7	1.5	2.16	1.30	2	4.032%	0.946%
5	120	6.6	2.7	1.89	2.43	18	5.706%	7.032%
6	150	4.0	1.4	1.43	1.31	4	1.134%	1.388%
7	180	2.9	1.5	1.88	1.31	3	3.122%	1.566%
8	210	5.5	1.8	1.00	1.79	21	-2.328%	2.009%
9	240	24.3	6.2	1.99	5.50	196	3.731%	2.013%
10	270	19.9	6.2	1.91	5.46	199	5.969%	3.002%
11	300	10.2	2.9	1.51	2.58	28	0.915%	1.528%
12	330	2.2	1.3	1.51	1.15	3	0.349%	1.272%
All (fitted)			3.5	1.15	3.29	94	-0.952%	1.301%
Source data					3.37	94		

Zacatecas. February 2009. 50m



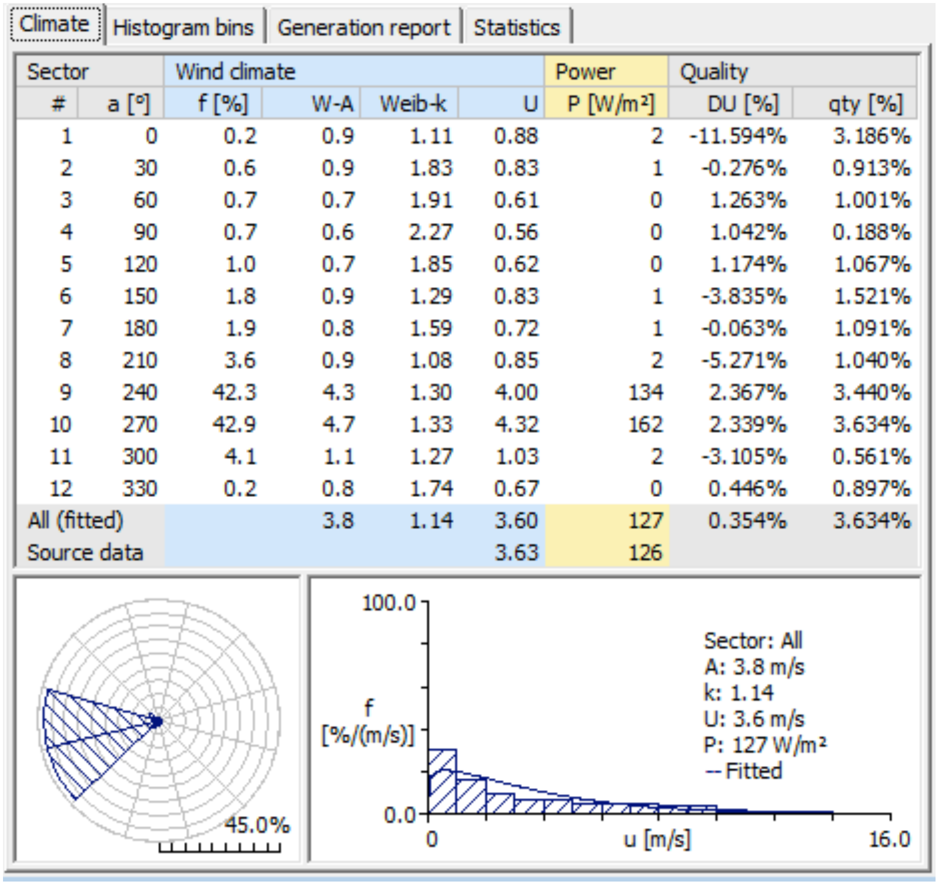
Sector		Wind climate				Power	Quality	
#	a [°]	f [%]	W-A	Weib-k	U	P [W/m²]	DU [%]	qty [%]
1	0	3.2	1.9	1.35	1.70	10	1.255%	6.365%
2	30	8.0	2.7	1.74	2.44	20	6.013%	8.009%
3	60	7.4	2.0	1.72	1.83	8	4.071%	5.678%
4	90	6.9	1.6	1.54	1.44	5	2.077%	1.984%
5	120	4.0	1.7	1.55	1.52	6	2.214%	4.205%
6	150	2.6	1.5	1.49	1.35	4	2.044%	1.466%
7	180	2.4	1.3	1.64	1.17	2	0.618%	2.853%
8	210	4.8	1.6	0.95	1.60	17	-7.380%	1.816%
9	240	22.2	5.9	2.69	5.24	132	6.419%	4.391%
10	270	27.3	7.3	3.54	6.56	223	5.399%	2.669%
11	300	9.1	3.4	1.89	3.00	34	3.421%	4.314%
12	330	2.3	2.3	1.83	2.08	11	6.980%	5.839%
All (fitted)			4.3	1.50	3.89	98	3.334%	4.579%
Source data					3.79	96		

Zacatecas. March 2009. 50m



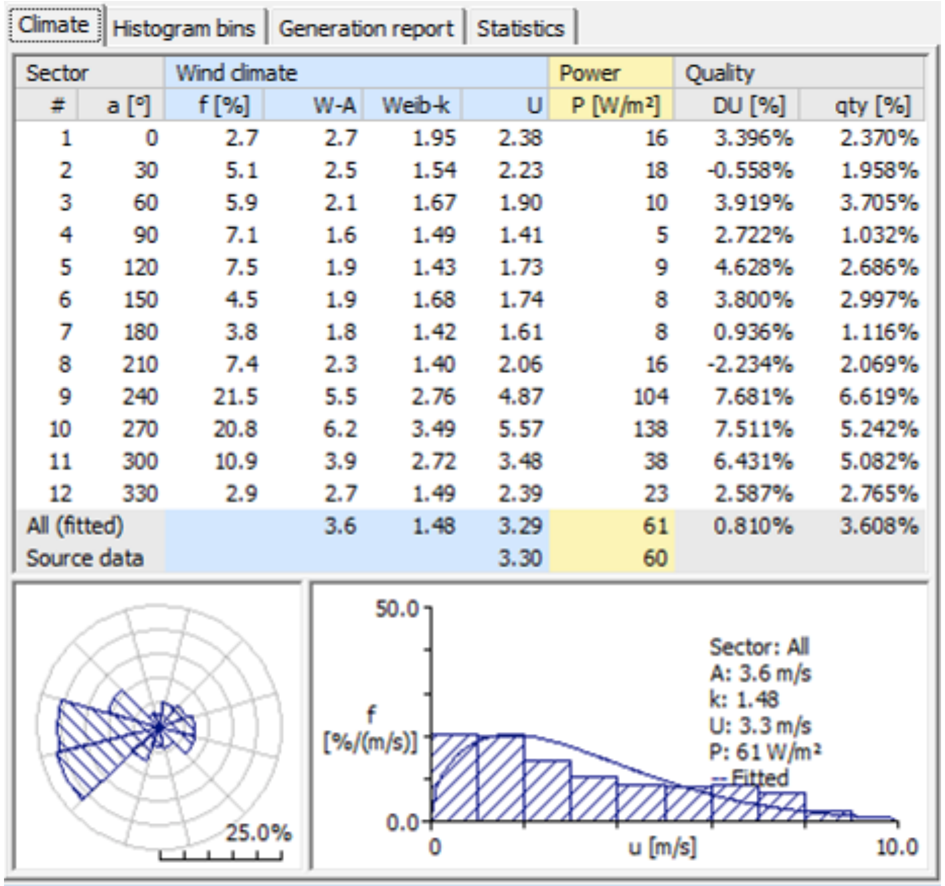
Sector		Wind climate				Power	Quality	
#	a [°]	f [%]	W-A	Weib-k	U	P [W/m²]	DU [%]	qty [%]
1	0	1.4	1.6	1.35	1.49	6	-0.966%	3.589%
2	30	3.0	1.9	1.39	1.71	9	4.219%	1.507%
3	60	6.0	1.5	1.11	1.48	9	4.744%	1.758%
4	90	8.1	1.7	1.39	1.53	7	0.510%	2.237%
5	120	6.6	1.8	1.38	1.69	9	1.773%	0.716%
6	150	4.4	1.8	1.37	1.61	8	4.212%	1.729%
7	180	3.1	1.4	1.73	1.28	3	2.682%	1.332%
8	210	5.5	1.5	1.22	1.41	7	1.353%	0.913%
9	240	22.4	5.7	2.03	5.02	146	5.102%	3.674%
10	270	31.1	7.2	3.27	6.49	225	4.440%	2.486%
11	300	6.6	4.5	2.48	4.03	64	9.164%	6.194%
12	330	1.6	1.5	1.25	1.40	6	-0.388%	3.078%
All (fitted)			4.4	1.45	3.98	110	3.397%	4.401%
Source data					3.88	109		

Zacatecas. April 2008. 50m



Sector		Wind climate				Power	Quality	
#	a [°]	f [%]	W-A	Weib-k	U	P [W/m²]	DU [%]	qty [%]
1	0	0.2	0.9	1.11	0.88	2	-11.594%	3.186%
2	30	0.6	0.9	1.83	0.83	1	-0.276%	0.913%
3	60	0.7	0.7	1.91	0.61	0	1.263%	1.001%
4	90	0.7	0.6	2.27	0.56	0	1.042%	0.188%
5	120	1.0	0.7	1.85	0.62	0	1.174%	1.067%
6	150	1.8	0.9	1.29	0.83	1	-3.835%	1.521%
7	180	1.9	0.8	1.59	0.72	1	-0.063%	1.091%
8	210	3.6	0.9	1.08	0.85	2	-5.271%	1.040%
9	240	42.3	4.3	1.30	4.00	134	2.367%	3.440%
10	270	42.9	4.7	1.33	4.32	162	2.339%	3.634%
11	300	4.1	1.1	1.27	1.03	2	-3.105%	0.561%
12	330	0.2	0.8	1.74	0.67	0	0.446%	0.897%
All (fitted)			3.8	1.14	3.60	127	0.354%	3.634%
Source data					3.63	126		

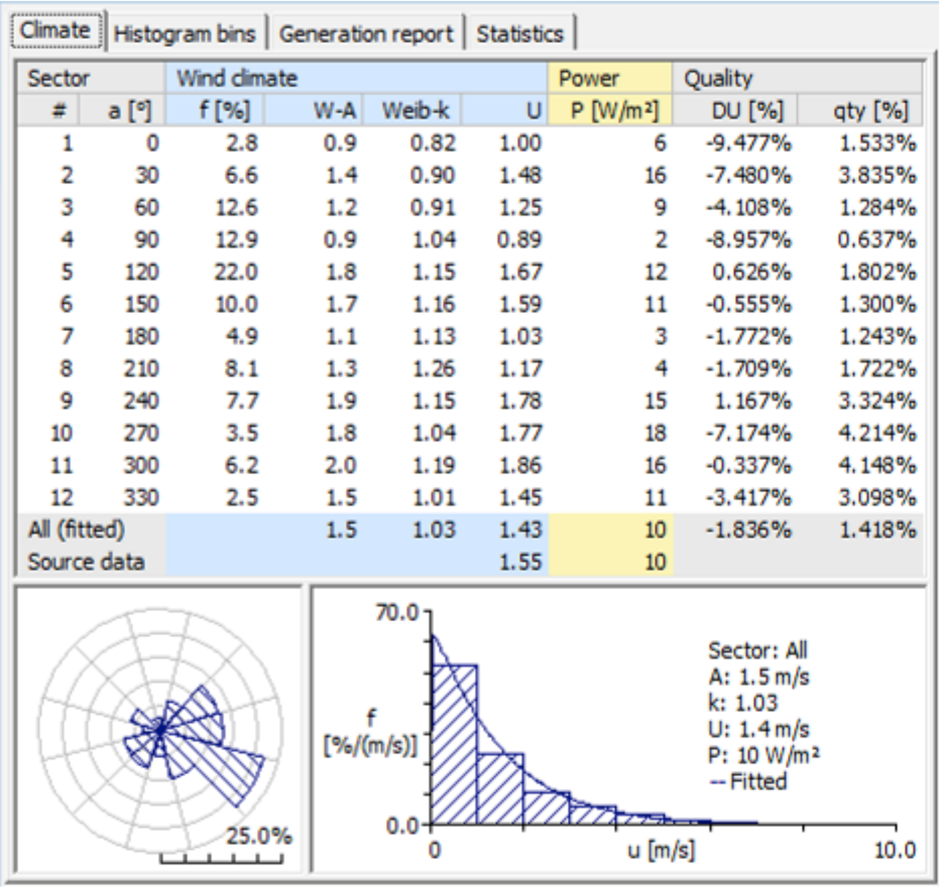
Zacatecas. May 2009. 50m



Sector		Wind climate				Power	Quality	
#	a [°]	f [%]	W-A	Weib-k	U	P [W/m²]	DU [%]	qty [%]
1	0	2.7	2.7	1.95	2.38	16	3.396%	2.370%
2	30	5.1	2.5	1.54	2.23	18	-0.558%	1.958%
3	60	5.9	2.1	1.67	1.90	10	3.919%	3.705%
4	90	7.1	1.6	1.49	1.41	5	2.722%	1.032%
5	120	7.5	1.9	1.43	1.73	9	4.628%	2.686%
6	150	4.5	1.9	1.68	1.74	8	3.800%	2.997%
7	180	3.8	1.8	1.42	1.61	8	0.936%	1.116%
8	210	7.4	2.3	1.40	2.06	16	-2.234%	2.069%
9	240	21.5	5.5	2.76	4.87	104	7.681%	6.619%
10	270	20.8	6.2	3.49	5.57	138	7.511%	5.242%
11	300	10.9	3.9	2.72	3.48	38	6.431%	5.082%
12	330	2.9	2.7	1.49	2.39	23	2.587%	2.765%
All (fitted)			3.6	1.48	3.29	61	0.810%	3.608%
Source data					3.30	60		

Sector: All
A: 3.6 m/s
k: 1.48
U: 3.3 m/s
P: 61 W/m²

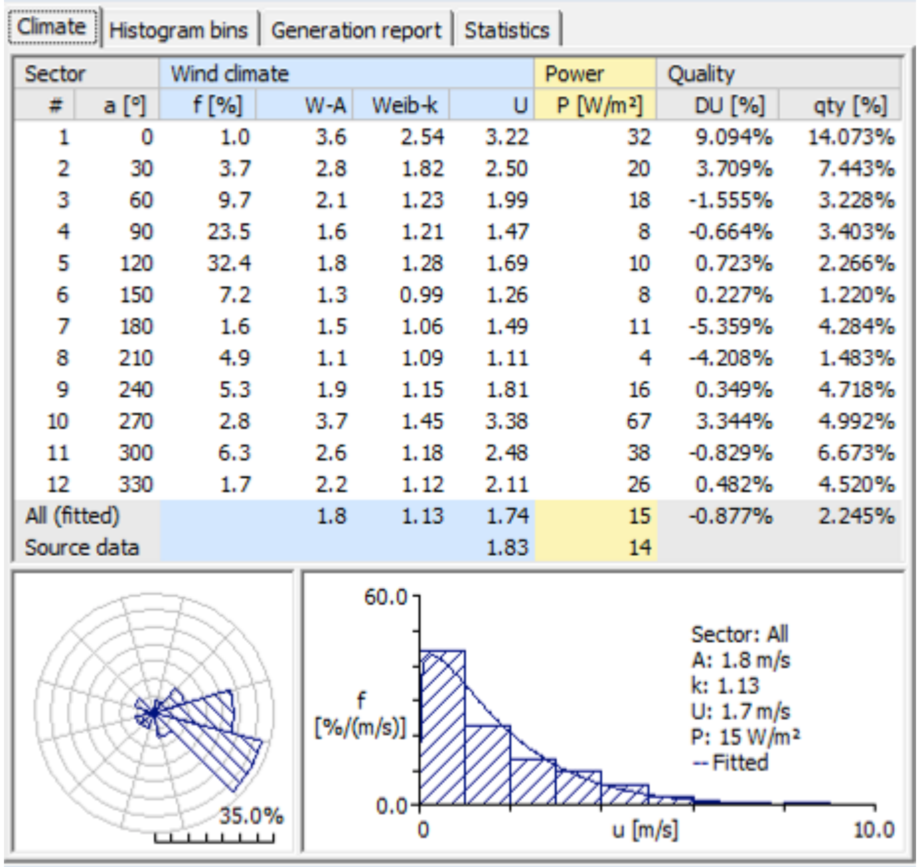
Zacatecas. June 2009. 50m



Sector		Wind climate				Power	Quality	
#	a [°]	f [%]	W-A	Weib-k	U	P [W/m²]	DU [%]	qty [%]
1	0	2.8	0.9	0.82	1.00	6	-9.477%	1.533%
2	30	6.6	1.4	0.90	1.48	16	-7.480%	3.835%
3	60	12.6	1.2	0.91	1.25	9	-4.108%	1.284%
4	90	12.9	0.9	1.04	0.89	2	-8.957%	0.637%
5	120	22.0	1.8	1.15	1.67	12	0.626%	1.802%
6	150	10.0	1.7	1.16	1.59	11	-0.555%	1.300%
7	180	4.9	1.1	1.13	1.03	3	-1.772%	1.243%
8	210	8.1	1.3	1.26	1.17	4	-1.709%	1.722%
9	240	7.7	1.9	1.15	1.78	15	1.167%	3.324%
10	270	3.5	1.8	1.04	1.77	18	-7.174%	4.214%
11	300	6.2	2.0	1.19	1.86	16	-0.337%	4.148%
12	330	2.5	1.5	1.01	1.45	11	-3.417%	3.098%
All (fitted)			1.5	1.03	1.43	10	-1.836%	1.418%
Source data					1.55	10		

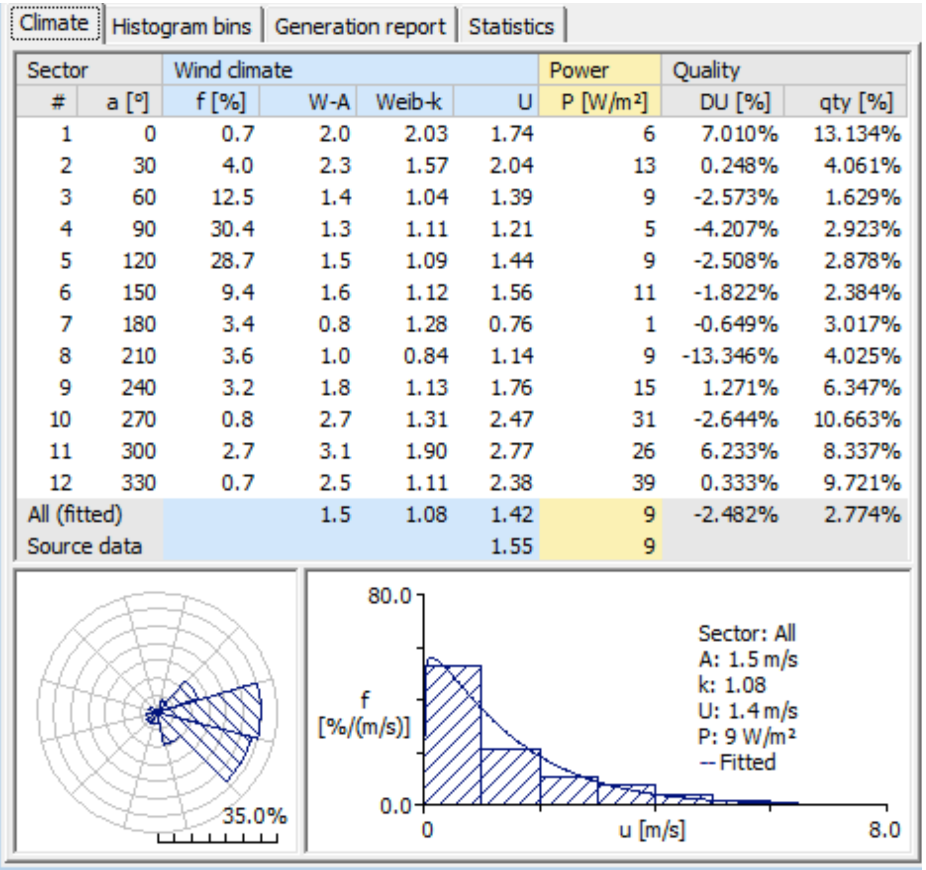
Sector: All
A: 1.5 m/s
k: 1.03
U: 1.4 m/s
P: 10 W/m²

Zacatecas. July 2009. 50m



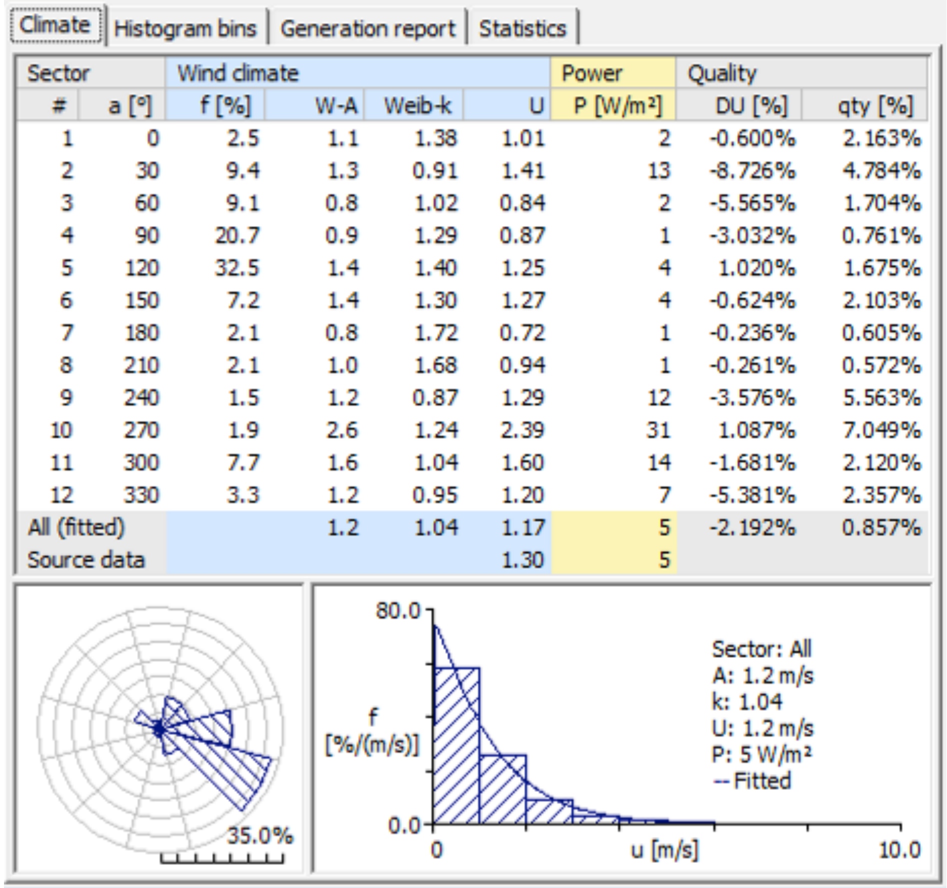
Sector		Wind climate				Power	Quality	
#	a [°]	f [%]	W-A	Weib-k	U	P [W/m²]	DU [%]	qty [%]
1	0	1.0	3.6	2.54	3.22	32	9.094%	14.073%
2	30	3.7	2.8	1.82	2.50	20	3.709%	7.443%
3	60	9.7	2.1	1.23	1.99	18	-1.555%	3.228%
4	90	23.5	1.6	1.21	1.47	8	-0.664%	3.403%
5	120	32.4	1.8	1.28	1.69	10	0.723%	2.266%
6	150	7.2	1.3	0.99	1.26	8	0.227%	1.220%
7	180	1.6	1.5	1.06	1.49	11	-5.359%	4.284%
8	210	4.9	1.1	1.09	1.11	4	-4.208%	1.483%
9	240	5.3	1.9	1.15	1.81	16	0.349%	4.718%
10	270	2.8	3.7	1.45	3.38	67	3.344%	4.992%
11	300	6.3	2.6	1.18	2.48	38	-0.829%	6.673%
12	330	1.7	2.2	1.12	2.11	26	0.482%	4.520%
All (fitted)			1.8	1.13	1.74	15	-0.877%	2.245%
Source data					1.83	14		

Zacatecas. August 2009. 50m



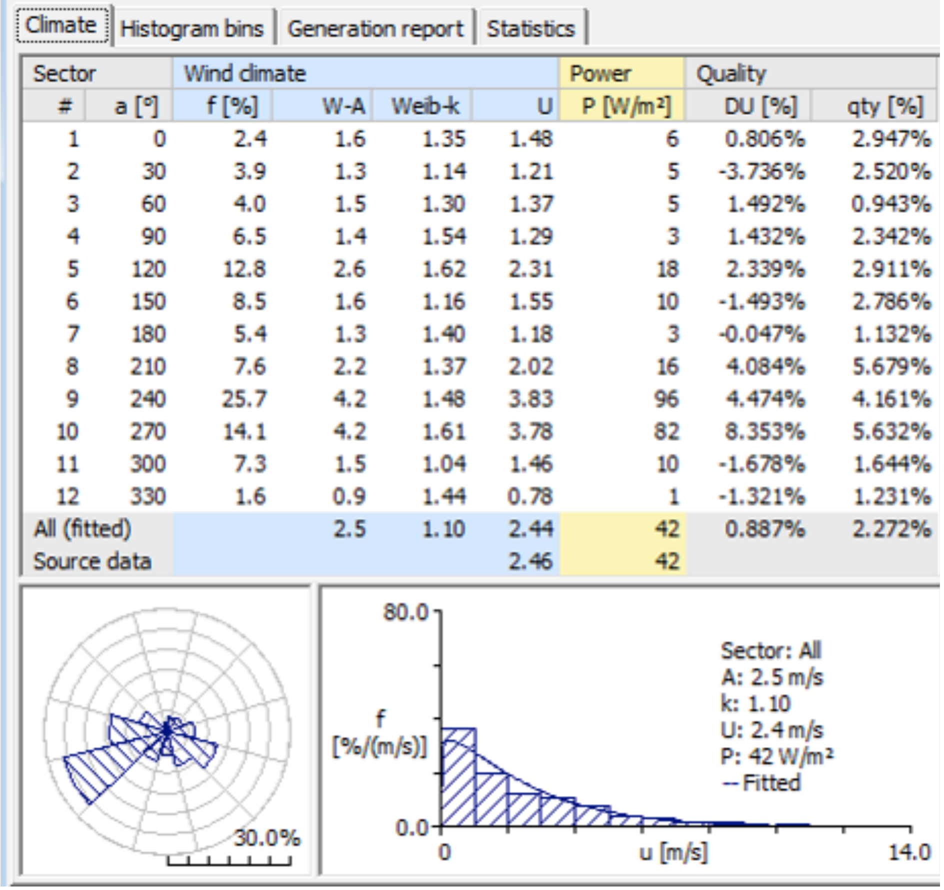
Sector		Wind climate				Power	Quality	
#	a [°]	f [%]	W-A	Weib-k	U	P [W/m²]	DU [%]	qty [%]
1	0	0.7	2.0	2.03	1.74	6	7.010%	13.134%
2	30	4.0	2.3	1.57	2.04	13	0.248%	4.061%
3	60	12.5	1.4	1.04	1.39	9	-2.573%	1.629%
4	90	30.4	1.3	1.11	1.21	5	-4.207%	2.923%
5	120	28.7	1.5	1.09	1.44	9	-2.508%	2.878%
6	150	9.4	1.6	1.12	1.56	11	-1.822%	2.384%
7	180	3.4	0.8	1.28	0.76	1	-0.649%	3.017%
8	210	3.6	1.0	0.84	1.14	9	-13.346%	4.025%
9	240	3.2	1.8	1.13	1.76	15	1.271%	6.347%
10	270	0.8	2.7	1.31	2.47	31	-2.644%	10.663%
11	300	2.7	3.1	1.90	2.77	26	6.233%	8.337%
12	330	0.7	2.5	1.11	2.38	39	0.333%	9.721%
All (fitted)			1.5	1.08	1.42	9	-2.482%	2.774%
Source data					1.55	9		

Zacatecas. September 2009. 50m



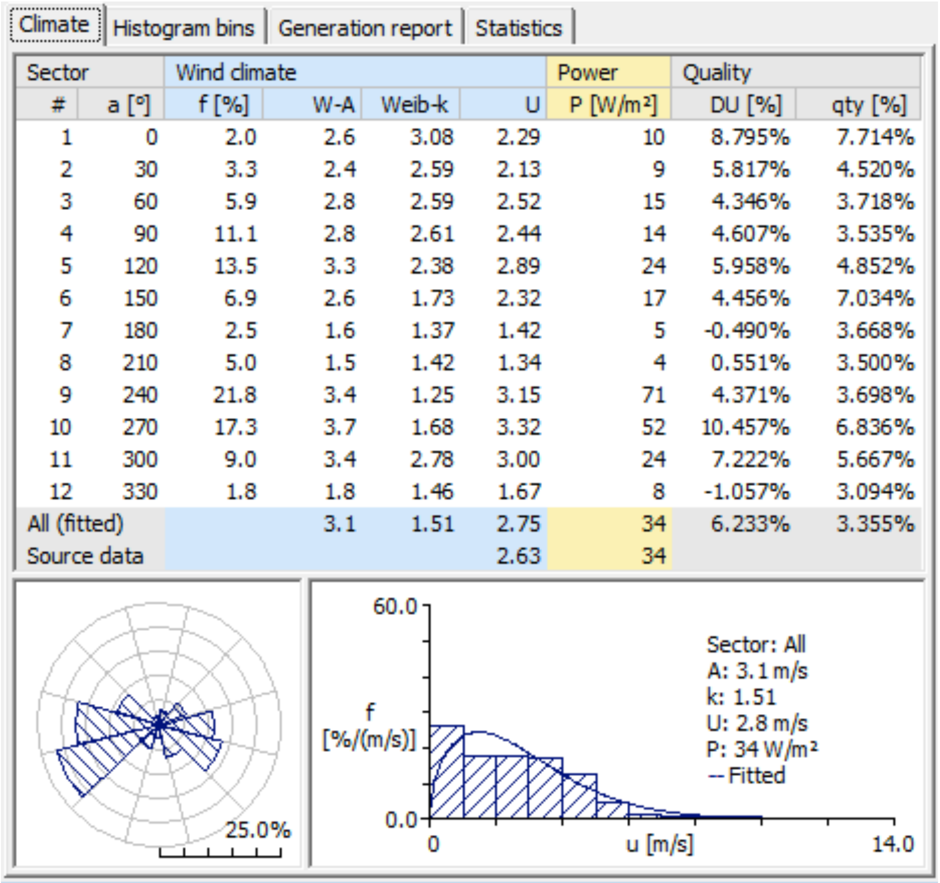
Sector		Wind climate				Power	Quality	
#	a [°]	f [%]	W-A	Weib-k	U	P [W/m²]	DU [%]	qty [%]
1	0	2.5	1.1	1.38	1.01	2	-0.600%	2.163%
2	30	9.4	1.3	0.91	1.41	13	-8.726%	4.784%
3	60	9.1	0.8	1.02	0.84	2	-5.565%	1.704%
4	90	20.7	0.9	1.29	0.87	1	-3.032%	0.761%
5	120	32.5	1.4	1.40	1.25	4	1.020%	1.675%
6	150	7.2	1.4	1.30	1.27	4	-0.624%	2.103%
7	180	2.1	0.8	1.72	0.72	1	-0.236%	0.605%
8	210	2.1	1.0	1.68	0.94	1	-0.261%	0.572%
9	240	1.5	1.2	0.87	1.29	12	-3.576%	5.563%
10	270	1.9	2.6	1.24	2.39	31	1.087%	7.049%
11	300	7.7	1.6	1.04	1.60	14	-1.681%	2.120%
12	330	3.3	1.2	0.95	1.20	7	-5.381%	2.357%
All (fitted)			1.2	1.04	1.17	5	-2.192%	0.857%
Source data					1.30	5		

Zacatecas. October 2009. 50m



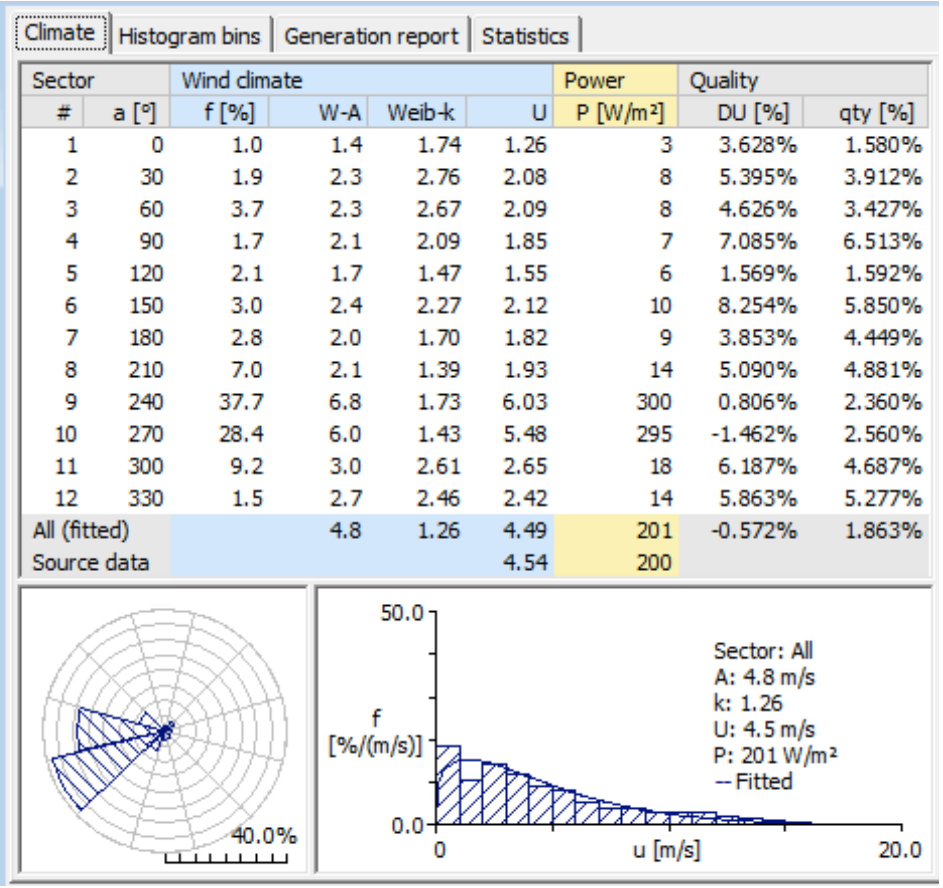
Sector		Wind climate				Power	Quality	
#	a [°]	f [%]	W-A	Weib-k	U	P [W/m²]	DU [%]	qty [%]
1	0	2.4	1.6	1.35	1.48	6	0.806%	2.947%
2	30	3.9	1.3	1.14	1.21	5	-3.736%	2.520%
3	60	4.0	1.5	1.30	1.37	5	1.492%	0.943%
4	90	6.5	1.4	1.54	1.29	3	1.432%	2.342%
5	120	12.8	2.6	1.62	2.31	18	2.339%	2.911%
6	150	8.5	1.6	1.16	1.55	10	-1.493%	2.786%
7	180	5.4	1.3	1.40	1.18	3	-0.047%	1.132%
8	210	7.6	2.2	1.37	2.02	16	4.084%	5.679%
9	240	25.7	4.2	1.48	3.83	96	4.474%	4.161%
10	270	14.1	4.2	1.61	3.78	82	8.353%	5.632%
11	300	7.3	1.5	1.04	1.46	10	-1.678%	1.644%
12	330	1.6	0.9	1.44	0.78	1	-1.321%	1.231%
All (fitted)			2.5	1.10	2.44	42	0.887%	2.272%
Source data					2.46	42		

Zacatecas. November 2009. 50m



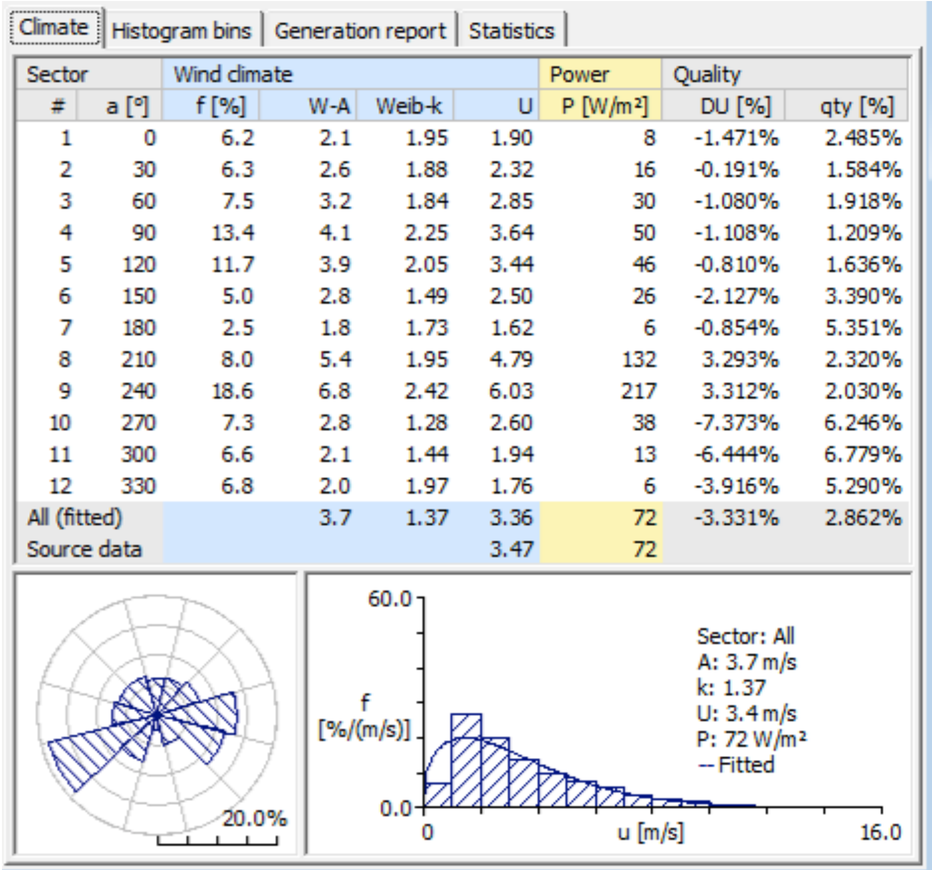
Sector		Wind climate				Power	Quality	
#	a [°]	f [%]	W-A	Weib-k	U	P [W/m²]	DU [%]	qty [%]
1	0	2.0	2.6	3.08	2.29	10	8.795%	7.714%
2	30	3.3	2.4	2.59	2.13	9	5.817%	4.520%
3	60	5.9	2.8	2.59	2.52	15	4.346%	3.718%
4	90	11.1	2.8	2.61	2.44	14	4.607%	3.535%
5	120	13.5	3.3	2.38	2.89	24	5.958%	4.852%
6	150	6.9	2.6	1.73	2.32	17	4.456%	7.034%
7	180	2.5	1.6	1.37	1.42	5	-0.490%	3.668%
8	210	5.0	1.5	1.42	1.34	4	0.551%	3.500%
9	240	21.8	3.4	1.25	3.15	71	4.371%	3.698%
10	270	17.3	3.7	1.68	3.32	52	10.457%	6.836%
11	300	9.0	3.4	2.78	3.00	24	7.222%	5.667%
12	330	1.8	1.8	1.46	1.67	8	-1.057%	3.094%
All (fitted)			3.1	1.51	2.75	34	6.233%	3.355%
Source data					2.63	34		

Zacatecas. December 2009. 50m



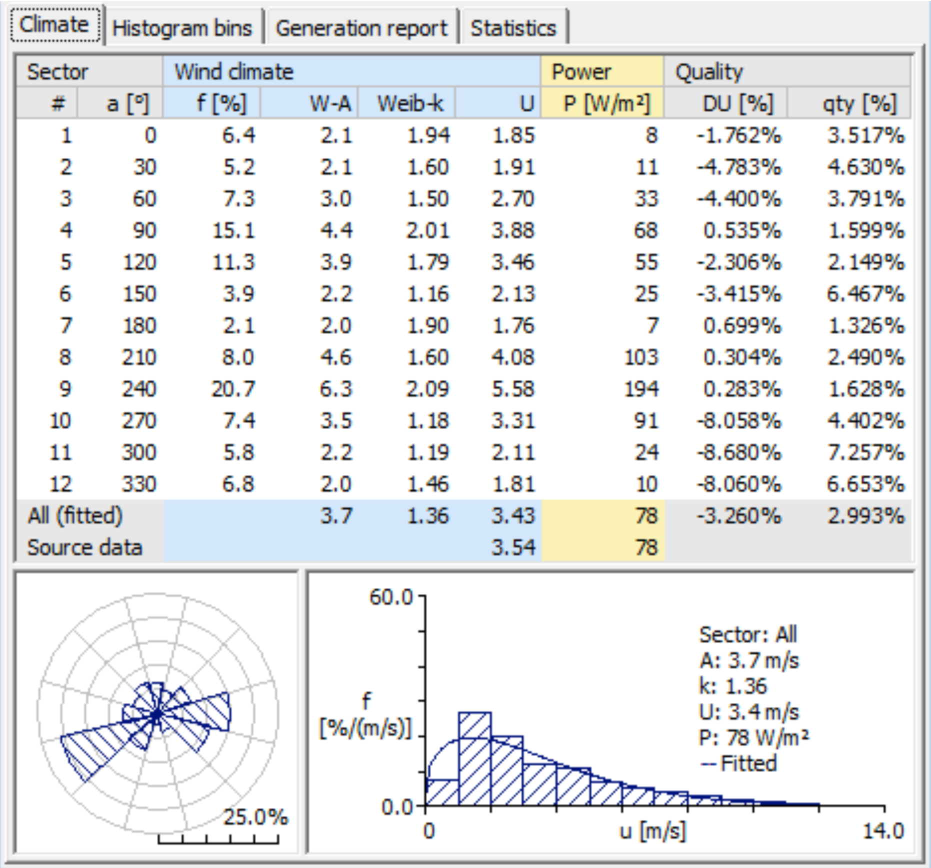
Sector		Wind climate				Power	Quality	
#	a [°]	f [%]	W-A	Weib-k	U	P [W/m²]	DU [%]	qty [%]
1	0	1.0	1.4	1.74	1.26	3	3.628%	1.580%
2	30	1.9	2.3	2.76	2.08	8	5.395%	3.912%
3	60	3.7	2.3	2.67	2.09	8	4.626%	3.427%
4	90	1.7	2.1	2.09	1.85	7	7.085%	6.513%
5	120	2.1	1.7	1.47	1.55	6	1.569%	1.592%
6	150	3.0	2.4	2.27	2.12	10	8.254%	5.850%
7	180	2.8	2.0	1.70	1.82	9	3.853%	4.449%
8	210	7.0	2.1	1.39	1.93	14	5.090%	4.881%
9	240	37.7	6.8	1.73	6.03	300	0.806%	2.360%
10	270	28.4	6.0	1.43	5.48	295	-1.462%	2.560%
11	300	9.2	3.0	2.61	2.65	18	6.187%	4.687%
12	330	1.5	2.7	2.46	2.42	14	5.863%	5.277%
All (fitted)			4.8	1.26	4.49	201	-0.572%	1.863%
Source data					4.54	200		

San Luis Potosí. January 2008. 10m



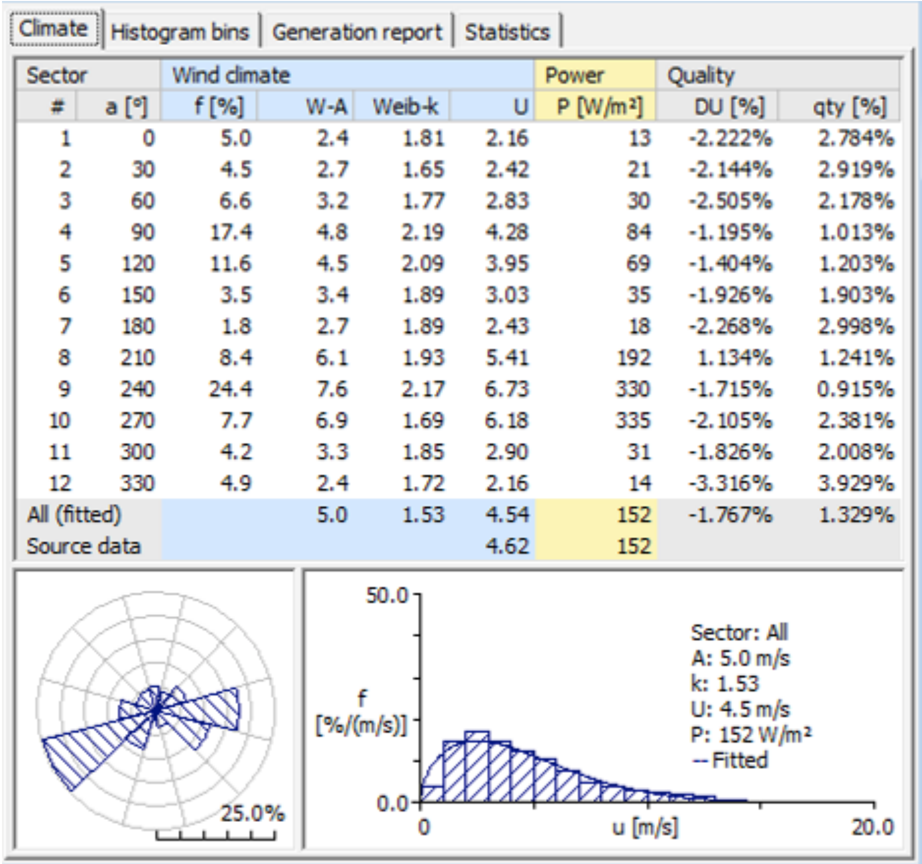
Sector		Wind climate				Power	Quality	
#	a [°]	f [%]	W-A	Weib-k	U	P [W/m²]	DU [%]	qty [%]
1	0	6.2	2.1	1.95	1.90	8	-1.471%	2.485%
2	30	6.3	2.6	1.88	2.32	16	-0.191%	1.584%
3	60	7.5	3.2	1.84	2.85	30	-1.080%	1.918%
4	90	13.4	4.1	2.25	3.64	50	-1.108%	1.209%
5	120	11.7	3.9	2.05	3.44	46	-0.810%	1.636%
6	150	5.0	2.8	1.49	2.50	26	-2.127%	3.390%
7	180	2.5	1.8	1.73	1.62	6	-0.854%	5.351%
8	210	8.0	5.4	1.95	4.79	132	3.293%	2.320%
9	240	18.6	6.8	2.42	6.03	217	3.312%	2.030%
10	270	7.3	2.8	1.28	2.60	38	-7.373%	6.246%
11	300	6.6	2.1	1.44	1.94	13	-6.444%	6.779%
12	330	6.8	2.0	1.97	1.76	6	-3.916%	5.290%
All (fitted)			3.7	1.37	3.36	72	-3.331%	2.862%
Source data					3.47	72		

San Luis Potosí. February 2008. 10m



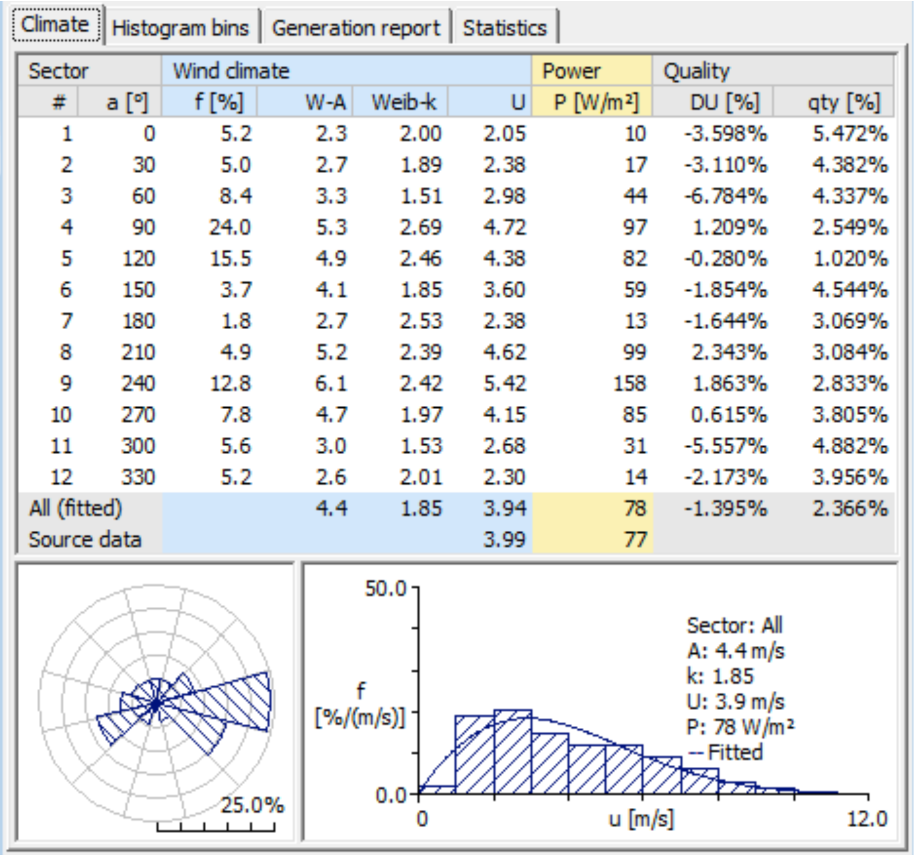
Sector		Wind climate				Power	Quality	
#	a [°]	f [%]	W-A	Weib-k	U	P [W/m²]	DU [%]	qty [%]
1	0	6.4	2.1	1.94	1.85	8	-1.762%	3.517%
2	30	5.2	2.1	1.60	1.91	11	-4.783%	4.630%
3	60	7.3	3.0	1.50	2.70	33	-4.400%	3.791%
4	90	15.1	4.4	2.01	3.88	68	0.535%	1.599%
5	120	11.3	3.9	1.79	3.46	55	-2.306%	2.149%
6	150	3.9	2.2	1.16	2.13	25	-3.415%	6.467%
7	180	2.1	2.0	1.90	1.76	7	0.699%	1.326%
8	210	8.0	4.6	1.60	4.08	103	0.304%	2.490%
9	240	20.7	6.3	2.09	5.58	194	0.283%	1.628%
10	270	7.4	3.5	1.18	3.31	91	-8.058%	4.402%
11	300	5.8	2.2	1.19	2.11	24	-8.680%	7.257%
12	330	6.8	2.0	1.46	1.81	10	-8.060%	6.653%
All (fitted)			3.7	1.36	3.43	78	-3.260%	2.993%
Source data					3.54	78		

San Luis Potosí. March 2008. 10m



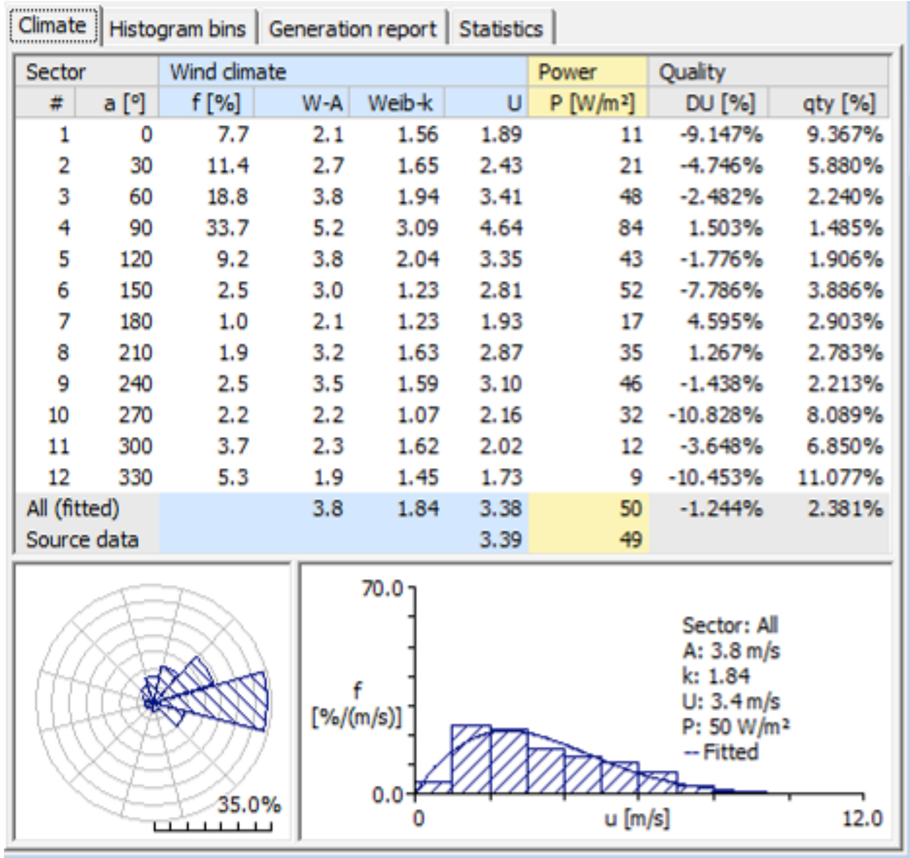
Sector		Wind climate				Power	Quality	
#	a [°]	f [%]	W-A	Weib-k	U	P [W/m²]	DU [%]	qty [%]
1	0	5.0	2.4	1.81	2.16	13	-2.222%	2.784%
2	30	4.5	2.7	1.65	2.42	21	-2.144%	2.919%
3	60	6.6	3.2	1.77	2.83	30	-2.505%	2.178%
4	90	17.4	4.8	2.19	4.28	84	-1.195%	1.013%
5	120	11.6	4.5	2.09	3.95	69	-1.404%	1.203%
6	150	3.5	3.4	1.89	3.03	35	-1.926%	1.903%
7	180	1.8	2.7	1.89	2.43	18	-2.268%	2.998%
8	210	8.4	6.1	1.93	5.41	192	1.134%	1.241%
9	240	24.4	7.6	2.17	6.73	330	-1.715%	0.915%
10	270	7.7	6.9	1.69	6.18	335	-2.105%	2.381%
11	300	4.2	3.3	1.85	2.90	31	-1.826%	2.008%
12	330	4.9	2.4	1.72	2.16	14	-3.316%	3.929%
All (fitted)			5.0	1.53	4.54	152	-1.767%	1.329%
Source data					4.62	152		

San Luis Potosí. April 2008. 10m



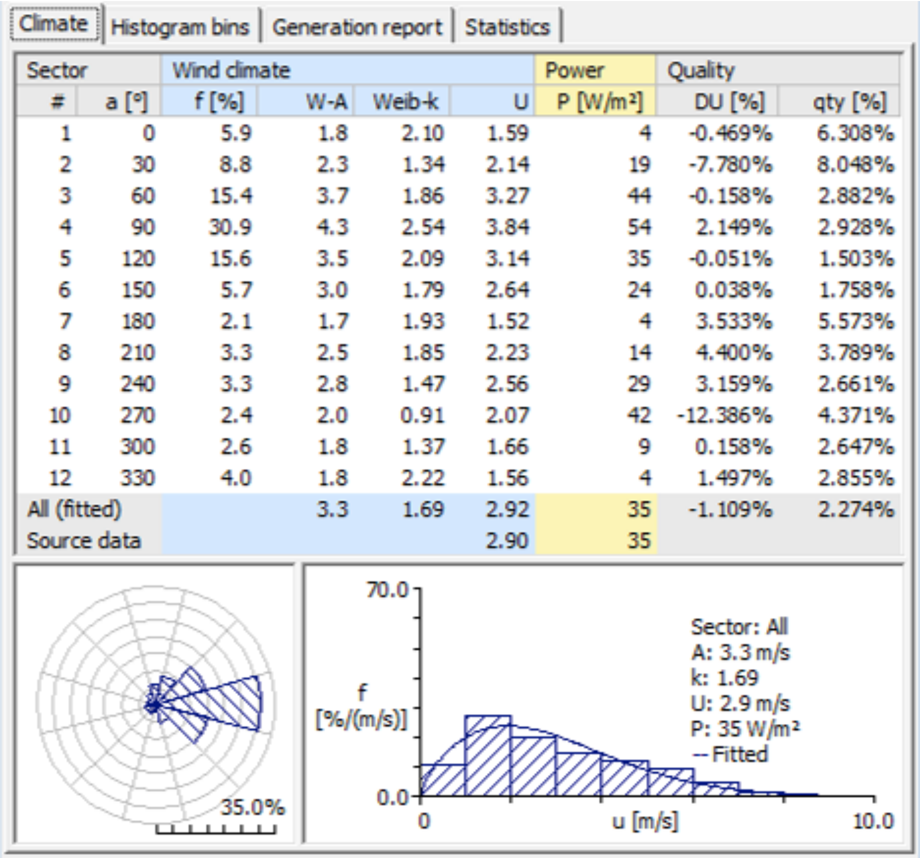
Sector		Wind climate				Power	Quality	
#	a [°]	f [%]	W-A	Weib-k	U	P [W/m²]	DU [%]	qty [%]
1	0	5.2	2.3	2.00	2.05	10	-3.598%	5.472%
2	30	5.0	2.7	1.89	2.38	17	-3.110%	4.382%
3	60	8.4	3.3	1.51	2.98	44	-6.784%	4.337%
4	90	24.0	5.3	2.69	4.72	97	1.209%	2.549%
5	120	15.5	4.9	2.46	4.38	82	-0.280%	1.020%
6	150	3.7	4.1	1.85	3.60	59	-1.854%	4.544%
7	180	1.8	2.7	2.53	2.38	13	-1.644%	3.069%
8	210	4.9	5.2	2.39	4.62	99	2.343%	3.084%
9	240	12.8	6.1	2.42	5.42	158	1.863%	2.833%
10	270	7.8	4.7	1.97	4.15	85	0.615%	3.805%
11	300	5.6	3.0	1.53	2.68	31	-5.557%	4.882%
12	330	5.2	2.6	2.01	2.30	14	-2.173%	3.956%
All (fitted)			4.4	1.85	3.94	78	-1.395%	2.366%
Source data					3.99	77		

San Luis Potosí. July 2008. 10m



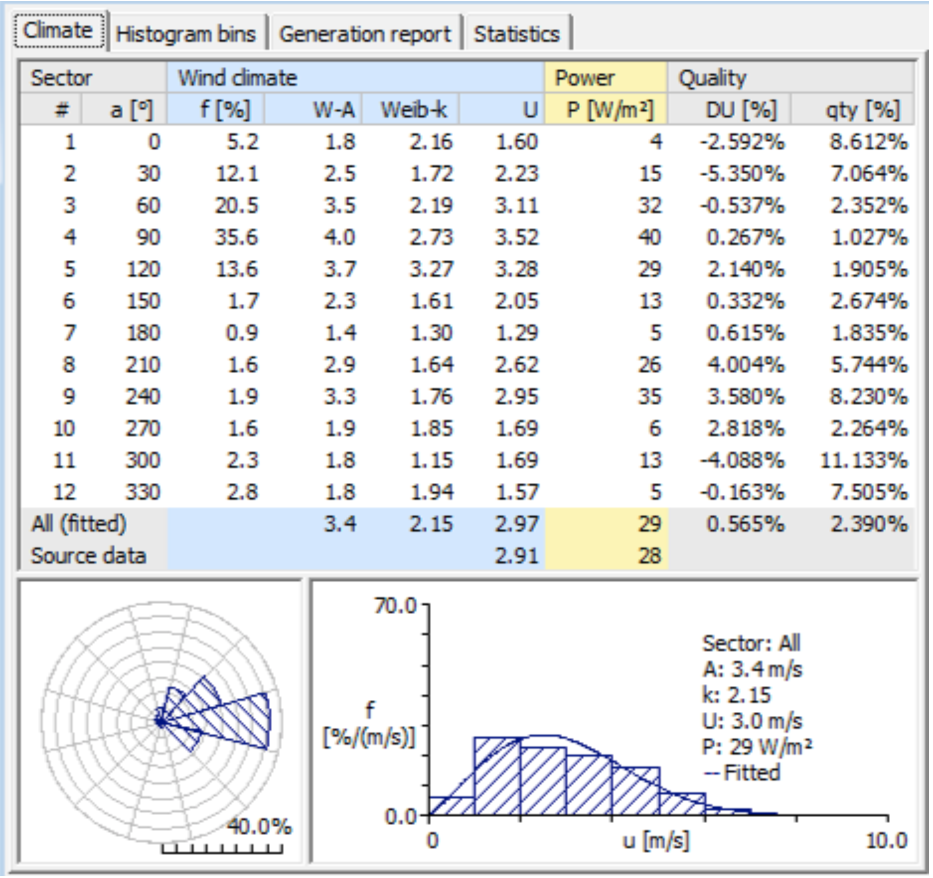
Sector		Wind climate				Power	Quality	
#	a [°]	f [%]	W-A	Weib-k	U	P [W/m²]	DU [%]	qty [%]
1	0	7.7	2.1	1.56	1.89	11	-9.147%	9.367%
2	30	11.4	2.7	1.65	2.43	21	-4.746%	5.880%
3	60	18.8	3.8	1.94	3.41	48	-2.482%	2.240%
4	90	33.7	5.2	3.09	4.64	84	1.503%	1.485%
5	120	9.2	3.8	2.04	3.35	43	-1.776%	1.906%
6	150	2.5	3.0	1.23	2.81	52	-7.786%	3.886%
7	180	1.0	2.1	1.23	1.93	17	4.595%	2.903%
8	210	1.9	3.2	1.63	2.87	35	1.267%	2.783%
9	240	2.5	3.5	1.59	3.10	46	-1.438%	2.213%
10	270	2.2	2.2	1.07	2.16	32	-10.828%	8.089%
11	300	3.7	2.3	1.62	2.02	12	-3.648%	6.850%
12	330	5.3	1.9	1.45	1.73	9	-10.453%	11.077%
All (fitted)			3.8	1.84	3.38	50	-1.244%	2.381%
Source data					3.39	49		

San Luis Potosí. August 2008. 10m



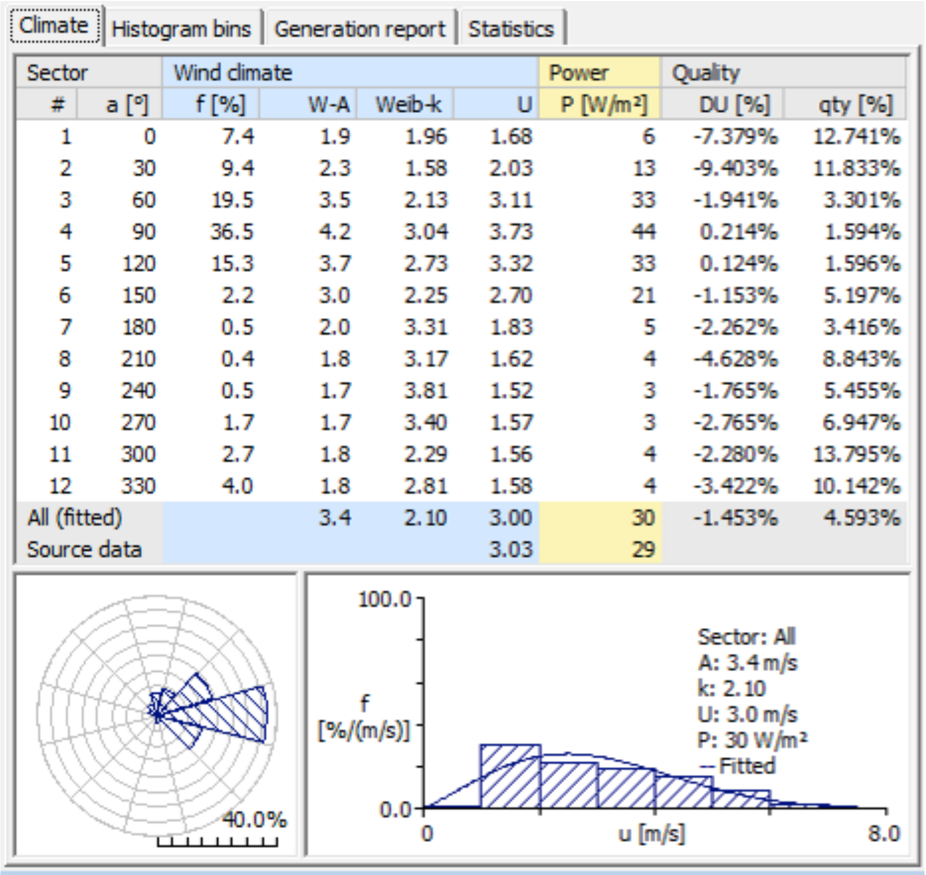
Sector		Wind climate				Power	Quality	
#	a [°]	f [%]	W-A	Weib-k	U	P [W/m²]	DU [%]	qty [%]
1	0	5.9	1.8	2.10	1.59	4	-0.469%	6.308%
2	30	8.8	2.3	1.34	2.14	19	-7.780%	8.048%
3	60	15.4	3.7	1.86	3.27	44	-0.158%	2.882%
4	90	30.9	4.3	2.54	3.84	54	2.149%	2.928%
5	120	15.6	3.5	2.09	3.14	35	-0.051%	1.503%
6	150	5.7	3.0	1.79	2.64	24	0.038%	1.758%
7	180	2.1	1.7	1.93	1.52	4	3.533%	5.573%
8	210	3.3	2.5	1.85	2.23	14	4.400%	3.789%
9	240	3.3	2.8	1.47	2.56	29	3.159%	2.661%
10	270	2.4	2.0	0.91	2.07	42	-12.386%	4.371%
11	300	2.6	1.8	1.37	1.66	9	0.158%	2.647%
12	330	4.0	1.8	2.22	1.56	4	1.497%	2.855%
All (fitted)			3.3	1.69	2.92	35	-1.109%	2.274%
Source data					2.90	35		

San Luis Potosí. September 2008. 10m



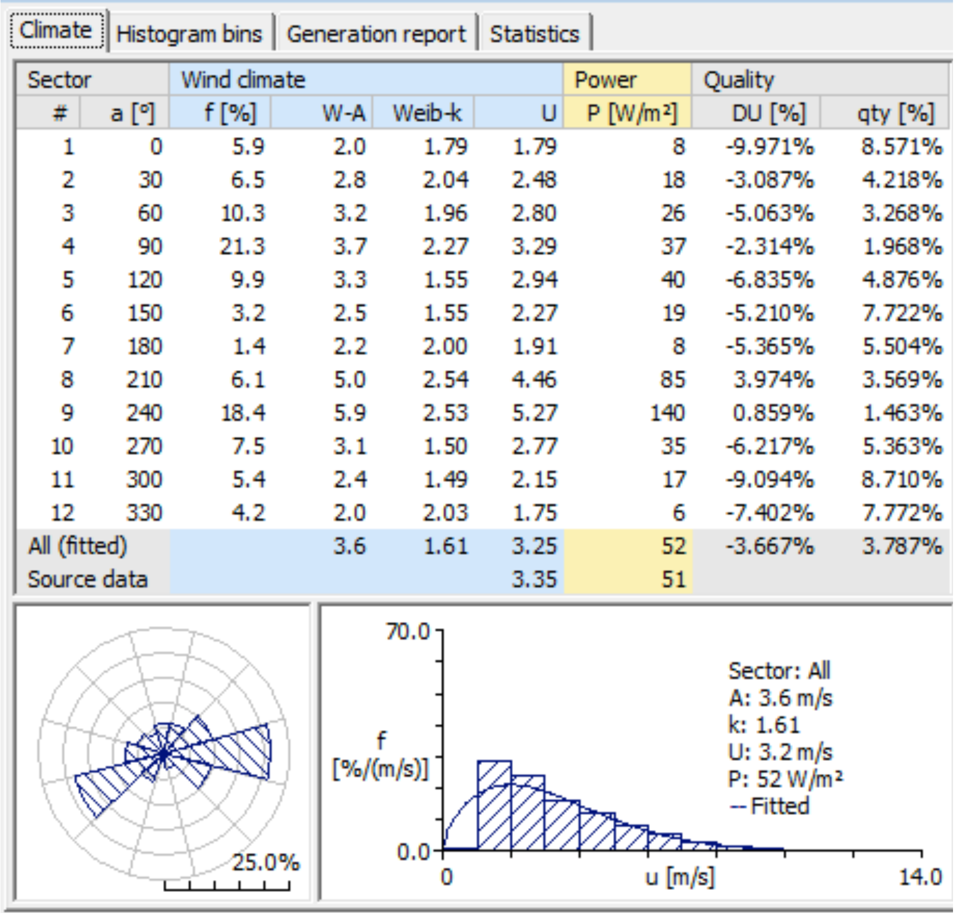
Sector		Wind climate				Power	Quality	
#	a [°]	f [%]	W-A	Weib-k	U	P [W/m²]	DU [%]	qty [%]
1	0	5.2	1.8	2.16	1.60	4	-2.592%	8.612%
2	30	12.1	2.5	1.72	2.23	15	-5.350%	7.064%
3	60	20.5	3.5	2.19	3.11	32	-0.537%	2.352%
4	90	35.6	4.0	2.73	3.52	40	0.267%	1.027%
5	120	13.6	3.7	3.27	3.28	29	2.140%	1.905%
6	150	1.7	2.3	1.61	2.05	13	0.332%	2.674%
7	180	0.9	1.4	1.30	1.29	5	0.615%	1.835%
8	210	1.6	2.9	1.64	2.62	26	4.004%	5.744%
9	240	1.9	3.3	1.76	2.95	35	3.580%	8.230%
10	270	1.6	1.9	1.85	1.69	6	2.818%	2.264%
11	300	2.3	1.8	1.15	1.69	13	-4.088%	11.133%
12	330	2.8	1.8	1.94	1.57	5	-0.163%	7.505%
All (fitted)			3.4	2.15	2.97	29	0.565%	2.390%
Source data					2.91	28		

San Luis Potosí. October 2008. 10m



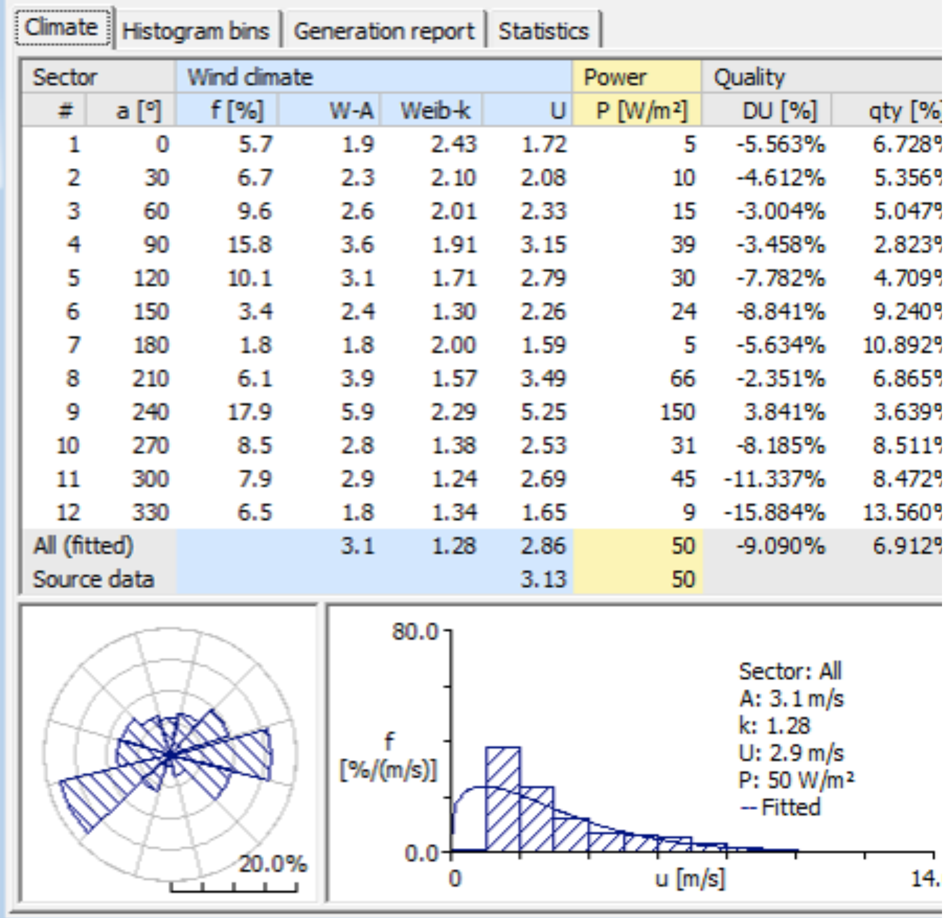
Sector		Wind climate				Power	Quality	
#	a [°]	f [%]	W-A	Weib-k	U	P [W/m²]	DU [%]	qty [%]
1	0	7.4	1.9	1.96	1.68	6	-7.379%	12.741%
2	30	9.4	2.3	1.58	2.03	13	-9.403%	11.833%
3	60	19.5	3.5	2.13	3.11	33	-1.941%	3.301%
4	90	36.5	4.2	3.04	3.73	44	0.214%	1.594%
5	120	15.3	3.7	2.73	3.32	33	0.124%	1.596%
6	150	2.2	3.0	2.25	2.70	21	-1.153%	5.197%
7	180	0.5	2.0	3.31	1.83	5	-2.262%	3.416%
8	210	0.4	1.8	3.17	1.62	4	-4.628%	8.843%
9	240	0.5	1.7	3.81	1.52	3	-1.765%	5.455%
10	270	1.7	1.7	3.40	1.57	3	-2.765%	6.947%
11	300	2.7	1.8	2.29	1.56	4	-2.280%	13.795%
12	330	4.0	1.8	2.81	1.58	4	-3.422%	10.142%
All (fitted)			3.4	2.10	3.00	30	-1.453%	4.593%
Source data					3.03	29		

San Luis Potosí. November 2008. 10m



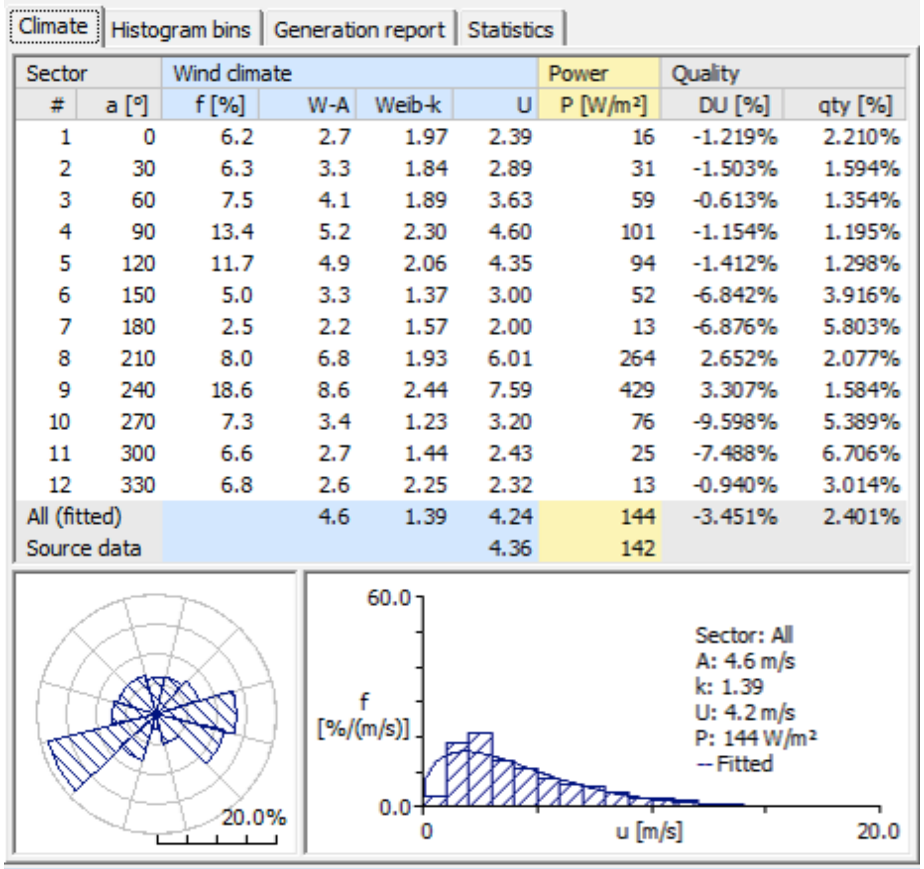
Sector		Wind climate				Power	Quality	
#	a [°]	f [%]	W-A	Weib-k	U	P [W/m²]	DU [%]	qty [%]
1	0	5.9	2.0	1.79	1.79	8	-9.971%	8.571%
2	30	6.5	2.8	2.04	2.48	18	-3.087%	4.218%
3	60	10.3	3.2	1.96	2.80	26	-5.063%	3.268%
4	90	21.3	3.7	2.27	3.29	37	-2.314%	1.968%
5	120	9.9	3.3	1.55	2.94	40	-6.835%	4.876%
6	150	3.2	2.5	1.55	2.27	19	-5.210%	7.722%
7	180	1.4	2.2	2.00	1.91	8	-5.365%	5.504%
8	210	6.1	5.0	2.54	4.46	85	3.974%	3.569%
9	240	18.4	5.9	2.53	5.27	140	0.859%	1.463%
10	270	7.5	3.1	1.50	2.77	35	-6.217%	5.363%
11	300	5.4	2.4	1.49	2.15	17	-9.094%	8.710%
12	330	4.2	2.0	2.03	1.75	6	-7.402%	7.772%
All (fitted)			3.6	1.61	3.25	52	-3.667%	3.787%
Source data					3.35	51		

San Luis Potosí. December 2008. 10m



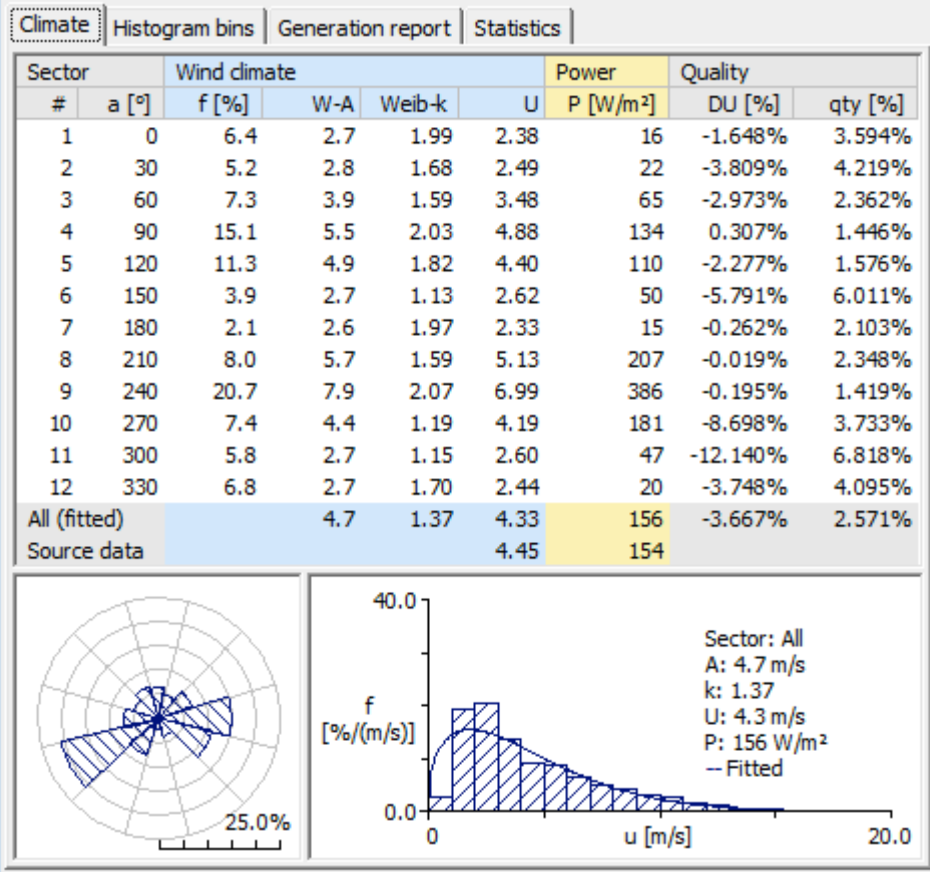
Sector		Wind climate				Power	Quality	
#	a [°]	f [%]	W-A	Weib-k	U	P [W/m²]	DU [%]	qty [%
1	0	5.7	1.9	2.43	1.72	5	-5.563%	6.728
2	30	6.7	2.3	2.10	2.08	10	-4.612%	5.356
3	60	9.6	2.6	2.01	2.33	15	-3.004%	5.047
4	90	15.8	3.6	1.91	3.15	39	-3.458%	2.823
5	120	10.1	3.1	1.71	2.79	30	-7.782%	4.709
6	150	3.4	2.4	1.30	2.26	24	-8.841%	9.240
7	180	1.8	1.8	2.00	1.59	5	-5.634%	10.892
8	210	6.1	3.9	1.57	3.49	66	-2.351%	6.865
9	240	17.9	5.9	2.29	5.25	150	3.841%	3.639
10	270	8.5	2.8	1.38	2.53	31	-8.185%	8.511
11	300	7.9	2.9	1.24	2.69	45	-11.337%	8.472
12	330	6.5	1.8	1.34	1.65	9	-15.884%	13.560
All (fitted)			3.1	1.28	2.86	50	-9.090%	6.912
Source data					3.13	50		

San Luis Potosí. January 2008. 20m



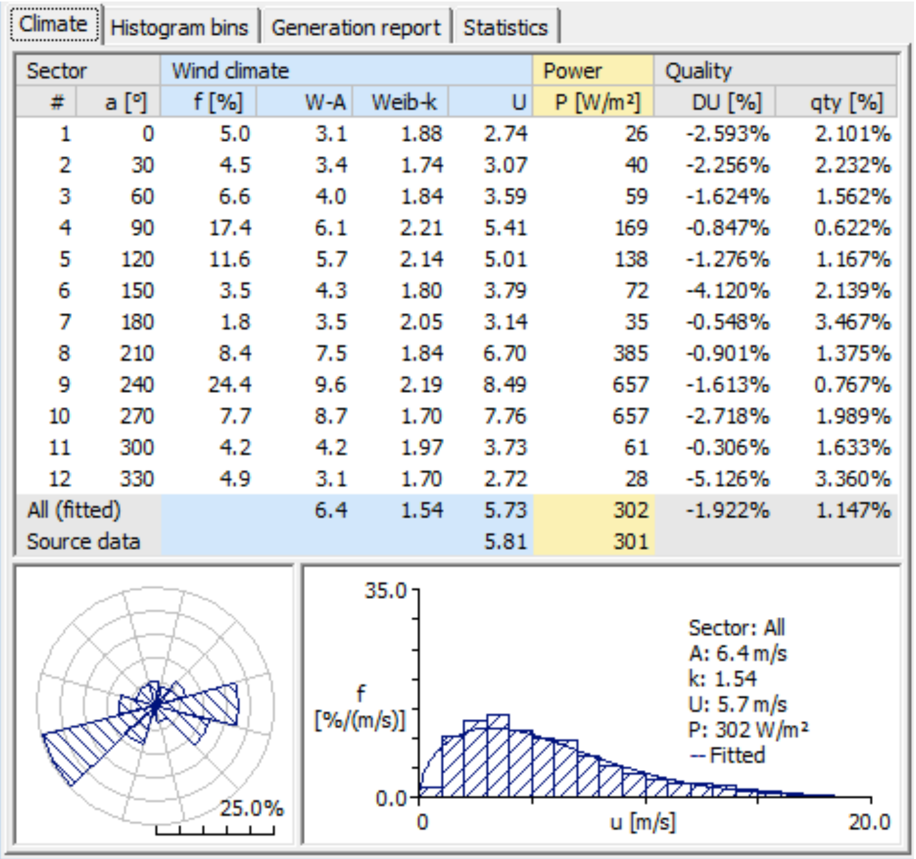
Sector		Wind climate				Power	Quality	
#	a [°]	f [%]	W-A	Weib-k	U	P [W/m²]	DU [%]	qty [%]
1	0	6.2	2.7	1.97	2.39	16	-1.219%	2.210%
2	30	6.3	3.3	1.84	2.89	31	-1.503%	1.594%
3	60	7.5	4.1	1.89	3.63	59	-0.613%	1.354%
4	90	13.4	5.2	2.30	4.60	101	-1.154%	1.195%
5	120	11.7	4.9	2.06	4.35	94	-1.412%	1.298%
6	150	5.0	3.3	1.37	3.00	52	-6.842%	3.916%
7	180	2.5	2.2	1.57	2.00	13	-6.876%	5.803%
8	210	8.0	6.8	1.93	6.01	264	2.652%	2.077%
9	240	18.6	8.6	2.44	7.59	429	3.307%	1.584%
10	270	7.3	3.4	1.23	3.20	76	-9.598%	5.389%
11	300	6.6	2.7	1.44	2.43	25	-7.488%	6.706%
12	330	6.8	2.6	2.25	2.32	13	-0.940%	3.014%
All (fitted)			4.6	1.39	4.24	144	-3.451%	2.401%
Source data					4.36	142		

San Luis Potosí. February 2008. 20m



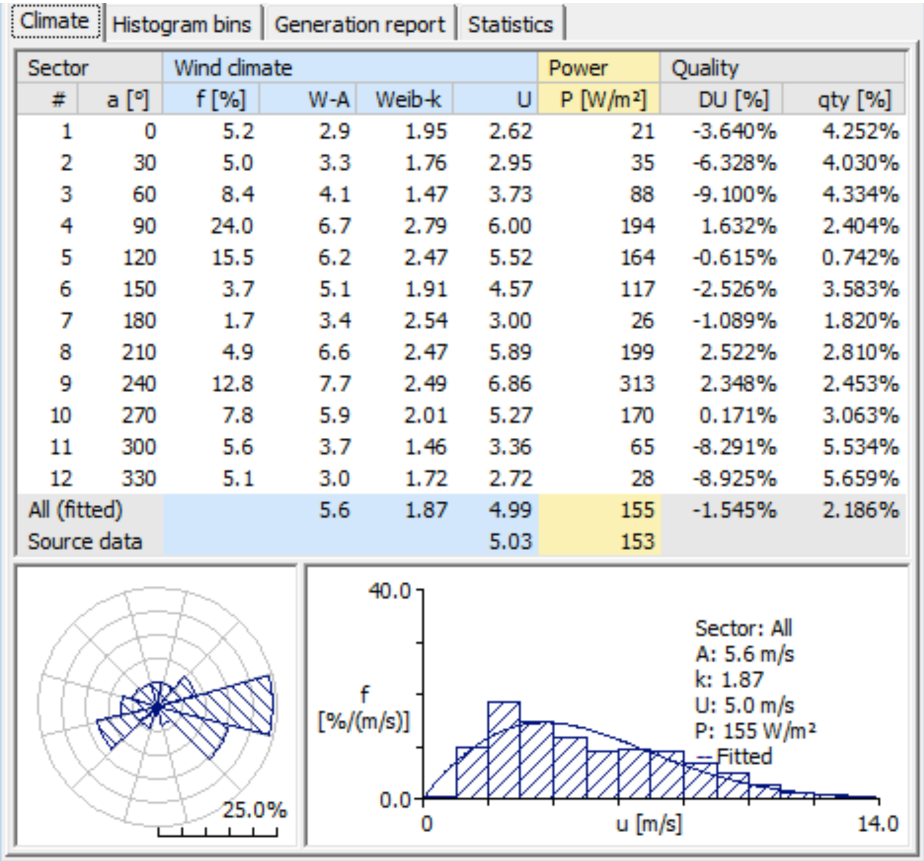
Sector		Wind climate				Power	Quality	
#	a [°]	f [%]	W-A	Weib-k	U	P [W/m²]	DU [%]	qty [%]
1	0	6.4	2.7	1.99	2.38	16	-1.648%	3.594%
2	30	5.2	2.8	1.68	2.49	22	-3.809%	4.219%
3	60	7.3	3.9	1.59	3.48	65	-2.973%	2.362%
4	90	15.1	5.5	2.03	4.88	134	0.307%	1.446%
5	120	11.3	4.9	1.82	4.40	110	-2.277%	1.576%
6	150	3.9	2.7	1.13	2.62	50	-5.791%	6.011%
7	180	2.1	2.6	1.97	2.33	15	-0.262%	2.103%
8	210	8.0	5.7	1.59	5.13	207	-0.019%	2.348%
9	240	20.7	7.9	2.07	6.99	386	-0.195%	1.419%
10	270	7.4	4.4	1.19	4.19	181	-8.698%	3.733%
11	300	5.8	2.7	1.15	2.60	47	-12.140%	6.818%
12	330	6.8	2.7	1.70	2.44	20	-3.748%	4.095%
All (fitted)			4.7	1.37	4.33	156	-3.667%	2.571%
Source data					4.45	154		

San Luis Potosí. March 2008. 20m



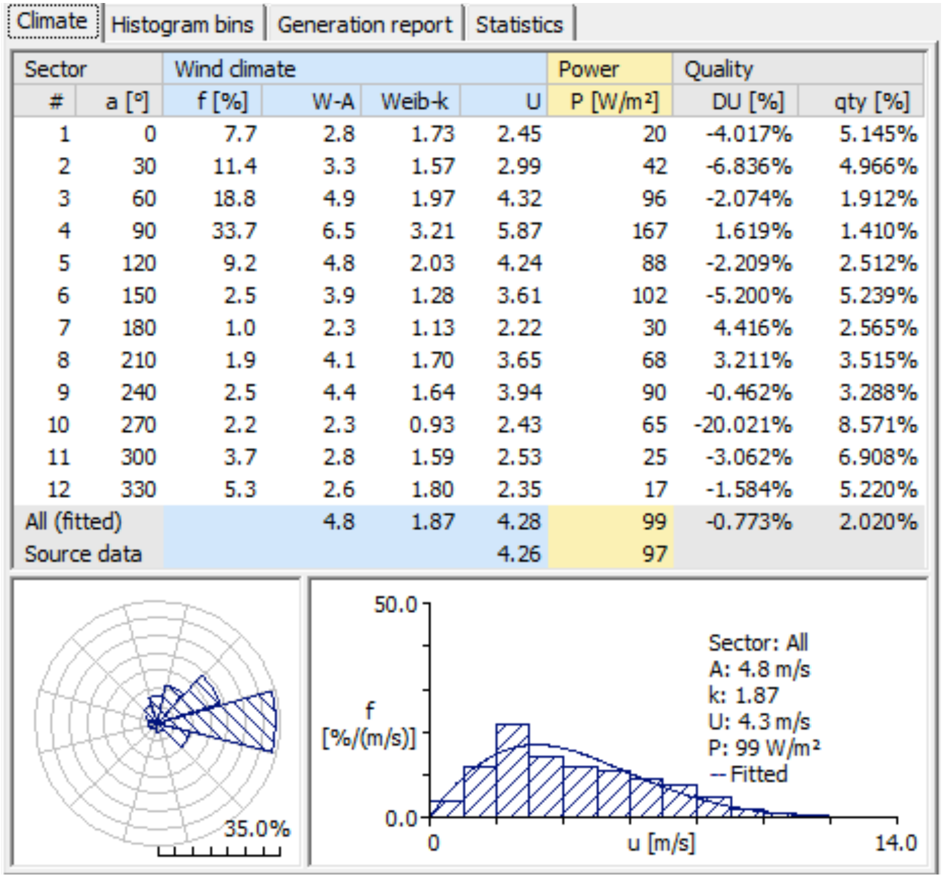
Sector		Wind climate				Power	Quality	
#	a [°]	f [%]	W-A	Weib-k	U	P [W/m²]	DU [%]	qty [%]
1	0	5.0	3.1	1.88	2.74	26	-2.593%	2.101%
2	30	4.5	3.4	1.74	3.07	40	-2.256%	2.232%
3	60	6.6	4.0	1.84	3.59	59	-1.624%	1.562%
4	90	17.4	6.1	2.21	5.41	169	-0.847%	0.622%
5	120	11.6	5.7	2.14	5.01	138	-1.276%	1.167%
6	150	3.5	4.3	1.80	3.79	72	-4.120%	2.139%
7	180	1.8	3.5	2.05	3.14	35	-0.548%	3.467%
8	210	8.4	7.5	1.84	6.70	385	-0.901%	1.375%
9	240	24.4	9.6	2.19	8.49	657	-1.613%	0.767%
10	270	7.7	8.7	1.70	7.76	657	-2.718%	1.989%
11	300	4.2	4.2	1.97	3.73	61	-0.306%	1.633%
12	330	4.9	3.1	1.70	2.72	28	-5.126%	3.360%
All (fitted)			6.4	1.54	5.73	302	-1.922%	1.147%
Source data					5.81	301		

San Luis Potosí. April 2008. 20m



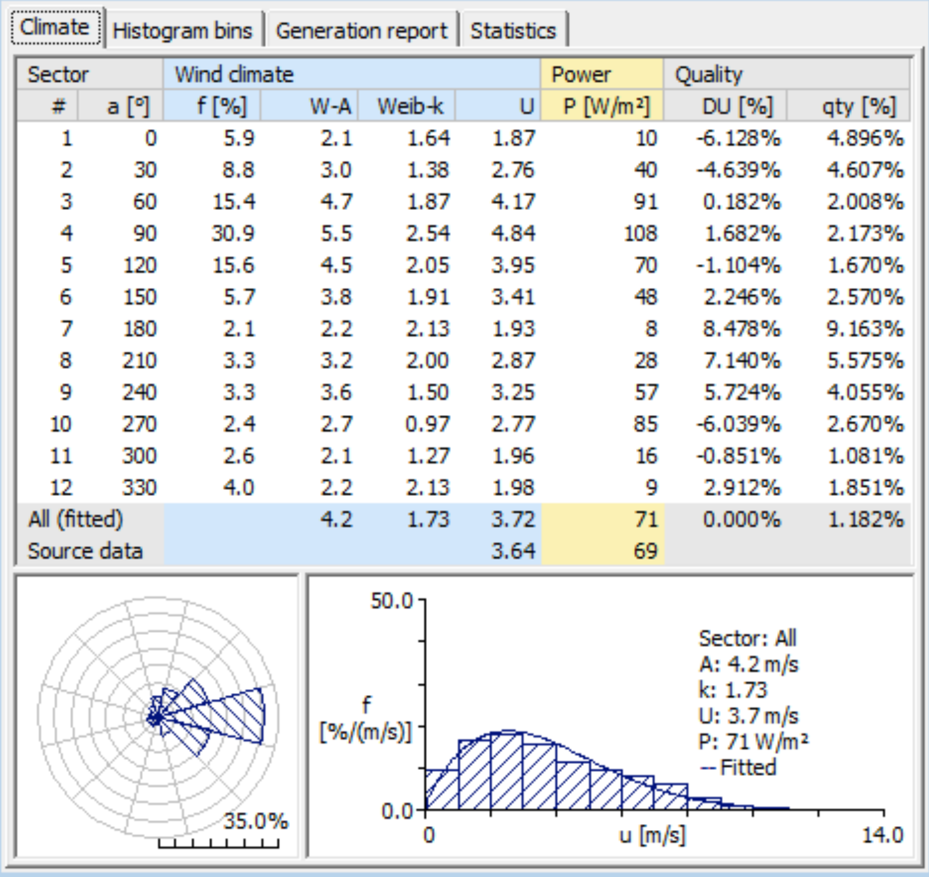
Sector		Wind climate				Power	Quality	
#	a [°]	f [%]	W-A	Weib-k	U	P [W/m²]	DU [%]	qty [%]
1	0	5.2	2.9	1.95	2.62	21	-3.640%	4.252%
2	30	5.0	3.3	1.76	2.95	35	-6.328%	4.030%
3	60	8.4	4.1	1.47	3.73	88	-9.100%	4.334%
4	90	24.0	6.7	2.79	6.00	194	1.632%	2.404%
5	120	15.5	6.2	2.47	5.52	164	-0.615%	0.742%
6	150	3.7	5.1	1.91	4.57	117	-2.526%	3.583%
7	180	1.7	3.4	2.54	3.00	26	-1.089%	1.820%
8	210	4.9	6.6	2.47	5.89	199	2.522%	2.810%
9	240	12.8	7.7	2.49	6.86	313	2.348%	2.453%
10	270	7.8	5.9	2.01	5.27	170	0.171%	3.063%
11	300	5.6	3.7	1.46	3.36	65	-8.291%	5.534%
12	330	5.1	3.0	1.72	2.72	28	-8.925%	5.659%
All (fitted)			5.6	1.87	4.99	155	-1.545%	2.186%
Source data					5.03	153		

San Luis Potosí. July 2008. 20m



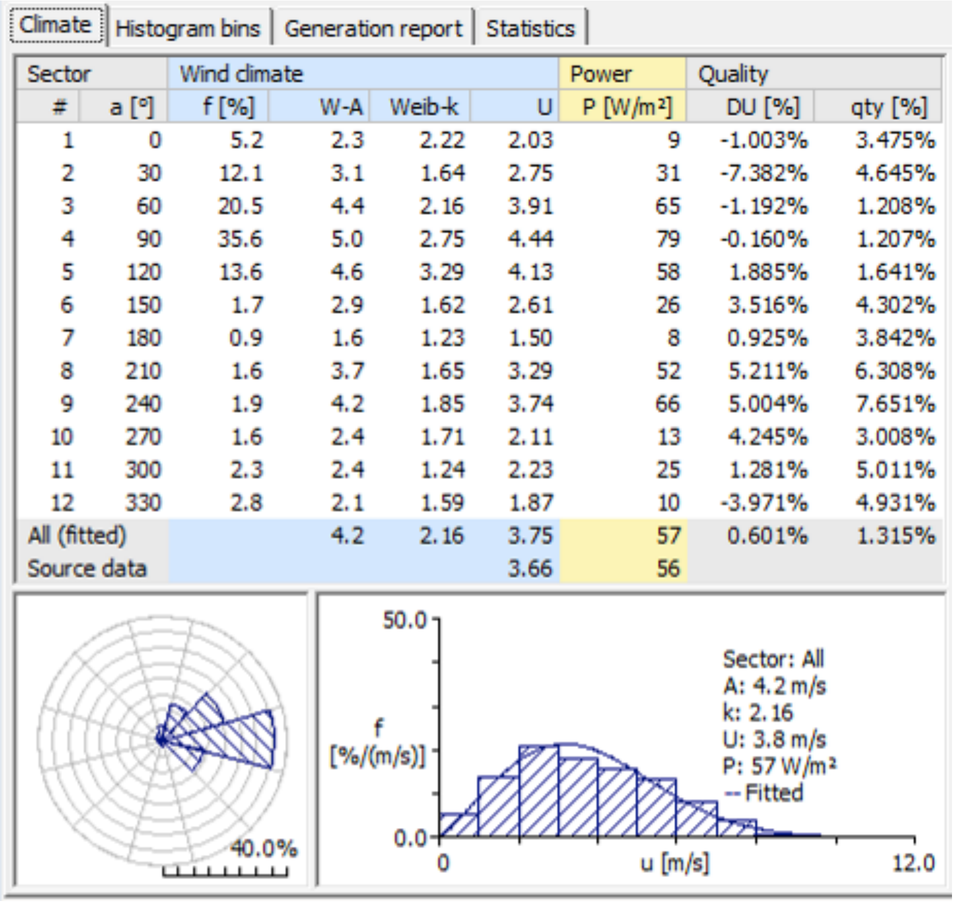
Sector		Wind climate				Power	Quality	
#	a [°]	f [%]	W-A	Weib-k	U	P [W/m²]	DU [%]	qty [%]
1	0	7.7	2.8	1.73	2.45	20	-4.017%	5.145%
2	30	11.4	3.3	1.57	2.99	42	-6.836%	4.966%
3	60	18.8	4.9	1.97	4.32	96	-2.074%	1.912%
4	90	33.7	6.5	3.21	5.87	167	1.619%	1.410%
5	120	9.2	4.8	2.03	4.24	88	-2.209%	2.512%
6	150	2.5	3.9	1.28	3.61	102	-5.200%	5.239%
7	180	1.0	2.3	1.13	2.22	30	4.416%	2.565%
8	210	1.9	4.1	1.70	3.65	68	3.211%	3.515%
9	240	2.5	4.4	1.64	3.94	90	-0.462%	3.288%
10	270	2.2	2.3	0.93	2.43	65	-20.021%	8.571%
11	300	3.7	2.8	1.59	2.53	25	-3.062%	6.908%
12	330	5.3	2.6	1.80	2.35	17	-1.584%	5.220%
All (fitted)			4.8	1.87	4.28	99	-0.773%	2.020%
Source data					4.26	97		

San Luis Potosí. August 2008. 20m



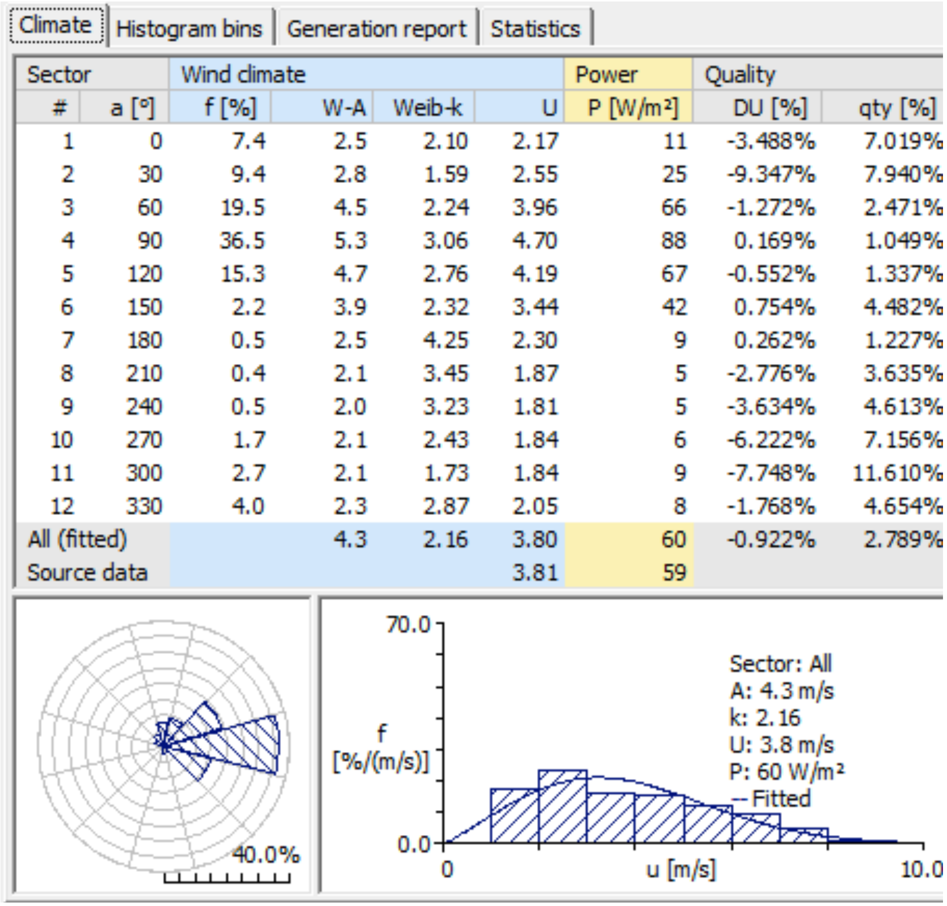
Sector		Wind climate				Power	Quality	
#	a [°]	f [%]	W-A	Weib-k	U	P [W/m²]	DU [%]	qty [%]
1	0	5.9	2.1	1.64	1.87	10	-6.128%	4.896%
2	30	8.8	3.0	1.38	2.76	40	-4.639%	4.607%
3	60	15.4	4.7	1.87	4.17	91	0.182%	2.008%
4	90	30.9	5.5	2.54	4.84	108	1.682%	2.173%
5	120	15.6	4.5	2.05	3.95	70	-1.104%	1.670%
6	150	5.7	3.8	1.91	3.41	48	2.246%	2.570%
7	180	2.1	2.2	2.13	1.93	8	8.478%	9.163%
8	210	3.3	3.2	2.00	2.87	28	7.140%	5.575%
9	240	3.3	3.6	1.50	3.25	57	5.724%	4.055%
10	270	2.4	2.7	0.97	2.77	85	-6.039%	2.670%
11	300	2.6	2.1	1.27	1.96	16	-0.851%	1.081%
12	330	4.0	2.2	2.13	1.98	9	2.912%	1.851%
All (fitted)			4.2	1.73	3.72	71	0.000%	1.182%
Source data					3.64	69		

San Luis Potosí. September 2008. 20m



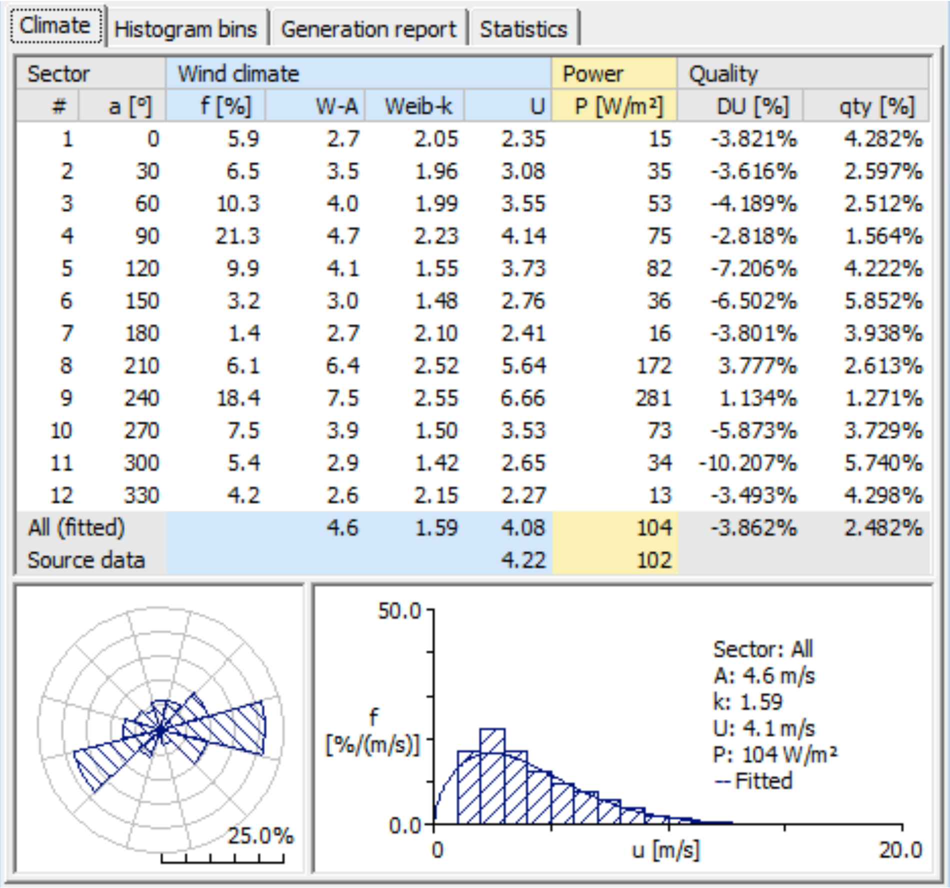
Sector		Wind climate				Power	Quality	
#	a [°]	f [%]	W-A	Weib-k	U	P [W/m²]	DU [%]	qty [%]
1	0	5.2	2.3	2.22	2.03	9	-1.003%	3.475%
2	30	12.1	3.1	1.64	2.75	31	-7.382%	4.645%
3	60	20.5	4.4	2.16	3.91	65	-1.192%	1.208%
4	90	35.6	5.0	2.75	4.44	79	-0.160%	1.207%
5	120	13.6	4.6	3.29	4.13	58	1.885%	1.641%
6	150	1.7	2.9	1.62	2.61	26	3.516%	4.302%
7	180	0.9	1.6	1.23	1.50	8	0.925%	3.842%
8	210	1.6	3.7	1.65	3.29	52	5.211%	6.308%
9	240	1.9	4.2	1.85	3.74	66	5.004%	7.651%
10	270	1.6	2.4	1.71	2.11	13	4.245%	3.008%
11	300	2.3	2.4	1.24	2.23	25	1.281%	5.011%
12	330	2.8	2.1	1.59	1.87	10	-3.971%	4.931%
All (fitted)			4.2	2.16	3.75	57	0.601%	1.315%
Source data					3.66	56		

San Luis Potosí. October 2008. 20m



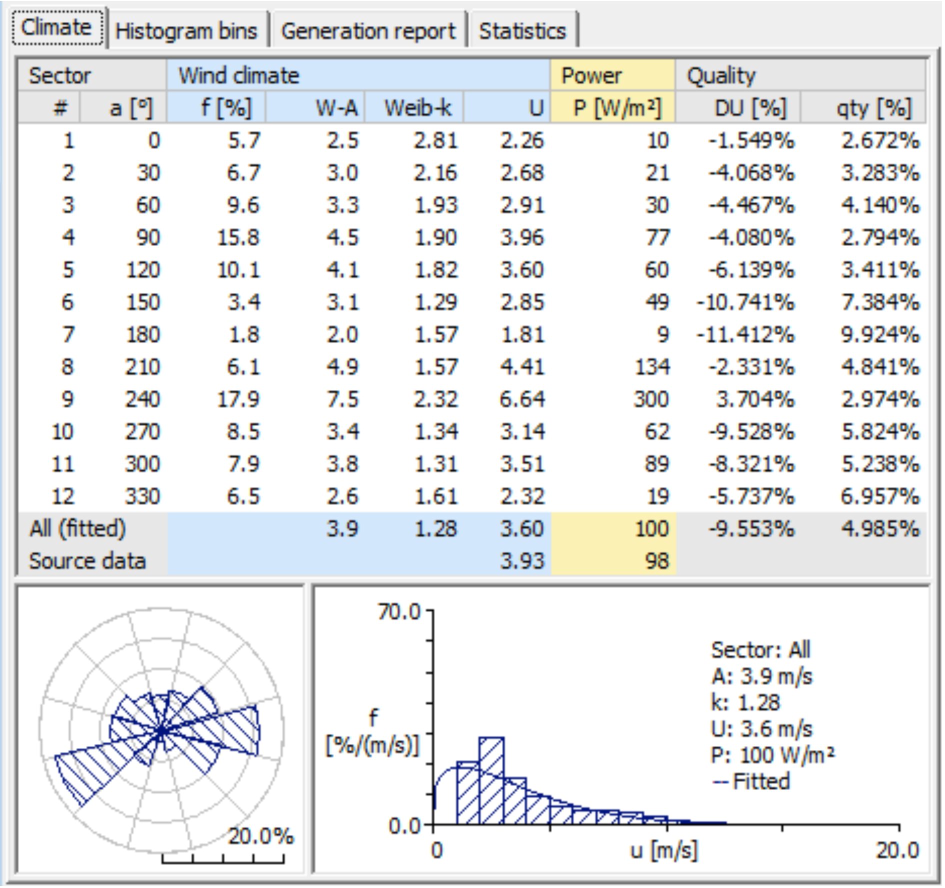
Sector		Wind climate				Power	Quality	
#	a [°]	f [%]	W-A	Weib-k	U	P [W/m²]	DU [%]	qty [%]
1	0	7.4	2.5	2.10	2.17	11	-3.488%	7.019%
2	30	9.4	2.8	1.59	2.55	25	-9.347%	7.940%
3	60	19.5	4.5	2.24	3.96	66	-1.272%	2.471%
4	90	36.5	5.3	3.06	4.70	88	0.169%	1.049%
5	120	15.3	4.7	2.76	4.19	67	-0.552%	1.337%
6	150	2.2	3.9	2.32	3.44	42	0.754%	4.482%
7	180	0.5	2.5	4.25	2.30	9	0.262%	1.227%
8	210	0.4	2.1	3.45	1.87	5	-2.776%	3.635%
9	240	0.5	2.0	3.23	1.81	5	-3.634%	4.613%
10	270	1.7	2.1	2.43	1.84	6	-6.222%	7.156%
11	300	2.7	2.1	1.73	1.84	9	-7.748%	11.610%
12	330	4.0	2.3	2.87	2.05	8	-1.768%	4.654%
All (fitted)			4.3	2.16	3.80	60	-0.922%	2.789%
Source data					3.81	59		

San Luis Potosí. November 2008. 20m



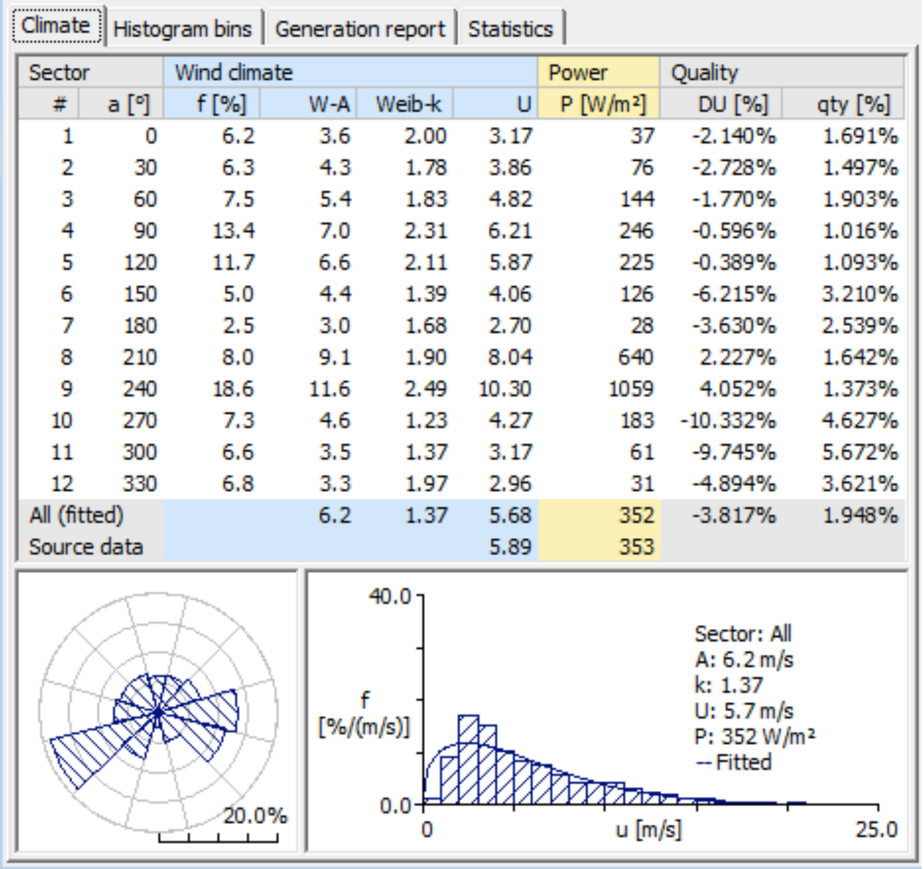
Sector		Wind climate				Power	Quality	
#	a [°]	f [%]	W-A	Weib-k	U	P [W/m²]	DU [%]	qty [%]
1	0	5.9	2.7	2.05	2.35	15	-3.821%	4.282%
2	30	6.5	3.5	1.96	3.08	35	-3.616%	2.597%
3	60	10.3	4.0	1.99	3.55	53	-4.189%	2.512%
4	90	21.3	4.7	2.23	4.14	75	-2.818%	1.564%
5	120	9.9	4.1	1.55	3.73	82	-7.206%	4.222%
6	150	3.2	3.0	1.48	2.76	36	-6.502%	5.852%
7	180	1.4	2.7	2.10	2.41	16	-3.801%	3.938%
8	210	6.1	6.4	2.52	5.64	172	3.777%	2.613%
9	240	18.4	7.5	2.55	6.66	281	1.134%	1.271%
10	270	7.5	3.9	1.50	3.53	73	-5.873%	3.729%
11	300	5.4	2.9	1.42	2.65	34	-10.207%	5.740%
12	330	4.2	2.6	2.15	2.27	13	-3.493%	4.298%
All (fitted)			4.6	1.59	4.08	104	-3.862%	2.482%
Source data					4.22	102		

San Luis Potosí. December 2008. 20m



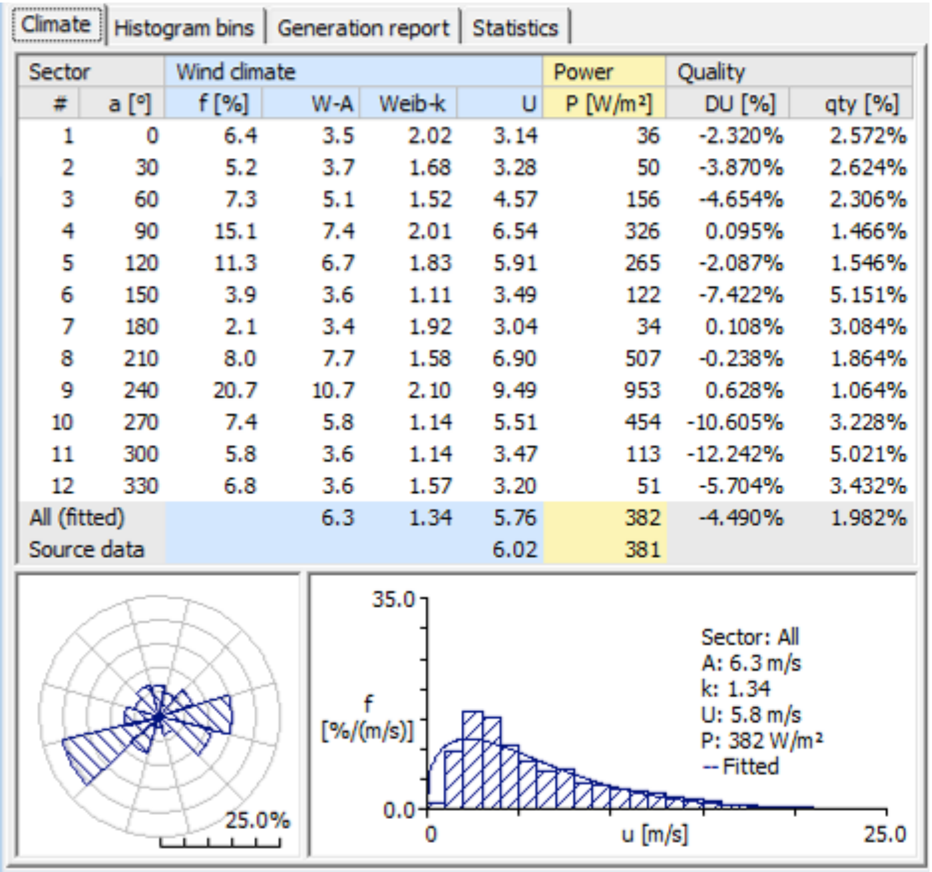
Sector		Wind climate				Power	Quality	
#	a [°]	f [%]	W-A	Weib-k	U	P [W/m²]	DU [%]	qty [%]
1	0	5.7	2.5	2.81	2.26	10	-1.549%	2.672%
2	30	6.7	3.0	2.16	2.68	21	-4.068%	3.283%
3	60	9.6	3.3	1.93	2.91	30	-4.467%	4.140%
4	90	15.8	4.5	1.90	3.96	77	-4.080%	2.794%
5	120	10.1	4.1	1.82	3.60	60	-6.139%	3.411%
6	150	3.4	3.1	1.29	2.85	49	-10.741%	7.384%
7	180	1.8	2.0	1.57	1.81	9	-11.412%	9.924%
8	210	6.1	4.9	1.57	4.41	134	-2.331%	4.841%
9	240	17.9	7.5	2.32	6.64	300	3.704%	2.974%
10	270	8.5	3.4	1.34	3.14	62	-9.528%	5.824%
11	300	7.9	3.8	1.31	3.51	89	-8.321%	5.238%
12	330	6.5	2.6	1.61	2.32	19	-5.737%	6.957%
All (fitted)			3.9	1.28	3.60	100	-9.553%	4.985%
Source data					3.93	98		

San Luis Potosí. January 2008. 50m



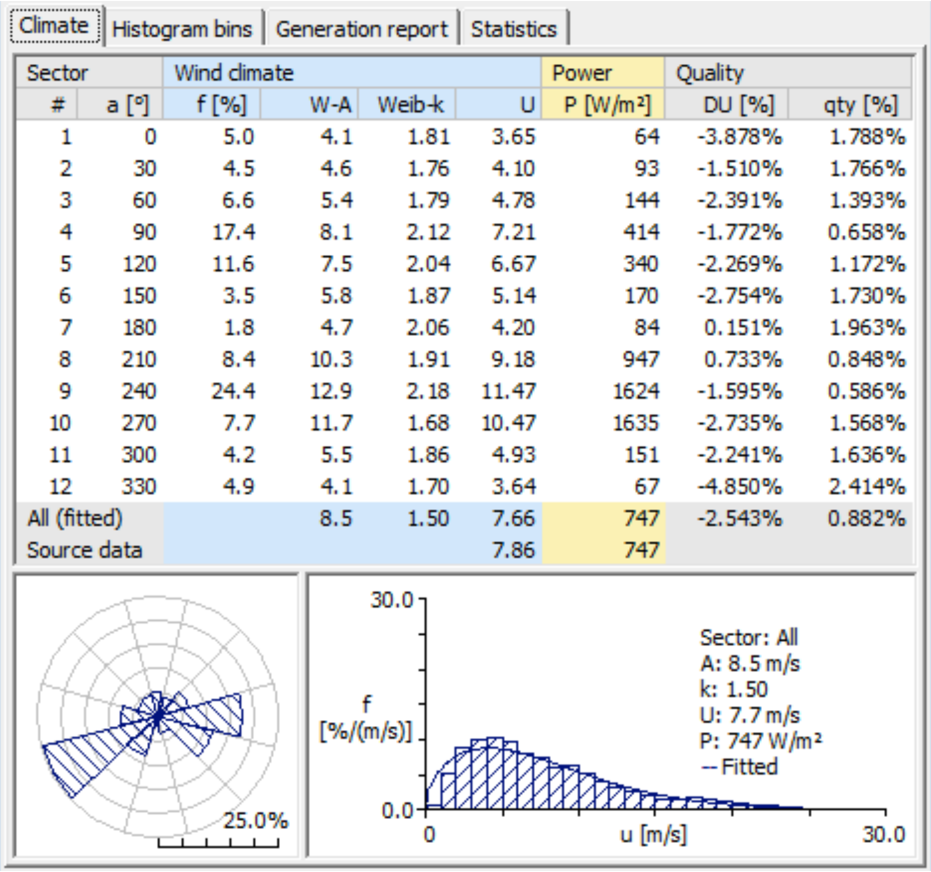
Sector		Wind climate				Power	Quality	
#	a [°]	f [%]	W-A	Weib-k	U	P [W/m²]	DU [%]	qty [%]
1	0	6.2	3.6	2.00	3.17	37	-2.140%	1.691%
2	30	6.3	4.3	1.78	3.86	76	-2.728%	1.497%
3	60	7.5	5.4	1.83	4.82	144	-1.770%	1.903%
4	90	13.4	7.0	2.31	6.21	246	-0.596%	1.016%
5	120	11.7	6.6	2.11	5.87	225	-0.389%	1.093%
6	150	5.0	4.4	1.39	4.06	126	-6.215%	3.210%
7	180	2.5	3.0	1.68	2.70	28	-3.630%	2.539%
8	210	8.0	9.1	1.90	8.04	640	2.227%	1.642%
9	240	18.6	11.6	2.49	10.30	1059	4.052%	1.373%
10	270	7.3	4.6	1.23	4.27	183	-10.332%	4.627%
11	300	6.6	3.5	1.37	3.17	61	-9.745%	5.672%
12	330	6.8	3.3	1.97	2.96	31	-4.894%	3.621%
All (fitted)			6.2	1.37	5.68	352	-3.817%	1.948%
Source data					5.89	353		

San Luis Potosí. February 2008. 50m



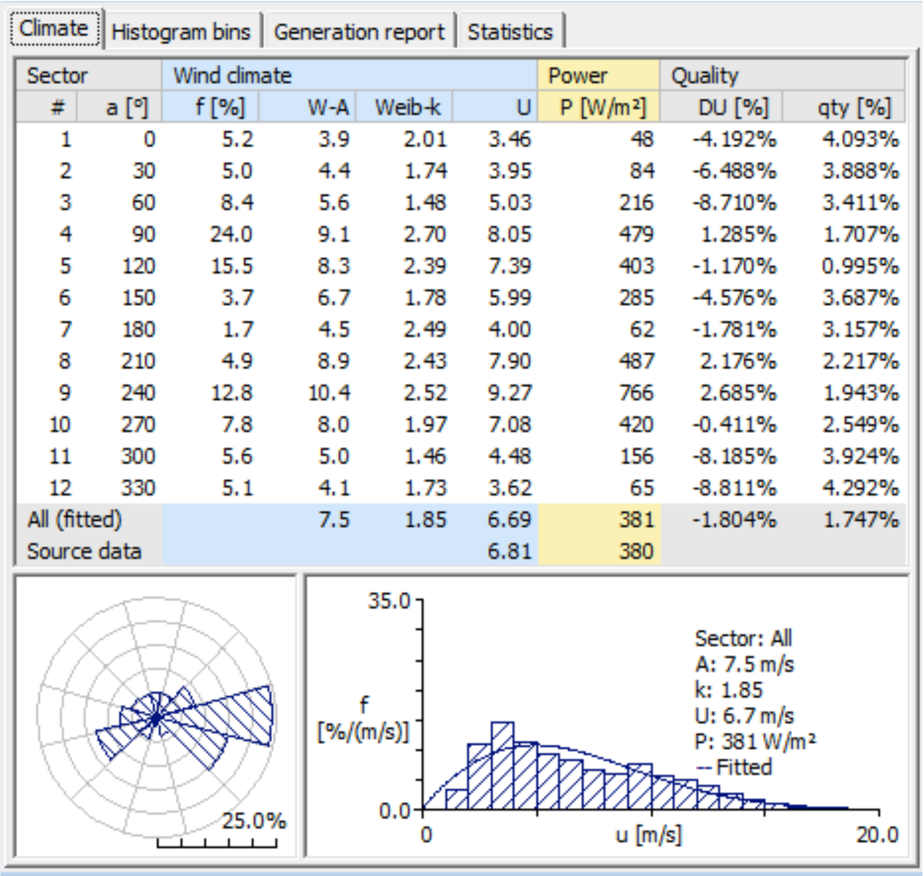
Sector		Wind climate				Power	Quality	
#	a [°]	f [%]	W-A	Weib-k	U	P [W/m²]	DU [%]	qty [%]
1	0	6.4	3.5	2.02	3.14	36	-2.320%	2.572%
2	30	5.2	3.7	1.68	3.28	50	-3.870%	2.624%
3	60	7.3	5.1	1.52	4.57	156	-4.654%	2.306%
4	90	15.1	7.4	2.01	6.54	326	0.095%	1.466%
5	120	11.3	6.7	1.83	5.91	265	-2.087%	1.546%
6	150	3.9	3.6	1.11	3.49	122	-7.422%	5.151%
7	180	2.1	3.4	1.92	3.04	34	0.108%	3.084%
8	210	8.0	7.7	1.58	6.90	507	-0.238%	1.864%
9	240	20.7	10.7	2.10	9.49	953	0.628%	1.064%
10	270	7.4	5.8	1.14	5.51	454	-10.605%	3.228%
11	300	5.8	3.6	1.14	3.47	113	-12.242%	5.021%
12	330	6.8	3.6	1.57	3.20	51	-5.704%	3.432%
All (fitted)			6.3	1.34	5.76	382	-4.490%	1.982%
Source data					6.02	381		

San Luis Potosí. March 2008. 50m



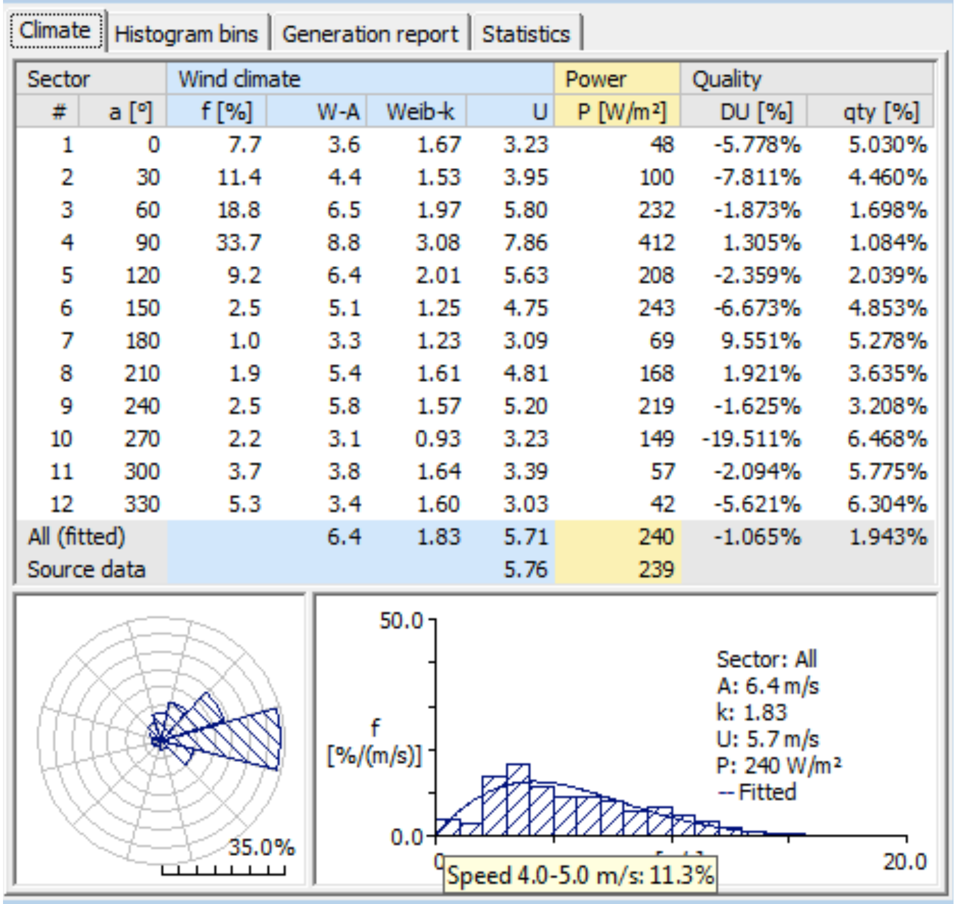
Sector		Wind climate				Power	Quality	
#	a [°]	f [%]	W-A	Weib-k	U	P [W/m²]	DU [%]	qty [%]
1	0	5.0	4.1	1.81	3.65	64	-3.878%	1.788%
2	30	4.5	4.6	1.76	4.10	93	-1.510%	1.766%
3	60	6.6	5.4	1.79	4.78	144	-2.391%	1.393%
4	90	17.4	8.1	2.12	7.21	414	-1.772%	0.658%
5	120	11.6	7.5	2.04	6.67	340	-2.269%	1.172%
6	150	3.5	5.8	1.87	5.14	170	-2.754%	1.730%
7	180	1.8	4.7	2.06	4.20	84	0.151%	1.963%
8	210	8.4	10.3	1.91	9.18	947	0.733%	0.848%
9	240	24.4	12.9	2.18	11.47	1624	-1.595%	0.586%
10	270	7.7	11.7	1.68	10.47	1635	-2.735%	1.568%
11	300	4.2	5.5	1.86	4.93	151	-2.241%	1.636%
12	330	4.9	4.1	1.70	3.64	67	-4.850%	2.414%
All (fitted)			8.5	1.50	7.66	747	-2.543%	0.882%
Source data					7.86	747		

San Luis Potosí. April 2008. 50m



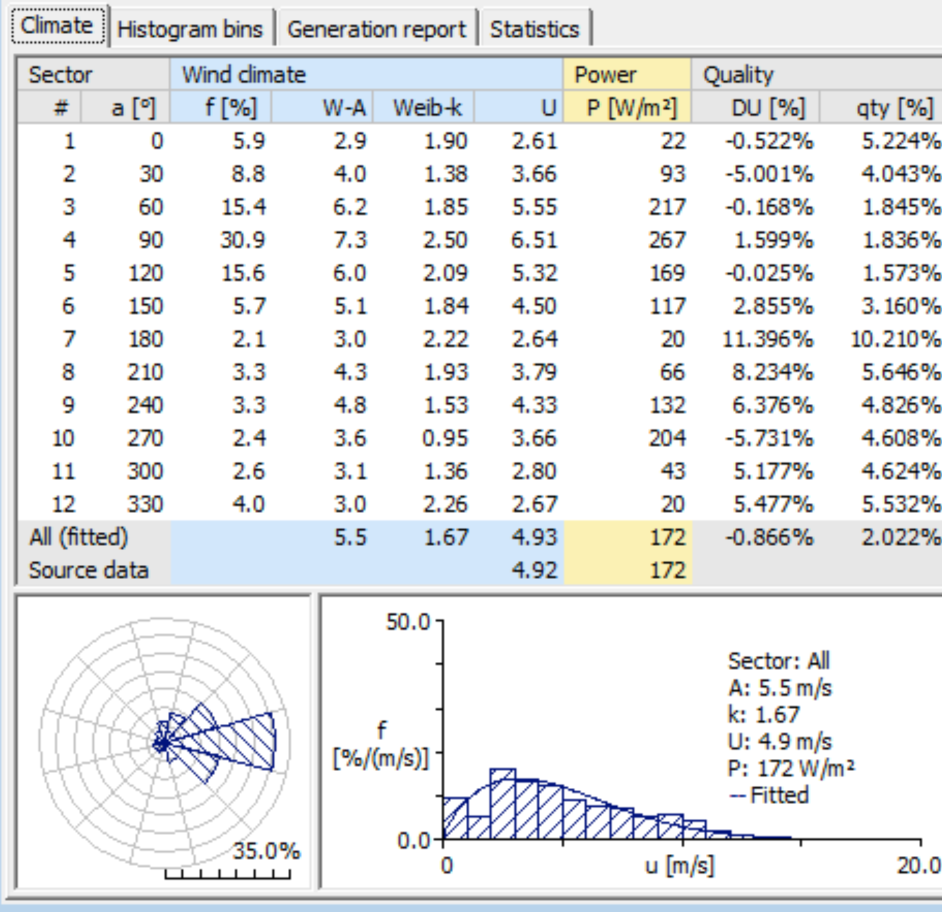
Sector		Wind climate				Power	Quality	
#	a [°]	f [%]	W-A	Weib-k	U	P [W/m²]	DU [%]	qty [%]
1	0	5.2	3.9	2.01	3.46	48	-4.192%	4.093%
2	30	5.0	4.4	1.74	3.95	84	-6.488%	3.888%
3	60	8.4	5.6	1.48	5.03	216	-8.710%	3.411%
4	90	24.0	9.1	2.70	8.05	479	1.285%	1.707%
5	120	15.5	8.3	2.39	7.39	403	-1.170%	0.995%
6	150	3.7	6.7	1.78	5.99	285	-4.576%	3.687%
7	180	1.7	4.5	2.49	4.00	62	-1.781%	3.157%
8	210	4.9	8.9	2.43	7.90	487	2.176%	2.217%
9	240	12.8	10.4	2.52	9.27	766	2.685%	1.943%
10	270	7.8	8.0	1.97	7.08	420	-0.411%	2.549%
11	300	5.6	5.0	1.46	4.48	156	-8.185%	3.924%
12	330	5.1	4.1	1.73	3.62	65	-8.811%	4.292%
All (fitted)			7.5	1.85	6.69	381	-1.804%	1.747%
Source data					6.81	380		

San Luis Potosí. July 2008. 50m



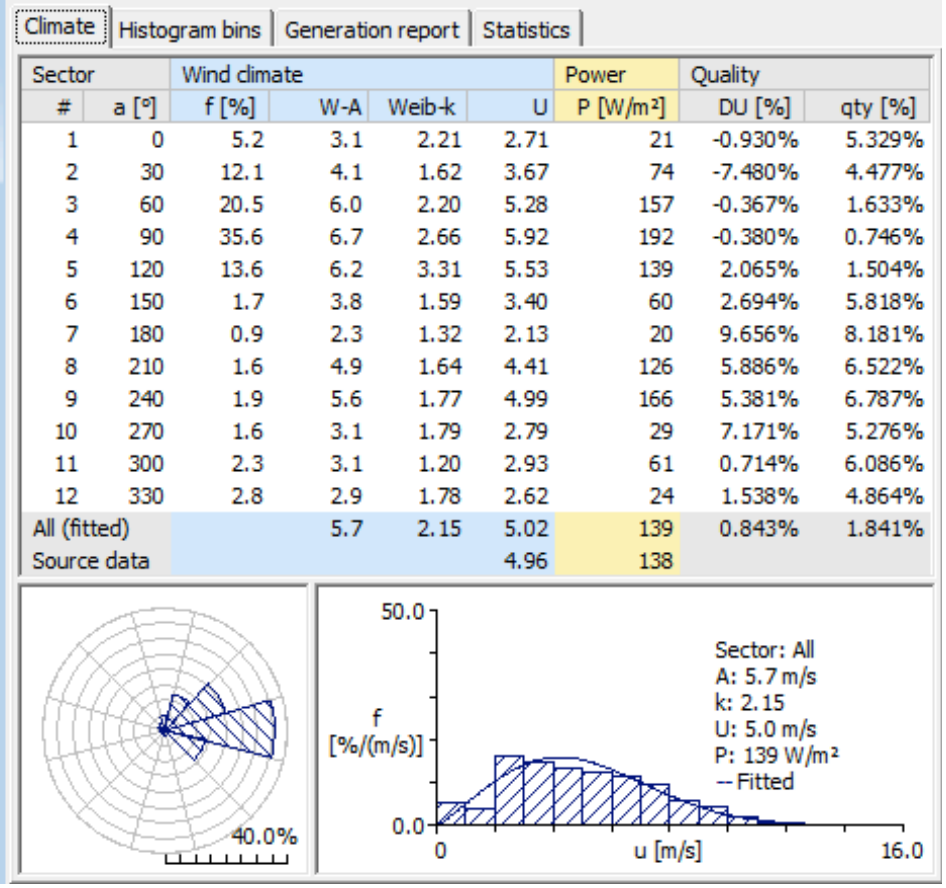
Sector		Wind climate				Power	Quality	
#	a [°]	f [%]	W-A	Weib-k	U	P [W/m²]	DU [%]	qty [%]
1	0	7.7	3.6	1.67	3.23	48	-5.778%	5.030%
2	30	11.4	4.4	1.53	3.95	100	-7.811%	4.460%
3	60	18.8	6.5	1.97	5.80	232	-1.873%	1.698%
4	90	33.7	8.8	3.08	7.86	412	1.305%	1.084%
5	120	9.2	6.4	2.01	5.63	208	-2.359%	2.039%
6	150	2.5	5.1	1.25	4.75	243	-6.673%	4.853%
7	180	1.0	3.3	1.23	3.09	69	9.551%	5.278%
8	210	1.9	5.4	1.61	4.81	168	1.921%	3.635%
9	240	2.5	5.8	1.57	5.20	219	-1.625%	3.208%
10	270	2.2	3.1	0.93	3.23	149	-19.511%	6.468%
11	300	3.7	3.8	1.64	3.39	57	-2.094%	5.775%
12	330	5.3	3.4	1.60	3.03	42	-5.621%	6.304%
All (fitted)			6.4	1.83	5.71	240	-1.065%	1.943%
Source data					5.76	239		

San Luis Potosí. August 2008. 50m



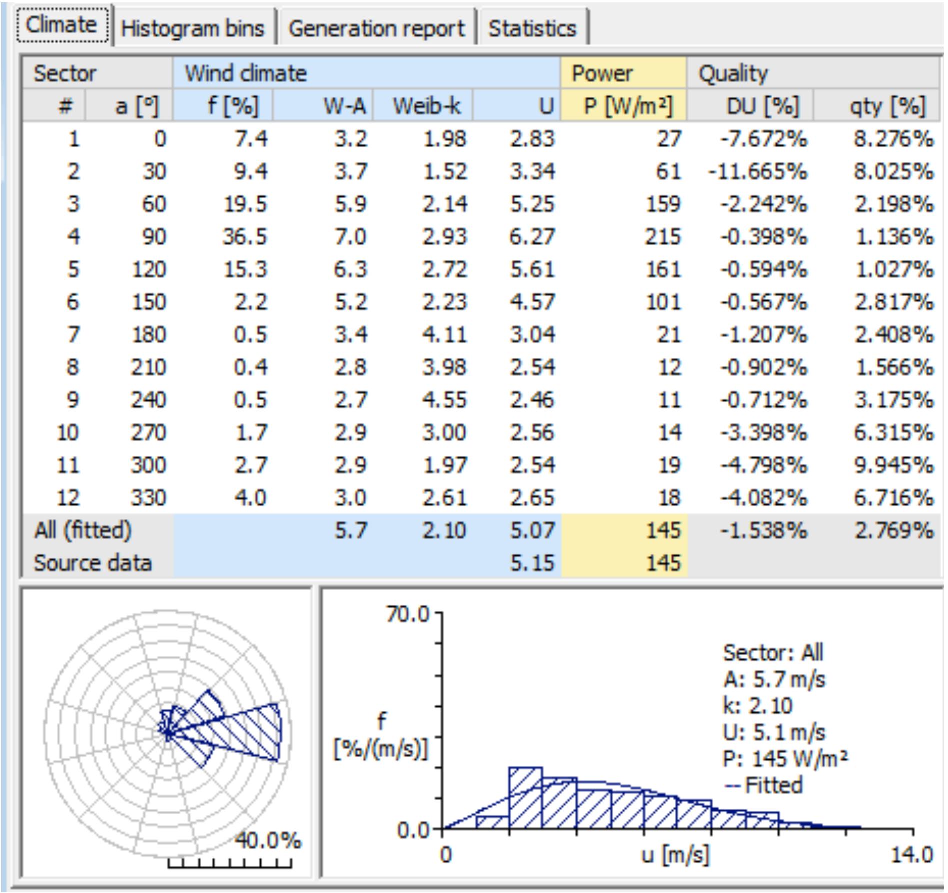
Sector		Wind climate				Power	Quality	
#	a [°]	f [%]	W-A	Weib-k	U	P [W/m²]	DU [%]	qty [%]
1	0	5.9	2.9	1.90	2.61	22	-0.522%	5.224%
2	30	8.8	4.0	1.38	3.66	93	-5.001%	4.043%
3	60	15.4	6.2	1.85	5.55	217	-0.168%	1.845%
4	90	30.9	7.3	2.50	6.51	267	1.599%	1.836%
5	120	15.6	6.0	2.09	5.32	169	-0.025%	1.573%
6	150	5.7	5.1	1.84	4.50	117	2.855%	3.160%
7	180	2.1	3.0	2.22	2.64	20	11.396%	10.210%
8	210	3.3	4.3	1.93	3.79	66	8.234%	5.646%
9	240	3.3	4.8	1.53	4.33	132	6.376%	4.826%
10	270	2.4	3.6	0.95	3.66	204	-5.731%	4.608%
11	300	2.6	3.1	1.36	2.80	43	5.177%	4.624%
12	330	4.0	3.0	2.26	2.67	20	5.477%	5.532%
All (fitted)			5.5	1.67	4.93	172	-0.866%	2.022%
Source data					4.92	172		

San Luis Potosí. September 2008. 50m



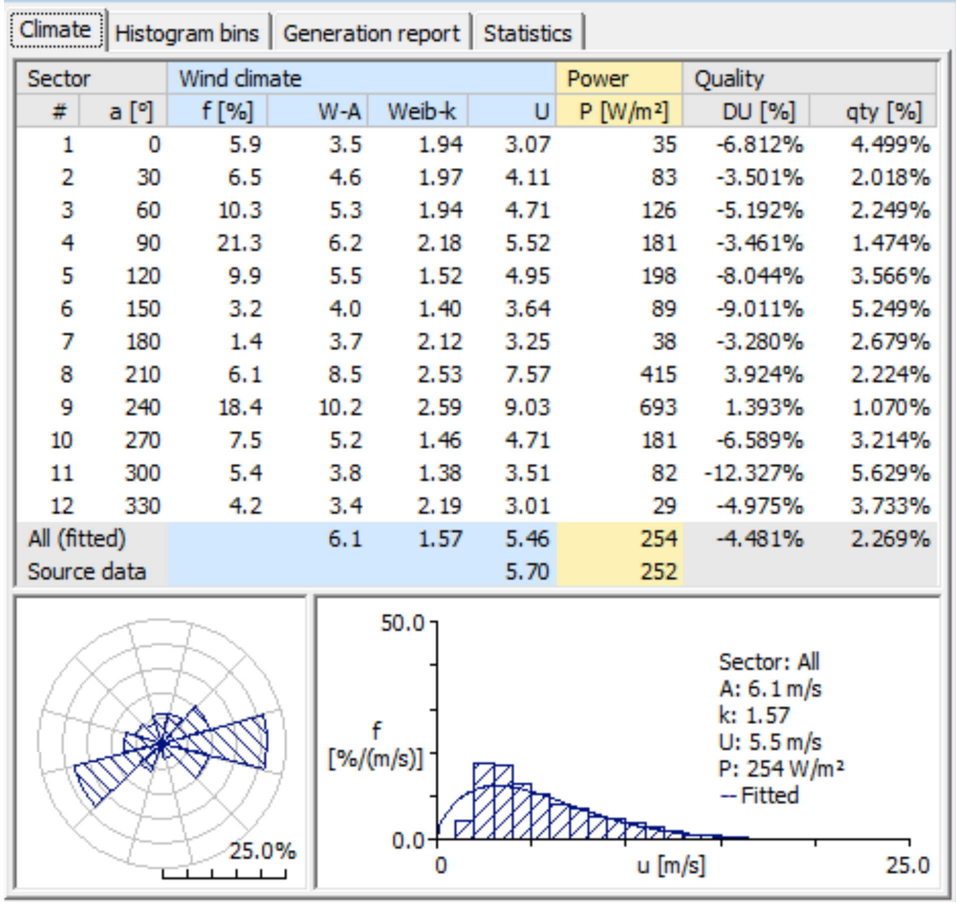
Sector		Wind climate				Power	Quality	
#	a [°]	f [%]	W-A	Weib-k	U	P [W/m²]	DU [%]	qty [%]
1	0	5.2	3.1	2.21	2.71	21	-0.930%	5.329%
2	30	12.1	4.1	1.62	3.67	74	-7.480%	4.477%
3	60	20.5	6.0	2.20	5.28	157	-0.367%	1.633%
4	90	35.6	6.7	2.66	5.92	192	-0.380%	0.746%
5	120	13.6	6.2	3.31	5.53	139	2.065%	1.504%
6	150	1.7	3.8	1.59	3.40	60	2.694%	5.818%
7	180	0.9	2.3	1.32	2.13	20	9.656%	8.181%
8	210	1.6	4.9	1.64	4.41	126	5.886%	6.522%
9	240	1.9	5.6	1.77	4.99	166	5.381%	6.787%
10	270	1.6	3.1	1.79	2.79	29	7.171%	5.276%
11	300	2.3	3.1	1.20	2.93	61	0.714%	6.086%
12	330	2.8	2.9	1.78	2.62	24	1.538%	4.864%
All (fitted)			5.7	2.15	5.02	139	0.843%	1.841%
Source data					4.96	138		

San Luis Potosí. October 2008. 50m



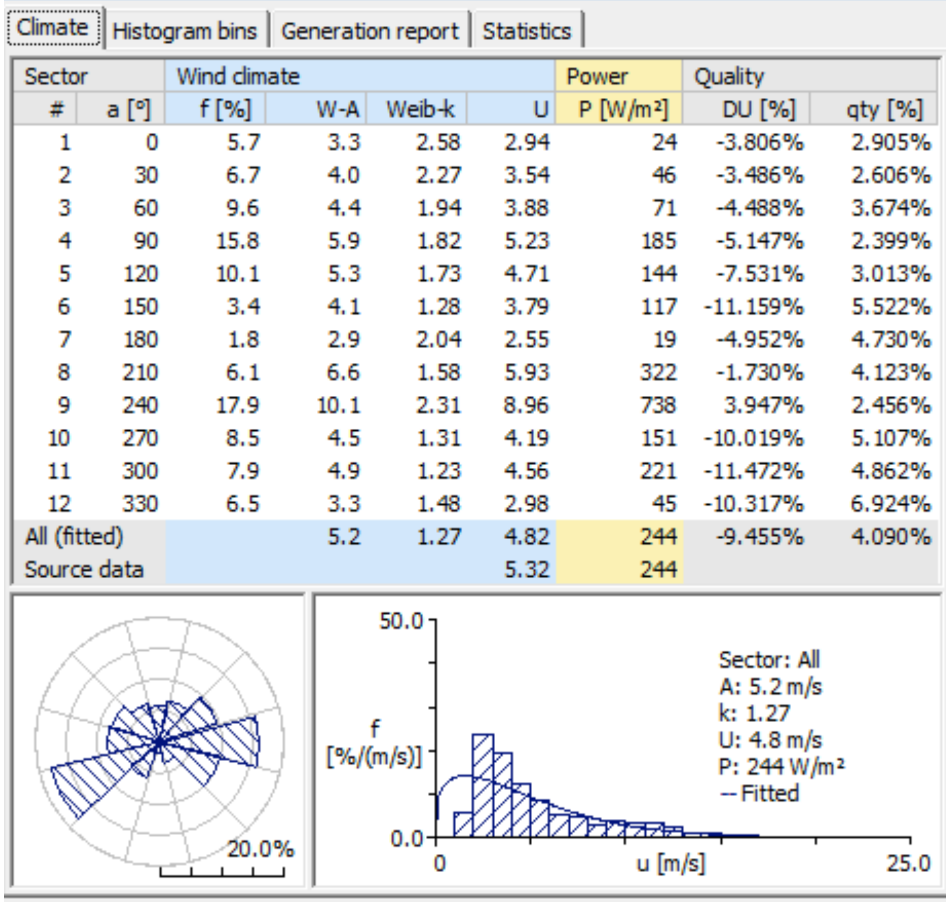
Sector		Wind climate				Power	Quality	
#	a [°]	f [%]	W-A	Weib-k	U	P [W/m²]	DU [%]	qty [%]
1	0	7.4	3.2	1.98	2.83	27	-7.672%	8.276%
2	30	9.4	3.7	1.52	3.34	61	-11.665%	8.025%
3	60	19.5	5.9	2.14	5.25	159	-2.242%	2.198%
4	90	36.5	7.0	2.93	6.27	215	-0.398%	1.136%
5	120	15.3	6.3	2.72	5.61	161	-0.594%	1.027%
6	150	2.2	5.2	2.23	4.57	101	-0.567%	2.817%
7	180	0.5	3.4	4.11	3.04	21	-1.207%	2.408%
8	210	0.4	2.8	3.98	2.54	12	-0.902%	1.566%
9	240	0.5	2.7	4.55	2.46	11	-0.712%	3.175%
10	270	1.7	2.9	3.00	2.56	14	-3.398%	6.315%
11	300	2.7	2.9	1.97	2.54	19	-4.798%	9.945%
12	330	4.0	3.0	2.61	2.65	18	-4.082%	6.716%
All (fitted)			5.7	2.10	5.07	145	-1.538%	2.769%
Source data					5.15	145		

San Luis Potosí. November 2008. 50m



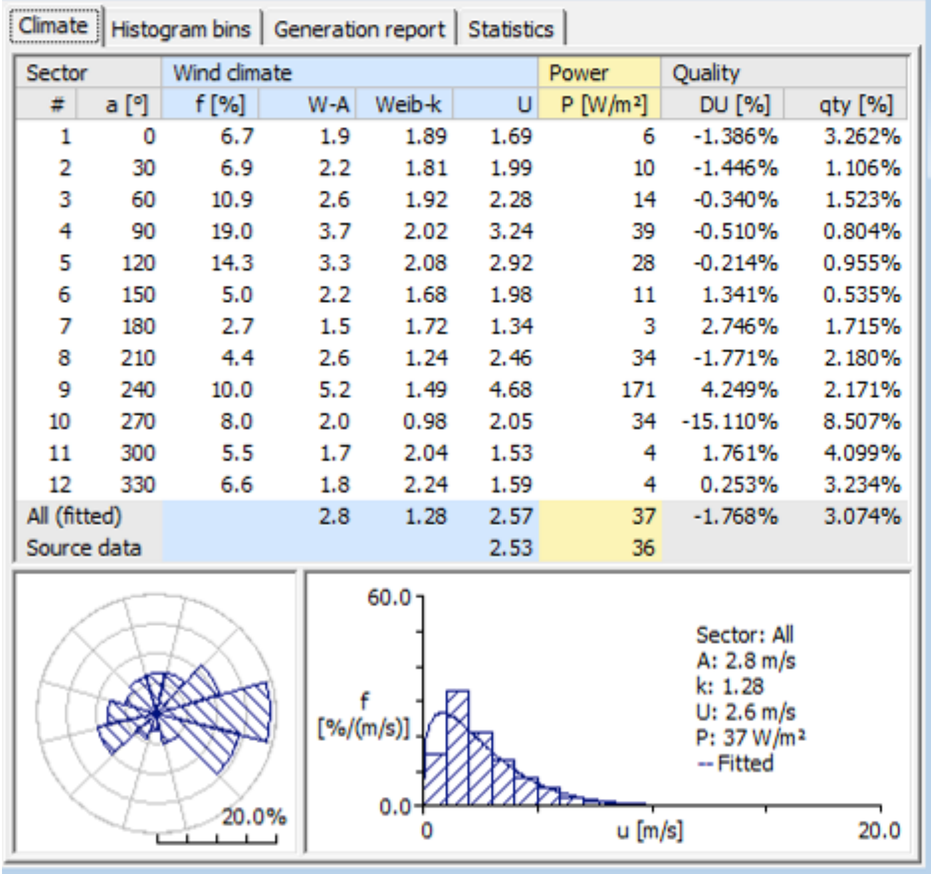
Sector		Wind climate				Power	Quality	
#	a [°]	f [%]	W-A	Weib-k	U	P [W/m²]	DU [%]	qty [%]
1	0	5.9	3.5	1.94	3.07	35	-6.812%	4.499%
2	30	6.5	4.6	1.97	4.11	83	-3.501%	2.018%
3	60	10.3	5.3	1.94	4.71	126	-5.192%	2.249%
4	90	21.3	6.2	2.18	5.52	181	-3.461%	1.474%
5	120	9.9	5.5	1.52	4.95	198	-8.044%	3.566%
6	150	3.2	4.0	1.40	3.64	89	-9.011%	5.249%
7	180	1.4	3.7	2.12	3.25	38	-3.280%	2.679%
8	210	6.1	8.5	2.53	7.57	415	3.924%	2.224%
9	240	18.4	10.2	2.59	9.03	693	1.393%	1.070%
10	270	7.5	5.2	1.46	4.71	181	-6.589%	3.214%
11	300	5.4	3.8	1.38	3.51	82	-12.327%	5.629%
12	330	4.2	3.4	2.19	3.01	29	-4.975%	3.733%
All (fitted)			6.1	1.57	5.46	254	-4.481%	2.269%
Source data					5.70	252		

San Luis Potosí. December 2008. 50m



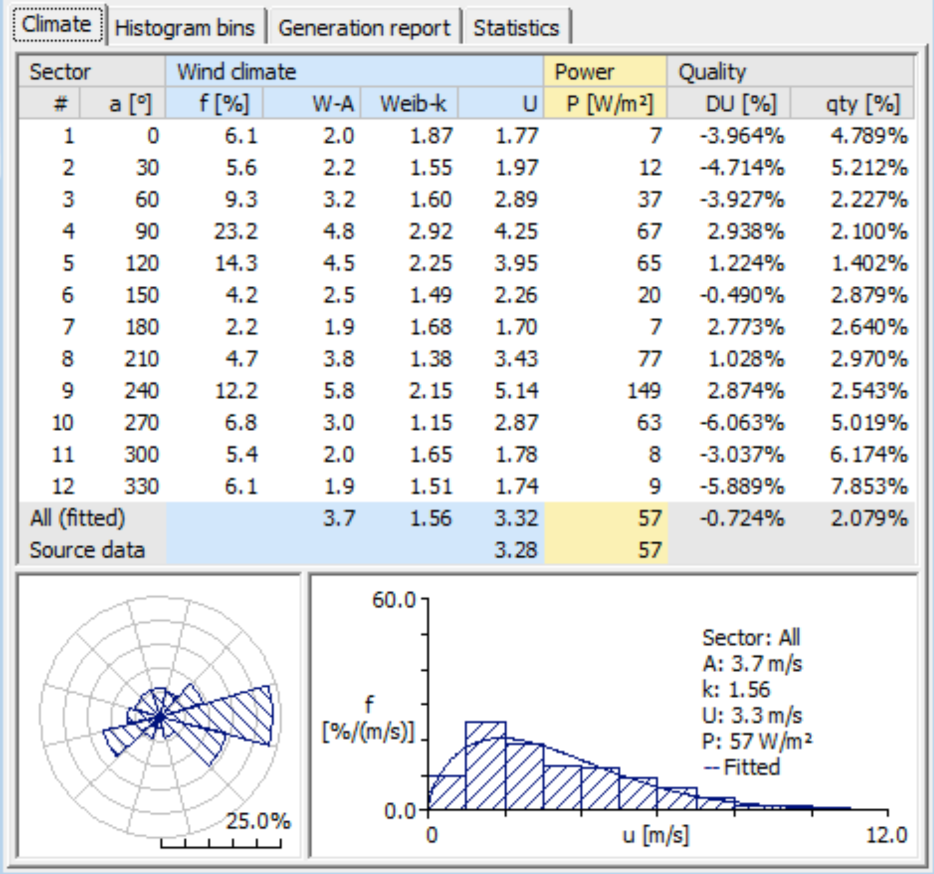
Sector		Wind climate				Power	Quality	
#	a [°]	f [%]	W-A	Weib-k	U	P [W/m²]	DU [%]	qty [%]
1	0	5.7	3.3	2.58	2.94	24	-3.806%	2.905%
2	30	6.7	4.0	2.27	3.54	46	-3.486%	2.606%
3	60	9.6	4.4	1.94	3.88	71	-4.488%	3.674%
4	90	15.8	5.9	1.82	5.23	185	-5.147%	2.399%
5	120	10.1	5.3	1.73	4.71	144	-7.531%	3.013%
6	150	3.4	4.1	1.28	3.79	117	-11.159%	5.522%
7	180	1.8	2.9	2.04	2.55	19	-4.952%	4.730%
8	210	6.1	6.6	1.58	5.93	322	-1.730%	4.123%
9	240	17.9	10.1	2.31	8.96	738	3.947%	2.456%
10	270	8.5	4.5	1.31	4.19	151	-10.019%	5.107%
11	300	7.9	4.9	1.23	4.56	221	-11.472%	4.862%
12	330	6.5	3.3	1.48	2.98	45	-10.317%	6.924%
All (fitted)			5.2	1.27	4.82	244	-9.455%	4.090%
Source data					5.32	244		

San Luis Potosí. January 2009. 10m



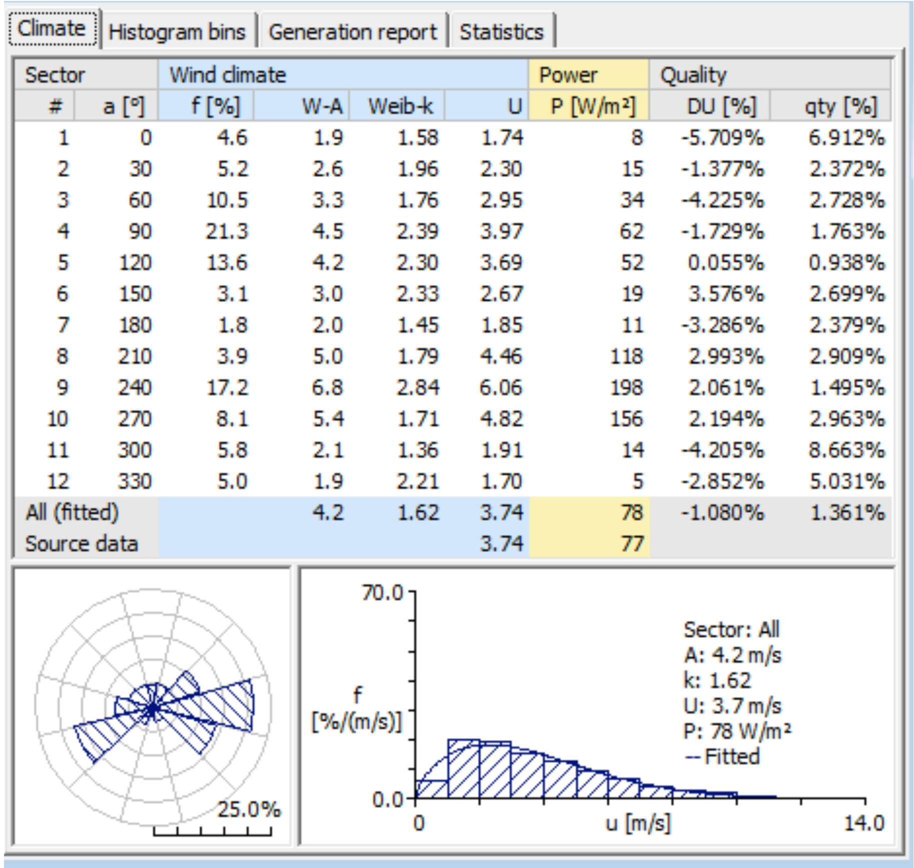
Sector		Wind climate				Power	Quality	
#	a [°]	f [%]	W-A	Weib-k	U	P [W/m²]	DU [%]	qty [%]
1	0	6.7	1.9	1.89	1.69	6	-1.386%	3.262%
2	30	6.9	2.2	1.81	1.99	10	-1.446%	1.106%
3	60	10.9	2.6	1.92	2.28	14	-0.340%	1.523%
4	90	19.0	3.7	2.02	3.24	39	-0.510%	0.804%
5	120	14.3	3.3	2.08	2.92	28	-0.214%	0.955%
6	150	5.0	2.2	1.68	1.98	11	1.341%	0.535%
7	180	2.7	1.5	1.72	1.34	3	2.746%	1.715%
8	210	4.4	2.6	1.24	2.46	34	-1.771%	2.180%
9	240	10.0	5.2	1.49	4.68	171	4.249%	2.171%
10	270	8.0	2.0	0.98	2.05	34	-15.110%	8.507%
11	300	5.5	1.7	2.04	1.53	4	1.761%	4.099%
12	330	6.6	1.8	2.24	1.59	4	0.253%	3.234%
All (fitted)			2.8	1.28	2.57	37	-1.768%	3.074%
Source data					2.53	36		

San Luis Potosí. February 2009. 10m



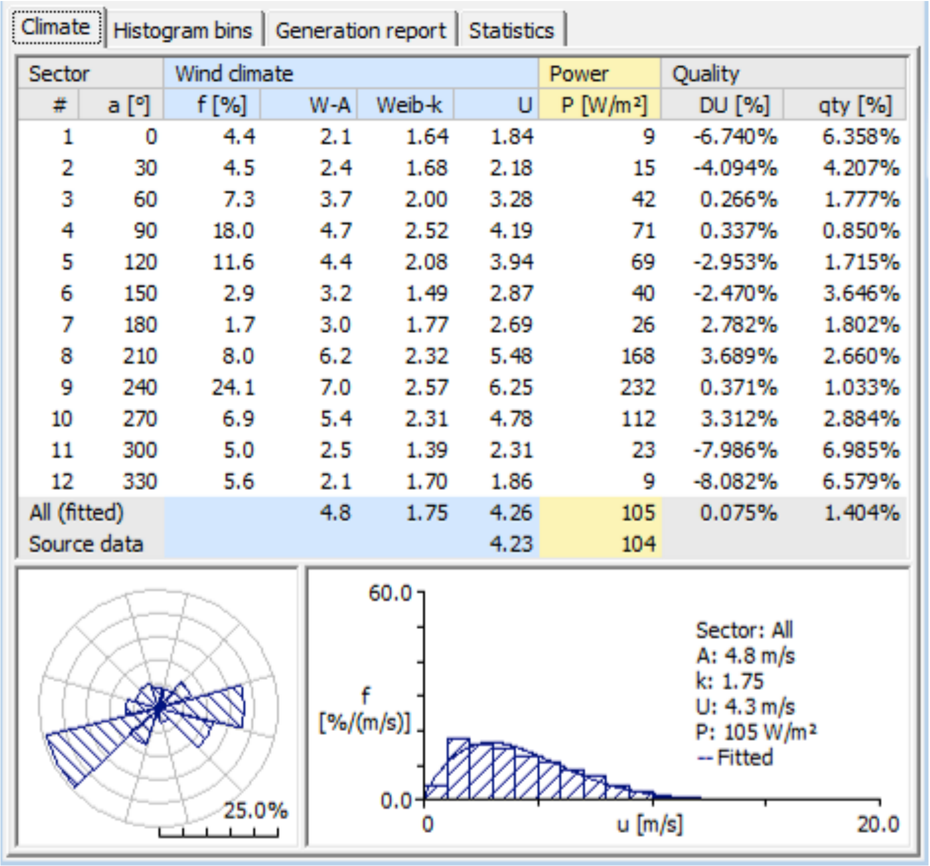
Sector		Wind climate				Power	Quality	
#	a [°]	f [%]	W-A	Weib-k	U	P [W/m²]	DU [%]	qty [%]
1	0	6.1	2.0	1.87	1.77	7	-3.964%	4.789%
2	30	5.6	2.2	1.55	1.97	12	-4.714%	5.212%
3	60	9.3	3.2	1.60	2.89	37	-3.927%	2.227%
4	90	23.2	4.8	2.92	4.25	67	2.938%	2.100%
5	120	14.3	4.5	2.25	3.95	65	1.224%	1.402%
6	150	4.2	2.5	1.49	2.26	20	-0.490%	2.879%
7	180	2.2	1.9	1.68	1.70	7	2.773%	2.640%
8	210	4.7	3.8	1.38	3.43	77	1.028%	2.970%
9	240	12.2	5.8	2.15	5.14	149	2.874%	2.543%
10	270	6.8	3.0	1.15	2.87	63	-6.063%	5.019%
11	300	5.4	2.0	1.65	1.78	8	-3.037%	6.174%
12	330	6.1	1.9	1.51	1.74	9	-5.889%	7.853%
All (fitted)			3.7	1.56	3.32	57	-0.724%	2.079%
Source data					3.28	57		

San Luis Potosí. March 2009. 10m



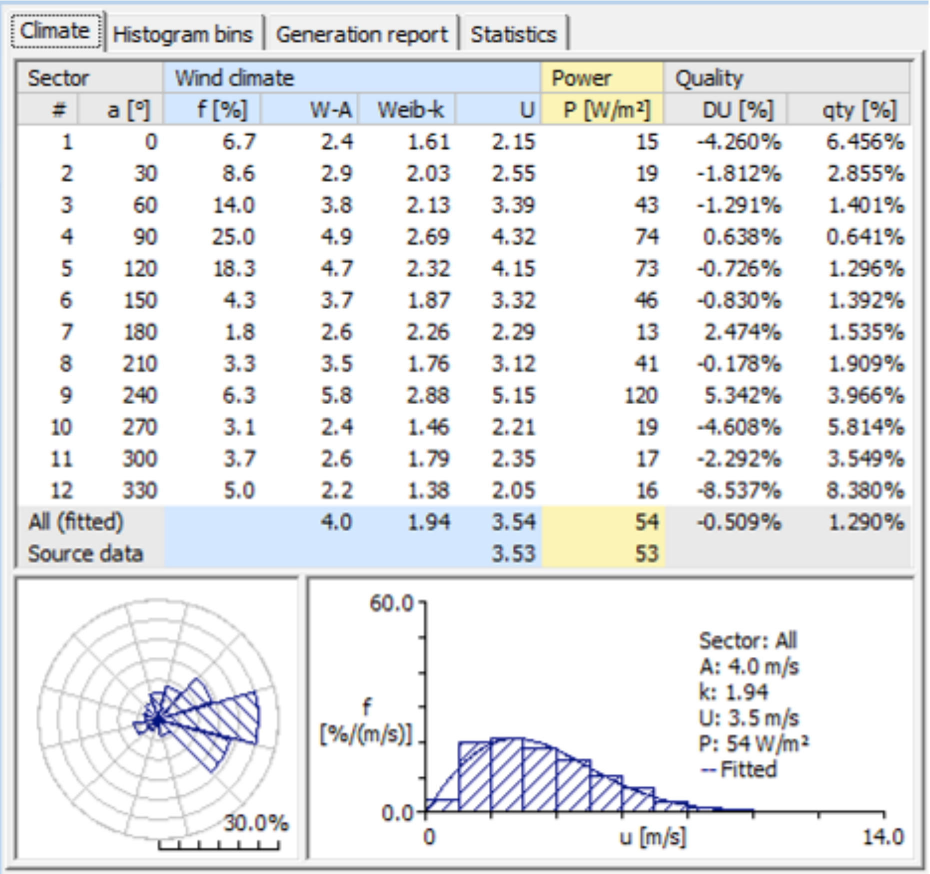
Sector		Wind climate				Power	Quality	
#	a [°]	f [%]	W-A	Weib-k	U	P [W/m²]	DU [%]	qty [%]
1	0	4.6	1.9	1.58	1.74	8	-5.709%	6.912%
2	30	5.2	2.6	1.96	2.30	15	-1.377%	2.372%
3	60	10.5	3.3	1.76	2.95	34	-4.225%	2.728%
4	90	21.3	4.5	2.39	3.97	62	-1.729%	1.763%
5	120	13.6	4.2	2.30	3.69	52	0.055%	0.938%
6	150	3.1	3.0	2.33	2.67	19	3.576%	2.699%
7	180	1.8	2.0	1.45	1.85	11	-3.286%	2.379%
8	210	3.9	5.0	1.79	4.46	118	2.993%	2.909%
9	240	17.2	6.8	2.84	6.06	198	2.061%	1.495%
10	270	8.1	5.4	1.71	4.82	156	2.194%	2.963%
11	300	5.8	2.1	1.36	1.91	14	-4.205%	8.663%
12	330	5.0	1.9	2.21	1.70	5	-2.852%	5.031%
All (fitted)			4.2	1.62	3.74	78	-1.080%	1.361%
Source data					3.74	77		

San Luis Potosí. April 2009. 10m



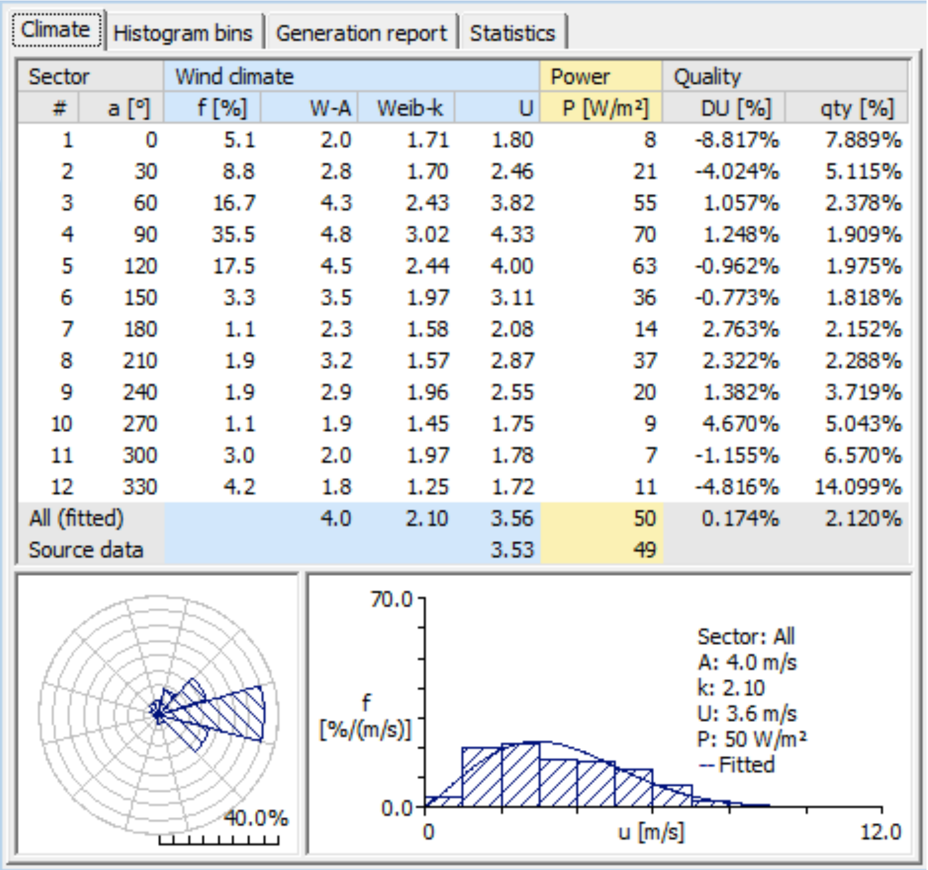
Sector		Wind climate				Power	Quality	
#	a [°]	f [%]	W-A	Weib-k	U	P [W/m²]	DU [%]	qty [%]
1	0	4.4	2.1	1.64	1.84	9	-6.740%	6.358%
2	30	4.5	2.4	1.68	2.18	15	-4.094%	4.207%
3	60	7.3	3.7	2.00	3.28	42	0.266%	1.777%
4	90	18.0	4.7	2.52	4.19	71	0.337%	0.850%
5	120	11.6	4.4	2.08	3.94	69	-2.953%	1.715%
6	150	2.9	3.2	1.49	2.87	40	-2.470%	3.646%
7	180	1.7	3.0	1.77	2.69	26	2.782%	1.802%
8	210	8.0	6.2	2.32	5.48	168	3.689%	2.660%
9	240	24.1	7.0	2.57	6.25	232	0.371%	1.033%
10	270	6.9	5.4	2.31	4.78	112	3.312%	2.884%
11	300	5.0	2.5	1.39	2.31	23	-7.986%	6.985%
12	330	5.6	2.1	1.70	1.86	9	-8.082%	6.579%
All (fitted)			4.8	1.75	4.26	105	0.075%	1.404%
Source data					4.23	104		

San Luis Potosí. May 2009. 10m



Sector		Wind climate				Power	Quality	
#	a [°]	f [%]	W-A	Weib-k	U	P [W/m²]	DU [%]	qty [%]
1	0	6.7	2.4	1.61	2.15	15	-4.260%	6.456%
2	30	8.6	2.9	2.03	2.55	19	-1.812%	2.855%
3	60	14.0	3.8	2.13	3.39	43	-1.291%	1.401%
4	90	25.0	4.9	2.69	4.32	74	0.638%	0.641%
5	120	18.3	4.7	2.32	4.15	73	-0.726%	1.296%
6	150	4.3	3.7	1.87	3.32	46	-0.830%	1.392%
7	180	1.8	2.6	2.26	2.29	13	2.474%	1.535%
8	210	3.3	3.5	1.76	3.12	41	-0.178%	1.909%
9	240	6.3	5.8	2.88	5.15	120	5.342%	3.966%
10	270	3.1	2.4	1.46	2.21	19	-4.608%	5.814%
11	300	3.7	2.6	1.79	2.35	17	-2.292%	3.549%
12	330	5.0	2.2	1.38	2.05	16	-8.537%	8.380%
All (fitted)			4.0	1.94	3.54	54	-0.509%	1.290%
Source data					3.53	53		

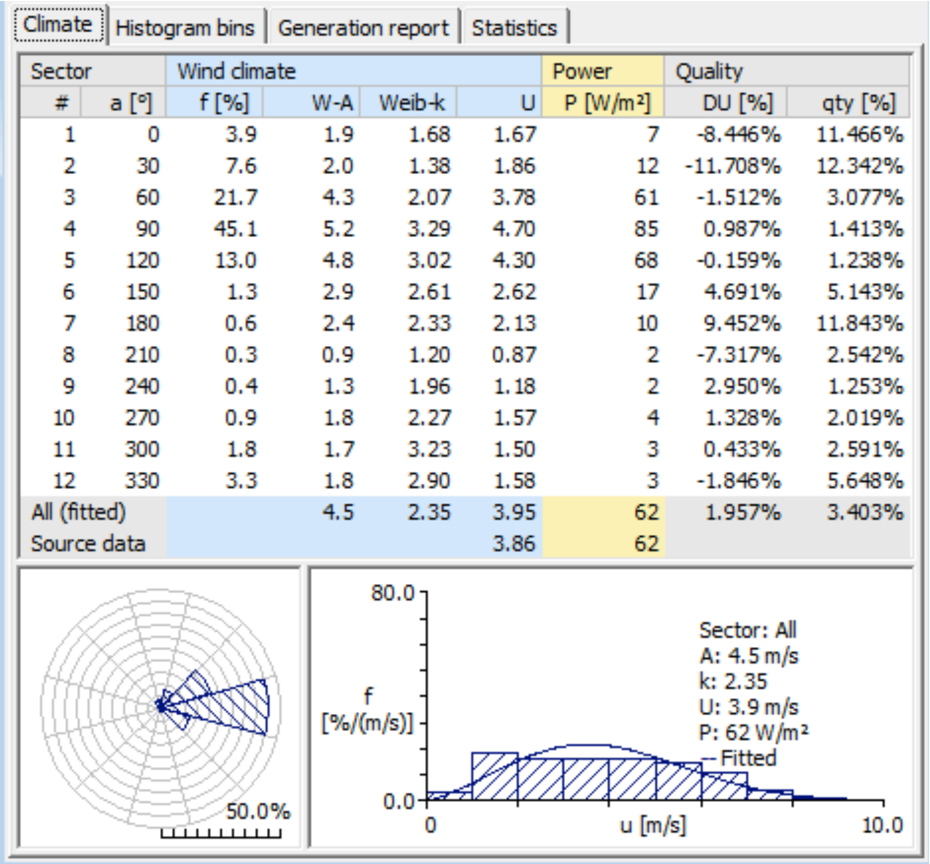
San Luis Potosí. June 2009. 10m



Sector		Wind climate				Power	Quality	
#	a [°]	f [%]	W-A	Weib-k	U	P [W/m²]	DU [%]	qty [%]
1	0	5.1	2.0	1.71	1.80	8	-8.817%	7.889%
2	30	8.8	2.8	1.70	2.46	21	-4.024%	5.115%
3	60	16.7	4.3	2.43	3.82	55	1.057%	2.378%
4	90	35.5	4.8	3.02	4.33	70	1.248%	1.909%
5	120	17.5	4.5	2.44	4.00	63	-0.962%	1.975%
6	150	3.3	3.5	1.97	3.11	36	-0.773%	1.818%
7	180	1.1	2.3	1.58	2.08	14	2.763%	2.152%
8	210	1.9	3.2	1.57	2.87	37	2.322%	2.288%
9	240	1.9	2.9	1.96	2.55	20	1.382%	3.719%
10	270	1.1	1.9	1.45	1.75	9	4.670%	5.043%
11	300	3.0	2.0	1.97	1.78	7	-1.155%	6.570%
12	330	4.2	1.8	1.25	1.72	11	-4.816%	14.099%
All (fitted)			4.0	2.10	3.56	50	0.174%	2.120%
Source data					3.53	49		

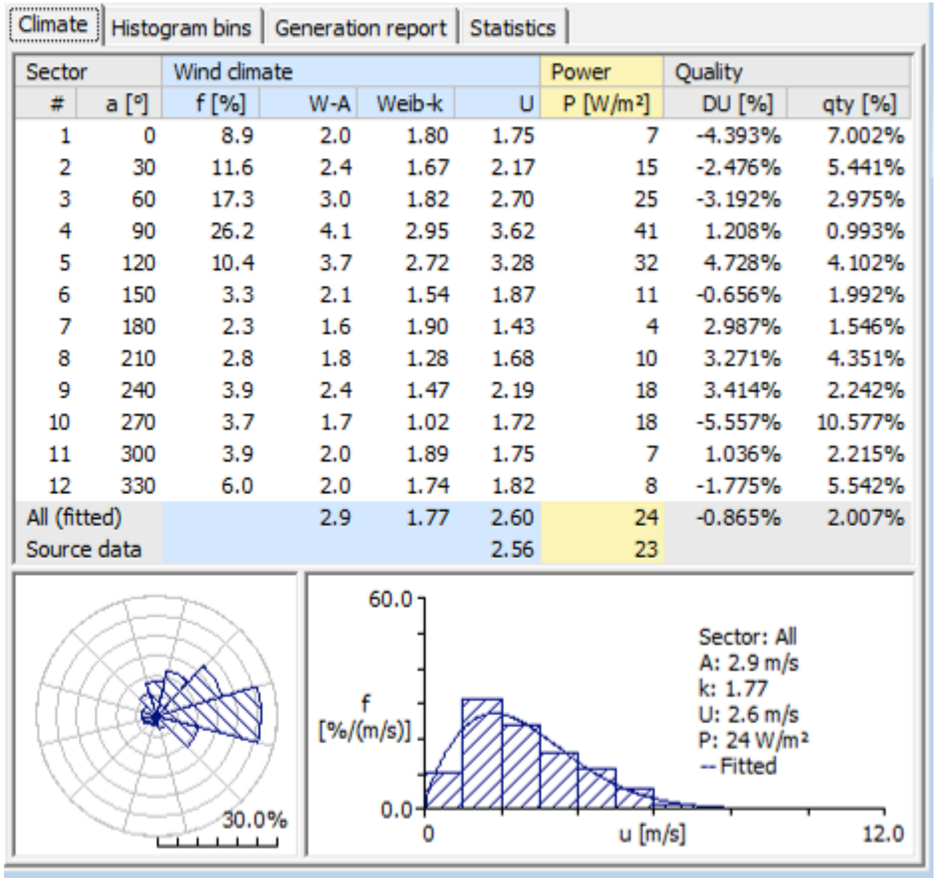
San Luis Potosí. July 2009. 10m

San Luis Potosí. August 2009. 10m



Sector		Wind climate				Power	Quality	
#	a [°]	f [%]	W-A	Weib-k	U	P [W/m²]	DU [%]	qty [%]
1	0	3.9	1.9	1.68	1.67	7	-8.446%	11.466%
2	30	7.6	2.0	1.38	1.86	12	-11.708%	12.342%
3	60	21.7	4.3	2.07	3.78	61	-1.512%	3.077%
4	90	45.1	5.2	3.29	4.70	85	0.987%	1.413%
5	120	13.0	4.8	3.02	4.30	68	-0.159%	1.238%
6	150	1.3	2.9	2.61	2.62	17	4.691%	5.143%
7	180	0.6	2.4	2.33	2.13	10	9.452%	11.843%
8	210	0.3	0.9	1.20	0.87	2	-7.317%	2.542%
9	240	0.4	1.3	1.96	1.18	2	2.950%	1.253%
10	270	0.9	1.8	2.27	1.57	4	1.328%	2.019%
11	300	1.8	1.7	3.23	1.50	3	0.433%	2.591%
12	330	3.3	1.8	2.90	1.58	3	-1.846%	5.648%
All (fitted)			4.5	2.35	3.95	62	1.957%	3.403%
Source data					3.86	62		

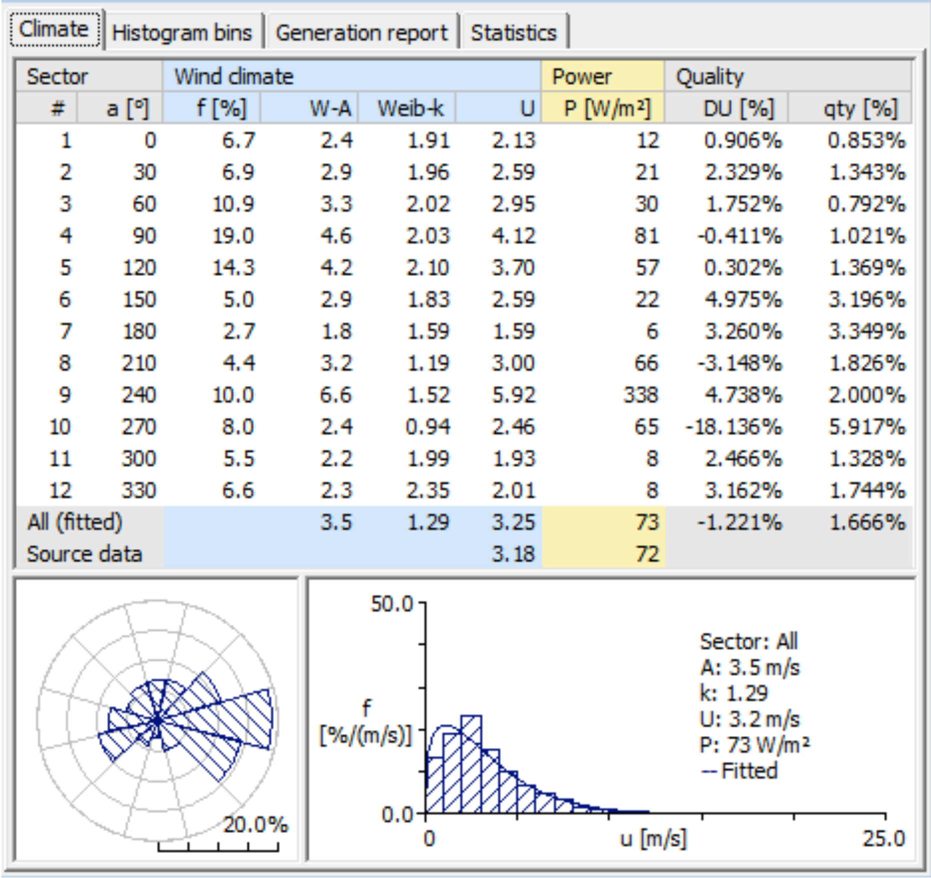
San Luis Potosí. September 2009. 10m



Sector		Wind climate				Power	Quality	
#	a [°]	f [%]	W-A	Weib-k	U	P [W/m²]	DU [%]	qty [%]
1	0	8.9	2.0	1.80	1.75	7	-4.393%	7.002%
2	30	11.6	2.4	1.67	2.17	15	-2.476%	5.441%
3	60	17.3	3.0	1.82	2.70	25	-3.192%	2.975%
4	90	26.2	4.1	2.95	3.62	41	1.208%	0.993%
5	120	10.4	3.7	2.72	3.28	32	4.728%	4.102%
6	150	3.3	2.1	1.54	1.87	11	-0.656%	1.992%
7	180	2.3	1.6	1.90	1.43	4	2.987%	1.546%
8	210	2.8	1.8	1.28	1.68	10	3.271%	4.351%
9	240	3.9	2.4	1.47	2.19	18	3.414%	2.242%
10	270	3.7	1.7	1.02	1.72	18	-5.557%	10.577%
11	300	3.9	2.0	1.89	1.75	7	1.036%	2.215%
12	330	6.0	2.0	1.74	1.82	8	-1.775%	5.542%
All (fitted)			2.9	1.77	2.60	24	-0.865%	2.007%
Source data					2.56	23		

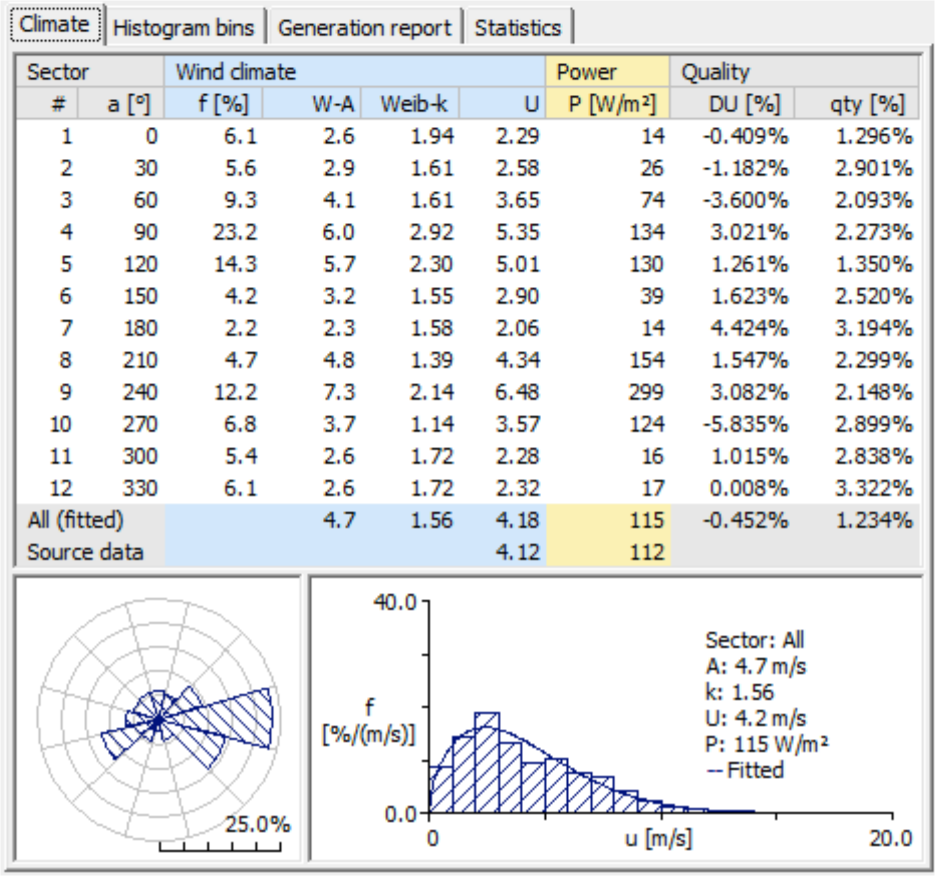
San Luis Potosí. October 2009. 10m

San Luis Potosí. January 2009. 20m



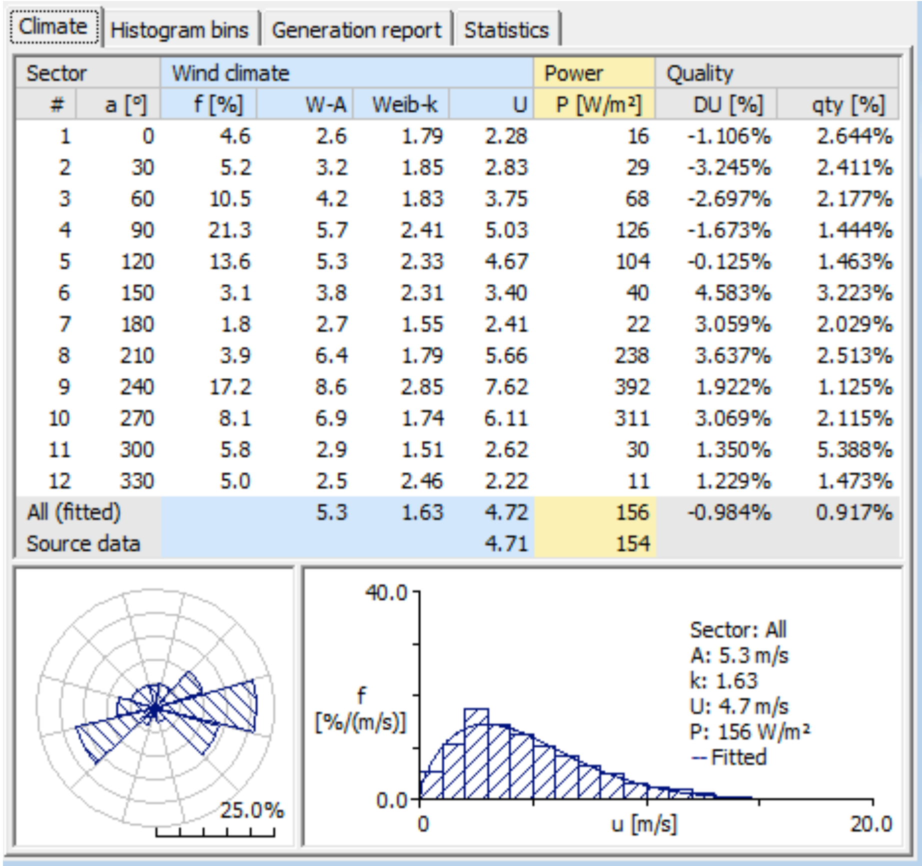
Sector		Wind climate				Power	Quality	
#	a [°]	f [%]	W-A	Weib-k	U	P [W/m²]	DU [%]	qty [%]
1	0	6.7	2.4	1.91	2.13	12	0.906%	0.853%
2	30	6.9	2.9	1.96	2.59	21	2.329%	1.343%
3	60	10.9	3.3	2.02	2.95	30	1.752%	0.792%
4	90	19.0	4.6	2.03	4.12	81	-0.411%	1.021%
5	120	14.3	4.2	2.10	3.70	57	0.302%	1.369%
6	150	5.0	2.9	1.83	2.59	22	4.975%	3.196%
7	180	2.7	1.8	1.59	1.59	6	3.260%	3.349%
8	210	4.4	3.2	1.19	3.00	66	-3.148%	1.826%
9	240	10.0	6.6	1.52	5.92	338	4.738%	2.000%
10	270	8.0	2.4	0.94	2.46	65	-18.136%	5.917%
11	300	5.5	2.2	1.99	1.93	8	2.466%	1.328%
12	330	6.6	2.3	2.35	2.01	8	3.162%	1.744%
All (fitted)			3.5	1.29	3.25	73	-1.221%	1.666%
Source data					3.18	72		

San Luis Potosí. February 2009. 20m



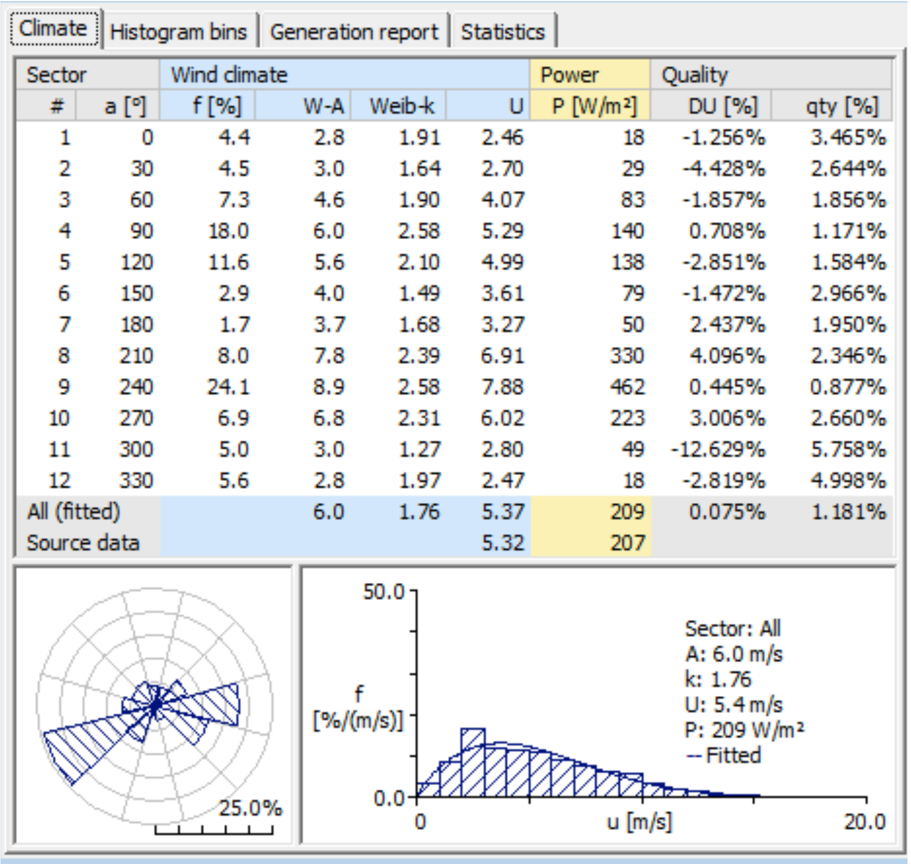
Sector		Wind climate				Power	Quality	
#	a [°]	f [%]	W-A	Weib-k	U	P [W/m²]	DU [%]	qty [%]
1	0	6.1	2.6	1.94	2.29	14	-0.409%	1.296%
2	30	5.6	2.9	1.61	2.58	26	-1.182%	2.901%
3	60	9.3	4.1	1.61	3.65	74	-3.600%	2.093%
4	90	23.2	6.0	2.92	5.35	134	3.021%	2.273%
5	120	14.3	5.7	2.30	5.01	130	1.261%	1.350%
6	150	4.2	3.2	1.55	2.90	39	1.623%	2.520%
7	180	2.2	2.3	1.58	2.06	14	4.424%	3.194%
8	210	4.7	4.8	1.39	4.34	154	1.547%	2.299%
9	240	12.2	7.3	2.14	6.48	299	3.082%	2.148%
10	270	6.8	3.7	1.14	3.57	124	-5.835%	2.899%
11	300	5.4	2.6	1.72	2.28	16	1.015%	2.838%
12	330	6.1	2.6	1.72	2.32	17	0.008%	3.322%
All (fitted)			4.7	1.56	4.18	115	-0.452%	1.234%
Source data					4.12	112		

San Luis Potosí. March 2009. 20m



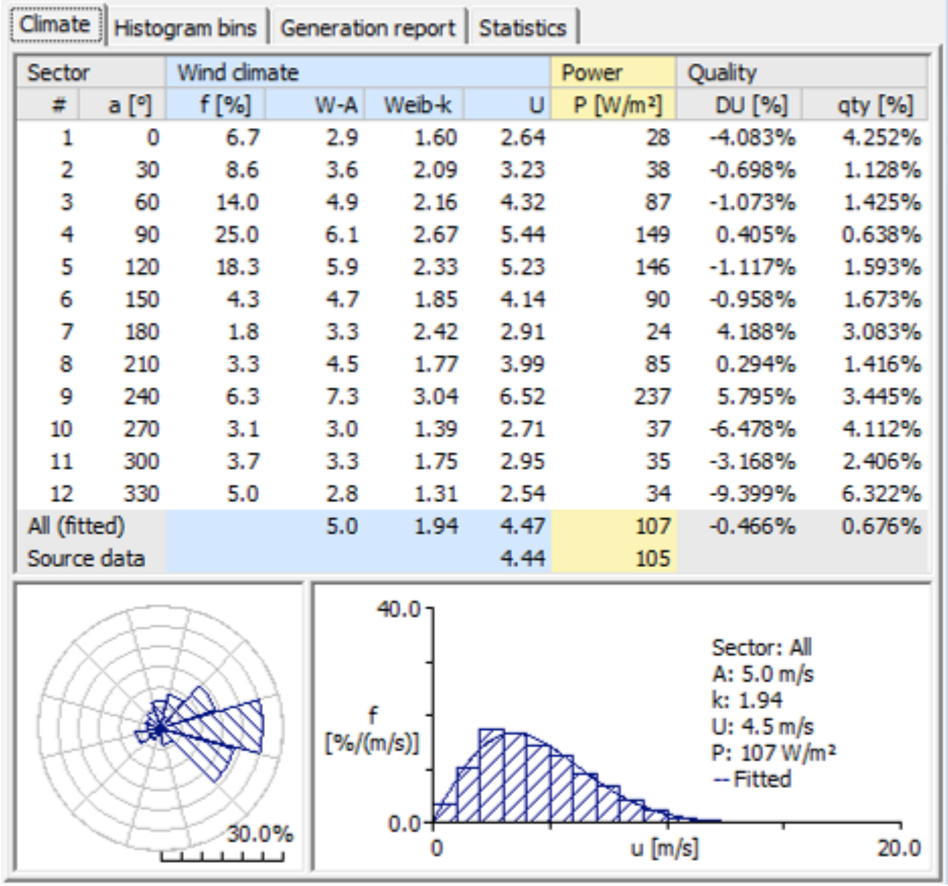
Sector		Wind climate				Power	Quality	
#	a [°]	f [%]	W-A	Weib-k	U	P [W/m²]	DU [%]	qty [%]
1	0	4.6	2.6	1.79	2.28	16	-1.106%	2.644%
2	30	5.2	3.2	1.85	2.83	29	-3.245%	2.411%
3	60	10.5	4.2	1.83	3.75	68	-2.697%	2.177%
4	90	21.3	5.7	2.41	5.03	126	-1.673%	1.444%
5	120	13.6	5.3	2.33	4.67	104	-0.125%	1.463%
6	150	3.1	3.8	2.31	3.40	40	4.583%	3.223%
7	180	1.8	2.7	1.55	2.41	22	3.059%	2.029%
8	210	3.9	6.4	1.79	5.66	238	3.637%	2.513%
9	240	17.2	8.6	2.85	7.62	392	1.922%	1.125%
10	270	8.1	6.9	1.74	6.11	311	3.069%	2.115%
11	300	5.8	2.9	1.51	2.62	30	1.350%	5.388%
12	330	5.0	2.5	2.46	2.22	11	1.229%	1.473%
All (fitted)			5.3	1.63	4.72	156	-0.984%	0.917%
Source data					4.71	154		

San Luis Potosí. April 2009. 20m



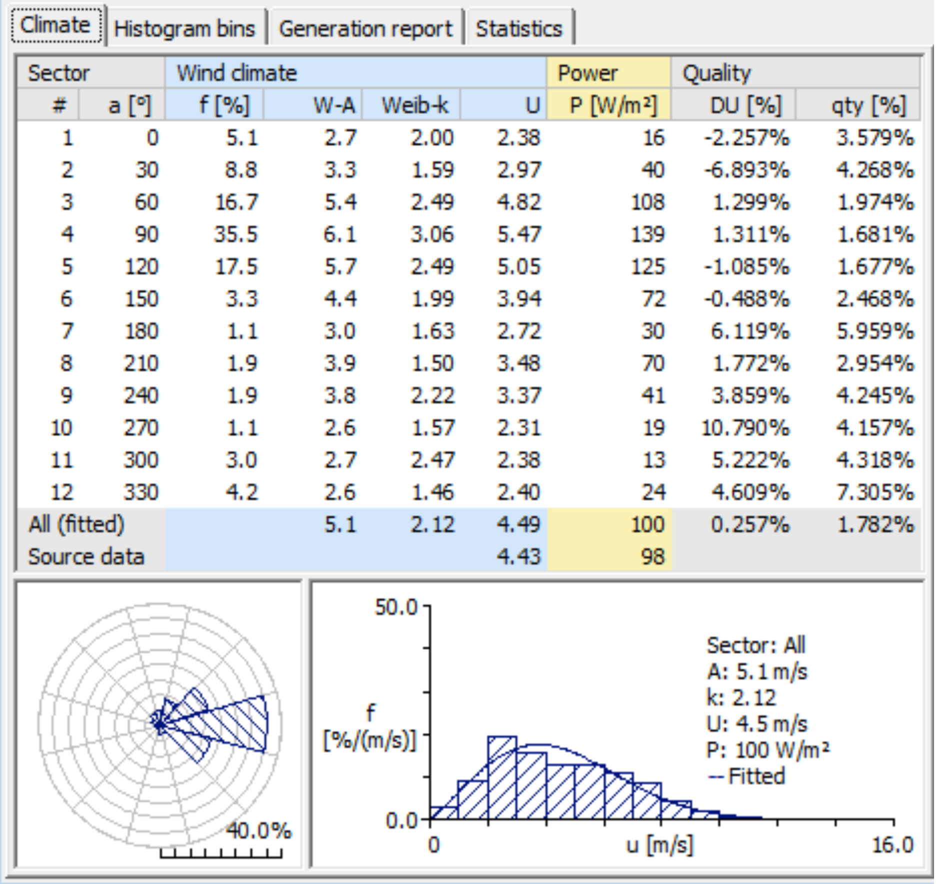
Sector		Wind climate				Power	Quality	
#	a [°]	f [%]	W-A	Weib-k	U	P [W/m²]	DU [%]	qty [%]
1	0	4.4	2.8	1.91	2.46	18	-1.256%	3.465%
2	30	4.5	3.0	1.64	2.70	29	-4.428%	2.644%
3	60	7.3	4.6	1.90	4.07	83	-1.857%	1.856%
4	90	18.0	6.0	2.58	5.29	140	0.708%	1.171%
5	120	11.6	5.6	2.10	4.99	138	-2.851%	1.584%
6	150	2.9	4.0	1.49	3.61	79	-1.472%	2.966%
7	180	1.7	3.7	1.68	3.27	50	2.437%	1.950%
8	210	8.0	7.8	2.39	6.91	330	4.096%	2.346%
9	240	24.1	8.9	2.58	7.88	462	0.445%	0.877%
10	270	6.9	6.8	2.31	6.02	223	3.006%	2.660%
11	300	5.0	3.0	1.27	2.80	49	-12.629%	5.758%
12	330	5.6	2.8	1.97	2.47	18	-2.819%	4.998%
All (fitted)			6.0	1.76	5.37	209	0.075%	1.181%
Source data					5.32	207		

San Luis Potosí. May 2009. 20m



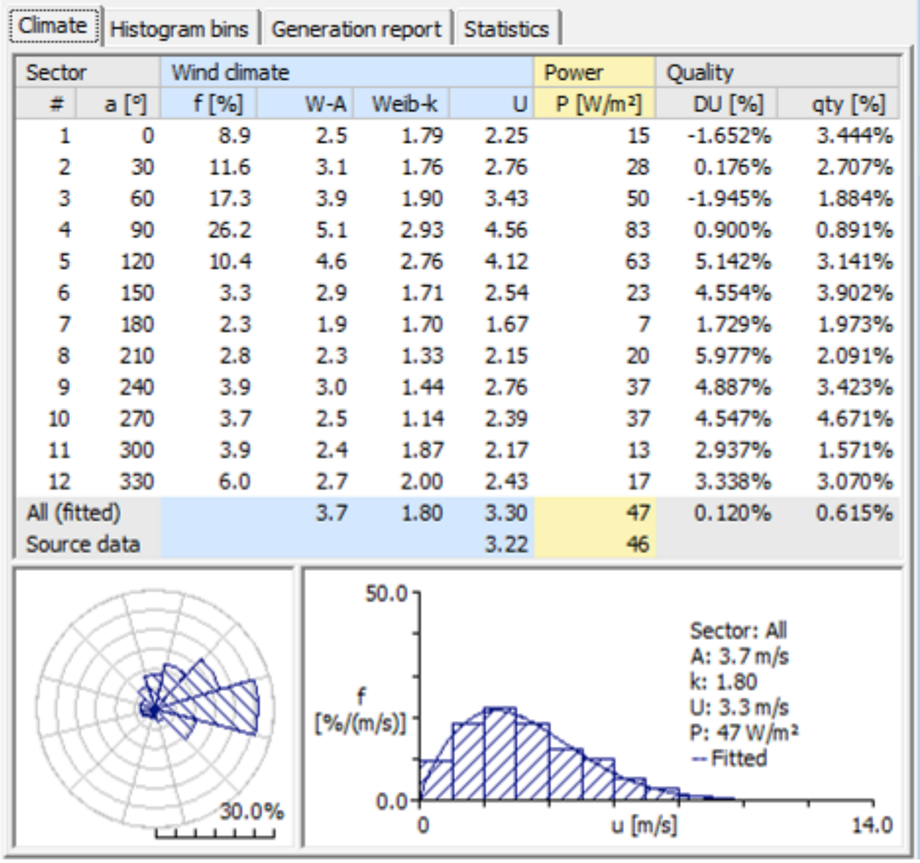
Sector		Wind climate				Power	Quality	
#	a [°]	f [%]	W-A	Weib-k	U	P [W/m²]	DU [%]	qty [%]
1	0	6.7	2.9	1.60	2.64	28	-4.083%	4.252%
2	30	8.6	3.6	2.09	3.23	38	-0.698%	1.128%
3	60	14.0	4.9	2.16	4.32	87	-1.073%	1.425%
4	90	25.0	6.1	2.67	5.44	149	0.405%	0.638%
5	120	18.3	5.9	2.33	5.23	146	-1.117%	1.593%
6	150	4.3	4.7	1.85	4.14	90	-0.958%	1.673%
7	180	1.8	3.3	2.42	2.91	24	4.188%	3.083%
8	210	3.3	4.5	1.77	3.99	85	0.294%	1.416%
9	240	6.3	7.3	3.04	6.52	237	5.795%	3.445%
10	270	3.1	3.0	1.39	2.71	37	-6.478%	4.112%
11	300	3.7	3.3	1.75	2.95	35	-3.168%	2.406%
12	330	5.0	2.8	1.31	2.54	34	-9.399%	6.322%
All (fitted)			5.0	1.94	4.47	107	-0.466%	0.676%
Source data					4.44	105		

San Luis Potosí. June 2009. 20m



Sector		Wind climate				Power	Quality	
#	a [°]	f [%]	W-A	Weib-k	U	P [W/m²]	DU [%]	qty [%]
1	0	5.1	2.7	2.00	2.38	16	-2.257%	3.579%
2	30	8.8	3.3	1.59	2.97	40	-6.893%	4.268%
3	60	16.7	5.4	2.49	4.82	108	1.299%	1.974%
4	90	35.5	6.1	3.06	5.47	139	1.311%	1.681%
5	120	17.5	5.7	2.49	5.05	125	-1.085%	1.677%
6	150	3.3	4.4	1.99	3.94	72	-0.488%	2.468%
7	180	1.1	3.0	1.63	2.72	30	6.119%	5.959%
8	210	1.9	3.9	1.50	3.48	70	1.772%	2.954%
9	240	1.9	3.8	2.22	3.37	41	3.859%	4.245%
10	270	1.1	2.6	1.57	2.31	19	10.790%	4.157%
11	300	3.0	2.7	2.47	2.38	13	5.222%	4.318%
12	330	4.2	2.6	1.46	2.40	24	4.609%	7.305%
All (fitted)			5.1	2.12	4.49	100	0.257%	1.782%
Source data					4.43	98		

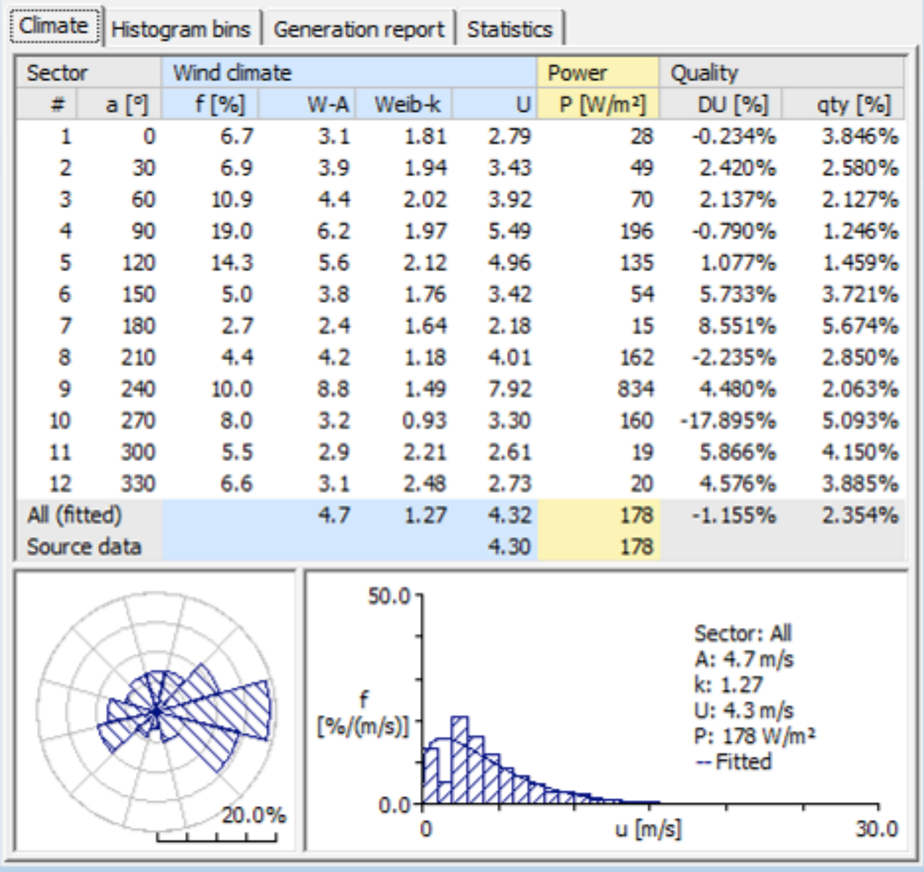
San Luis Potosí. September 2009. 20m



Sector		Wind climate				Power	Quality	
#	a [°]	f [%]	W-A	Weib-k	U	P [W/m²]	DU [%]	qty [%]
1	0	8.9	2.5	1.79	2.25	15	-1.652%	3.444%
2	30	11.6	3.1	1.76	2.76	28	0.176%	2.707%
3	60	17.3	3.9	1.90	3.43	50	-1.945%	1.884%
4	90	26.2	5.1	2.93	4.56	83	0.900%	0.891%
5	120	10.4	4.6	2.76	4.12	63	5.142%	3.141%
6	150	3.3	2.9	1.71	2.54	23	4.554%	3.902%
7	180	2.3	1.9	1.70	1.67	7	1.729%	1.973%
8	210	2.8	2.3	1.33	2.15	20	5.977%	2.091%
9	240	3.9	3.0	1.44	2.76	37	4.887%	3.423%
10	270	3.7	2.5	1.14	2.39	37	4.547%	4.671%
11	300	3.9	2.4	1.87	2.17	13	2.937%	1.571%
12	330	6.0	2.7	2.00	2.43	17	3.338%	3.070%
All (fitted)			3.7	1.80	3.30	47	0.120%	0.615%
Source data					3.22	46		

San Luis Potosí. October 2009. 20m

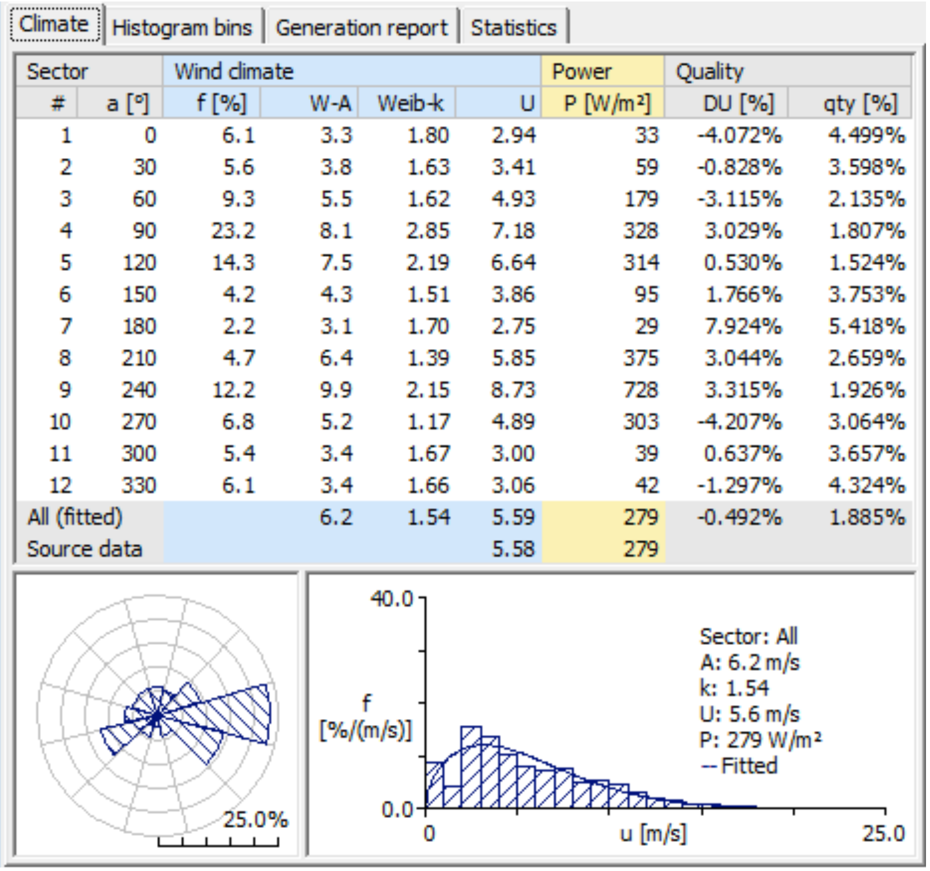
San Luis Potosí. January 2009. 50m



Sector		Wind climate				Power	Quality	
#	a [°]	f [%]	W-A	Weib-k	U	P [W/m²]	DU [%]	qty [%]
1	0	6.7	3.1	1.81	2.79	28	-0.234%	3.846%
2	30	6.9	3.9	1.94	3.43	49	2.420%	2.580%
3	60	10.9	4.4	2.02	3.92	70	2.137%	2.127%
4	90	19.0	6.2	1.97	5.49	196	-0.790%	1.246%
5	120	14.3	5.6	2.12	4.96	135	1.077%	1.459%
6	150	5.0	3.8	1.76	3.42	54	5.733%	3.721%
7	180	2.7	2.4	1.64	2.18	15	8.551%	5.674%
8	210	4.4	4.2	1.18	4.01	162	-2.235%	2.850%
9	240	10.0	8.8	1.49	7.92	834	4.480%	2.063%
10	270	8.0	3.2	0.93	3.30	160	-17.895%	5.093%
11	300	5.5	2.9	2.21	2.61	19	5.866%	4.150%
12	330	6.6	3.1	2.48	2.73	20	4.576%	3.885%
All (fitted)			4.7	1.27	4.32	178	-1.155%	2.354%
Source data					4.30	178		

Sector: All
A: 4.7 m/s
k: 1.27
U: 4.3 m/s
P: 178 W/m²
-- Fitted

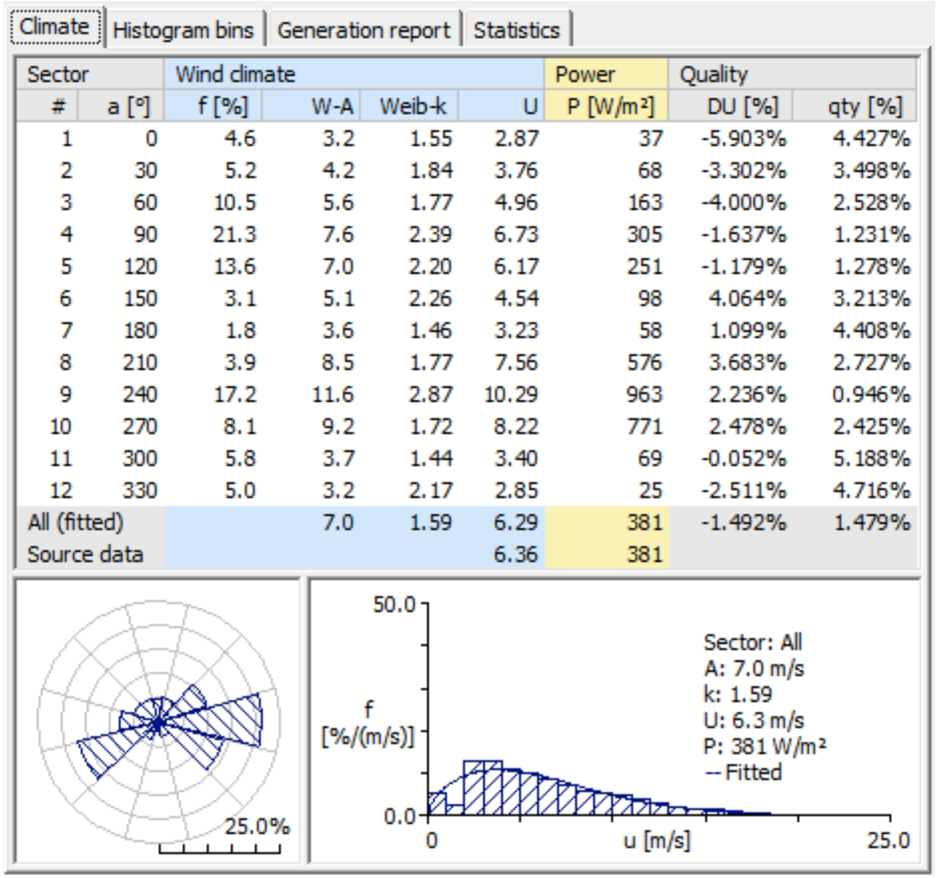
San Luis Potosí. February 2009. 50m



Sector		Wind climate				Power	Quality	
#	a [°]	f [%]	W-A	Weib-k	U	P [W/m²]	DU [%]	qty [%]
1	0	6.1	3.3	1.80	2.94	33	-4.072%	4.499%
2	30	5.6	3.8	1.63	3.41	59	-0.828%	3.598%
3	60	9.3	5.5	1.62	4.93	179	-3.115%	2.135%
4	90	23.2	8.1	2.85	7.18	328	3.029%	1.807%
5	120	14.3	7.5	2.19	6.64	314	0.530%	1.524%
6	150	4.2	4.3	1.51	3.86	95	1.766%	3.753%
7	180	2.2	3.1	1.70	2.75	29	7.924%	5.418%
8	210	4.7	6.4	1.39	5.85	375	3.044%	2.659%
9	240	12.2	9.9	2.15	8.73	728	3.315%	1.926%
10	270	6.8	5.2	1.17	4.89	303	-4.207%	3.064%
11	300	5.4	3.4	1.67	3.00	39	0.637%	3.657%
12	330	6.1	3.4	1.66	3.06	42	-1.297%	4.324%
All (fitted)			6.2	1.54	5.59	279	-0.492%	1.885%
Source data					5.58	279		

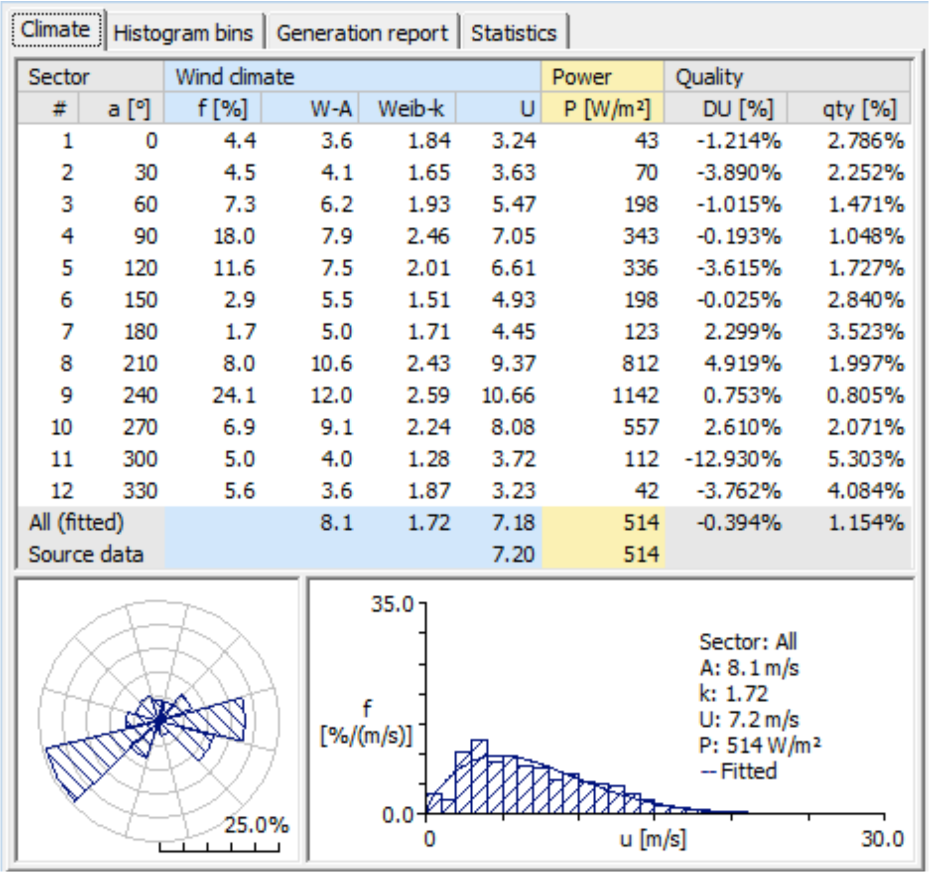
Sector: All
A: 6.2 m/s
k: 1.54
U: 5.6 m/s
P: 279 W/m²
-- Fitted

San Luis Potosí. March 2009. 50m



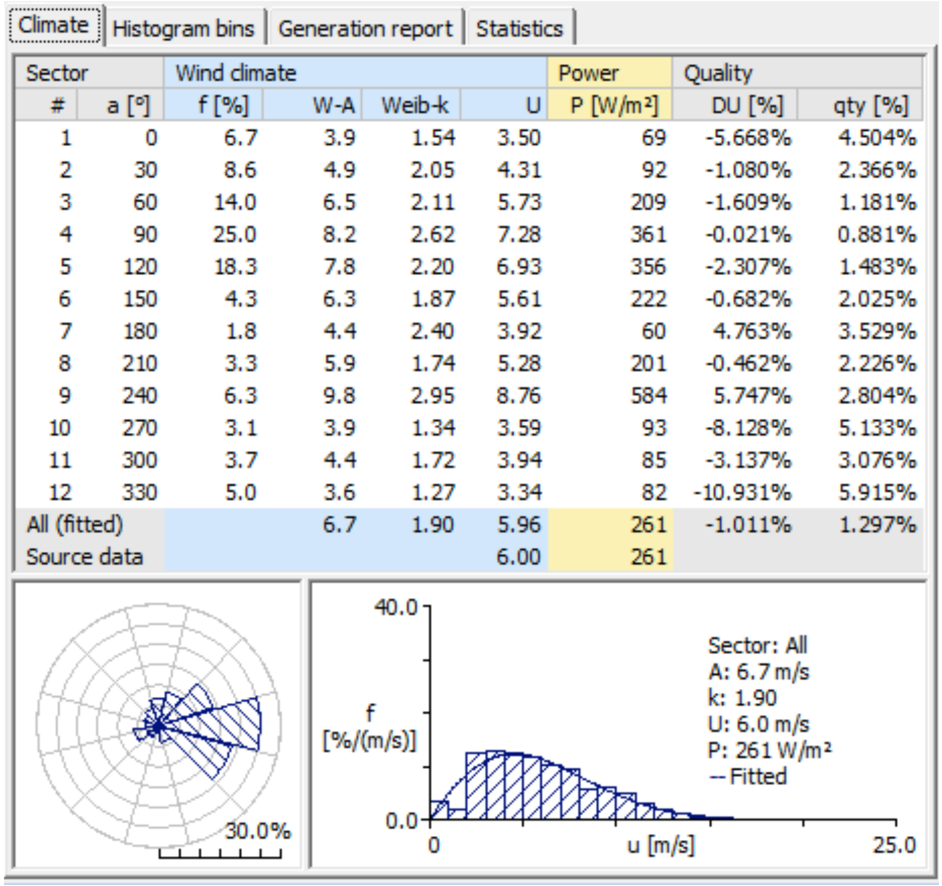
Sector		Wind climate				Power	Quality	
#	a [°]	f [%]	W-A	Weib-k	U	P [W/m²]	DU [%]	qty [%]
1	0	4.6	3.2	1.55	2.87	37	-5.903%	4.427%
2	30	5.2	4.2	1.84	3.76	68	-3.302%	3.498%
3	60	10.5	5.6	1.77	4.96	163	-4.000%	2.528%
4	90	21.3	7.6	2.39	6.73	305	-1.637%	1.231%
5	120	13.6	7.0	2.20	6.17	251	-1.179%	1.278%
6	150	3.1	5.1	2.26	4.54	98	4.064%	3.213%
7	180	1.8	3.6	1.46	3.23	58	1.099%	4.408%
8	210	3.9	8.5	1.77	7.56	576	3.683%	2.727%
9	240	17.2	11.6	2.87	10.29	963	2.236%	0.946%
10	270	8.1	9.2	1.72	8.22	771	2.478%	2.425%
11	300	5.8	3.7	1.44	3.40	69	-0.052%	5.188%
12	330	5.0	3.2	2.17	2.85	25	-2.511%	4.716%
All (fitted)			7.0	1.59	6.29	381	-1.492%	1.479%
Source data					6.36	381		

San Luis Potosí. April 2009. 50m



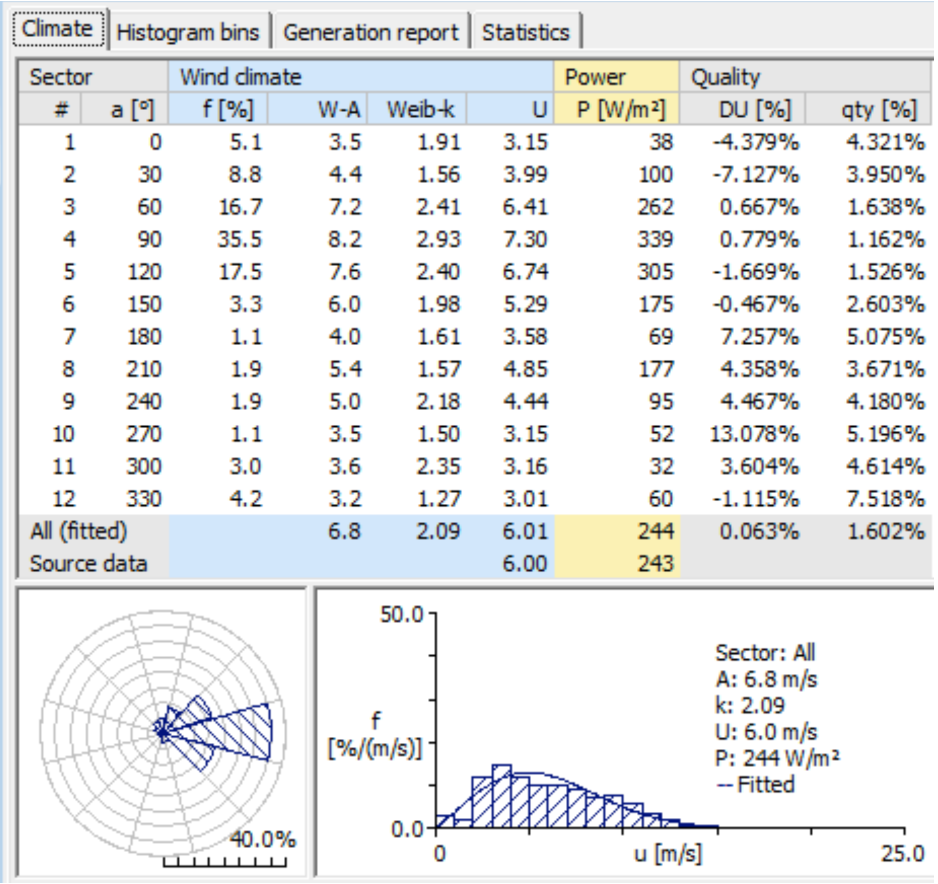
Sector		Wind climate				Power	Quality	
#	a [°]	f [%]	W-A	Weib-k	U	P [W/m²]	DU [%]	qty [%]
1	0	4.4	3.6	1.84	3.24	43	-1.214%	2.786%
2	30	4.5	4.1	1.65	3.63	70	-3.890%	2.252%
3	60	7.3	6.2	1.93	5.47	198	-1.015%	1.471%
4	90	18.0	7.9	2.46	7.05	343	-0.193%	1.048%
5	120	11.6	7.5	2.01	6.61	336	-3.615%	1.727%
6	150	2.9	5.5	1.51	4.93	198	-0.025%	2.840%
7	180	1.7	5.0	1.71	4.45	123	2.299%	3.523%
8	210	8.0	10.6	2.43	9.37	812	4.919%	1.997%
9	240	24.1	12.0	2.59	10.66	1142	0.753%	0.805%
10	270	6.9	9.1	2.24	8.08	557	2.610%	2.071%
11	300	5.0	4.0	1.28	3.72	112	-12.930%	5.303%
12	330	5.6	3.6	1.87	3.23	42	-3.762%	4.084%
All (fitted)			8.1	1.72	7.18	514	-0.394%	1.154%
Source data					7.20	514		

San Luis Potosí. May 2009. 50m



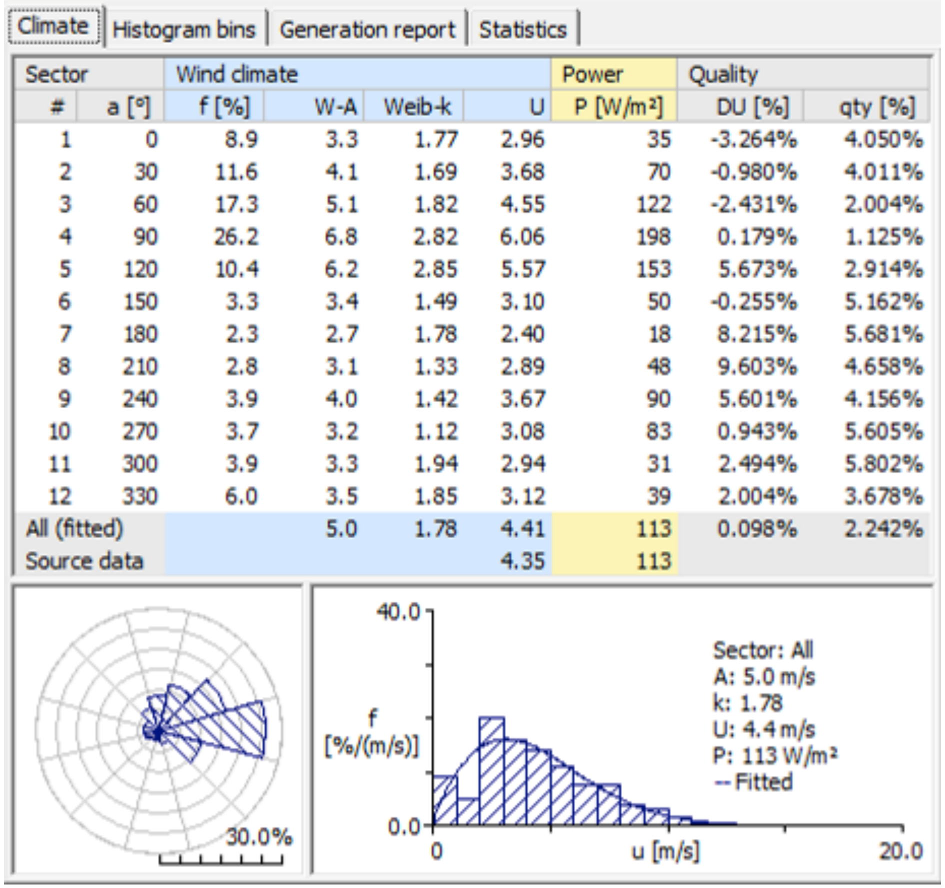
Sector		Wind climate				Power	Quality	
#	a [°]	f [%]	W-A	Weib-k	U	P [W/m²]	DU [%]	qty [%]
1	0	6.7	3.9	1.54	3.50	69	-5.668%	4.504%
2	30	8.6	4.9	2.05	4.31	92	-1.080%	2.366%
3	60	14.0	6.5	2.11	5.73	209	-1.609%	1.181%
4	90	25.0	8.2	2.62	7.28	361	-0.021%	0.881%
5	120	18.3	7.8	2.20	6.93	356	-2.307%	1.483%
6	150	4.3	6.3	1.87	5.61	222	-0.682%	2.025%
7	180	1.8	4.4	2.40	3.92	60	4.763%	3.529%
8	210	3.3	5.9	1.74	5.28	201	-0.462%	2.226%
9	240	6.3	9.8	2.95	8.76	584	5.747%	2.804%
10	270	3.1	3.9	1.34	3.59	93	-8.128%	5.133%
11	300	3.7	4.4	1.72	3.94	85	-3.137%	3.076%
12	330	5.0	3.6	1.27	3.34	82	-10.931%	5.915%
All (fitted)			6.7	1.90	5.96	261	-1.011%	1.297%
Source data					6.00	261		

San Luis Potosí. June 2009. 50m



Sector		Wind climate				Power	Quality	
#	a [°]	f [%]	W-A	Weib-k	U	P [W/m²]	DU [%]	qty [%]
1	0	5.1	3.5	1.91	3.15	38	-4.379%	4.321%
2	30	8.8	4.4	1.56	3.99	100	-7.127%	3.950%
3	60	16.7	7.2	2.41	6.41	262	0.667%	1.638%
4	90	35.5	8.2	2.93	7.30	339	0.779%	1.162%
5	120	17.5	7.6	2.40	6.74	305	-1.669%	1.526%
6	150	3.3	6.0	1.98	5.29	175	-0.467%	2.603%
7	180	1.1	4.0	1.61	3.58	69	7.257%	5.075%
8	210	1.9	5.4	1.57	4.85	177	4.358%	3.671%
9	240	1.9	5.0	2.18	4.44	95	4.467%	4.180%
10	270	1.1	3.5	1.50	3.15	52	13.078%	5.196%
11	300	3.0	3.6	2.35	3.16	32	3.604%	4.614%
12	330	4.2	3.2	1.27	3.01	60	-1.115%	7.518%
All (fitted)			6.8	2.09	6.01	244	0.063%	1.602%
Source data					6.00	243		

San Luis Potosí. September 2009. 50m



Sector		Wind climate				Power	Quality	
#	a [°]	f [%]	W-A	Weib-k	U	P [W/m²]	DU [%]	qty [%]
1	0	8.9	3.3	1.77	2.96	35	-3.264%	4.050%
2	30	11.6	4.1	1.69	3.68	70	-0.980%	4.011%
3	60	17.3	5.1	1.82	4.55	122	-2.431%	2.004%
4	90	26.2	6.8	2.82	6.06	198	0.179%	1.125%
5	120	10.4	6.2	2.85	5.57	153	5.673%	2.914%
6	150	3.3	3.4	1.49	3.10	50	-0.255%	5.162%
7	180	2.3	2.7	1.78	2.40	18	8.215%	5.681%
8	210	2.8	3.1	1.33	2.89	48	9.603%	4.658%
9	240	3.9	4.0	1.42	3.67	90	5.601%	4.156%
10	270	3.7	3.2	1.12	3.08	83	0.943%	5.605%
11	300	3.9	3.3	1.94	2.94	31	2.494%	5.802%
12	330	6.0	3.5	1.85	3.12	39	2.004%	3.678%
All (fitted)			5.0	1.78	4.41	113	0.098%	2.242%
Source data					4.35	113		

San Luis Potosí. October 2009. 50m