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In this paper, ten distribution functions are used to analyze the characteristics of wind speed at three selected regions (Tripoli, Nault, and Esspeea) in Libya. The monthly wind speed data are used and measured at 10m height. The results indicated that the mean monthly wind speeds in the studied regions are within the range of 2.121 m/s to 4.349 m/s at 10m height. Annual distribution parameters are calculated for each distribution using Maximum likelihood method. Kolmogorov–Smirnov (KS) statistic is determined to evaluate the distribution suitability to fit the actual wind speed data. In addition, the wind power density at each region is calculated. The results showed that Nault has the highest mean actual wind power (50.3W/m^2) compared with Tripoli (30.972W/m^2) and Esspeea (5.844W/m^2). Moreover, since the hub height of many wind turbines is higher than the measurement height, the distribution parameters and wind power density are estimated at various heights using power law method. The result demonstrated that small-scale wind turbines can be exploited the wind at different regions. Consequently, the present value cost method (PVC) is used to evaluate energy cost of electricity using various wind turbine models. Economically, the lowest value of electricity cost was obtained from Finn Wind Tuule C 200 with a value of 0.001427 \$/kW for Tripoli, 0.0010 \$/kW for Nault and 0.013194\$/kW for Esspeea.

Keyword: Economic analysis; Libya; horizontal axis wind turbines; statistical distribution; vertical axis wind turbine; wind speed characteristics

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A THESIS SUBMITTED TO THE GRADUATE SCHOOL OF APPLIED SCIENCES OF NEAR EAST UNIVERSITY

By
MOHAMED ABDUALATIH ABUGHARARA

In Partial Fulfillment of the Requirements for the Degree of Master of Science in Mechanical Engineering

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Approval of Director of Graduate School of

Applied Sciences

Prof. Dr. Nadire ÇAVUŞ

We certify this thesis is satisfactory for the award of the degree of Master of Science in Civil Engineering

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I hereby declare that, all the information in this document has been obtained and presented in accordance with academic rules and ethical conduct. I also declare that, as required by these rules and conduct, I have fully cited and referenced all material and results that are not original to this work.

Name, Last Name: **Mohamed Abugharara**

Signature:

Date:

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To my parents ...

ABSTRACT

In this paper, ten distribution functions are used to analyze the characteristics of wind speed at three selected regions (Tripoli, Nault, and Esspeea) in Libya. The monthly wind speed data are used and measured at 10m height. The results indicated that the mean monthly wind speeds in the studied regions are within the range of 2.121 m/s to 4.349 m/s at 10m height. Annual distribution parameters are calculated for each distribution using Maximum likelihood method. Kolmogorov–Smirnov (KS) statistic is determined to evaluate the distribution suitability to fit the actual wind speed data. In addition, the wind power density at each region is calculated. The results showed that Nault has the highest mean actual wind power (50.3W/m^2) compared with Tripoli (30.972W/m^2) and Esspeea (5.844W/m^2). Moreover, since the hub height of many wind turbines is higher than the measurement height, the distribution parameters and wind power density are estimated at various heights using power law method. The result demonstrated that small-scale wind turbines can be exploited the wind at different regions. Consequently, the present value cost method (PVC) is used to evaluate energy cost of electricity using various wind turbine models. Economically, the lowest value of electricity cost was obtained from Finn Wind Tuule C 200 with a value of 0.001427 \$/kW for Tripoli, 0.0010 \$/kW for Nault and 0.013194\$/kW for Esspeea.

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ÖZET

Bu yazıda, Libya'da seçilen üç bölgede (Trablus, Nault ve Esspeea) rüzgar hızının özelliklerini analiz etmek için on dağıtım işlevi kullanılmıştır. Aylık rüzgar hızı verileri, 10 m yükseklikte kullanılır ve ölçülür. Sonuçlar, çalışılan bölgelerdeki aylık ortalama rüzgar hızlarının 10 m yükseklikte 2,121 m / s ila 4,349 m / s aralığında olduğunu göstermiştir. Yıllık dağılım parametreleri, her bir dağılım için Maksimum olabilirlik yöntemi kullanılarak hesaplanmaktadır. Kolmogorov-Smirnov (KS) istatistiği, gerçek rüzgar hızı verilerine göre dağıtım uygunluğunu değerlendirmek için belirlenir. Ek olarak, her bölgedeki rüzgar gücü yoğunluğu hesaplanmaktadır. Sonuçlar Nault'un Trablus (30.972W / m2) ve Esspeea'ya (5.844W / m2) kıyasla en yüksek ortalama gerçek rüzgar gücüne (50.3W / m2) sahip olduğunu gösterdi. Ayrıca, birçok rüzgar türbininin göbek yüksekliği ölçüm yüksekliğinden daha yüksek olduğundan, dağıtım parametreleri ve rüzgar gücü yoğunluğu, güç yasası yöntemi kullanılarak çeşitli yüksekliklerde tahmin edilmektedir. Sonuç, küçük ölçekli rüzgar türbinlerinin farklı bölgelerde rüzgardan yararlanılabileceğini göstermiştir. Sonuç olarak, bugünkü değer maliyet yöntemi (PVC), çeşitli rüzgar türbini modelleri kullanılarak elektriğin enerji maliyetini değerlendirmek için kullanılır. Ekonomik olarak, elektrik maliyetinin en düşük değeri, Finn Wind Tuule C 200'den, Tripoli için 0.001427 $ / kW, Nault için 0.0010 $ / kW ve Esspeea için 0.013194 $ / kW değerlerinde elde edildi.

Kelimeler: Ekonomik analiz; Libya; yatay eksenli rüzgar türbinleri; istatistiksel dağılım; dikey eksenli rüzgar türbini; rüzgar hızı özellikleri

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A: Swept area

C_{omr}: Cost of operation and maintenance

CF: Capacity factor

C_p: Coefficient of performance

d: Distance from the sun

E: Total amount of wind energy density

E_{wt}: Total energy generated

$f(v)$: The probability density function

i: Inflation rate

I: Investment

J: The intensity of the radiation

n: Life time of wind turbine

P: The power of electromagnetic radiation

$\overline{P}$: Mean power density

P_r: Rated power of wind turbine

P_{wt}: Output power of wind turbine

v: Wind speed

v_{ci}: The cut-in wind speed

v_{co}: Cut-off wind speed

v_i: Vector of possible wind speed

v_r: Rated wind speed

v_{10}: The wind speed at original height

T: The period in hours

z: Wind turbine hub height

z_{10}: Measurement height (10m height)

ρ: Air density

α: Surface roughness

CHAPTER 1
INTRODUCTION

1.1 Background

Libya is a North African country bordered by the Mediterranean Sea to the north, Egypt to the east, Sudan to the southeast, Chad and the Niger to the south, Algeria to Tunisia to the west (Davies, 2009). It has an area of nearly 1.8 million square kilometers (700,000 square miles) and Libya is the fourth largest country in Africa and occupies the 17th largest country in the world. Ranking ninth among 10 countries with the world's largest proven oil reserves (Hubbard, 2014). The increases of populations and energy demand have increased in recent years the significance of renewable energy as alternative source.

Renewable energy sources are considered as clean alternatives to fossil fuels that can provide sustainable energy solutions (Ishaq et al., 2018; Woldeyohannes et al., 2016; Owus and Asumadu-Sarkodie, 2016). Renewable energies such as wind energy are recognized as alternative resources for generating electricity in the future (Razmjoo et al., 2017). A key advantage of wind energy is that they avoid carbon dioxide emissions (Best and Burke, 2018).Wind energy can be converted directly into electricity using wind turbines (Chang and Starcher, 2019). It now used extensively for meeting the electricity demand in many countries such India (Khare et al., 2013), Pakistan (Kamra, 2018), Turkey (Kaplan, 2015) and Saudi Arabia (Düştegör et al., 2018).

Several researchers have studied the wind potential of various locations around the world. For instance, Alayat et al. (2018) evaluate the wind potential and estimate the electricity cost per kWh using small-scale vertical axis wind turbine at eight selected regions in Northern Cyprus. The results showed that Aeolos-V2 with a rating of 5kWuse could be suitable for generating electricity in the studied locations.

Kassem et al. (2018) evaluated the economic feasibility of 12MW grid-connected wind farms and PV plants for producing electricity in Girne and Lefkoşa in Northern Cyprus.

The authors concluded that PV plants are the most economical option compared to wind farms for generating electricity in the studied regions.

Kassem et al. (2018) analyzed the wind power potential in the Salamis region of Northern Cyprus. They found that high capacity wind turbines (MW) are not suitable for electricity production in the region based on the value of wind power density.

Solyali et al. (2016) studied the wind power potential for the Selvili-Tepe location in Northern Cyprus. The authors found that the wind energy resources at this location are classified as marginal (wind power class is 2).

Azad et al. (2014) investigated the wind energy assessment at different hub heights in desired locations using the Weibull distribution function. The results showed that the wind power sources in the site are categorized as poor.

Albani and Ibrahim (2017) analyzed the wind energy potential at three coastal locations in Malaysia. They concluded that the production of wind energy is only feasible and practical at certain locations in Malaysia.

1.2 Objectives of the Research

To our knowledge, no studies have been carried out so far on this area of Libya. This work is divided into two objectives.

First objective, the wind speed characteristics, and wind potential are analyzed at three selected regions; namely, Tripoli, Nault, and Esspeea during various years. The second objective of this current work is to estimate the electricity generated cost of three different wind turbine models using present value of costs (PVC) method.

To achieve these objectives, ten distribution functions and power law method are used to present the characteristics of the wind turbines in this study.

1.3 Thesis Outlines

Chapter 1 is provided a short description of renewable energy in terms of wind and solar energy and the objective of this work. In chapter 2 is explained the fundamental concept of renewable energy and wind turbine. Chapter 3 is described the methods used to analyze the climate data including wind, solar radiation and sunshine duration. In addition, simulation tools that used to study the economic evolution of renewable rooftop system are explained. The electricity cost generated by renewable system and environmental effect is discussed in chapter 4. The conclusion on the current study is described in chapter 5.

CHAPTER 2
RENEWABLE ENERGY AND ECONOMIC ANALYSIS

2.1 Renewable energy

Among the naturally existing phenomenon on the earth surface is the wind, which we deal with on a regular basis if not in our daily lives. The directional air movement in the atmosphere towards a specific bearing at a certain speed is referred to as the wind. The difference existing between the distinguished pressure points results to the direction at which the wind movement will be, which always goes towards the direction of the lower pressure, and being dependent on the speed of the amount of pressure prevailing between the two points.

For over a century, the wind power has been utilized in a variety of fields. Pushing sailboats and grinding grains are amongst the most popular tasks that are performed by applying wind power via windmills converting mechanical energy to electrical energy and for pumping water. The wind power gained more interest all over the world after the discovery of numerous uses of fossil fuels and its harmful effect, as well as the fear of its depletion (Owusu and Asumadu-Sarkodie, 2016).

Electric power generation using wind power, are generating electricity from wind using turbines, which was the first time the conversion of wind energy into electrical energy was performed in Scotland in the year 1887 (Price, 2005). However, this invention for its high cost did not succeed; however, scientists later developed continuously various means to exploit wind power generation.

The wind power against the turbine is enough to generate electricity for the entire cities all as a whole. The turbines in variety of shapes, sizes, and as regards to the purpose they are to serve are connected to electricity generators and are placed at highly windy areas. The fans of the turbines are moved by the wind to generate electricity. Numerous wind farms exist around the world that generates thousands of megawatts, example of these farms exist in China and the United States (International Energy Agency, 2017).

Energy is an essential component of the universe and one of the forms of existence. Energy is usually derived from both natural and non-natural sources, so it is divided into two main types: renewable energy (Figure 2.1), which is dependent on natural resources, non-renewable and dependent on non-natural sources, but formed over time and under a combination of factors.

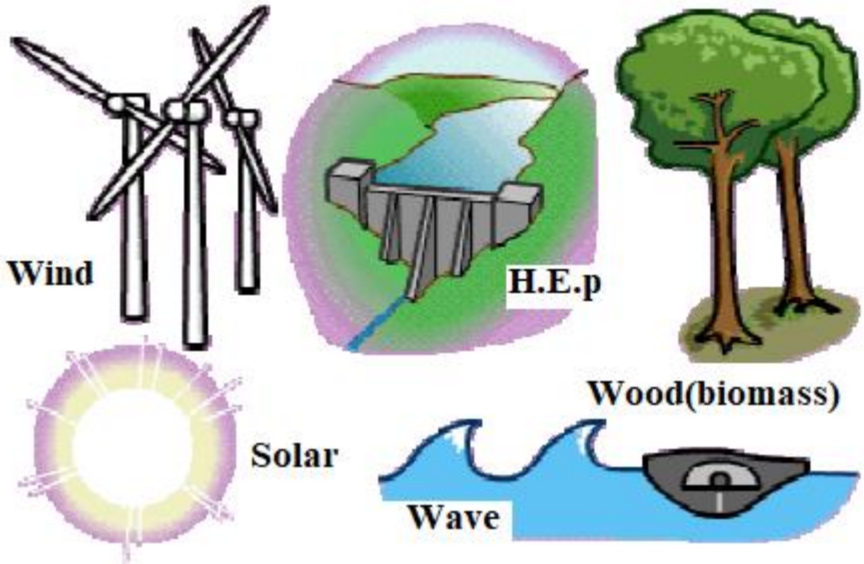

Figure 2.1: Renewable energy sources

When we look at the environment around us, we will notice large quantities of energy, which are clean and present periodically, leading to a good definition of renewable energy, which is a permanent energy in nature and generated naturally. Because the sun, for example, supplies the globe with light and heat, but with the development of technology, it has been helping to generate energy. It is not only energy, but also the energy needed to capture energy from nature.

Renewable energy has proved its importance and its many advantages have achieved its important status as an alternative energy for the future instead of the fossil fuels that will be depleted one day. You need simple and inexpensive machinery to physically convert renewable energy into any other form of energy used in homes, institutions, factories and others. The constant availability of this type of energy and each country can rely on the source most available.

For example, Arab countries, where the sun shines most months of the year, can use solar energy to generate electricity and water heating and others. Renewable energy is clean and environmentally friendly and does not result in the use of any toxic, harmful, solid or liquid residues or gases emitted into the air, spilled in water or buried underground. The use of natural forces in the production of energy reduces its destructive damage, for example, the spread of solar panels limits the temperature rise.

2.2 Solar Energy

The sun or the heart of the solar system, the closest star to the Earth, estimated at 26,000 light years, is estimated to be 4.5 billion years old. The massive gravity of the sun is responsible for the stability of the solar system to prove all the components of the solar system from large planets to small parts.

Solar energy, or solar radiation, is the energy that is emitted from the sun mainly in the form of heat and light. It is the result of the nuclear interactions within the star closest to us, the sun. This energy is very important in the Earth and the organisms on its surface The amount of this energy is far superior to the current energy requirements in the world in general, and if harnessed and exploited appropriately may meet all future energy needs.

The importance of solar energy lies in the fact that sunlight has facilitated the evolution of organisms and is responsible for photosynthesis in plants to produce food and biomass as well as the role of these rays in hydropower and wind. In addition, the growth of crops and food drying to prevent it from damage as well as the use of greenhouses to raise the heat. In addition, solar energy is responsible for the so - called renewable energy sources and most important, and the importance of increasing solar energy as a source of energy Of renewable because it is not decreasing, The emitted radiation is removed actinic by the aster to the space and the intensity of the radiation J, is calculated according to the equation below:

$$J = \frac{P}{4\pi d^2} \quad (2.1)$$

Where P is the power of electromagnetic radiation and d is the distance from the sun.

For solar cells, which convert sunlight into direct electricity, the amount of energy generated in a single cell is relatively small so it is necessary to collect a large number of cells together in the solar panels on the roofs of buildings to generate sufficient energy

2.3 Wind Energy

Wind energy is considered a type of solar power. This energy (also known as wind power) illustrates the mechanism by which wind is utilized in generating electricity. Wind turbines convert the kinetic energy in the wind into mechanical power. An electrical generator on the other hand has the capability of converting mechanical power into electricity. This mechanical energy is then used in particular areas, for example water pumps.

There is a number of reasons which causes the wind. One reason is assigned to the thermal heat radiating by the sun, which is then heated in the atmosphere in an unevenly manner. Another is because the earth rotates around its own axis. And the discrepancy in the levels of the earth also causes the wind.

Regardless of the speedy improvement of the wind power in recent times, its future remains unclear and so ambiguous. Even though about fifty countries in the world are currently utilizing wind power, with the greatest effort of few countries under the lead of Germany, Spain, and Denmark. It will be necessary for other countries to radically raise the standard of their industries for wind energy generation to bring about realization of overall goals. Hence, the prediction that 12% of the used energy all over the world by 2020 will be from wind power is not to be considered definite as shown in Figure 2.2 (International Energy Agency2018).

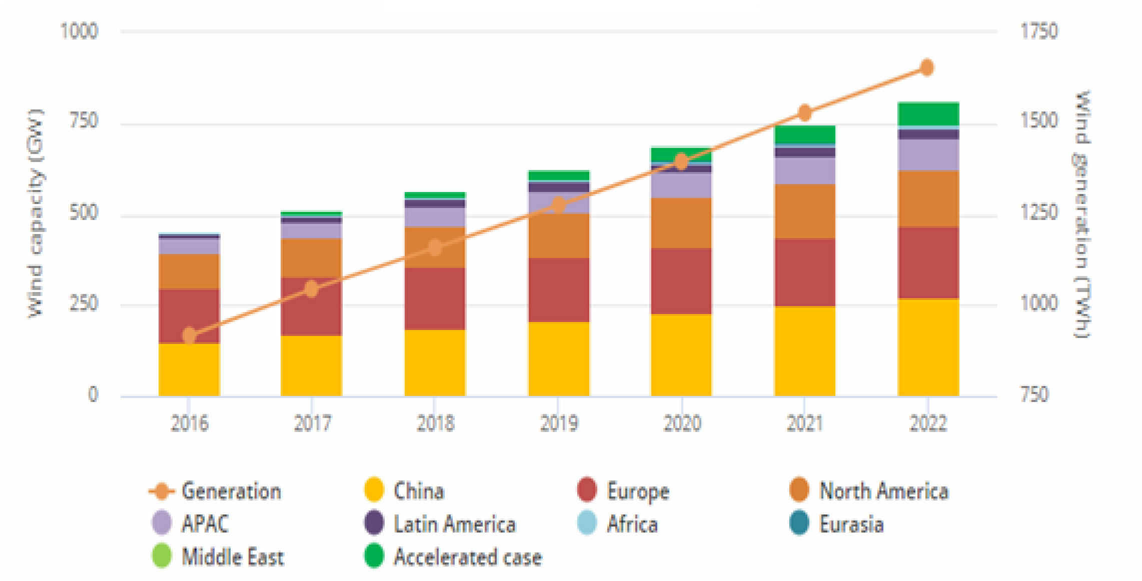

Figure 2.2: Annual rate of wind power generation (International Energy Agency2018)

Wind turbines are classified into two; Vertical Axis Wind Turbines (VAWT) and Horizontal Axis Wind Turbines (HAWT) (Hemami, 2012; Tong, 2010). The HAWT have axis of their rotation parallel to the earth surface. It could be mounted directly facing the wind or in opposition to the wind direction. The wind turbines are usually affected by the wind in a direct manner. The VAWT has its axis of rotation perpendicular to the earth surface. Both categories could be adopted for generating electricity, however, VAWT are mostly utilized for mechanical activities like water pumping (Hemami, 2012; Tong, 2010).

Currently, wind turbines are manufactured in a wide variety of types in the form of vertical and horizontal turbines due to nearly a thousand years of improvement and engineering carried out in windmills. Small sized turbines are deployed for numerous kind of usages like charging of batteries for boats and energy powered road traffic symbols. The larger sized turbines could be utilized in making a significantly small contribution to the source of power while selling out the unutilized power of the resource through the electrical grid. Numerous large turbines known as wind farms are currently transforming into highly significant sources of renewable energy. These turbines are now being utilized by many countries as a way to reduce the consumption of fossil fuels.

2.4 Mean wind power density and energy density

The theoretically available kinetic energy that wind possesses at a certain location can be expressed as the mean wind power density (WPD). In other words, it is the maximum available wind power at each unit area. The mathematical expression for wind power density is given with the following relation (Irwanto et al., 2014; Ayodele et al., 2013):

$$\frac{\bar{P}}{A} = \frac{1}{2}\rho\bar{v}^3 \qquad (2.2)$$

Periodic wind power density per unit area (Monthly or annually) is given with the following expression (Ayodele et al., 2013):

$$\frac{\bar{P}}{A} = \frac{1}{2}\rho\bar{v}^3 \, f(v) \qquad (2.3)$$

where $\overline{P}$ is the available power for wind per unit area in W/m^2 , $f(v)$ is the probability density function and ρ is the density of air in kg/m^3.

The total amount of wind energy density (Wh/m^2) for a specific period can be calculated with the following equation (Irwanto et al., 2014):

$$E = \bar{P}T \qquad (2.4)$$

where T is the period in hours (8760h).

2.5 Wind speed at different hub height

In order to determine the energy produced by the wind turbine, the power law model is used to estimate the wind speed at different hub heights (Irwanto et al., 2014; Masseran, 2015).

$$\frac{v}{v_{10}} = \left(\frac{z}{z_{10}}\right)^{\alpha} \tag{2.5}$$

where v is the wind speed at the wind turbine hub height z, v_{10} is the wind speed at original height z_{10}, and α is the surface roughness coefficient (Eq. (12)).

$$\alpha = \frac{0.37 - 0.088 ln(v_{10})}{1 - 0.088 ln(z_{10}/10)} \tag{2.6}$$

2.6 Wind turbine energy output and capacity factor

The output power of wind turbine (P_{wt}) is estimated from the wind speed of the specific region and the characteristics of the wind turbine (Ayodele et al., 2013; Pallabazzer, 2003). It is expressed as

$$P_{wt(i)} = \begin{cases} \mathrm{P_r} \dfrac{v_i^2 - v_{ci}^2}{v_r^2 - v_{ci}^2} & v_{ci} \leq v_i \leq v_r \\ \dfrac{1}{2}\rho A C_p v_r^2 & v_r \leq v_i \leq v_{co} \\ 0 & v_i \leq v_{ci} \; and \; v_i \geq v_{co} \end{cases} \tag{2.7}$$

where v_i is the vector of possible wind speed at a given site, $P_{wt(i)}$ is the vector of corresponding wind turbine output power (W), $\mathrm{P_r}$ is the rated power of the turbine (W), v_{ci} is the cut-in wind speed (m/s), v_r is the rated wind speed (m/s) and v_{co} is the cut-off wind speed (m/s) of the wind turbine. The coefficient of performance (C_p) can be calculated as

$$C_p = 2\frac{P_r}{\rho A v_r^3} \tag{2.8}$$

The total energy generated (E_{wt})by the operation of the wind turbine over a period (t) can be determined as (Ayodele et al., 2013):

$$E_{wt} = \sum_{i=1}^{n} P_{wt(i)} \times t \tag{2.9}$$

Finally, the capacity factor (CF) of a wind turbine can be estimated as (Ayodele et al., 2013):

$$CF = \frac{E_{wt}}{P_r.t} \tag{2.10}$$

2.7 Economic analysis of wind turbines

The capital cost of the project, cost of operation and maintenance system and the economic design life of the turbine are the main factors that govern wind power costs at a specific region (Gökçek and Genç , 2009; Gölçek, et al., 2007). The present value of costs (PVC) method is widely used to determine the wind energy cost (Adaramola et al., 2011; Ohunakin et al., 2013). It can be expressed as

$$PVC = \left[I + C_{omr}\left(\frac{1+i}{r-i}\right) \times \left[1 - \left(\frac{1+i}{1+r}\right)^n\right] - S\left(\frac{1+i}{1+r}\right)^n\right] \tag{2.11}$$

where r is the discount rate, *i* is the inflation rate, *n* is the machine life as designed by the manufacturer, C_{omr} is the cost of operation and maintenance, *I* is the investment summation of turbine price and other initial costs, including provisions for civil work, land, infrastructure, installation and grid integration, and *S* is the scrap value of the turbine price and civil work.

The electricity generated cost per kWh (EGC) can be estimated as (Adaramola et al., 2011; Ohunakin et al., 2013):

$$EGC = \frac{PVC}{t \times P_r \times CF} \tag{2.12}$$

CHAPTER 3
METHODOLOGY

3.1 Materials and Methods

In this section, the statistical analysis of wind speed measured at a height of 10m at three regions in Libya is discussed. Ten distributions are used to determine the wind power density at the studied regions. The power law method is utilized to estimate the wind speed at various hub heights. The annual energy outputs, capacity factors and electricity-generated cost were derived for small-scale wind turbines of various sizes and type. Figure 3.1 illustrates the procedure analysis of the current study.

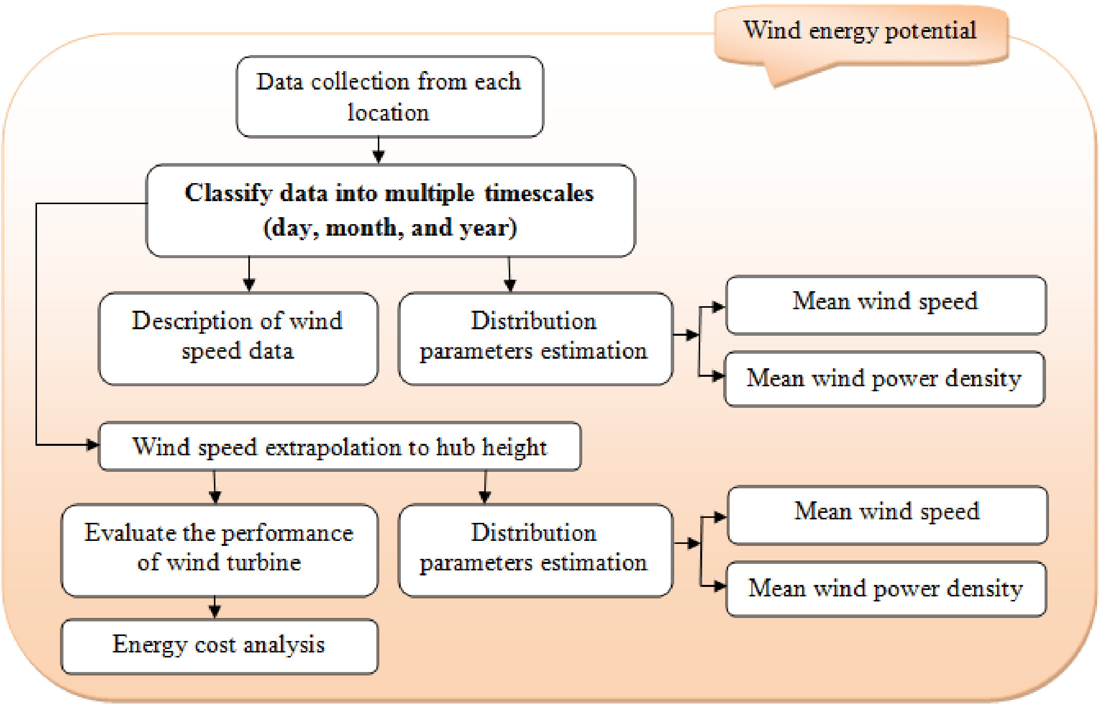

Figure 3.1: The flowchart for analysis steps of the study

3.2 Wind Data Source

Figure 3.2 shows the locations of the selected regions (Tripoli, Nalut, and Esspeea) considered in this study. Table 3.1 presents the information of the studied regions in terms of longitude, latitude, measurement height, and the period.

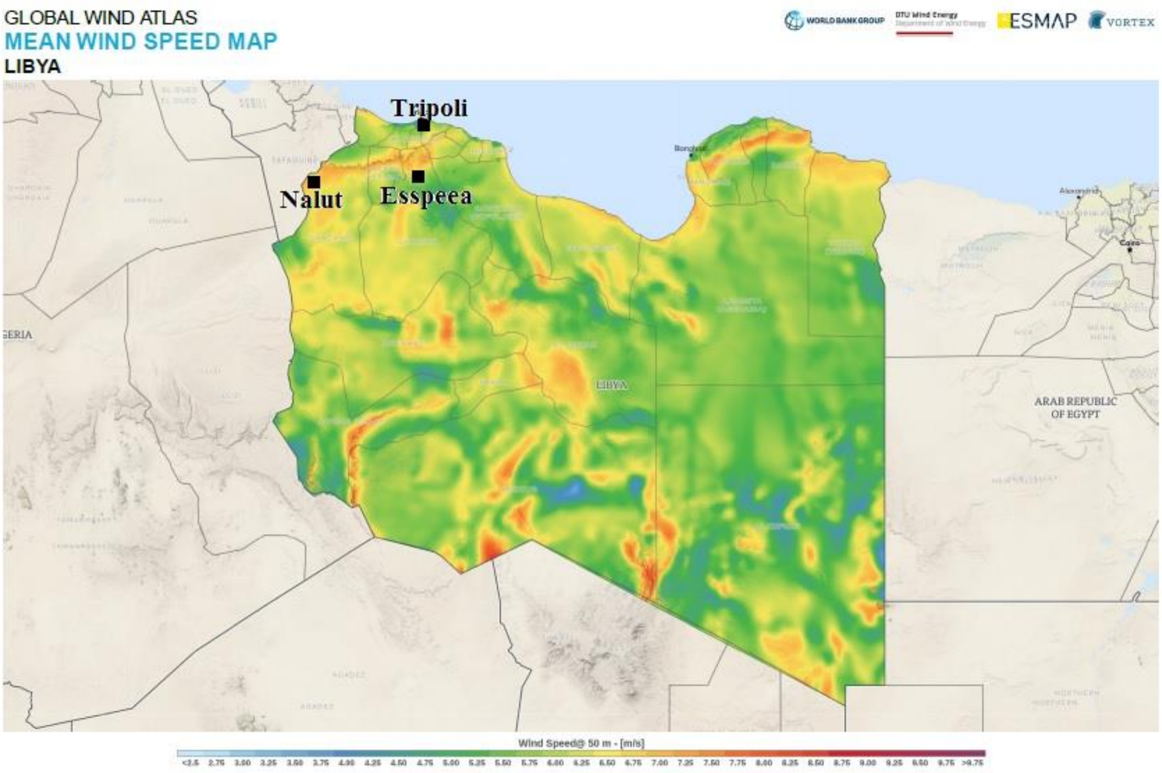

Figure 3.2: Wind Atlas map of Libya at 50m height

Table 3.1: Summarization of meteorological locations adopted in this study

Region	Longitude (°E)	Latitude (°N)	Altitude [m]	Period records	Height [m]	Year
Tripoli	32.892	13.173	81	1981-2010	10	30
Nault	31.874	10.979	568	1981-2010	10	30
Esspeea	32.892	13.173	73	1993-2009	10	17

3.3 Description of the Selected Regions

3.3.1 Tripoli

Tripoli is the capital of Libya and its largest city. It has a population of (940,653) thousand in 2012, located in the north-west of Libya. The city is built on a rocky top overlooking the Mediterranean Sea opposite the southern tip of the island of Sicily. It is bordered by the Tajoura area, west of Janzur, south of the Suwani area, and the Mediterranean Sea to the north.

3.3.2 Nault

Nalut Libyan city, the center of the province of Nalut in the mountain "Nafusa mountain", located 276 kilometers from the capital city of Tripoli, at latitude (31.52) and on a longitude (10.59) degree. Nalut is one of the third largest mountain ranges after Green and Yefran, the last of these cities in the West. The importance of the city dates back to its position on the coastline between the Sahel and the Sahara and its proximity to the Tunisian-Algerian border.

3.3.3 Esspeea

Esspeea is a residential and agricultural area of Libya located south of Tripoli on the outskirts of the town of Qasr Ben Ghachir in the north, and up to the mountain of Gharyan in the south and its elevation from the sea surface is about 73 meters and has a semi-rocky climate. It is less than 40 kilometers south of Tripoli.

3.4 Distribution Functions and Estimation Model

Wind speed data are significantly required for the assessment of renewable resources. Several distribution functions provide wind speed data for chosen regions (Ouarda et al., 2015; Aries et al., 2018; Allouhi et al., 2017). In the current study, ten different probability distribution functions are utilized to study of the wind speed distribution at the studied regions. The probability distribution function (PDF) and cumulative distribution function (CDF) of the ten distribution functions used in this study can be expressed as follow

Weibull distribution function (W)

The Weibull distribution of wind speed is represented as a probability distribution function (PDF) and as a cumulative distribution function (CDF) given as

$$PDF = \left(\frac{k}{c}\right)\left(\frac{v}{c}\right)^{k-1} exp\left(-\left(\frac{v}{c}\right)^{k}\right) \tag{3.1}$$

$$CDF = 1 - exp\left(-\left(\frac{v}{c}\right)^{k}\right) \tag{3.2}$$

Gamma Distribution function (G)

The probability distribution function (PDF) and cumulative distribution function (CDF) of Gamma distribution function can be given as

$$PDF = \frac{v^{\beta-1}}{\alpha^{\beta}\Gamma(\beta)} exp\left(-\frac{v}{\beta}\right) \tag{3.3}$$

$$CDF = \frac{\gamma\left(\beta, \frac{v}{\alpha}\right)}{\Gamma(\beta)} \tag{3.4}$$

Log-normal Distribution function (LN)

The following equation presents how the PDF of this function could be determined as

$$PDF = \frac{1}{v\sigma\sqrt{2\pi}} exp\left[-\frac{1}{2}\left(\frac{ln(v) - \mu}{\sigma}\right)^{2}\right] \tag{3.5}$$

The cumulative distribution is given by:

$$CDF = \frac{1}{2} + erf\left[\frac{ln(v) - \mu}{\sigma\sqrt{2}}\right] \tag{3.6}$$

Logistic Distribution function (L)

The Logistic distribution is given by:

$$PDF = \frac{exp\left(-\frac{v-\mu}{\sigma}\right)}{\sigma\left\{1 + exp\left(-\frac{v-\mu}{\sigma}\right)\right\}^2} \tag{3.7}$$

The Logistic cumulative distribution is given by:

$$CDF = \frac{1}{1 + exp\left(-\frac{v-\mu}{\sigma}\right)} \tag{3.8}$$

Log-logistic distribution function (LL)

This function is applied to distribute the logistic form logarithmic variables of the wind speed. It is given by:

$$PDF = \left(\left(\frac{\beta}{\alpha}\left(\frac{v}{\alpha}\right)^{\beta-1}\right) \Big/ \left(1 + \frac{v}{\alpha}\right)^{\beta}\right)^2 \tag{3.9}$$

The Log-logistic cumulative distribution is given by:

$$CDF = \frac{1}{\left(1 + \frac{v}{\alpha}\right)^{-\beta}} \tag{3.10}$$

Inverse Gaussian distribution function (IG)

The Inverse Gaussian distribution of wind speed is represented as a probability distribution function (PDF) and as a cumulative distribution function (CDF) given as

$$PDF = \left(\frac{\lambda}{2\pi v^2}\right)^{1/2} e^{\left[\frac{-\lambda(v-\mu)^2}{2\mu^2 v}\right]} \tag{3.11}$$

$$CDF = \Phi\left(\sqrt{\frac{\lambda}{v}}\left(\frac{v}{\mu}-1\right)\right) + exp\left(\frac{2\lambda}{\mu}\right)\Phi\left(-\sqrt{\frac{\lambda}{v}}\left(\frac{v}{\mu}+1\right)\right) \tag{3.12}$$

Generalized Extreme Value distribution function (GEV)

The following equation presents PDF and CDF of this function that could be determined as

$$PDF = \frac{1}{\alpha}\left[1-\frac{\zeta(v)-\mu}{\alpha}\right]^{\frac{1}{\zeta}-1} exp\left[-\left(1-1-\frac{\zeta(v)-\mu}{\alpha}\right)^{\frac{1}{\zeta}}\right] \tag{3.13}$$

$$CDF = exp\left[-\left(1-1-\frac{\zeta(v)-\mu}{\alpha}\right)^{\frac{1}{\zeta}}\right] \tag{3.14}$$

Nakagami distribution function (Na)

Nakagami distribution is one of the common distributions in communication system. it is given by:

$$PDF = \frac{2m^m}{\Gamma(m)\Omega^{\mathrm{m}}} v^{2m-1} e^{\left(-\frac{m}{\Omega}G^2\right)} \tag{3.15}$$

The cumulative distribution function (CDF) written by:

$$CDF = \frac{\gamma\left(m, \frac{m}{\Omega}v^2\right)}{\Gamma(m)} \tag{3.16}$$

Normal distribution function (N)

The normal distribution is the most common statistical distribution function used in the various nature problems. PDF and CDF are given as follow

$$PDF = \frac{1}{\sqrt{2\pi\sigma^2}} exp\left(-\frac{v-\mu}{2\sigma^2}\right) \tag{3.17}$$

Rayleigh distribution function (R)

The Rayleigh probability density function is expressed as

$$PDF = \frac{2v}{c^2} e^{-\left(\frac{v}{c}\right)^2} \tag{3.18}$$

The corresponding cumulative probability function of Rayleigh distribution

$$CDF = 1 - exp\left[-\left(\frac{v}{c}\right)^2\right] \tag{3.19}$$

Table 3.2 is summarized PDF and CDF of the ten distribution functions used in the study.

Table 3.2: Expressions of statistical distributions used in this study

Distribution function	PDF	CDF
Weibull (W)	$PDF = \left(\frac{k}{c}\right)\left(\frac{v}{c}\right)^{k-1} exp\left(-\left(\frac{v}{c}\right)^{k}\right)$	$CDF = 1 - exp\left(-\left(\frac{v}{c}\right)^{k}\right)$
Gamma (G)	$PDF = \frac{v^{\beta-1}}{\alpha^{\beta}\Gamma(\beta)} exp\left(-\frac{v}{\beta}\right)$	$CDF = \frac{\gamma\left(\beta, \frac{v}{\alpha}\right)}{\Gamma(\beta)}$
Lognormal (LN)	$PDF = \frac{1}{v\sigma\sqrt{2\pi}} exp\left[-\frac{1}{2}\left(\frac{ln(v)-\mu}{\sigma}\right)^{2}\right]$	$CDF = \frac{1}{2} + erf\left[\frac{ln(v)-\mu}{\sigma\sqrt{2}}\right]$
Logistic (L)	$PDF = \frac{exp\left(-\frac{v-\mu}{\sigma}\right)}{\sigma\left\{1 + exp\left(-\frac{v-\mu}{\sigma}\right)\right\}^{2}}$	$CDF = \frac{1}{1 + exp\left(-\frac{v-\mu}{\sigma}\right)}$
Log-Logistic (LL)	$PDF = \left(\left(\frac{\beta}{\alpha}\left(\frac{v}{\alpha}\right)^{\beta-1}\right) \Big/ \left(1+\frac{v}{\alpha}\right)^{\beta}\right)^{2}$	$CDF = \frac{1}{\left(1+\frac{v}{\alpha}\right)^{-\beta}}$
Inverse Gaussian (IG)	$PDF = \left(\frac{\lambda}{2\pi v^{2}}\right)^{1/2} e^{\left[\frac{-\lambda(v-\mu)^{2}}{2\mu^{2}v}\right]}$	$CDF = \Phi\left(\sqrt{\frac{\lambda}{v}}\left(\frac{v}{\mu}-1\right)\right) + exp\left(\frac{2\lambda}{\mu}\right)\Phi\left(-\sqrt{\frac{\lambda}{v}}\left(\frac{v}{\mu}+1\right)\right)$
Generalized Extreme Value (GEV)	$PDF = \frac{1}{\alpha}\left[1 - \frac{\zeta(v)-\mu}{\alpha}\right]^{\frac{1}{\zeta}-1} exp\left[-\left(1 - 1 - \frac{\zeta(v)-\mu}{\alpha}\right)^{\frac{1}{\zeta}}\right]$	$CDF = exp\left[-\left(1 - 1 - \frac{\zeta(v)-\mu}{\alpha}\right)^{\frac{1}{\zeta}}\right]$
Nakagami (Na)	$PDF = \frac{2m^{m}}{\Gamma(m)\Omega^{m}} v^{2m-1} e^{\left(-\frac{m}{\Omega}G^{2}\right)}$	$CDF = \frac{\gamma\left(m, \frac{m}{\Omega}v^{2}\right)}{\Gamma(m)}$
Normal (N)	$PDF = \frac{1}{\sqrt{2\pi\sigma^{2}}} exp\left(-\frac{v-\mu}{2\sigma^{2}}\right)$	$CDF = \frac{1}{2}\left[1 + erf\left(\frac{v-\mu}{\sigma\sqrt{2}}\right)\right]$
Rayleigh (R)	$PDF = \frac{2v}{c^{2}} e^{-\left(\frac{v}{c}\right)^{2}}$	$CDF = 1 - exp\left[-\left(\frac{v}{c}\right)^{2}\right]$

W	**k**	Shape parameter	LL	β	Shape parameter	Na	m	Shape parameter
	c [m/s]	Scale parameter		α	Scale Parameter		Ω	Scale parameter
G	β	Shape parameter	IG	λ	Shape parameter	N	σ	Standard deviation
	α	Scale Parameter		μ	Mean parameter		μ	Mean parameter
LN	σ	Shape parameter	GEV	μ	Location Parameter	R	**c [m/s]**	Scale parameter
	μ	Scale Parameter		ζ	Scale Parameter			
L	μ	Location Parameter		α	Shape Parameter			
	σ	Scale Parameter						

CHAPTER 4
RESULTS AND DISCUSSION

4.1 Description of wind speed data

The descriptive statistics of each studied region in terms of mean, maximum, median, standard deviation (SD), the coefficient of variation (C_v), Skewness, and kurtosis are presented in Tables 4.1. It is found the mean wind speed values are ranged from 2.121 m/s to 4.349 m/s at 10m height. The maximum and minimum mean wind speeds are recorded in Nault and Esspeea with a value of 4.349m/s and 2.121 m/s, respectively. In addition, the variation coefficients are moderately high and ranged from 10.33 to 15.36. It is also found that annual values of skewness are positive which indicated that all distributions are right-skewed except Nault. One of the most important factors that explain the wind speed at a specific region is the altitude of the region above ground level (Ouarda et al., 2015). For this study, the largest median wind speed occurred at Nault, which is located at the latitude of 568m (see Table 3.1). While the lowest median wind speed has occurred at Esspeea (altitude above the ground level is 73m)

Table 4.1: Descriptive statistics of wind speed series during the investigation period

Region	**height [m]**	**Maximum [m/s]**	**Mean [m/s]**	**Median [m/s]**	**SD [m/s]**	**C_v**	**Skewness**	**Kurtosis**
Tripoli	10	4.649	3.698	3.626	0.498	13.47	0.82	-0.44
Nault	10	4.843	4.349	4.538	0.449	10.33	-0.36	-1.83
Esspeea	10	2.7992	2.121	2.088	0.3257	15.36	0.87	0.46

Monthly wind speed data are used in this study, which can be determined from hourly and daily wind speed data. Figure 3 shows the seasonally wind speed data for three selected sites. During the winter season, the maximum and minimum wind speeds were occurred in 2003 and 1989, respectively, at Tripoli. In addition, for Nault site, the highest and lowest wind speed was recorded in 1987 and 1997, respectively. For Esspeea site, the minimum wind speed was recorded in 2008 with a value of 1.2m/s. In spring season, the wind speed values were varied from 3.2m/s to 4.9m/s for Tripoli, 3.5m/s to 6.1m/s for Nault and 2.0m/s to 3.2 m/s for Esspeea. In the summer season, the wind speed level was reached 4.6m/s in 2003 at Tripoli, 5m/s in 1987 at Nault and 2.7m/s in 1993 at Esspeea. For the autumn season, the wind speed values are ranged from 2.3 and 4.4 for Tripoli, 2.8 and 5.2 m/s for Nault and 1.3 and 2.7m/s for Esspeea. Generally, Figure 3 gives the following findings:

1). The highest values of the mean monthly wind speed of all stations occurred during winter and spring seasons;

2). For all seasons, Nault has the maximum values of mean monthly wind speed.

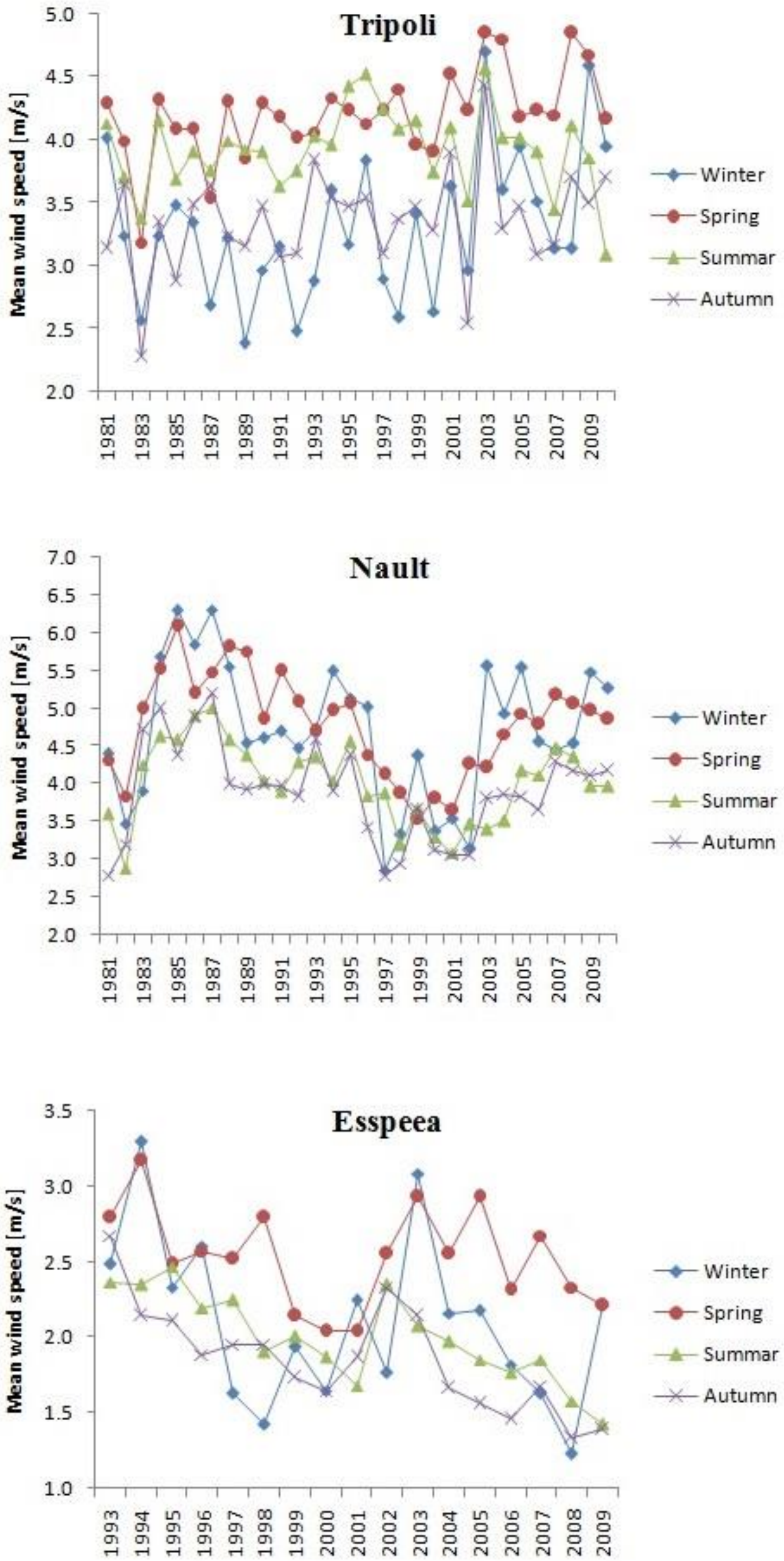

Figure 4.1: Seasonally wind speeds for three studied regions

The monthly wind speeds for all selected sites are shown in Figure 4.2. It observed that the monthly wind speed varies between 1.70 and 4.7 m/s. The maximum value of the mean monthly wind speed of 4.7 m/s was recorded in May in Tripoli while the minimum value as 1.70 m/s was recorded in October in Esspeea. The maximum value of the annual wind speed of 4.1 m/s is recorded in Nault, while the minimum value of 2.1 m/s is recorded in Esspeea.

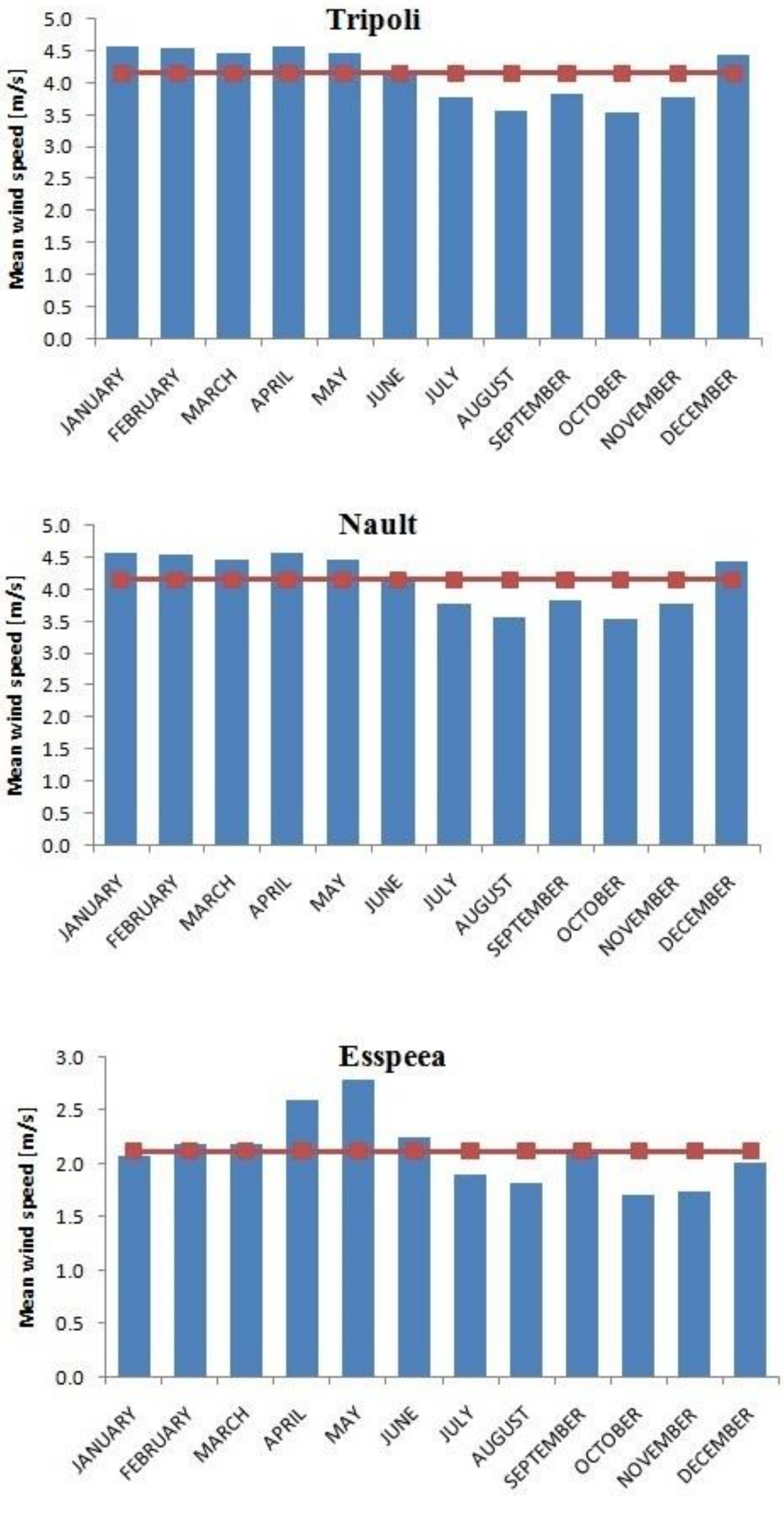

Figure 4.2: Monthly wind speed at the selected regions

4.2 Distribution function parameters at 10m height

Maximum like-hood method and Kolmogorov-Smirnov test were used to estimate the distribution parameters and choosing the best distribution among the ten distribution functions for each location, respectively. Table 4.2 is tabulated the mean, variance and the parameters of each distribution function. Furthermore, the fitted PDF and CDF models for each location were presented in Figures 4.3-4.8.

Additionally, Table 4.3 presents the goodness-of-fit statistics in terms of the Kolmogorov-Smirnov tests for each distribution function. The distribution with the lowest Kolmogorov-Smirnov value will be selected to be the best model for the wind speed distribution in the studied location. Therefore, based on the result, Generalized Extreme Value distribution has the lowest value, which is considered as the best distribution function to study the wind speed distribution of all studied sites. Moreover, it is observed that the Rayleigh distribution function cannot be used to analyze the wind potential in the studied Location, as shown in Table 4.3.

Table 4.2: Parameter values of different distribution functions over the investigated period 10m height

Model	Parameters	Tripoli	Nault	Esspeea
Actual	**mean**	3.698	4.349	2.121
Gamma	**Mean**	3.708	4.342	2.121
	Variance	0.208	0.188	0.092
	β	65.978	100.531	48.764
	α	0.056	0.043	0.044
Generalized Extreme Value	**Mean**	3.715	4.294	2.121
	Variance	0.306	0.324	0.107
	ζ	0.164	-1.122	0.052
	α	0.328	0.537	0.237
	μ	3.463	4.322	1.971
Inverse Gaussian	**Mean**	3.708	4.342	2.121
	Variance	0.206	0.191	0.091
	μ	3.708	4.342	2.121
	λ	247.257	427.983	104.424
Logistic	**Mean**	3.658	4.369	2.092
	Variance	0.245	0.236	0.101
	μ	3.658	4.369	2.092
	σ	0.273	0.268	0.175
Log-Logistic	**Mean**	3.674	4.379	2.105
	Variance	0.237	0.252	0.100
	β	1.293	1.470	0.733
	α	0.072	0.063	0.082
Lognormal	**Mean**	3.710	4.344	2.123
	Variance	0.226	0.209	0.100
	σ	1.303	1.463	0.742
	μ	0.128	0.105	0.148
Nakagami	**Mean**	3.709	4.341	2.122
	Variance	0.212	0.184	0.094
	m	16.355	25.682	12.080
	Ω	13.969	19.033	4.597
Normal	**Mean**	3.708	4.342	2.121
	Variance	0.237	0.199	0.106
	μ	3.708	4.342	2.121
	σ	0.487	0.446	0.326
Rayleigh	**Mean**	3.312	3.866	1.900
	Variance	2.998	4.084	0.987
	c	2.643	3.085	1.516
Weibull	**Mean**	3.696	4.354	2.111
	Variance	0.294	0.169	0.134
	c	3.922	4.531	2.261
	k	8.101	12.920	6.759

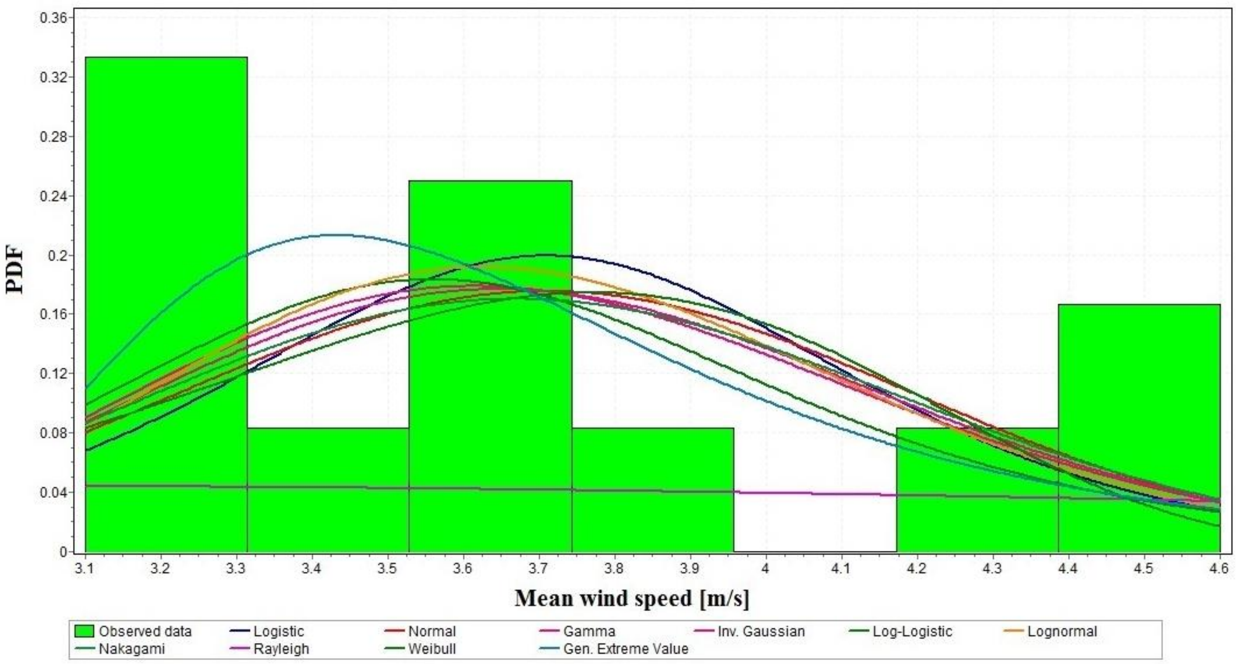

Figure 4.3: Fitting PDF models to the wind speed data at the 10m height of Tripoli

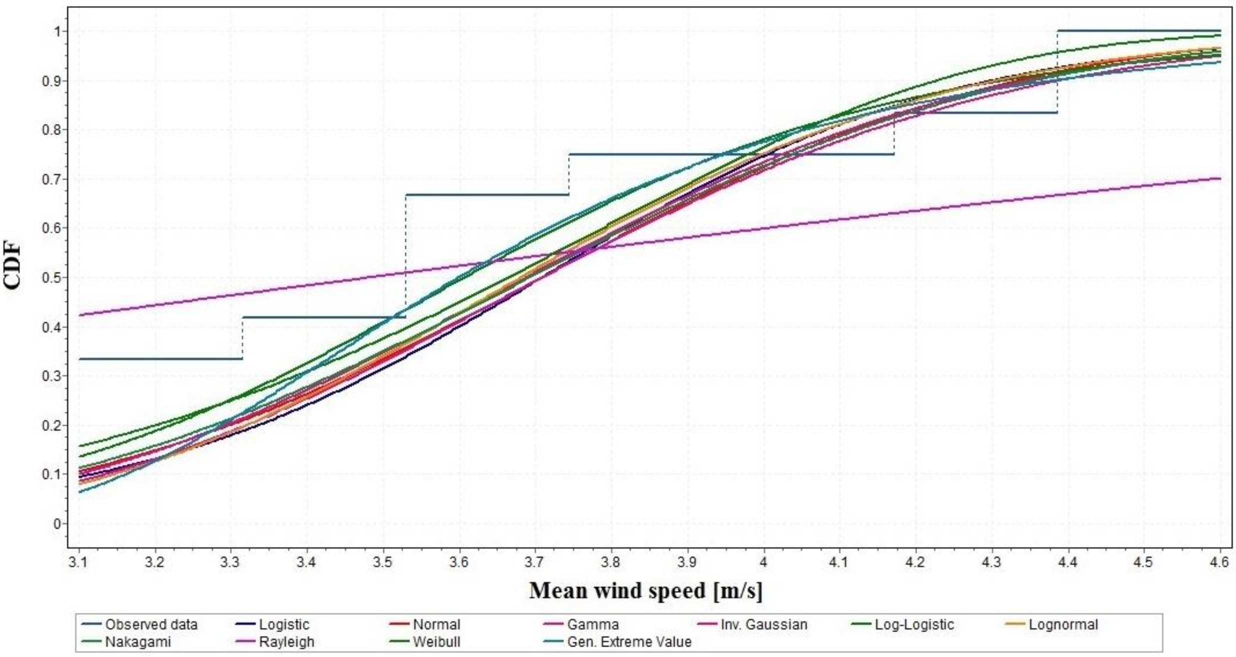

Figure 4.4: Fitting CDF models to the wind speed data at the 10m height of Tripoli

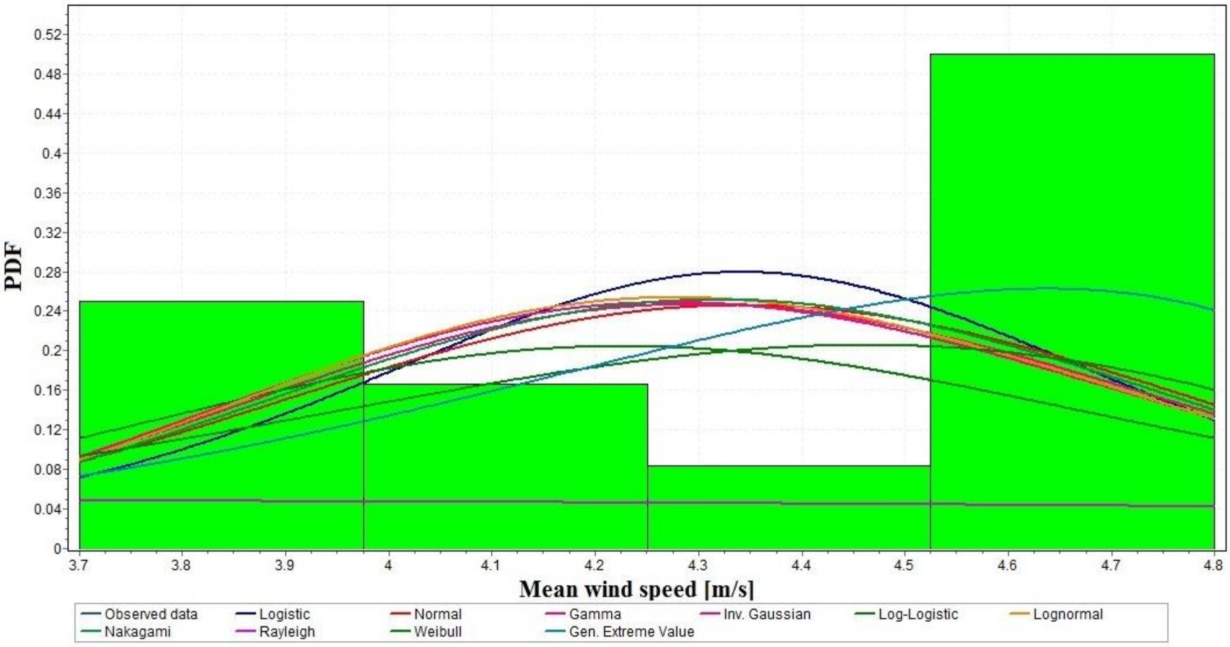

Figure 4.5: Fitting PDF models to the wind speed data at the 10m height of Nault

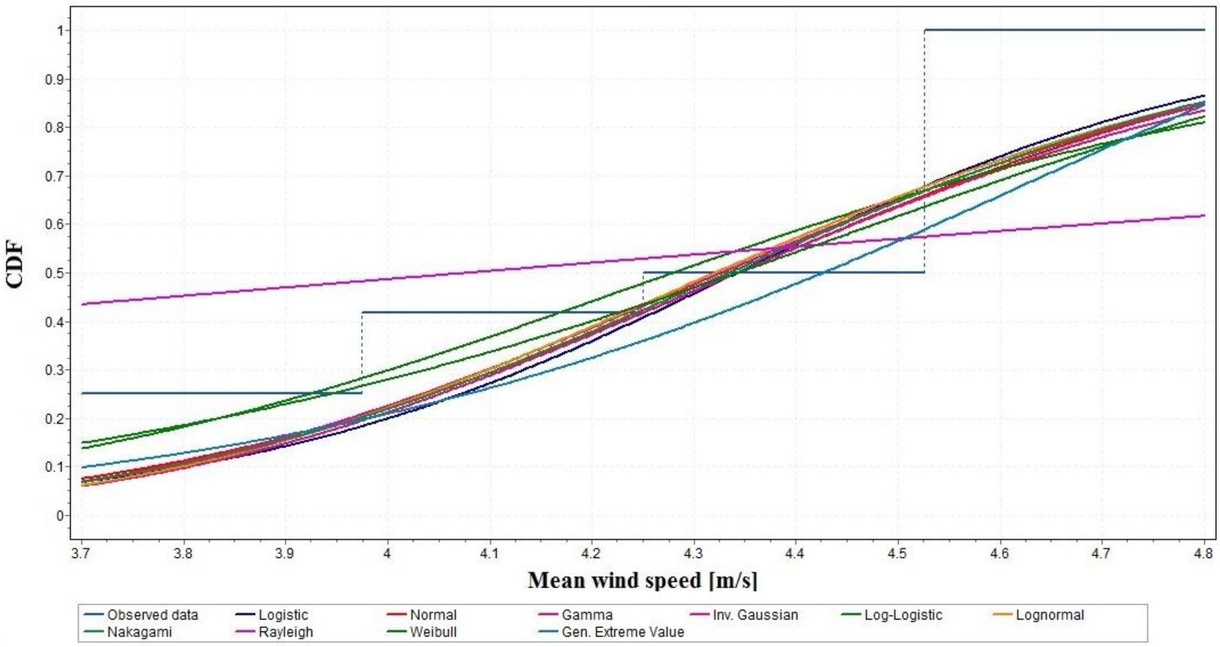

Figure 4.6: Fitting CDF models to the wind speed data at the 10m height of Nault

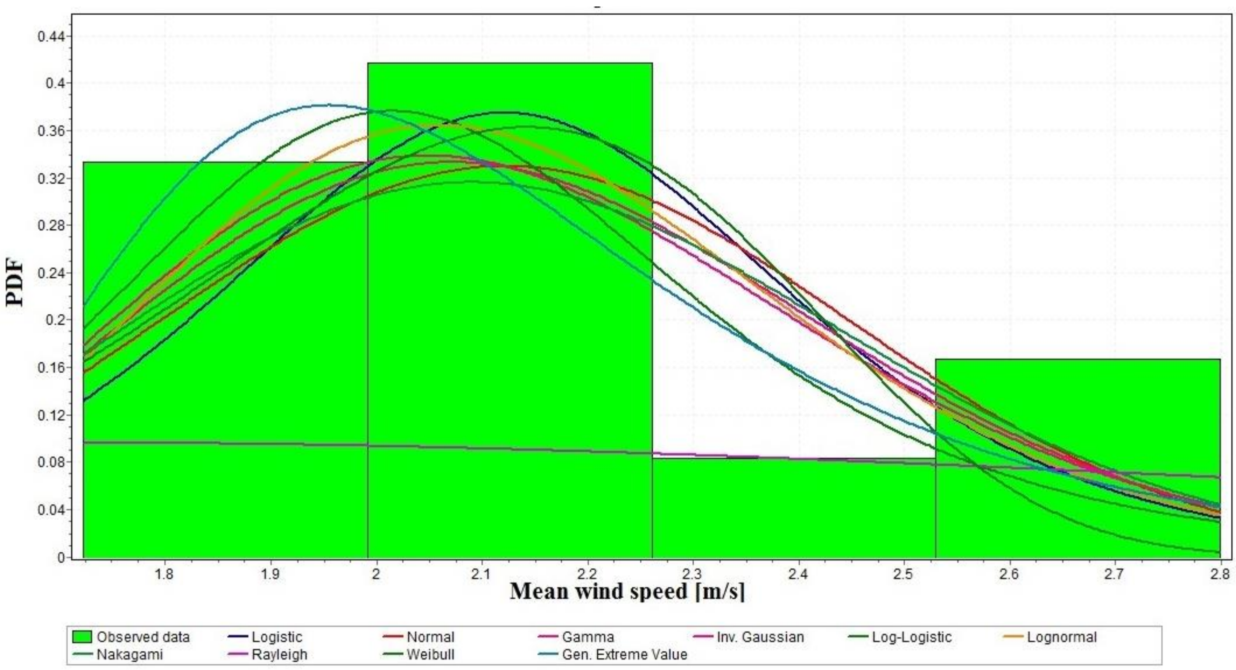

Figure 4.7: Fitting PDF models to the wind speed data at the 10m height of Esspeea

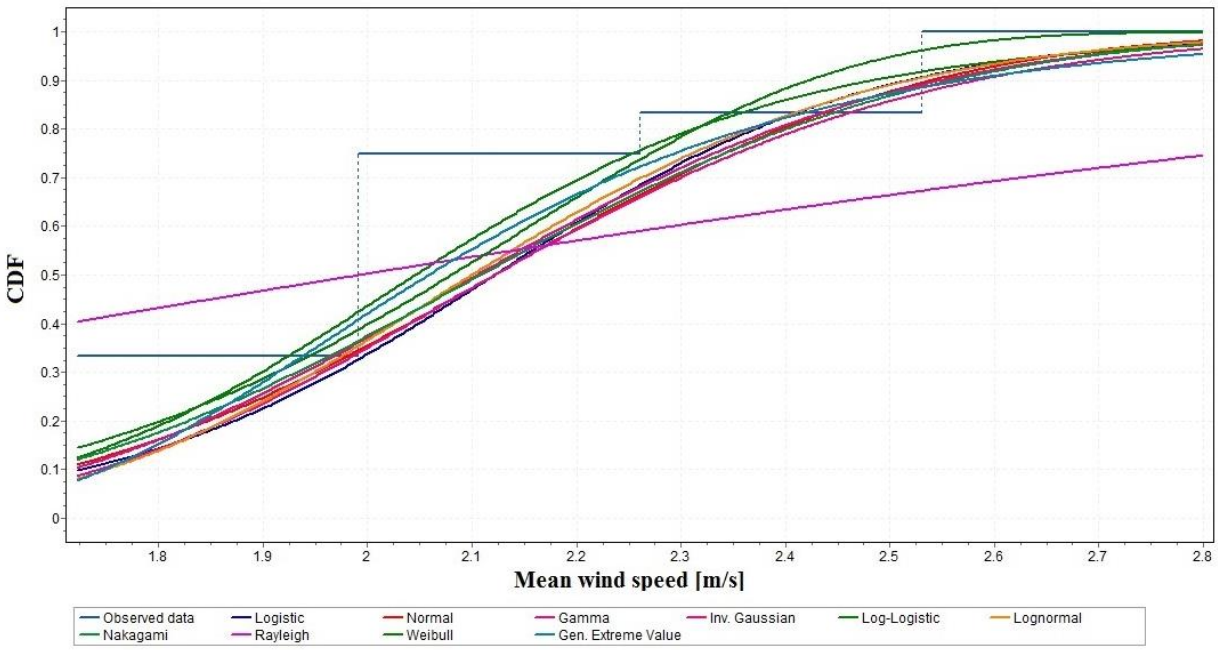

Figure 4.8: Fitting CDF models to the wind speed data at the 10m height of Esspeea

Table 4.3: Results of goodness-of-fit and the selected distribution (in bold) for each location at 10m height

Site	Model	Kolmogorov Smirnov test	Ranked
Tripoli	Gamma	0.15889	2
	Generalized Extreme Value	**0.13161**	**1**
	Inverse Gaussian	0.17625	8
	Logistic	0.17587	7
	Log-Logistic	0.16840	5
	Lognormal	0.15844	3
	Nakagami	0.16550	4
	Normal	0.17535	6
	Rayleigh	0.42239	10
	Weibull	0.18045	9
Nault	Gamma	0.29280	6
	Generalized Extreme Value	**0.25502**	**1**
	Inverse Gaussian	0.27995	4
	Logistic	0.31106	9
	Log-Logistic	0.26614	3
	Lognormal	0.29910	8
	Nakagami	0.29645	7
	Normal	0.28908	5
	Rayleigh	0.43470	10
	Weibull	0.26051	2
Esspeea	Gamma	0.15277	6
	Generalized Extreme Value	**0.11781**	**1**
	Inverse Gaussian	0.17278	9
	Logistic	0.14870	4
	Log-Logistic	0.13747	3
	Lognormal	0.13469	2
	Nakagami	0.16203	7
	Normal	0.16789	8
	Rayleigh	0.40397	10
	Weibull	0.15032	5

4.3 Distribution function parameters at various heights

Generally, the value of wind speed depends on the measurement height. Therefore, in order to yield an accurate determination of wind energy potential, the winds speed is calculated at different wind turbine hub height using Equations (2.5) and (2.6). As results, the monthly wind speed at different height is evaluated and illustrated as shown in Figure 4.9. It noticed that as the height above the ground increases, the wind speed would increase.

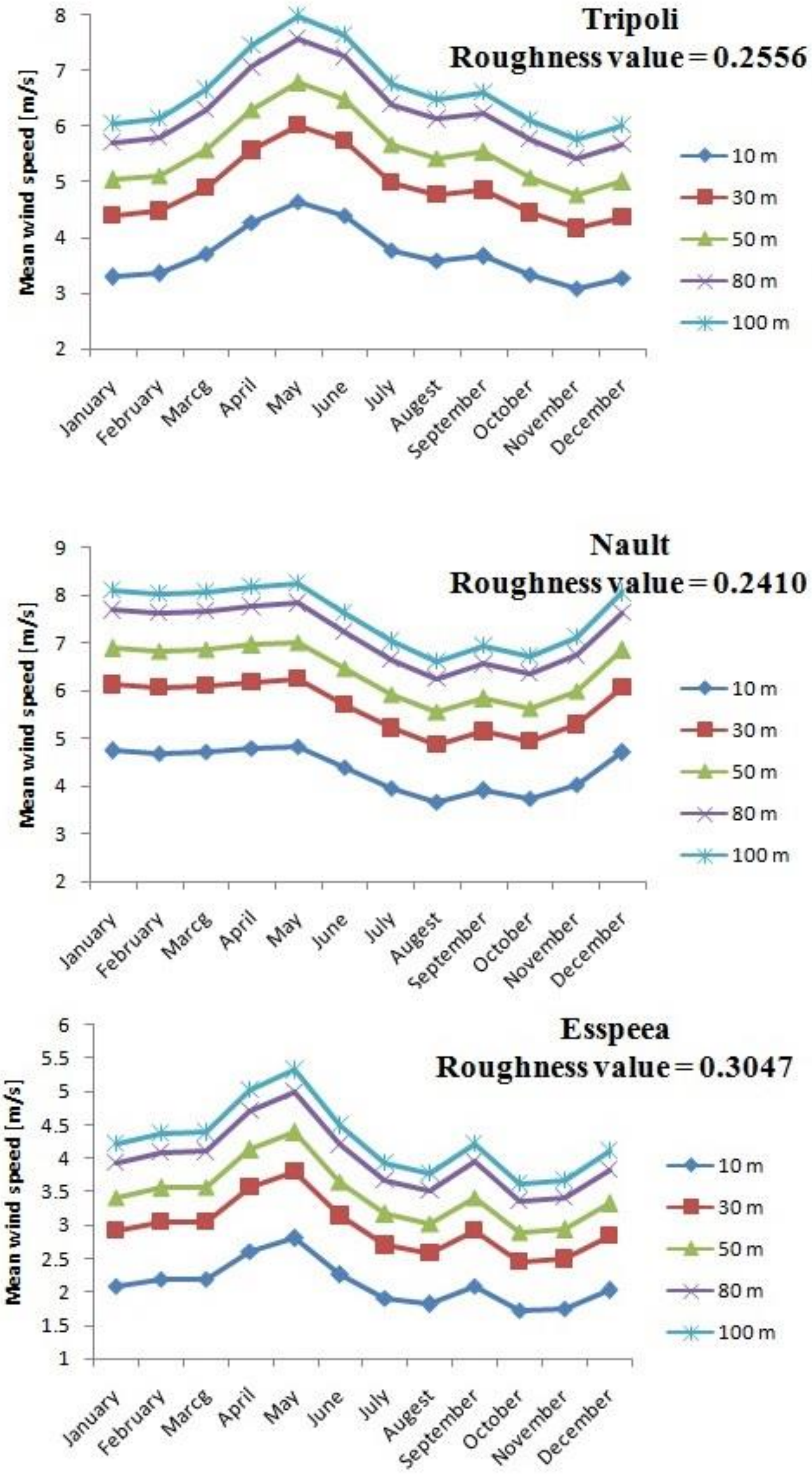

Figure 4.9: Monthly mean wind speed profile at various heights

Data collected from each site at a height of 10m have been extrapolated to various heights, which is characterized as a good to very good wind resource height in the literature (Mostafaeipour, 2010). In order to ensure the Generalized Extreme Value as the best distribution to study the wind speed characteristics for all studied site, Table 4.4 tabulates the parameters of ten distributions at various heights. In addition, goodness-of-fit statistics in terms of the Kolmogorov-Smirnov tests for each distribution function is summarized in Table 4.5. It is observed that Generalized Extreme Value can be used to study the wind speed distribution at any heights for all selected sites.

Table 4.4: Parameter values of different distribution functions over the investigated period at various heights

Hub height			**30 m**	
Model	**Parameters**	**Tripoli**	**Nault**	**Esspeea**
Actual	**mean**	4.889	5.663	2.959
Gamma	**Mean**	4.889	5.663	2.959
	Variance	0.309	0.263	0.146
	β	77.419	121.759	59.843
	α	0.063	0.047	0.049
Generalized Extreme Value	**Mean**	4.901	5.661	2.958
	Variance	0.482	0.383	0.166
	ζ	0.189	-1.063	0.039
	α	0.389	0.602	0.301
	μ	4.587	5.677	2.772
Inverse Gaussian	**Mean**	4.889	5.663	2.959
	Variance	0.305	0.268	0.145
	μ	4.889	5.663	2.959
	λ	383.279	678.238	178.820
Logistic	**Mean**	4.826	5.693	2.924
	Variance	0.359	0.333	0.160
	μ	4.826	5.693	2.924
	σ	0.330	0.318	0.220
Log-Logistic	**Mean**	4.843	5.704	2.939
	Variance	0.345	0.352	0.158
	β	1.570	1.736	1.069
	α	0.066	0.057	0.074
Lognormal	**Mean**	4.891	5.665	2.961
	Variance	0.333	0.293	0.158
	σ	1.581	1.730	1.077
	μ	0.118	0.095	0.134
Nakagami	**Mean**	4.890	5.663	2.960
	Variance	0.314	0.260	0.149
	m	19.145	30.999	14.819
	Ω	24.227	32.327	8.910
Normal	**Mean**	4.889	5.663	2.959
	Variance	0.352	0.281	0.167
	μ	4.889	5.663	2.959
	σ	0.593	0.530	0.409
Rayleigh	**Mean**	4.362	5.039	2.645
	Variance	5.199	6.937	1.912
	c	3.480	4.020	2.111
Weibull	**Mean**	4.871	5.677	2.945
	Variance	0.451	0.242	0.216
	c	5.153	5.890	3.137
	k	8.652	14.119	7.483

Table 4.4: Continued

Hub height		**100 m**		
Model	**Parameters**	**Tripoli**	**Nault**	**Esspeea**
Actual	**mean**	6.642	7.563	4.263
Gamma	**Mean**	6.642	7.563	4.263
	Variance	0.443	0.367	0.236
	β	99.533	155.980	76.928
	α	0.067	0.048	0.055
Generalized Extreme Value	**Mean**	6.653	7.611	4.261
	Variance	0.664	0.447	0.263
	ζ	0.176	-1.052	0.024
	α	0.471	0.653	0.387
	μ	6.283	7.626	4.028
Inverse Gaussian	**Mean**	6.642	7.563	4.263
	Variance	0.438	0.372	0.234
	μ	6.642	7.563	4.263
	λ	669.008	1163.330	331.151
Logistic	**Mean**	6.567	7.599	4.220
	Variance	0.514	0.465	0.258
	μ	6.567	7.599	4.220
	σ	0.395	0.376	0.280
Log-Logistic	**Mean**	6.585	7.611	4.237
	Variance	0.496	0.487	0.254
	β	1.879	2.025	1.437
	α	0.059	0.050	0.065
Lognormal	**Mean**	6.644	7.566	4.265
	Variance	0.479	0.406	0.256
	σ	1.888	2.020	1.443
	μ	0.104	0.084	0.118
Nakagami	**Mean**	6.642	7.563	4.263
	Variance	0.450	0.362	0.240
	m	24.618	39.598	19.048
	Ω	44.572	57.563	18.418
Normal	**Mean**	6.642	7.563	4.263
	Variance	0.502	0.392	0.268
	μ	6.642	7.563	4.263
	σ	0.709	0.626	0.518
Rayleigh	**Mean**	5.917	6.724	3.803
	Variance	9.565	12.353	3.952
	c	4.721	5.365	3.035
Weibull	**Mean**	6.618	7.580	4.243
	Variance	0.658	0.340	0.356
	c	6.962	7.834	4.493
	k	9.801	15.995	8.477

Table 4.5: Results of goodness-of-fit and the selected distribution (in bold) for each location at various heights

hub height		30 m	
Site	**Model**	**Kolmogorov Smirnov test**	**Ranked**
Tripoli	Gamma	0.16724	2
	Generalized Extreme Value	**0.13893**	**1**
	Inverse Gaussian	0.18331	8
	Logistic	0.19623	9
	Log-Logistic	0.15330	3
	Lognormal	0.18279	7
	Nakagami	0.17172	4
	Normal	0.18089	6
	Rayleigh	0.43374	10
	Weibull	0.17419	5
Nault	Gamma	0.27786	6
	Generalized Extreme Value	**0.23233**	**1**
	Inverse Gaussian	0.26602	4
	Logistic	0.29607	9
	Log-Logistic	0.25920	3
	Lognormal	0.28501	8
	Nakagami	0.28047	7
	Normal	0.27363	5
	Rayleigh	0.44052	10
	Weibull	0.25111	2
Esspeea	Gamma	0.15180	6
	Generalized Extreme Value	**0.11755**	**1**
	Inverse Gaussian	0.16983	9
	Logistic	0.14590	4
	Log-Logistic	0.13747	3
	Lognormal	0.13469	2
	Nakagami	0.16037	7
	Normal	0.16528	8
	Rayleigh	0.41711	10
	Weibull	0.15032	5

Table 4.5: Continued

hub height		100 m	
Site	**Model**	**Kolmogorov Smirnov test**	**Ranked**
Tripoli	Gamma	0.16801	3
	Generalized Extreme Value	**0.13889**	**1**
	Inverse Gaussian	0.18210	7
	Logistic	0.19625	9
	Log-Logistic	0.15330	2
	Lognormal	0.18279	8
	Nakagami	0.17040	4
	Normal	0.17818	6
	Rayleigh	0.44648	10
	Weibull	0.17419	5
Nault	Gamma	0.27754	5
	Generalized Extreme Value	**0.23223**	**1**
	Inverse Gaussian	0.26705	4
	Logistic	0.29626	9
	Log-Logistic	0.25920	3
	Lognormal	0.28501	8
	Nakagami	0.27988	7
	Normal	0.27382	5
	Rayleigh	0.45238	10
	Weibull	0.25111	2
Esspeea	Gamma	0.15073	6
	Generalized Extreme Value	**0.11726**	**1**
	Inverse Gaussian	0.16660	9
	Logistic	0.14287	4
	Log-Logistic	0.13747	3
	Lognormal	0.13469	2
	Nakagami	0.15847	7
	Normal	0.16246	8
	Rayleigh	0.43165	10
	Weibull	0.15032	5

4.4 The wind power density at various heights

The values of wind power density at 10m height for each studied site were estimated using Equation (2.3) and tabulated in Table 4.6. It can be seen that Nault has the highest mean actual wind power (50.3/m^2) compared with Tripoli (30.972W/m^2) and Esspeea (5.844W/m^2). When the Generalized Extreme Value distribution is used, the estimated power density at an extrapolated height of 10m and was varied from 5.843 to 48.493W/m^2. The highest calculated power density values are 48.493 W/m^2 at Nault, while the minimum WPD was observed at Esspeea with 5.843 W/m^2. For comparison purposes, the calculated annual WPD at various is presented in Table 4.6.

The kinetic energy potential of the wind at each site is characterized by the mean power density ranges given in the literature [30, 31]. Among the sites investigated in this study, the maximum estimated power density became prominent in the Nault site, where the highest density is 264.998 W/m^2 at a height of 100m (Table 4.6).

According to the results listed in Tables 9 and the wind power classification [30, 31], all of the locations chosen for investigation indicate poor wind energy potential. Therefore, high capacity wind turbines (MWs) are not feasible to be investigated in these sites. Nevertheless, small-scale wind turbines can be used to gather the wind energy potential in these locations.

Table 4.6: Mean wind power density in W/m^2 of all selected regions at various heights

Hub height	**10 m**		
Model	**Tripoli**	**Nault**	**Esspeea**
Actual	30.975	50.382	5.844
Gamma	31.235	50.128	5.847
Generalized Extreme Value	31.409	48.493	5.843
Inverse Gaussian	31.235	50.128	5.847
Logistic	29.99	51.069	5.607
Log-Logistic	30.364	51.431	5.715
Lognormal	31.285	50.207	5.859
Nakagami	31.254	50.12	5.853
Normal	31.235	50.128	5.847
Rayleigh	22.258	35.399	4.202
Weibull	30.928	50.551	5.763
Hub height	**30 m**		
Model	**Tripoli**	**Nault**	**Esspeea**
Actual	71.585	111.238	15.871
Gamma	71.585	111.238	15.871
Generalized Extreme Value	72.086	111.108	15.854
Inverse Gaussian	71.585	111.238	15.871
Logistic	68.835	113.017	15.305
Log-Logistic	69.559	113.679	15.544
Lognormal	71.682	111.381	15.899
Nakagami	71.622	111.225	15.883
Normal	71.585	111.238	15.871
Rayleigh	50.838	78.36	11.339
Weibull	70.793	112.052	15.644

Table 4.6: Continued

Hub height	100 m		
Model	**Tripoli**	**Nault**	**Esspeea**
Actual	179.444	264.998	47.445
Gamma	179.444	264.999	47.445
Generalized Extreme Value	180.378	270.092	47.381
Inverse Gaussian	179.444	264.999	47.445
Logistic	173.492	268.795	46.015
Log-Logistic	174.916	270.016	46.575
Lognormal	179.637	265.26	47.511
Nakagami	179.505	264.978	47.468
Normal	179.444	264.999	47.445
Rayleigh	126.861	186.191	33.696
Weibull	177.505	266.726	46.777

4.5 Economic analysis of electricity generation potential

In this study, the performance of two types of wind turbine, namely a horizontal axis wind turbine (HAWT) and vertical axis wind turbine (VAWT) was investigated (see appendix 1). Generally, HAWTs are the most commonly used for generating electricity today. However, vertical axis wind turbines are good for low wind speed and can be installed on the rooftop of the building or on top of communication towers. The characteristic of the selected small-scale wind turbines is presented in Table 4.7.

Table 4.7 Characteristics of the selected wind turbine

Turbine type	Model	P_r [KW]	Hub height [m]	v_{ci} [m/s]	v_r [m/s]	v_{c0} [m/s]
HAWT	**Finn Wind Tuule C 200**	3	27	1.9	10	-
HAWT	**Aircon10**	10	12/18/24/30	2.5	11	32
VAWT	**Winddam**	4	12/18/24/30	2.5	12	-
VAWT	**Windside (WS-12)**	8	12/18/24/30	2	20	-

The total energy power of wind turbine in kW, capacity factor and the electricity cost of each wind turbine were calculated using Equations (2.7), (2.10), and (2.12), respectively.

Table 4.8 shows the effect of hub height on the annual energy and capacity factor from the chosen wind turbine. For a horizontal axis wind turbine, it is found that Finn Wind Tuule C 200 with 3kW rated has the minimum of annual energy and capacity factor corresponding to the hub height (27m) for all regions. For a vertical axis wind turbine, Winddam with 4kW was found to be most efficient with a maximum of annual energy and capacity factor corresponding to various hub heights.

Economically, the lowest value of electricity cost was obtained from Finn Wind Tuule C 200 with a value of 0.001427 $/kW for Tripoli, 0.0010 $/kW for Nault and 0.013194$/kW for Esspeea as shown in Table 11. Most of the roofs building on these regions are flat and the majority of the people in these regions probably can be used vertical axis wind turbine. Thus, it would be recommended for the selected regions to adapt turbine model Winddam (VWAT).

Table 4.8: Annual electricity production and financial indices at three regions

Region	Model	Hub height [m]	Total energy power of wind turbine [kW]	CF [%]	COEG [$/kWh]
Tripoli	Windside (WS-12)	12	146.814	76.466	0.011563
		18	167.028	86.994	0.010164
		24	219.345	114.242	0.007740
		30	263.620	137.302	0.006440
	Winddam	12	162.418	169.186	0.005226
		18	191.474	199.452	0.004433
		24	266.674	277.785	0.003183
		30	330.314	344.077	0.002570
	Aircon10	12	487.432	203.097	0.004354
		18	574.631	239.430	0.003693
		24	800.312	333.463	0.002652
		30	991.302	413.043	0.002141
	Finn Wind Tuule C 200	27	446.121	619.613	0.001427
Nault	Windside (WS-12)	12	229.607	119.587	0.007394
		18	256.220	133.448	0.006626
		24	324.498	169.010	0.005232
		30	381.705	198.805	0.004448
	Winddam	12	281.424	293.149	0.003016
		18	319.677	332.997	0.002655
		24	417.820	435.229	0.002032
		30	500.048	520.884	0.001697
	Aircon10	12	844.577	351.907	0.002513
		18	959.379	399.741	0.002212
		24	1253.915	522.464	0.001692
		30	1500.690	625.287	0.001414
	Finn Wind Tuule C 200	27	636.854	884.519	0.001000
Esspeea	Windside (WS-12)	12	4.226	2.201	0.401759
		18	5.148	2.681	0.329761
		24	11.959	6.229	0.141954
		30	20.841	10.855	0.081459
	Winddam	12	1.370	1.427	0.619762
		18	2.696	2.808	0.314882
		24	7.782	8.106	0.109080
		30	14.276	14.870	0.059460
	Aircon10	12	4.110	1.713	0.516281
		18	8.090	3.371	0.262306
		24	23.354	9.731	0.090867
		30	42.842	17.851	0.049532
	Finn Wind Tuule C 200	27	48.250	67.014	0.013194

CHAPTER 5
CONCLUSIONS AND FUTURE WORKS

5.1 Conclusions

In this paper, the wind speed characteristics and wind power potential at three locations in Libya: Tripoli, Nault, and Esspeea for various periods were investigated. Moreover, the capabilities of a horizontal axis wind turbine and a vertical axis wind turbine to generate power at the selected locations were examined and compared their functionality in the urban environment. The following are the major conclusion from the analysis:

- Annual mean wind speed for the three regions considered in this study is ranging from 2.1 to 4.1 m/s at 10 m, which indicates that the investigated regions have low wind energy potential.
- Among the studied locations, it was noticed that Nault has the highest winds. The wind power analysis shows that Nault is the best location for harvesting wind energy.
- As a result, the annual wind power values were ranged from 5.844W/m^2 to 30.975W/m^2 at 10m height and 15.871W/m^2 to 71.585W/m^2 at 30m height. These values demonstrated that the wind power potential of these regions could be possible to exploit the wind power using small-scale wind turbines at the region.
- Based on the results, it was concluded that VAWT with a comparable rated output would produce more power in the urban environment than a HAWT due to less noisy and higher efficiency in the urban environment.
- In comparison, it was found that Winddam with a power rating of 4kW had the lowest energy production cost among the considered vertical axis wind turbine. In addition, it was observed that Finn Wind Tuule C 200 with a power rating of 3kW had the lowest energy production cost among the considered horizontal axis wind turbine.

5.2 Future Work

The prediction of wind speed in the built environment is difficult due to the varying roughness and the drag exerted by surface-mounted obstacles on the flow, which reduce the wind speed close to the ground. Therefore, it is conceivable that there is a lack of accurate approaches for the assessment of wind speed in urban areas. An interesting area for future study is Computational Fluid Dynamics (CFD), which can be used to predict the wind speed in urban environments (selected regions) for conventional buildings. In addition, the evaluation of potential locations for the installation of small-scale wind turbines in urban areas can be investigated using CFD.

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APPENDIX

CATALOGUE OF EUROPEAN URBAN WIND TURBINE MANUFACTURERS

Catalogue of European Urban Wind Turbine Manufacturers






Supported by the
European Commission under the
Intelligent Energy - Europe
Programme



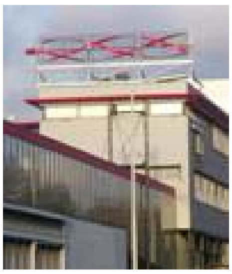



Table of contents

Aircon

HAWT - 10 kW

Contact name:	Aircon GmbH & Co.KG
Address:	Nessestraße 27, 26789 Leer
Telephone:	+49 491 454 44 84
Country :	**Germany**

Aircon 10 references

Site	Use	Country
Nordhausen	University	Germany
Bremerhaven	University	Germany
Hamburg	Greenpeace building	Germany
Warnungs	Solartechn. Hubert Kuhn	Austria
Sopelana	Zero CO2/ Environmental assoc	Spain

Aircon 10/ 10 kW

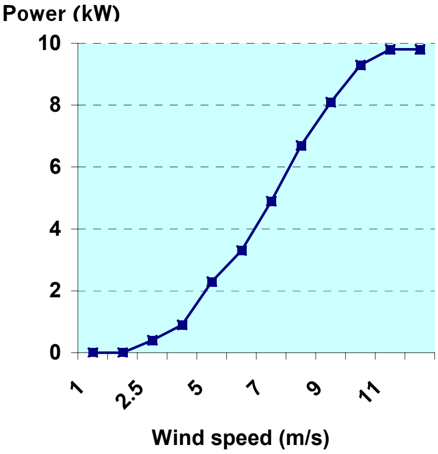
Technical information

POWER		Unit
1) Rated power	10	kW
2) Rated wind speed	11	m/s
3) Cut-in wind speed	2,5	m/s
4) Cut-out wind speed	32	m/s
5) Maximum wind speed the turbine can withstand	190	Km/h
DIMENSIONS		
6) Rotor weight	144	kg
7) Rotor diameter	7,1	m
8) Rotor height (for VAWT only)		m
9) Swept area	39,6	m^2
10) Height of the mast	12/18/24/30	m
OTHER INFORMATION		
11) Maximum rpm	130	At rated wind speed
12) Gear box type	Gearless	
13) Brake system	Pitch-control + generator overload regulation	
14) Number of blades	3	
15) Blades material	Composite fibre glass	
16) Output voltage	400	V
17) Minimum operation temperature	- 20	°C
18) Maximum operation temperature	+ 40	°C
19) Acoustic levels at a distance of 20 m ? at nacelle ? (wind = 5 m/s)	< 40	DB
20) Lifetime	> 20	Years
21) Is the machine self-starting	Yes	
22) Use of an asynchronous generator	No	
23) Yaw control system	Azimut motor	
24) Upwind or downwind	Upwind turbine	

Calculated power curve

Wind speed (m/s)	Power (kW)
1	0
2	0
2,5	0,4
4	0,9
5	2,3
6	3,3
7	4,9
8	6,7
9	8,1
10	9,3
11	9,8
11,5- 25	9,8

Power curve:



Ampair

HAWT – 0,1 to 0,3 kW

Contact name: George Durrant
Address: The Doughty Building, Crow Arch Lane, Ringwood, Hampshire, BH24 1NZ
Telephone: +44 (0) 1425 480 780
Country: **United Kingdom**

Ampair 0,1 kW references

Site	Use	Country
Regis Road Recycling Centre, Camden, London	Electricity generation	UK

Ampair Pacific Hawk / 0,1 kW

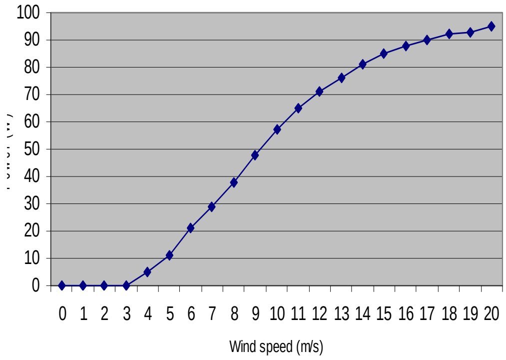
Technical information

POWER		Unit
1) Rated power	0,1	kW
2) Rated wind speed	20	m/s
3) Cut-in wind speed	3,5	m/s
4) Cut-out wind speed	None	m/s
5) Maximum wind speed the turbine can withstand	Storm-proof	km/h
DIMENSIONS		
6) Nacelle and rotor weight	12,6	kg
7) Rotor diameter	0,928	m
8) Rotor height (for VAWT only)	-	m
9) Swept area	0,68	m^2
10) Height of the mast	Variable	m
OTHER INFORMATION		
11) Maximum rpm	DK	At rated wind speed
12) Gear box type	None	
13) Brake system	Inductors	
14) Number of blades	6	
15) Blades material	Glass filled polypropylene	
16) Output voltage	12 / 24	V
17) Minimum operation temperature	- 30	°C
18) Maximum operation temperature	High temperatures not a problem	°C
19) Acoustic levels at a distance of 20 m? at nacelle? (wind = 5 m/s)	20 at nacelle in strong winds	DB
20) Lifetime	10	Years
21) Is the machine self-starting	Yes	
22) Use of an asynchronous generator	No	
23) Yaw control system	Wind vane, free yaw	
24) Upwind or downwind	Upwind	

Calculated power curve

Wind speed (m/s)	Power (W)
1	0
2	0
3	0
4	05
5	11
6	21
7	29
8	38
9	48
10	57
11	65
12	71
13	76
14	81
15	85
16	88
17	90
18	92
19	93
20	95

Power curve



Ampair

HAWT – 0,1 to 0,3 kW

Contact name: George Durrant
Address: The Doughty Building, Crow Arch Lane, Ringwood, Hampshire, BH24 1NZ
Telephone: +44 (0) 1425 480 780
Country: **United Kingdom**

Ampair 0,3 kW references

Site	Use	Country
None available yet		

Ampair Pacific Hawk / 0,3 kW

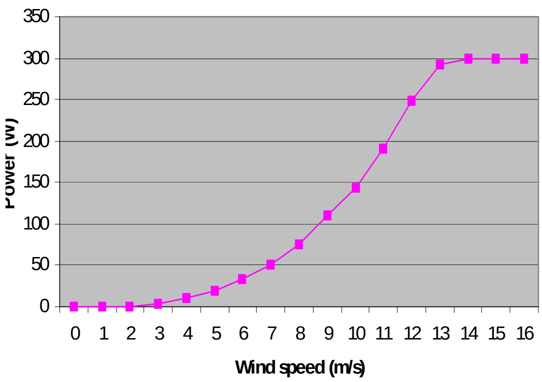
Technical information

POWER		Unit
1) Rated power	0,3	kW
2) Rated wind speed	12,6	m/s
3) Cut-in wind speed	3	m/s
4) Cut-out wind speed	None	m/s
5) Maximum wind speed the turbine can withstand	180	km/h
DIMENSIONS		
6) Nacelle and rotor weight	12	kg
7) Rotor diameter	1,2	m
8) Rotor height (for VAWT only)	-	m
9) Swept area	1.13	m^2
10) Height of the mast	Variable	m
OTHER INFORMATION		
11) Maximum rpm	DK	At rated wind speed
12) Gear box type	None	
13) Brake system	Blade pitch control	
14) Number of blades	3	
15) Blades material	Glass filled polypropylene	
16) Output voltage	12 / 24, or grid-connected	V
17) Minimum operation temperature	Perhaps - 20	°C
18) Maximum operation temperature	Perhaps + 35	°C
19) Acoustic levels at a distance of 20 m? at nacelle ? (wind = 5 m/s)	Not dB tested yet	DB
20) Lifetime	10	Years
21) Is the machine self-starting	Yes	
22) Use of an asynchronous generator	No	
23) Yaw control system	Wind vane, free yaw	
24) Upwind or downwind	Upwind	

Calculated power curve

Wind speed (m/s)	Power (W)
1	0
2	0
3	4
4	10
5	20
6	34
7	51
8	76
9	110
10	144
11	192
12	248
13	293
14	300
15	300
16	300

Power curve



ATLANTIS Windkraft

HAWT from 0,3 kW to 0,6 kW.

WB 15 / 0,3 kW

Contact name: Kottwitz Raimund
Address: Holzstr. 10, 31556 Wölpinghausen
Telephone: +49 5037 988 03
Country : **Germany**

Atlantis WB 15 references

Site	Use	Country
Berlin	About 20 projects in Berlin (7 schools, 1 high school, 4 practical education centres, …).	Germany

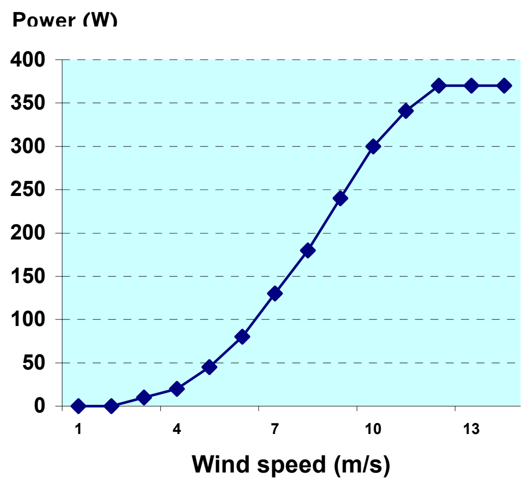
Technical information

		Unit
1) Rated power	0,3	kW
2) Rated wind speed	10	m/s
3) Cut-in wind speed	3	m/s
4) Cut-out wind speed	None	m/s
5) Maximum wind speed the turbine can withstand	No limit	Km/h
DIMENSIONS		
6) Rotor weight	23	kg
7) Rotor diameter	1,5	m
8) Rotor height (for VAWT only)		m
9) Swept area	1,8	m^2
10) Height of the mast	3/6/ 9/12	m
OTHER INFORMATION		
11) Maximum rpm		At rated wind speed
12) Gear box type		
13) Brake system		
14) Number of blades		3
15) Blades material		Composite fibre glass
16) Output voltage	12 – 24	V
17) Minimum operation temperature	Tested in arctic	°C
18) Maximum operation temperature	+ 90	°C
19) Acoustic levels at a distance of 20 m ? at nacelle ? (wind = 5 m/s)	78	DB
20) Lifetime	20	Years
21) Is the machine self-starting		Yes
22) Use of an asynchronous generator		No
23) Yaw control system		Wind vane
24) Upwind or downwind		

Calculated power curve

Wind speed (m/s)	Power (W)
1	0
2	0
3	10
4	20
5	
6	80
7	
8	180
9	
10	300
11	
12	370
13	
14	370

Power curve:



ATLANTIS Windkraft

HAWT from 0,3 kW to 0,6 kW.

Contact name: Kottwitz Raimund
Address: Holzstr. 10, 31556 Wölpinghausen
Telephone: +49 5037 988 03
Country : **Germany**

WB 20/ 0,6 kW

Atlantis WB 20 references

Site	Use	Country
Berlin	About 20 projects in Berlin: 7 schools, 1 high school, 4 practical education centres, …	Germany

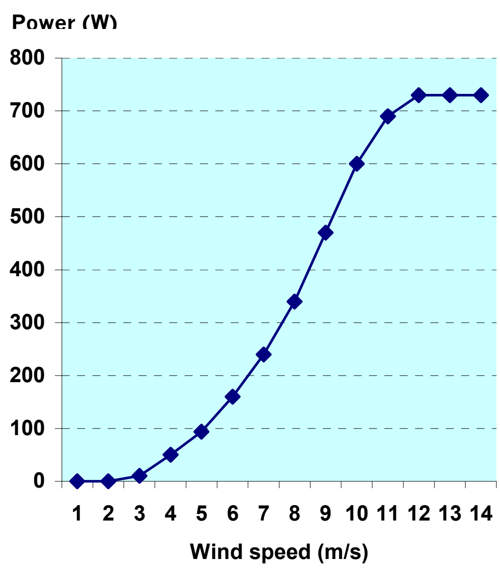
Technical information

POWER		Unit
1) Rated power	0,6	kW
2) Rated wind speed	10	m/s
3) Cut-in wind speed	3	m/s
4) Cut-out wind speed	None	m/s
5) Maximum wind speed the turbine can withstand	No limit	Km/h
DIMENSIONS		
6) Rotor weight	37	kg
7) Rotor diameter	2	m
8) Rotor height (for VAWT only)		m
9) Swept area	3,14	m^2
10) Height of the mast	3/6/ 9/12	m
OTHER INFORMATION		
11) Maximum rpm		At rated wind speed
12) Gear box type		
13) Brake system		
14) Number of blades		4
15) Blades material		Carbon fibre
16) Output voltage	24- 48	V
17) Minimum operation temperature	Tested in arctic	°C
18) Maximum operation temperature	+ 90	°C
19) Acoustic levels at a distance of 20 m ? at nacelle ? (wind = 5 m/s)	78	DB
20) Lifetime	20	Years
21) Is the machine self-starting		Yes
22) Use of an asynchronous generator		No
23) Yaw control system		Wind vane
24) Upwind or downwind		

Calculated power curve

Wind speed (m/s)	Power (W)
1	0
2	0
3	10
4	50
5	
6	160
7	
8	340
9	
10	600
11	
12	730
13	
14	730

Power curve:



Eclectic Energy

HAWT – 0,4 kW

Contact name:	Peter Anderson
Address:	Edwinstowe House, High Street, Edwinstowe, Nottinghamshire NG21 9PR
Telephone:	+44 (0) 162 382 15 35

Stealth Gen D400 / 0,4 kW

D400 – 0,4 kW references

Site	Use	Country
Nottingham University	Testing / monitoring	UK
Building Research Establishment (BRE), Watford	Testing / Monitoring	UK

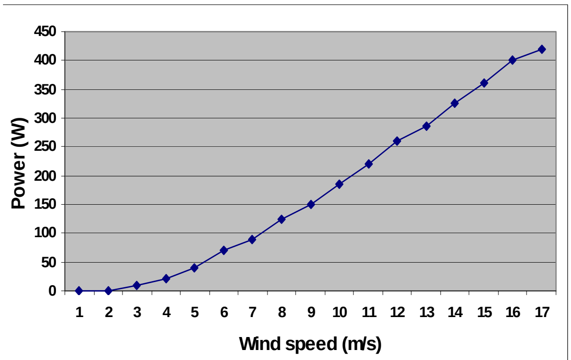
Technical information

POWER		Unit
1) Rated power	0,4	kW
2) Rated wind speed	16	m/s
3) Cut-in wind speed	2	m/s
4) Cut-out wind speed	None	m/s
5) Maximum wind speed the turbine can withstand	130	km/h
DIMENSIONS		
6) Nacelle and rotor weight	15	kg
7) Rotor diameter	1,1	m
8) Rotor height (for VAWT only)	-	m
9) Swept area	0,95	m^2
10) Height of the mast	Variable	m
OTHER INFORMATION		
11) Maximum rpm	1 200	At rated wind speed
12) Gear box type		None
13) Brake system		Electrical
14) Number of blades		5
15) Blades material		Glass reinforced nylon
16) Output voltage	12/24/48/150	V
17) Minimum operation temperature	-20	°C
18) Maximum operation temperature	120	°C
19) Acoustic levels at a distance of 20 m? at nacelle? (wind = 5 m/s)	3 above background	DB
20) Lifetime	20	Years
21) Is the machine self-starting		Yes
22) Use of an asynchronous generator		No
23) Yaw control system		Wind vane, free yaw
24) Upwind or downwind		Upwind

Calculated power curve

Wind speed (m/s)	Power (W)
1	0
2	0
3	10
4	20
5	40
6	70
7	90
8	125
9	150
10	185
11	220
12	260
13	285
14	325
15	360
16	400

Power curve:



Ecofys

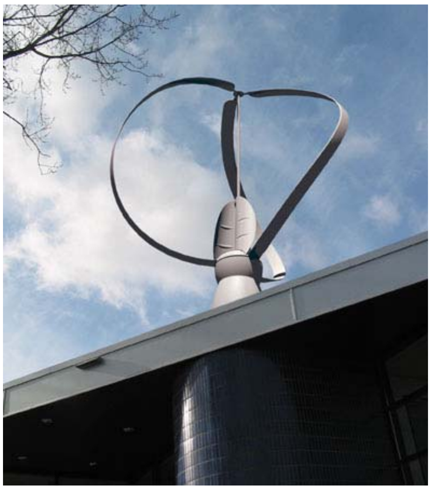
VAWT 3 kW.

Contact name:	Geert Timmers
Address:	PO Box 8408, 3503 RK Utrecht
Telephone:	+31-30 3808300
Country :	Netherlands

Neoga references: no references

Site	Use	Country

Neoga 3 kW



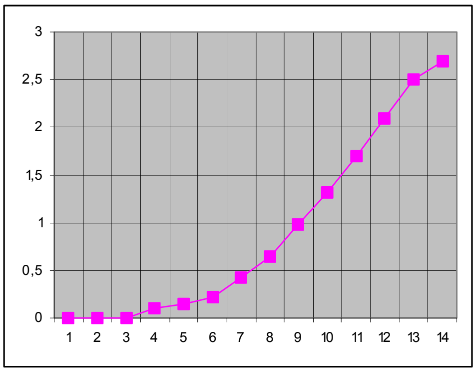
Technical information

POWER		Unit
1) Rated power	3	kW
2) Rated wind speed	14	m/s
3) Cut-in wind speed	3,5	m/s
4) Cut-out wind speed	20	m/s
5) Maximum wind speed the turbine can withstand	Not available	Km/h
DIMENSIONS		
6) Rotor weight	200	kg
7) Rotor diameter	2,8	m
8) Rotor height (for VAWT only)	4	m
9) Swept area	5,5	m^2
10) Height of the mast	Variable 1-12	m
OTHER INFORMATION		
11) Maximum rpm	300	At rated wind speed
12) Gear box type	No gear box	
13) Brake system	Electrical brake + disc brake	
14) Number of blades	5	
15) Blades material	Aluminium	
16) Output voltage	230	V
17) Minimum operation temperature	- 30	°C
18) Maximum operation temperature	+ 50	°C
19) Acoustic levels at a distance of 20 m ? at nacelle ? (wind = 5 m/s)	Not available	DB
20) Lifetime	20	Years
21) Is the machine self-starting	Yes	
22) Use of an asynchronous generator	No	
23) Yaw control system	Independent of wind direction	
24) Upwind or downwind	Not applicable	

Calculated power curve

Wind speed (m/s)	Power* (W)
1	0
2	0
3	0
4	100
5	
6	220
7	420
8	650
9	980
10	1320
11	1700
12	2100
13	2500
14	2700
15	

Power curve



Eoltec

HAWT from 6 kW to 250 kW.

Contact name: Thomas Schulthess
Address: 455, promenade des Anglais, 06299 Nice
Telephone: +33 6 85 30 35 05
Country : **France**

Sirocco/ 6 kW

Eoltec Sirocco 6 kW references

Site	Use	Country
Nice	Demonstration turbine connected to the grid	France
Orkney Island	Extreme winds test site	UK
	Hybrid electrification stand-alone or grid-tied, water pumping, heating,...	4 continents

Technical information

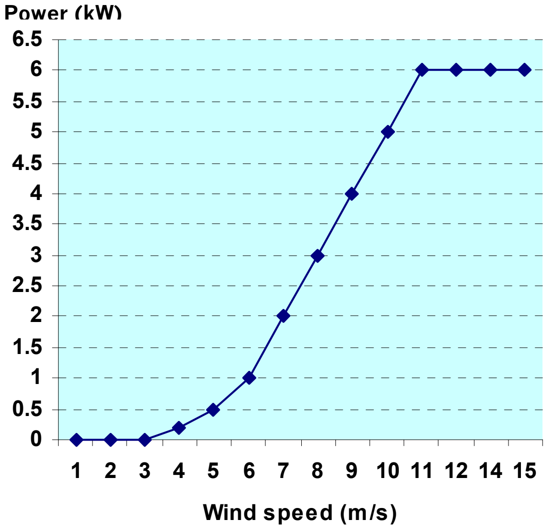
POWER		Unit
1) Rated power	6	kW
2) Rated wind speed	12	m/s
3) Cut-in wind speed	4	m/s
4) Cut-out wind speed	None	m/s
5) Maximum wind speed the turbine can withstand	216	Km/h
DIMENSIONS		
6) Rotor weight (+ generator)	202	kg
7) Rotor diameter	5,6	m
8) Rotor height (for VAWT only)		m
9) Swept area	24,7	m^2
10) Height of the mast	18/24/30	m
OTHER INFORMATION		
11) Maximum rpm	245	At rated wind speed
12) Gear box type		
13) Brake system	Optional remote control at tower base	
14) Number of blades	2	
15) Blades material	Composite fibre glass	
16) Output voltage	230	V
17) Minimum operation temperature	- 40	°C
18) Maximum operation temperature	+ 50	°C
19) Acoustic levels at a distance of 20 m ? at nacelle ? (wind = 5 m/s)	65	DB
20) Lifetime	25	Years
21) Is the machine self-starting	Yes	
22) Use of an asynchronous generator	No	
23) Yaw control system	Wind vane	
24) Upwind or downwind	Upwind turbine	

Calculated power curve

Wind speed (m/s)	Power (kW)
1	0
2	0
3	0
4	0,2
5	0.5
6	1.1
7	1.8
8	2.7
9	3.8
10	5
11	5.7
12	6
13	6
14	6
15	6

Inland site, altitude 300 m, 18 m tower
Rayleigh distribution (k= 2)
Shear ratio 0,143 / Turbulence factor 10 %

Power curve:



Eoltec

HAWT from 6 kW to 250 kW.

Contact name: Thomas Schulthess
Address: 455, promenade des Anglais, 06299 Nice
Telephone: +33 6 85 30 35 05
Country : **France**

Eoltec Wind runner 25 kW references

Site	Use	Country
Orkney Island	Prototype	UK

Wind Runner/ 25 kW

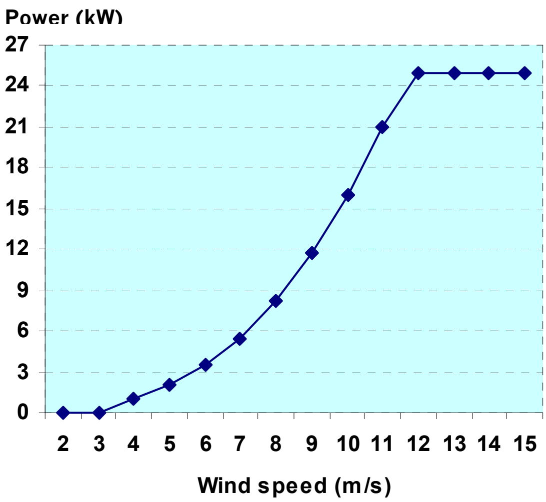
Technical information

POWER		Unit
1) Rated power	25	kW
2) Rated wind speed	12	m/s
3) Cut-in wind speed	3	m/s
4) Cut-out wind speed	None	m/s
5) Maximum wind speed the turbine can withstand	216	Km/h
DIMENSIONS		
6) Rotor weight (+ generator)	620	kg
7) Rotor diameter	10	m
8) Rotor height (for VAWT only)		m
9) Swept area	78,6	m^2
10) Height of the mast	18/24/32	m
OTHER INFORMATION		
11) Maximum rpm	140	At rated wind speed
12) Gear box type	none – direct drive	
13) Brake system	Optional remote control (blades stalling)	
14) Number of blades	2	
15) Blades material	Composite fiber glass	
16) Output voltage	400	V
17) Minimum operation temperature	- 40	°C
18) Maximum operation temperature	+ 50	°C
19) Acoustic levels at a distance of 20 m ? at nacelle ? (wind = 5 m/s)	65	DB
20) Lifetime	25	Years
21) Is the machine self-starting	Yes	
22) Use of an asynchronous generator	No	
23) Yaw control system	Wind vane	
24) Upwind or downwind	Upwind turbine	

Calculated power curve

Wind speed (m/s)	Power (kW)
1	0
2	0
3	0.5
4	1
5	2
6	3.5
7	5.5
8	8.2
9	11.7
10	16
11	21
12	25
13	25
14	25
15	25

Power curve:



Eurowind Small Turbines Ltd

VAWT – from 1,3 kW to 30 kW

Contact name: Steven Peace
Address: 38 Kings Avenue, Newhaven, East Sussex BN9 0NA
Telephone: +44 (0) 12 73 61 23 83
Country: **United Kingdom**

Eurowind 1,3 kW references

Site	Use	Country
Unknown	Prototype	UK

Eurowind / 1,3 kW

Technical information

POWER		Unit
1) Rated power	1,3	kW
2) Rated wind speed	12	m/s
3) Cut-in wind speed	3 to 4	m/s
4) Cut-out wind speed	28 to 32	m/s
5) Maximum wind speed the turbine can withstand	255	km/h
DIMENSIONS		
6) Nacelle and rotor weight	DK	kg
7) Rotor diameter	2,25	m
8) Rotor height (for VAWT only)	2	m
9) Swept area	4,5	m^2
10) Height of the mast	Site dependent	m
OTHER INFORMATION		
11) Maximum rpm	DK	At rated wind speed
12) Gear box type	DK	
13) Brake system	DK	
14) Number of blades	3	
15) Blades material	Composite fibre glass	
16) Output voltage	24 – 240	V
17) Minimum operation temperature	Not known	°C
18) Maximum operation temperature	Not known	°C
19) Acoustic levels at a distance of 20 m ? at nacelle ? (wind = 5 m/s)	Dk	DB
20) Lifetime	20	Years
21) Is the machine self-starting	Yes	
22) Use of an asynchronous generator	No	
23) Yaw control system	Not necessary	
24) Upwind or downwind	N/a	

Calculated power curve

Not available

Wind speed (m/s)	Power (kW)
1	
2	
3	
4	
5	
6	
7	
8	
9	
10	
11	
12	
13	
14	
15	

Power curve

Not available

Eurowind Small Turbines Ltd

VAWT – from 1,3 kW to 30 kW

Contact name: Steven Peace
Address: 38 Kings Avenue, Newhaven, East Sussex BN9 0NA
Telephone: +44 (0) 12 73 61 23 83
Country : **United Kingdom**

Eurowind 5 kW references

Site	Use	Country

Eurowind / 5 kW

Technical information

POWER		Unit
1) Rated power	5	kW
2) Rated wind speed	12	m/s
3) Cut-in wind speed	3 to 4	m/s
4) Cut-out wind speed	28 to 32	m/s
5) Maximum wind speed the turbine can withstand	255	km/h
DIMENSIONS		
6) Nacelle and rotor weight	DK	kg
7) Rotor diameter	4,25	m
8) Rotor height (for VAWT only)	4	m
9) Swept area	17	m^2
10) Height of the mast	Site dependent	m
OTHER INFORMATION		
11) Maximum rpm	DK	At rated wind speed
12) Gear box type	DK	
13) Brake system	DK	
14) Number of blades	3	
15) Blades material	Composite fibre glass	
16) Output voltage	24 – 240	V
17) Minimum operation temperature	Not known	°C
18) Maximum operation temperature	Not known	°C
19) Acoustic levels at a distance of 20 m ? at nacelle ? (wind = 5 m/s)		DB
20) Lifetime	20	Years
21) Is the machine self-starting	Yes	
22) Use of an asynchronous generator	No	
23) Yaw control system	Not necessary	
24) Upwind or downwind	N/a	

Calculated power curve

Not available

Wind speed (m/s)	Power (kW)
1	
2	
2,5	
4	
5	
6	
7	
8	
9	
10	
11	
12	
13	
14	
15	

Power curve

Not available

Eurowind Small Turbines Ltd

VAWT – from 1,3 kW to 30 kW

Contact name: Steven Peace
Address: 38 Kings Avenue, Newhaven, East Sussex BN9 0NA
Telephone: +44 (0) 12 73 61 23 83
Country: **United Kingdom**

Eurowind 10,8 kW references

Site	Use	Country

Eurowind / 10,8 kW

Technical information

POWER		Unit
1) Rated power	10,8	kW
2) Rated wind speed	12	m/s
3) Cut-in wind speed	3 to 4	m/s
4) Cut-out wind speed	28 to 32	m/s
5) Maximum wind speed the turbine can withstand	255	Km/h
DIMENSIONS		
6) Nacelle and rotor weight	DK	kg
7) Rotor diameter	6,26	m
8) Rotor height (for VAWT only)	5	m
9) Swept area	37	m^2
10) Height of the mast	Site dependent	m
OTHER INFORMATION		
11) Maximum rpm	DK	At rated wind speed
12) Gear box type	DK	
13) Brake system	DK	
14) Number of blades	3	
15) Blades material	Composite fibre glass	
16) Output voltage	24 – 240	V
17) Minimum operation temperature	DK	°C
18) Maximum operation temperature	DK	°C
19) Acoustic levels at a distance of 20 m ? at nacelle ? (wind = 5 m/s)	DK	DB
20) Lifetime	20	Years
21) Is the machine self-starting	Yes	
22) Use of an asynchronous generator	No	
23) Yaw control system	Not necessary	
24) Upwind or downwind	N/a	

Calculated power curve

Not available

Wind speed (m/s)	Power (kW)
1	
2	
2,5	
4	
5	
6	
7	
8	
9	
10	
11	
12	
13	
14	
15	

Power curve

Not available

Eurowind Small Turbines Ltd

VAWT – from 1,3 kW to 30 kW

Contact name: Steven Peace
Address: 38 Kings Avenue, Newhaven, East Sussex BN9 0NA
Telephone: +44 (0) 12 73 61 23 83
Country: **United Kingdom**

Eurowind 19 kW references

Site	Use	Country
No references available yet		

Eurowind / 19 kW

Photo Montage

Technical information

POWER		Unit
1) Rated power	19	kW
2) Rated wind speed	12	m/s
3) Cut-in wind speed	3 to 4	m/s
4) Cut-out wind speed	28 to 32	m/s
5) Maximum wind speed the turbine can withstand	255	Km/h
DIMENSIONS		
6) Nacelle and rotor weight	DK	kg
7) Rotor diameter	8,25	m
8) Rotor height (for VAWT only)	8	m
9) Swept area	66	m^2
10) Height of the mast	Site dependent	m
OTHER INFORMATION		
11) Maximum rpm	DK	At rated wind speed
12) Gear box type	DK	
13) Brake system	DK	
14) Number of blades	3	
15) Blades material	Composite fibre glass	
16) Output voltage	24 – 240	V
17) Minimum operation temperature	DK	°C
18) Maximum operation temperature	DK	°C
19) Acoustic levels at a distance of 20 m ? at nacelle ? (wind = 5 m/s)	DK	DB
20) Lifetime	20	Years
21) Is the machine self-starting	Yes	
22) Use of an asynchronous generator	No	
23) Yaw control system	Not necessary	
24) Upwind or downwind	N/a	

Calculated power curve

Not available

Wind speed (m/s)	Power (kW)
1	
2	
3	
4	
5	
6	
7	
8	
9	
10	
11	
12	
13	
14	
15	

Power curve

Not available

Eurowind Small Turbines Ltd

VAWT – from 1,3 kW to 30 kW

Contact name: Steven Peace
Address: 38 Kings Avenue, Newhaven, East Sussex BN9 0NA
Telephone: +44 (0) 12 73 61 23 83
Country: **United Kingdom**

Eurowind 30 kW references

Site	Use	Country
No references available yet		

Eurowind / 30 kW

Photo Montage

Technical information

POWER		Unit
1) Rated power	30	kW
2) Rated wind speed	12	m/s
3) Cut-in wind speed	3 to 4	m/s
4) Cut-out wind speed	28 to 32	m/s
5) Maximum wind speed the turbine can withstand	255	Km/h
DIMENSIONS		
6) Nacelle and rotor weight	DK	kg
7) Rotor diameter	10,25	m
8) Rotor height (for VAWT only)	10	m
9) Swept area	102,5	m^2
10) Height of the mast	Site dependent	m
OTHER INFORMATION		
11) Maximum rpm	DK	At rated wind speed
12) Gear box type	DK	
13) Brake system	DK	
14) Number of blades	3	
15) Blades material	Composite fibre glass	
16) Output voltage	24 – 240	V
17) Minimum operation temperature	DK	°C
18) Maximum operation temperature	DK	°C
19) Acoustic levels at a distance of 20 m ? at nacelle ? (wind = 5 m/s)	DK	DB
20) Lifetime	20	Years
21) Is the machine self-starting	Yes	
22) Use of an asynchronous generator	No	
23) Yaw control system	Not necessary	
24) Upwind or downwind	N/a	

Calculated power curve

Not available

Wind speed (m/s)	Power (kW)
1	
2	
3	
4	
5	
6	
7	
8	
9	
10	
11	
12	
13	
14	
15	

Power curve

Not available

Fortis Wind Energy

HAWT from 0,8 kW to 10 kW.

Contact name: Johan Kuikman
Address: Botanicuslaan 14, 9751 AC Haren
Telephone: +31 – 50 5340104
Country : **Netherlands**

Espada references

Site	Use	Country
Xingang Nat. Machinery Corp.	Technology transfer	China
Windsund, Sunderland	Offshore application	UK
Brussel	Ecole Royale Miltaire	Belgium
Galeforce	Stand alone application	UK

Espada / 0,8 kW

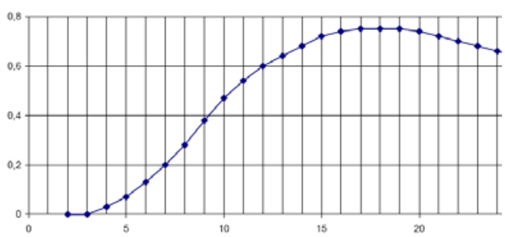
Technical information

POWER		Unit
1) Rated power	0,8	kW
2) Rated wind speed	14	m/s
3) Cut-in wind speed	3	m/s
4) Cut-out wind speed	No	m/s
5) Maximum wind speed the turbine can withstand	60	Km/h
DIMENSIONS		
6) Rotor weight	52	kg
7) Rotor diameter	2,2	m
8) Rotor height (for VAWT only)	---	m
9) Swept area	3,80	m^2
10) Height of the mast	12 – 18	m
OTHER INFORMATION		
11) Maximum rpm	1000	At rated wind speed
12) Gear box type	No brake system	
13) Brake system	Short circuit in generator	
14) Number of blades	2	
15) Blades material	Composite fibre glass	
16) Output voltage	12 - 240	V (DC)
17) Minimum operation temperature	- 30	°C
18) Maximum operation temperature	+ 50	°C
19) Acoustic levels at a distance of 20 m ? (wind = 10 m/s)	< 60	DB
20) Lifetime	20	Years
21) Is the machine self-starting	Yes	
22) Use of an asynchronous generator	No	
23) Yaw control system	Wind vane	
24) Upwind or downwind	Upwind	

Calculated power curve

Wind speed (m/s)	Power (W)
1	0
2	0
3	0
4	0,03
5	0,07
6	0,13
7	0,20
8	0,28
9	0,38
10	0,47
11	0,57
12	0,66
13	0,74
14	0,78
15	0,8

Power curve



Fortis Wind Energy

HAWT from 0,8 kW to 10 kW.

Contact name: Johan Kuikman
Address: Botanicuslaan 14, 9751 AC Haren
Telephone: +31-50 5340104
Country : Nethrelands

Passaat references

Site	Use	Country
Dieren	Stand alone electricity	Netherlands
Split	Roof university building	Croatia
Lapan	Rural electrification	Indonesia
Trontheim	Radio repeaters	Norway

Passaat 1,4 kW

Technical information

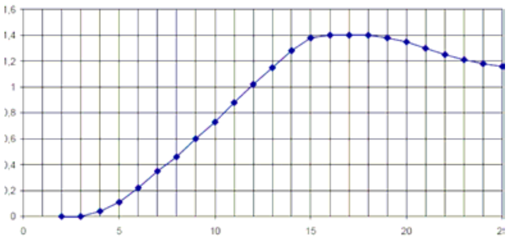
POWER		Unit
1) Rated power	1,4	kW
2) Rated wind speed	16	m/s
3) Cut-in wind speed	2,5	m/s
4) Cut-out wind speed	None	m/s
5) Maximum wind speed the turbine can withstand	60	Km/h
DIMENSIONS		
6) Rotor weight	75	kg
7) Rotor diameter	3,12	m
8) Rotor height (for VAWT only)	---	m
9) Swept area	7,65	m^2
10) Height of the mast	12 - 24	m
OTHER INFORMATION		
11) Maximum rpm	775	At rated wind speed
12) Gear box type	No gear box	
13) Brake system	Short circuit of generator	
14) Number of blades	3	
15) Blades material	Composite fibre glass	
16) Output voltage	24-240	V (DC)
17) Minimum operation temperature	- 30	°C
18) Maximum operation temperature	+ 50	°C
19) Acoustic levels at a distance of 20 m ? (wind = 10 m/s)	< 60	DB
20) Lifetime	20	Years
21) Is the machine self-starting	Yes	
22) Use of an asynchronous generator	No	
23) Yaw control system	Wind vane	
24) Upwind or downwind	Upwind	

Calculated power curve

Wind speed (m/s)	Power* (W)
1	0
2	0
3	0,001
4	0,040
5	0,110
6	0,220
7	0,350
8	0,460
9	0,600
10	0,730
11	0,880
12	1,020
13	1,150
14	1,280
15	1,400

*power on axis, sea level, temp. 15°C

Power curve



Fortis Montana

HAWT from 0,8 kW to 10 kW.

Contact name:	Johan Kuikman
Address:	Botanicuslaan 14, 9751 AC Haren
Telephone:	+31 – 50 5340104
Country :	Netherlands

Montana references

Site	Use	Country
Stompetoren	Demonstration at installation company	Netherlands
Waregem	On the roof of industrial building	Belgium
Perugia	Plasto Work and Wind Engineering	Italy
CREST	Stand alone electricity	Greece

Montana 5,6 kW

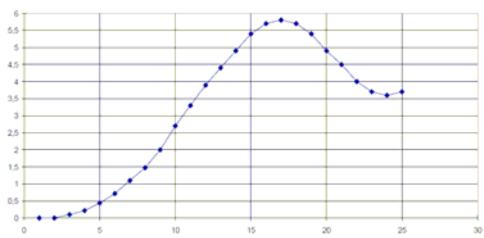
Technical information

POWER		Unit
1) Rated power	5,6	kW
2) Rated wind speed	17	m/s
3) Cut-in wind speed	2,5	m/s
4) Cut-out wind speed	No	m/s
5) Maximum wind speed the turbine can withstand	60	Km/h
DIMENSIONS		
6) Rotor weight	170	kg
7) Rotor diameter	5	m
8) Rotor height (for VAWT only)	---	m
9) Swept area	19,6	m^2
10) Height of the mast	18	m
OTHER INFORMATION		
11) Maximum rpm	450	At rated wind speed
12) Gear box type	No gear box	
13) Brake system	Short circuit at generator	
14) Number of blades	3	
15) Blades material	Composite fibre glass	
16) Output voltage	24 - 400	V (DC)
17) Minimum operation temperature	- 30	°C
18) Maximum operation temperature	+ 50	°C
19) Acoustic levels at a distance of 20 m ? (wind = 10 m/s)	< 60	DB
20) Lifetime	20	Years
21) Is the machine self-starting	Yes	
22) Use of an asynchronous generator	No	
23) Yaw control system	Wind vane	
24) Upwind or downwind	Upwind	

Calculated power curve

Wind speed (m/s)	Power (W)
1	0
2	0
3	0,10
4	0,22
5	0,44
6	0,72
7	1,10
8	1,43
9	2,00
10	2,70
11	3,30
12	3,90
13	4,40
14	4,90
15	5,40

Power curve



Fortis Wind Energy

HAWT from 0,8 kW to 10 kW.

Contact name: Johan Kuikman
Address: Botanicuslaan 14, 9751 AC Haren
Telephone: +31-50 5340104
Country : Netherlands

Alize references

Site	Use	Country
Dronrijp	Farm	Netherlands
Lutjegast	Farm	Netherlands
Opende	Farm	Netherlands
St. Cruz de la Palma	Desalination plant	Spain, Canary Islands

Alize, 10 kW

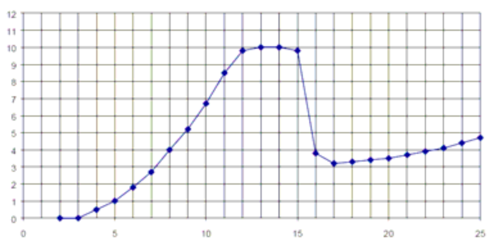
Technical information

POWER		Unit
1) Rated power	10	kW
2) Rated wind speed	12	m/s
3) Cut-in wind speed	3	m/s
4) Cut-out wind speed	No	m/s
5) Maximum wind speed the turbine can withstand	60	Km/h
DIMENSIONS		
6) Rotor weight	285	kg
7) Rotor diameter	7	m
8) Rotor height (for VAWT only)	---	m
9) Swept area	38,5	m^2
10) Height of the mast	18 – 36	m
OTHER INFORMATION		
11) Maximum rpm	300	At rated wind speed
12) Gear box type	No gear box	
13) Brake system	Short circuit of generator	
14) Number of blades	3	
15) Blades material	Composite fibre glass	
16) Output voltage	120 - 400	V (DC)
17) Minimum operation temperature	- 30	°C
18) Maximum operation temperature	+ 50	°C
19) Acoustic levels at a distance of 20 m ? (wind = 10 m/s)	< 60	DB
20) Lifetime	20	Years
21) Is the machine self-starting	Yes	
22) Use of an asynchronous generator	No	
23) Yaw control system	Wind vane	
24) Upwind or downwind	Upwind	

Calculated power curve

Wind speed (m/s)	Power* (W)
1	0
2	0
3	0
4	0,4
5	1,0
6	1,8
7	2,8
8	3,9
9	5,2
10	6,8
11	8,5
12	9,8
13	10,0
14	10,0
15	10,0

Power curve



Fuhrländer

HAWT from 30 kW to 2 700 kW.

Contact name: Carina Demuth / A. Kloos
Address: Auf der Höhe 4, 56477 Waigandshain
Telephone: +49 266 49 96 60
Country : **Germany**

Fürländer FL30 references

Site	Use	Country
Zistersdorf	Government	Austria
Cody / Wyoming	Privat Ranch	USA
Köln	Public Services	Germany

FL 30/ 30 kW

Technical information

POWER		Unit
1) Rated power	30	kW
2) Rated wind speed	12	m/s
3) Cut-in wind speed	2,5	m/s
4) Cut-out wind speed	25	m/s
5) Maximum wind speed the turbine can withstand	55	m/s
DIMENSIONS		
6) Rotor weight	640	kg
7) Rotor diameter	13	m
8) Rotor height (for VAWT only)		m
9) Swept area	133	m^2
10) Height of the mast	18/27	m
OTHER INFORMATION		
11) Maximum rpm	70	At rated wind speed
12) Gear box type	Spur gear/planet gears	
13) Brake system	Disk brake+ Mech tip brake	
14) Number of blades	3	
15) Blades material	Glass Fibre Composite	
16) Output voltage	400	V
17) Minimum operation temperature	-20°C	°C
18) Maximum operation temperature	+ 50°C	°C
19) Acoustic levels at a distance of 20 m ? at nacelle ? (wind = 5 m/s)	93	DB
20) Lifetime		Years
21) Is the machine self-starting	Yes	
22) Use of an asynchronous generator	Yes	
23) Yaw control system	1 gearbox motors	
24) Upwind or downwind		

Calculated power curve

Wind speed (m/s)	Power (W)
1	0
2	0
3	
4	
5	
6	
7	
8	
9	
10	
11	
12	
13	
14	
15	
16	
17	
18	

Power curve

Fuhrländer

HAWT from 30 kW to 2 700 kW.

Contact name: Carina Demuth / A. Kloos
Address: Auf der Höhe 4, 56477 Waigandshain
Telephone: +49 266 49 96 60
Country : **Germany**

Fuhrländer FL 100 references

Site	Use	Country
Rennerod	Company " Spedition Pracht"	Germany
Iwata /Shizuoka	Iwata Factory	Japan
Vilemov	Orthodox Akademie	Czech Republic
Boston	IBEW Local	USA

FL 100/ 100 kW

Technical information

POWER		Unit
1) Rated power	100	kW
2) Rated wind speed	13	m/s
3) Cut-in wind speed	2,5	m/s
4) Cut-out wind speed	25	m/s
5) Maximum wind speed the turbine can withstand	67	m/s
DIMENSIONS		
6) Rotor weight (incl. hub)	2 300	kg
7) Rotor diameter	21	m
8) Rotor height (for VAWT only)		m
9) Swept area	346	m^2
10) Height of the mast	35	m
OTHER INFORMATION		
11) Maximum rpm	47	At rated wind speed
12) Gear box type	Combined spur gear/planet gears	
13) Brake system	Disc brake + rotor tip brake + parking brake system + aerodynamic safety system "stall"	
14) Number of blades	3	
15) Blades material	Glass Fibre Composite	
16) Output voltage	400	V
17) Minimum operation temperature	-20°C	°C
18) Maximum operation temperature	+ 50°C	°C
19) Acoustic levels at a distance of 20 m ? at nacelle ? (wind = 5 m/s)	95	DB
20) Lifetime	25	Years
21) Is the machine self-starting	Yes	
22) Use of an asynchronous generator	Yes	
23) Yaw control system	Wind vane	
24) Upwind or downwind	Upwind	

Calculated power curve

Wind speed (m/s)	Power (W)
1	
2	
3	
4	
5	
6	
7	
8	
9	
10	
11	
12	
13	
14	
15	
16	
17	
18	

Power curve

Gaia-Wind A/S

HAWT 11 kW.

Contact name: Jesper Andersen
Address: Håndværkervej 1, 8840 Rødkærsbro
Telephone: +45 87 76 22 00
Country : **Denmark**

Gaia/ 11 kW

Gaia 11 kW references: have not provided any references

Site	Use	Country

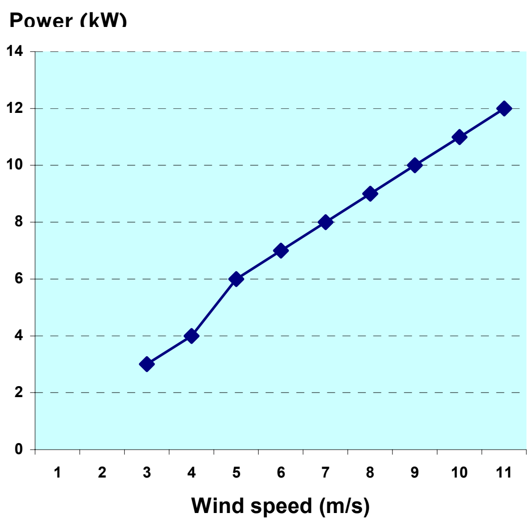
Technical information

POWER		Unit
1) Rated power	11	kW
2) Rated wind speed	10	m/s
3) Cut-in wind speed	3	m/s
4) Cut-out wind speed	25	m/s
5) Maximum wind speed the turbine can withstand	65	Km/h
DIMENSIONS		
6) Rotor weight	208-248	kg
7) Rotor diameter	13	m
8) Rotor height (for VAWT only)	Not relevant	m
9) Swept area	132	m^2
10) Height of the mast	18	m
OTHER INFORMATION		
11) Maximum rpm	56	At rated wind speed
12) Gear box type	Compact shaft mounted gear	
13) Brake system	Disc brake	
14) Number of blades	2	
15) Blades material	Composite fiber glass	
16) Output voltage	380-400	V
17) Minimum operation temperature	- 20	°C
18) Maximum operation temperature	+ 50	°C
19) Acoustic levels at a distance of 20 m ? at nacelle ? (wind = 5 m/s)	45 Db at 59 meters	DB
20) Lifetime	20	Years
21) Is the machine self-starting	Yes	
22) Use of an asynchronous generator	Yes	
23) Yaw control system	Wind vane	
24) Upwind or downwind	Downwind turbine	

Calculated power curve

Wind speed (m/s)	Power(kW)
1	
2	
3	3
4	4
5	6
6	7
7	8
8	9
9	10
10	11
11	12

Power curve:



Gazelle Wind Turbines Ltd

HAWT – 20 kW

Contact name: Ken Chaplin
Address: Stargate Ind Est, Ryton, Tyne & Wear, NE40 3 EX
Telephone: +44 (0) 191 413 00 12
Country: **United Kingdom**

Gazelle 20 kW references

Site	Use	Country
Southport Eco Centre,	Electricity generation for building	UK
Montagne Jeunesse Eco Factory, Swansea	Electricity generation for building	UK
Sunderland Enterprise Park, Sunderland	Electricity generation for building	UK

Gazelle / 20 kW

Technical information

POWER		Unit
1) Rated power	20	kW
2) Rated wind speed	13	m/s
3) Cut-in wind speed	4	m/s
4) Cut-out wind speed	20	m/s
5) Maximum wind speed the turbine can withstand	DK	km/h
DIMENSIONS		
6) Nacelle and rotor weight	1600	kg
7) Rotor diameter	11	m
8) Rotor height (for VAWT only)	-	m
9) Swept area	95	m^2
10) Height of the mast	12,5 to 20	m
OTHER INFORMATION		
11) Maximum rpm	106	At rated wind speed
12) Gear box type	None	
13) Brake system	-	
14) Number of blades	3	
15) Blades material	Carbon fibre epoxy	
16) Output voltage	400	V
17) Minimum operation temperature	DK	°C
18) Maximum operation temperature	DK	°C
19) Acoustic levels at a distance of 20 m ? at nacelle ? (wind = 5 m/s)	DK	DB
20) Lifetime	20 to 25	Years
21) Is the machine self-starting	Yes	
22) Use of an asynchronous generator	Yes	
23) Yaw control system	Free yaw	
24) Upwind or downwind	Downwind	

Calculated power curve

Not available

Wind speed (m/s)	Power (kW)
1	
2	
3	
4	
5	
6	
7	
8	
9	
10	
11	
12	
13	
14	
15	

Power curve

Not available

Iskra Wind Turbines

HAWT – 5 kW

Contact name: John Balson
Address: 261, Woodborough Road, St Anns, Nottingham, NG3 4 JZ
Telephone: +44 (0) 115 841 32 83
Country: **United Kingdom**

Iskra 5 kW references

Site	Use	Country
The Turbine, Shireoaks Business Innovation Centre, Worksop	Electricity generation for building	UK
Westergate Business Centre, Brighton	Electricity generation for building	UK
Hockerton Housing Project, Hockerton	Electricity generation for homes and visitor centre	UK

Iskra / 5 kW

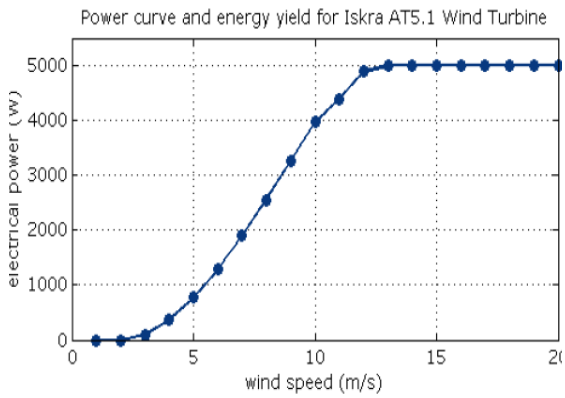
Technical information

POWER		Unit
1) Rated power	5	kW
2) Rated wind speed	11	m/s
3) Cut-in wind speed	3	m/s
4) Cut-out wind speed	60	m/s
5) Maximum wind speed the turbine can withstand	216	km/h
DIMENSIONS		
6) Nacelle and rotor weight	280	kg
7) Rotor diameter	5.4	m
8) Rotor height (for VAWT only)	-	m
9) Swept area	22.9	m^2
10) Height of the mast	12 to 30	m
OTHER INFORMATION		
11) Maximum rpm	200	At rated wind speed
12) Gear box type	None	
13) Brake system	Electro-dymamic	
14) Number of blades	3	
15) Blades material	Composite fibre glass	
16) Output voltage	Variable	V
17) Minimum operation temperature	-20	°C
18) Maximum operation temperature	+50	°C
19) Acoustic levels at a distance of 20 m ? at nacelle ? (wind = 5 m/s)	DK	DB
20) Lifetime	20	Years
21) Is the machine self-starting	Yes	
22) Use of an asynchronous generator	No	
23) Yaw control system	Tail vane	
24) Upwind or downwind	Upwind	

Calculated power curve

Wind speed (m/s)	Power (W)
1	0
2	0
3	96
4	367
5	771
6	1284
7	1901
8	2547
9	3253
10	3965
11	4397
12	4888
13	5000
14	5000
15	5000

Power curve:



Jonica Impianti

HAWT of 20 kW.

Contact name: Nicola De Luca
Address: Via Poerio 226, 74020 Lizzano
Telephone: +39 099 955 12 08
Country : **Italy**

Jonica Impianti 20 kW references

City (Province)	Use	Country
Lizzano (Taranto)	Jonica Impianti factory	Italy
Perarolo di Cadore (Belluno)	Industrial area	Italy
Pos al Pago (Belluno)	Industrial area	Italy
Quero (Belluno)	Industrial area	Italy
Colle Salvetti (Livorno)	AGIP Service station	Italy

Jonica Impianti/ 20 kW

Technical information

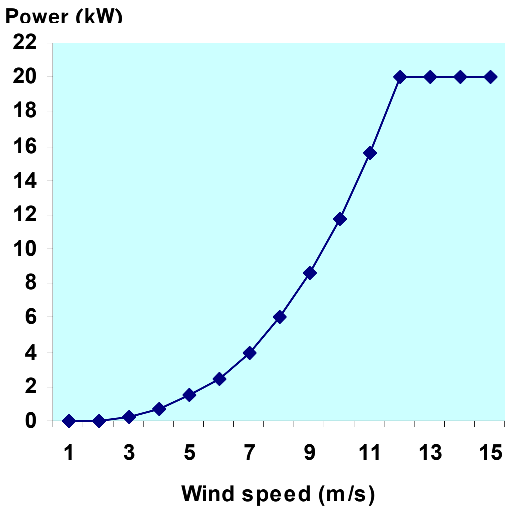
POWER		Unit
1) Rated power	20	KW
2) Rated wind speed	12,5	m/s
3) Cut-in wind speed	3,5	m/s
4) Cut-out wind speed	37,5	m/s
5) Maximum wind speed the turbine can withstand	153	Km/h
DIMENSIONS		
6) Rotor weight (blades)	100	Kg
7) Rotor diameter	8	m
8) Rotor height (for VAWT only)		m
9) Swept area	50,3	m^2
10) Height of the mast	12/18	m
OTHER INFORMATION		
11) Maximum rpm	200	At rated wind speed
12) Gear box type	Not present	
13) Brake system	Aerodynamic with pitch control	
14) Number of blades	3	
15) Blades material	Composite fiber glass	
16) Output voltage	380	V
17) Minimum operation temperature	- 20	°C
18) Maximum operation temperature	+ 50	°C
19) Acoustic levels at a distance of 50 m (wind = 9 m/s)	50	DB
20) Lifetime	20	Years
21) Is the machine self-starting	Yes	
22) Use of an asynchronous generator	No	
23) Yaw control system	Wind vane	
24) Upwind or downwind	Upwind turbine	

Calculated power curve

Wind speed (m/s)	Power (kW)
1	0
2	0
3	0,.25
4	0,.50
5	1, 5
6	2, 5
7	4
8	6
9	8, 6
10	11, 8
11	15, 6
12	20
13	20
14	20
15	20

Sea level, Raleygh distrib k = 2
Tower height= 18 m, Shear coef = 0,14
Turbulence factor = 15%

Power curve:



Marlec Engineering Co Ltd

HAWT – From 0,025 kW to 0,34 kW

Contact name:	Teresa Auciello
Address:	Rutland House, Trevithick Rd, Corby, Northants NN17 5XY
Telephone:	+44 (0) 1536 201 588
Country:	**United Kingdom**

Rutland 503 – 0,025 kW references

Site	Use	Country
Elliott Durham Comprehensive School, Nottingham	Educational	UK
Sandy Upper School and Community Sports College	Educational	UK
Cromwell Park Primary School, Huntingdon	Educational	UK

Rutland 503 / 0,025 kW

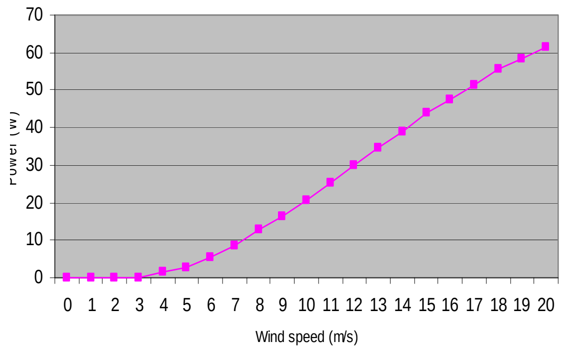
Technical information

POWER		Unit
1) Rated power	0, 025	kW
2) Rated wind speed	10	m/s
3) Cut-in wind speed	2,6	m/s
4) Cut-out wind speed	None	m/s
5) Maximum wind speed the turbine can withstand	> 137	km/h
DIMENSIONS		
6) Nacelle and rotor weight	3	kg
7) Rotor diameter	0,500	m
8) Rotor height (for VAWT only)	-	m
9) Swept area	0,196	m^2
10) Height of the mast	Variable up to 6,5	m
OTHER INFORMATION		
11) Maximum rpm	DK	At rated wind speed
12) Gear box type	None	
13) Brake system	DK	
14) Number of blades	6	
15) Blades material	Glass reinforced plastic	
16) Output voltage	12 or 24	V
17) Minimum operation temperature	-25	°C
18) Maximum operation temperature	DK	°C
19) Acoustic levels at a distance of 20 m? at nacelle? (wind = 5 m/s)	DK	DB
20) Lifetime	15	Years
21) Is the machine self-starting	Yes	
22) Use of an asynchronous generator	No	
23) Yaw control system	Wind vane	
24) Upwind or downwind	Upwind	

Calculated power curve

Wind speed (m/s)	Power (W)
1	0
2	0
3	1
4	2
5	4
6	6
7	10
8	14
9	20
10	26
11	28
12	36
13	39
14	44
15	56

Power curve:



Marlec Engineering Co Ltd

HAWT – From 0,025 kW to 0,34 kW

Contact name:	Teresa Auciello
Address:	Rutland House, Trevithick Rd, Corby, Northants NN17 5XY
Telephone:	+44 (0) 1536 201 588
Country :	**United Kingdom**

Rutland 910-3 / 0,09 kW

Rutland 910-3 – 0,09 kW references

Site	Use	Country
Hagbourne Primary School, Oxon	Educational and Electricity generation	UK
A43 roadside	Traffic signals	UK
Tokyo	Street lighting	Japan

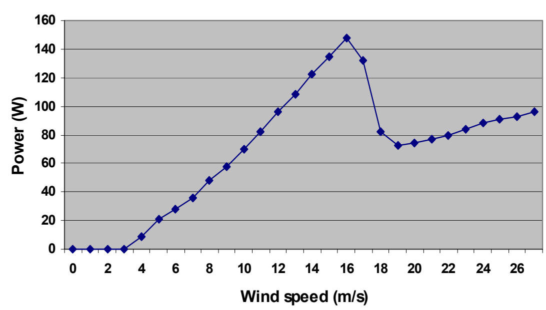
Technical information

POWER		Unit
1) Rated power	0,09	kW
2) Rated wind speed	10	m/s
3) Cut-in wind speed	2,6	m/s
4) Cut-out wind speed	It furls at 15 m/s but no real cut out	m/s
5) Maximum wind speed the turbine can withstand	> 137	km/h
DIMENSIONS		
6) Nacelle and rotor weight	17	kg
7) Rotor diameter	0,910	m
8) Rotor height (for VAWT only)	-	m
9) Swept area	0,655	m^2
10) Height of the mast	Up to 6,5	m
OTHER INFORMATION		
11) Maximum rpm	DK	At rated wind speed
12) Gear box type	None	
13) Brake system	DK	
14) Number of blades	6	
15) Blades material	Glass reinforced plastic	
16) Output voltage	12 or 24	V
17) Minimum operation temperature	Artic	°C
18) Maximum operation temperature	Sahara	°C
19) Acoustic levels at a distance of 20 m? at nacelle? (wind = 5 m/s)	DK	DB
20) Lifetime	15	Years
21) Is the machine self-starting	Yes	
22) Use of an asynchronous generator	No	
23) Yaw control system	Wind vane	
24) Upwind or downwind	Upwind	

Calculated power curve

Wind speed (m/s)	Power (W)
1	0
2	0
3	2
4	14
5	21
6	28
7	44
8	50
9	66
10	83
11	87
12	92
13	121
14	138
15	159

Power curve:



Marlec Engineering Co Ltd

HAWT – From 0,025 kW to 0,34 kW

Contact name:	Teresa Auciello
Address:	Rutland House, Trevithick Rd, Corby, Northants NN17 5XY
Telephone:	+44 (0) 1536 201 588
Country :	**United Kingdom**

Rutland 913/ 0,09 kW

Rutland 913 – 0,09 kW references

Site	Use	Country
Rutland Water	Water level monitoring	UK
Southampton	Sailing boat	UK
	Street lighting	Taiwan
A6006 road sign	Safety sign	UK

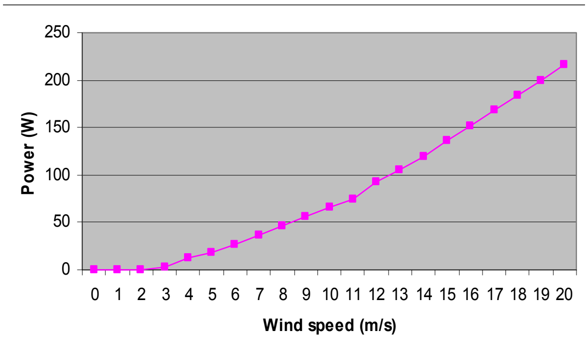
Technical information

POWER		Unit
1) Rated power	0,09	kW
2) Rated wind speed	10	m/s
3) Cut-in wind speed	2,6	m/s
4) Cut-out wind speed	None	m/s
5) Maximum wind speed the turbine can withstand	> 137	Km/h
DIMENSIONS		
6) Nacelle and rotor weight	13	Kg
7) Rotor diameter	0,913	m
8) Rotor height (for VAWT only)	-	m
9) Swept area	0,655	m^2
10) Height of the mast	Variable up to 6,5	m
OTHER INFORMATION		
11) Maximum rpm	DK	At rated wind speed
12) Gear box type	None	
13) Brake system	DK	
14) Number of blades	6	
15) Blades material	Glass reinforced plastic	
16) Output voltage	12 or 24	V
17) Minimum operation temperature	-25	°C
18) Maximum operation temperature	DK	°C
19) Acoustic levels at a distance of 20 m? at nacelle? (wind = 5 m/s)	DK	DB
20) Lifetime	15	Years
21) Is the machine self-starting	Yes	
22) Use of an asynchronous generator	No	
23) Yaw control system	Wind vane	
24) Upwind or downwind	Upwind	

Calculated power curve

Wind speed (m/s)	Power (W)
1	0
2	0
3	2
4	14
5	21
6	28
7	44
8	50
9	66
10	83
11	87
12	92
13	121
14	138
15	159

Power curve:



OY Windside Production Ltd

VAWT from 1 kW to 8 kW.

Contact name: Risto Joutsiniemi
Address: Niemenharjuntie 85, 44800 Pihtipudas
Telephone: +358 208 350 700
Country : **Finland**

WS-4B & 4C/ 1-2 kW

Oy Windside WS-4B/4C references

Site	Use	Country
Doncaster	Earth Centre	England
Helsinki	Arabianranta	Finland
Chicago	Millenium Park	U.S.A
Yurigaoka, Fukuoka	Sports centre	Japan
Oulu	In a Park wind art work Synergia	Finland

Technical information

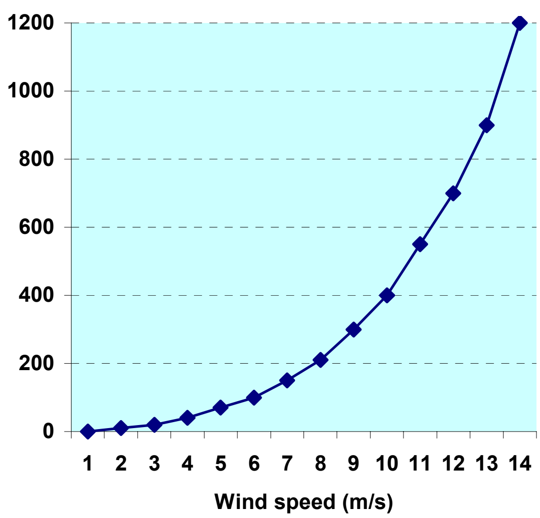
POWER		Unit
1) Rated power	1	KW
2) Rated wind speed	18	m/s
3) Cut-in wind speed	2	m/s
4) Cut-out wind speed	None	m/s
5) Maximum wind speed the turbine can withstand	144	Km/h
DIMENSIONS		
6) Rotor weight	400	Kg
7) Rotor diameter	1	m
8) Rotor height (for VAWT only)	4	m
9) Swept area	4	m^2
10) Height of the mast	Not relevant	m
OTHER INFORMATION		
11) Maximum rpm	170 - 400	At rated wind speed
12) Gear box type	No gear box	
13) Brake system	Disk brake	
14) Number of blades	2	
15) Blades material	Composite fibre glass	
16) Output voltage	0 - 200	V
17) Minimum operation temperature	- 60	°C
18) Maximum operation temperature	+ 80	°C
19) Acoustic levels at a distance of 20 m ? at nacelle ? (wind = 5 m/s)	0	DB
20) Lifetime	100	Years
21) Is the machine self-starting	Yes	
22) Use of an asynchronous generator	Yes	
23) Yaw control system	Not needed	
24) Upwind or downwind		

Calculated power curve

Wind speed (m/s)	Power (W)
1	0
2	10
3	20
4	40
5	70
6	100
7	150
8	210
9	300
10	400
11	550
12	700
13	900
14	1 200

In battery charging the electricity production will be changing according to the voltage level chosen by the client. 3-phase Generator 25 Ampers

Power curve



OY Windside Production Ltd

VAWT from 1 kW to 8 kW.

Contact name: Risto Joutsiniemi
Address: Niemenharjuntie 85, 44800 Pihtipudas
Telephone: +358 208 350 700
Country : **Finland**

Oy Windside WS-12 references

Site	Use	Country
Raisio	Shopping centre	Finland

WS-12/ 8 kW

Technical information

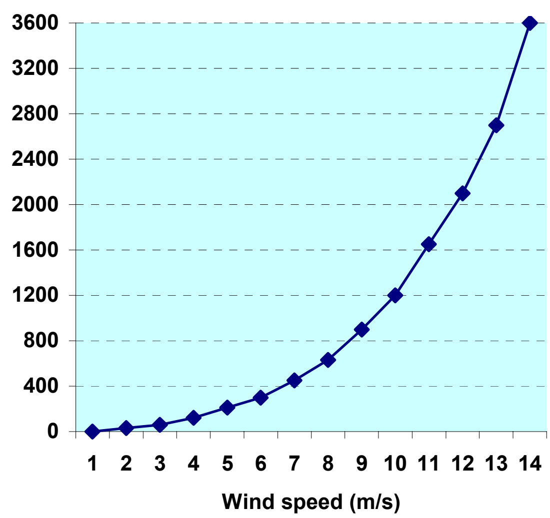
POWER		Unit
1) Rated power	8	kW
2) Rated wind speed	20	m/s
3) Cut-in wind speed	2	m/s
4) Cut-out wind speed	None	m/s
5) Maximum wind speed the turbine can withstand	216	Km/h
DIMENSIONS		
6) Rotor weight	3000	kg
7) Rotor diameter	2	m
8) Rotor height (for VAWT only)	6	m
9) Swept area	12	m^2
10) Height of the mast	Not relevant	m
OTHER INFORMATION		
11) Maximum rpm	100 - 300	At rated wind speed
12) Gear box type		No gear box
13) Brake system		Disk brake
14) Number of blades		2
15) Blades material		Aluminium
16) Output voltage	0 - 200	V
17) Minimum operation temperature	- 60	°C
18) Maximum operation temperature	+ 80	°C
19) Acoustic levels at a distance of 20 m ? at nacelle ? (wind = 5 m/s)	0	DB
20) Lifetime	100	Years
21) Is the machine self-starting		Yes
22) Use of an asynchronous generator		Yes
23) Yaw control system		Not needed
24) Upwind or downwind		

Calculated power curve

Wind speed (m/s)	Power (W)
1	0
2	30
3	60
4	120
5	211
6	300
7	450
8	630
9	900
10	1 200
11	1 650
12	2 100
13	2 700
14	3 600

In battery charging the electricity production will be changing according to the voltage level chosen by the client.

Power curve



Pitchwind Systems AB

HAWT from 20 kW to 30 kW

Contact name: Lars Akeson
Address: PO Box 89, 44 322 Lerum
Telephone: +46 708 237 219
Country : **Sweden**

Pitchwind 30 kW Grid connected references

Site	Use	Country

Pitchwind/ 30 kW Grid

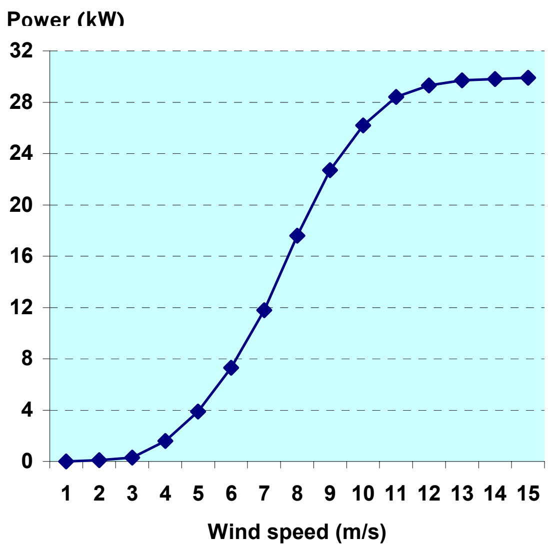
Technical information

POWER		Unit
1) Rated power	30	kW
2) Rated wind speed	15	m/s
3) Cut-in wind speed	2	m/s
4) Cut-out wind speed	None	m/s
5) Maximum wind speed the turbine can withstand	250	Km/h
DIMENSIONS		
6) Rotor weight	550	kg
7) Rotor diameter	14	m
8) Rotor height (for VAWT only)		m
9) Swept area	154	m^2
10) Height of the mast	20 / 62	m
OTHER INFORMATION		
11) Maximum rpm	81	At rated wind speed
12) Gear box type	None	
13) Brake system	Pitch by electrical actuator at service parking brake	
14) Number of blades	2	
15) Blades material	Steel polyster	
16) Output voltage	380 – 500	V
17) Minimum operation temperature	- 40	°C
18) Maximum operation temperature	+ 40	°C
19) Acoustic levels at a distance of 30m from tower base (wind speed 5 m/s & rotor speed = 48 rpm)	50	DB
20) Lifetime	20	Years
21) Is the machine self-starting	Yes	
22) Use of an asynchronous generator	No	
23) Yaw control system	Wind wheels	
24) Upwind or downwind	Upwind	

Calculated power curve

Wind speed (m/s)	Power (kW)
1	0
2	0,1
3	0,3
4	1,6
5	3,9
6	7,3
7	11,8
8	17,6
9	22,7
10	26,2
11	28,4
12	29,3
13	29,7
14	29,8
15	29,9

Power curve:



Proven Energy Products Ltd

HAWT – From 0,6 kW to 15 kW

Contact name: David Watson
Address: Wardhead Park, Stewarton, Ayrshire, KA3 5 LH, Scotland
Telephone: +44 (0) 1560 485 570
Country : **United Kingdom**

Proven WT 600 references

Site	Use	Country

Proven WT 600/ 0,6 kW

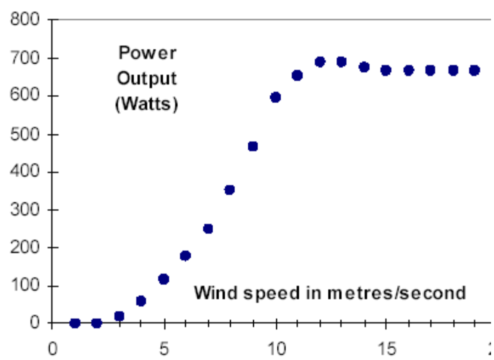
Technical information

POWER		Unit
1) Rated power	0,6	KW
2) Rated wind speed	10	m/s
3) Cut-in wind speed	2,5	m/s
4) Cut-out wind speed	None	m/s
5) Maximum wind speed the turbine can withstand	234	Km/h
DIMENSIONS		
6) Rotor weight	70	Kg
7) Rotor diameter	2,55	m
8) Rotor height (for VAWT only)		m
9) Swept area	5,11	m^2
10) Height of the mast	5,5	m
OTHER INFORMATION		
11) Maximum rpm		At rated wind speed
12) Gear box type		
13) Brake system		
14) Number of blades		3
15) Blades material		Polypropylene / P.U.
16) Output voltage	14 / 24/ 48	V
17) Minimum operation temperature	Artic circle	°C
18) Maximum operation temperature	South America	°C
19) Acoustic levels at a distance of 20 m ? at nacelle ? (wind = 5 m/s)	21 at 20 m 35 at mast	DB
20) Lifetime	20-25	Years
21) Is the machine self-starting		Yes
22) Use of an asynchronous generator		No
23) Yaw control system		
24) Upwind or downwind		Downwind

Calculated power curve

Wind speed (m/s)	Power (W)
1	0
2	0
3	15
4	60
5	110
6	190
7	260
8	350
9	480
10	600
11	660
12	700
13	700
14	700

Power curve:



Proven Energy Products Ltd

HAWT – From 0,6 kW to 15 kW

Contact name: David Watson
Address: Wardhead Park, Stewarton, Ayrshire, KA3 5 LH, Scotland
Telephone: +44 (0) 1560 485 570
Country : **United Kingdom**

Proven WT 6 000 references

Site	Use	Country

Proven WT 6 000/ 6 kW

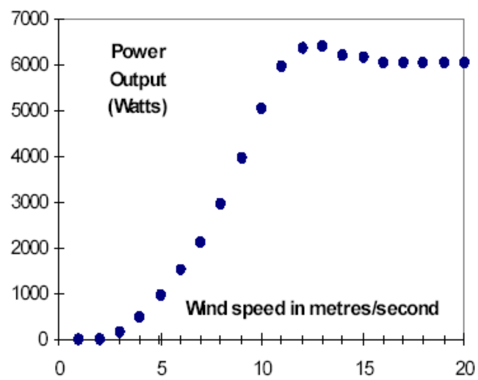
Technical information

POWER		Unit
1) Rated power	6	KW
2) Rated wind speed	12	m/s
3) Cut-in wind speed	2,5	m/s
4) Cut-out wind speed	None	m/s
5) Maximum wind speed the turbine can withstand	234	Km/h
DIMENSIONS		
6) Rotor weight	539	Kg
7) Rotor diameter	5,5	m
8) Rotor height (for VAWT only)		m
9) Swept area	23,76	m^2
10) Height of the mast	9 / 15	m
OTHER INFORMATION		
11) Maximum rpm		At rated wind speed
12) Gear box type		
13) Brake system		
14) Number of blades		3
15) Blades material		Wood/ Epoxy / P.U.
16) Output voltage	48 to 300	V
17) Minimum operation temperature	Artic circle	°C
18) Maximum operation temperature	South America	°C
19) Acoustic levels at a distance of 20 m ? at nacelle ? (wind = 5 m/s)	45 dB at mast 36 dB at 20 m	DB
20) Lifetime	20-25	Years
21) Is the machine self-starting		Yes
22) Use of an asynchronous generator		No
23) Yaw control system		
24) Upwind or downwind		Downwind

Calculated power curve

Wind speed (m/s)	Power (W)
1	0
2	0
3	100
4	450
5	1 000
6	1 500
7	2 050
8	3 000
9	4 000
10	5 000
11	6 000
12	6 200
13	6 250
14	6 150

Power curve:



Proven Energy Products Ltd

HAWT – From 0,6 kW to 15 kW

Contact name: David Watson
Address: Wardhead Park, Stewarton, Ayrshire, KA3 5 LH, Scotland
Telephone: +44 (0) 1560 485 570
Country : **United Kingdom**

Proven WT 15 000 references

Site	Use	Country

Proven WT 15 000/ 15 kW

Technical information

POWER		Unit
1) Rated power	15	KW
2) Rated wind speed	12	m/s
3) Cut-in wind speed	2,5	m/s
4) Cut-out wind speed	None	m/s
5) Maximum wind speed the turbine can withstand	234	Km/h
DIMENSIONS		
6) Rotor weight	1 100	Kg
7) Rotor diameter	9	m
8) Rotor height (for VAWT only)		m
9) Swept area	63,62	m^2
10) Height of the mast	15 /20	m
OTHER INFORMATION		
11) Maximum rpm		At rated wind speed
12) Gear box type		
13) Brake system		
14) Number of blades	3	
15) Blades material	Glass Epoxy	
16) Output voltage	48 DC or 230 AC or 240 AC	V
17) Minimum operation temperature	Artic circle	°C
18) Maximum operation temperature	South America	°C
19) Acoustic levels at a distance of 20 m ? at nacelle ? (wind = 5 m/s)	65 dB at mast 48 dB at 20 m	DB
20) Lifetime	20-25	Years
21) Is the machine self-starting	Yes	
22) Use of an asynchronous generator	No	
23) Yaw control system		
24) Upwind or downwind	Downwind	

Calculated power curve

Wind speed (m/s)	Power (W)
1	0
2	0
3	300
4	1 200
5	2 200
6	4 000
7	5 500
8	7 500
9	10 000
10	12 500
11	15 000
12	16 000
13	16 000
14	16 500

Power curve:

Renewable Devices Swift Turbines

HAWT – 1,5 kW

Contact name:	
Address:	Bush Estate, Edinburgh, EH26 OPH
Telephone:	+44 (0) 131 535 33 01
Country :	**United Kingdom**

Swift Rooftop/ 1,5 kW

Swift Rooftop 1,5 kW references

Site	Use	Country
Fife School / Collidean	Primary school (rooftop)	England

Technical information

POWER		Unit
1) Rated power	1,5	KW
2) Rated wind speed	12	m/s
3) Cut-in wind speed	4	m/s
4) Cut-out wind speed	17	m/s
5) Maximum wind speed the turbine can withstand	223	Km/h
DIMENSIONS		
6) Rotor weight	15	Kg
7) Rotor diameter	2	m
8) Rotor height (for VAWT only)		m
9) Swept area	3,14	m^2
10) Height of the mast	5	m
OTHER INFORMATION		
11) Maximum rpm		At rated wind speed
12) Gear box type		
13) Brake system		
14) Number of blades	5	
15) Blades material	Moulded carbon fibre	
16) Output voltage	60 DC	V
17) Minimum operation temperature	DK	°C
18) Maximum operation temperature	DK	°C
19) Acoustic levels at a distance of 20 m ? at nacelle ? (wind = 5 m/s)	DK	DB
20) Lifetime	20	Years
21) Is the machine self-starting	Yes	
22) Use of an asynchronous generator	No	
23) Yaw control system	Wind vane	
24) Upwind or downwind	Upwind	

Calculated power curve

Wind speed (m/s)	Power (W)
1	
2	
3	
4	
5	
6	
7	
8	
9	
10	
11	
12	
13	
14	
15	

Power curve:

Ropatec S.p.a.

VAWT from 0,75 kW to 6 kW.

Contact name: Hannes Riegler
Address: Via Siemens 19
Telephone: +39 0471 568 180
Country : **Italy**

Ropatec WRE.007 references

Site	Use	Country
Near Bristol	Battery charging for a LNG-station	England
	Demonstration unit on a rooftop	Korea
Ihoshy	Energy supply for a radio station	Madagascar
Hammerfest	Battery charging	Norway

WRE.007 / 0,75 kW

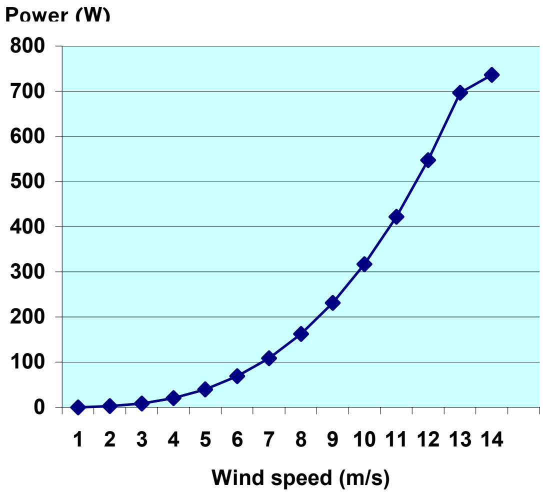
Technical information

		Unit
1) Rated power	0,75	kW
2) Rated wind speed	14	m/s
3) Cut-in wind speed	2	m/s
4) Cut-out wind speed	None	m/s
5) Maximum wind speed the turbine can withstand	> 150	Km/h
DIMENSIONS		
6) Rotor weight	150	kg
7) Rotor diameter	1,5	m
8) Rotor height (for VAWT only)	1,5	m
9) Swept area	2,25	m^2
10) Height of the mast	Not relevant	m
OTHER INFORMATION		
11) Maximum rpm	350	At rated wind speed
12) Gear box type	No gear box – direct driven	
13) Brake system	None	
14) Number of blades	2	
15) Blades material	Aluminium	
16) Output voltage	200	V
17) Minimum operation temperature	- 30	°C
18) Maximum operation temperature	+ 50	°C
19) Acoustic levels at a distance of 20 m ? at nacelle ? (wind = 5 m/s)	Not audible	DB
20) Lifetime	15/20	Years
21) Is the machine self-starting	Yes	
22) Use of an asynchronous generator	No	
23) Yaw control system	Independent of wind direction	
24) Upwind or downwind	Upwind turbine	

Calculated power curve

Wind speed (m/s)	Power* (W)
1	0,32
2	2,54
3	8,56
4	20,28
5	39,62
6	68,46
7	108,71
8	162,28
9	231,05
10	316,94
11	421,85
12	547,68
13	696,33
14	736,27
15	
*power on axis, sea level, temp. 15°C	

Power curve:



Ropatec S.p.a.

VAWT from 0,75 kW to 6 kW.

Contact name:	Hannes Riegler
Address:	Via Siemens 19
Telephone:	+39 0471 568 180
Country :	**Italy**

Ropatec WRE.30 references

Site	Use	Country
Monte Cimone	Research station	Italy
Foggia	Support for electrical pumps	Italy
Sennes	Refuge	Italy
Marchetti	Refuge	Italy

WRE.030 / 3 kW

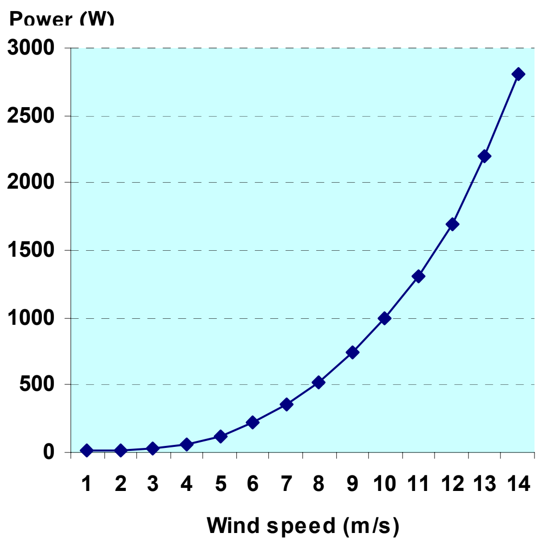
Technical information

POWER		Unit
1) Rated power	3	kW
2) Rated wind speed	14	m/s
3) Cut-in wind speed	2	m/s
4) Cut-out wind speed	None	m/s
5) Maximum wind speed the turbine can withstand	> 150	Km/h
DIMENSIONS		
6) Rotor weight	~430	kg
7) Rotor diameter	3,3	m
8) Rotor height (for VAWT only)	2,2	m
9) Swept area	7,26	m^2
10) Height of the mast	Not relevant	m
OTHER INFORMATION		
11) Maximum rpm	100 to 120	At rated wind speed
12) Gear box type	No gear box – direct driven	
13) Brake system	Not required	
14) Number of blades	2	
15) Blades material	Aluminium	
16) Output voltage	0 - 220	V
17) Minimum operation temperature	- 30	°C
18) Maximum operation temperature	+ 50	°C
19) Acoustic levels at a distance of 20 m ? at nacelle ? (wind = 5 m/s)	Not audible	DB
20) Lifetime	15/20	Years
21) Is the machine self-starting	Yes	
22) Use of an asynchronous generator	No	
23) Yaw control system	Independent of wind direction	
24) Upwind or downwind	Upwind turbine	

Calculated power curve

Wind speed (m/s)	Power* (kW)
1	0,01
2	0,02
3	0,03
4	0,06
5	0,12
6	0,22
7	0,35
8	0,52
9	0,74
10	1
11	1,3
12	1,7
13	2,2
14	2,8
15	
* electrical output, sea level, temp. 15°C	

Power curve:



Ropatec S.p.a.

VAWT from 0,75 kW to 6 kW.

Contact name: Hannes Riegler
Address: Via Siemens 19
Telephone: +39 0471 568 180
Country : **Italy**

WRE.060 / 6 kW

Ropatec WRE.060 references

Site	Use	Country
Valley of Aoste	Water heating system	Italy
Hallau	On-grid system	Switzerland
Townsville	Demonstration unit	Australia

Technical information

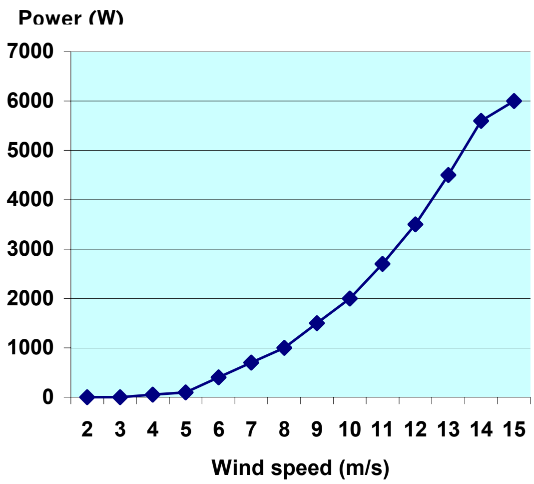
POWER		Unit
1) Rated power	6	kW
2) Rated wind speed	14	m/s
3) Cut-in wind speed	2	m/s
4) Cut-out wind speed	None	m/s
5) Maximum wind speed the turbine can withstand	> 150	Km/h
DIMENSIONS		
6) Rotor weight	750	kg
7) Rotor diameter	3,3	m
8) Rotor height (for VAWT only)	4,4	m
9) Swept area	14,52	m^2
10) Height of the mast	Not relevant	m
OTHER INFORMATION		
11) Maximum rpm	110	At rated wind speed
12) Gear box type	No gear box – direct driven	
13) Brake system	None	
14) Number of blades	2	
15) Blades material	Aluminium	
16) Output voltage	220	V
17) Minimum operation temperature	- 30	°C
18) Maximum operation temperature	+ 50	°C
19) Acoustic levels at a distance of 20 m ? at nacelle ? (wind = 5 m/s)	Not audible	DB
20) Lifetime	15/20	Years
21) Is the machine self-starting	Yes	
22) Use of an asynchronous generator	No	
23) Yaw control system	Independent of wind direction	
24) Upwind or downwind	Upwind turbine	

Calculated power curve

Wind speed (m/s)	Power*(kW)
1	0
2	0
3	0.05
4	0.10
5	0.25
6	0.40
7	0.70
8	1
9	1.5
10	2
11	2.7
12	3.5
13	4.5
14	5.6
15	6

* electrical output, sea level, temp. 15°C

Power curve:



Rugged renewables

VAWT – 0,4 kW

Contact name: Ken England
Address: Gear House, unit 3, Saltmeadows road, Gateshead, NE8 3 AH
Telephone: +44 (0) 191 478 51 11
Country : **England**

0,4 kW

EMAT references

Site	Use	Country

Technical information

POWER		Unit
1) Rated power	0,4	kW
2) Rated wind speed	12	m/s
3) Cut-in wind speed	~4,5	m/s
4) Cut-out wind speed	DK	m/s
5) Maximum wind speed the turbine can withstand	170	Km/h
DIMENSIONS		
6) Rotor weight	50	kg
7) Rotor diameter	0,8	m
8) Rotor height (for VAWT only)	2,5	m
9) Swept area	n/a	m^2
10) Height of the mast		m
OTHER INFORMATION		
11) Maximum rpm		At rated wind speed
12) Gear box type		
13) Brake system		
14) Number of blades		2
15) Blades material		Aluminium
16) Output voltage		V
17) Minimum operation temperature	- 40	°C
18) Maximum operation temperature	+ 100	°C
19) Acoustic levels at a distance of 20 m ? at nacelle ? (wind = 5 m/s)	Silent	DB
20) Lifetime	20 to 30	Years
21) Is the machine self-starting		Yes
22) Use of an asynchronous generator		No
23) Yaw control system		n/a
24) Upwind or downwind		n/a

Calculated power curve

Wind speed (m/s)	Power (kW)
1	
2	
2,5	
4	
5	
6	
7	
8	
9	
10	
11	
12	
13	
14	
15	

Power curve

Surface Power Technologies

HAWT – 0,46 kW

Contact name: John Quinn
Address: Castlebar, Co.Mayo
Telephone: +353 (0) 8795 45117
Country: **Ireland**

SP 460W / 0,46 kW

SP 460 – 0,46 kW references

Site	Use	Country
Dorset	Home Electricity	England
Cork	Home Electricity	Ireland
Orkney Island	Home Electricity	Scotland
Donegal	Home Electricity	Ireland

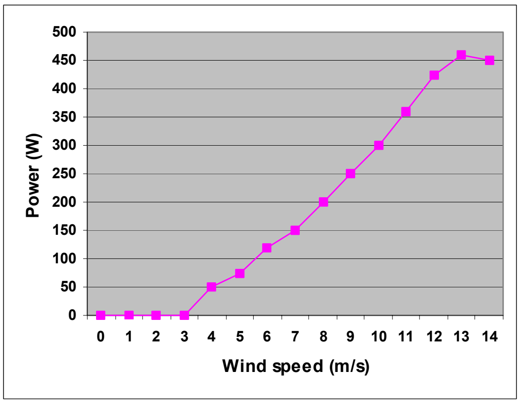
Technical information

POWER		Unit
1) Rated power	0,46	kW
2) Rated wind speed	12,5	m/s
3) Cut-in wind speed	3	m/s
4) Cut-out wind speed	None	m/s
5) Maximum wind speed the turbine can withstand	216	km/h
DIMENSIONS		
6) Nacelle and rotor weight	17	kg
7) Rotor diameter	1,4	m
8) Rotor height (for VAWT only)	-	m
9) Swept area	1,96	m^2
10) Height of the mast	7+	m
OTHER INFORMATION		
11) Maximum rpm	DK	At rated wind speed
12) Gear box type	None	
13) Brake system	Electromagnetic	
14) Number of blades	3	
15) Blades material	Composite fibre glass	
16) Output voltage	12	V
17) Minimum operation temperature	DK	°C
18) Maximum operation temperature	DK	°C
19) Acoustic levels at a distance of 20 m ? at nacelle ? (wind = 5 m/s)	Silent	DB
20) Lifetime	30	Years
21) Is the machine self-starting	Yes	
22) Use of an asynchronous generator	No	
23) Yaw control system	Wind vane	
24) Upwind or downwind	Upwind	

Calculated power curve

Wind speed (m/s)	Power (W)
1	0
2	0
3	0
4	50
5	75
6	120
7	150
8	200
9	250
10	300
11	360
12	425
13	460
14	450

Power curve:



Sviab

HAWT of 0,75 kW

Contact name: Lars Wikberg
Address: Vettershaga, 76010 Bergshamra
Telephone: +46 176 26 42 24
Country : **Sweden**

Sviab VK 240 references

Site	Use	Country
Orraids Ltd	Radio communication	Canada
Phuket	Test station	Thaïland
National Swedish Building Research	Test station	Antarctic
ASEA/ABB	Test station	New Zealand

Sviab VK 240 / 0,75 kW

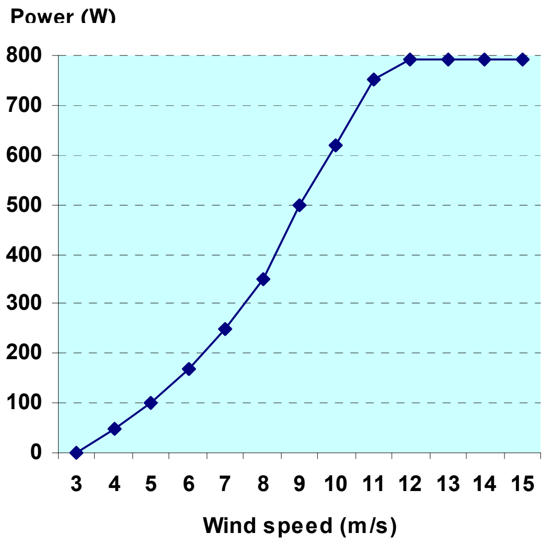
Technical information

POWER		Unit
1) Rated power	0,75	kW
2) Rated wind speed	12	m/s
3) Cut-in wind speed	2,5	m/s
4) Cut-out wind speed	None	m/s
5) Maximum wind speed the turbine can withstand	216	Km/h
DIMENSIONS		
6) Rotor weight	18	kg
7) Rotor diameter	2,4	m
8) Rotor height (for VAWT only)		m
9) Swept area	4,91	m^2
10) Height of the mast	7 / 11	m
OTHER INFORMATION		
11) Maximum rpm	270-1000	At rated wind speed
12) Gear box type	Answer not provided	
13) Brake system	Answer not provided	
14) Number of blades	3	
15) Blades material	Polyuréthane	
16) Output voltage	12 – 24	V
17) Minimum operation temperature	- 40	°C
18) Maximum operation temperature	+ 50	°C
19) Acoustic levels at a distance of 20 m ? at nacelle ? (wind = 5 m/s)	Answer not provided	DB
20) Lifetime	Answer not provided	Years
21) Is the machine self-starting	Yes	
22) Use of an asynchronous generator	No	
23) Yaw control system	Answer not provided	
24) Upwind or downwind	Answer not provided	

Calculated power curve

Wind speed (m/s)	Power (W)
1	0
2	0
3	0
4	50
5	100
6	170
7	250
8	350
9	500
10	620
11	750
12	790
13	790
14	790
15	790

Power curve:



TH Rijswijk, University of Applied Sciences
HAWT 5 – 5,5 kW

Contact name: Eize de Vries
Address: Lange Kleiweg 80, 2288 GK Rijswijk
Telephone: +31- 70 3401516
Country : Netherlands

No references

Site	Use	Country

TH Rijswijk / 5 kW

Technical information

POWER		Unit
1) Rated power	5	kW
2) Rated wind speed	10,5	m/s
3) Cut-in wind speed	2,75	m/s
4) Cut-out wind speed	>10,5	m/s
5) Maximum wind speed the turbine can withstand	Not available	Km/h
DIMENSIONS		
6) Rotor weight	175	kg
7) Rotor diameter	5	m
8) Rotor height (for VAWT only)	---	m
9) Swept area	19,6	m^2
10) Height of the mast	6 – 18	m
OTHER INFORMATION		
11) Maximum rpm	Not available	At rated wind speed
12) Gear box type	No gear box	
13) Brake system	Not available	
14) Number of blades	3	
15) Blades material	Glass fibre reinforced epoxy composite	
16) Output voltage	400	V
17) Minimum operation temperature	- 20	°C
18) Maximum operation temperature	+ 50	°C
19) Acoustic levels at a distance of 20 m ? at nacelle ? (wind = 5 m/s)	Not available	DB
20) Lifetime	20	Years
21) Is the machine self-starting	Yes	
22) Use of an asynchronous generator	Yes	
23) Yaw control system	Wind vane	
24) Upwind or downwind	Upwind	

Calculated power curve n.a.

Wind speed (m/s)	Power* (W)
1	
2	
3	
4	
5	
6	
7	
8	
9	
10	
11	
12	
13	
14	
15	

Power curve

Travere Industries

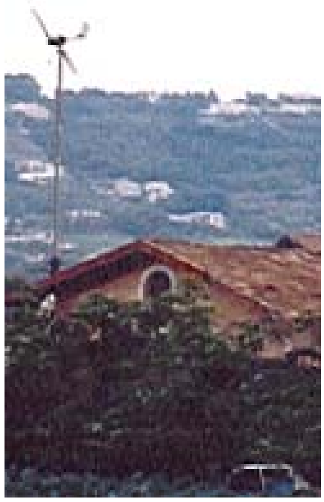
HAWT from 0,9 kW to 50 kW.

Contact name:	Adrien Orieux
Address:	27 bis imp. Pichon, 83 140 Six Fours
Telephone:	+33 4 94 10 10 29
Country :	**France**

Travere 0,9 kW references

Site	Use	Country
Corsica	Radio station	France
Guadeloupe	Dwelling	Overseas Departments
South of France	Dwelling	France
	Dwelling	Morocco

TI/2.4/0.9 (*0.9Kw/h*)



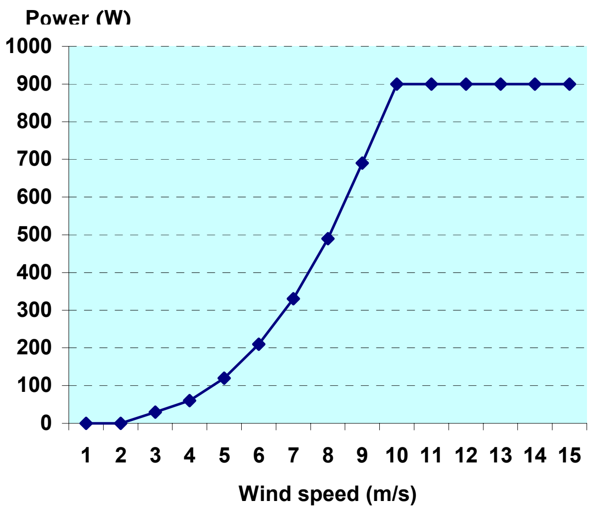
Technical information

POWER		Unit
1) Rated power	0.9	kW
2) Rated wind speed	10	m/s
3) Cut-in wind speed	2.3	m/s
4) Cut-out wind speed	60	m/s
5) Maximum wind speed the turbine can withstand	216	Km/h
DIMENSIONS		
6) Rotor weight (+ generator)	50	kg
7) Rotor diameter	2.4	m
8) Rotor height (for VAWT only)	0.2	m
9) Swept area	4.52	m^2
10) Height of the mast	12	m
OTHER INFORMATION		
11) Maximum rpm	750	At rated wind speed
12) Gear box type	None	
13) Brake system	Electronic	
14) Number of blades	2	
15) Blades material	Carbon composite	
16) Output voltage	55	V
17) Minimum operation temperature	-20	°C
18) Maximum operation temperature	80	°C
19) Acoustic levels at a distance of 20 m ? at nacelle ? (wind = 5 m/s)	<40	DB
20) Lifetime	25	Years
21) Is the machine self-starting	Yes	
22) Use of an asynchronous generator	Yes	
23) Yaw control system	*"Variable stall"* commanded centrifugal system / Rudder	
24) Upwind or downwind	Upwind	

Calculated power curve

Wind speed (m/s)	Power (kW)
1	0
2	0
3	0,03
4	0.60
5	0,12
6	0,21
7	0,33
8	0,49
9	0,69
10	0,90
11	0,90
12	0,90
13	0,90
14	0,90
15	0,90
Altitude 300 m, Tower height = 10 m Shear coeff = 0,11 ; Weibull K = 2 Turbulence factor = 10 %	

Power curve:



Travere Industries

HAWT from 0,9 kW to 50 kW.

Contact name: Adrien Orieux
Address: 27 bis imp. Pichon, 83 140 Six Fours
Telephone: +33 4 94 10 10 29
Country : **France**

Travere 1.6 kW references

Site	Use	Country
Ciotat	University	France
	University	India
South of France	Dwellings + pumping	France
South Pacific	Dwellings	Overseas Departments

TI/3.2/1.6 (*1.6Kw/h*)

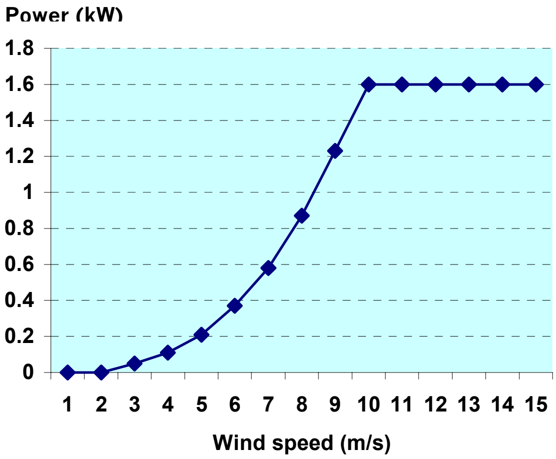
Technical information

POWER		Unit
1) Rated power	1.6	kW
2) Rated wind speed	10	m/s
3) Cut-in wind speed	2.5	m/s
4) Cut-out wind speed	60	m/s
5) Maximum wind speed the turbine can withstand	216	Km/h
DIMENSIONS		
6) Rotor weight (+ generator)	60	kg
7) Rotor diameter	3.2	m
8) Rotor height (for VAWT only)	0.3	m
9) Swept area	8.04	m^2
10) Height of the mast	12	m
OTHER INFORMATION		
11) Maximum rpm	600	At rated wind speed
12) Gear box type	No	
13) Brake system	Electronic	
14) Number of blades	2	
15) Blades material	Carbon composit	
16) Output voltage	220 to 380	V
17) Minimum operation temperature	-20	°C
18) Maximum operation temperature	80	°C
19) Acoustic levels at a distance of 20 m ? at nacelle ? (wind = 5 m/s)	<40	DB
20) Lifetime	25	Years
21) Is the machine self-starting	Yes	
22) Use of an asynchronous generator	Yes	
23) Yaw control system	*"Variable stall"* commanded centrifugal system / Rudder	
24) Upwind or downwind	Upwind	

Calculated power curve

Wind speed (m/s)	Power (kW)
1	0
2	0
3	0,05
4	0,11
5	0,21
6	0,37
7	0,58
8	0,87
9	1,23
10	1,60
11	1,60
12	1,60
13	1,60
14	1,60
15	1,60
Altitude 300 m ; Tower height = 10 m	
Shear coeff = 0,11 ; Weibull K = 2	
Turbulence factor = 10 %	

Power curve:



Travere Industries

HAWT from 0,9 kW to 50 kW.

Contact name:	Adrien Orieux
Address:	27 bis imp. Pichon, 83 140 Six Fours
Telephone:	+33 4 94 10 10 29
Country :	**France**

Travere 3 kW references

Site	Use	Country
North	Grid connection	France
	Direct heating	Turkey
North	Grid connection	France
North	Grid connection	France

TI/3.6/3 (*3Kw/h*)

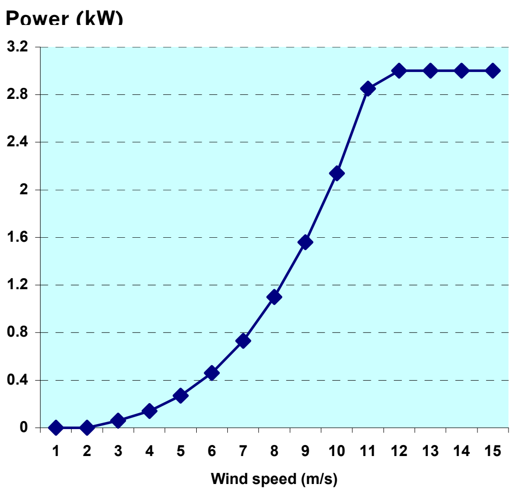
Technical information

POWER		Unit
1) Rated power	3	kW
2) Rated wind speed	12	m/s
3) Cut-in wind speed	2.8	m/s
4) Cut-out wind speed	60	m/s
5) Maximum wind speed the turbine can withstand	216	Km/h
DIMENSIONS		
6) Rotor weight (+ generator)	60	kg
7) Rotor diameter	3.6	m
8) Rotor height (for VAWT only)	0.6	m
9) Swept area	10.18	m^2
10) Height of the mast	12	m
OTHER INFORMATION		
11) Maximum rpm	550	At rated wind speed
12) Gear box type		No
13) Brake system		Electronic
14) Number of blades		2
15) Blades material		Carbon composit
16) Output voltage	220 to 380	V
17) Minimum operation temperature	-20	°C
18) Maximum operation temperature	80	°C
19) Acoustic levels at a distance of 20 m ? at nacelle ? (wind = 5 m/s)	<40	DB
20) Lifetime	25	Years
21) Is the machine self-starting		Yes
22) Use of an asynchronous generator		Yes
23) Yaw control system		*"Variable stall"* commanded centrifugal system / Rudder
24) Upwind or downwind		Upwind

Calculated power curve

Wind speed (m/s)	Power (kW)
1	0
2	0
3	0.06
4	0.14
5	0.27
6	0.46
7	0.73
8	1.10
9	1.56
10	2.14
11	2.85
12	3.00
13	3.00
14	3.00
15	3.00
Altitude = 300 m ; Tower height = 10 m	
Shear coeff = 0,11 ; Weibull K = 2	
Turbulence factor = 10 %	

Power curve:



Travere Industries

HAWT from 0,9 kW to 50 kW.

Contact name: Adrien Orieux
Address: 27 bis imp. Pichon, 83 140 Six Fours
Telephone: +33 4 94 10 10 29
Country : **France**

Travere 2.1 kW references

Site	Use	Country
Off shore	Platform Total Energie	Nigeria
Center	Habitation	France
South	Pumping + Dwelling	France
Center	Grid connexion	France

TI/6/2.1 (*2.1Kw/h*)

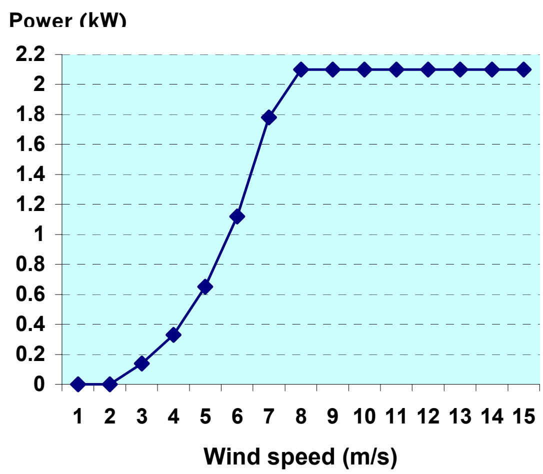
Technical information

POWER		Unit
1) Rated power	2.1	kW
2) Rated wind speed	8	m/s
3) Cut-in wind speed	2.5	m/s
4) Cut-out wind speed	60	m/s
5) Maximum wind speed the turbine can withstand	216	Km/h
DIMENSIONS		
6) Rotor weight (+ generator)	60	kg
7) Rotor diameter	6	m
8) Rotor height (for VAWT only)	0.9	m
9) Swept area	28.27	m^2
10) Height of the mast	12	m
OTHER INFORMATION		
11) Maximum rpm	440	At rated wind speed
12) Gear box type		No
13) Brake system		Electronic
14) Number of blades		2
15) Blades material		Carbon composite
16) Output voltage	220 to 380	V
17) Minimum operation temperature	-20	°C
18) Maximum operation temperature	80	°C
19) Acoustic levels at a distance of 20 m ? at nacelle ? (wind = 5 m/s)	<40	DB
20) Lifetime	25	Years
21) Is the machine self-starting		Yes
22) Use of an asynchronous generator		Yes
23) Yaw control system		"*Variable stall*" commanded centrifugal system / Rudder
24) Upwind or downwind		Upwind

Calculated power curve

Wind speed (m/s)	Power (kW)
1	0
2	0
3	0,14
4	0,33
5	0,65
6	1,12
7	1,78
8	2,10
9	2,10
10	2,10
11	2,10
12	2,10
13	2,10
14	2,10
15	2,10
Altitude = 300 m ; Tower height = 10 m	
Shear coeff = 0,11 ; Weibull K = 2	
Turbulence factor = 10 %	

Power curve:



Travere Industries

HAWT from 0,9 kW to 50 kW.

Contact name: Adrien Orieux
Address: 27 bis imp. Pichon, 83 140 Six Fours
Telephone: +33 4 94 10 10 29
Country : **France**

Travere 5.5 kW references

Site	Use	Country
Aude	EDF-GDF	France
Pacific	Dwelling	Overseas Departments
	CETMEF/ Ligth House	France
South/Addrar	Pumping	Algéria

TI/6/5.5 *(5.5Kw/h)*

Technical information

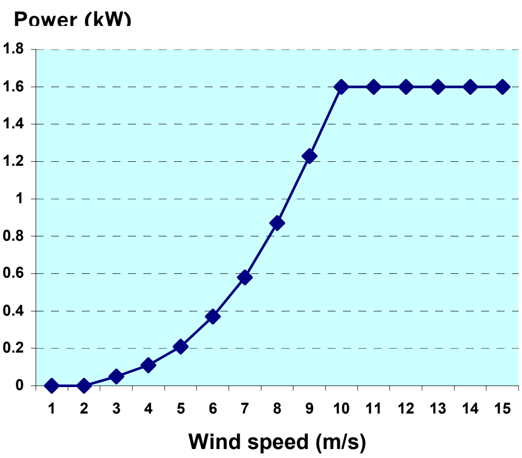
POWER		Unit
1) Rated power	5.5	kW
2) Rated wind speed	10	m/s
3) Cut-in wind speed	3	m/s
4) Cut-out wind speed	60	m/s
5) Maximum wind speed the turbine can withstand	216	Km/h
DIMENSIONS		
6) Rotor weight (+ generator)	60	kg
7) Rotor diameter	6	m
8) Rotor height (for VAWT only)	0.9	m
9) Swept area	28.27	m^2
10) Height of the mast	12	m
OTHER INFORMATION		
11) Maximum rpm	240	At rated wind speed
12) Gear box type	No	
13) Brake system	Electronic	
14) Number of blades	2	
15) Blades material	Carbon composite	
16) Output voltage	220 to 380	V
17) Minimum operation temperature	-30	°C
18) Maximum operation temperature	80	°C
19) Acoustic levels at a distance of 20 m ? at nacelle ? (wind = 5 m/s)	<40	DB
20) Lifetime	25	Years
21) Is the machine self-starting	Yes	
22) Use of an asynchronous generator	Yes	
23) Yaw control system	*"Variable stall"* commanded centrifugal system / Rudder	
24) Upwind or downwind	Upwind	

Calculated power curve

Wind speed (m/s)	Power (W)
1	0
2	0
3	0.16
4	0.38
5	0.74
6	1.29
7	2.04
8	3.05
9	4.34
10	5.50
11	5.50
12	5.50
13	5.50
14	5.50
15	5.50

Altitude = 300 m ; Tower height = 10 m ; Shear coeff = 0,11 ; Weibull K = 2 ; Turbulence factor = 10 %.

Power curve:



Tulipower

HAWT 2,5 kW

Contact name: Hans Duivenvoorden
Address: Van der Palmkade 44, 1051 RE Amsterdam
Telephone: +31 – 6 19618369
Country : Netherlands

Tulipower references

Site	Use	Country
Boxtel	Environmental Information Centre	Netherlands
Elst	Installer company, demonstration	Netherlands
Zevenbergen	Turbine distributor, demonstration	Netherlands

Tulipower / 2,5 kW

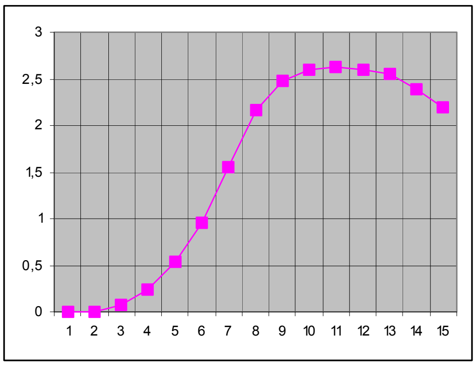
Technical information

POWER		Unit
1) Rated power	2,5	KW
2) Rated wind speed	10	m/s
3) Cut-in wind speed	3	m/s
4) Cut-out wind speed	18	m/s
5) Maximum wind speed the turbine can withstand	42,5	m/s
DIMENSIONS		
6) Total weight	200	Kg
7) Rotor diameter	5	M
8) Rotor height (for VAWT only)	---	M
9) Swept area	19,6	m^2
10) Height of the mast	12,5	M
OTHER INFORMATION		
11) Maximum rpm	140	At rated wind speed
12) Gear box type	No gear box	
13) Brake system	spring powered electro magnetic brake	
14) Number of blades	3	
15) Blades material	Composite fibre glass	
16) Output voltage	230	V
17) Minimum operation temperature	- 20	°C
18) Maximum operation temperature	+ 40	°C
19) Acoustic levels at a distance of 20 m ? (wind = 5 m/s)	< 35	DB
20) Lifetime	15	Years
21) Is the machine self-starting	Yes	
22) Use of an asynchronous generator	Yes	
23) Yaw control system	Independent of wind direction	
24) Upwind or downwind	Upwind	

Calculated power curve

Wind speed (m/s)	Power* (W)
1	0
2	0
3	68
4	243
5	530
6	958
7	1553
8	2159
9	2474
10	2595
11	2625
12	2598
13	2552
14	2382
15	2192

Power curve



Turby B.V.

VAWT 2,5 kW

Contact name:	Dick Sidler
Address:	Heuvelenweg 18, 7241 HZ Lochem
Telephone:	+31 - 6-55822169
Country :	Netherlands

Turby 2,5 kW references

Site	Use	Country
Amsterdam	Proof public building (former school)	Netherlands
Tlburg	Roof flat building	Netherlands
Den Haag	Roof town hall	Netherlands
Delft	Technical University	Netherlands

Turby 2,5 kW

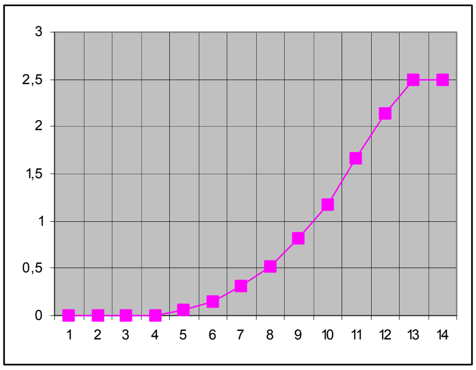
Technical information

POWER		Unit
1) Rated power	2,5	kW
2) Rated wind speed	14	m/s
3) Cut-in wind speed	4	m/s
4) Cut-out wind speed	14	m/s
5) Maximum wind speed the turbine can withstand	55	m/s
DIMENSIONS		
6) Rotor weight	135	kg
7) Rotor diameter	1,99	m
8) Rotor height (for VAWT only)	2,88	m
9) Swept area	5,3	m^2
10) Height of the mast	6 – 7,5	m
OTHER INFORMATION		
11) Maximum rpm	400	At rated wind speed
12) Gear box type	No gears	
13) Brake system	Electrical brake system	
14) Number of blades	3	
15) Blades material	Carbon epoxy composite	
16) Output voltage	230	V
17) Minimum operation temperature	- 20	°C
18) Maximum operation temperature	+ 40	°C
19) Acoustic levels at a distance of 20 m ? wind = 10 m/s)	45	DB
20) Lifetime	20	Years
21) Is the machine self-starting	No	
22) Use of an asynchronous generator	No	
23) Yaw control system	Independent	
24) Upwind or downwind	Both	

Calculated power curve

Wind speed (m/s)	Power (W)
1	0
2	0
3	0
4	6
5	56
6	155
7	310
8	527
9	812
10	1171
11	1659
12	2136
13	2500
14	2500
15	--

Power curve



Venturi Wind b.v.(i.o.)

VAWT from 0,11 kW to 0,50 k W

Contact name: D.P. Elzinga
Address: Stationsweg 18–7429 AD Deventer-Colmschate
Telephone: +31 0570-510246
Country : Netherlands

Venturi 110-500 references

Site	Use	Country
Waalwijk	Test battery charging	Netherlands
Beek & Donk	Test battery charging	Netherlands
Deventer	Test battery charging + grid con.	Netherlands

Venturi 110-500

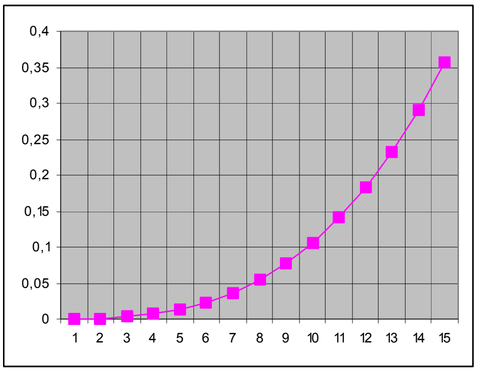
Technical information

POWER		Unit
1) Rated power	0,5	kW
2) Rated wind speed	17	m/s
3) Cut-in wind speed	2	m/s
4) Cut-out wind speed	None	m/s
5) Maximum wind speed the turbine can withstand	>145	km/h
DIMENSIONS		
6) Rotor weight	30	Kg
7) Rotor diameter	1,1	m
8) Rotor height (for VAWT only)	1,3	m
9) Swept area	1	m^2
10) Height of the mast	11	m
OTHER INFORMATION		
11) Maximum rpm	803	At rated wind speed
12) Gear box type	None	
13) Brake system	Electrical	
14) Number of blades	6	
15) Blades material	Flat blade polyester	
16) Output voltage	100	V
17) Minimum operation temperature	-25	-°C
18) Maximum operation temperature	50	°C
19) Acoustic levels at a distance of 20 m ? at nacelle ? (wind = 5 m/s)	Not audible	DB
20) Lifetime	15	Years
21) Is the machine self-starting	Yes	
22) Use of an asynchronous generator	No	
23) Yaw control system	Vane	
24) Upwind or downwind	Upwind	

Calculated power curve

Wind speed (m/s)	Power* (W)
1	0
2	0,7
3	3
4	7
5	13
6	23
7	36
8	54
9	77
10	106
11	141
12	183
13	232
14	290
15	357

Power curve

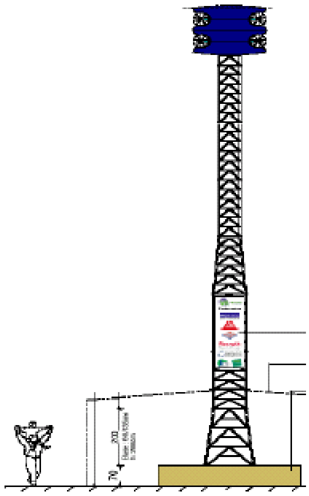


VR & Tech

VAWT from 2,5 kW to 100 kW.

Contact name: Alain Van Ranst
Address: Rue Trou du Sart 5 C-D 5 380 Fernelmont
Telephone: +32 (0) 81 22 42 14
Country : **Belgium**

Telecom Tower / 2 m



VR & Tech Telecom tower / 2 m references

Site	Use	Country
Namur	Industrial use in the field of telecom	Belgium

Technical information

POWER		Unit
1) Rated power	Minimum 2,5*	kW
2) Rated wind speed	8	m/s
3) Cut-in wind speed	4	m/s
4) Cut-out wind speed	None	m/s
5) Maximum wind speed the turbine can withstand	No limit	Km/h
DIMENSIONS		
6) Rotor weight (+ generator)	Variable *	kg
7) Rotor diameter	2	m
8) Rotor height (for VAWT only)	~2 or 3	m
9) Swept area	Variable *	m^2
10) Height of the mast	Not relevant	m
OTHER INFORMATION		
11) Maximum rpm	800	At rated wind speed
12) Gear box type	Direct drive	
13) Brake system	Electronic constant braking	
14) Number of blades	9	
15) Blades material	Fibre glass and Epoxy	
16) Output voltage	400	V
17) Minimum operation temperature	n.a	°C
18) Maximum operation temperature	100	°C
19) Acoustic levels at a distance of 20 m ? at nacelle ? (wind = 5 m/s)	40	DB
20) Lifetime	15	Years
21) Is the machine self-starting	Yes	
22) Use of an asynchronous generator	No	
23) Yaw control system	None	
24) Upwind or downwind	Not applicable	

Calculated power curve

Wind speed (m/s)	Power (W)
1	
2	
3	
4	
5	
6	
7	
8	
9	
10	
11	
12	
13	
14	
15	

Each project is different because the manufacturer stick several TARP to create a single WARP tower and integrate a mix of renewable energies (solar, CHP) in the same WARP tower.

Power curve :

* The rated power and the rotor weight vary accordingly with the number of stacked “TARP” modules vertically piled along the tower. 1 TARP corresponds to ~2,5 kW and a same tower can be designed with more than 10 TARPS depending on the energy needs.

VR & Tech

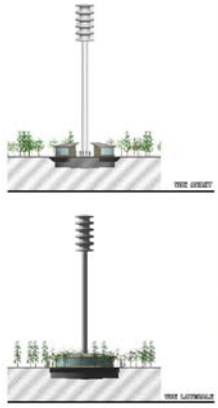
VAWT from 2,5 kW to 100 kW.

Contact name: Alain Van Ranst
Address: Rue Trou du Sart 5 C-D 5 380 Fernelmont
Telephone: +32 (0) 81 22 42 14
Country : **Belgium**

VR & Tech House tower/ 4 m references

Site	Use	Country
Bastogne	Training centre in renewable energies	Belgium

House tower / 4 m



Technical information

POWER		Unit
1) Rated power	Minimum 10*	kW
2) Rated wind speed	8	m/s
3) Cut-in wind speed	4	m/s
4) Cut-out wind speed	None	m/s
5) Maximum wind speed the turbine can withstand	No limit	Km/h
DIMENSIONS		
6) Rotor weight (+ generator)	Variable *	kg
7) Rotor diameter	4	m
8) Rotor height (for VAWT only)	~4 or 5	m
9) Swept area	Variable	m^2
10) Height of the mast		m
OTHER INFORMATION		
11) Maximum rpm	800	At rated wind speed
12) Gear box type	Direct drive	
13) Brake system	Electronic constant braking	
14) Number of blades	9	
15) Blades material	Fibre glass and Epoxy	
16) Output voltage	400	V
17) Minimum operation temperature	n.a	°C
18) Maximum operation temperature	100	°C
19) Acoustic levels at a distance of 20 m ? at nacelle ? (wind = 5 m/s)	40	DB
20) Lifetime	15	Years
21) Is the machine self-starting	Yes	
22) Use of an asynchronous generator	No	
23) Yaw control system	None	
24) Upwind or downwind	Not applicable	

Calculated power curve

Wind speed (m/s)	Power (W)
1	
2	
3	
4	
5	
6	
7	
8	
9	
10	
11	
12	
13	
14	
15	
Each project is different because the manufacturer stick several TARP to create a single WARP tower and integrate a mix of renewable energies (solar, CHP) in the same WARP tower.	

Power curve:

* The rated power and the rotor weight vary accordingly with the number of stacked "TARP" modules vertically piled along the tower.

VR & Tech

VAWT from 2,5 kW to 100 kW.

Contact name: Alain Van Ranst
Address: Rue Trou du Sart 5 C-D 5 380 Fernelmont
Telephone: +32 (0) 81 22 42 14
Country : **Belgium**

House tower / 6 m

VR & Tech House tower/6 m references

Site	Use	Country
Andenne	Food industry (Interagri)	Belgium

Technical information

POWER		Unit
1) Rated power	Minimum 25*	kW
2) Rated wind speed	8	m/s
3) Cut-in wind speed	4	m/s
4) Cut-out wind speed	None	m/s
5) Maximum wind speed the turbine can withstand	No limit	Km/h
DIMENSIONS		
6) Rotor weight (+ generator)	Variable*	kg
7) Rotor diameter	6	m
8) Rotor height (for VAWT only)	Minimum 6	m
9) Swept area	Variable*	m^2
10) Height of the mast		m
OTHER INFORMATION		
11) Maximum rpm	800	At rated wind speed
12) Gear box type	Direct drive	
13) Brake system	Electronic constant braking	
14) Number of blades	9	
15) Blades material	Fibre glass and epoxy	
16) Output voltage	400	V
17) Minimum operation temperature	n.a	°C
18) Maximum operation temperature	100	°C
19) Acoustic levels at a distance of 20 m ? at nacelle ? (wind = 5 m/s)	40	DB
20) Lifetime	15	Years
21) Is the machine self-starting	Yes	
22) Use of an asynchronous generator	No	
23) Yaw control system	None	
24) Upwind or downwind	Not applicable	

Calculated power curve

Wind speed (m/s)	Power (W)
1	
2	
3	
4	
5	
6	
7	
8	
9	
10	
11	
12	
13	
14	
15	
Each project is different because the manufacturer stick several TARP to create a single WARP tower and integrate a mix of renewable energies (solar, CHP) in the same WARP tower.	

Power curve :

* The rated power and the rotor weight vary accordingly with the number of stacked “TARP” modules vertically piled along the tower.

Wind Energy Solutions (WES)

HAWT from 2 kW to 250 kW

Contact name:	Marcel Kloesmeijer
Address:	De Weel, 1736 KB Zijdewind
Telephone:	+31 – 226 425150
Country :	Netherlands

WES[5] Tulipo references

Site	Use	Country
Elst	Installer company, demonstration	Netherlands
Zevenbergen	Turbine distributor, demonstration	Netherlands

WES[5] Tulipo / 2,5 kW

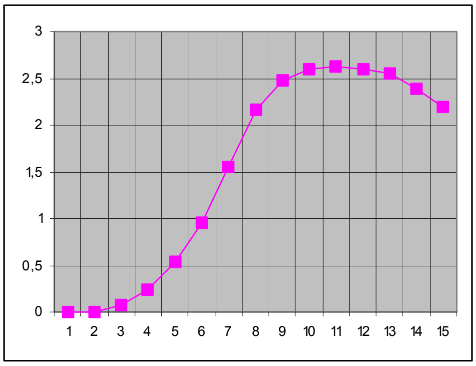
Technical information

POWER		Unit
1) Rated power	2,5	kW
2) Rated wind speed	8,5	m/s
3) Cut-in wind speed	3	m/s
4) Cut-out wind speed	20	m/s
5) Maximum wind speed the turbine can withstand	35	m/s
DIMENSIONS		
6) Total weight	200	kg
7) Rotor diameter	5	m
8) Rotor height (for VAWT only)	---	m
9) Swept area	19,6	m^2
10) Height of the mast	6 or 12	m
OTHER INFORMATION		
11) Maximum rpm	140	At rated wind speed
12) Gear box type	No gear box	
13) Brake system	spring powered electro magnetic brake	
14) Number of blades	3	
15) Blades material	Glass reinforced epoxy	
16) Output voltage	400	V
17) Minimum operation temperature	- 20	°C
18) Maximum operation temperature	+ 40	°C
19) Acoustic levels at a distance of 20 m ? (wind = 5 m/s)	< 35	DB
20) Lifetime	20	Years
21) Is the machine self-starting	Y	
22) Use of an asynchronous generator	Y	
23) Yaw control system	Active yaw control	
24) Upwind or downwind	Upwind	

Calculated power curve

Wind speed (m/s)	Power* (W)
1	0
2	0
3	68
4	243
5	530
6	958
7	1553
8	2159
9	2474
10	2595
11	2625
12	2598
13	2552
14	2382
15	2192

Power curve



Winddam

VAWT – 2 kW

AWT(1)2000/ 2 kW

Contact name:	Julie Trevithick
Address:	1 Riverside House, Heron Way, Truro,TR1 2 XN
Telephone:	+44 (0) 180 387 39 56
Country:	**United Kingdom**

Winddam 2 kW references

Site	Use	Country
Moss Side Industrial Estate	Testing	UK

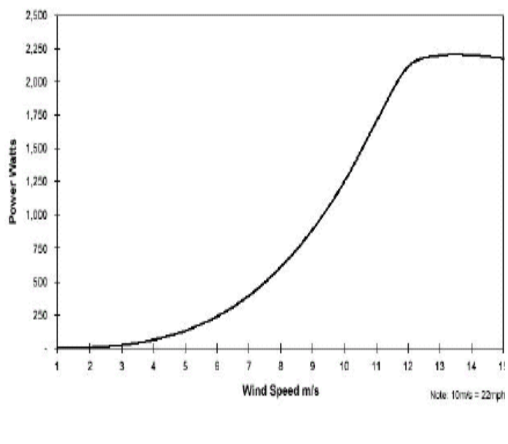
Technical information

POWER		Unit
1) Rated power	2	kW
2) Rated wind speed	12	m/s
3) Cut-in wind speed	2	m/s
4) Cut-out wind speed	None	m/s
5) Maximum wind speed the turbine can withstand	234	Km/h
DIMENSIONS		
6) Nacelle and Rotor weight	DK	Kg
7) Rotor diameter	2.56	m
8) Rotor height (for VAWT only)	2	m
9) Swept area	5.12	m^2
10) Height of the mast	DK	m
OTHER INFORMATION		
11) Maximum rpm	108	At rated wind speed
12) Gear box type	None	
13) Brake system	Mechanical	
14) Number of blades	5	
15) Blades material	Resin Composite	
16) Output voltage	12/24/48/120/ 240	V
17) Minimum operation temperature	DK	°C
18) Maximum operation temperature	DK	°C
19) Acoustic levels at a distance of 20 m ? at nacelle ? (wind = 5 m/s)	Silent	DB
20) Lifetime	25+	Years
21) Is the machine self-starting	DK	
22) Use of an asynchronous generator	No	
23) Yaw control system	N/A	
24) Upwind or downwind	N/A	

Calculated power curve

Wind speed (m/s)	Power (W)
1	0
2	0
3	35
4	75
5	110
6	250
7	400
8	600
9	850
10	1250
11	1750
12	2100
13	2200
14	2200
15	2150

Power curve:



Winddam

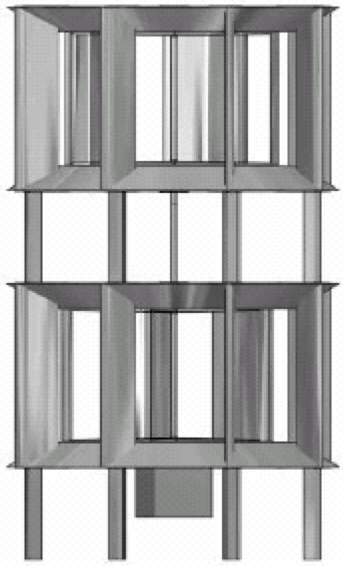
VAWT – 4 kW

Contact name:	Julie Trevithick
Address:	1 Riverside House, Heron Way, Truro,TR1 2 XN
Telephone:	+44 (0) 180 387 39 56
Country:	**United Kingdom**

Winddam 2 kW references

Site	Use	Country
DK		

AWT(2)2x2000/ 4 kW



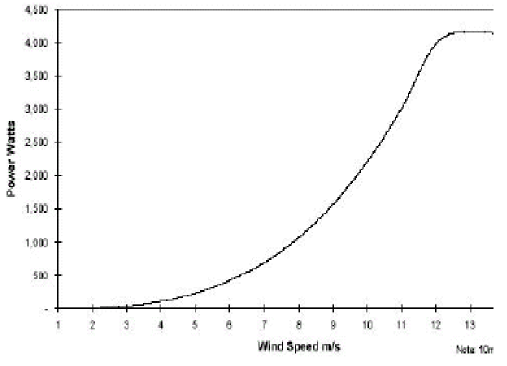
Technical information

POWER		Unit
1) Rated power	4	kW
2) Rated wind speed	12	m/s
3) Cut-in wind speed	2.5	m/s
4) Cut-out wind speed	None	m/s
5) Maximum wind speed the turbine can withstand	234	Km/h
DIMENSIONS		
6) Nacelle and Rotor weight	DK	Kg
7) Rotor diameter	2.56	m
8) Rotor height (for VAWT only)	2 x 2	m
9) Swept area	2 x 5.12	m^2
10) Height of the mast	DK	m
OTHER INFORMATION		
11) Maximum rpm	200	At rated wind speed
12) Gear box type	None	
13) Brake system	Mechanical	
14) Number of blades	2 x 3	
15) Blades material	Resin Composite	
16) Output voltage	12/24/48/120/240	V
17) Minimum operation temperature	DK	°C
18) Maximum operation temperature	DK	°C
19) Acoustic levels at a distance of 20 m ? at nacelle ? (wind = 5 m/s)	Whisper	DB
20) Lifetime	25+	Years
21) Is the machine self-starting	DK	
22) Use of an asynchronous generator	No	
23) Yaw control system	N/A	
24) Upwind or downwind	N/A	

Calculated power curve

Wind speed (m/s)	Power (W)
1	0
2	0
3	Tiny
4	100
5	205
6	400
7	665
8	1000
9	1540
10	2205
11	3000
12	4000
13	4150
14	4110
15	4000

Power curve:



Windsave

HAWT – 1 kW

Contact name: Graham Reed
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Telephone: +44 (0) 141 353 68 41
Country : **United Kingdom**

WS 1000/ 1 kW

WS 1000 1 kW references

Site	Use	Country
Burbank		England
Livingston		England
Teesside		England
Glasgow		Scotland

Technical information

POWER		Unit
1) Rated power	1	KW
2) Rated wind speed	12	m/s
3) Cut-in wind speed	2,9	m/s
4) Cut-out wind speed	15	m/s
5) Maximum wind speed the turbine can withstand	216	Km/h
DIMENSIONS		
6) Rotor weight		Kg
7) Rotor diameter	1,75	m
8) Rotor height (for VAWT only)		m
9) Swept area	2,41	m^2
10) Height of the mast		m
OTHER INFORMATION		
11) Maximum rpm		At rated wind speed
12) Gear box type		
13) Brake system		
14) Number of blades	3	
15) Blades material	Polyamide Glass Reinforced	
16) Output voltage	240	V
17) Minimum operation temperature	Not tested	°C
18) Maximum operation temperature	Not tested	°C
19) Acoustic levels at a distance of 20 m ? at nacelle ? (wind = 5 m/s)	30 DB at 4m/s	DB
20) Lifetime	10	Years
21) Is the machine self-starting	Yes	
22) Use of an asynchronous generator	No	
23) Yaw control system	Wind vane	
24) Upwind or downwind	Upwind	

Calculated power curve

Wind speed (m/s)	Power (W)
1	
2	
3	
4	
5	
6	
7	
8	
9	
10	
11	
12	1 000
13	
14	
15	

Power curve:

WindWall B.V.

VAWT from 2,9 kW to 60 kW.

Contact name: Rob Roelofs
Address: De Eiken 5D, 7491 HP Delden
Telephone: +31 – 74 2434885
Country : Netherlands

WW2000 / 2,9 kW

WW2000 references

Site	Use	Country
Zwolle	Roof high school	Netherlands
Den Haag	Office building (Siemens)	Netherlands
Den Haag	Office building (government)	Netherlands
Rotterdam	Erasmus MC (University Medical Centre)	Netherlands

Technical information

POWER		Unit
1) Rated power	2,9	kW
2) Rated wind speed	10,5	m/s
3) Cut-in wind speed	4	m/s
4) Cut-out wind speed	20	m/s
5) Maximum wind speed the turbine can withstand	55	m/s
DIMENSIONS		
6) Rotor weight	3000	kg
7) Rotor diameter	2	m
8) Rotor height (for VAWT only)	5 (horizontal) – 15 (vertical)	m
9) Swept area	10	m^2
10) Height of the mast	n.a.	m
OTHER INFORMATION		
11) Maximum rpm	500	At rated wind speed
12) Gear box type	No gears	
13) Brake system	Electrical + disc brake system	
14) Number of blades	6	
15) Blades material	Aluminium	
16) Output voltage	400	V
17) Minimum operation temperature	- 20	°C
18) Maximum operation temperature	+ 40	°C
19) Acoustic levels at nacelle ? (wind = 5 m/s)	74	DB
20) Lifetime	20	Years
21) Is the machine self-starting	Yes	
22) Use of an asynchronous generator	Yes	
23) Yaw control system	Independent	
24) Upwind or downwind	Downwind	

Calculated power curve

Wind speed (m/s)	Power* (W)
1	0
2	0
3	0
4	1%
5	
6	
7	
8	50%
9	
10	100%
11	100%
12	100%
13	100%
14	100%
15	100%

Power curve

XCO2

VAWT – 6 kW

Contact name: Richard Cochrane
Address: 1-5 Offord Street, London, N1 1DH
Telephone: +44 (0) 207 700 1000
Country : **United Kingdom**

EMAT references

Site	Use	Country
Southwark Bridge Rd, London	Pilot installation – due 12 / 2005	UK
Temple Meads Roundabout, Bristol	Pilot installation – due 1 / 2006	UK

XCO2 / 6 kW

Technical information

POWER		Unit
1) Rated power	6	kW
2) Rated wind speed	~ 12,5	m/s
3) Cut-in wind speed	4,5	m/s
4) Cut-out wind speed	16	m/s
5) Maximum wind speed the turbine can withstand	DK	Km/h
DIMENSIONS		
6) Nacelle and rotor weight	DK	kg
7) Rotor diameter	3,1	m
8) Rotor height (for VAWT only)	5	m
9) Swept area	15,5	m^2
10) Height of the mast	5-10	m
OTHER INFORMATION		
11) Maximum rpm	DK	At rated wind speed
12) Gear box type		None
13) Brake system		DK
14) Number of blades		3
15) Blades material		Carbon fibre
16) Output voltage	48 dc or 240 ac	V
17) Minimum operation temperature	-40	°C
18) Maximum operation temperature	100	°C
19) Acoustic levels at a distance of 20 m? at nacelle ? (wind = 5 m/s)	Silent	DB
20) Lifetime	20	Years
21) Is the machine self-starting		Yes
22) Use of an asynchronous generator		No
23) Yaw control system		n/a
24) Upwind or downwind		n/a

Calculated power curve

Not available

Wind speed (m/s)	Power (kW)
1	
2	
3	
4	
5	
6	
7	
8	
9	
10	
11	
12	
13	
14	
15	

Power curve

ÖZET

Bu yazıda, Libya'da seçilen üç bölgede (Trablus, Nault ve Esspeea) rüzgar hızının özelliklerini analiz etmek için on dağıtım işlevi kullanılmıştır. Aylık rüzgar hızı verileri, 10 m yükseklikte kullanılır ve ölçülür. Sonuçlar, çalışılan bölgelerdeki aylık ortalama rüzgar hızlarının 10 m yükseklikte 2,121 m / s ila 4,349 m / s aralığında olduğunu göstermiştir. Yıllık dağılım parametreleri, her bir dağılım için Maksimum olabilirlik yöntemi kullanılarak hesaplanmaktadır. Kolmogorov-Smirnov (KS) istatistiği, gerçek rüzgar hızı verilerine göre dağıtım uygunluğunu değerlendirmek için belirlenir. Ek olarak, her bölgedeki rüzgar gücü yoğunluğu hesaplanmaktadır. Sonuçlar Nault'un Trablus (30.972W / m2) ve Esspeea'ya (5.844W / m2) kıyasla en yüksek ortalama gerçek rüzgar gücüne (50.3W / m2) sahip olduğunu gösterdi. Ayrıca, birçok rüzgar türbininin göbek yüksekliği ölçüm yüksekliğinden daha yüksek olduğundan, dağıtım parametreleri ve rüzgar gücü yoğunluğu, güç yasası yöntemi kullanılarak çeşitli yüksekliklerde tahmin edilmektedir. Sonuç, küçük ölçekli rüzgar türbinlerinin farklı bölgelerde rüzgardan yararlanılabileceğini göstermiştir. Sonuç olarak, bugünkü değer maliyet yöntemi (PVC), çeşitli rüzgar türbini modelleri kullanılarak elektriğin enerji maliyetini değerlendirmek için kullanılır. Ekonomik olarak, elektrik maliyetinin en düşük değeri, Finn Wind Tuule C 200'den, Tripoli için 0.001427 $ / kW, Nault için 0.0010 $ / kW ve Esspeea için 0.013194 $ / kW değerlerinde elde edildi.

Kelimeler: Ekonomik analiz; Libya; yatay eksenli rüzgar türbinleri; istatistiksel dağılım; dikey eksenli rüzgar türbini; rüzgar hızı özellikleri