Universitatea Transilvania din Brașov

Universitatea Transilvania din Brașov
FACULTATEA DE INGINERIE ELECTRICĂ ȘI ȘTIINȚA CALCULATOARELOR

Master's Degree in Advanced Electrical Systems

Dissertation thesis

Optimum integration of small power wind turbines into the urban environment

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Trilingual summary | Rezumat trilingv | Resumen trilingüe

- The following document presents a study on the feasibility of installing small wind turbines in the urban environment. This will require an understanding of all the elements and stages that make up the project. A simulation has been carried out using Homer Pro software in order to contrast the results obtained manually. The economic viability and compliance with current regulations in the field of administrative, technical and economic conditions for wind turbines in urban environments has also been studied.
- Următorul document prezintă un studiu privind fezabilitatea instalării de mici turbine eoliene în mediul urban. Pentru aceasta, va fi necesar să înțelegem toate elementele și etapele care alcătuiesc proiectul. O simulare a fost efectuată folosind software-ul Homer Pro pentru a contrasta rezultatele obținute manual. De asemenea, au fost studiate viabilitatea sa economică și respectarea reglementărilor actuale în domeniul condițiilor administrative, tehnice și economice ale instalațiilor eoliene în mediul urban.
- El siguiente documento presenta un estudio sobre la viabilidad de la instalación de turbinas eólicas de pequeño tamaño en el entorno urbano. Para ello, será necesaria la comprensión de todos los elementos y etapas que componen el proyecto. Se ha realizado una simulación mediante el software Homer Pro para contrastar los resultados obtenidos manualmente. Se ha estudiado, asimismo, su viabilidad económica y el cumplimiento de la normativa vigente en el campo de las condiciones administrativas, técnicas y económicas de las instalaciones eólicas en entornos urbanos.

Keywords | Cuvinte cheie | Palabras clave

- Self-consumption, energy saving, efficiency, environment, renewable energy
- Autoconsum, economie de energie, eficiență, mediu, energie regenerabilă
- Autoconsumo, ahorro de energía, eficiencia, medioambiente, energía renovable

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1. Introduction

This paper presents a study on the feasibility of installing small wind turbines (up to 2kW) in urban environments.

For the correct development of this project, the computer programs Matlab, Homer Pro and Microsoft Excel will be used.

The project originates from the need to improve energy efficiency in urban environments. As a starting point, a location will be taken as the basis for this study: the municipality of Bilbao (Spain), so that the calculations and conclusions reached here can serve as a background for other projects of the same nature.

To begin with, a brief summary of the location is presented, as well as the data of interest that may be useful to demonstrate the suitability of the site for the elaboration of this study.

The objectives to be achieved and the economic, social and environmental benefits of such a project are then presented.

The theoretical content on wind energy is subsequently presented.

Several alternatives that imply the use of wind energy for electricity generation, as well as the different types of configurations and/or existing wind turbines within the wind technology, are presented in the paper.

Once the basis has been established, all the calculations about the energy that can be produced have been carried out and detailed.

To finalise the project, the respective economic analysis will be carried out to demonstrate the viability of this type of project.

At the end of the document, a conclusion about the results obtained is included.

1.1. Context

The study will be carried out in the municipality of Bilbao (Spain). The following criteria have been taken into account for the selection of the location:

- Due to the proximity of the municipality to the sea, the wind data of the area are ideal for the installation of wind turbines. In addition to the proximity of the sea, the fact that the municipality is surrounded by hills causes pressure changes that have the effect of increasing the wind in the area. In fact, in the province of Bizkaia, to which Bilbao belongs, there are currently two wind farms, one located in the port of Bilbao, with an installed capacity of 10 MW, and the other located on Oiz Mountain, with an installed capacity of 8.5 MW.
- Wind is one of the most abundant renewable energy resources in Bilbao. As a municipality located in the north of Spain, it does not have as many hours of sunshine as the rest of the country, so using wind energy, as a source of renewable energy, would be the most appropriate decision.
- The installation of small wind turbines (up to 100kW of power) is permitted in the municipality of Bilbao, as long as the municipal and state ordinances are respected with regard to:

1. Administrative procedures for municipal authorisation for the construction of the building.
2. Equipment requirements.
3. Installation requirements, both electrical and mechanical-structural.
4. Limitations on the installation, in terms of acoustic and visual impact.

The municipality of Bilbao, capital of the province of Vizcaya, one of the three provinces of the autonomous community of the Basque Country, is located in the north of Spain, on the shores of the Cantabrian Sea. Its geographical coordinates are 43° 15' 46.7460'' N and 2° 56' 6.0468'' W. It has a population of 350,184 people and a surface area of 41.6 km2, making it the tenth most populated city in Spain.

Figure 1. Picture and location of Bilbao [Source: [17], [18]]

Bilbao has a humid oceanic climate, with a predominance of westerly winds, which moderates the temperatures and favours mild weather throughout the year. Due to its proximity to the sea, the climate is mild, with no marked temperature contrasts between seasons: an average temperature of 8ºC in winter and 20ºC in summer.

The average wind data for the municipality is shown in Figure 2.

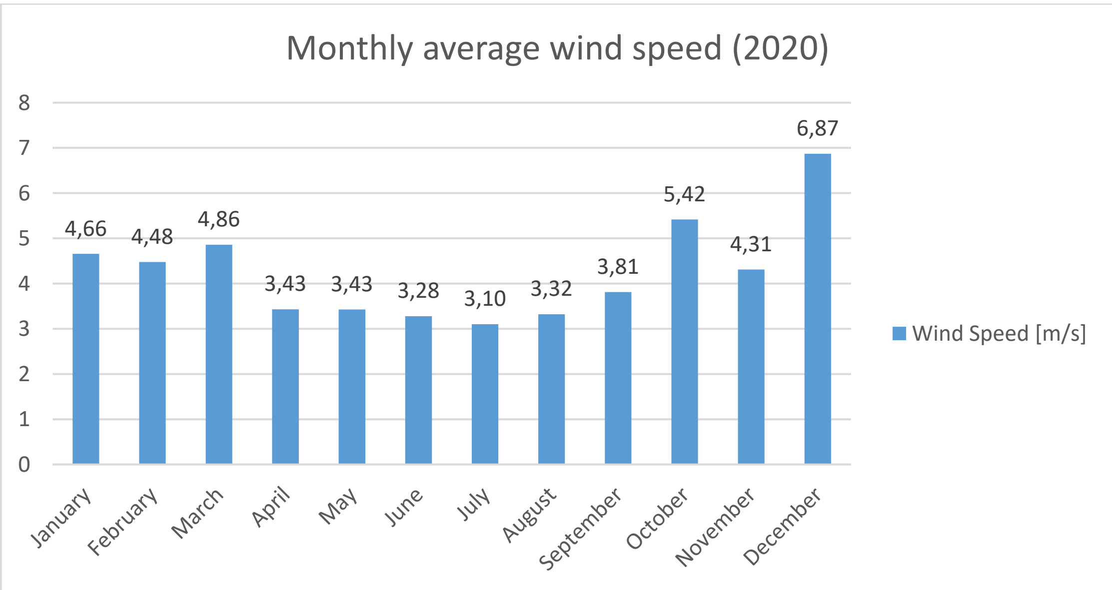


Figure 2. Monthly average wind speed in Bilbao. [Source: [10]]

1.2. Project objectives and scope

The objective of this project is to demonstrate the economic viability of installing low-power wind turbines in urban environments, for which the study has been carried out in a specific location as a starting point, and this study will serve as a reference for subsequent projects of the same type.

The search for an environmentally friendly alternative to conventional energy sources is a necessity due to the proven evidence of climate change caused by pollution from these energy sources. As a result, major advances are being made in the field of renewable energies such as photovoltaics, solar thermal energy or, as in this particular study, wind energy and many countries are investing in the installation of such power plants.

However, there is some controversy over the environmental impact, in terms of visual impact, of power plants of this type, as many of them are built in environments whose landscape impact has been the subject of complaints by many people. This is why, through this study, the aim is to look for already built-up areas for the construction of plants of renewable origin, so that the visual impact is reduced to a minimum.

As far as urban environments are concerned, photovoltaic panels are currently being installed on the buildings themselves. However, this solution is not viable, or sometimes not even possible, if we consider geographical areas where the incidence of solar radiation is minimal. For this reason, it is necessary to search for renewable alternatives that are also valid for areas of the globe where the hours of sunlight are scarce. The solution proposed in this document is wind energy for areas where the wind is sufficiently strong to take advantage of this resource for electricity production.

Wind energy is currently one of the cheapest and cleanest sources of energy available. Economically, costs are only incurred in the construction, purchase and installation of the system, because once it is installed, it can generate energy continuously and free of charge until the end of its useful life.

In order to carry out the work correctly, the main priority will be to obtain the maximum amount of energy possible at the lowest cost, taking into account at all times the dimensions available in the area dedicated to the installation and the economic, technical and administrative aspects, as well as complying with the current urban planning regulations for the installation of wind turbines in urban environments.

2. Benefits of the work

2.1. Environmental benefit

The use of wind technology allows us to dispense with conventional and much more polluting generation technologies, such as those that produce energy from burning fossil fuels. In this way, we contribute to the decarbonisation of the economy, an objective pursued by many countries and organisations around the world.

Wind energy is a source of energy that does not emit CO_2, one of the main greenhouse gases that are contributing to climate change, so by using it we are slowing down the advance of this catastrophic process.

The direct effect of the increase in the atmosphere's composition of greenhouse gases is climate change and the rise in temperatures. The world is getting hotter and projections suggest that temperatures will continue to increase. During the last 100 years, the global average surface temperature has increased about 0.74°C. Over the past 50 years, more widespread changes in extreme temperatures and precipitation have been reported and the rate of change has increased over time.

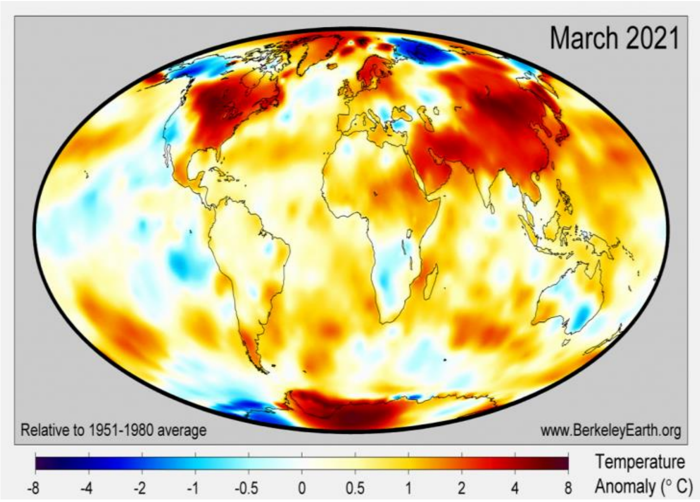


Figure 3. Temperature anomaly worldwide. [Source: Berkeley Earth]

Scientists have high confidence that global temperatures will continue to rise for decades to come, largely due to greenhouse gases produced by human activities. Some of the long-term effects of global climate change may include the glacier melting and sea level rise, more violent storms, desertification of areas that were not deserts before, alterations in the life cycles of animals, even leading to the extinction of some species and the change of the seasons.

2.2. Economic benefit

The only cost of the energy source selected in this work is the purchase and installation of the equipment, since, from that moment on, it is able to produce electricity free of charge, except for maintenance costs.

One of the main disadvantages is the need for a very high initial investment. However, the latest advances in technology have favoured a decrease in the price of the equipment necessary for an installation of this type. In any case, the initial investment is always amortised in the long term, as the equipment can last up to 25 years and the savings from the amount of energy produced in that time offset the initial investment.

Regardless of the economic savings in terms of energy savings, as far as the preparation of this study is concerned, it will be carried out by contrasting the results with a simulation in Homer Pro. Software modelling of the generation plant when analysing grid connection studies or other types of studies is a great improvement over field tests or even laboratory tests, not only because it is a faster, more flexible and simpler method, but also because of the economic savings in both human and physical resources. In addition, if the model is accurate, it can save a considerable number of hours in the search for solutions to problems, and these additional hours would be translated into costs.

A software model of this type generates a decisive economic benefit in the long run. Due to its ability to foresee situations, it can reduce the ageing of the elements that form part of the wind farm, saving a large amount of money in possible repairs or replacements of any component of the installation. In addition to the economic benefits obtained from the savings in repairs to the wind farm, thanks to the predictive repair model supported by the software model, it is possible to talk about the economic savings that will be produced by working in optimal generation circumstances.

2.3. Social benefit

Socially, it is a highly accepted type of energy.

The fact that they do not emit any gas emissions leads to a general acceptance and satisfaction in society, which favours public support for the installation of these systems. Not only because of the impact it may have on climate change due to the greenhouse effect, but also because of the direct effect it may have on the reduction of emissions of polluting gases into the atmosphere due to the production of energy in conventional power plants, since the gases emitted by these plants have repercussions on all kinds of alterations in the health of the population. In fact, air pollution is the fourth largest risk factor to global health, according to World Health Organization, after high blood pressure, dietary risks, and smoking. It also is the biggest environmental health risk factor. The inhalation of outdoor air pollution causes millions (7–9.5 million) of premature deaths in addition to exposing more than six billion people to adverse health effects.

The array of health effects linked to ambient air pollution is extensive and includes increased risk for respiratory infections, exacerbation of asthma, and chronic obstructive pulmonary disease and cardiac events, contributions to development of major chronic diseases, such as coronary heart disease and cancer, and impaired lung growth and respiratory symptoms during childhood.

Additional adverse health outcomes are under investigation: autism and other neurodevelopmental disorders, adverse reproductive outcomes, and more rapid “brain aging”, for example. The increased risk for cancer causally linked to air pollution likely comes primarily from the presence of specific carcinogens in ambient air pollution.

On the other hand, wind energy is also gaining acceptance in the reduction of electricity prices. Wind is free and by pricing energy in a competitive market with different energy sources, many of which are not free like wind, wind power plants can offer the lowest electricity price and remain competitive. Lazard's latest annual Levelized Cost of Energy Analysis of 2020 (LCOE 14.0), shows that wind energy had an average cost of 26$/MWh-54$/MWh while other conventional energy resources, such us nuclear energy, reached peaks of 198$/MWh.

Figure 4. Levelized cost of electricity depending on the source. [Source: [19]]

It is also worth mentioning the employment impact of wind energy as it produces quality and stable jobs.

3. Wind energy - State of the art

3.1. Origin of the wind

All renewable energy (except tidal and geothermal power), and even the energy in fossil fuels, ultimately comes from the sun. The sun radiates $1.74423*10^{+14}$ kWh of energy to the earth per hour. About 1 to 2 per cent of the energy coming from the sun is converted into wind energy.

3.2. Classification of wind types

3.2.1. Global scale wind (10000 km)

Due to unequal global warming the regions around equator, at 0° latitude are heated more by the sun than the rest of the globe.

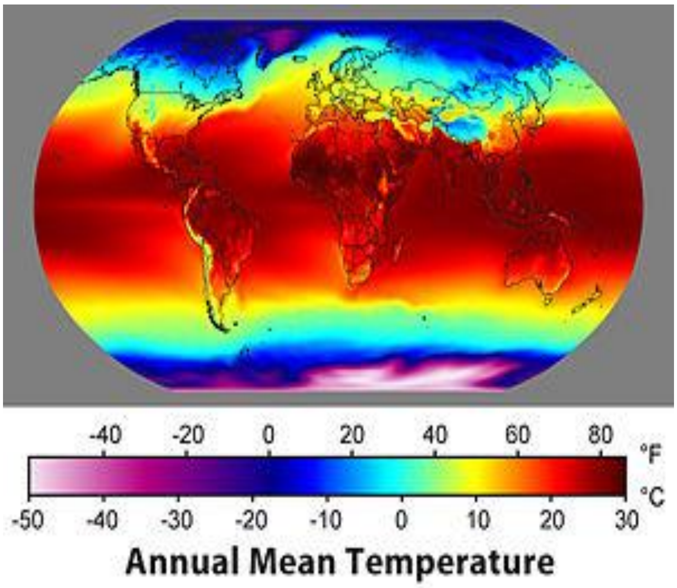


Figure 5. Annual mean temperature worldwide. [Source: [20]]

Hot air is lighter than cold air and will rise into the sky until it reaches approximately 10 km altitude and will spread to the North and the South. If the globe did not rotate, the air would simply arrive at the North Pole and the South Pole, sink down, and return to the equator.

On a global scale, wind is also caused by the so-called Coriolis Effect. Since the globe is rotating, any movement on the Northern hemisphere is diverted to the right, if we look at it from our own position on the ground. Likewise, in the southern hemisphere it is bent to the left. This apparent bending force is known as the Coriolis force (named after the French mathematician Gustave Gaspard Coriolis 1792-1843).

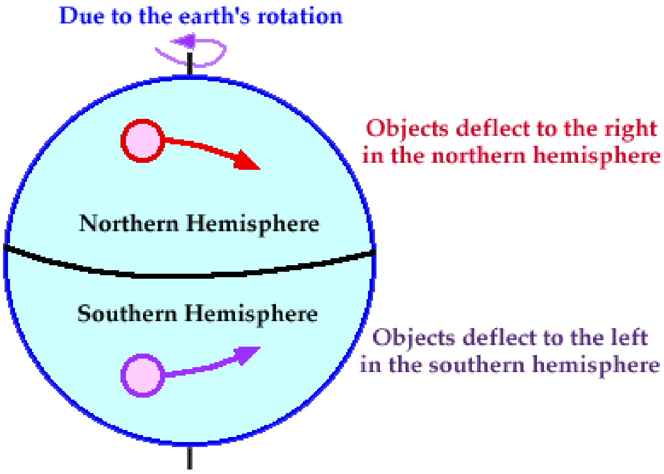


Figure 6. Coriolis Effect. [Source: [21]]

3.2.2. Macroscale wind (1000km)

Winds in this category are a combination of the Coriolis Effect, mentioned above, and atmospheric pressure forces.

3.2.3. Mesoscale wind (100 km)

In this category we can categorise two types of wind origin:

Sea breezes

During the day the land heats up faster than the sea due to the effect of the sun (because of the lower specific heat of the water). The air rises, circulates towards the sea, and creates a depression at ground level that attracts cold air from the sea. This is called a sea breeze. There is often a period of calm in the evening, when the ground and sea temperatures equalise. During the night the winds blow in the opposite direction. Normally during the night the land breeze has lower speeds, because the temperature difference between land and sea is smaller.

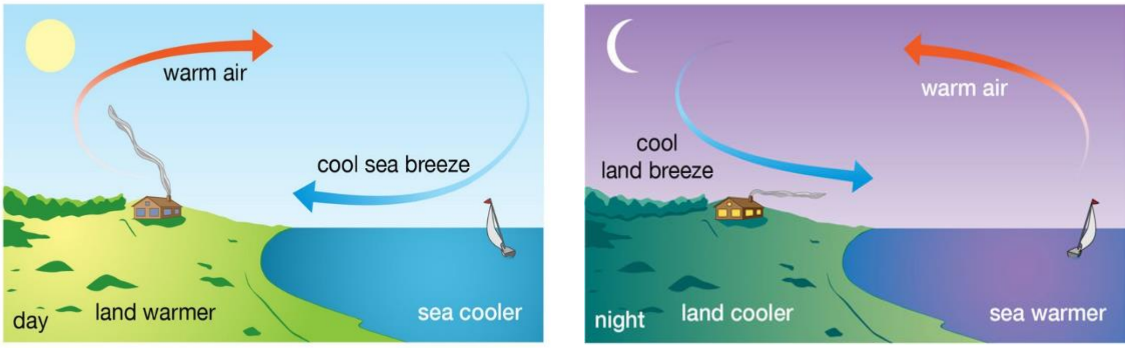


Figure 7. Sea breezes. [Source: [22]]

Mountain winds

The valley wind originates from south-facing slopes in the northern hemisphere (or north-facing slopes in the southern hemisphere). When the slopes and the air near them are warm, the air density decreases, and the air rises to the top following the surface of the slope. During the night the wind direction reverses, becoming a downhill flowing wind. If the valley floor is sloped, the air can rise and fall down the valley; this effect is known as a canyon wind. Winds blowing on leeward slopes can be quite powerful.

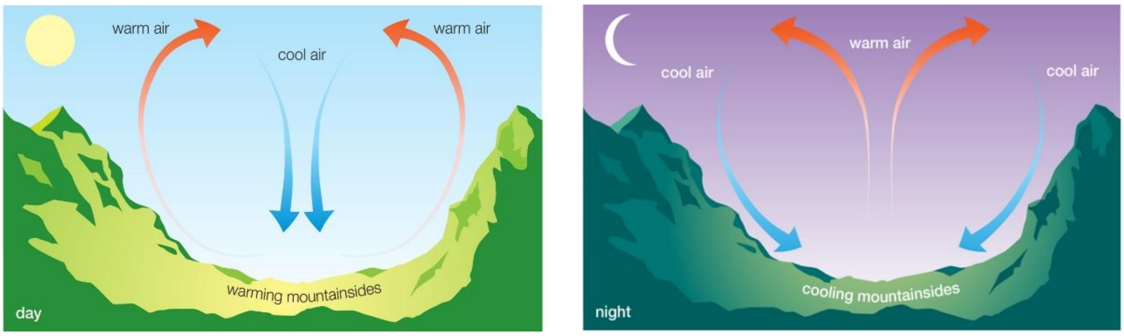


Figure 8. Mountain winds. [Source: [23]]

3.2.4. Microscale wind (10 km)

It involves turbulences due to small obstacles, hills, wind turbine wakes or others.

3.3. Energy in the wind

A wind turbine obtains its power input by converting the force of the wind into torque (turning force) acting on the rotor blades. The amount of energy which the wind transfers to the rotor depends on the density of the air, the rotor area, and the wind speed.

$$Power = \frac{Work}{time} \tag{1}$$

Taking into account the work obtained from the wind is, according to the kinetic energy equation:

$$Power = \frac{\frac{1}{2} * m * V^2}{t} \tag{2}$$

Being V the wind speed and m the air mass flow:

$$m = \rho * A * d \tag{3}$$

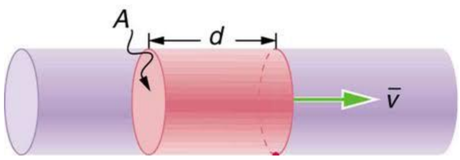


Figure 9. Air mass flow geometrical representation. [Source: [24]]

Where d is the infinitesimal distance of an air particle:

$$d = V * t \tag{4}$$

Replacing all these terms in the equation [2]:

$$Power = \frac{\frac{1}{2} * \rho * A * V * V^2 * t}{t} = \frac{1}{2} * \rho * A * V^3 \tag{5}$$

Equation [5] represents all the power contained in the wind. In practice, not all of this power is extracted from the wind turbine, as this would imply that the wind speed at the output of the wind turbine would be null, which is impossible.

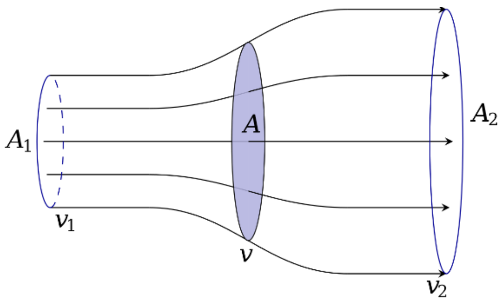


Figure 10. Input and output of air mass flow in a wind turbine. [Source: [25]]

For this reason, and in accordance with Betz's Law, only a fraction of the wind's energy can be extracted from the wind. This law states that only less than 16/27 (59 %) of the kinetic energy can be converted into mechanical energy using a wind turbine.

Therefore, introducing this power loss coefficient Cp in equation (5), the maximum extractable power of the wind would be:

$$Power = C_p * \frac{1}{2} * \rho * A * V^3 = 0.59 * \frac{1}{2} * \rho * A * V^3 \qquad (6)$$

However, this value is still unrealistic for the final power output of the turbine, since, in addition to the physical factor determined from Betz's law, a number of other factors have to be taken into account, such as:

- Propeller efficiency: 85%.
- Gearbox efficiency: 98%.
- Alternator efficiency: 95%.
- Transformer efficiency: 98%

An overall efficiency of the installation of around 46% is obtained, although these values are approximate, as the efficiency values offered by the manufacturers of each component would have to be taken into account.

3.4. Wind speed variability

3.4.1. Short-term

The wind speed is always fluctuating, so the energy content of the wind varies continuously. Exactly how great this fluctuation is depends on weather conditions as well as local surface conditions and obstacles. The energy output of a wind turbine will vary as the wind varies.

3.4.2. Day cycle

In most parts of the world, the wind blows stronger during the day than at night, mainly due to greater temperature differences. The wind is also more turbulent and tends to change direction more rapidly during the day than at night.

3.4.3. Seasonal factor

In warm areas, summer winds are generally weaker than winter winds. Electricity consumption is generally higher in winter than in summer in these regions. In cold areas of the world, electric heating is perfect in combination with wind energy, as the cooling of houses varies with wind speed in the same way as the electricity production in wind turbines varies with wind speeds.

3.4.4. Weibull distribution

The wind variation at a typical site is usually described using the so-called Weibull Distribution.

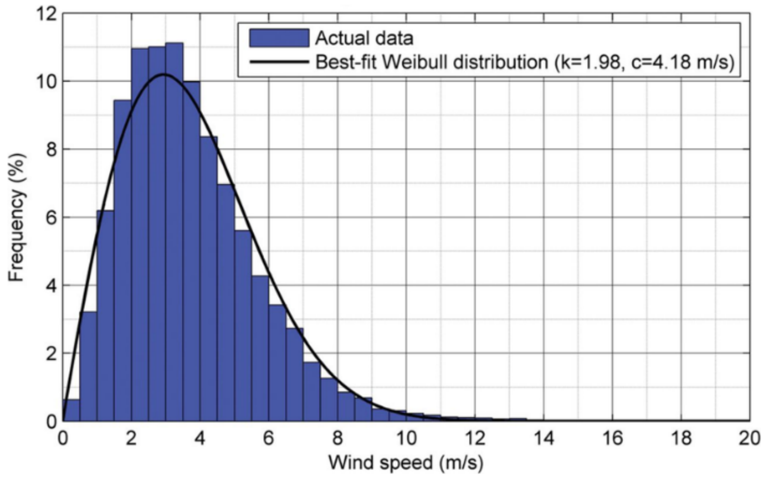


Figure 11. Wind speed approximation using Weibull distribution. Example [Source: [26]]

The Weibull distribution is a probability distribution. The area under the curve is always exactly 1, since the probability of the wind blowing at any of the speeds, including zero, must be 100%.

The statistical distribution of wind speeds varies from place to place on the planet, depending on local climatic conditions, the landscape and its surface. Therefore, the Weibull Distribution can vary in both shape and mean value.

3.5. Power curve of a wind turbine

If we multiply the power of each wind speed with the corresponding probability on the Weibull plot, we will have calculated the distribution of wind energy at different wind speeds.

Most of the wind energy will be found at speeds above the average wind speed at the site, as high wind speeds have higher energy content. At low wind speeds the efficiency is not as high, as there is not much energy to collect. At high wind speeds, the turbine must dissipate any excess of energy above that for which the generator is designed. Thus, efficiency is of most interest in the wind speed zone where most of the energy is found.

The power curve of a wind turbine is a graph that indicates what the electrical power available to the wind turbine will be at different wind speeds.

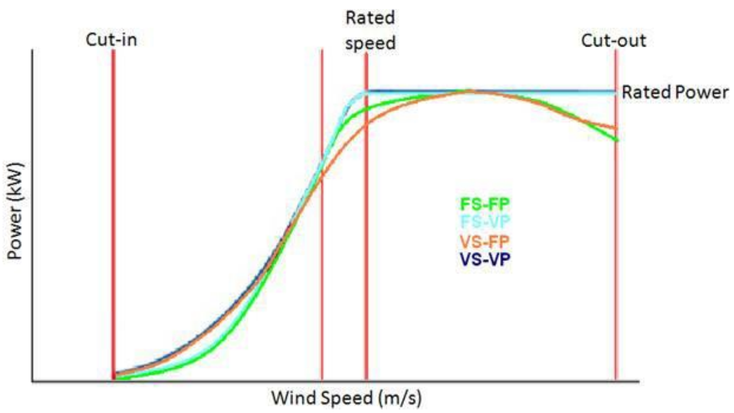


Figure 12. Power curve of a wind turbine. Example. [Source: [27]]

The power curves are obtained from field measurements, where an anemometer is placed on a mast relatively close to the wind turbine. In practice the wind speed always fluctuates, and it is not possible to measure exactly the wind column passing through the rotor of the wind turbine. An average of the different measurements for each wind speed must be taken, and the graph with these averages must be drawn. The power curves are based on measurements made in areas of low turbulence intensity, and with the wind coming directly towards the front of the turbine.

Two characteristic speeds on these curves are:

3.5.1. Cut-in speed

This is the speed at which wind turbines are designed to start rotating. Typically, this value is between 3-5m/s. There is a small amount of power loss due to the fact that the turbine only starts to run at this speed.

3.5.2. Cut-out speed

The wind turbine will be programmed to stop at high wind speeds, around 25 m/s, to avoid possible damage to the turbine or its surroundings. The stall wind speed is called the cut-out speed.

3.6. Types of wind turbines

Depending on the orientation of the axis of rotation of the wind turbine, there are two main groups:

3.6.1. Horizontal axis wind turbines (HAWT)

Horizontal axis wind turbines or HAWTs are built with a propeller-type rotor with the shaft arranged horizontally. Its purpose is to transform the linear motion of the wind into a rotary motion that will drive the alternator to produce electricity.

This type of wind turbine has to be oriented with the wind direction in such a way that the axis of rotation of the rotor is parallel to the wind direction.

Horizontal axis wind turbines are more energy-efficient, partly due to the use of wing profiles in their blades, and achieve higher rotational speeds, which mean that they require gearboxes with a lower gear ratio. In addition, due to the elevated construction on a tower, they take greater advantage of the increase in wind speed with height.

Horizontal axis models can be classified according to the orientation of the rotor in relation to the wind direction and the number of blades used.

Upwind

This is the name given when the rotor faces the direction of the dominant wind. Greater advantage is taken of the wind force than in the opposite option, known as downwind, as it does not present aerodynamic interferences with the tower. It requires a mechanical mechanism capable of orienting the machine into the wind. In small wind turbines, orientation can be achieved by means of a directional fin located on the nacelle in the opposite position to the rotor. This is currently the most widely used design for wind turbines.

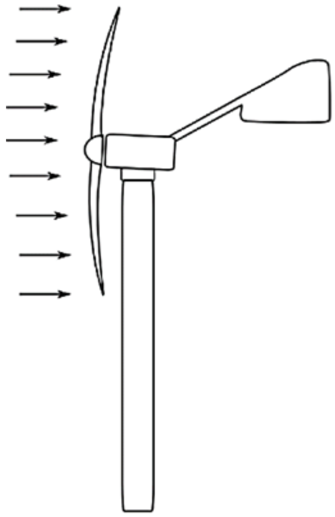


Figure 13. Upwind wind turbine. [Source: [28]]

On the other hand, every time the rotor blades pass close to the tower, the power that the wind has, and that they capture, drops significantly due to what is known as tower turbulence. In high power wind turbines, in order to minimise this turbulence, the rotor presents a small angle with respect to the tower. This angle is known as the tilt angle.

Among its disadvantages, we can point out the need to incorporate a more rigid rotor, located at a certain distance from the tower. Otherwise, there is a risk of interference with the tower due to the stresses that tend to bend the blades in the direction of the tower. This considerably increases the cost of the rotor blades because it will require better mechanical properties and materials.

They also require a rotor orientation system to keep the rotor facing into the wind as they are not capable of automatic orientation.

Downwind

This is the name given when the rotor is focused in the opposite direction to the prevailing wind direction.

The structure of the tower and the nacelle reduces the rotor's use of the wind. In this case, it is the wind that guides the nacelle with its own force, which means that automated guidance elements are not necessary in theory, although they are often used as a safety feature.

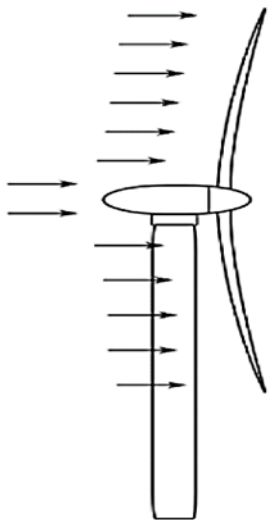


Figure 14. Downwind wind turbine. [Source: [28]]

Another important advantage is that the blades are made of more flexible materials than in the case of wind turbines oriented upwind, as there is no possibility of interference between the blades and the rotor.

The reduced weight due to less rigid blades means that the dynamic loads are lower in magnitude as at high wind speeds, e.g. during gusts, the blades can start to bend (flap bending) relieving the tower and the whole support structure to some extent.

The most important disadvantage is the fluctuation of wind power due to what is known as tower shadow. This results in higher fatigue loads on the turbine and blades than in a windward system.

Three-bladed wind turbines

It consists of three blades placed at an angle of 120º to each other.

Figure 15. Three-bladed wind turbine [Source: [29]]

A larger number of blades increase the cost and weight of the wind turbine, which is why larger blade designs are not used for power generators on a commercial basis.

One of the many reasons for the use of 3 blades on the propeller is the constant, almost zero, Coriolis torque of the rotor with respect to the operational movements around the longitudinal axis of the tower. All rotors with 3 or more blades have this favourable property. Consequently, no load is induced on the structure due to this phenomenon, which results in structural simplification and reduced manufacturing costs.

Two-bladed wind turbines

Two-bladed wind turbines have the advantage of saving the cost of a blade and, of course, its weight. However, they have the disadvantage of requiring a higher rotational speed to generate the same energy output.

Figure 16. Two-bladed wind turbine [Source: [30]]

This rotor can be mounted on the ground and hoisted up to the nacelle as a single piece, which makes it easier to install. Due to the variation of wind speed with height and the fact that the rotor has only two blades, the rotor is more unstable than a three-bladed rotor.

Single-bladed wind turbine

These designs are not very widespread commercially, because in addition to the higher rotational speed, noise and visual intrusion problems, they need a counterweight on the side of the hub opposite the blade to balance the rotor. This of course negates the weight savings compared to a two-bladed design.

Figure 17. Single-bladed wind turbine [Source: [31]]

Wind turbines with one and two blades require a more complex design, with a tilting rotor. The rotor has to be prepared to tilt in order to avoid strong jolts in the turbine every time one of the blades passes the tower. This may require additional dampers to prevent the rotor blades from hitting the tower.

Multi-bladed wind turbines

Multi-bladed turbines still bear some resemblance to the old multi-bladed mills used to pump water from wells.

Figure 18. Multi-bladed wind turbine [Source: [32]]

These wind turbines are characterised by low rotational speeds and high torque. They are used in applications that require a lot of torque, such as water extraction by means of wind pumps.

3.6.2. Vertical axis wind turbines (VAWT)

A vertical axis wind turbine is basically a wind turbine in which the rotor shaft is positioned vertically, allowing it to generate electrical power regardless of the direction from which the wind is coming.

One of the main advantages of vertical axis wind turbines is that they do not need an orientation system as they are omnidirectional. Also, that the great majority of the mechanical components and those of greater mass such as the generator, the gearbox and the cooling system are installed at ground level, giving the wind turbine greater stability by lowering the centre of gravity, as well as making it easier to maintain and reducing assembly costs. In some models, the rotor shaft reaches a great height and must be braced to avoid inertial problems.

Their disadvantages are their lower efficiencies, the need for external start-up systems for some models due to their high starting torque, and the fact that disassembly of the rotor for maintenance tasks requires the dismantling of the entire wind turbine machinery.

The most commonly used vertical axis wind turbines are the Savonius, Darrieus and Panemona types.

Savonius wind turbine

They are made up of blades in the shape of a half cylinder cut lengthwise and positioned with respect to the axis of rotation of the wind turbine in such a way that the incidence of the wind on the concave part of them causes a torque, while the convex part offers less rotational resistance.

Figure 19. Savonious wind turbine [Source: [33]]

It is one of the simplest turbines, due to its geometry it supports turbulences well and can start to rotate with low intensity winds, but in a limited range. As their blades cannot rotate on their longitudinal axis, a secondary mechanical braking system is necessary, as well as a robust structure to support high wind intensities if necessary, as they have a large surface area exposed to the wind.

Their rotational speed is not very high compared to other types of wind turbines, thus classifying them as "slow" wind turbines.

Darrieus wind turbine

It consists of two or three arches that rotate around an axis. They use the lift of the blades as the blade surface has a wing profile capable of generating a pressure distribution along the blade. They are characterised by low starting torque and high rotational speed, which designates them as "fast" wind turbines.

These turbines are composed of two blades in the form of thin blades with an airfoil, joined to the shaft at the ends with a curve designed to improve performance. They do not require a guidance system and start to operate at wind speeds of 2 m/s.

These rotors are generally only used as generators connected to the grid, as they cannot start on their own. They are more efficient than other vertical axis wind turbines due to the fact that they have an aerodynamic profile in their blades which results in lower friction losses.

It is very efficient for winds with a vertical component, which makes it suitable for sites with a high inclination such as hills, and it is currently being installed on the roofs of buildings to take advantage of the "corner effect".

There are different types of Darrieus wind turbines depending on the type of blade used.

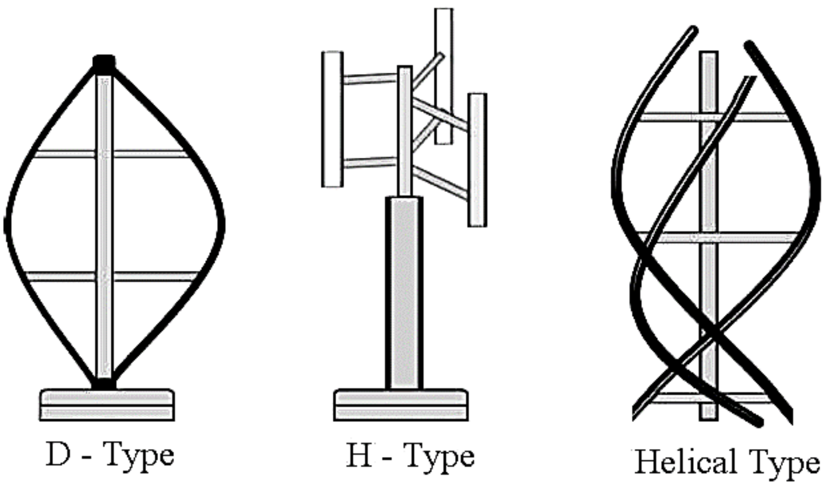


Figure 20. Darrieus wind turbines. Types. [Source: [34]]

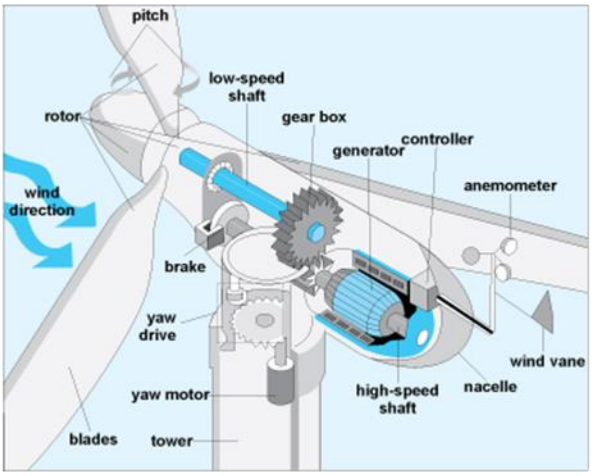
Panémone wind turbines

It consists of blades parallel to the axis of rotation of the rotor in the shape of a half cylinder in longitudinal section, separated from it by a rigid arm. Unlike Savonius rotors, the blades are separated from the axis of rotation, as mentioned above, which results in a higher torque than in Savonius rotors and, at the same time, greater power can be obtained.

Figure 21. Panémone wind turbine [Source: [35]]

Unlike Darrieus rotors, its blade does not have an aerodynamic profile and therefore its performance is lower.

3.7. Components of a wind turbine



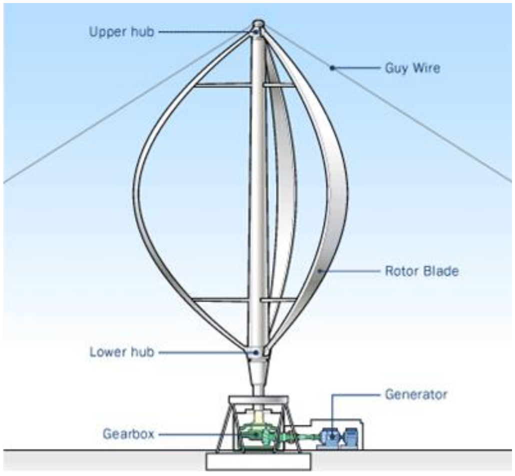


Figure 22. Components of a wind turbine [Source: [36], [37]]

Some of the components are common in VAWT and in HAWT. The major difference lies in the structural components.

3.7.1. Nacelle

It contains the key components of the wind turbine, including the gearbox and the electric generator.

3.7.2. Hub

Ensures the link between wind turbine blades and the low speed shaft.

In VAWT there are two hubs upper and lower because blades are attached at two points. It is the centre of the rotor to which the rotor blades are attached. Cast iron or cast steel is most often used.

3.7.3. Rotor blades

They capture the wind and transmit its power to the hub. In HAWT, their design is similar to the wings of an aeroplane. In the case of VAWT, their design depends on the type of wind turbine used.

3.7.4. Yaw mechanism. Yaw drive and yaw motor

A wind turbine's yaw mechanism is used to turn the turbine rotor against the wind.

3.7.5. Low-speed shaft

It connects the rotor hub to the gearbox and contains hydraulic system lines to allow operation of the aerodynamic brakes.

3.7.6. Pitch

Monitors and adjusts the angle of the wind turbine's rotor blades, which can measure up to 65 meters long, and thus controls the rotational speed of the turbine.

3.7.7. High-speed shaft

It rotates at approximately 1500 rpm, which allows the electric generator to operate. It is equipped with a mechanical emergency disc brake. The mechanical brake is used in case of failure of the aerodynamic brake, or during turbine maintenance.

3.7.8. Braking system

The braking system stops the rotor automatically when its rotational speed exceeds its cut-out point to prevent any mechanical or electrical damage. The primary braking system for most modern wind turbines is the aerodynamic braking system, which stops the turbine in a matter of a couple of rotations. In addition, the aerodynamic braking system offers a very gentle way of braking the turbine without any major stress, tear and wear on the tower and the machinery.

3.7.9. Gearbox

It allows the high-speed shaft to rotate 50 times faster than the low-speed shaft.

3.7.10. Generator

It converts the mechanical rotational energy of the high-speed shaft into electrical energy.

3.7.11. The anemometer and the wind vane

They are used to measure wind speed and direction. The electronic signals from the anemometer are used by the electronic wind turbine controller to switch the wind turbine on and off. The wind vane signals are used by the electronic wind turbine controller to turn the wind turbine upwind.

3.7.12. Controller

It consists of a computer that continuously monitors the wind turbine conditions and controls the yaw mechanism. In the event of any malfunction, it automatically stops the wind turbine and calls the computer of the operator in charge.

3.7.13. Tower

It supports the nacelle and the rotor.

3.7.14. Guy wire

VAWT normally needs guide wire to keep the rotor shaft in a fixed position and maximised possible mechanical vibration.

3.8. Main wind turbine electrical circuit configurations

Induction generators are largely the most popular electric machines in wind turbines industry. Although synchronous generators can also be found, especially in autonomous systems, induction generators by far dominate the market for grid-connected wind turbines. Furthermore, modern wind turbines include sophisticated power electronics that modify the fundamental behaviour of the induction machines.

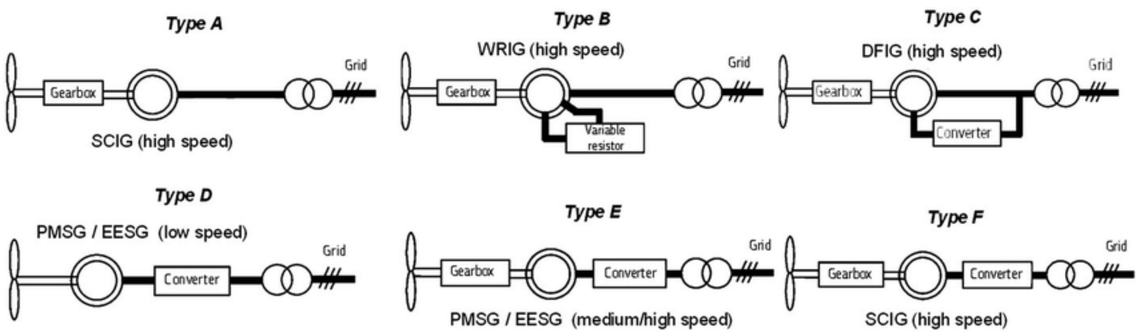


Figure 23. Main wind turbine electrical circuit configurations [Source: [38]]

3.8.1. Type A

Fixed-speed generator: it is usually used a squirrel cage induction generator (SCIG) because of its constructive simplicity and robustness. The rotational speed of the electric (asynchronous) generator is constrained by the spinning speed of the blades with very limited range response to variations in wind speed. Neither power converter nor other speed regulation techniques are employed in this configuration.

3.8.2. Type B

The speed of the asynchronous generator is controlled by a variable resistance that enables modifying the current circulating in the rotor. As a consequence, wounded rotor induction generators are employed in this configuration.

This solution provides higher control flexibility than type A. However, the electrical losses are relatively high, and the response to grid requirements is very limited.

3.8.3. Type C

This configuration is known as DFIG. The current in the electric generator's rotor is controlled by a power converter. Thus, electrical losses are lower, and the response to grid requirements is enhanced. Since the power converter is only connected to the rotor of the generator, the converter only covers around 30% of the energy generated by the wind turbine.

3.8.4. Type D

A full-power converter enables decoupling the generator from the grid frequency, so that the frequency (and hence the rotational speed) of the generator can be fully controlled and the use of a gearbox can be avoided. Additionally, the full converter provides enhanced grid services.

3.8.5. Type E

Gearbox-equipped wind turbine with a full converter and medium-/high-speed synchronous generator (EESG or PMSG). In practice, all type E wind turbines use permanent magnets.

3.8.6. Type F

Gearbox-equipped wind turbine with a full converter and high-speed asynchronous generator. Thanks to the use of the full converter, a simpler generator (SCIG) can be used, which is the case for the most popular turbines under this configuration

3.9. Wind turbine aerodynamics

The movement of wind turbines is based on two principles:

3.9.1. Lift force

The air moving along the upper surface of the wing moves faster than the air on the lower surface. This implies (by Venturi effect) a lower pressure on the upper surface, which creates lift, that is, the upward pushing force.

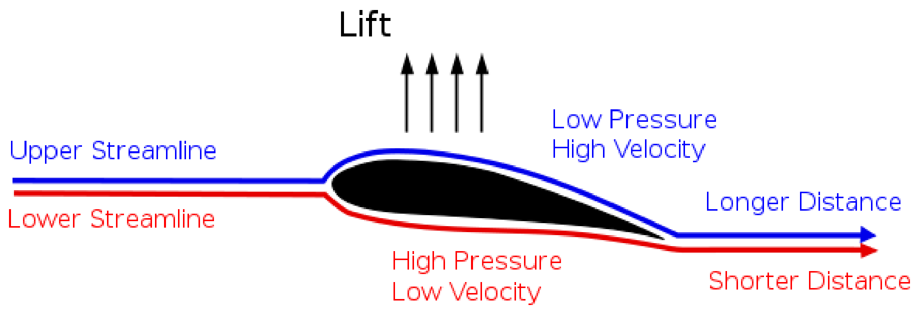


Figure 24. Lift force. [Source: [39]]

3.9.2. Aerodynamic resistance

Air resistance: it will increase if the area oriented in the direction of movement increases.

The wind that reaches the rotor blades of a wind turbine does not come from the direction in which the wind blows in the surroundings, that is, from the front of the turbine. This is because the rotor blades themselves are moving. The wind speed as seen from a point on the blade is the vector sum of the wind speed (as seen by a fixed observer) plus the velocity of that point on the blade, which is:

$$v = \omega * r \tag{7}$$

Being r the radius of the blade.

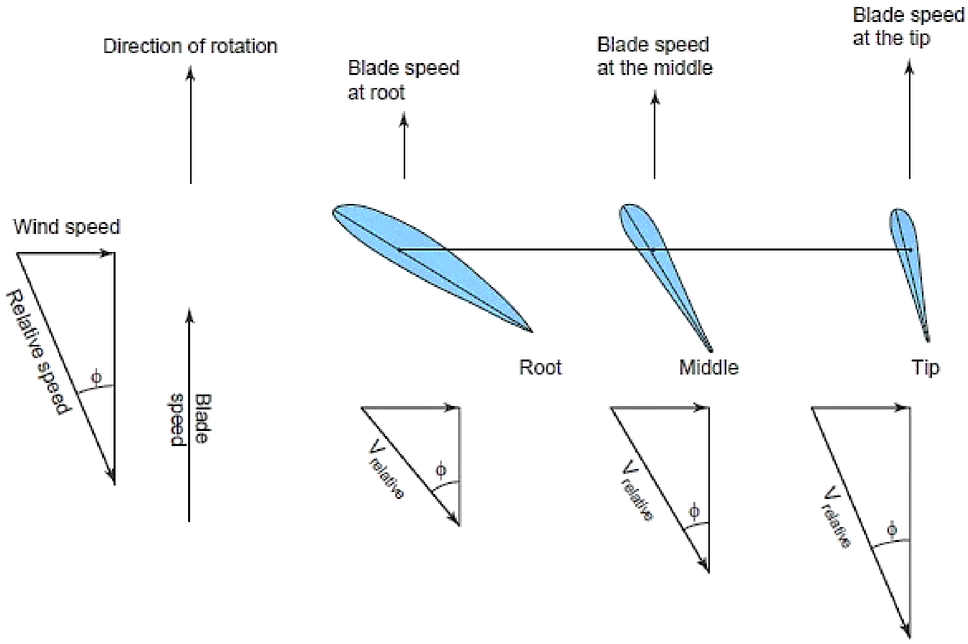


Figure 25. Speed of the blade. Graphical representation. [Source: [40]]

Since most turbines have a constant rotational speed, the speed at which the tip of the blade moves (peripheral speed) is usually higher, while it is zero at the centre of the hub. Also, variations in wind speed have a greater effect on the angle of attack near the base of the blade than at its tip.

The rotor blades of large wind turbines are always twisted. Viewed from the rotor blade, the wind will come from a much greater angle as you move towards the base of the blade, in the centre of the rotor. The blade must therefore be warped, so that the angle of attack is optimal along the entire length of the blade. However, in the particular case of stall controlled wind turbines, it is important that the blade is constructed in such a way that the loss of lift occurs gradually from the root of the blade and outwards at high wind speeds.

3.10. Power control in wind turbines

All wind turbines are designed with some form of power control:

3.10.1. Pitch-controlled power control

The turbine's electronic controller checks the generated power several times per second. When this reaches a value that is too high, the controller sends an order to the pitch-angle change mechanism, which immediately rotates the rotor blades slightly out of the wind (and vice versa). The design of pitch controlled wind turbines requires highly developed engineering to ensure that the blades rotate at exactly the desired angle. Generally it will rotate the blades a few degrees each time the wind changes, to maintain an optimum angle that provides maximum performance at all wind speeds. The pitch angle change mechanism is usually hydraulically operated.

3.10.2. Stall-controlled power control, passive control

Wind turbines have the rotor blades attached to the hub at a fixed angle. However, the blade profile has been aerodynamically designed to ensure that, when the wind speed is too high, turbulence is created on the part of the blade that does not face the wind, and a loss of lift prevents the upward force of the blade acting on the rotor.

The blade is slightly twisted along its longitudinal axis. This is partly to ensure that the blade loses lift gradually, rather than abruptly, when the wind speed reaches its critical value.

The main advantage is that moving rotor parts and a complex control system are avoided. On the other hand, it represents a very complex aerodynamic design problem, and involves challenges in the design of the structural dynamics of the entire turbine to avoid vibrations caused by the loss of lift.

3.10.3. Stall controlled power control, active control

They are similar to the pitch-controlled ones in the sense that they both have blades that can rotate. However, when the machine reaches its rated power, if the generator is to be overloaded, the machine will rotate the blades in the opposite direction to a pitch-controlled machine, increasing the pitch angle of the blades to bring them to a position of higher lift loss, and thus consume the excess energy from the wind.

One of the advantages is that the power output can be controlled more accurately than with passive control, in order to prevent the rated output from being exceeded at the beginning of a gust of wind. Another advantage is that the machine can be operated almost exactly at the rated output at all wind speeds.

The pitch angle change mechanism is usually operated by means of hydraulics or electric stepper motors.

3.10.4. Guidance mechanism

In order to get the most power from the wind, the rotor must be correctly oriented in the direction of the wind.

A yaw error means that a smaller proportion of the wind energy will pass through the rotor area. The part of the rotor closest to the direction of the wind source will be exposed to more stress (bending torque) than the rest of the rotor. This means that the rotor will have a natural tendency to turn upwind, regardless of whether it is a downwind or an upwind turbine. On the other hand, it also means that the blades will be twisted to both sides in the flap direction (direction perpendicular to the rotor plane) at every turn of the rotor. Therefore, wind turbines that are operating with an orientation error will be subject to higher fatigue loads than those oriented in a direction perpendicular to the wind.

Almost all horizontal axis wind turbines employ forced yaw, i.e. they use a mechanism that keeps the turbine oriented upwind by means of electric motors and multipliers.

3.11. Location criteria

At a great height above the ground surface, around one kilometre, the earth's surface has hardly any influence on the wind. However, in the lower levels of the atmosphere, wind speeds are affected by friction with the earth's surface. In the wind industry, a distinction is made between the roughness of the terrain, the influence of obstacles, and the influence of the contour of the terrain, also called the orography of the area.

3.11.1. Roughness of the terrain

In general, the more pronounced the roughness of the terrain, the greater the slowing down of the wind.

In the wind industry, roughness class or roughness length (z_0) is often referred to when it comes to assessing the wind conditions of a landscape. A high roughness class 3 or 4 refers to a landscape with many trees and buildings, while a sea surface has a roughness class 0.

Table 1. Roughness class or roughness lenght for various terrain types. [Source: [41]]

Terrain Category	Class	Surface	Landscape Description	Z_o(m)
1	1	Sea	Open sea, fetch at least 5 km	0.0002
1	2	Smooth	Mud flats, snow, little vegetation, no obstacles	0.005
2	3	Open	Flat terrain: grass few isolated obstacles	0.03
3	4	Roughly Open	Low crops: occasional large obstacles	0.1
3	5	Rough	High Crops: scattered obstacles	0.25
3	6	Very Rough	Orchards, bushes: numerous obstacle	0.5
4	7	Closed	Regular large obstacle coverage (suburban area, forest)	1.0
4	8	Chaotic	City centre with high and low rise building	>2

The wind speed at a certain height above ground level is:

$$V = V_{ref} * \frac{\log(\frac{z}{z_0})}{\log(\frac{z_{ref}}{z_0})} \quad (8)$$

Where:

- V: Wind speed at a height z above ground level
- V_{ref}: Reference wind speed, that is, an already known wind speed at a given altitude
- z: Height above ground level for the desired speed
- z_0: Roughness length in the current wind direction
- z_{ref}: Reference height, that is, the height at which the exact wind speed v_{ref} is known.

That the wind profile moves towards lower speeds as we approach ground level is often referred to as wind shear. Wind shear can also be important in wind turbine design, the forces acting on the rotor blade when it is in its highest position are much greater than when it is in its lowest position.

3.11.2. Obstacles

Turbulence

They originate in areas where the surface is very rough and behind obstacles such as buildings. They are very irregular air flows, with swirls and vortices in the surroundings.

Turbulences decrease the possibility of using wind energy effectively in a wind turbine. They also lead to increased damage and wear on the wind turbine. Wind turbine towers are usually built high enough to avoid wind turbulence near ground level. Wind obstacles can slow wind speed significantly and often create turbulence around them. The turbulence zone can extend to a height of about 3 times the height of the obstacle.

Turbulence is more pronounced behind the obstacle than in front of it. Therefore, it is better to avoid large obstacles close to wind turbines, especially if they are on the side where the wind blows.

Wind shelter

This is the phenomenon that occurs when the wind decreases behind a blunt obstacle, that is, an obstacle that is not aerodynamic and has zero porosity.

Screening at the wind farm

Screening in the wind farm is caused by the wake effect. The wind leaving the turbine must have lower energy content than the wind arriving at the turbine. A wind turbine will always create a shelter in the downwind direction. In fact, there will be a wake behind the turbine, that is, a long tail of wind that is quite turbulent and slowed down compared to the wind arriving at the turbine. To avoid excessive turbulence downwind around the turbines, each turbine is usually separated from the others by a minimum distance equivalent to three rotor diameters. In dominant wind directions this separation is even greater.

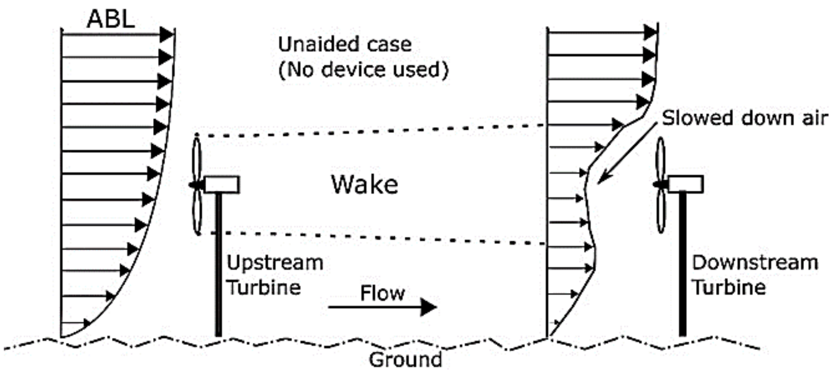


Figure 26. Screening effect of a wind farm. [Source: [42]]

3.11.3. Orography

Tunnel effect

This effect occurs between 2 tall buildings or in narrow passages between mountains. The air is compressed in the part of the buildings or the mountain that is exposed to the wind, and its speed increases considerably between the wind obstacles. Placing a wind turbine in such a tunnel is a clever way to obtain higher wind speeds than in the surrounding areas. To obtain a good tunnel effect, the tunnel must be "softly" embedded in the landscape. If the hills are very rough, there can be a lot of turbulence in that area.

Hill effect

On hills, wind speeds are always higher than in the surrounding areas. Again, this is because the wind is compressed on the downwind side of the mountain, and once the air reaches the top of the hill it can expand again as it descends into the low pressure zone down the leeward side of the hill.

4. Wind turbines implementation analysis

4.1. According to energy source

As alternatives, renewable energy sources have been studied at all times, since, as mentioned above, one of the fundamental objectives is to reduce the production of energy from polluting energy sources or with some kind of environmental impact.

4.1.1. Photovoltaic solar energy

Photovoltaic solar energy is obtained by converting sunlight into electricity using a technology based on the photoelectric effect.

It is a clean and inexpensive source of energy given the recent advances in the photovoltaic energy sector. However, this type of generation requires a source of energy that is not available, or is very scarcely available in many parts of the world. The aim of this study is precisely to propose an alternative to conventional non-polluting generation sources in urban environments where the resource is available in many geographical locations. This is not the case.

4.1.2. Thermal solar energy

Solar thermal energy consists of using the sun's energy to produce heat that can be used for cooking food or for the production of hot water for domestic water consumption, heating, or for the production of mechanical energy and, from this, electrical energy.

This is a viable solution if, like solar PV, the geographical area has more hours of sunlight. Furthermore, compared to the alternative described above, the amount of switchgear required would be much higher, which is why this alternative is used in larger power plants. However, this study is intended for smaller scale generation, and therefore, in the proposed solution, smaller and less powerful machines will be used

4.1.3. Bioenergy or biomass energy

Bioenergy or biomass energy comes from the use of organic or industrial matter formed in some biological or mechanical process; it is generally obtained from the substances that constitute living organisms (plants, animals, among others), or their remains and waste. Biomass energy is used directly (e.g. by combustion) or by transformation into other substances that can be used later as fuel or food.

In addition to producing electricity from a renewable energy source, the production of electricity from biomass would confront a major problem present in large cities around the world: Waste management. However, the study focuses on the feasibility of a source of electricity generation in an urban environment, and the construction of a biomass plant in the middle of a city would be inappropriate.

4.1.4. Geothermal energy

Geothermal energy is obtained by exploiting heat from the Earth's interior that is transmitted through hot rock bodies or conduction and convection, which interact with groundwater, giving rise to geothermal systems from which energy can be extracted and converted into electricity.

As with bioenergy, the construction of a geothermal power plant in the city centre would not be socially accepted. Moreover, geothermal energy is not equally distributed all over the world. In some places, the construction of such plants would not be economically justified, as it would require the development of ultra-deep deposits that are economically unfeasible.

4.1.5. Tidal and wave energy

Tidal energy is produced thanks to the movement generated by the tides; this energy is harnessed by turbines, which in turn move the mechanics of an alternator that generates electrical energy.

Wave energy, on the other hand, is the capture of energy from the wave motion produced by the wind to do useful work.

Although the functioning of the two energy sources is different, they can be categorised in the same group, as both are obtained from the movement of the sea. However, this would require the need to be close to the sea for the production of electricity, and this does not occur in the case of inland cities, and even less so in the urban centre.

4.1.6. Wind energy

Wind energy is obtained by converting the movement of the blades of a wind turbine, which are driven by the wind, into electrical energy.

For our study, this is the most suitable energy source as wind is a widely available resource in all parts of the world, and thanks to the availability of small wind turbines, they can be installed in any geographical location, including urban environments.

4.2. According to the system configuration

4.2.1. Off-grid system

According to this type of connection, the energy generated in the wind turbine would be stored in batteries for later use. It would be a viable option for off-grid environments where grid connection would be impossible or highly unfeasible. This is not the case, as the study deals with the feasibility of installing wind turbines in urban environments, whose connection to the grid is perfectly feasible, and therefore, it would mean greater savings if the energy were injected, for example, directly into the grid or if it were consumed at the same time as it is being produced.

Moreover, as far as the switchgear is concerned, the installation costs would be reduced, because it would not be necessary to purchase batteries, elements that make installations of this type very expensive.

4.2.2. Off-grid system, with partial supply

According to this type of connection, the energy generated in the wind turbine would be also stored in batteries for later use, but in this case, it would only supply a part of the energy of the location to which the wind turbine provides energy, e.g. lighting system, telecommunication system, etc.

Like the alternative described above, in a location where access to the grid would be possible, in order to save on the purchase of batteries, alternatives of this type would be discarded.

4.2.3. On-grid system, with direct energy injection

According to this type of connection, the energy generated in the wind turbine would be fed directly into the grid and the user would be able to sell this energy.

This is a viable option, although not optimal in the case where the user has to buy back a certain amount of energy for its own supply.

4.2.4. On-grid system, with partial power supply

According to this type of connection, the energy generated in the wind turbine would be directly consumed by the user, and in case of insufficient energy, the user would purchase the rest of the energy needed from the grid. In the same way, and conversely, if at any time the energy generated by the wind turbine were greater than that consumed by the user, this energy could be injected into the grid and thus the user could sell it and obtain an economic benefit. Nowadays, this is possible thanks to the development of smart grids, which allow the free circulation of energy in any direction, and not only from the large generation plants to the points of consumption.

4.3. According to the type of technology used

In this section, we focus on the types of small wind turbines currently available on the market. The following table provides a comparative analysis of these types:

Table 2. Types of wind turbines. Advantages and disadvantages

Vertical axis wind turbines (VAWT)	
Advantages	**Disadvantages**
✓ No braking mechanisms are required ✓ They can be located closer to the ground, so it is easier to maintain moving parts. ✓ VAWTs have lower starting wind speeds than HAWTs. ✓ VAWTs can be built in locations where taller structures are prohibited. ✓ VAWTs located close to the ground can take advantage of places where roofs, hills, ridges, and passes channel the wind and increase wind speed.	× Most VAWTs have a lower average efficiency than a common HAWT, mainly due to the additional friction their blades have when rotating in the wind. × They have rotors located close to the ground, where wind speeds are lower and do not take advantage of the higher wind speeds higher up. × In the event of a breakdown, the entire shaft must be disassembled for repair.
Horizontal axis wind turbines (HAWT)	
Advantages	**Disadvantages**
✓ High towers allow access to strong winds at sites with wind shear. ✓ They are highly efficient, as the blades always move perpendicular to the wind, receiving energy throughout the rotation. ✓ In the event of a breakdown, the blades do not have to be dismantled for repair.	× Tower construction is required to support the heavy blades, gearbox, and generator. × Their height makes them visible across large areas, which alters the appearance of the landscape and sometimes generates local opposition. × HAWTs require an additional control mechanism to turn the blades into the wind. × HAWTs generally require a braking device in high winds to stop the turbine.

In this case, either technology is valid for the study presented in this document, as both types of wind turbines comply with the current wind energy legislation and regulations in the area. Therefore, both types of wind turbines will be included in the study.

4.4. Location analysis

The urban layout of a city would only contemplate the construction of wind turbines on top of buildings, on hills on the outskirts of the city, close to consumption areas, or in parks. The latter option would be completely out of the question, as there would be a great deal of opposition from society.

4.4.1. On top of the buildings

If there is enough space on the roof, this would be a completely viable option. However, it would be important to carry out a structural study of the building, in order to check that the structure can support the weight of the wind turbines. For this reason, it is advisable to reserve this alternative for smaller wind turbines, which consequently produce less energy.

4.4.2. On hills on the outskirts of the city

These are areas of the city which, due to the roughness of the terrain, are not intended for any use, but which could be used for the construction of wind turbines, as they do not require a large amount of foundation work for their construction.

However, it must be ensured that the consumption areas are sufficiently close to the wind turbines so that no power losses occur in the transmission lines. In the case of Bilbao, the existence of these areas is abundant, as it is a city surrounded by mountains, and in some areas there are even residences on the mountains' edge.

The illustration 27 shows the specific case of a small hill where the construction of wind turbines would be perfectly possible, and that its proximity to buildings is absolute.

Figure 27. Picture of a possible location of the wind turbines. [Source: [43]]

5. Simulations and discussion

This chapter shows the calculations made to determine the energy produced by each of the wind turbines used as an example for the study.

In Figure 28, the block diagram of the system is detailed.

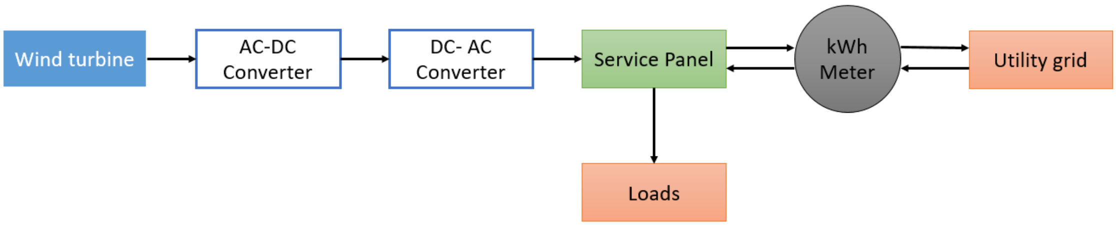


Figure 28. Block diagram for grid interface with wind turbine source

Firstly, the energy that would have been produced based on the daily wind speed data for each month of the year 2020 was calculated manually using the Matlab computer tool.

These results were then compared with those obtained in the simulations carried out in the Homer Pro programme.

For the study, the following set of wind turbines has been taken as reference:

Table 3. Case study wind turbines

Company	Model	Configuration	Nominal power [W]	Nominal voltage [V]	Maximum power [W]	Nominal wind speed [m/s]	Start-up/Cut-in wind speed [m/s]
Automaxx	400 Watts Wind Turbine	Horizontal	400	15		12,5	3
Automaxx	600 Watts Wind Turbine	Horizontal	600	12/24		12,5	2
Automaxx	1500 Watt Wind Turbine	Horizontal	1500	24/48		14	2,5
Bornay	Wind 13+	Horizontal	1000	12/24/48	1500	12	3
Fortis	Passaat 1.4kW wind turbine	Horizontal	900	24	1400	16	2,5

Hi-VAWT	DS700	Vertical	700			12	3
Hi-VAWT	DS1500	Vertical	1500			12	3
Superwind	Superwind 1250	Horizontal	1250	24/48		11,5	3,5

5.1. Power obtained in 2020

This section shows the calculations obtained manually with the tool Matlab of the average power and energy produced in each month, based on the daily wind data recorded each month of the year 2020.

The average generator power can be calculated as:

$$P_{WG_{avg}} = \int_0^\infty Powerdensity\ (v)dv = \int_0^\infty f(v) * P_{WG}\,(v)\ dv \quad (9)$$

Where f(v) is the Weibull function approximated to the wind speed data obtained from each month and P_{WG} is the power curve equation of each wind turbine model under study.

The power curve equation for each wind turbine is obtained from the power-wind speed curve provided by each manufacturer. With this curve, and by using Matlab, the equations of the power curves of all the wind turbines can be obtained, which are detailed in annex 1.

The next step is to calculate the parameters of the Weibull equation for the available wind speed data. This equation has the following form:

$$f(v) = a * b * v^{b-1} * e^{-a*v^b} \quad (10)$$

Where a and b are the coefficients and given in the annexes.

To obtain the Weibull approximation, the first step is to plot the density function curve. This curve can be approximated to a curve of the form of the Weibull curve and thus obtain the parameters of the Weibull equation. This step will be performed for each month for which wind speed data are available, obtaining a Weibull curve, and its respective equation and parameters. The results are shown in annex 2.

Once f(v) and P_{WG} are obtained, the power density curve can be calculated, and the average generator power, according to [9]. And, finally, the energy can be calculated as:

$$Energy = P_{WG_{avg}} * Hours \quad (11)$$

The value of the number of hours that has been introduced in each month follows the criteria of the following table:

Table 4. Hours of each month

Month	Number of days	Number of hours = Number of days*24
January	31	744
February	28	672
March	31	744
April	30	720
May	31	744
June	30	720
July	31	744
August	31	744
September	30	720
October	31	744
November	30	720
December	31	744

The power and energy generated for each month and for each wind turbine can be checked in the annex 3.

5.2. Energy produced according to wind forecast vs. energy produced according to real wind speed

As electricity is currently not a storable resource, it is necessary to forecast the amount of energy that can be produced on a daily basis. To this end, a comparative study has been carried out on the energy that would have been produced if the wind speed forecasts for May 2021 had been met, compared to the wind speeds that actually occurred.

For this purpose, hourly forecasts of wind speeds for the month of May 2021 were recorded from three different sources. This data is included in annex 4.

In the same way, the data of the speeds that have actually occurred, collected from the NASA data source, have been used to carry out the comparative study.

Table 5. Energy produced. Wind forecast vs. real data

Company	Model	Energy produced [kWh]			
		Source: AEMET	Source: The Weather Channel	Source: eltiempo.es	Source: NASA (Real wind data)
Automaxx	400 Watts Wind Turbine	7,571	18,019	16,242	41,558
Automaxx	600 Watts Wind Turbine (12V)	11,419	19,788	19,203	37,880
Automaxx	600 Watts Wind Turbine (24V)	12,231	19,867	19,609	36,216
Automaxx	1500 Watt Wind Turbine	22,305	37,708	36,882	69,347
Bornay	Wind 13+	12,339	27,608	25,464	61,399
Fortis	Passaat 1.4kW wind turbine	5,922	15,264	13,326	35,822
Hi-VAWT	DS700	4,911	11,537	10,455	26,259
Hi-VAWT	DS1500	6,441	15,673	13,941	35,897

Superwind	Superwind 1250	3,289	10,712	8,735	26,861

The results obtained show a clear increase in the energy produced if the actual wind speed data is taken into account, compared to the weather forecasts. Furthermore, depending on the source from which the wind speed forecasts are obtained, certain differences can also be detected. This will always depend on the area in which the field measurements are made or how accurate the forecasts themselves are.

We can conclude, therefore, that with respect to daily forecasts, and for the purpose of predicting daily production, we can make calculations with a certain margin.

In Figure 29, we can appreciate more visually the difference between the results obtained.

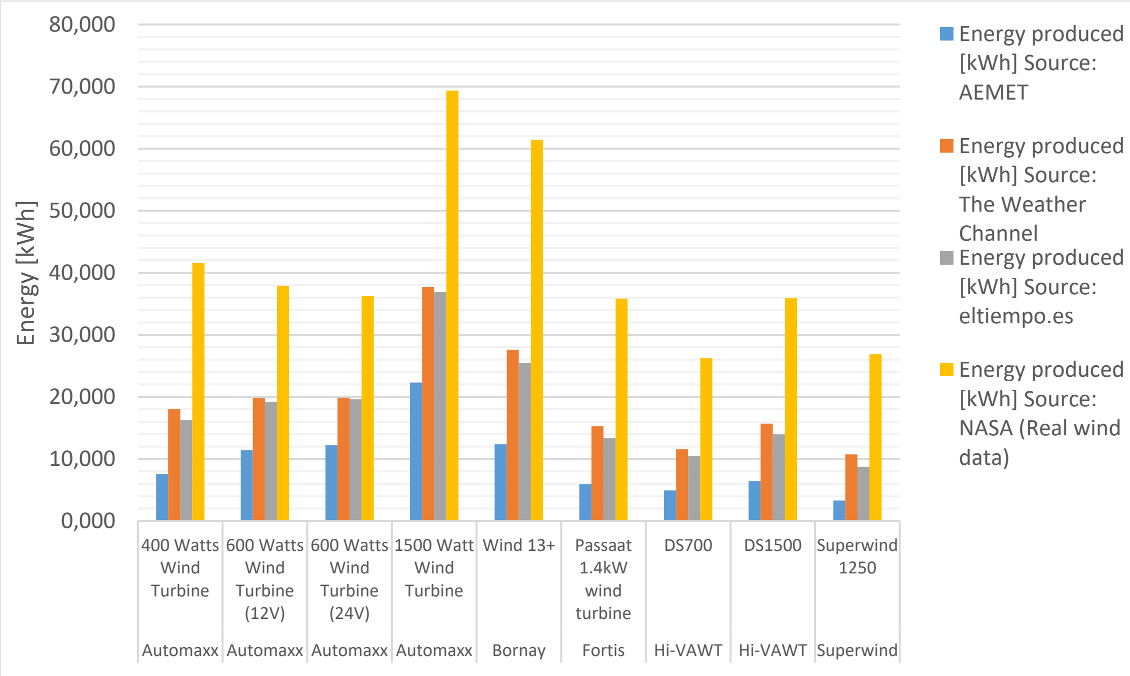


Figure 29. Energy produced. Wind forecast vs. real data

5.3. Simulation in Homer Pro

The results obtained in the previous section are based on average wind speed data for each day of each month. These results suffer a deviation, since taking the average speed to calculate the energy generated each month implies that each wind turbine is generating the same energy at all times of the day, when this is not the case, since during the day the wind is greater than in the night, and for this reason, the energy generated is also greater. However, the power curves of generators are not linear, that is, wind turbines will produce much more energy for a higher wind for a shorter time, than if a smaller and constant wind blows, but for a longer period of time.

Consider, for example, one of the wind turbines under study, where the power-wind speed curve is as shown below:

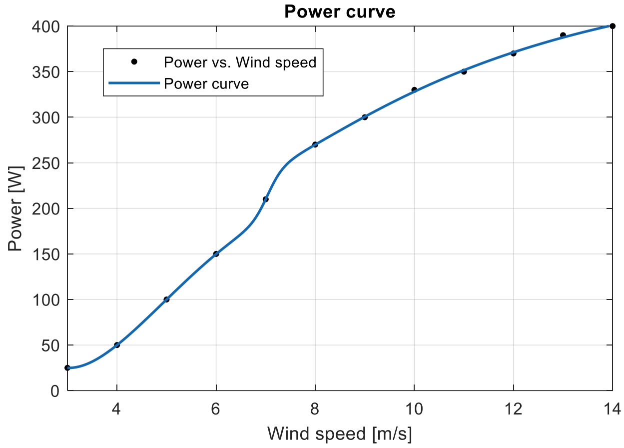


Figure 30. Power curve of Automaxx 400W wind turbine

According to this, if we assume that only a wind of 9 [m/s] blows for 4 hours of the day, with no wind the rest of the day, the energy produced would be:

$$Energy = 300 * 4 = 1.2\ [kWh] \qquad (12)$$

On this day, the average wind speed would be 1.5 [m/s] and according to the wind turbine power curve, the energy produced would be zero, as the wind turbine would not even reach the cut-in wind speed.

Therefore, the results obtained in the simulation in the Homer Pro software are more reliable, as the data used to carry out the simulations are hourly, not daily averages.

In the simulation, it was only necessary to enter the average wind speed data from the NASA source in Homer Pro, as the software itself has a standard model that allows it to know the time periods in which the highest wind speeds occur.

Table 6. Energy produced. Manual results vs. results in Homer Pro

Company	Model	Energy produced [kWh] (manual calculations)	Energy produced [kWh] Homer Pro
Automaxx	400 Watts Wind Turbine	768.9	1026
Automaxx	600 Watts Wind Turbine (12V)	610.3	1006
Automaxx	600 Watts Wind Turbine (24V)	538.9	889
Automaxx	1500 Watt Wind Turbine	1250.4	1391
Bornay	Wind 13+	1198.4	1912
Fortis	Passaat 1.4kW wind turbine	895.8	1598
Hi-VAWT	DS700	584.8	1000

Hi-VAWT	DS1500	862.7	1852
Superwind	Superwind 1250	873.6	1568

In these results, it can be seen that, taking into consideration the hourly wind speed data, the energy produced is greater.

It should also be taken into account that wind data are not constant every year, they fluctuate. This means that this deviation also has to be taken into consideration for the final conclusion. In the manual calculations only the wind data from the year 2020 has been entered, while Homer Pro has the option to calculate the energy produced with wind data from the year 1984 (Source: NASA). The following graph shows the average wind speeds in Homer Pro, compared to which were introduced manually.

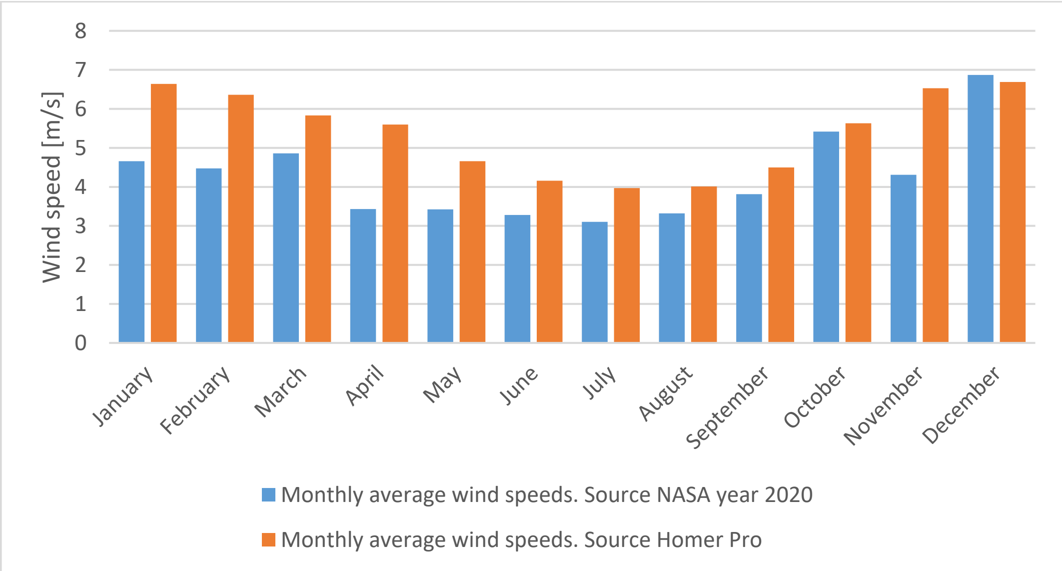


Figure 31. Energy produced. Graphical representation of manual results vs. results in Homer Pro.

If we consider the new wind speed data, the energy produced is, compared to what we calculated first:

Table 7 Energy produced. Manual results vs. results in Homer Pro vs. results in Homer Pro (Data from 1984-2013).

Company	Model	Energy produced [kWh] (manual calculations)	Energy produced [kWh] Homer Pro	Energy produced [kWh] Homer Pro Wind speed 1984-2013
Automaxx	400 Watts Wind Turbine	768.9	1026	1407
Automaxx	600 Watts Wind Turbine (12V)	610.3	1006	2142
Automaxx	600 Watts Wind Turbine (24V)	538.9	889	1320
Automaxx	1500 Watt Wind Turbine	1250.4	1391	2575

Bornay	Wind 13+	1198.4	1912	2922
Fortis	Passaat 1.4kW wind turbine	895.8	1598	2994
Hi-VAWT	DS700	584.8	1000	1808
Hi-VAWT	DS1500	862.7	1852	3357
Superwind	Superwind 1250	873.6	1568	2968

As can be appreciated, the difference between using many wind data, and using less, has a remarkable consequence on the results. In some cases, the difference between the energy produced can be up to three times higher. This is also because the default wind speed data used by Homer Pro is at 50m, while that used for manual calculations is at 10m. It is therefore perfectly understandable that the energy obtained is much higher, as the wind speed increases considerably with height.

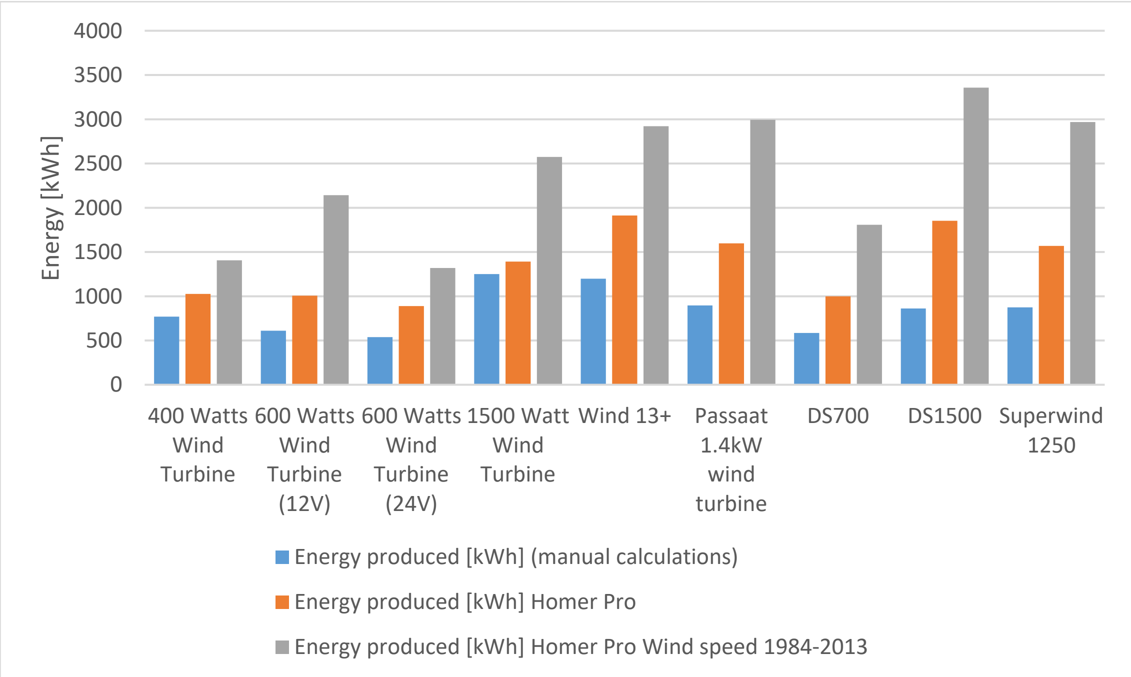


Figure 32. Energy produced. Graphical representation of manual results vs. results in Homer Pro vs. results in Homer Pro (Data from 1984-2013)

6. Profitability study

As described above, the results obtained in the simulation are the most reliable and, therefore, the profitability analysis has been carried out based on these results.

The aim of this project is to demonstrate the profitability of integrating small wind turbines in urban environments. For this reason, the profitability of each of the wind turbines taken as the basis for this study has been analysed by performing the calculations in the Homer Pro tool.

Firstly, the costs of each wind turbine, including the cost of all necessary components, are shown below.

In all cases, it has been taken into account that the required components are based on an on-grid system, and not on a stand-alone battery supply system.

Table 8. Price of the wind turbines used in the study

Company	Model	Costs [€]
Automaxx	400 Watts Wind Turbine	315
Automaxx	600 Watts Wind Turbine (12V)	450
Automaxx	600 Watts Wind Turbine (24V)	450
Automaxx	1500 Watt Wind Turbine	1232.62
Bornay	Wind 13+	3249.78
Fortis	Passaat 1.4kW wind turbine	3979.5
Hi-VAWT	DS700	1099.90
Hi-VAWT	DS1500	1485.09
Superwind	Superwind 1250	4739.50

According to manufacturers, during their lifetime, those wind turbines do not require any type of maintenance, so there will not be expenses of this kind.

The lifetime of wind turbines is estimated to be 25 years. In this interval, the time it would take to recover the investment made for the purchase of the wind turbine will be calculated.

The following aspects will be taken into account for the calculations:

- The average consumption of a house in Bilbao will be taken as a starting point. For this purpose, consumption data and electricity prices and other rates, such as the contracted power rate, have been acquired.
- Priority will be given to energy from the wind turbine to be consumed in the house. If there is not enough energy available, it will be purchased from the grid at the appropriate purchase price. Similarly, if there is any excess energy from the wind turbine, it will be sold to the grid at the appropriate selling price. This is known as “Net Metering”.

- Homer Pro has a standard profile of daily residential consumption. These profiles will be used to calculate the energy consumed, and will be scaled according to the average daily energy consumed in a house at the location.
- All calculations on energy consumption, as well as the sale and purchase of energy from the grid, will be made on the basis of the data obtained in Homer Pro. These data are detailed in annex 9.

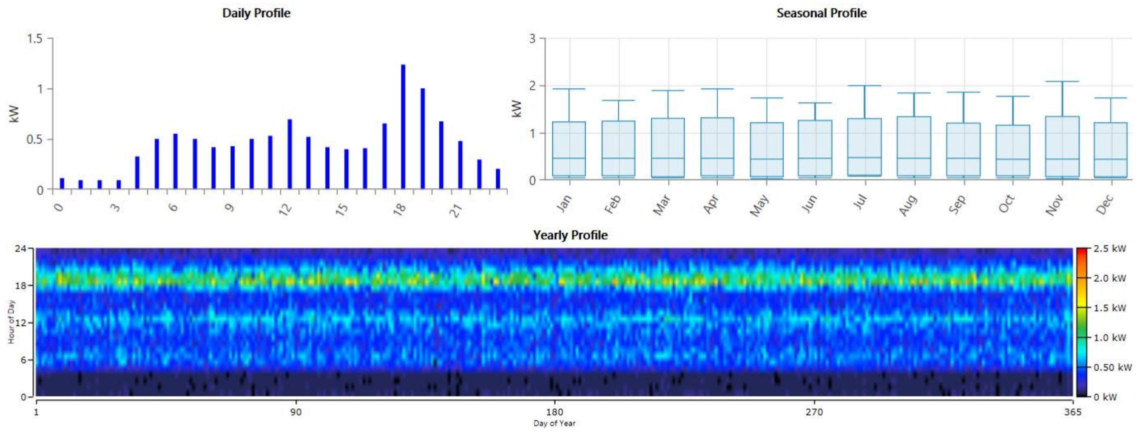


Figure 33. Standard profile of residential energy consumption

As mentioned above, the data entered in Homer Pro are as follows:

Table 9. Hourly daily market price. Source tarifaluzhora.es

Hourly daily market price. Source tarifaluzhora.es	
Hour	**Price [€/kWh]**
0:00	0,11
1:00	0,106
2:00	0,103
3:00	0,104
4:00	0,105
5:00	0,108
6:00	0,112
7:00	0,113
8:00	0,149
9:00	0,142
10:00	0,233
11:00	0,232
12:00	0,232
13:00	0,23
14:00	0,133
15:00	0,124
16:00	0,123
17:00	0,127
18:00	0,226
19:00	0,235
20:00	0,237

21:00	0,242
22:00	0,15
23:00	0,147

Table 10. Demand rate

Demand rate	
Base	Unitary price €/kW/day
3,45 kW	0,1039

Table 11. Sellback rate (Net Metering. Source OMIE)

Sellback rate (Net Metering. Source OMIE)	
Month	Price [€/kWh]
1	0,041
2	0,036
3	0,027
4	0,018
5	0,021
6	0,031
7	0,035
8	0,036
9	0,042
10	0,037
11	0,042
12	0,042

Table 12. Electricity consumption of a household

Month	Consumption [kWh]	Daily consumption [kWh]
1	243	7,839
2	211	7,536
3	181	5,839
4	166	5,533
5	183	5,903
6	193	6,433
7	212	6,839
8	115	3,710
9	198	6,600
10	162	5,226
11	172	5,733
12	249	8,032

With all these data, the results obtained for a cycle of 25 years obtained are shown in Table 12:

Table 13. Results of the profitability obtained for a 25-year cycle.

Company	Model	Rated power [W]	Net present cost with a wind turbine [€]	Net present cost without a wind turbine [€]	Savings in 25 years [€]	Payback time [years]
Automaxx	400 Watts Wind Turbine	400	3169	5798	2629	1,4
Automaxx	600 Watts Wind Turbine (12V)	600	2287	5798	3511	1,5
Automaxx	600 Watts Wind Turbine (24V)	600	3457	5798	2341	2,1
Automaxx	1500 Watt Wind Turbine	1500	2433	5798	3365	3,5
Bornay	Wind 13+	1000	4019	5798	1779	8,4
Fortis	Passaat 1.4kW wind turbine	1400	4527	5798	1271	9,8
Hi-VAWT	DS700	700	3324	5798	2474	4
Hi-VAWT	DS1500	1500	2041	5798	3757	3,7
Superwind	Superwind 1250	1250	5640	5798	158	13

In the case of the wind turbines chosen for the study, a clear profitability can be observed, although in some of them it is very tight, due to the high price of these particular wind turbines.

We can observe that the lower power wind turbines have better profitability indicators. This favours our study, since lower power means smaller size, and for the placement of wind turbines in urban environments, it is more likely that the smaller the size of the wind turbines, the greater the social approval.

It is also worth noting that in cases where more energy is sold to the grid, profitability decreases. A solution to this would be to make the systems autonomous, although this would involve an increase in the initial investment due to the necessary purchase of batteries. For this reason, in any case it is advisable that the wind turbine produces the amount of energy that is calculated to be consumed by the consumer.

7. Conclusion

The conclusions reached after carrying out this work are as follows:

- The evidence of the profitability of carrying out projects for energy generation facilities from renewable sources is clear. This project shows how, in spite of the possible high initial investment required to carry out this type of project, the amortisation of these projects is sometimes achieved in a very short period of time, given the savings in electricity consumption that they entail. Furthermore, this initial investment is increasingly being reduced, as the advance of technologies in this field is making it possible for equipment costs to fall considerably.
- According to the latest reports from Red Eléctrica de España, the average CO2 emission factor in the period 2009-2018 in Spain is 0.267 tCO2/MWh per year. The energy we avoid consuming from the power grid thanks to the energy produced by means of renewable energy sources means a considerable reduction in annual CO2 emissions, so we contribute very favourably to the fight against climate change caused mainly by excess emissions of this compound.
- The wind turbines on which the cost-effectiveness values have been calculated are mostly of European manufacture. However, there is a large Asian market which is highly competitive with the European market. If this study had been carried out with Chinese wind turbines, the profitability values would have been even higher. This, in part, is beneficial in demonstrating our hypothesis: The feasibility of small wind turbines in urban environments. However, it also implies that progress is needed in the European wind energy sector in the field of small wind turbines in order for it to once again become a serious competitor to the Asian one.
- Although the viability of small wind turbines has been demonstrated, projects of this type continue to face a serious obstacle, as is also the case with large wind farms: public opposition due to the acoustic or visual impact they may generate.

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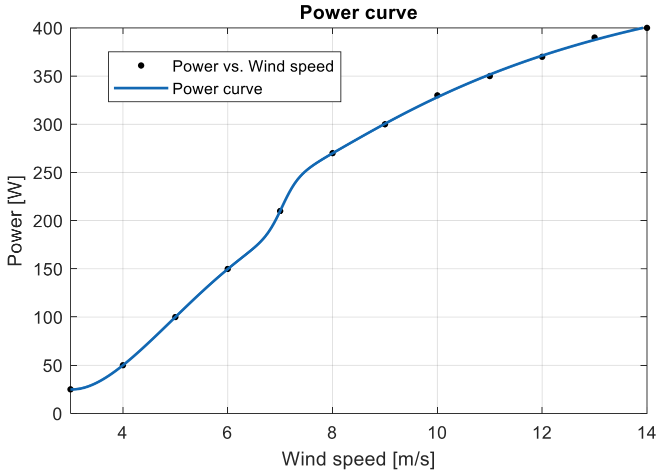
Annex 1 – Power curves and equations for each wind turbine

Automaxx 400W wind turbine

Power [W]	Wind Speed [m/s]
25	3
50	4
100	5
150	6
210	7
270	8
300	9
330	10
350	11
370	12
390	13
400	14



$$f(x) = \frac{p_1 * x^5 + p_2 * x^4 + p_3 * x^3 + p_4 * x^2 + p_5 * x + p_6}{x^4 + q_1 * x^3 + q_2 * x^2 + q_3 * x + q_4} \quad (13)$$

$$p_1 = -7.884 \quad (14)$$

$$p_2 = 929.3 \quad (15)$$

$$p_3 = -1.643 * 10^4 \quad (16)$$

$$p_4 = 1.116 * 10^5 \quad (17)$$

$$p_5 = -3.25 * 10^5 \quad (18)$$

$$p_6 = 3.491 * 10^5 \quad (19)$$

$$q_1 = -14.06 \quad (20)$$

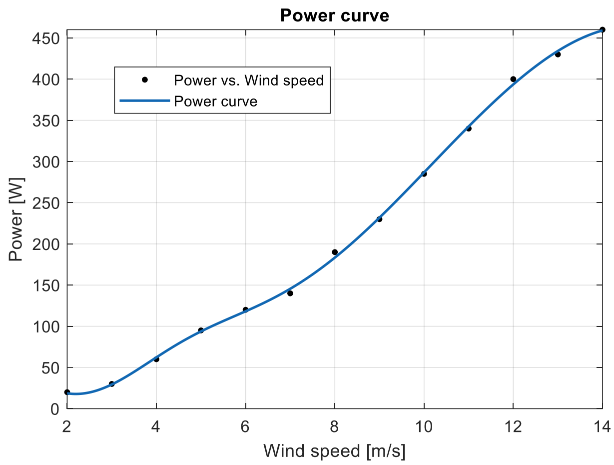
$$q_2 = 59.69 \quad (21)$$

$$q_3 = -141.1 \quad (22)$$

$$q_4 = 499 \quad (23)$$

Automaxx 600W wind turbine (12V)

Power [W] 12V	Wind Speed [m/s]
20	2
30	3
60	4
95	5
120	6
140	7
190	8
230	9
285	10
340	11
400	12
430	13
460	14



$$f(x) = \frac{p_1 * x^5 + p_2 * x^4 + p_3 * x^3 + p_4 * x^2 + p_5 * x + p_6}{x^3 + q_1 * x^2 + q_2 * x + q_3} \quad (24)$$

$$p_1 = -7005 \quad (25)$$

$$p_2 = 2.535 * 10^5 \quad (26)$$

$$p_3 = -2.994 * 10^6 \quad (27)$$

$$p_4 = 1.634 * 10^7 \quad (28)$$

$$p_5 = -3.897 * 10^7 \quad (29)$$

$$p_6 = 3.566 * 10^7 \quad (30)$$

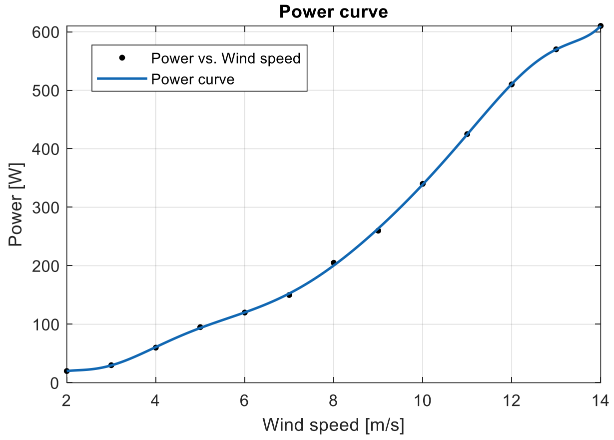
$$q_1 = 8850 \quad (31)$$

$$q_2 = -7.34 * 10^4 \quad (32)$$

$$q_3 = 2.696 * 10^5 \quad (33)$$

Automaxx 600W wind turbine (24V)

Power [W] 24V	Wind Speed [m/s]
20	2
30	3
60	4
95	5
120	6
150	7
205	8
260	9
340	10
425	11
510	12
570	13
610	14



$$f(x) = p_1 * x^9 + p_2 * x^8 + p_3 * x^7 + p_4 * x^6 + p_5 * x^5 + p_6 * x^4 + p_7 * x^3 + p_8 * x^2 + p_9 * x + p_{10} \quad (34)$$

$$p_1 = 6.102 * 10^{-5} \quad (35)$$

$$p_2 = -0.004287 \quad (36)$$

$$p_3 = 0.1291 \quad (37)$$

$$p_4 = -2.175 \quad (38)$$

$$p_5 = 22.44 \quad (39)$$

$$p_6 = -145.7 \quad (40)$$

$$p_7 = 588.5 \quad (41)$$

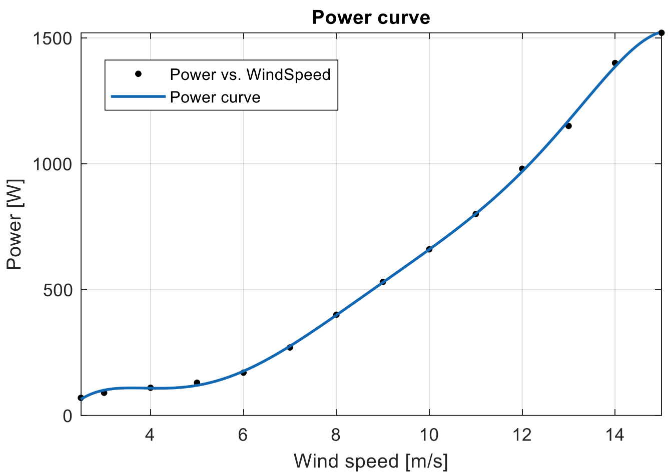
$$p_8 = -1408 \quad (42)$$

$$p_9 = 1811 \quad (43)$$

$$p_{10} = -938.7 \quad (44)$$

Automaxx 1500W wind turbine

Power [W]	Wind Speed [m/s]
70	2,5
90	3
110	4
130	5
170	6
270	7
400	8
530	9
660	10
800	11
980	12
1150	13
1400	14
1520	15



$$f(x) = p_1 * x^6 + p_2 * x^5 + p_3 * x^4 + p_4 * x^3 + p_5 * x^2 + p_6 * x + p_7 \quad (45)$$

$$p_1 = -0.01179 \quad (46)$$

$$p_2 = 0.6162 \quad (47)$$

$$p_3 = -12.76 \quad (48)$$

$$p_4 = 132.7 \quad (49)$$

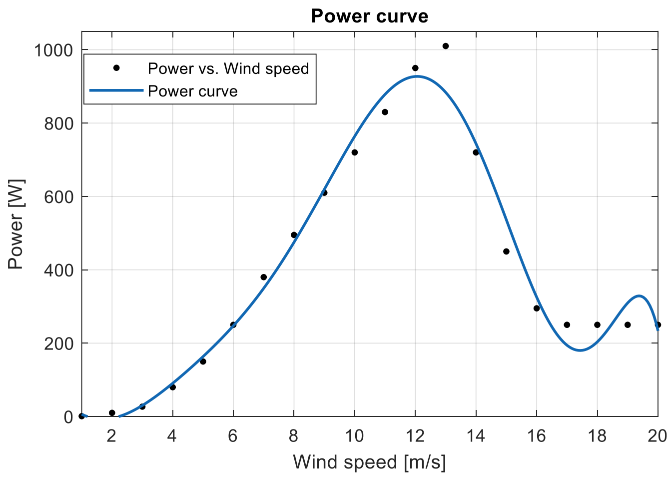
$$p_5 = -710.8 \quad (50)$$

$$p_6 = 1867 \quad (51)$$

$$p_7 = -1792 \quad (52)$$

Bornay Wind 13+ wind turbine

Power [W]	Wind Speed [m/s]
1	1
10	2
27	3
80	4
150	5
250	6
380	7
495	8
610	9
720	10
830	11
950	12
1010	13
720	14
450	15
295	16
250	17
250	18
250	19
250	20



$$f(x) = p_1 * x^8 + p_2 * x^7 + p_3 * x^6 + p_4 * x^5 + p_5 * x^4 + p_6 * x^3 + p_7 * x^2 + p_8 * x + p_9 \quad (53)$$

$$p_1 = -4.016 * 10^{-5} \quad (54)$$

$$p_2 = 0.002765 \quad (55)$$

$$p_3 = -0.07404 \quad (56)$$

$$p_4 = 0.9769 \tag{57}$$

$$p_5 = -6.649 \tag{58}$$

$$p_6 = 21.25 \tag{59}$$

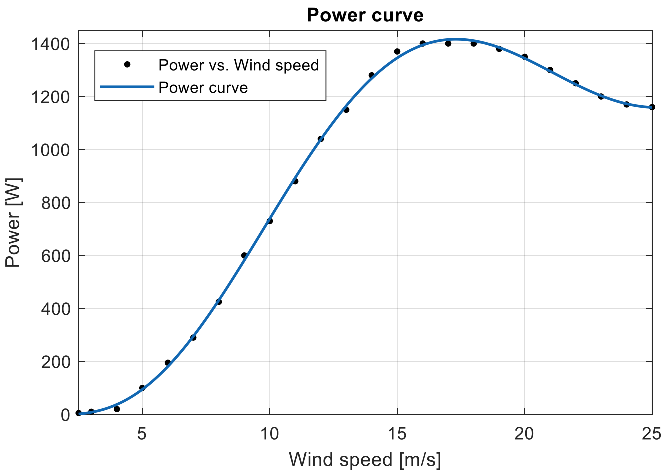
$$p_7 = -6.78 \tag{60}$$

$$p_8 = -65.12 \tag{61}$$

$$p_9 = 62.45 \tag{62}$$

Fortis Passaat 1.4kW wind turbine

Power [W]	Wind Speed [m/s]
5	2,5
10	3
20	4
100	5
195	6
290	7
425	8
600	9
730	10
880	11
1040	12
1150	13
1280	14
1370	15
1400	16
1400	17
1400	18
1380	19
1350	20
1300	21
1250	22
1200	23
1170	24
1160	25



$$f(x) = p_1 * x^6 + p_2 * x^5 + p_3 * x^4 + p_4 * x^3 + p_5 * x^2 + p_6 * x + p_7 \quad (63)$$

$$p_1 = -0.0001796 \quad (64)$$

$$p_2 = 0.01615 \quad (65)$$

$$p_3 = -0.5168 \quad (66)$$

$$p_4 = 6.685 \quad (67)$$

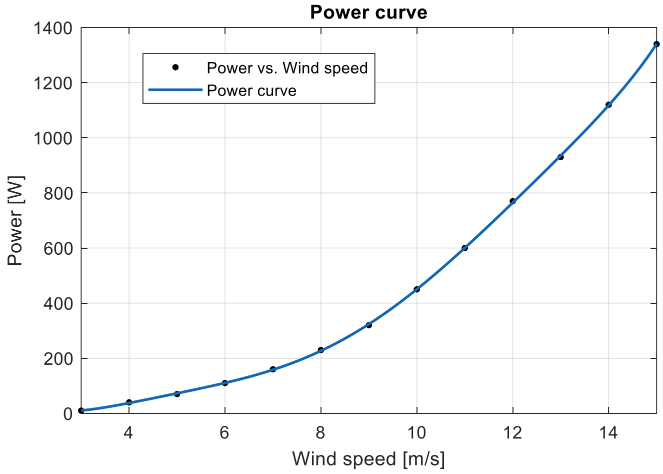
$$p_5 = -26.26 \quad (68)$$

$$p_6 = 44.34 \quad (69)$$

$$p_7 = -31.02 \quad (70)$$

Hi-VAWT DS700

Power [W]	Wind Speed [m/s]
10	3
40	4
70	5
110	6
160	7
230	8
320	9
450	10
600	11
770	12
930	13
1120	14
1340	15



$$f(x) = p_1 * x^6 + p_2 * x^5 + p_3 * x^4 + p_4 * x^3 + p_5 * x^2 + p_6 * x + p_7 \quad (71)$$

$$p_1 = 0.004429 \quad (72)$$

$$p_2 = -0.2275 \quad (73)$$

$$p_3 = 4.55 \quad (74)$$

$$p_4 = -44.57 \quad (75)$$

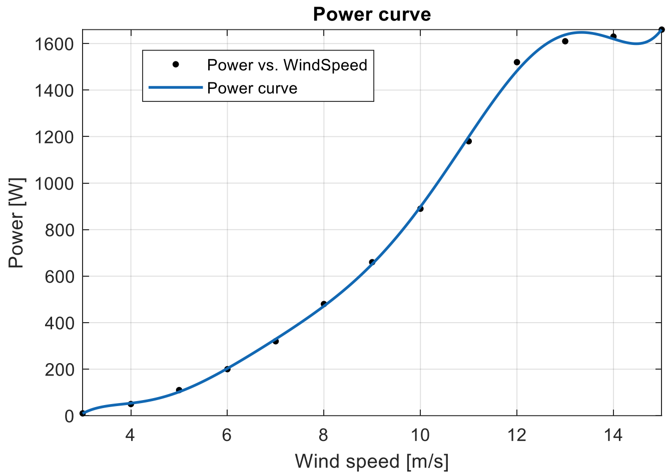
$$p_5 = 229.7 \quad (76)$$

$$p_6 = -565 \quad (77)$$

$$p_7 = 525.5 \quad (78)$$

Hi-VAWT DS1500

Power [W]	Wind Speed [m/s]
10	3
50	4
110	5
200	6
320	7
480	8
660	9
890	10
1180	11
1520	12
1610	13
1630	14
1660	15



$$f(x) = p_1 * x^7 + p_2 * x^6 + p_3 * x^5 + p_4 * x^4 + p_5 * x^3 + p_6 * x^2 + p_7 * x + p_8 \quad (79)$$

$$p_1 = 0.006103 \quad (80)$$

$$p_2 = -0.3603 \quad (81)$$

$$p_3 = 8.714 \quad (82)$$

$$p_4 = -111.8 \quad (83)$$

$$p_5 = 820.5 \quad (84)$$

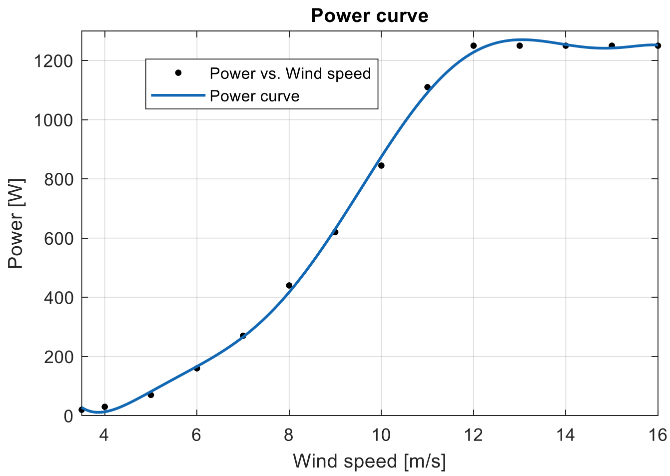
$$p_6 = -3427 \quad (85)$$

$$p_7 = 7556 \quad (86)$$

$$p_8 = -6785 \quad (87)$$

Superwind 1250 wind turbine

Power [W]	Wind Speed [m/s]
20	3,5
30	4
70	5
160	6
270	7
440	8
620	9
845	10
1110	11
1250	12
1250	13
1250	14
1250	15
1250	16



$$f(x) = p_1 * x^7 + p_2 * x^6 + p_3 * x^5 + p_4 * x^4 + p_5 * x^3 + p_6 * x^2 + p_7 * x + p_8 \quad (88)$$

$$p_1 = -0.00337 \quad (89)$$

$$p_2 = 0.2342 \quad (90)$$

$$p_3 = -6.663 \quad (91)$$

$$p_4 = 100.1 \quad (92)$$

$$p_5 = -855.4 \quad (93)$$

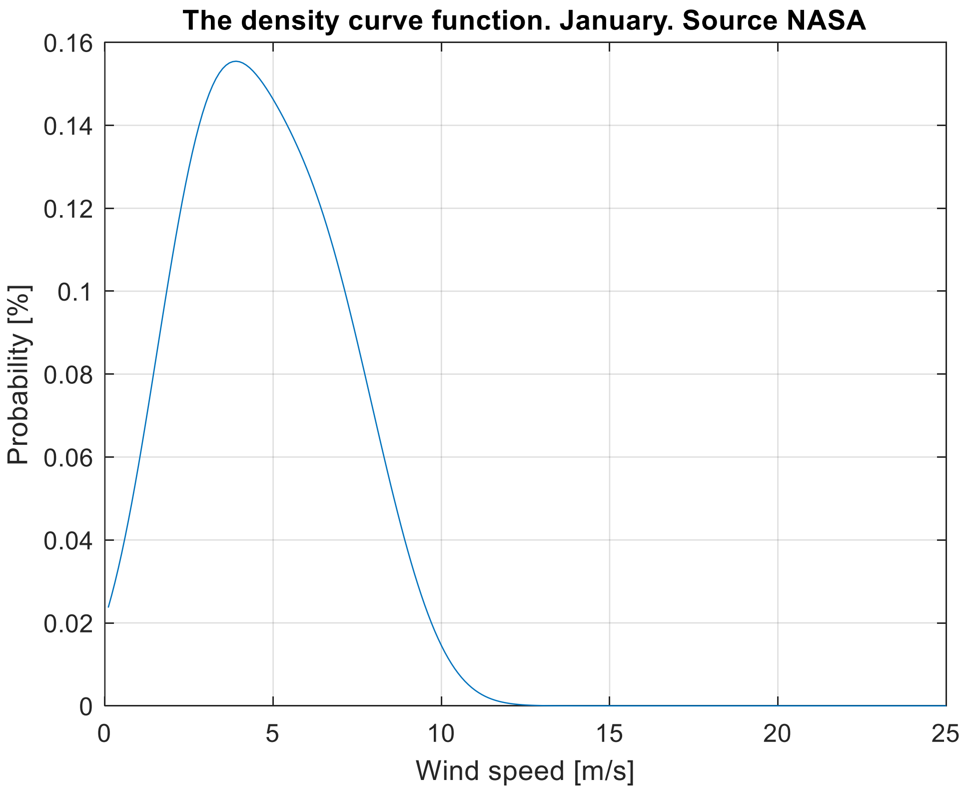
$$p_6 = 4173 \quad (94)$$

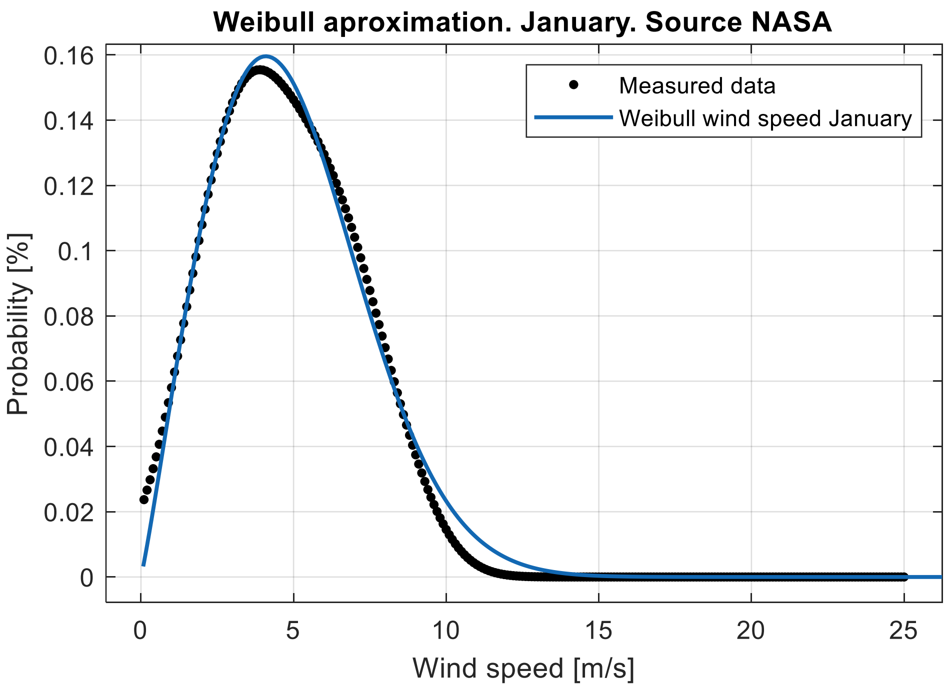
$$p_7 = -1.074 * 10^4 \quad (95)$$

$$p_8 = 1.124 * 10^4 \quad (96)$$

Annex 2 – Weibull curves and parameters for the year 2020

January

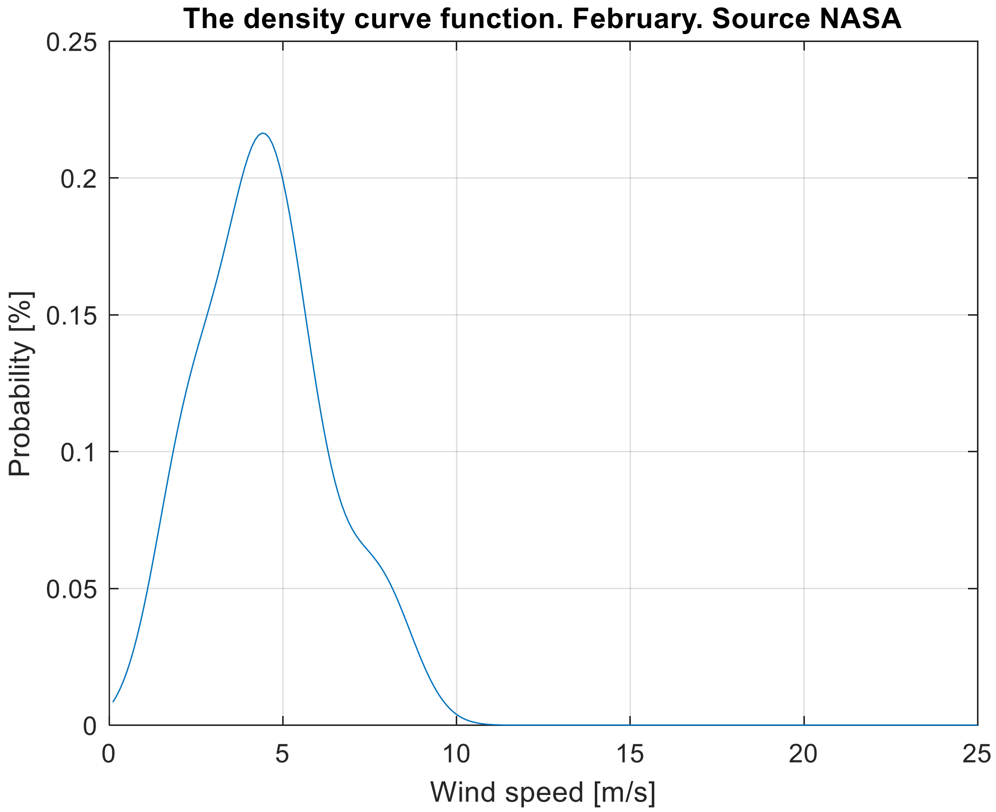


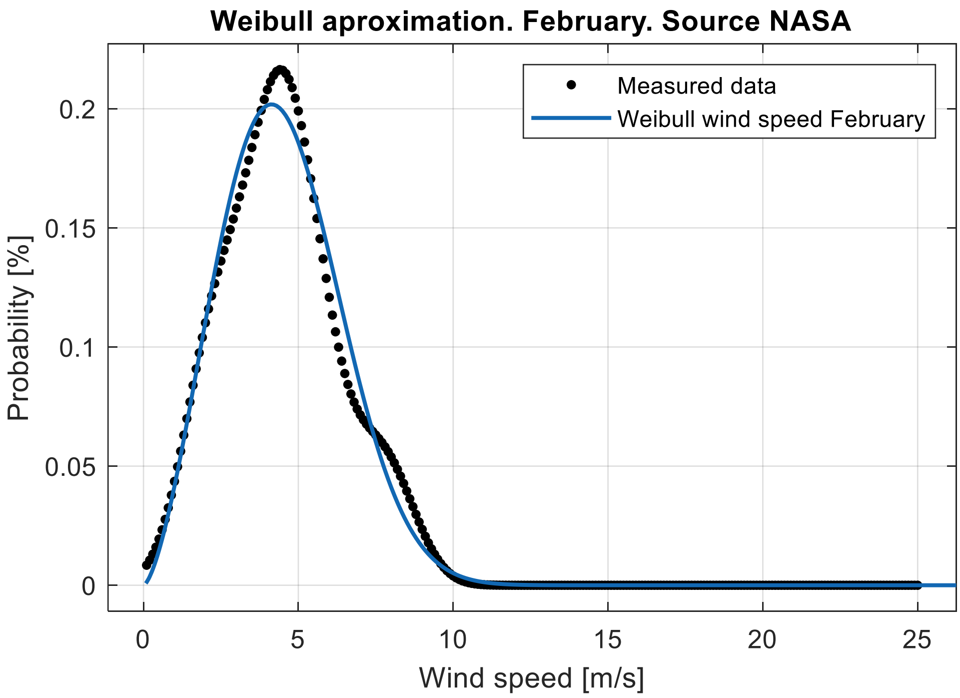


$$a = 0.02705 \tag{97}$$

$$b = 2.104 \tag{98}$$

February

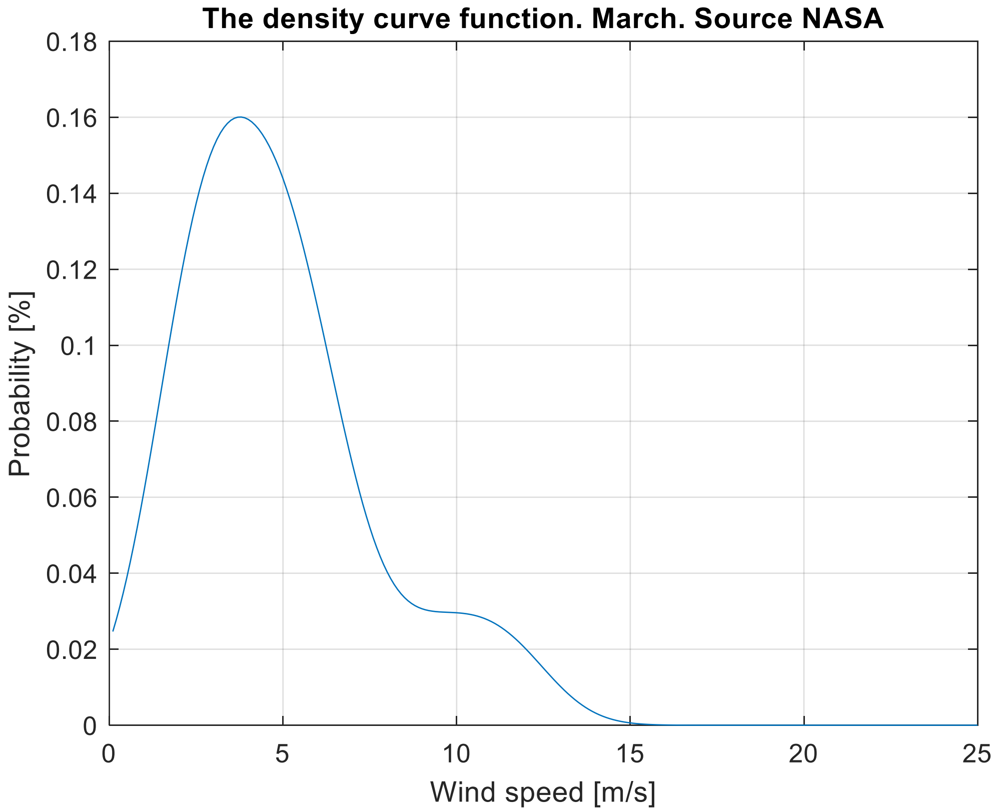


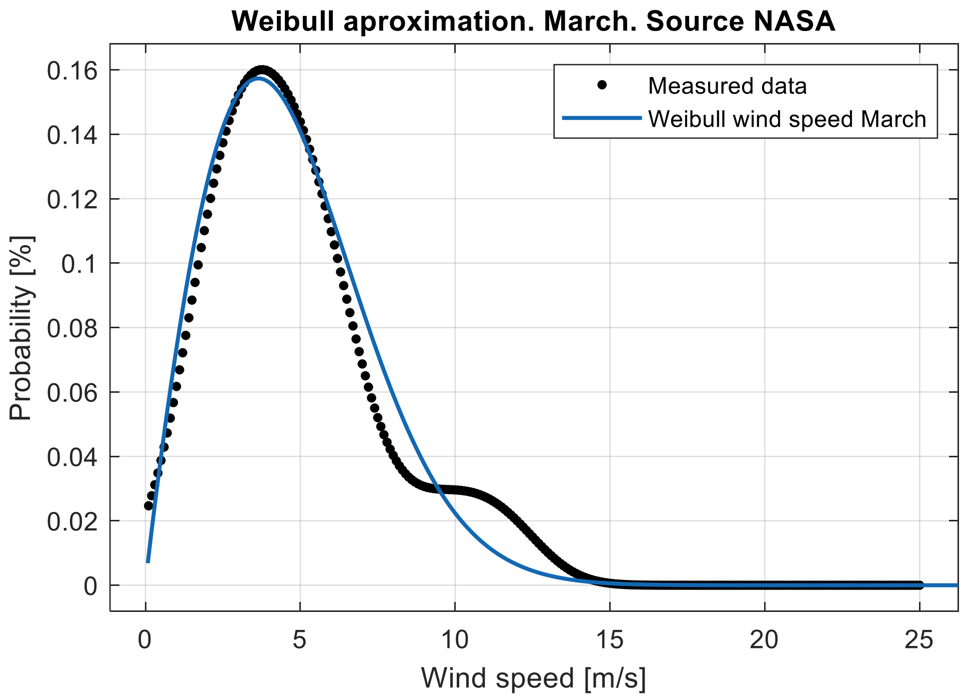


$$a = 0.01673 \tag{99}$$

$$b = 2.527 \tag{100}$$

March

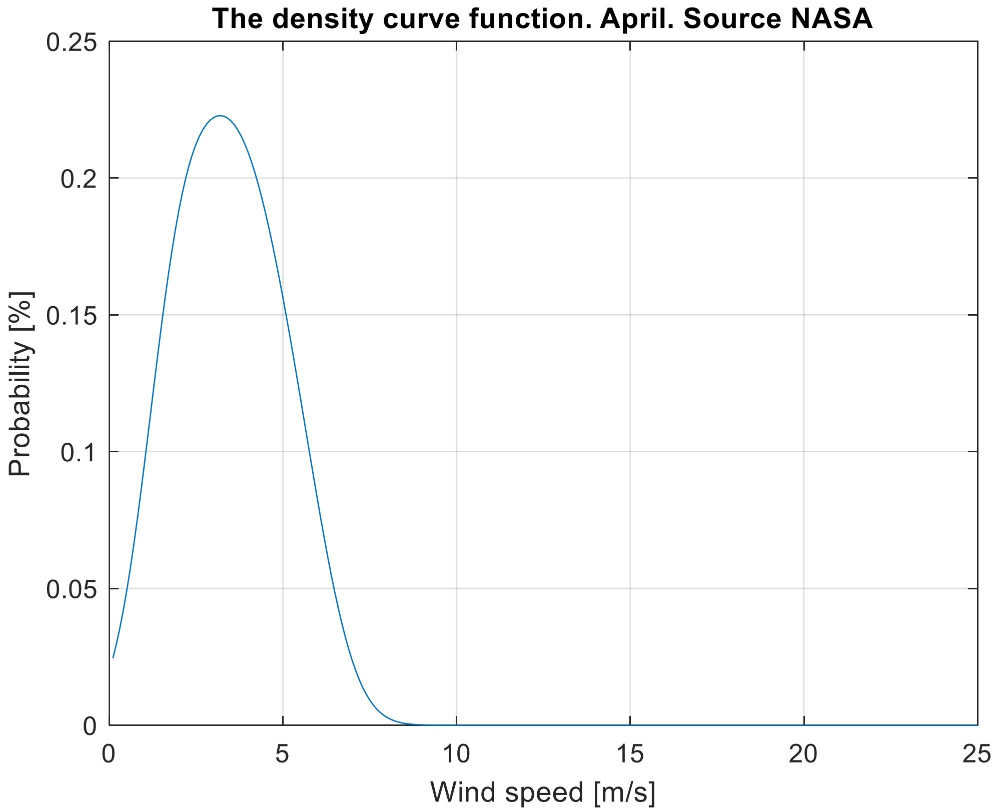


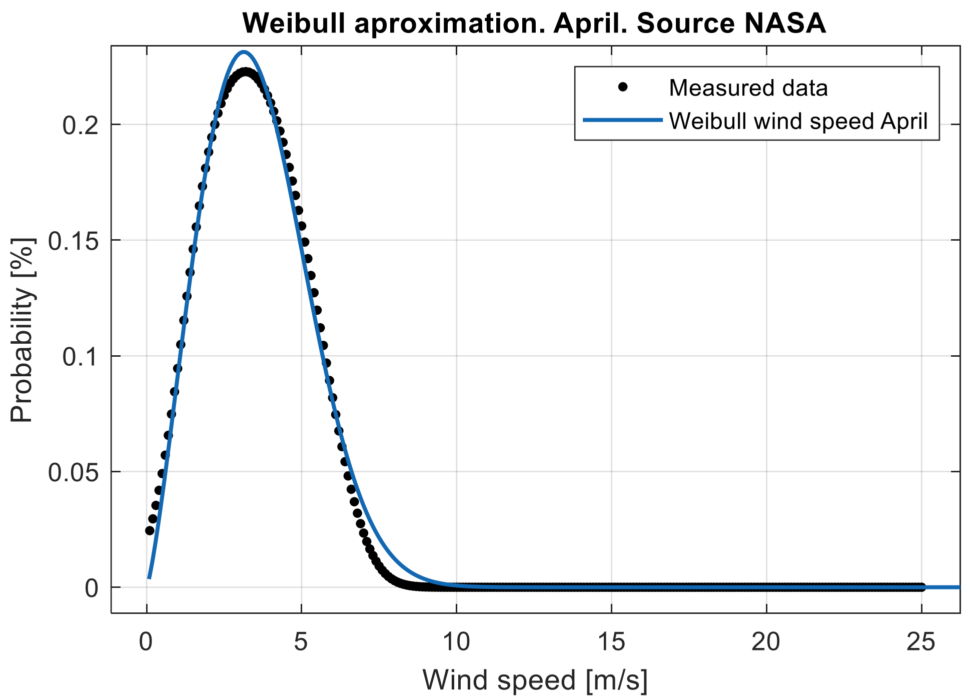


$$a = 0.03969 \quad (101)$$

$$b = 1.929 \quad (102)$$

April

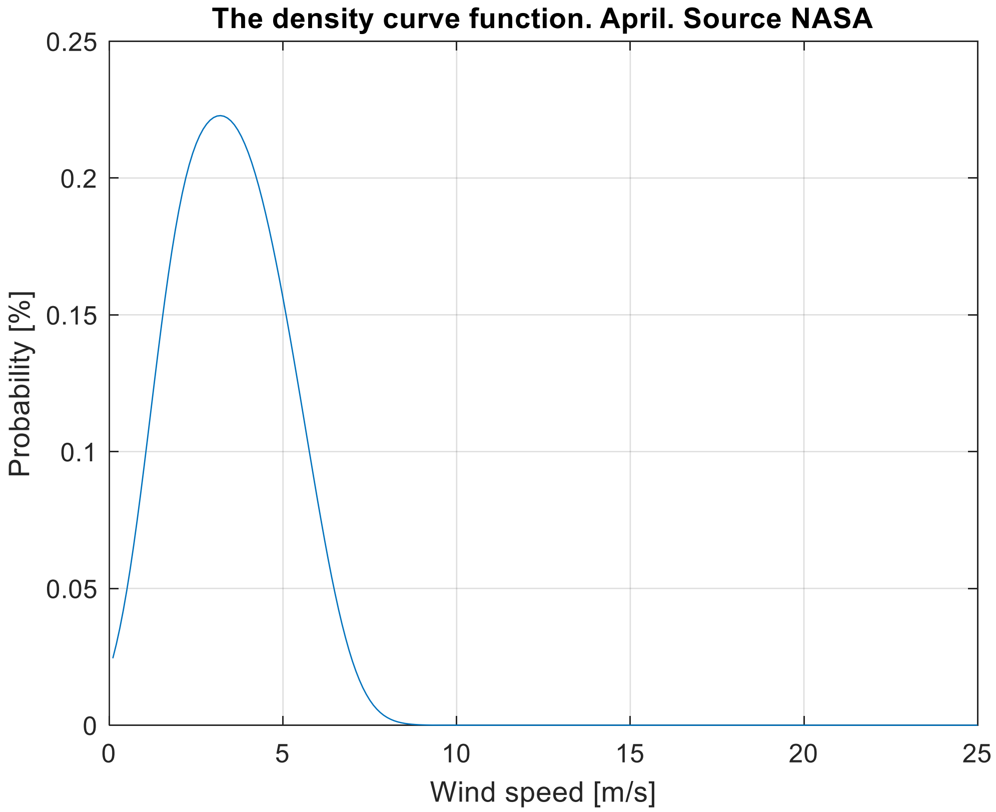


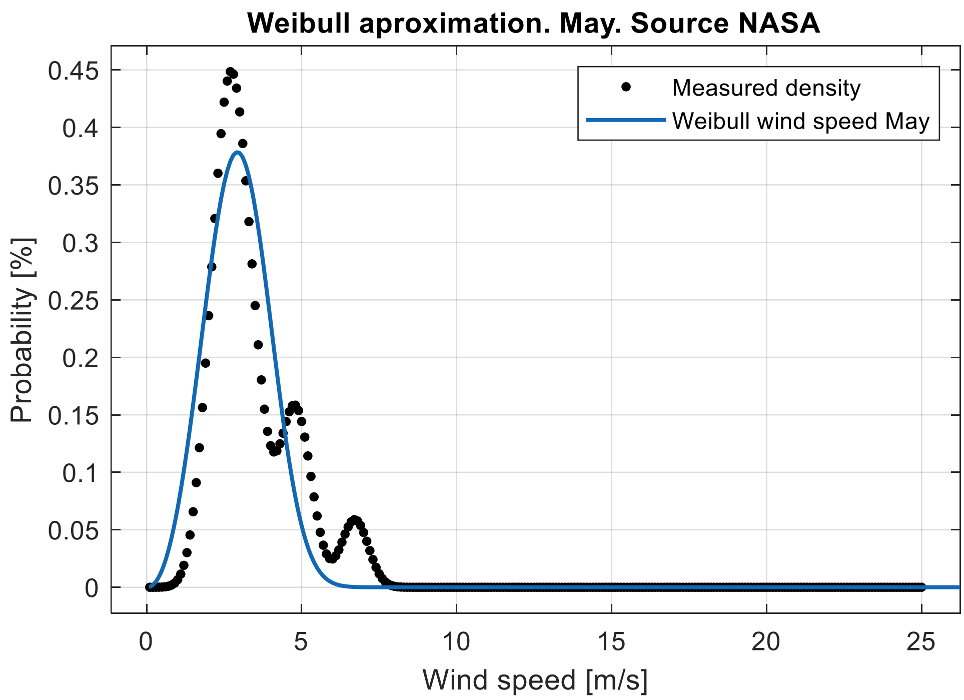


$$a = 0.04196 \tag{103}$$

$$b = 2.267 \tag{104}$$

May

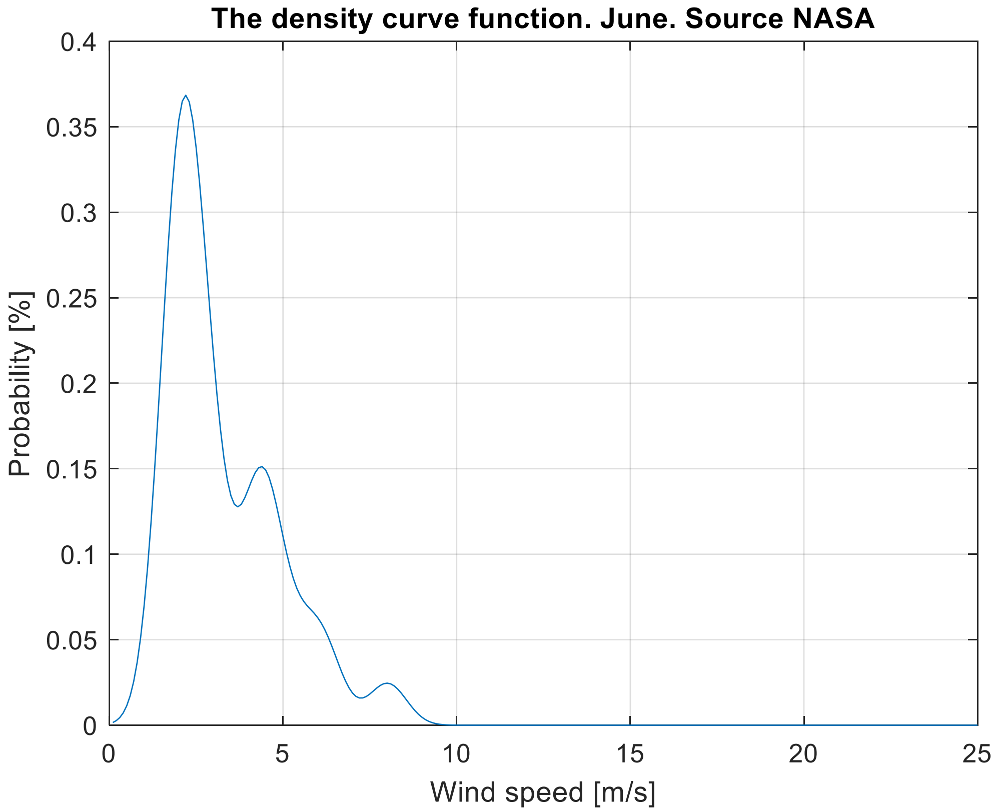


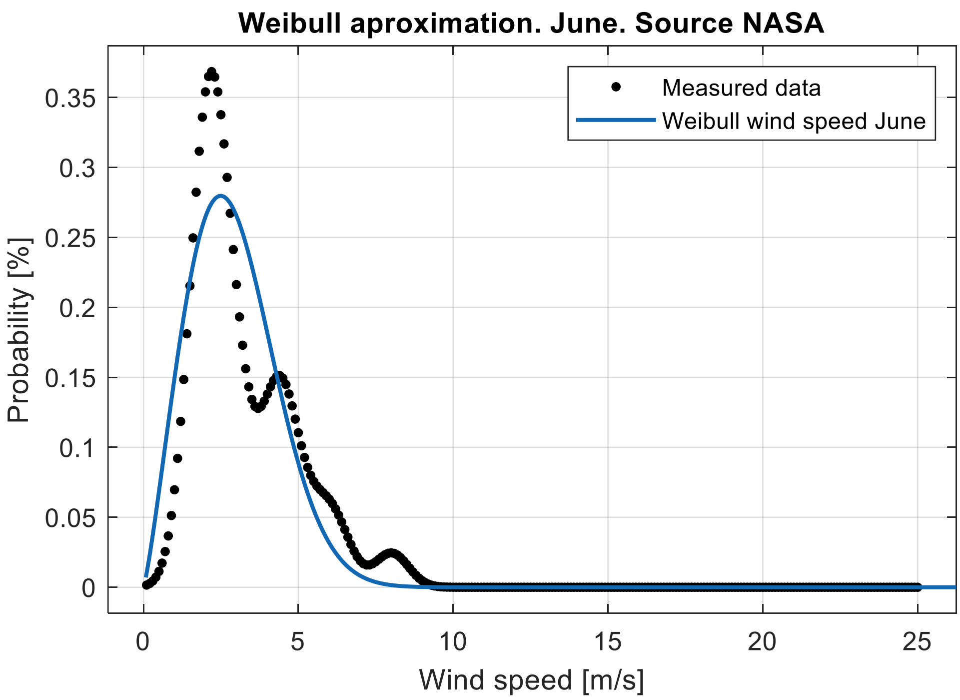


$$a = 0.02202 \tag{105}$$

$$b = 3.204 \tag{106}$$

June

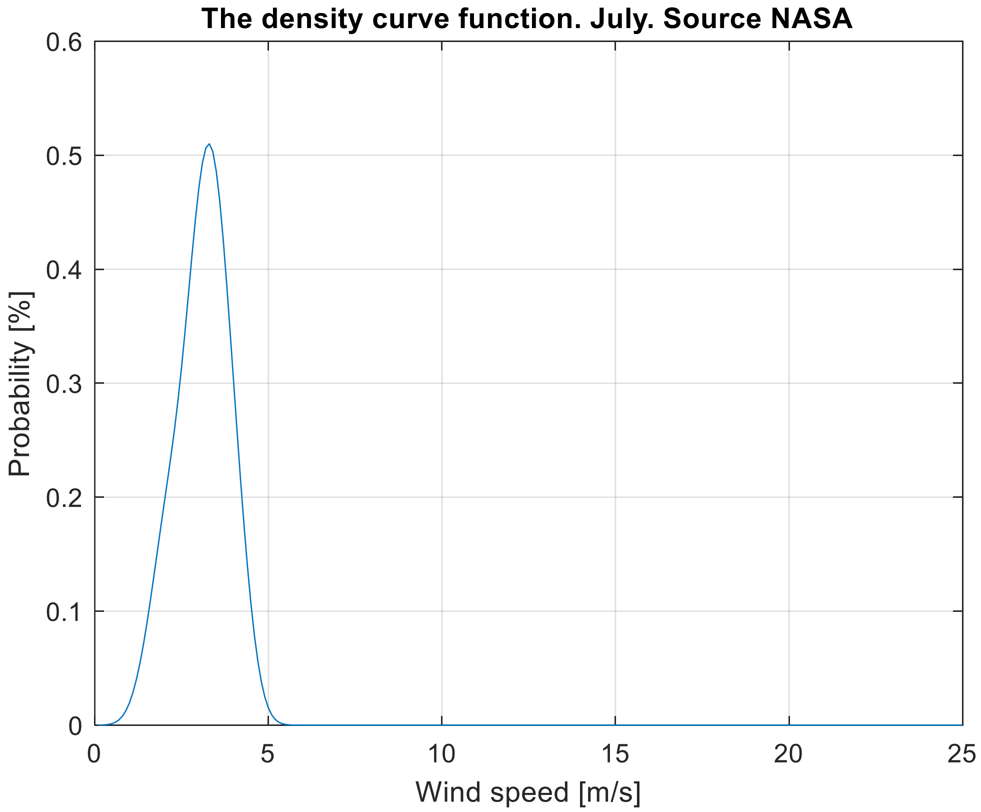


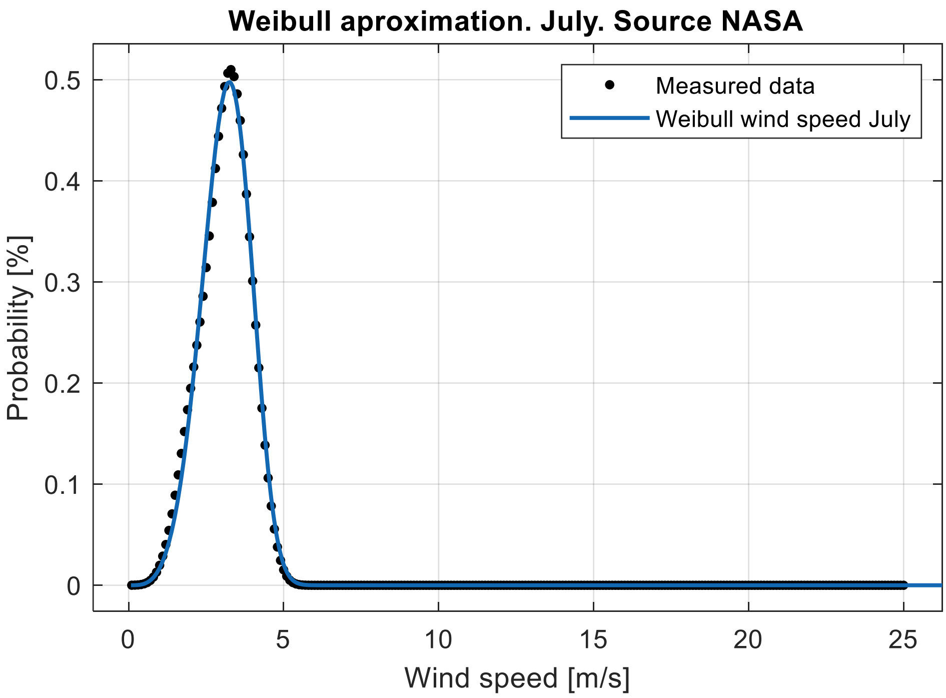


$$a = 0.07283 \tag{107}$$

$$b = 2.205 \tag{108}$$

July

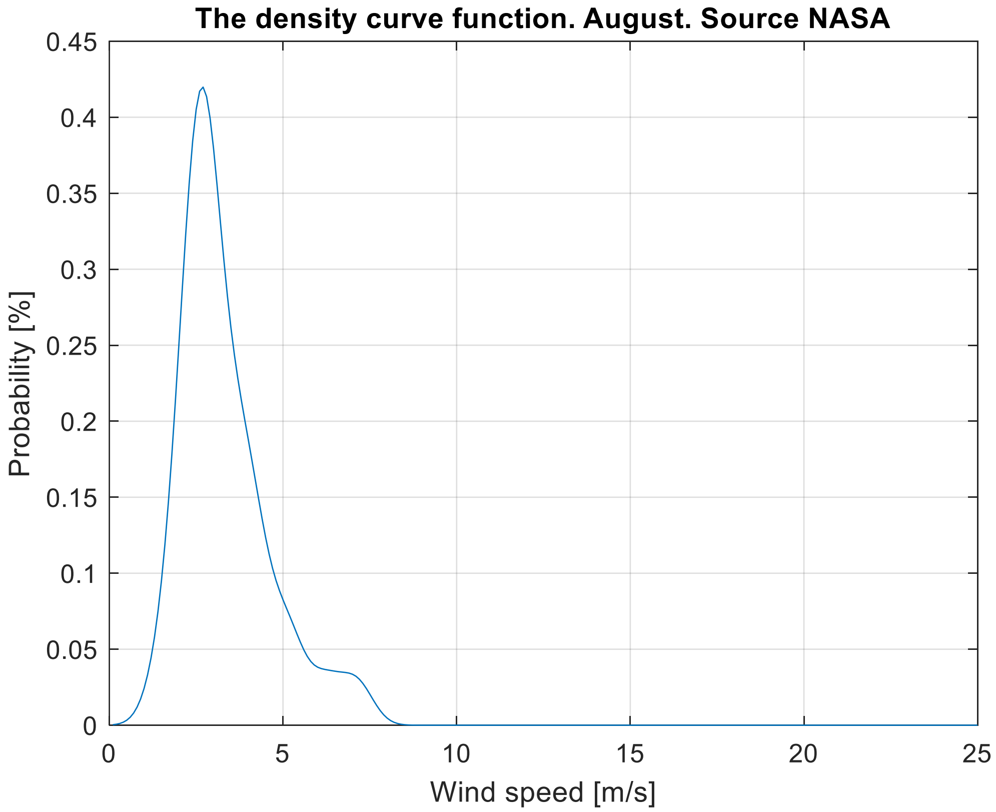


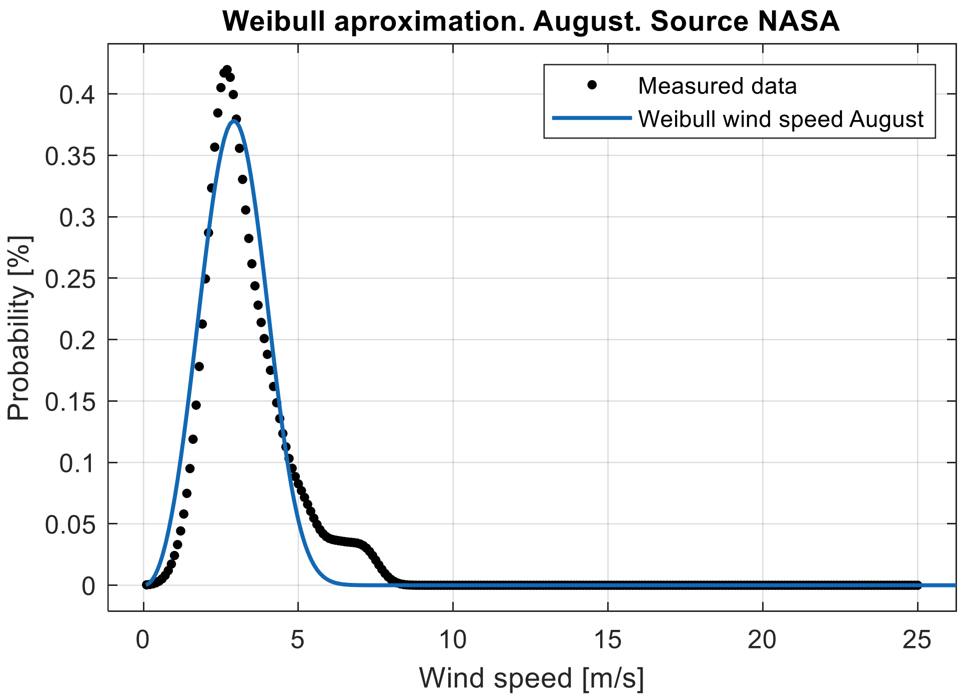


$$a = 0.003778 \quad (109)$$

$$b = 4.523 \quad (110)$$

August

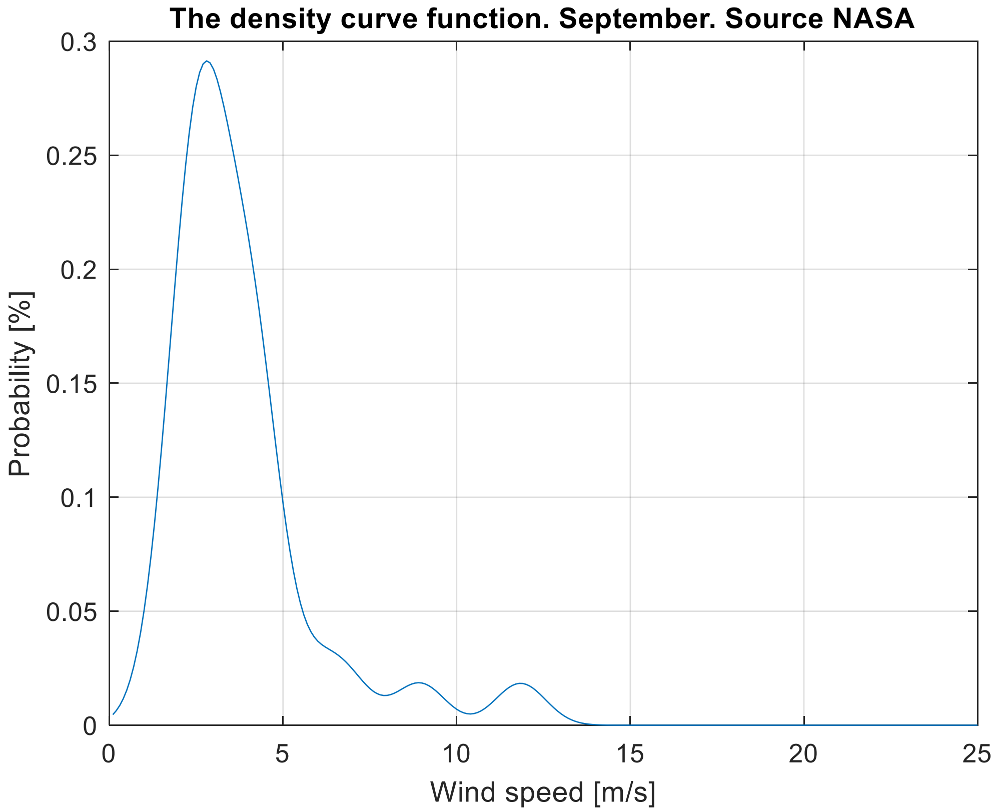


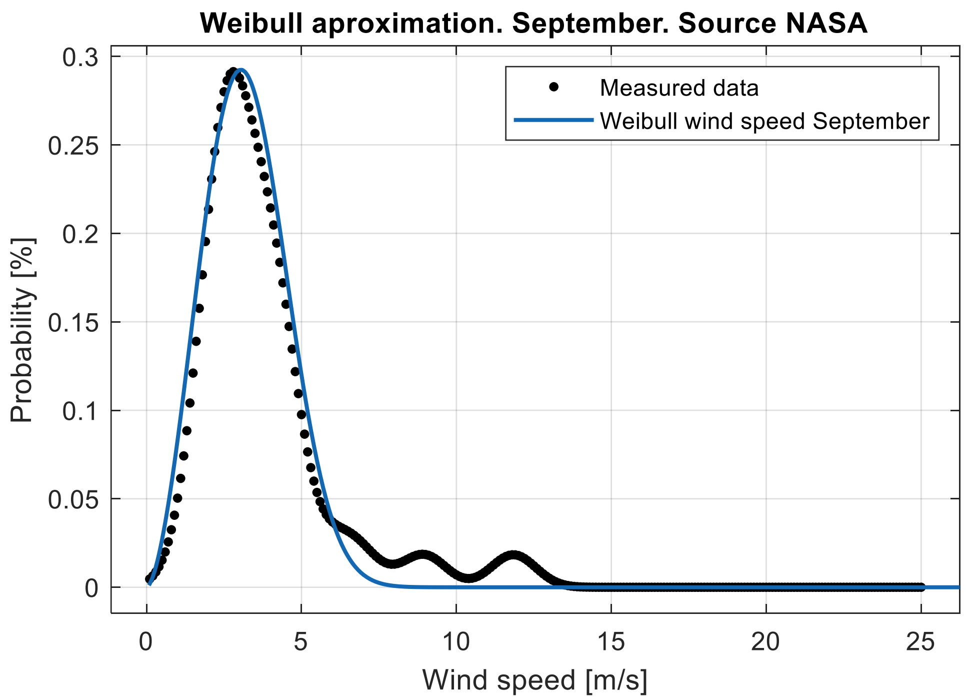


$$a = 0.02246 \tag{111}$$

$$b = 3.193 \tag{112}$$

September

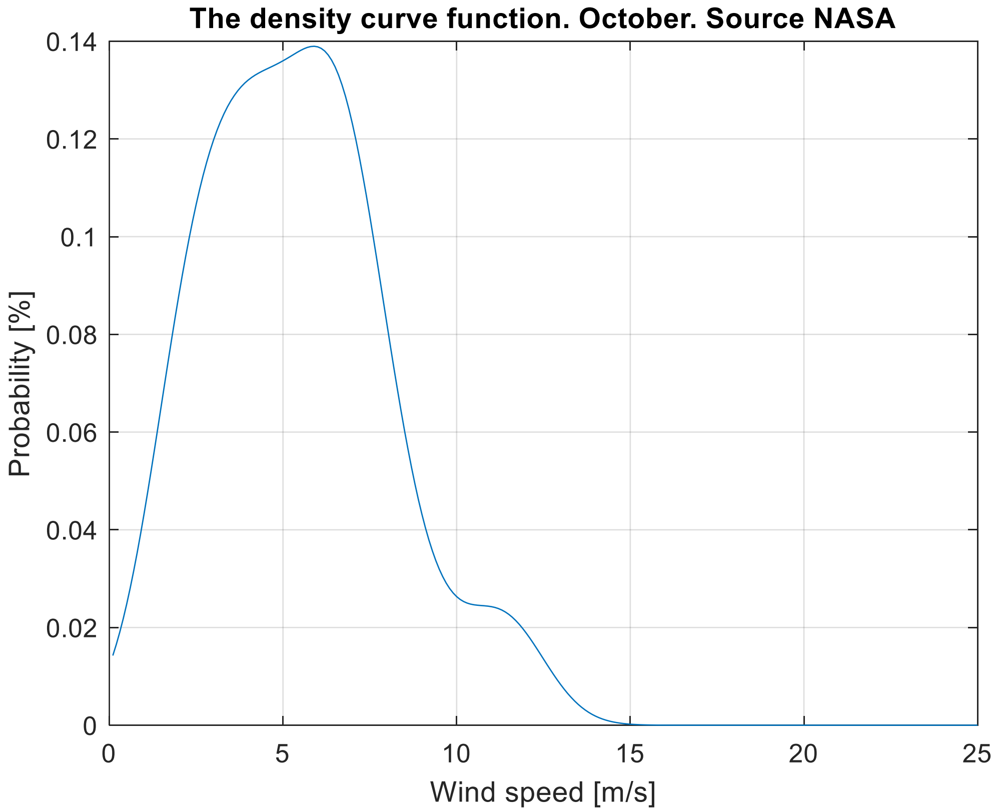


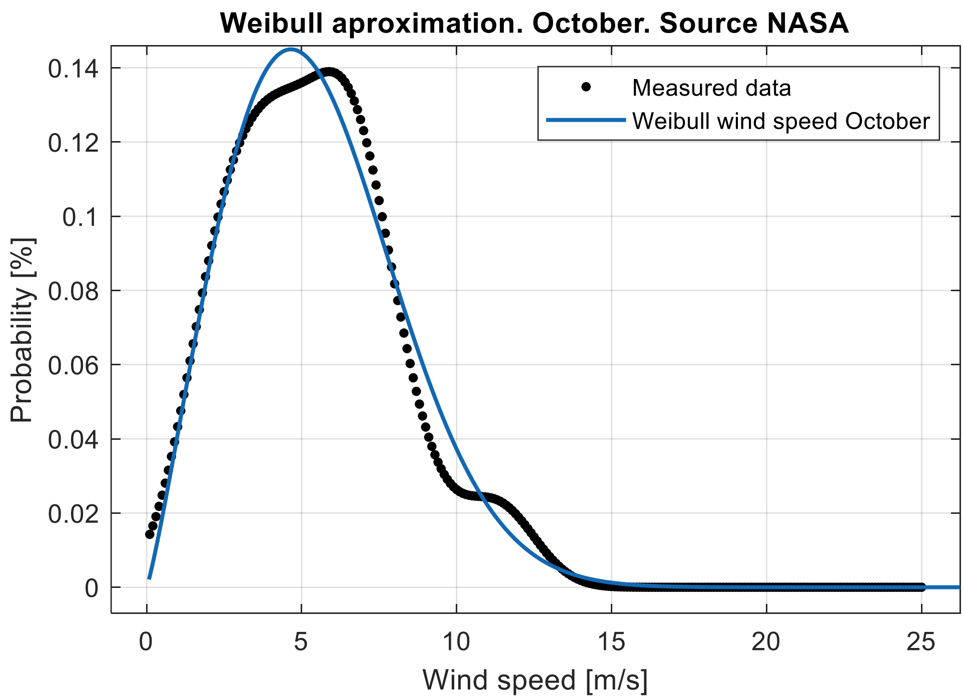


$$a = 0.03223 \tag{113}$$

$$b = 2.662 \tag{114}$$

October

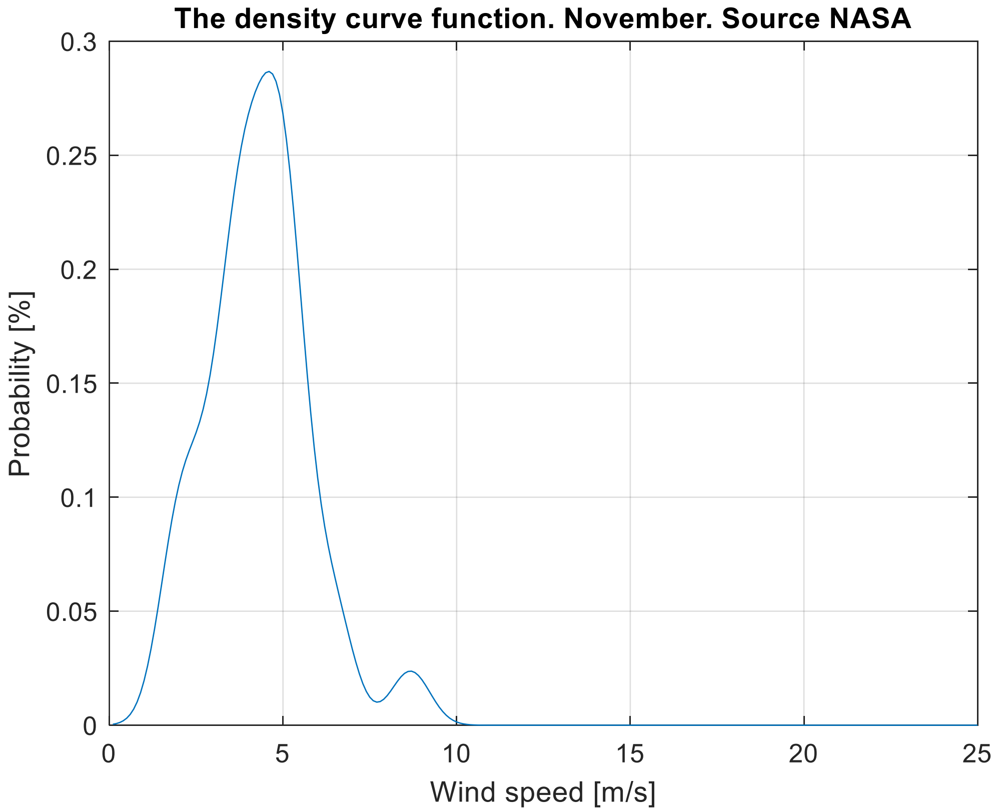


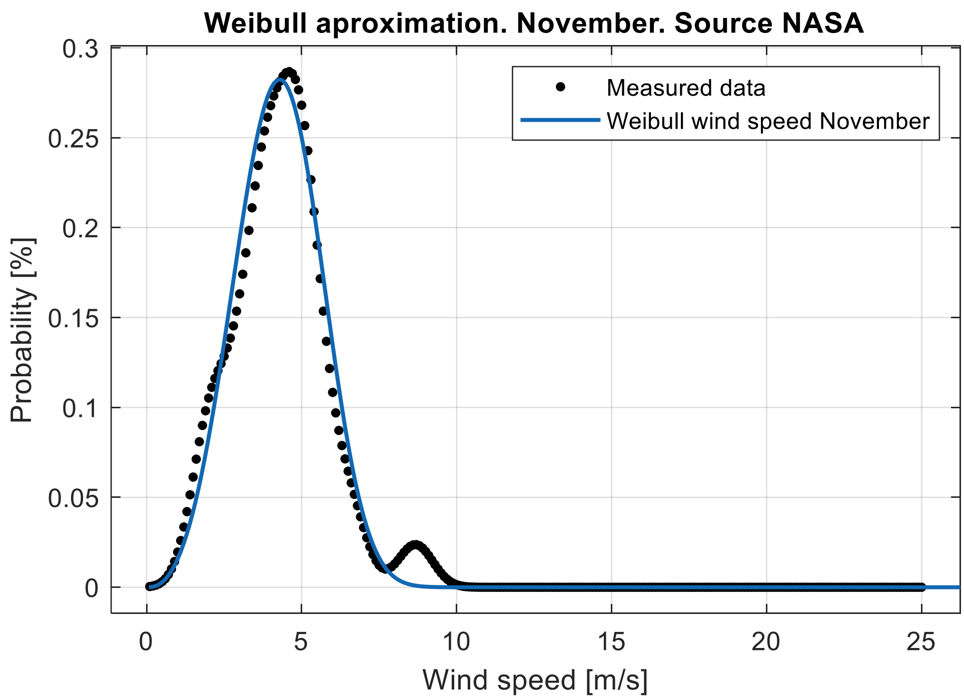


$$a = 0.0195 \quad (115)$$

$$b = 2.154 \quad (116)$$

November

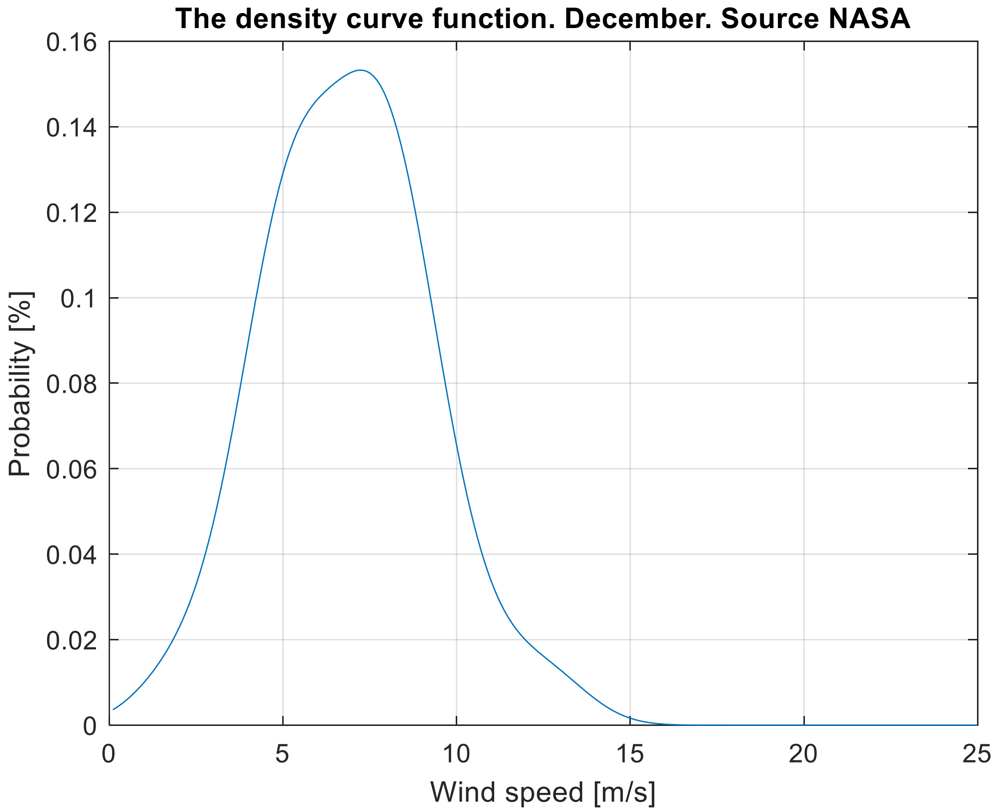


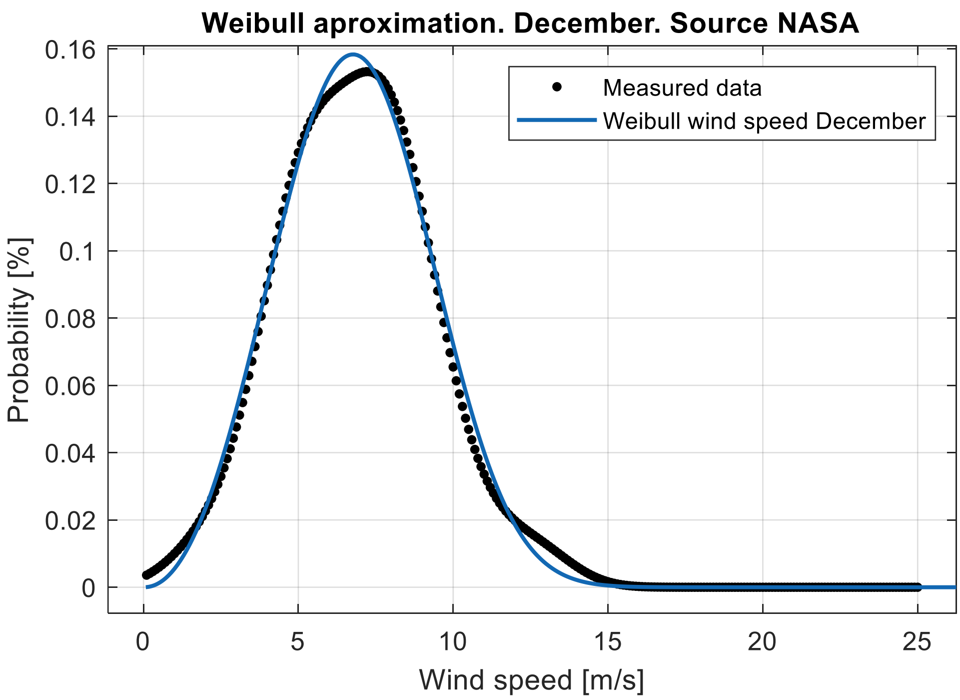


$$a = 0.004566 \tag{117}$$

$$b = 3.467 \tag{118}$$

December





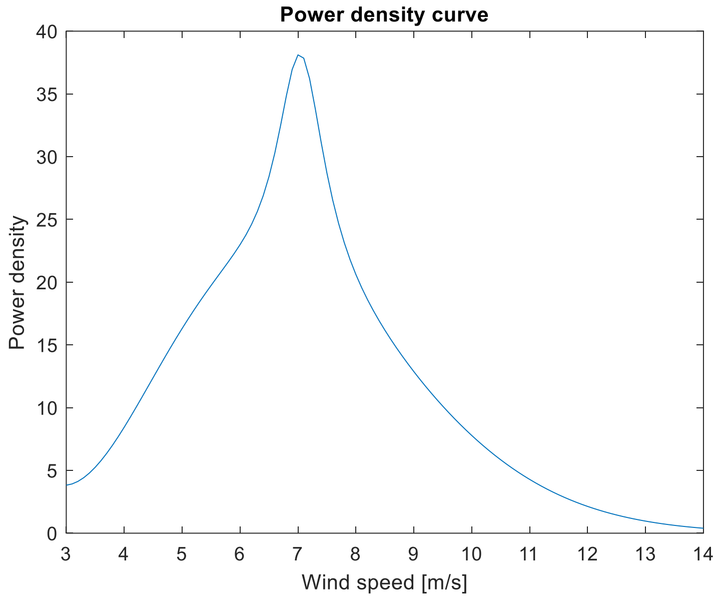
$$a = 0.001764 \quad (119)$$

$$b = 3.113 \quad (120)$$

Annex 3 – Power obtained in 2020. Manual calculations.

January

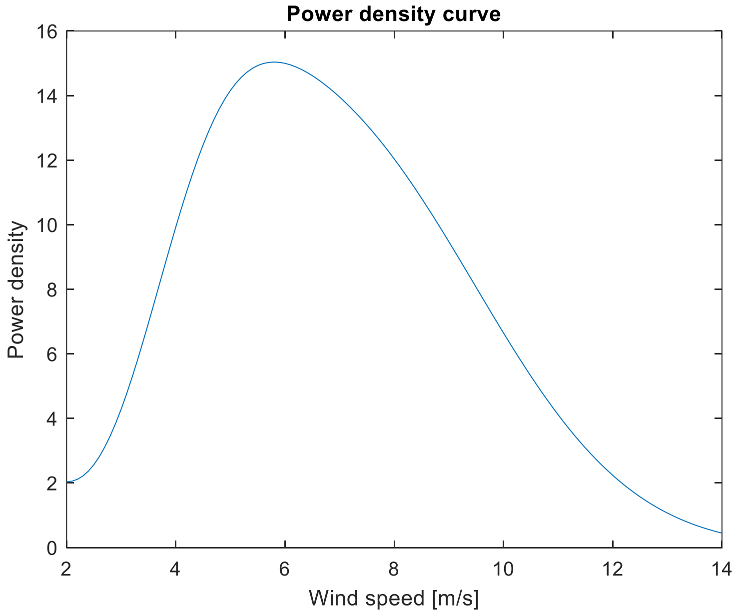
Automaxx 400W wind turbine



$$P_{WG_{avg}} = 134.1056\ [W] \tag{121}$$

$$Energy = 99.775\ [kWh] \tag{122}$$

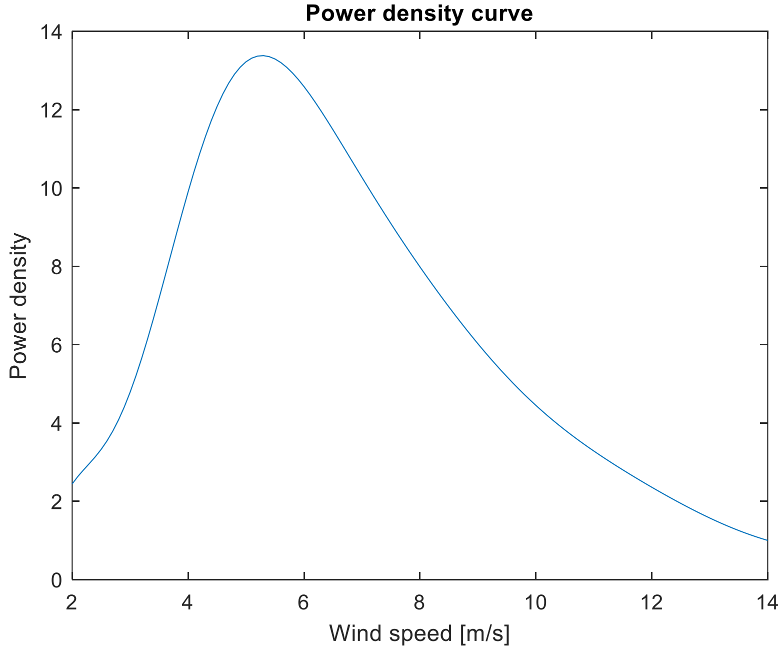
Automaxx 600W (12V) wind turbine



$$P_{WG_{avg}} = 94.1717\ [W] \tag{123}$$

$$Energy = 70.064\ [kWh] \tag{124}$$

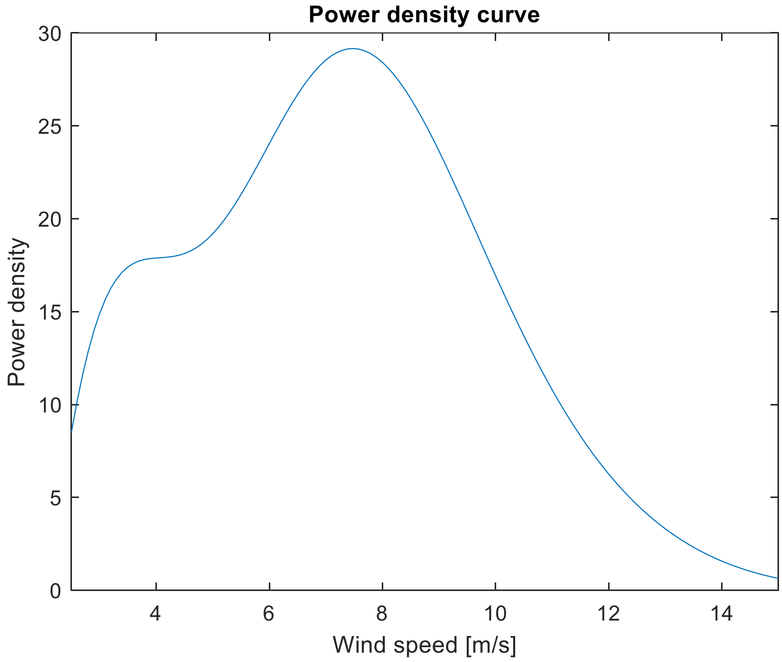
Automaxx 600W wind turbine (24V)



$$P_{WG_{avg}} = 78.3498\ [W] \tag{125}$$

$$Energy = 58.292\ [kWh] \tag{126}$$

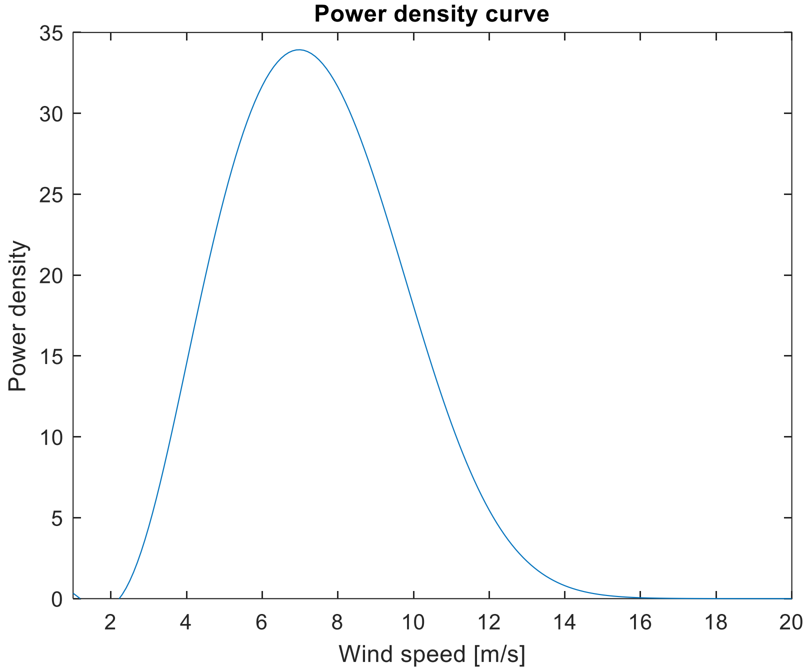
Automaxx 1500W wind turbine



$$P_{WG_{avg}} = 195.1042\ [W] \tag{127}$$

$$Energy = 145.16\ [kWh] \tag{128}$$

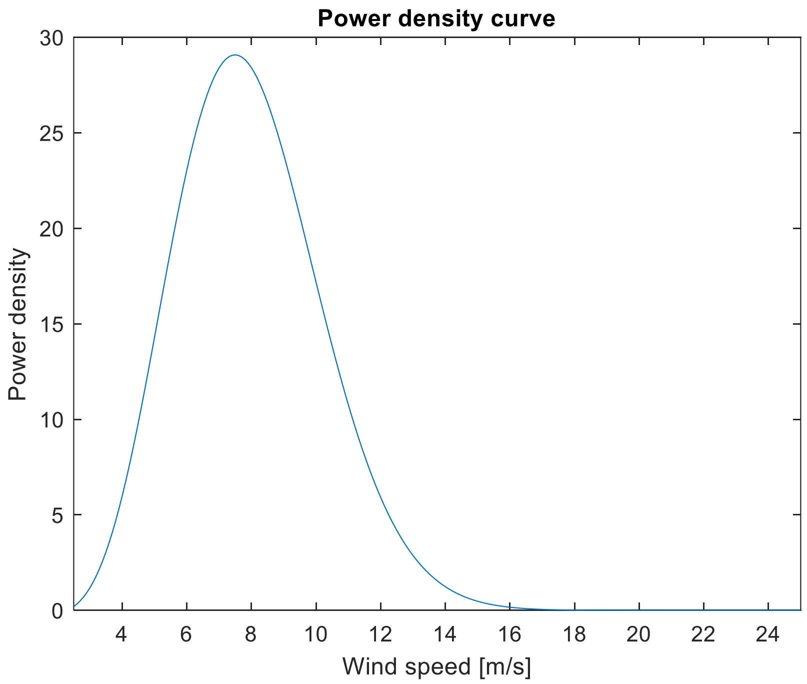
Bornay Wind 13+ wind turbine



$$P_{WG_{avg}} = 204.1329\ [W] \quad (129)$$

$$Energy = 151.87\ [kWh] \quad (130)$$

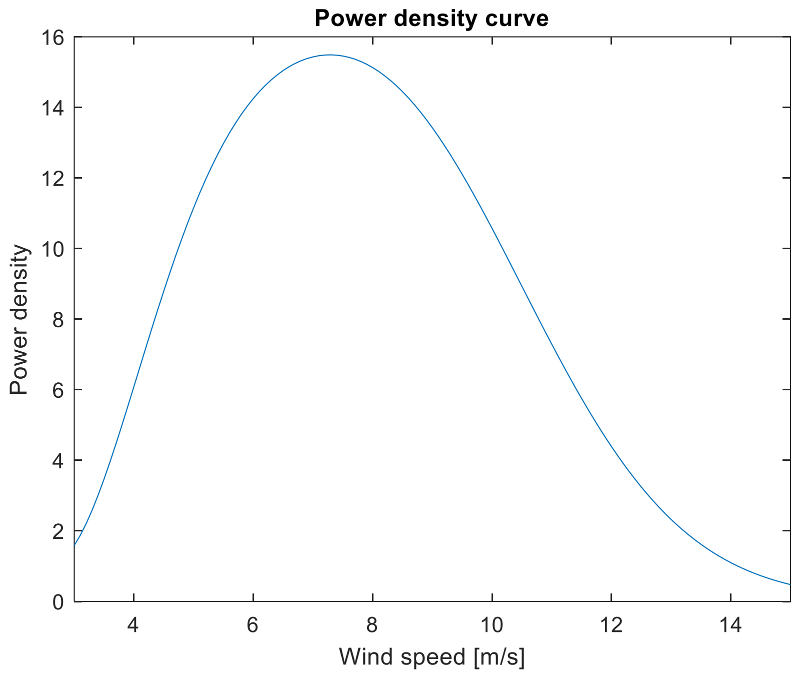
Fortis Passaat 1.4kW wind turbine



$$P_{WG_{avg}} = 163.7939\ [W] \quad (131)$$

$$Energy = 121.86\ [kWh] \quad (132)$$

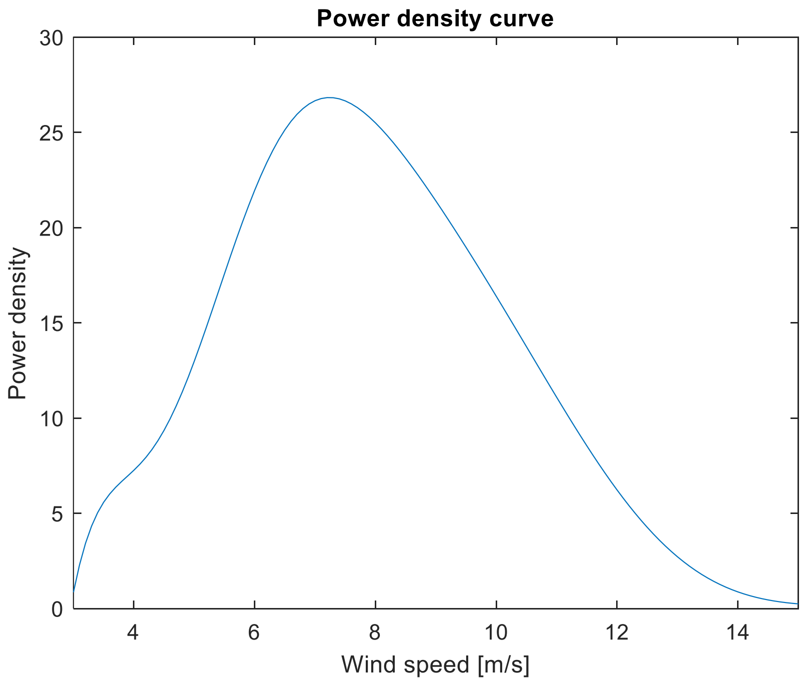
Hi-VAWT DS700



$$P_{WG_{avg}} = 102.4435\ [W] \tag{133}$$

$$Energy = 76.218\ [kWh] \tag{134}$$

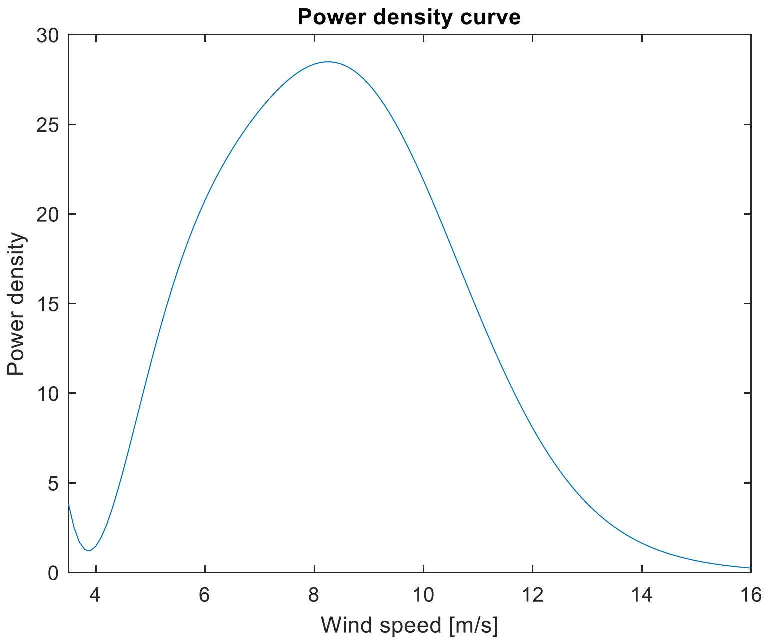
Hi-VAWT DS1500



$$P_{WG_{avg}} = 154.9121\ [W] \tag{135}$$

$$Energy = 115.25\ [kWh] \tag{136}$$

Superwind 1250 wind turbine

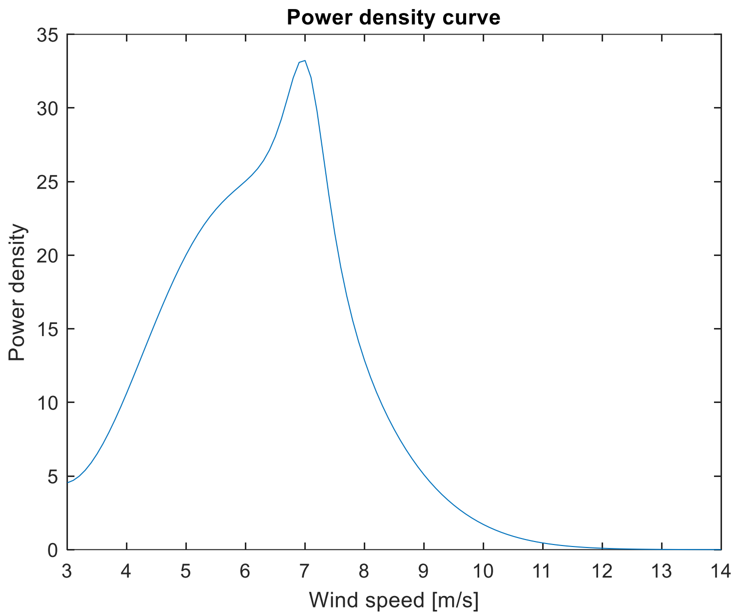


$$P_{WG_{avg}} = 166.4595\ [W] \tag{137}$$

$$Energy = 123.85\ [kWh] \tag{138}$$

February

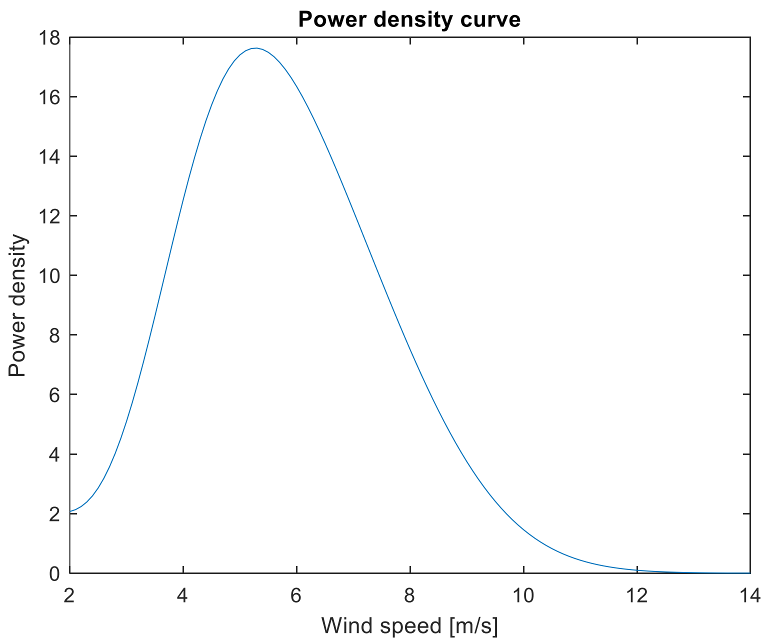
Automaxx 400W wind turbine



$$P_{WG_{avg}} = 109.2167\ [W] \quad (139)$$

$$Energy = 73.394\ [kWh] \quad (140)$$

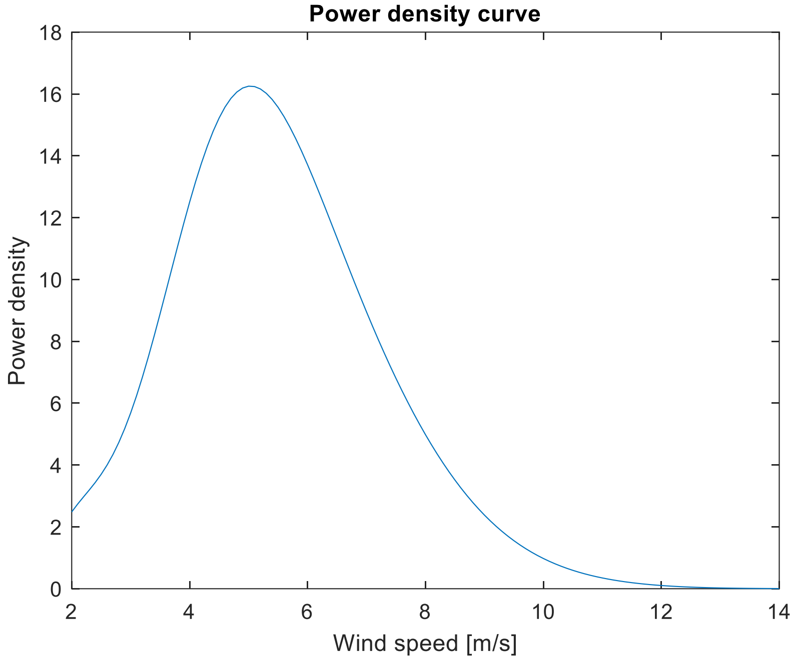
Automaxx 600W (12V) wind turbine



$$P_{WG_{avg}} = 77.8584\ [W] \quad (141)$$

$$Energy = 52.321\ [kWh] \quad (142)$$

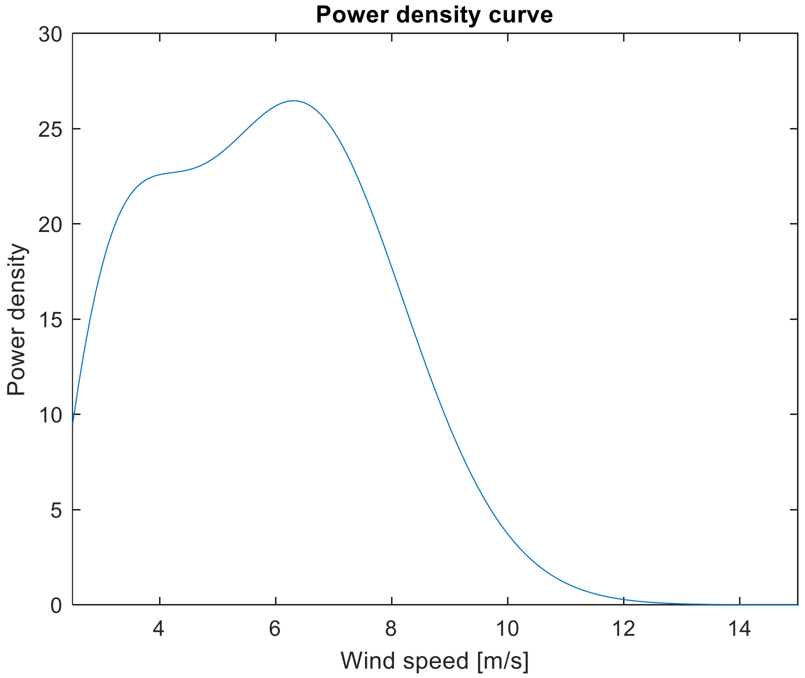
Automaxx 600W wind turbine (24V)



$$P_{WG_{avg}} = 67.3573\ [W] \quad (143)$$

$$Energy = 45.264\ [kWh] \quad (144)$$

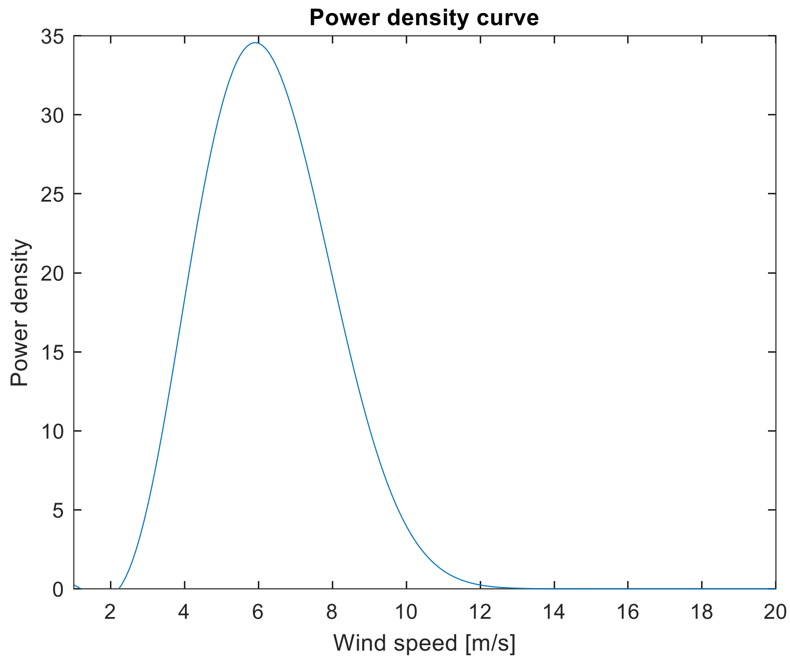
Automaxx 1500W wind turbine



$$P_{WG_{avg}} = 146.2898\ [W] \quad (145)$$

$$Energy = 98.307\ [kWh] \quad (146)$$

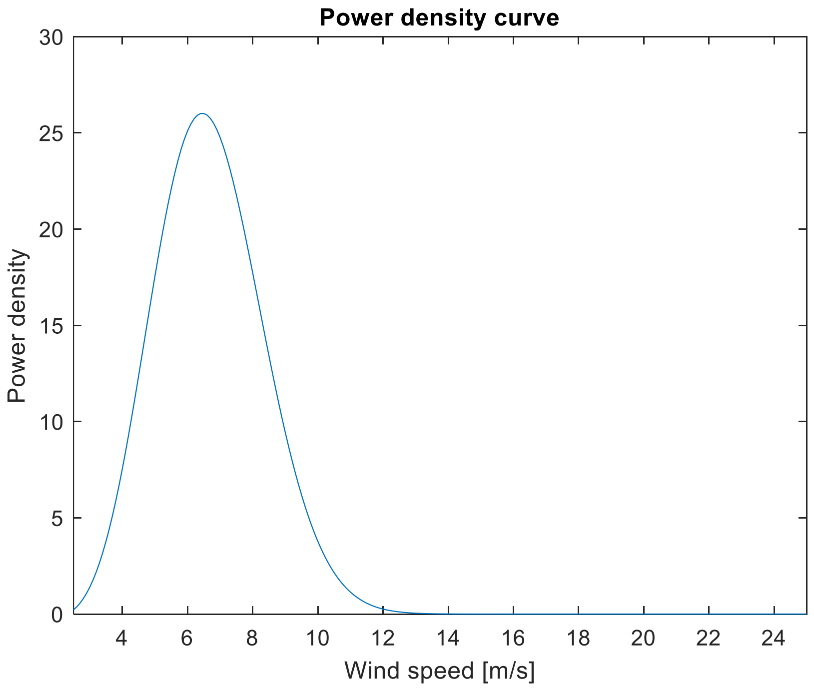
Bornay Wind 13+ wind turbine



$$P_{WG_{avg}} = 153.0795\ [W] \quad (147)$$

$$Energy = 102.87\ [kWh] \quad (148)$$

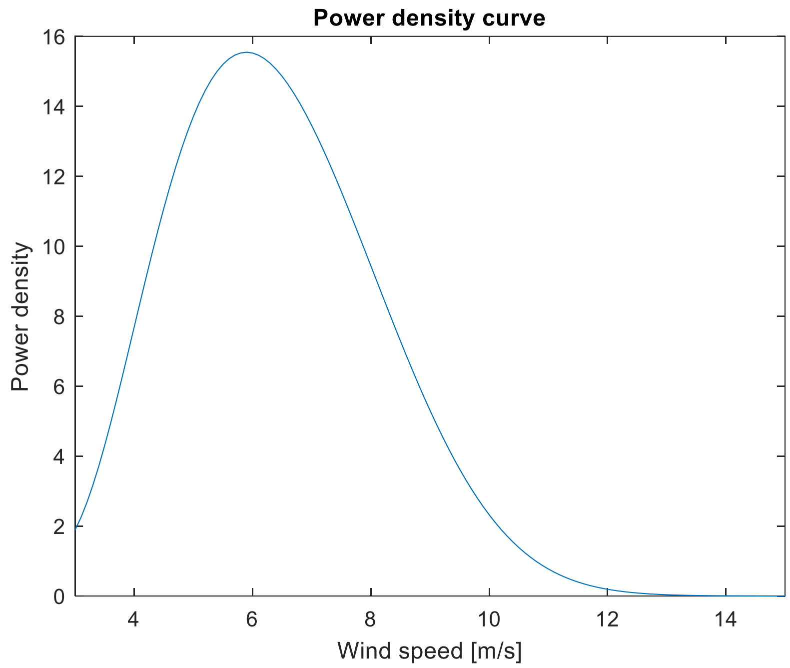
Fortis Passaat 1.4kW wind turbine



$$P_{WG_{avg}} = 108.6898\ [W] \quad (149)$$

$$Energy = 73.04\ [kWh] \quad (150)$$

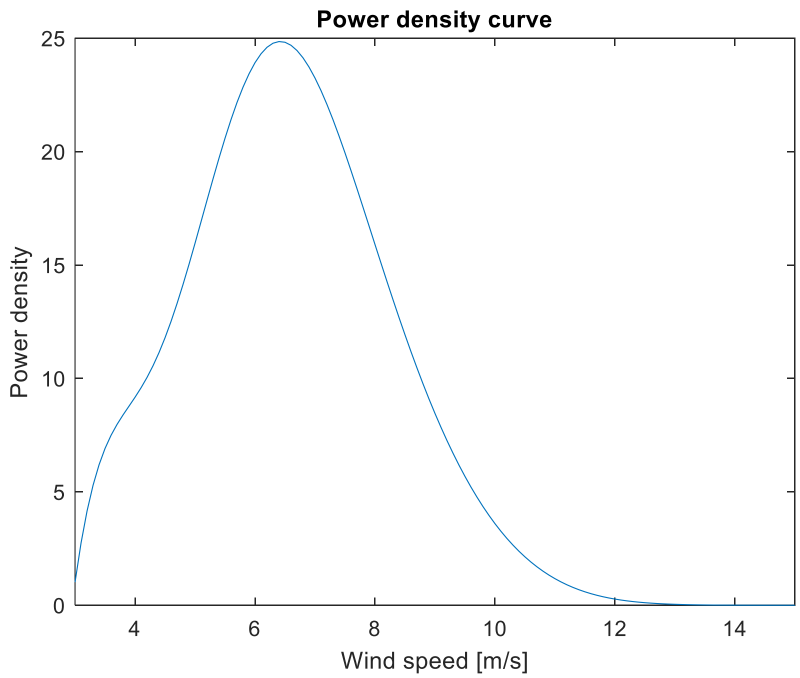
Hi-VAWT DS700



$$P_{WG_{avg}} = 69.6667\ [W] \quad (151)$$

$$Energy = 46.816\ [kWh] \quad (152)$$

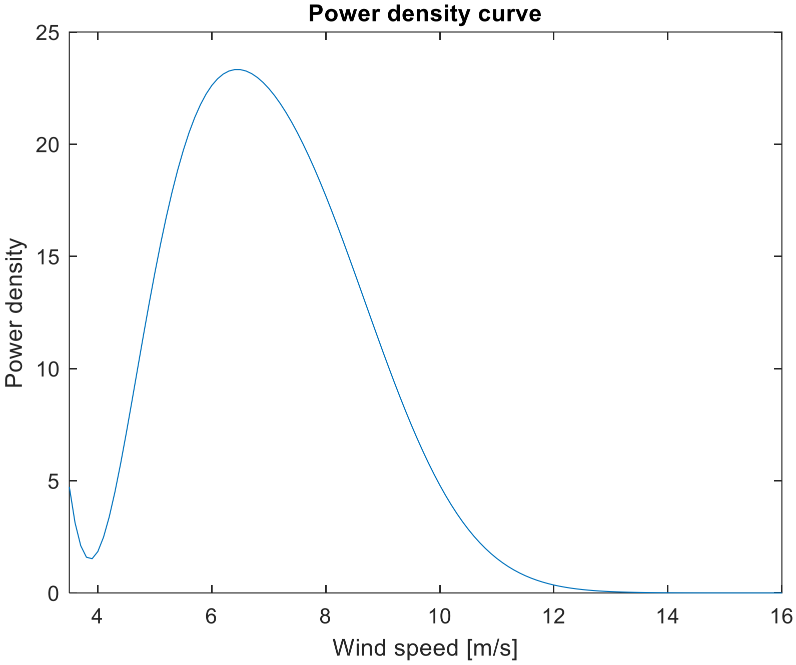
Hi-VAWT DS1500



$$P_{WG_{avg}} = 103.7777\ [W] \quad (153)$$

$$Energy = 69.739\ [kWh] \quad (154)$$

Superwind 1250 wind turbine

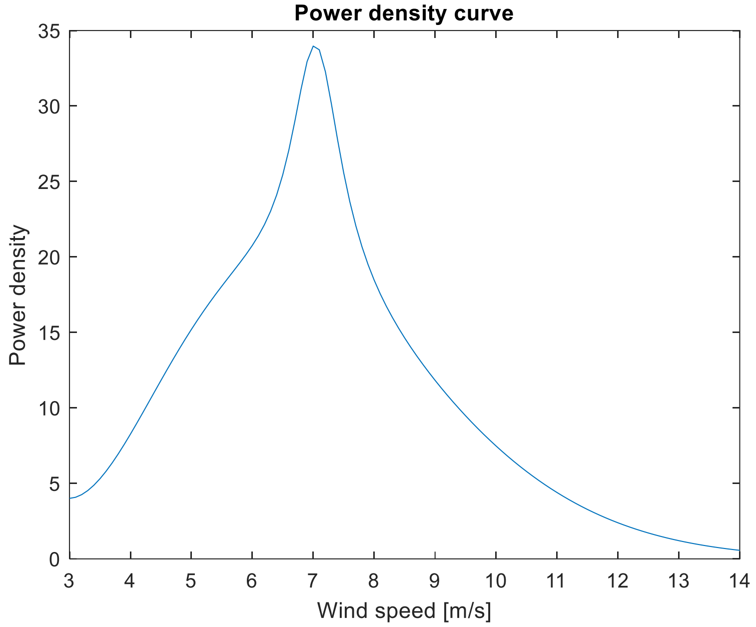


$$P_{WG_{avg}} = 97.1462\ [W] \quad (155)$$

$$Energy = 65.282\ [kWh] \quad (156)$$

March

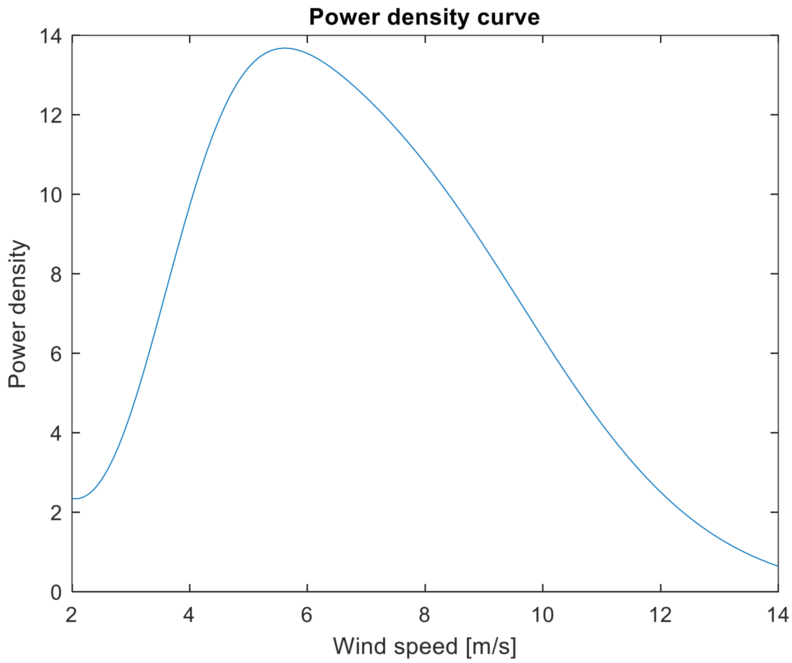
Automaxx 400W wind turbine



$$P_{WG_{avg}} = 124.0152\ [W] \tag{157}$$

$$Energy = 92.267\ [kWh] \tag{158}$$

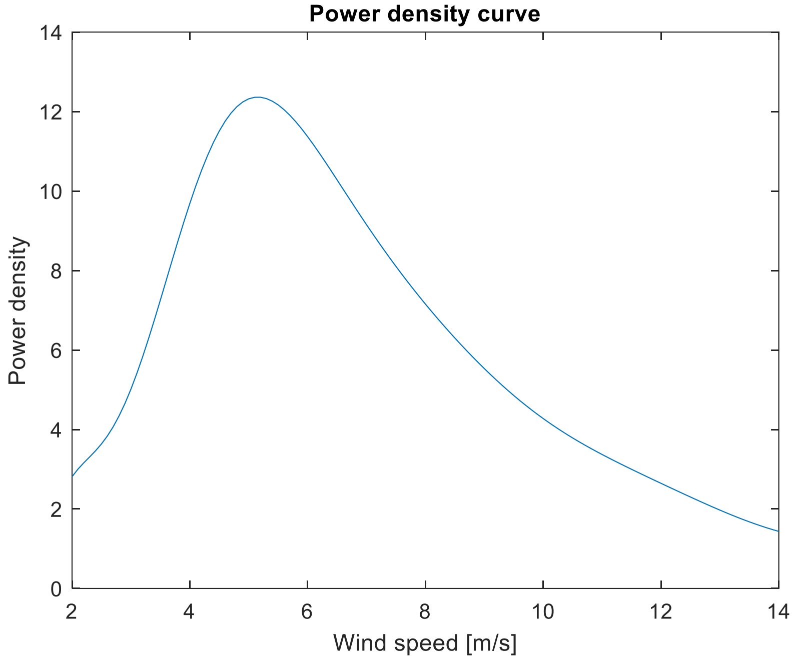
Automaxx 600W (12V) wind turbine



$$P_{WG_{avg}} = 88.8394\ [W] \tag{159}$$

$$Energy = 66.097\ [kWh] \tag{160}$$

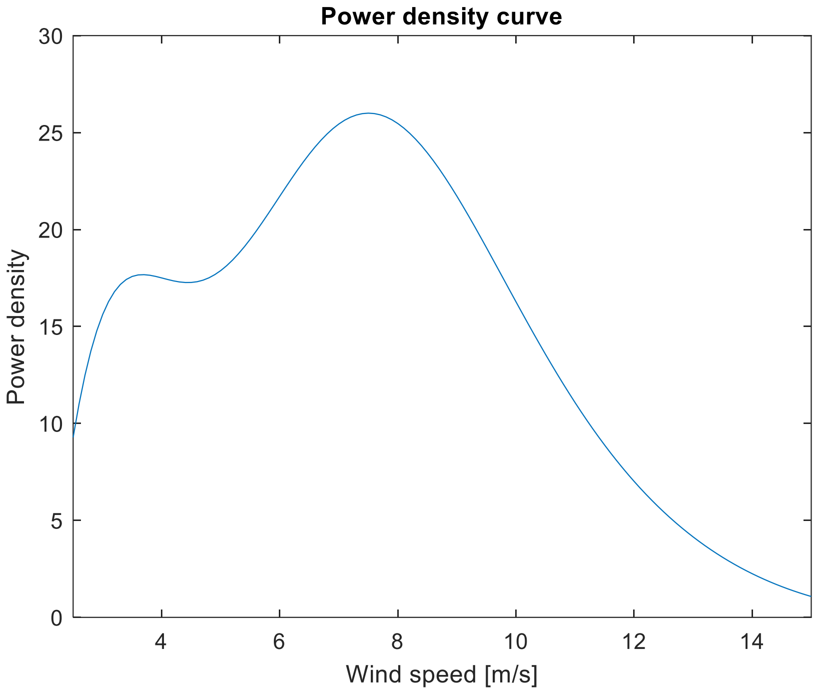
Automaxx 600W wind turbine (24V)



$$P_{WG_{avg}} = 74.8034\ [W] \quad [161]$$

$$Energy = 55.654\ [kWh] \quad [162]$$

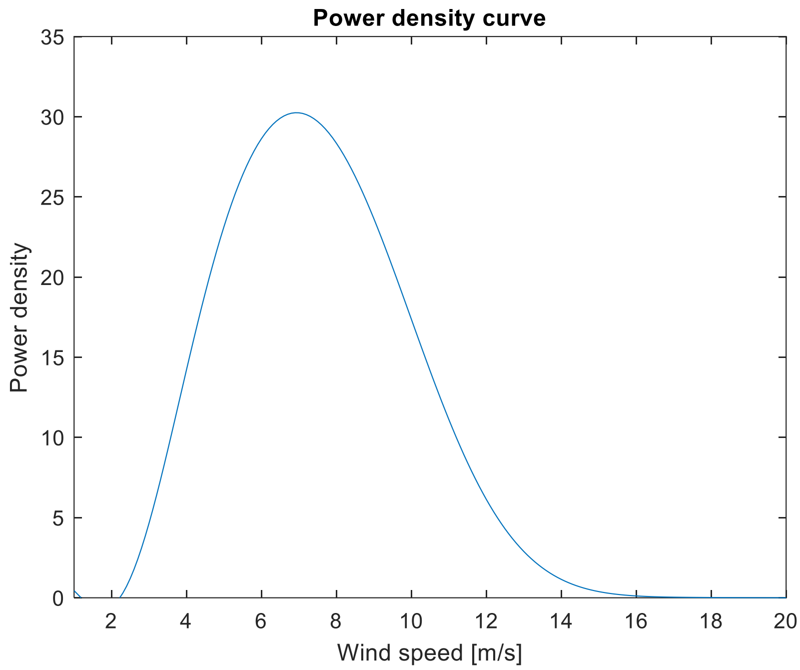
Automaxx 1500W wind turbine



$$P_{WG_{avg}} = 185.9417\ [W] \quad (163)$$

$$Energy = 138.34\ [kWh] \quad (164)$$

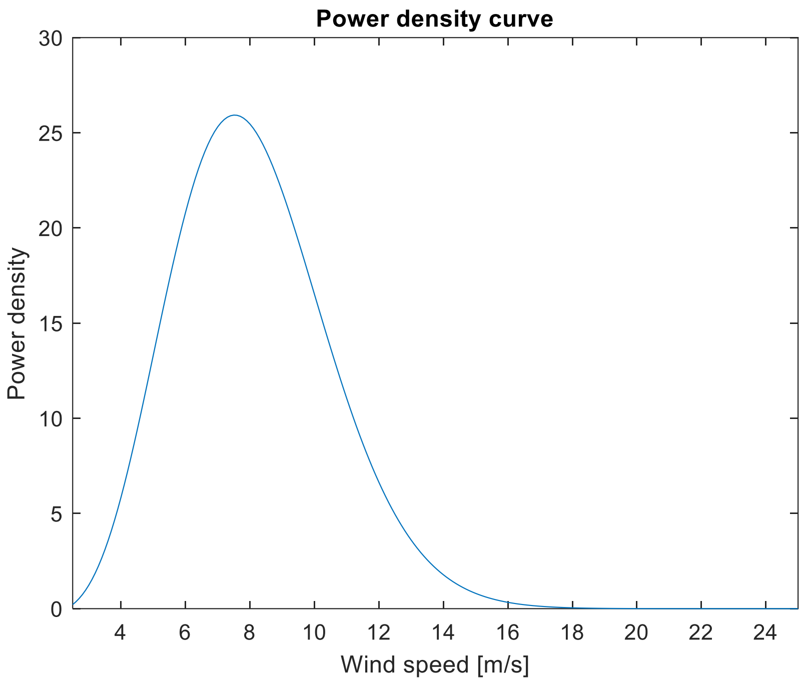
Bornay Wind 13+ wind turbine



$$P_{WG_{avg}} = 191.5612\ [W] \tag{165}$$

$$Energy = 142.52\ [kWh] \tag{166}$$

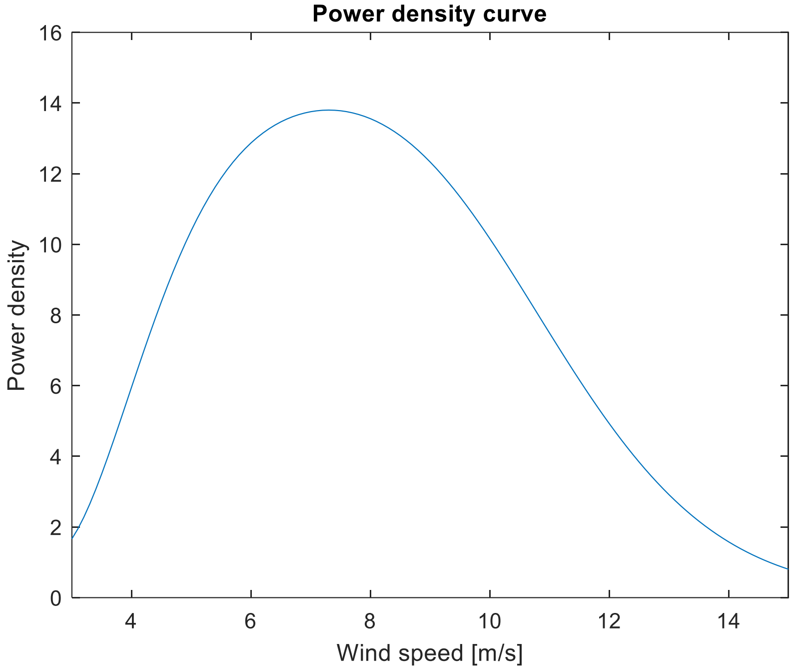
Fortis Passaat 1.4kW wind turbine



$$P_{WG_{avg}} = 154.7491\ [W] \tag{167}$$

$$Energy = 115.13\ [kWh] \tag{168}$$

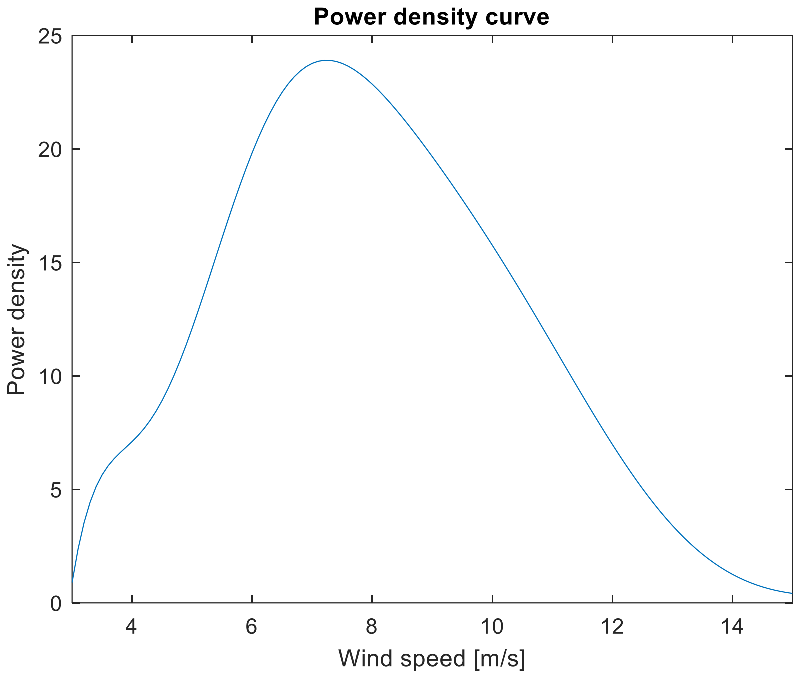
Hi-VAWT DS700



$$P_{WG_{avg}} = 97.4257\ [W] \quad (169)$$

$$Energy = 72.485\ [kWh] \quad (170)$$

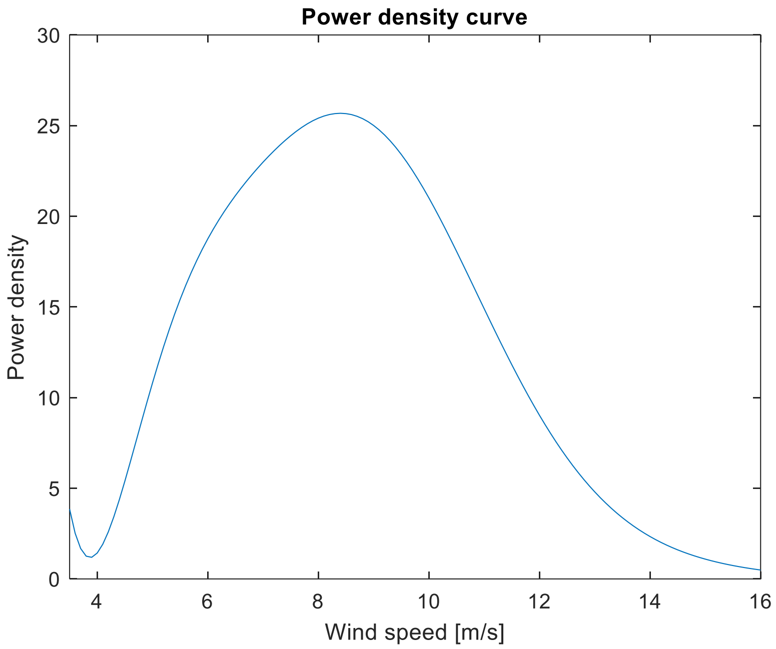
Hi-VAWT DS1500



$$P_{WG_{avg}} = 146.0897\ [W] \quad (171)$$

$$Energy = 108.69\ [kWh] \quad (172)$$

Superwind 1250 wind turbine

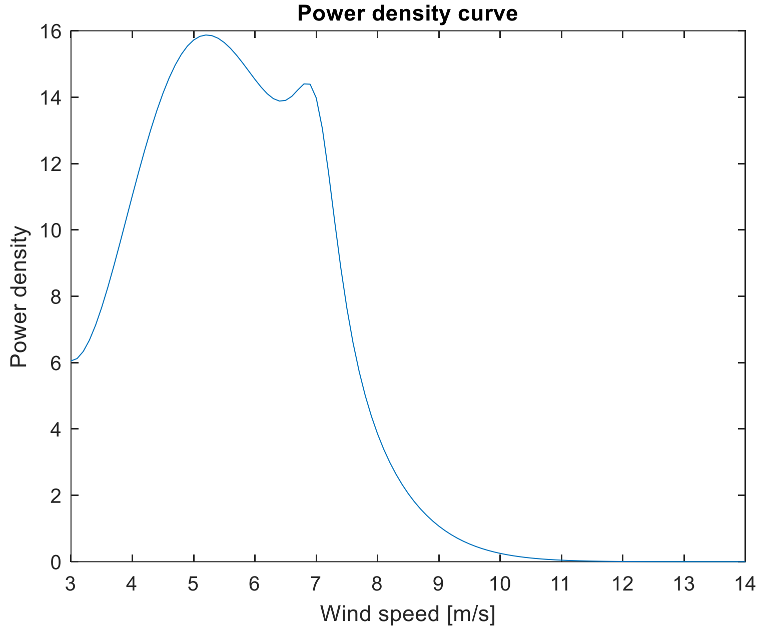


$$P_{WG_{avg}} = 158.4327 \; [W] \tag{173}$$

$$Energy = 117.87 \; [kWh] \tag{174}$$

April

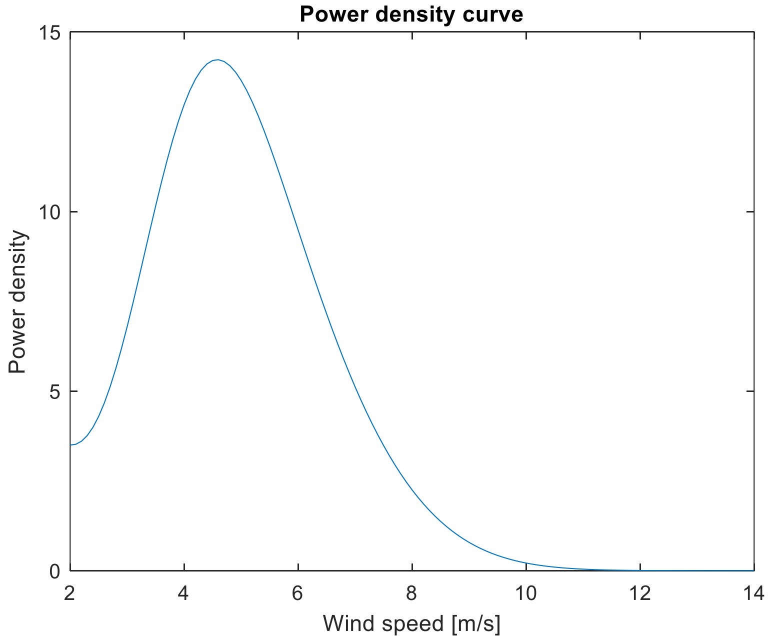
Automaxx 400W wind turbine



$$P_{WG_{avg}} = 62.5566\ [W] \quad (175)$$

$$Energy = 45.041\ [kWh] \quad (176)$$

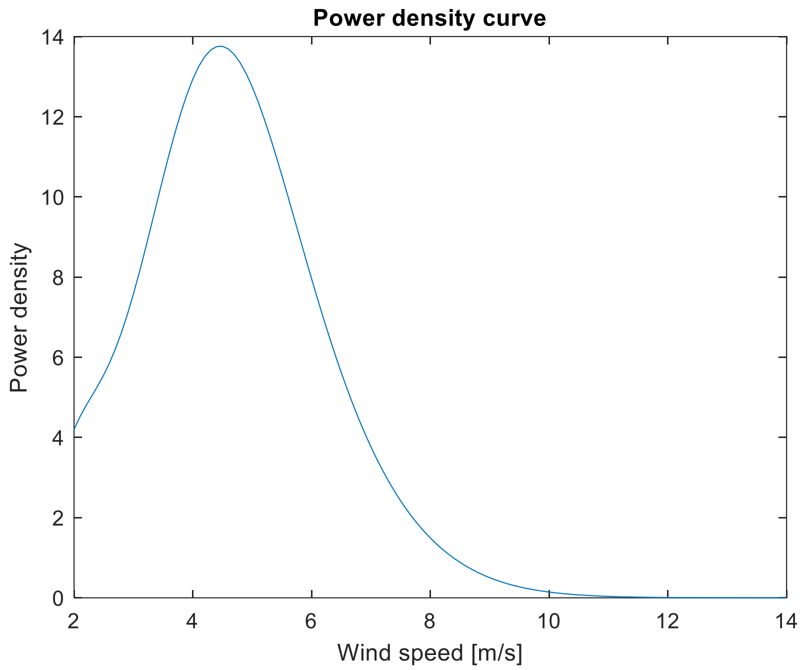
Automaxx 600W (12V) wind turbine



$$P_{WG_{avg}} = 53.0576\ [W] \quad (177)$$

$$Energy = 38.201\ [kWh] \quad (178)$$

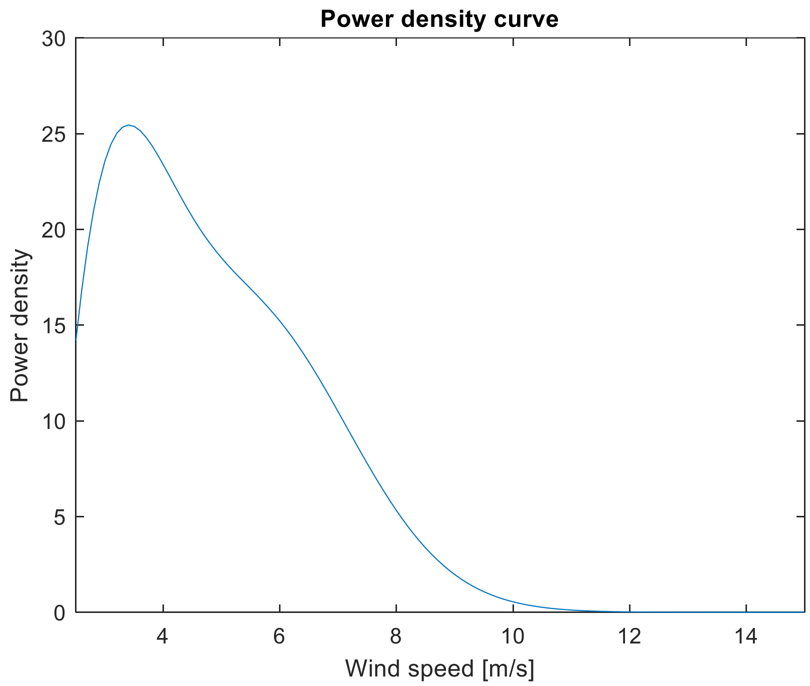
Automaxx 600W wind turbine (24V)



$$P_{WG_{avg}} = 49.5140\ [W] \tag{179}$$

$$Energy = 35.65\ [kWh] \tag{180}$$

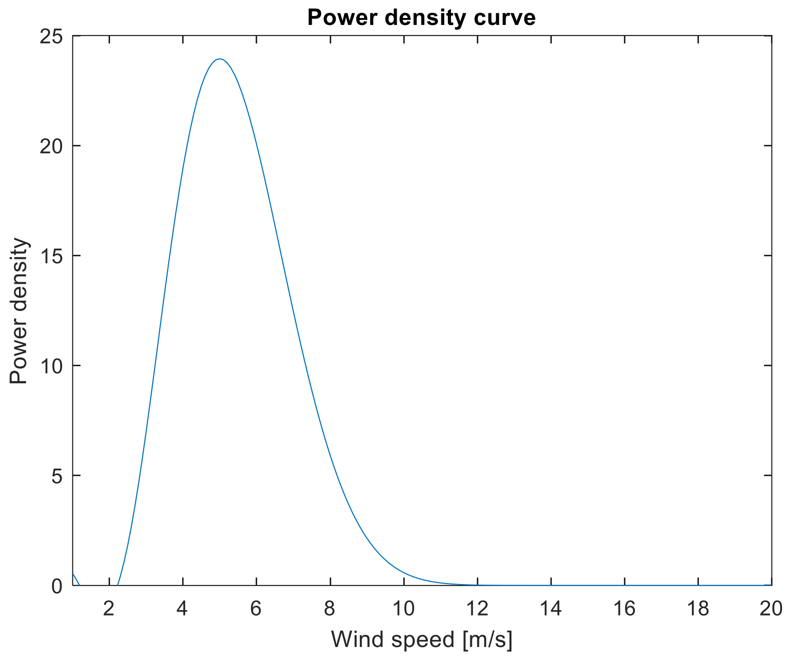
Automaxx 1500W wind turbine



$$P_{WG_{avg}} = 97.8996\ [W] \tag{181}$$

$$Energy = 70.488\ [kWh] \tag{182}$$

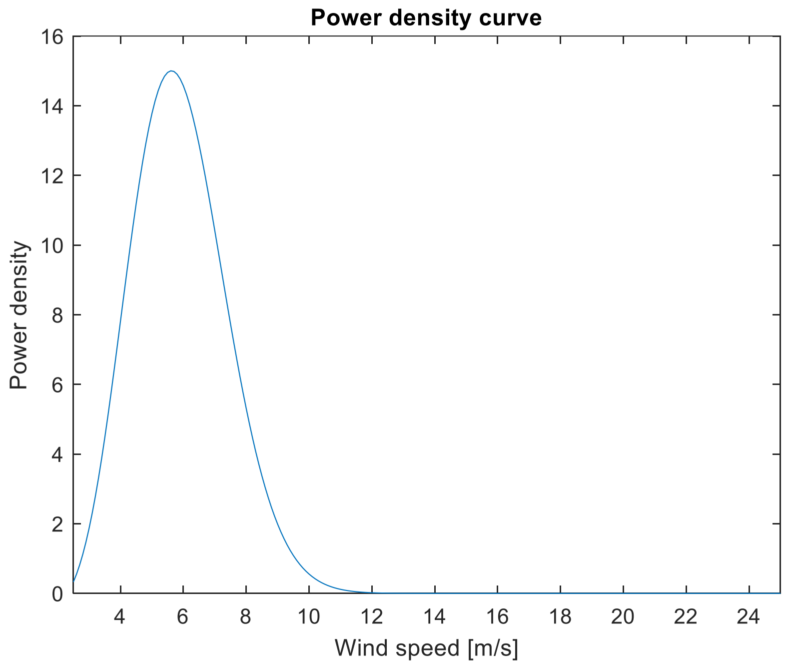
Bornay Wind 13+ wind turbine



$$P_{WG_{avg}} = 90.4119[W] \tag{183}$$

$$Energy = 65.097\ [kWh] \tag{184}$$

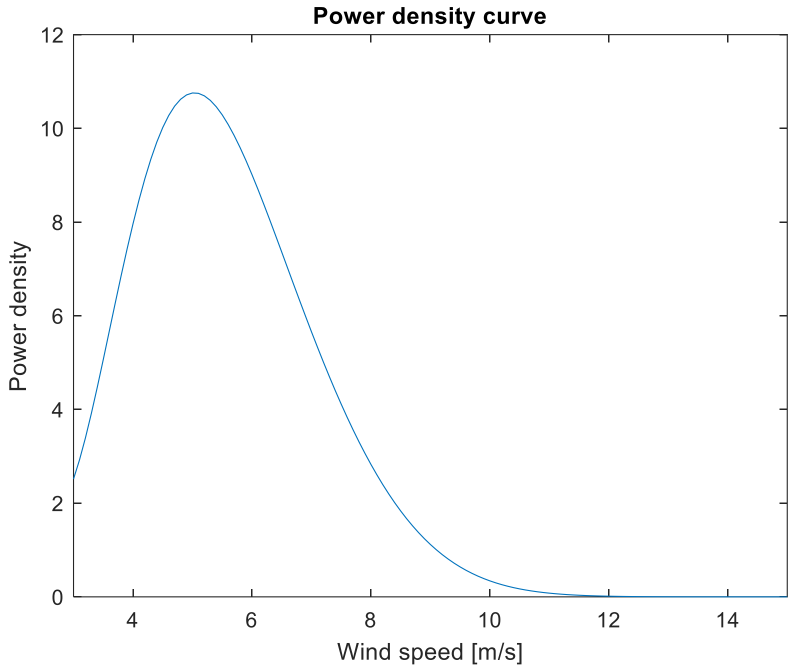
Fortis Passaat 1.4kW wind turbine



$$P_{WG_{avg}} = 56.3497\ [W] \tag{185}$$

$$Energy = 40.572\ [kWh] \tag{186}$$

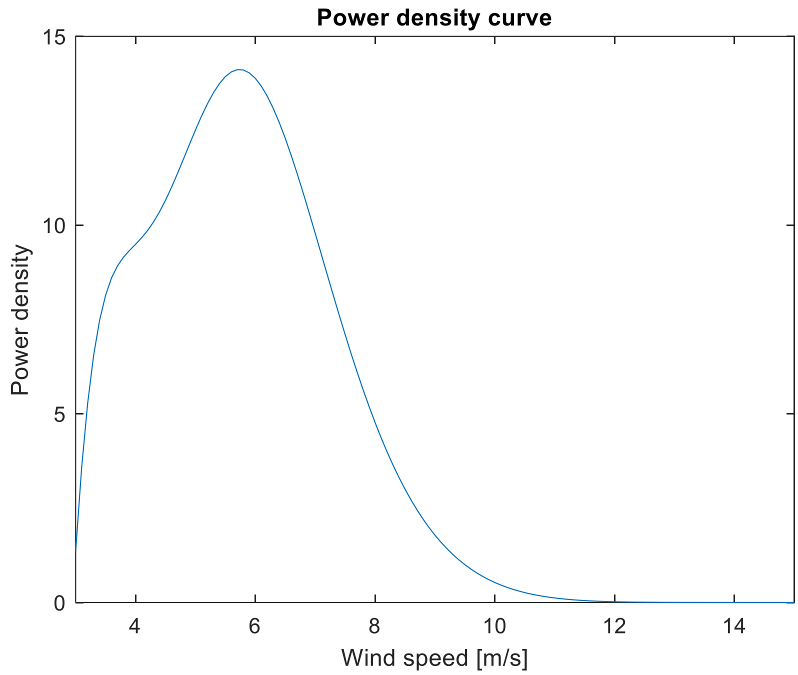
Hi-VAWT DS700



$$P_{WG_{avg}} = 39.3499\ [W] \quad (187)$$

$$Energy = 28.332\ [kWh] \quad (188)$$

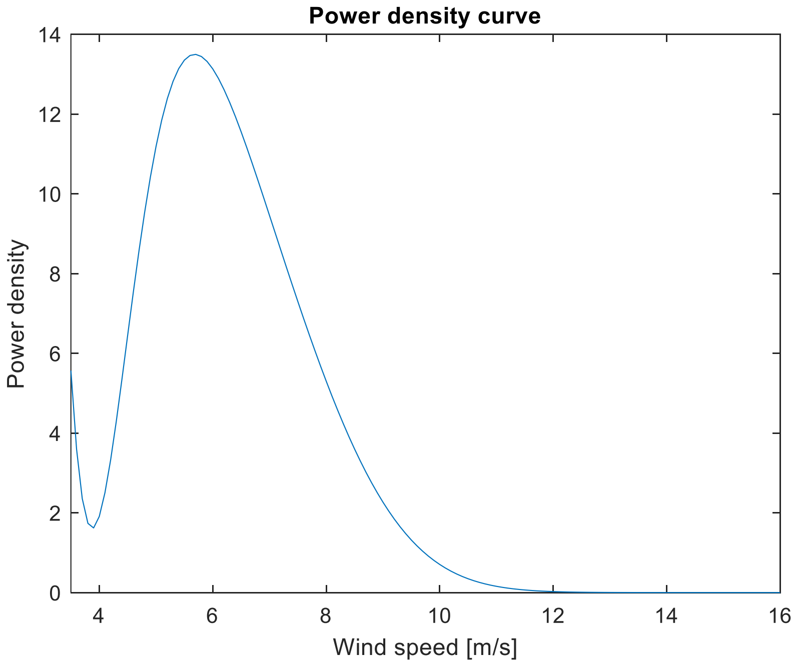
Hi-VAWT DS1500



$$P_{WG_{avg}} = 55.5028\ [W] \quad (189)$$

$$Energy = 39.962\ [kWh] \quad (190)$$

Superwind 1250 wind turbine

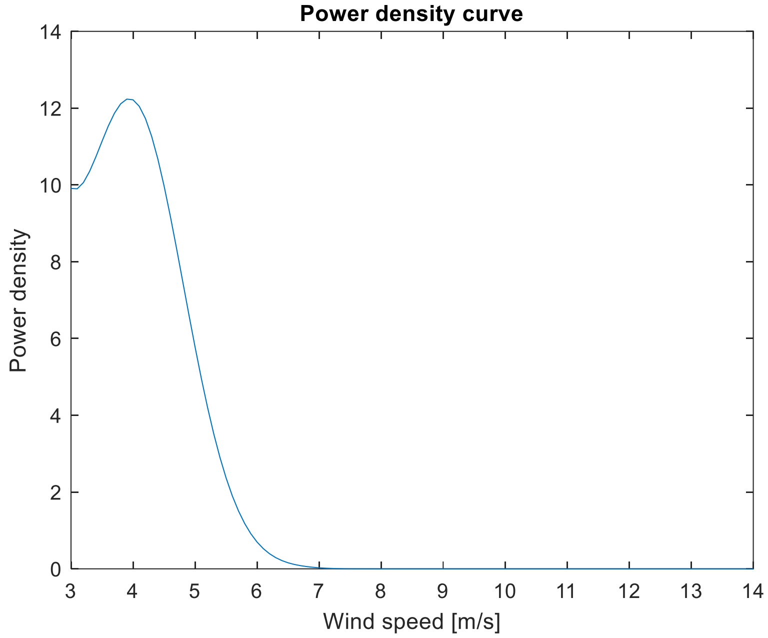


$$P_{WG_{avg}} = 44.9929\ [W] \quad (191)$$

$$Energy = 32.395\ [kWh] \quad (192)$$

May

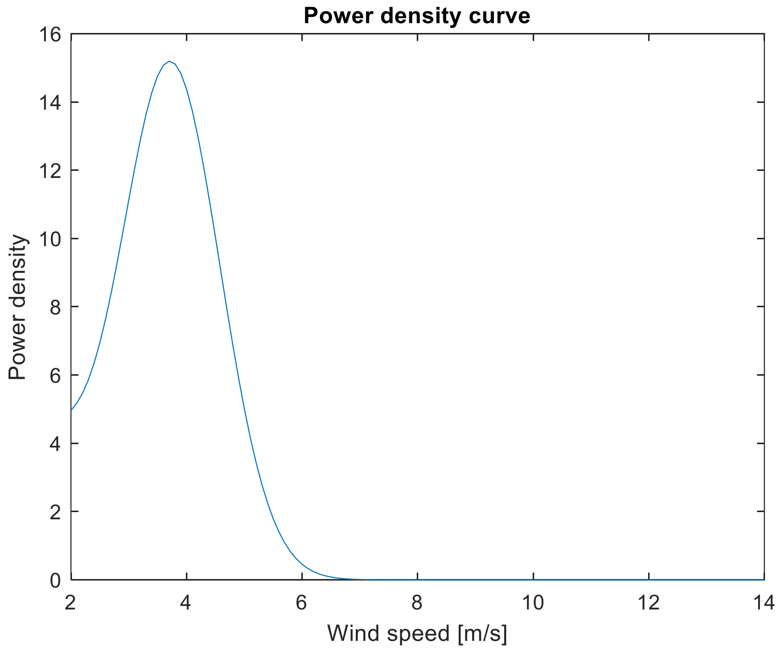
Automaxx 400W wind turbine



$$P_{WG_{avg}} = 23.6383\ [W] \quad (193)$$

$$Energy = 17.587\ [kWh] \quad (194)$$

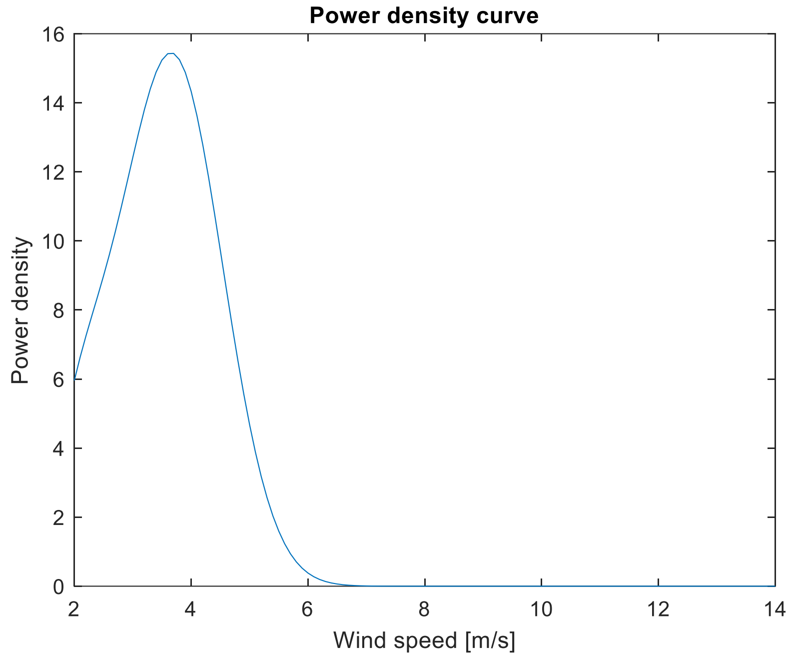
Automaxx 600W (12V) wind turbine



$$P_{WG_{avg}} = 33.5759\ [W] \quad (195)$$

$$Energy = 24.98\ [kWh] \quad (196)$$

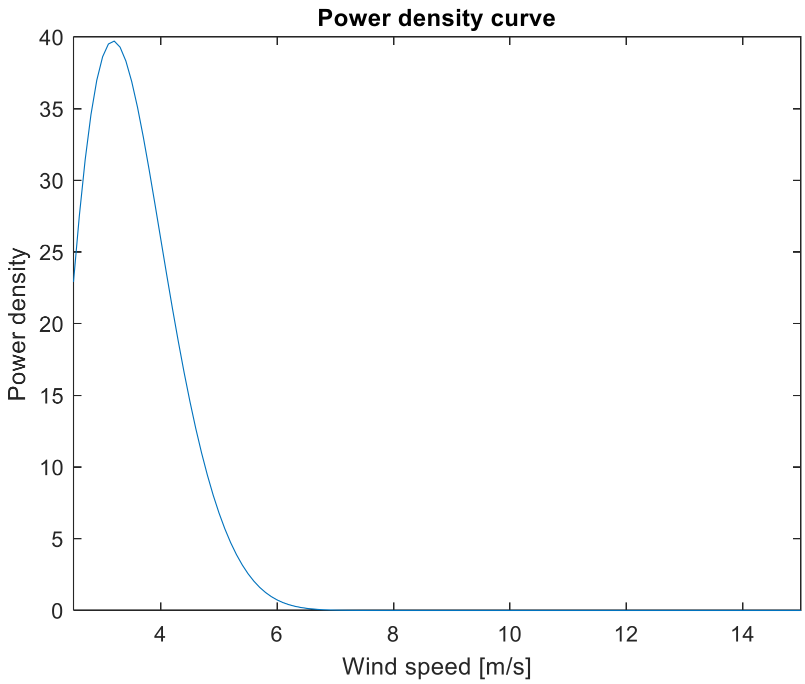
Automaxx 600W wind turbine (24V)



$$P_{WG_{avg}} = 35.3405\ [W] \quad (197)$$

$$Energy = 26.293\ [kWh] \quad (198)$$

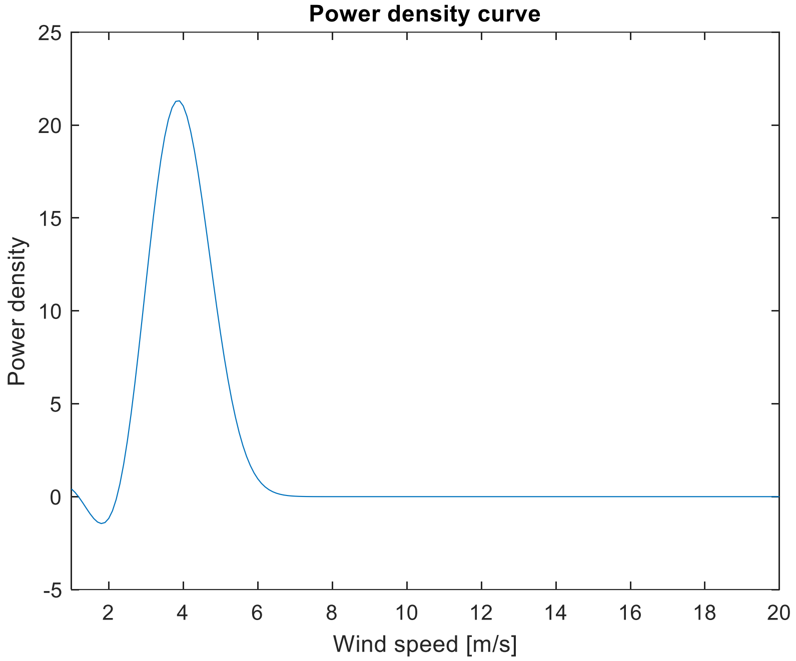
Automaxx 1500W wind turbine



$$P_{WG_{avg}} = 69.8462\ [W] \quad (199)$$

$$Energy = 51.966\ [kWh] \quad (200)$$

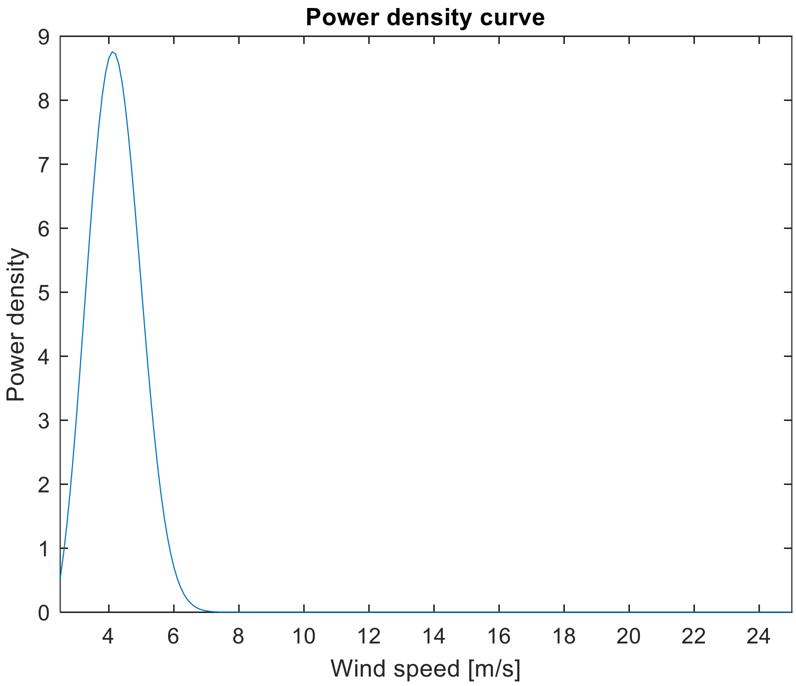
Bornay Wind 13+ wind turbine



$$P_{WG_{avg}} = 41.2001[W] \tag{201}$$

$$Energy = 30.653\ [kWh] \tag{202}$$

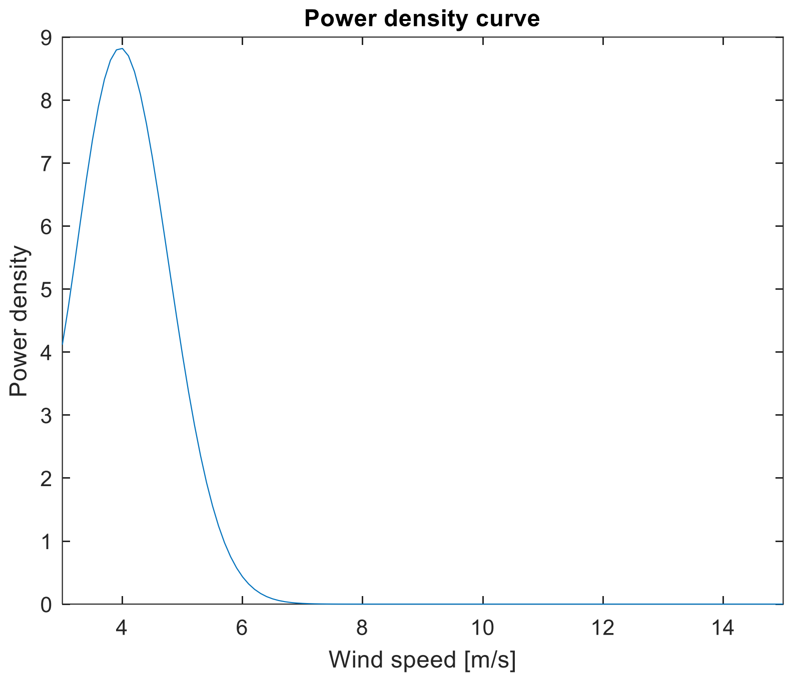
Fortis Passaat 1.4kW wind turbine



$$P_{WG_{avg}} = 17.3594\ [W] \tag{203}$$

$$Energy = 12.915\ [kWh] \tag{204}$$

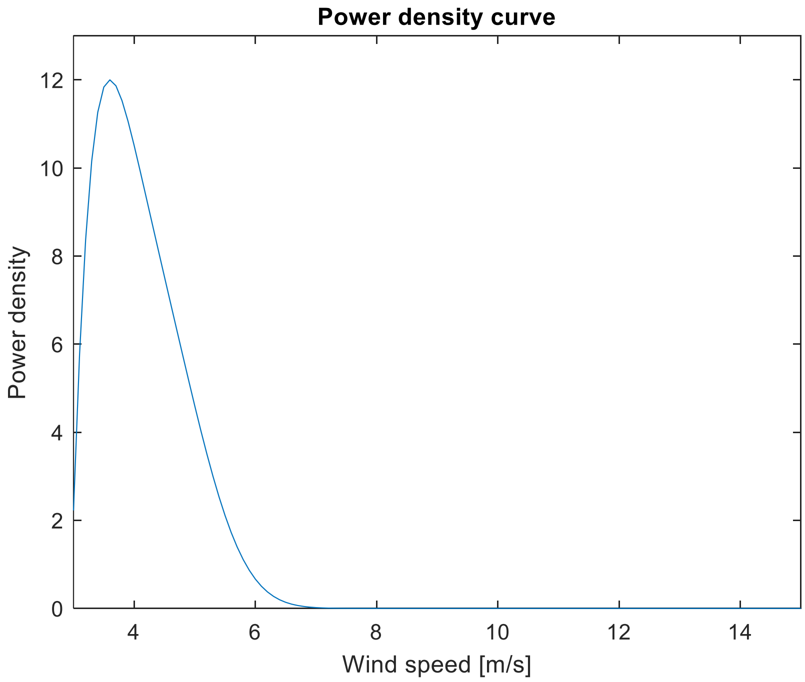
Hi-VAWT DS700



$$P_{WG_{avg}} = 15.7944\ [W] \quad (205)$$

$$Energy = 11.751\ [kWh] \quad (206)$$

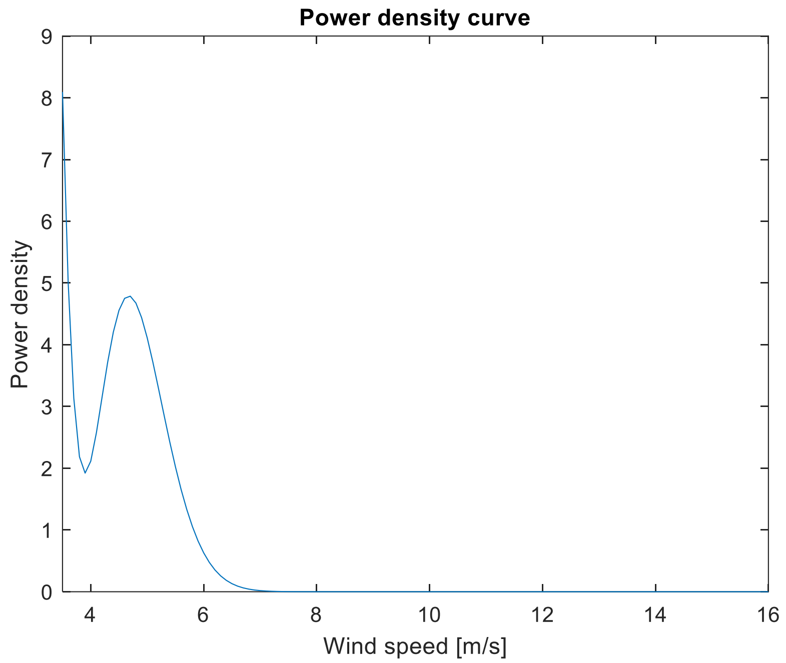
Hi-VAWT DS1500



$$P_{WG_{avg}} = 20.0691\ [W] \quad (207)$$

$$Energy = 14.931\ [kWh] \quad (208)$$

Superwind 1250 wind turbine

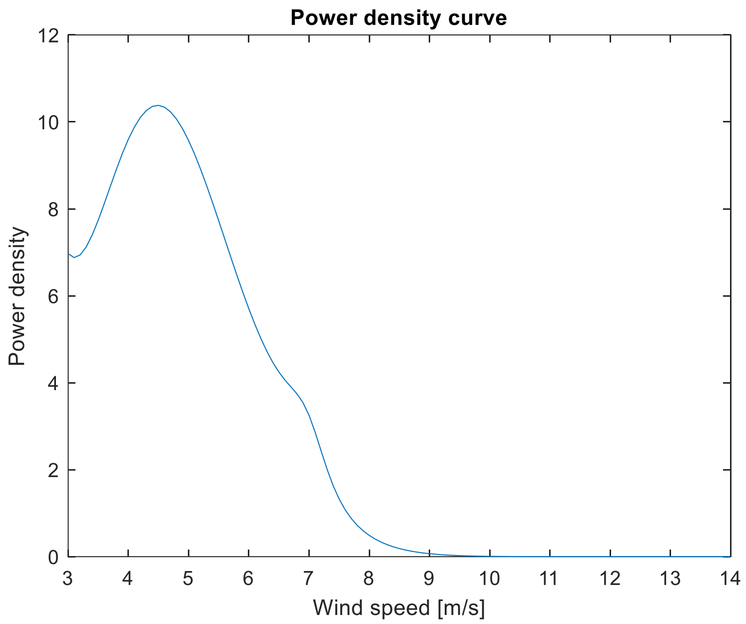


$$P_{WG_{avg}} = 8.0855\ [W] \quad (209)$$

$$Energy = 6.0156\ [kWh] \quad (210)$$

June

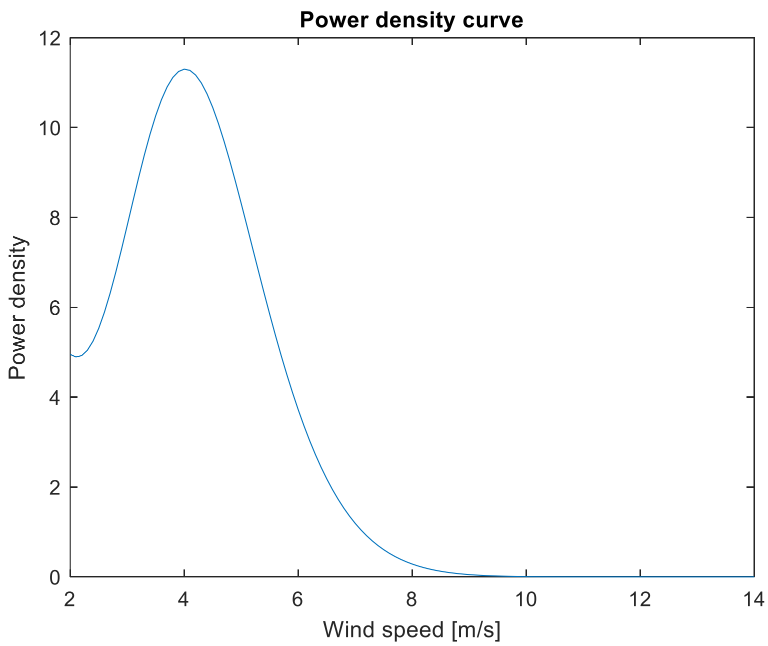
Automaxx 400W wind turbine



$$P_{WG_{avg}} = 31.8598\ [W] \quad (211)$$

$$Energy = 22.939\ [kWh] \quad (212)$$

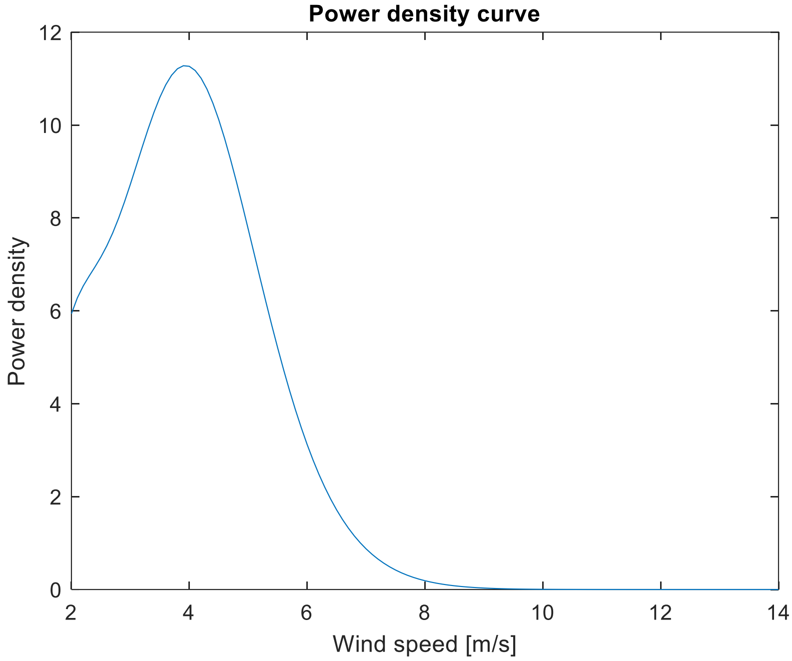
Automaxx 600W (12V) wind turbine



$$P_{WG_{avg}} = 35.0686\ [W] \quad (213)$$

$$Energy = 25.249\ [kWh] \quad (214)$$

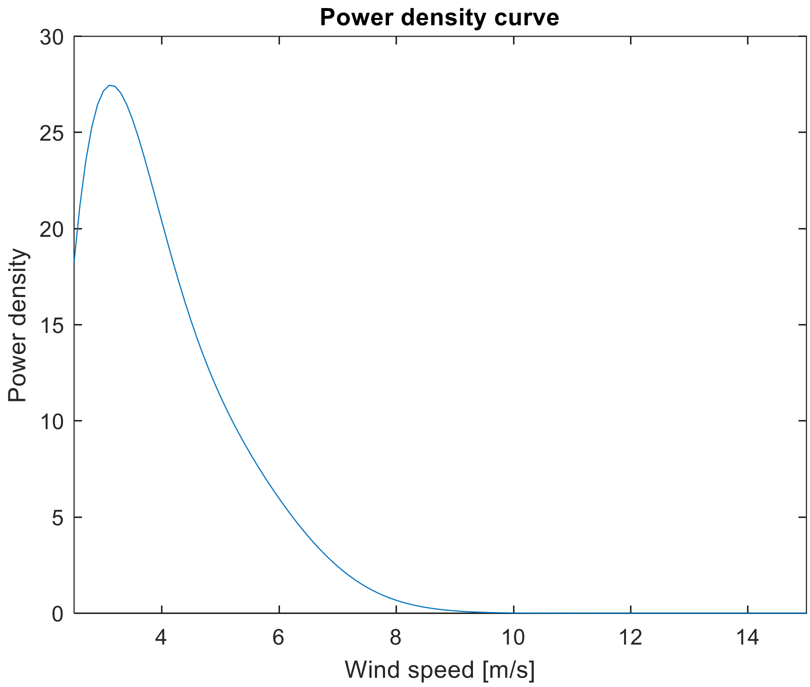
Automaxx 600W wind turbine (24V)



$$P_{WG_{avg}} = 35.1965[W] \quad (215)$$

$$Energy = 25.341\ [kWh] \quad (216)$$

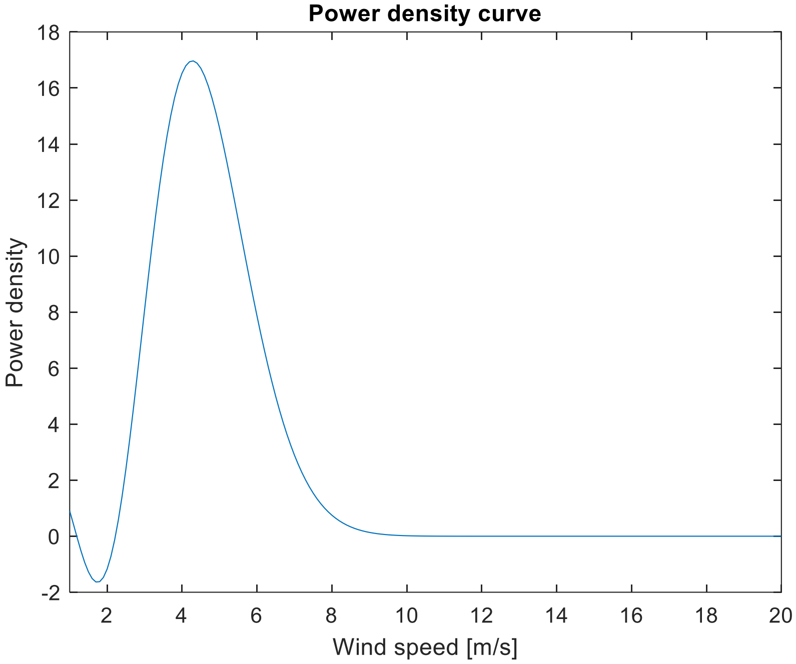
Automaxx 1500W wind turbine



$$P_{WG_{avg}} = 66.6389\ [W] \quad (217)$$

$$Energy = 47.980\ [kWh] \quad (218)$$

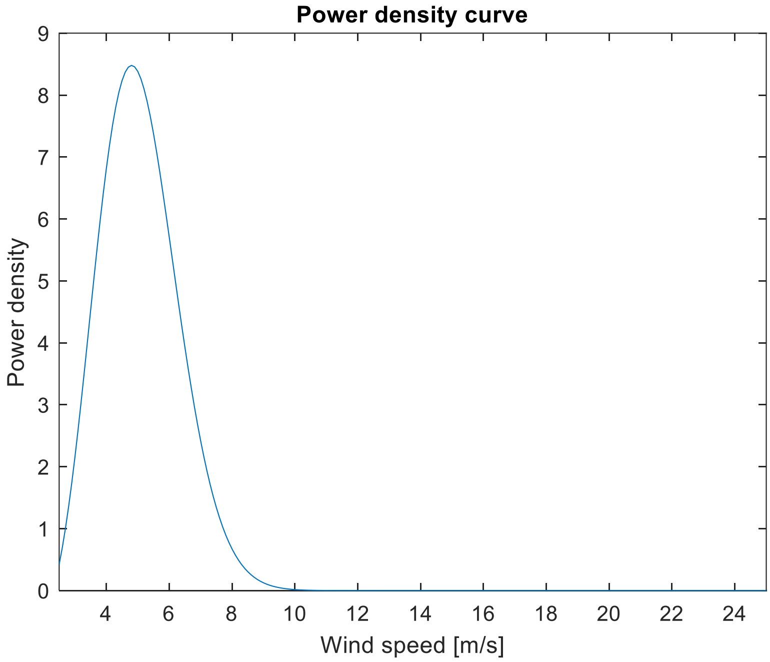
Bornay Wind 13+ wind turbine



$$P_{WG_{avg}} = 49.7069\ [W] \quad (219)$$

$$Energy = 35.789\ [kWh] \quad (220)$$

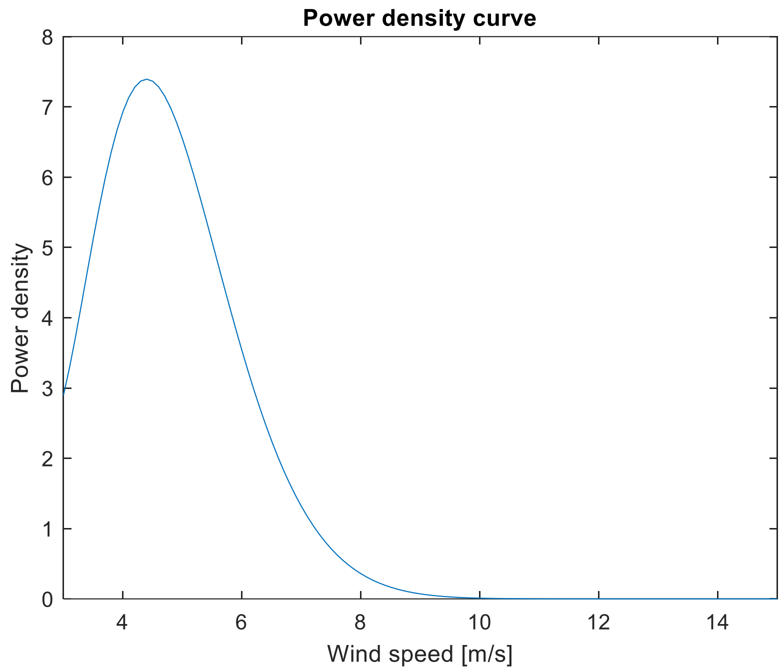
Fortis Passaat 1.4kW wind turbine



$$P_{WG_{avg}} = 26.1890\ [W] \quad (221)$$

$$Energy = 18.856\ [kWh] \quad (222)$$

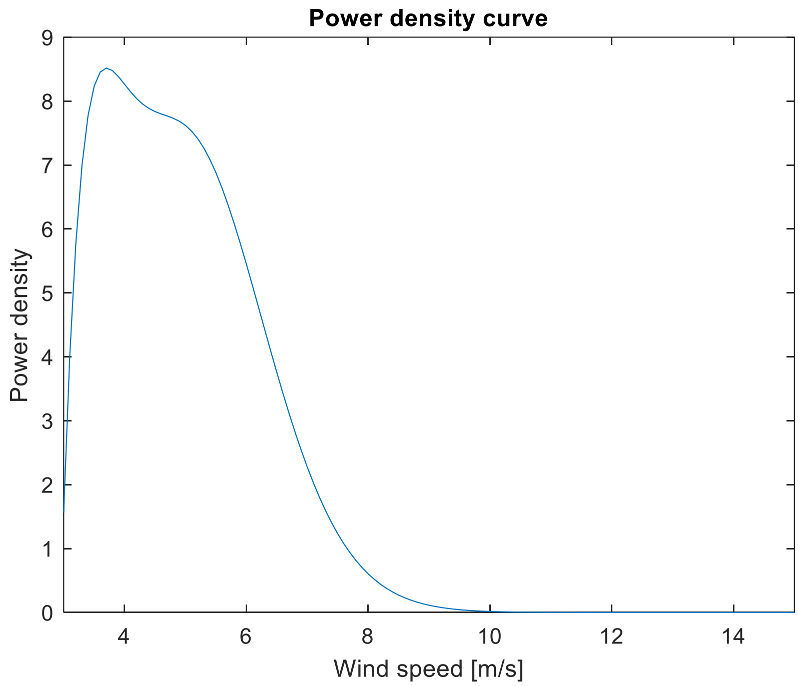
Hi-VAWT DS700



$$P_{WG_{avg}} = 20.5435\ [W] \tag{223}$$

$$Energy = 14.791\ [kWh] \tag{224}$$

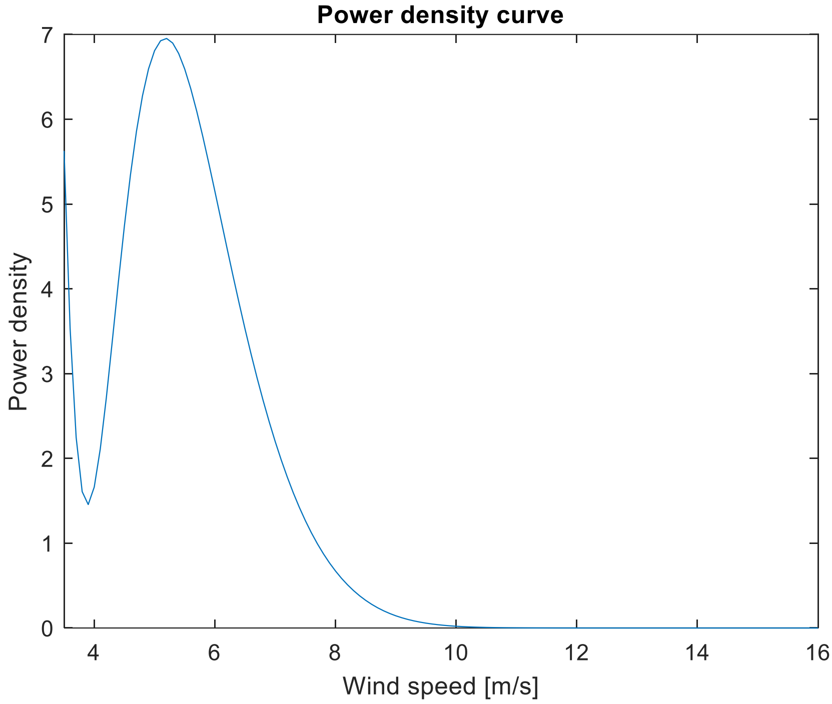
Hi-VAWT DS1500



$$P_{WG_{avg}} = 27.2431[W] \tag{225}$$

$$Energy = 19.615\ [kWh] \tag{226}$$

Superwind 1250 wind turbine

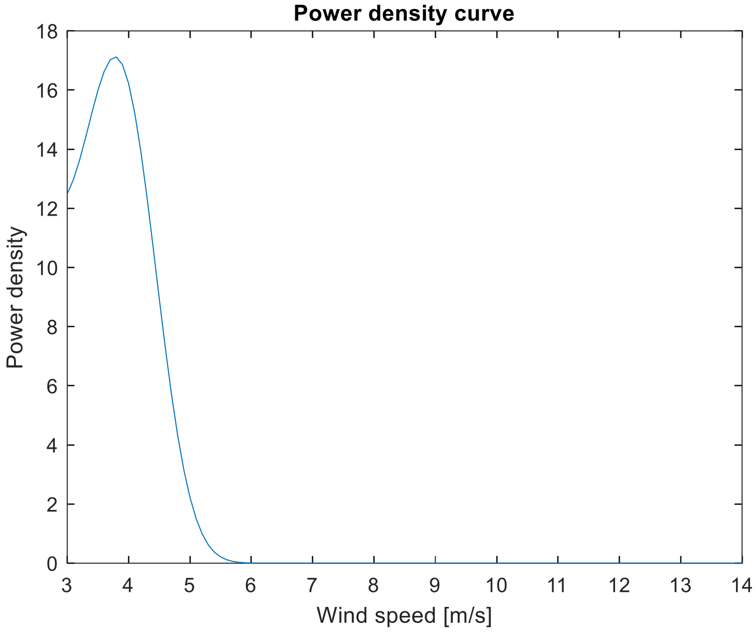


$$P_{WG_{avg}} = 17.5012\ [W] \tag{227}$$

$$Energy = 12.601\ [kWh] \tag{228}$$

July

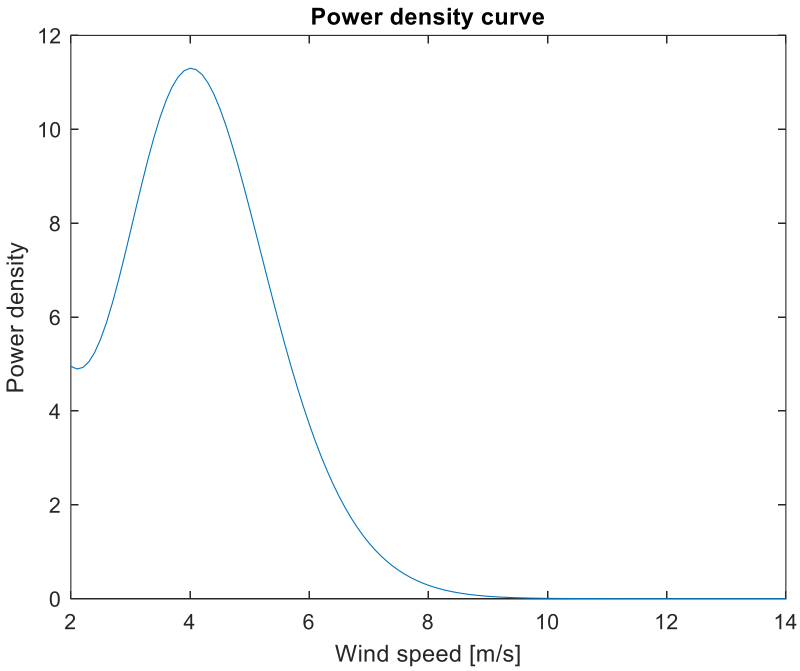
Automaxx 400W wind turbine



$$P_{WG_{avg}} = 25.0027\ [W] \quad (229)$$

$$Energy = 18.602\ [kWh] \quad (230)$$

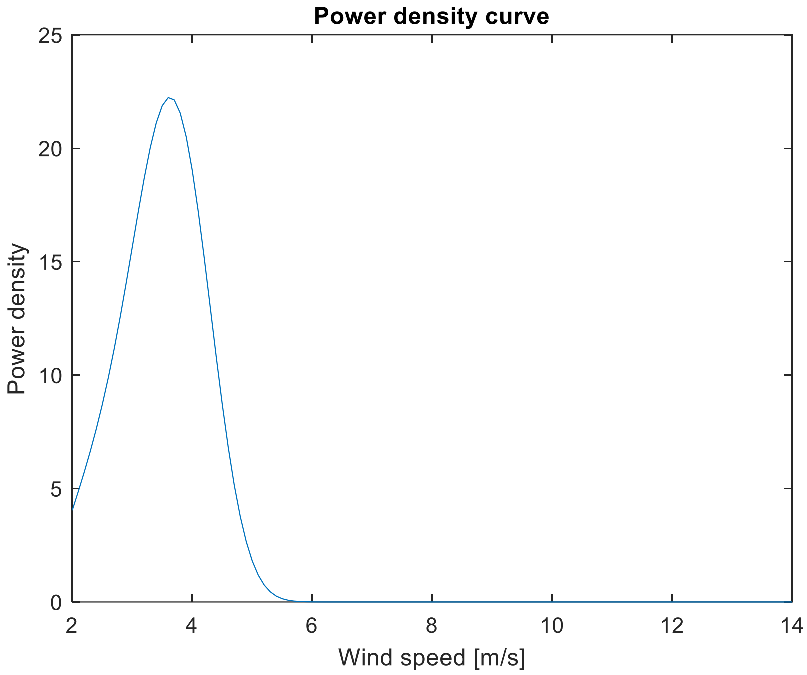
Automaxx 600W (12V) wind turbine



$$P_{WG_{avg}} = 36.9821\ [W] \quad (231)$$

$$Energy = 27.515\ [kWh] \quad (232)$$

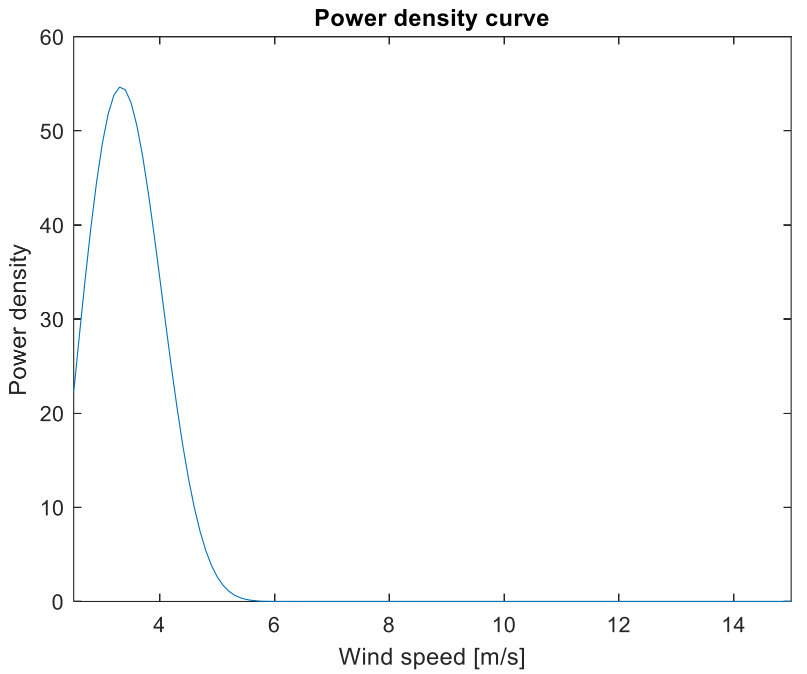
Automaxx 600W wind turbine (24V)



$$P_{WG_{avg}} = 39.1282\ [W] \tag{233}$$

$$Energy = 29.111\ [kWh] \tag{234}$$

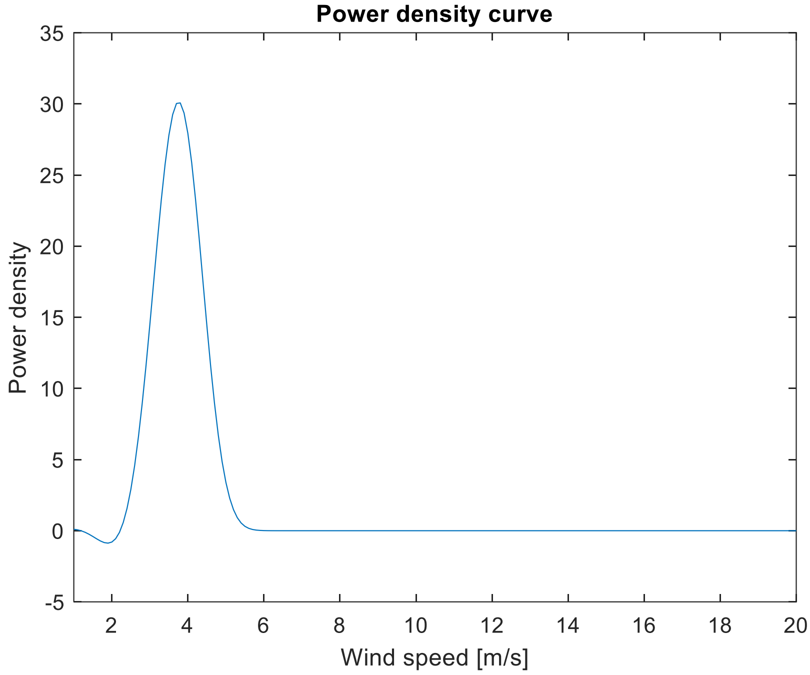
Automaxx 1500W wind turbine



$$P_{WG_{avg}} = 82.7769\ [W] \tag{235}$$

$$Energy = 61.586\ [kWh] \tag{236}$$

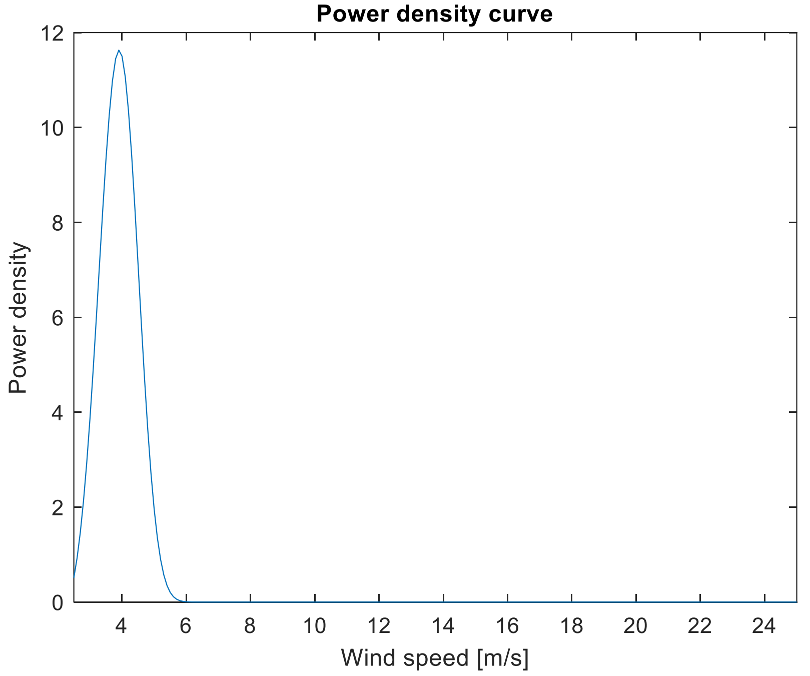
Bornay Wind 13+ wind turbine



$$P_{WG_{avg}} = 45.0220\ [W] \tag{237}$$

$$Energy = 33.496\ [kWh] \tag{238}$$

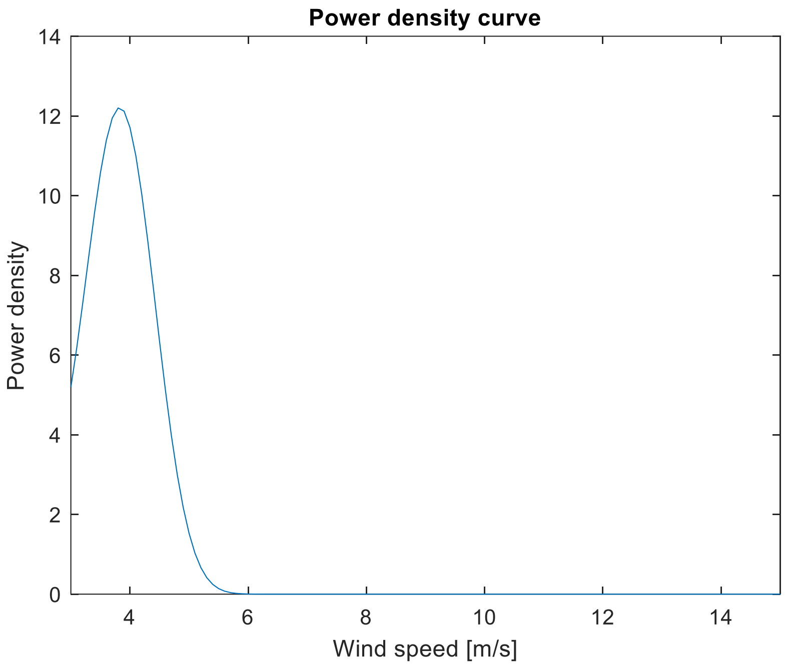
Fortis Passaat 1.4kW wind turbine



$$P_{WG_{avg}} = 17.1677\ [W] \tag{239}$$

$$Energy = 12.773\ [kWh] \tag{240}$$

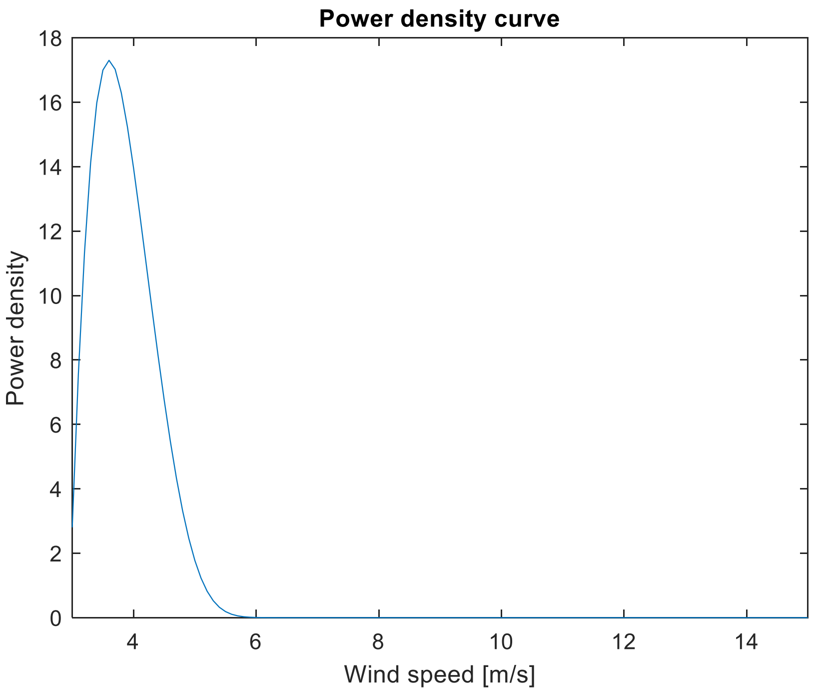
Hi-VAWT DS700



$$P_{WG_{avg}} = 16.6350\ [W] \tag{241}$$

$$Energy = 12.376\ [kWh] \tag{242}$$

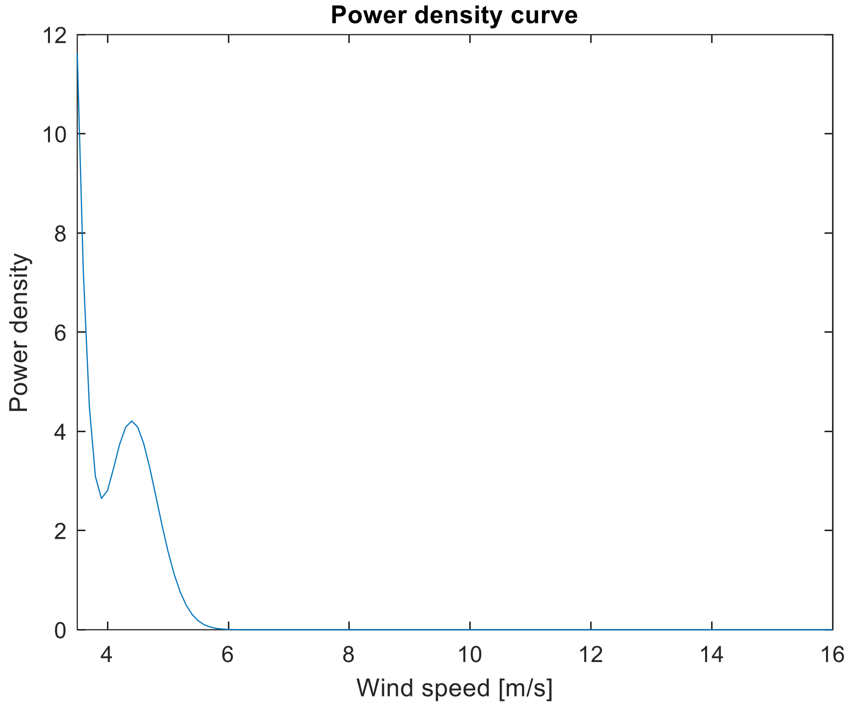
Hi-VAWT DS1500



$$P_{WG_{avg}} = 21.5974\ [W] \tag{243}$$

$$Energy = 16.068\ [kWh] \tag{244}$$

Superwind 1250 wind turbine

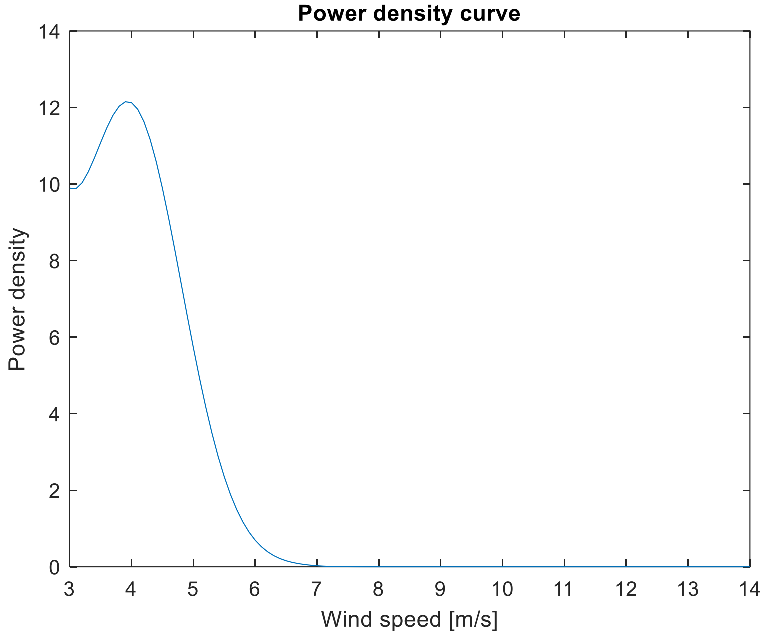


$$P_{WG_{avg}} = 6.1950\ [W] \quad (245)$$

$$Energy = 4.6091\ [kWh] \quad (246)$$

August

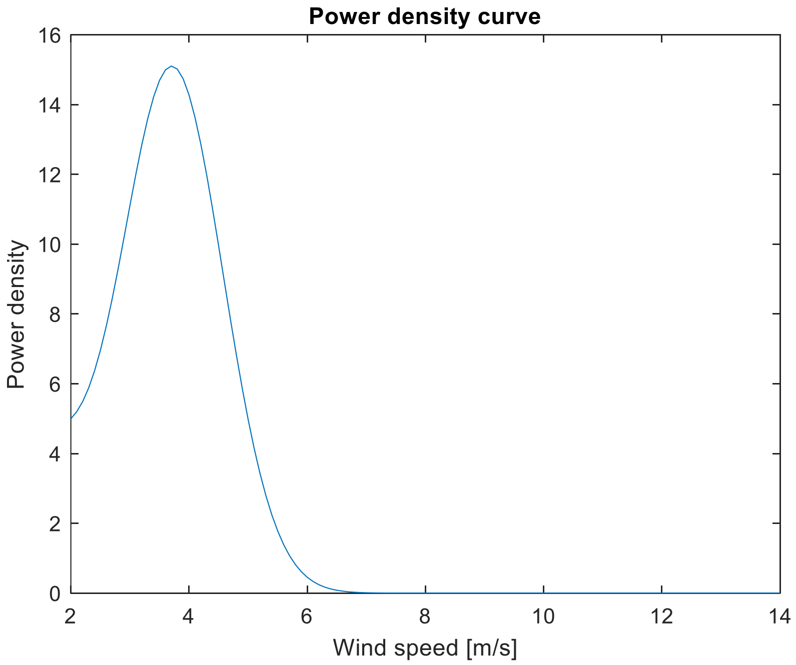
Automaxx 400W wind turbine



$$P_{WG_{avg}} = 23.4799\ [W] \tag{247}$$

$$Energy = 17.469\ [kWh] \tag{248}$$

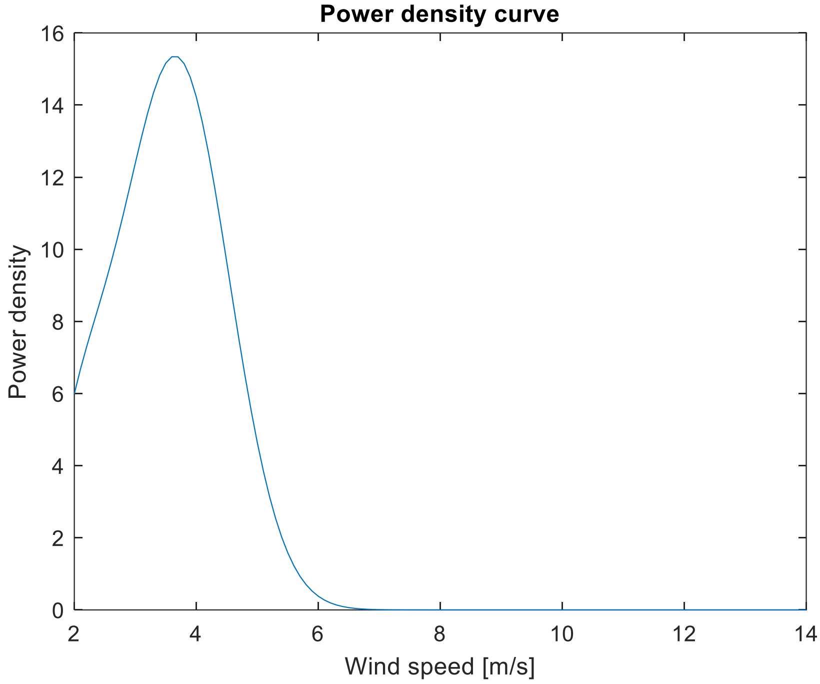
Automaxx 600W (12V) wind turbine



$$P_{WG_{avg}} = 33.4182\ [W] \tag{249}$$

$$Energy = 24.863\ [kWh] \tag{250}$$

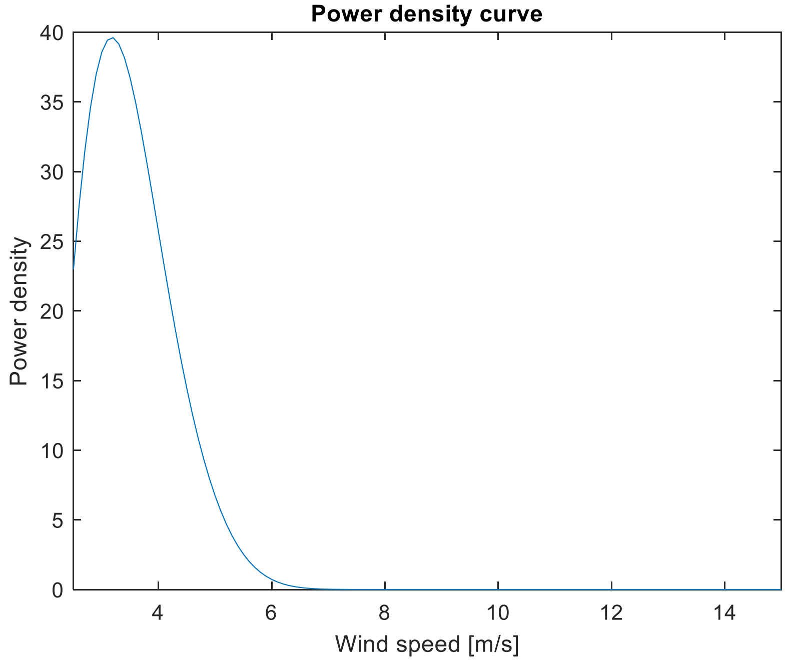
Automaxx 600W wind turbine (24V)



$$P_{WG_{avg}} = 35.1890\ [W] \tag{251}$$

$$Energy = 26.181\ [kWh] \tag{252}$$

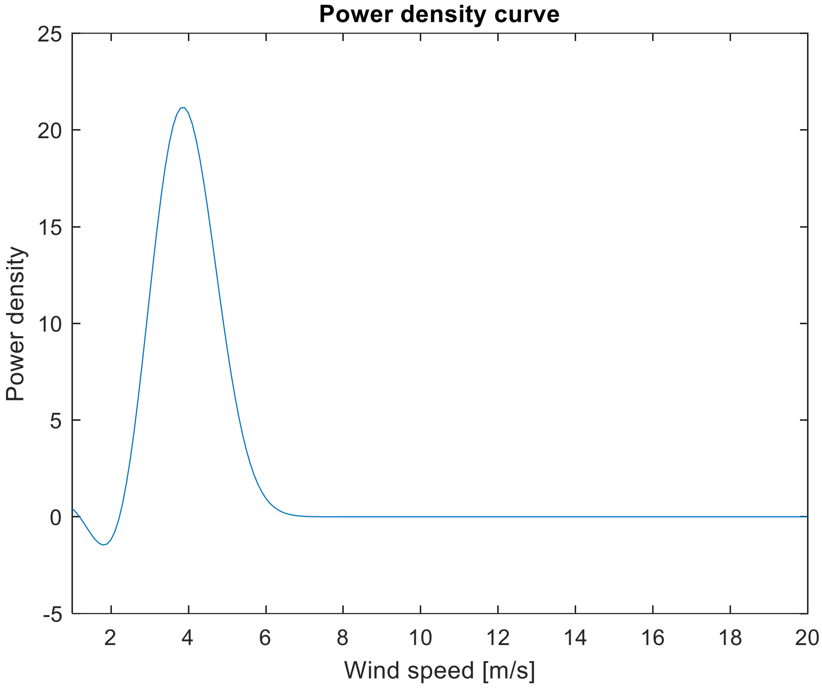
Automaxx 1500W wind turbine



$$P_{WG_{avg}} = 69.5371\ [W] \tag{253}$$

$$Energy = 51.736\ [kWh] \tag{254}$$

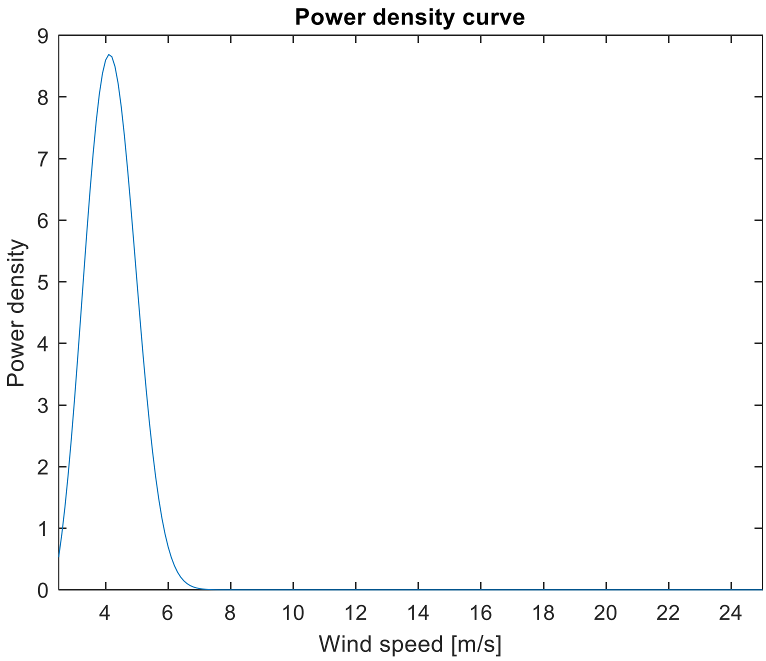
Bornay Wind 13+ wind turbine



$$P_{WG_{avg}} = 40.9357\ [W] \tag{255}$$

$$Energy = 30.456\ [kWh] \tag{256}$$

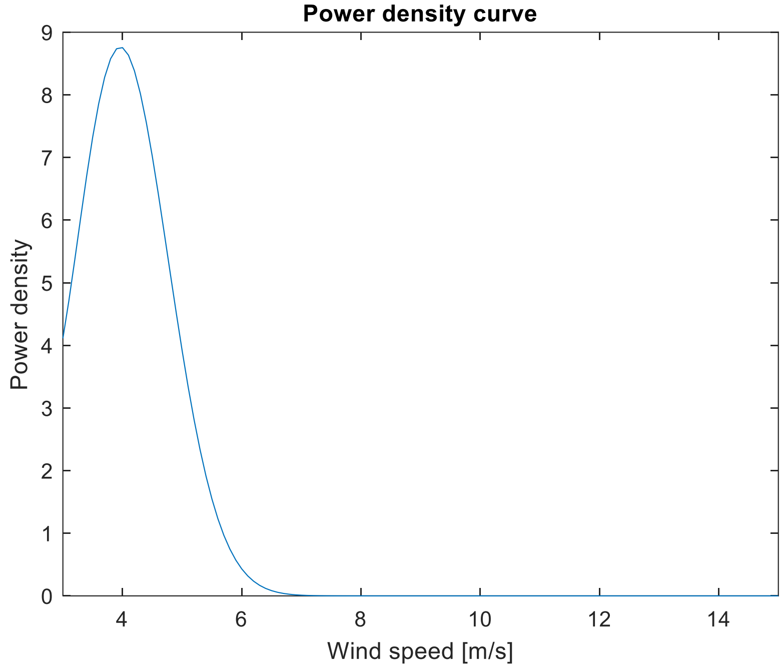
Fortis Passaat 1.4kW wind turbine



$$P_{WG_{avg}} = 17.2412\ [W] \tag{257}$$

$$Energy = 12.827\ [kWh] \tag{258}$$

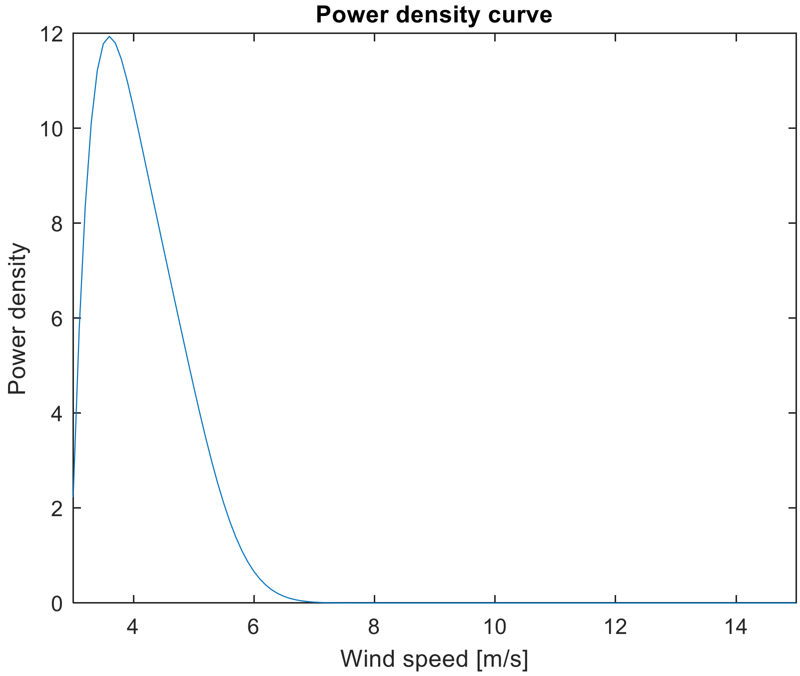
Hi-VAWT DS700



$$P_{WG_{avg}} = 15.6852\ [W] \tag{259}$$

$$Energy = 11.670\ [kWh] \tag{260}$$

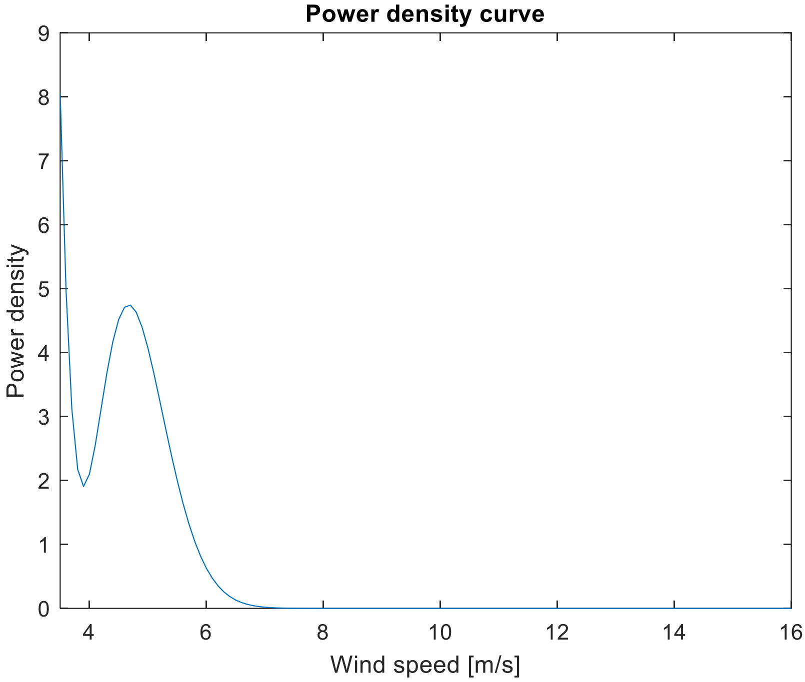
Hi-VAWT DS1500



$$P_{WG_{avg}} = 19.9352\ [W] \tag{261}$$

$$Energy = 14.832\ [kWh] \tag{262}$$

Superwind 1250 wind turbine

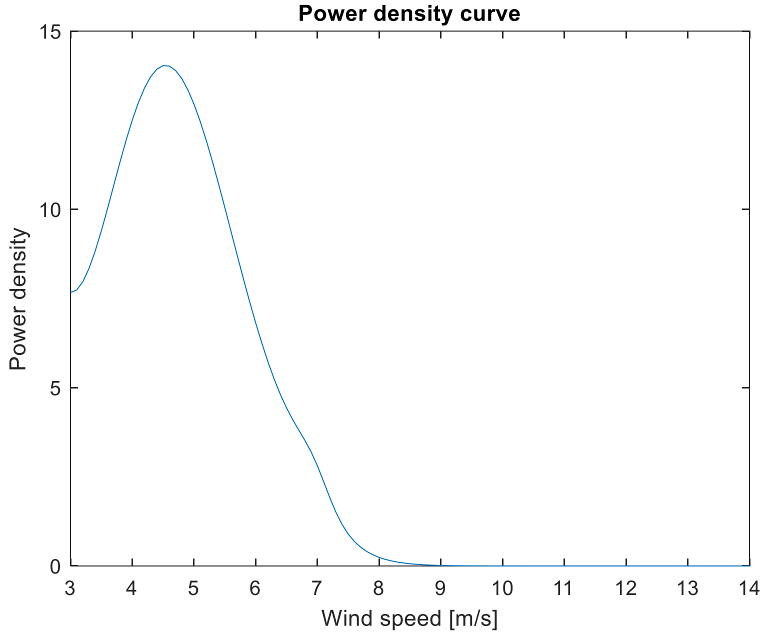


$$P_{WG_{avg}} = 8.0226\ [W] \quad (263)$$

$$Energy = 5.9688\ [kWh] \quad (264)$$

September

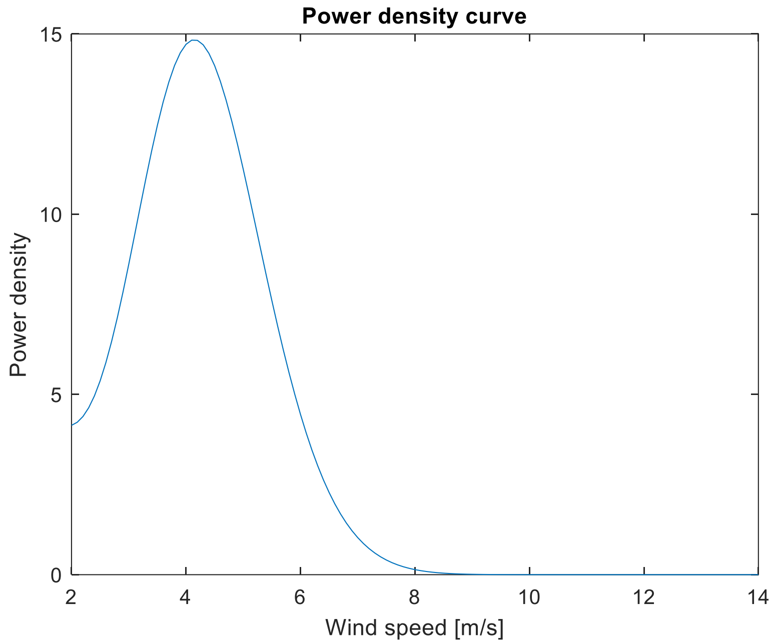
Automaxx 400W wind turbine



$$P_{WG_{avg}} = 39.0113\ [W] \quad (265)$$

$$Energy = 28.088\ [kWh] \quad (266)$$

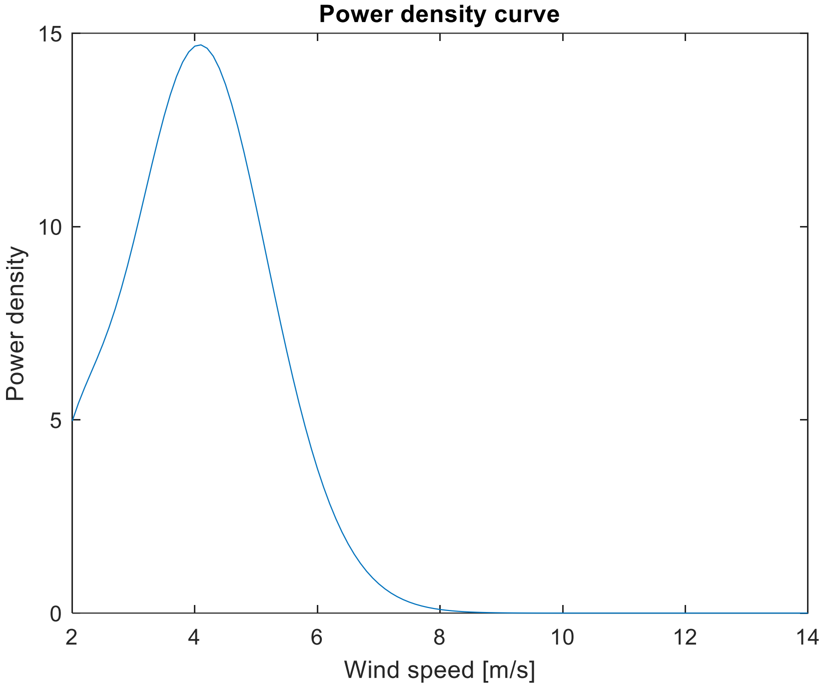
Automaxx 600W (12V) wind turbine



$$P_{WG_{avg}} = 42.2904\ [W] \quad [267]$$

$$Energy = 30.449\ [kWh] \quad [268]$$

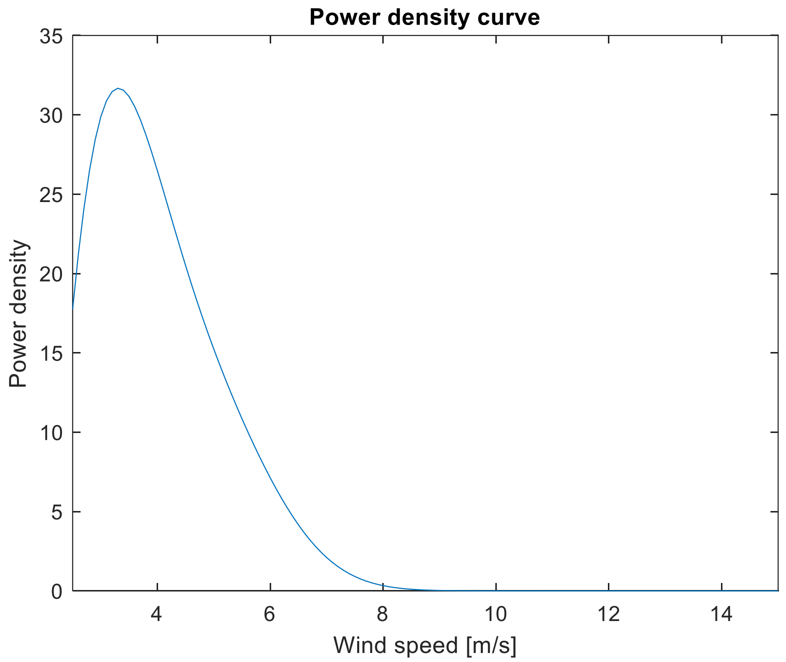
Automaxx 600W wind turbine (24V)



$$P_{WG_{avg}} = 42.2037\ [W] \tag{269}$$

$$Energy = 30.387\ [kWh] \tag{270}$$

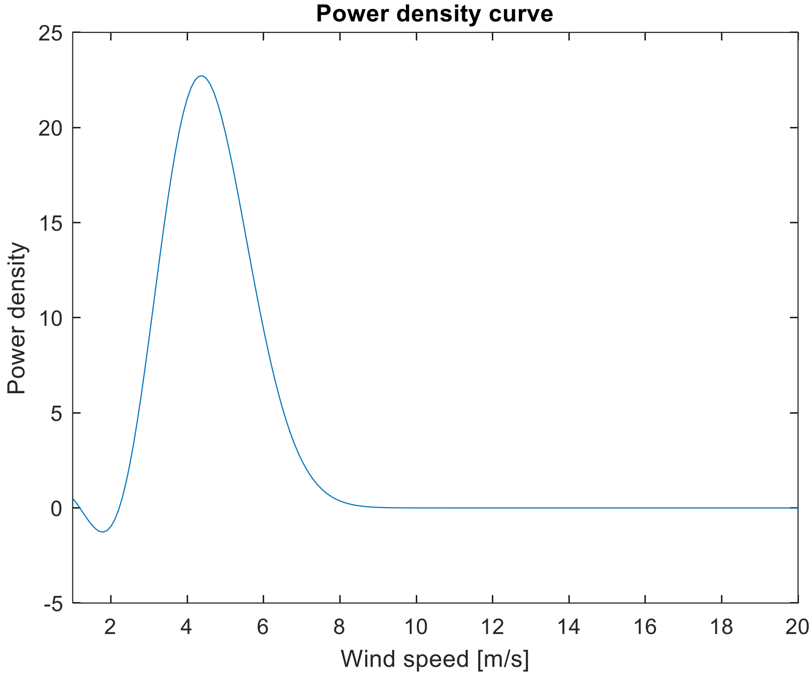
Automaxx 1500W wind turbine



$$P_{WG_{avg}} = 79.6315\ [W] \tag{271}$$

$$Energy = 57.335\ [kWh] \tag{272}$$

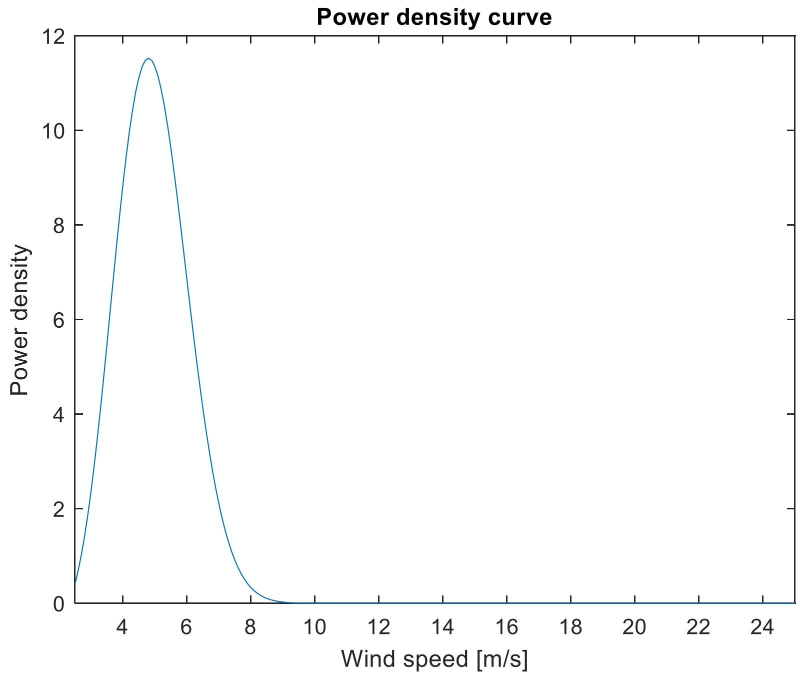
Bornay Wind 13+ wind turbine



$$P_{WG_{avg}} = 61.5061\ [W] \tag{273}$$

$$Energy = 44.284\ [kWh] \tag{274}$$

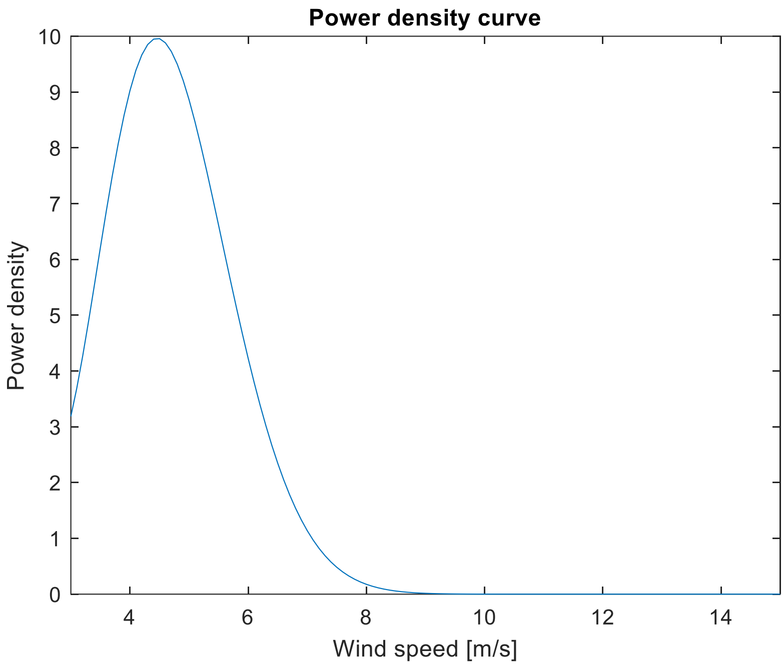
Fortis Passaat 1.4kW wind turbine



$$P_{WG_{avg}} = 31.7551\ [W] \tag{275}$$

$$Energy = 22.864\ [kWh] \tag{276}$$

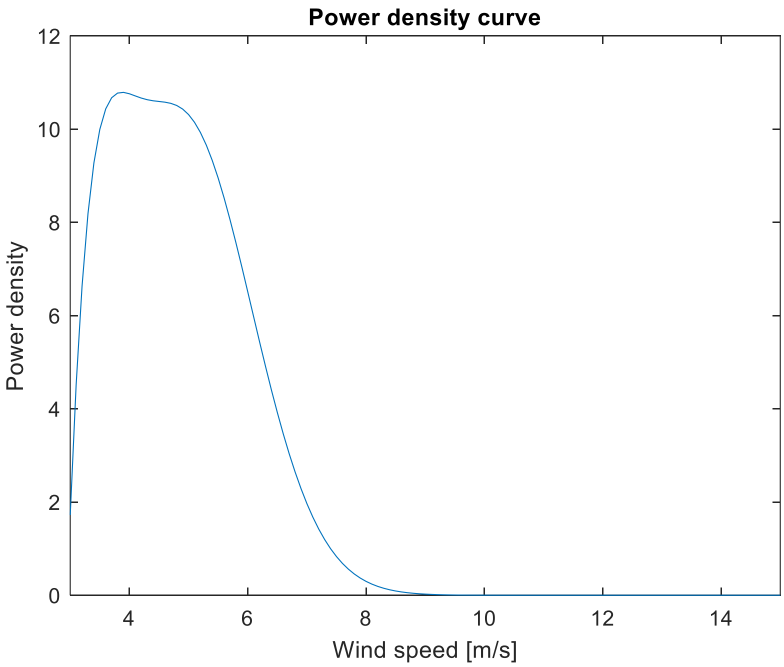
Hi-VAWT DS700



$$P_{WG_{avg}} = 25.4454\ [W] \quad (277)$$

$$Energy = 18.321\ [kWh] \quad (278)$$

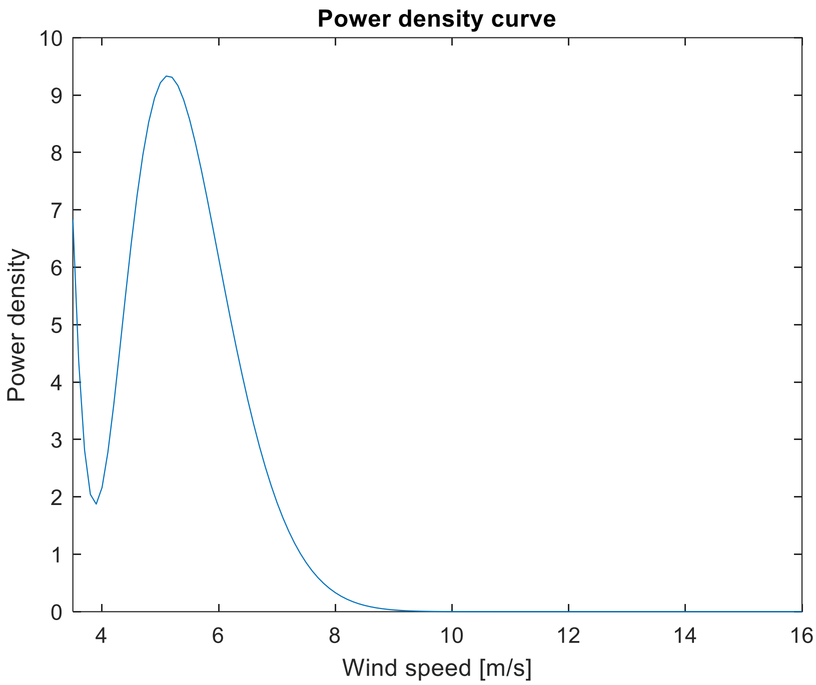
Hi-VAWT DS1500



$$P_{WG_{avg}} = 33.1831\ [W] \quad (279)$$

$$Energy = 23.892\ [kWh] \quad (280)$$

Superwind 1250 wind turbine

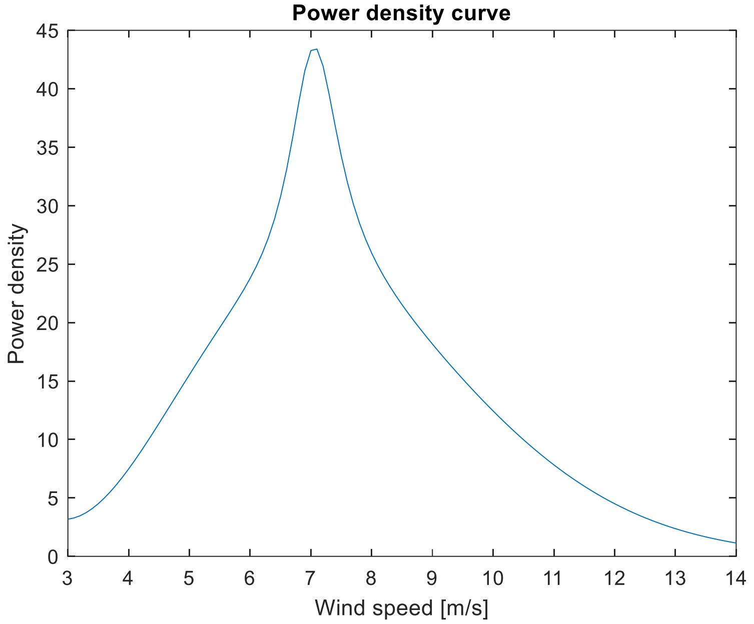


$$P_{WG_{avg}} = 20.8437\ [W] \tag{281}$$

$$Energy = 15.007\ [kWh] \tag{282}$$

October

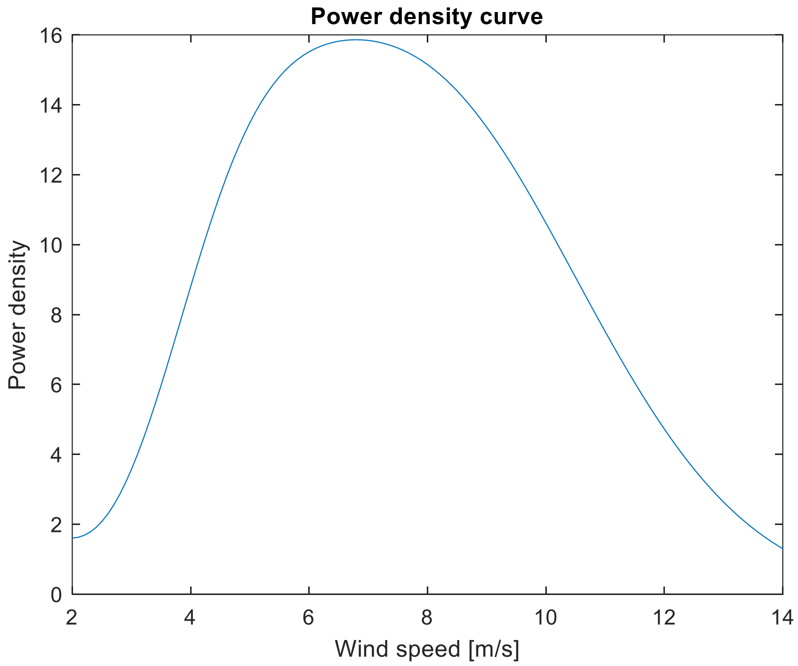
Automaxx 400W wind turbine



$$P_{WG_{avg}} = 160.713\ [W] \tag{283}$$

$$Energy = 119.57\ [kWh] \tag{284}$$

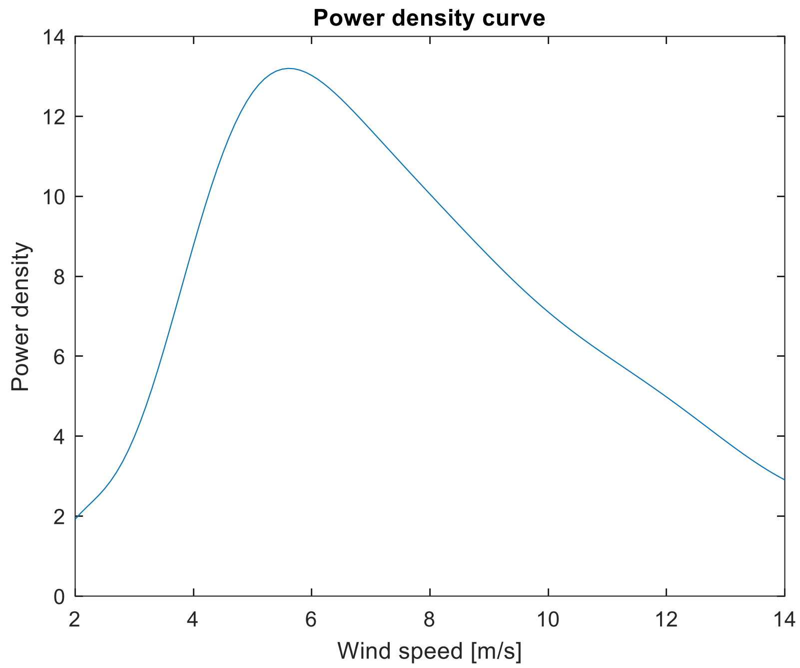
Automaxx 600W (12V) wind turbine



$$P_{WG_{avg}} = 112.7501\ [W] \tag{285}$$

$$Energy = 83.886\ [kWh] \tag{286}$$

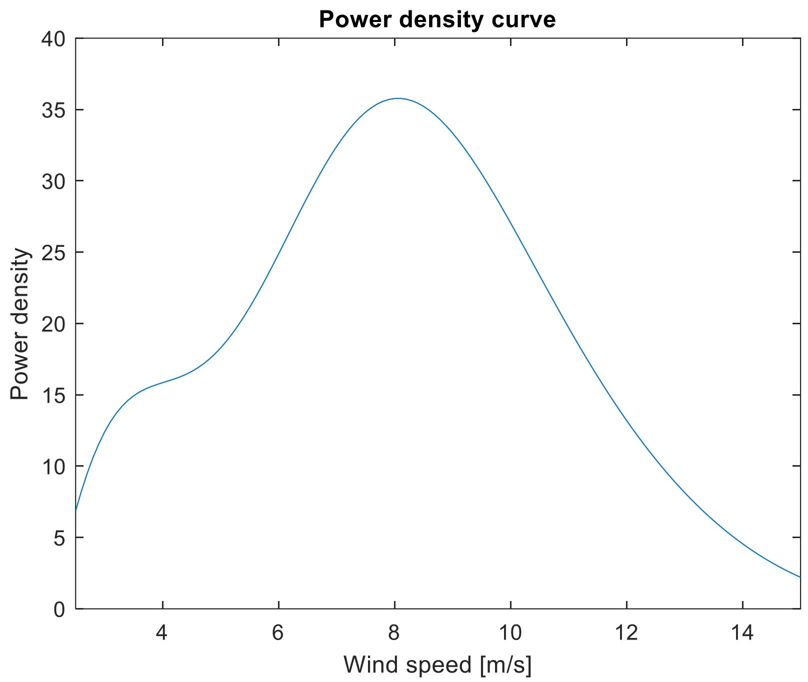
Automaxx 600W wind turbine (24V)



$$P_{WG_{avg}} = 93.1564\ [W] \quad (287)$$

$$Energy = 69.308\ [kWh] \quad (288)$$

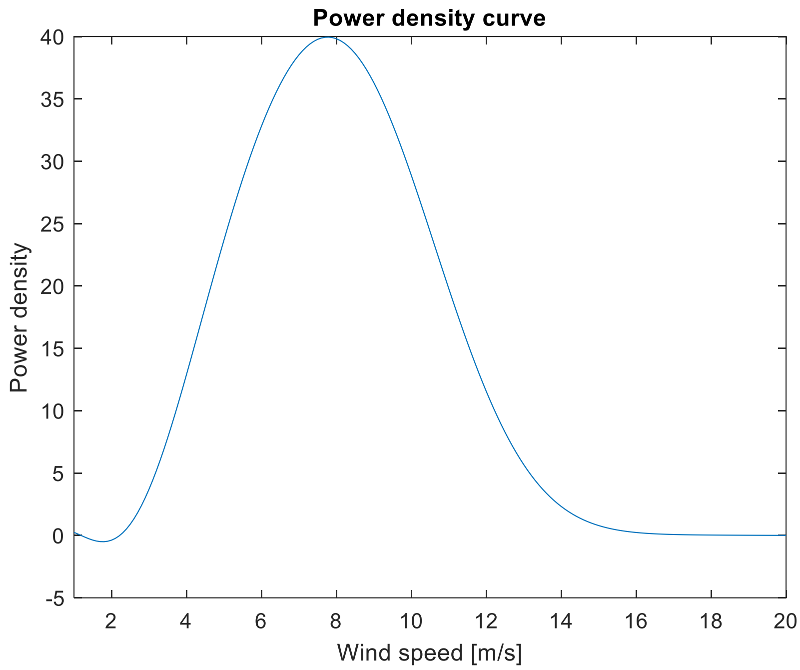
Automaxx 1500W wind turbine



$$P_{WG_{avg}} = 246.2462\ [W] \quad (289)$$

$$Energy = 177.3\ [kWh] \quad (290)$$

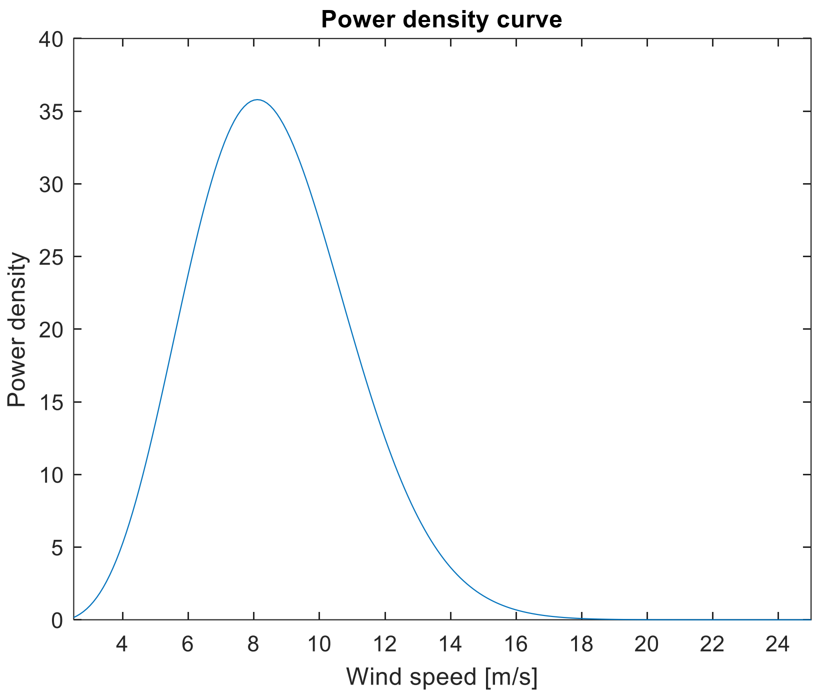
Bornay Wind 13+ wind turbine



$$P_{WG_{avg}} = 256.6922\ [W] \tag{291}$$

$$Energy = 190.98\ [kWh] \tag{292}$$

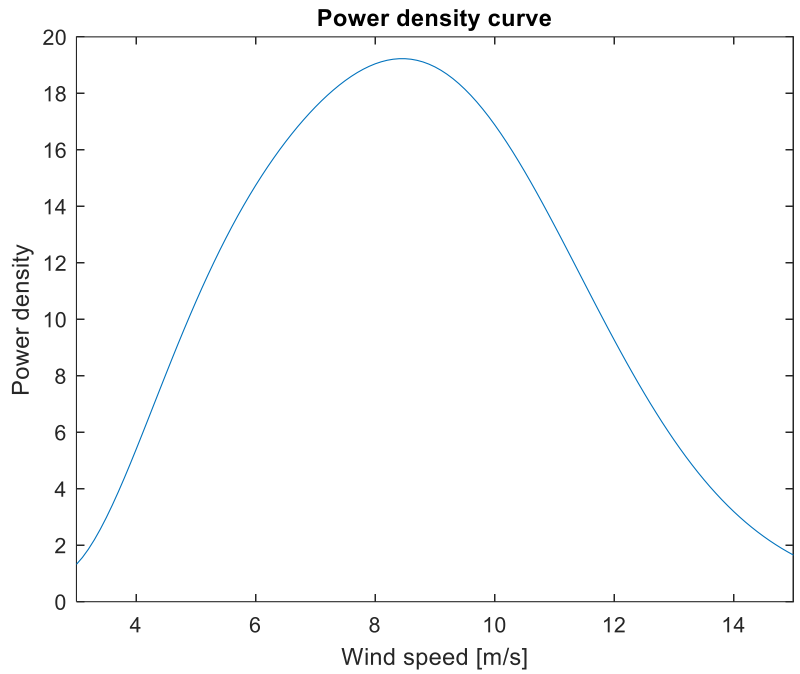
Fortis Passaat 1.4kW wind turbine



$$P_{WG_{avg}} = 218.3450\ [W] \tag{293}$$

$$Energy = 162.45\ [kWh] \tag{294}$$

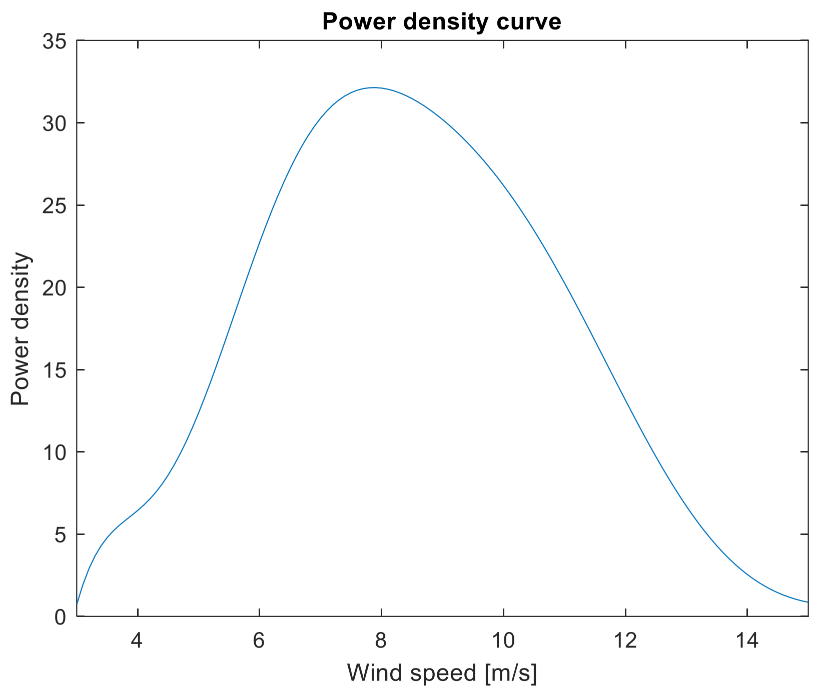
Hi-VAWT DS700



$$P_{WG_{avg}} = 136.4307\ [W] \tag{295}$$

$$Energy = 101.5\ [kWh] \tag{296}$$

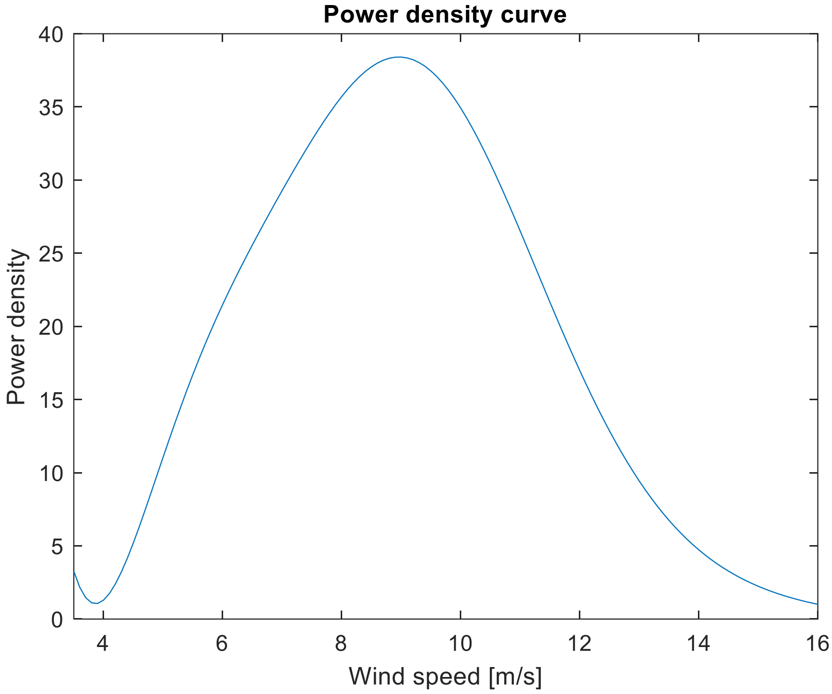
Hi-VAWT DS1500



$$P_{WG_{avg}} = 204.8425\ [W] \tag{297}$$

$$Energy = 152.4\ [kWh] \tag{298}$$

Superwind 1250 wind turbine

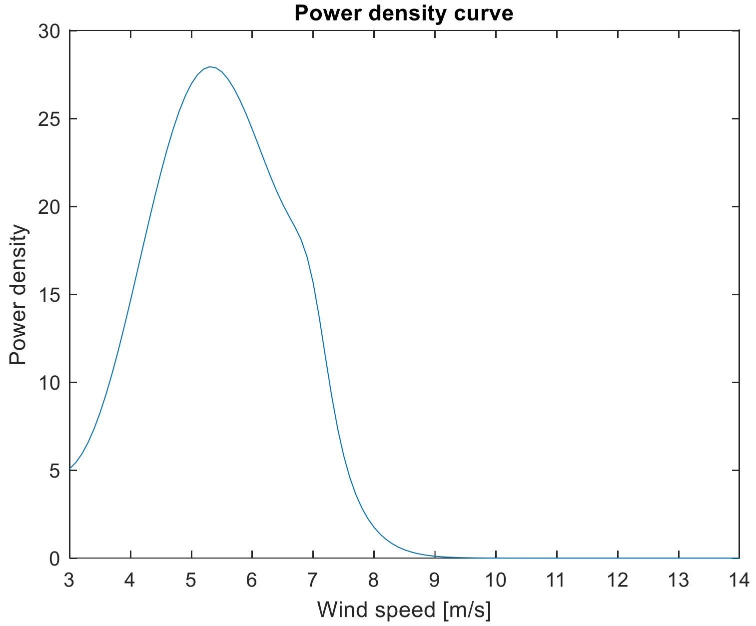


$$P_{WG_{avg}} = 233.1287\ [W] \quad (299)$$

$$Energy = 173.45\ [kWh] \quad (300)$$

November

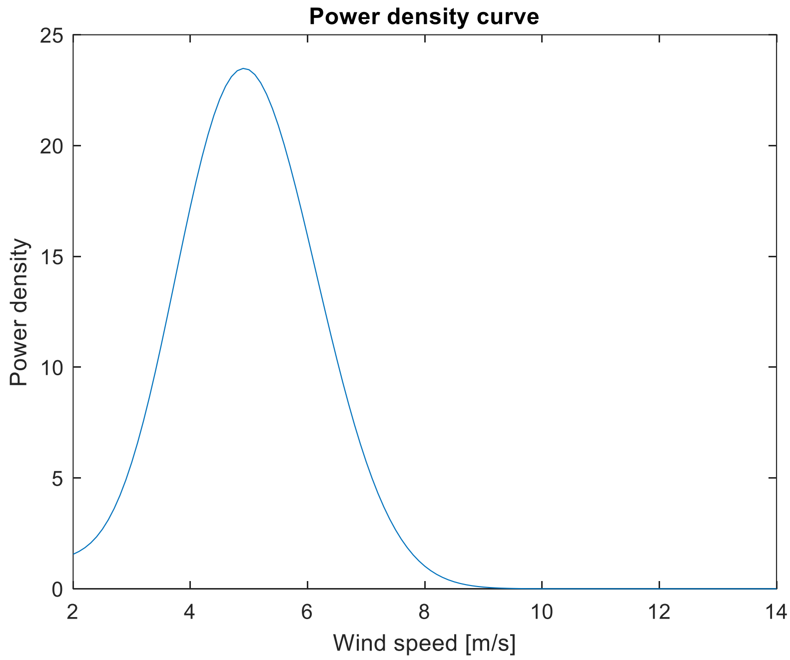
Automaxx 400W wind turbine



$$P_{WG_{avg}} = 85.1793\ [W] \quad (301)$$

$$Energy = 61.329\ [kWh] \quad (302)$$

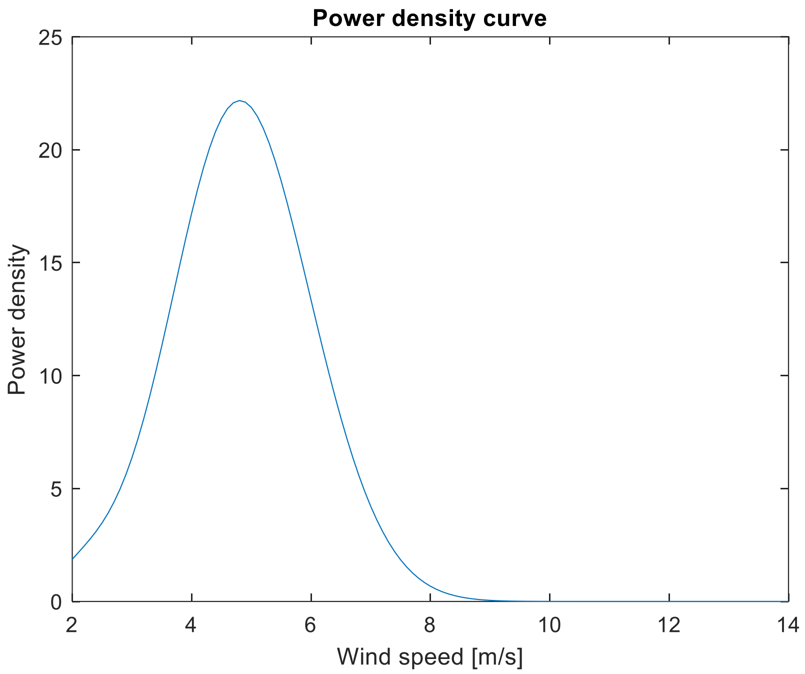
Automaxx 600W (12V) wind turbine



$$P_{WG_{avg}} = 69.9552\ [W] \quad (303)$$

$$Energy = 50.368\ [kWh] \quad (304)$$

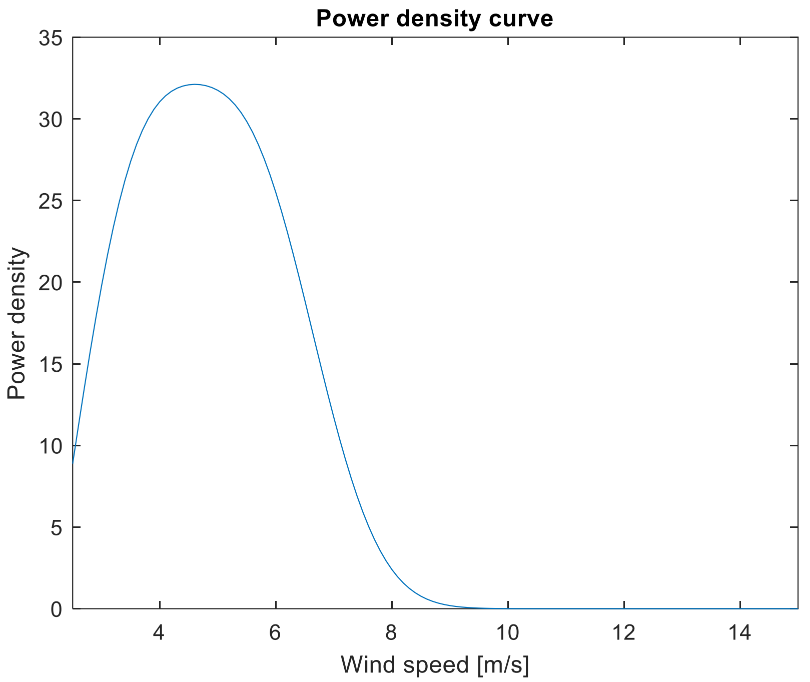
Automaxx 600W wind turbine (24V)



$$P_{WG_{avg}} = 64.8828\ [W] \quad (305)$$

$$Energy = 46.716\ [kWh] \quad (306)$$

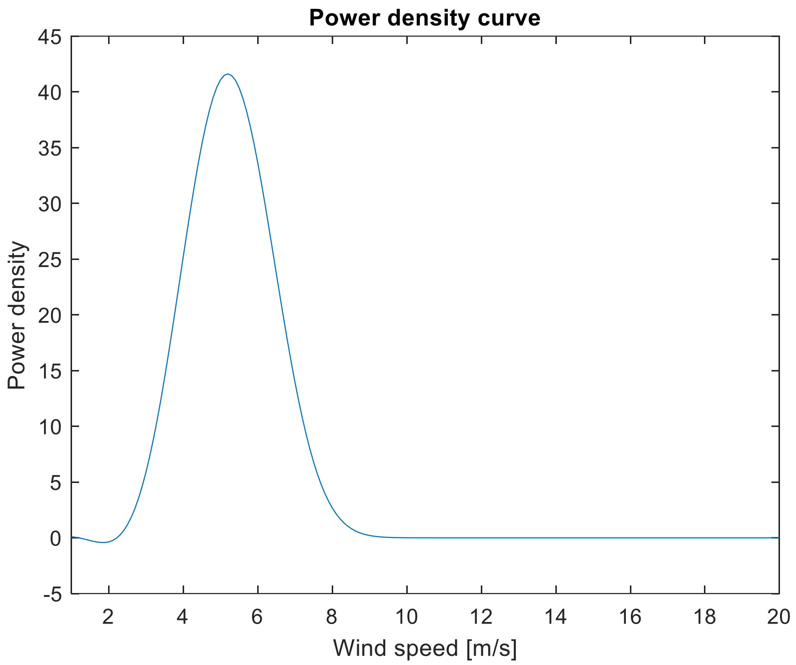
Automaxx 1500W wind turbine



$$P_{WG_{avg}} = 121.3883\ [W] \quad (307)$$

$$Energy = 87.4\ [kWh] \quad (308)$$

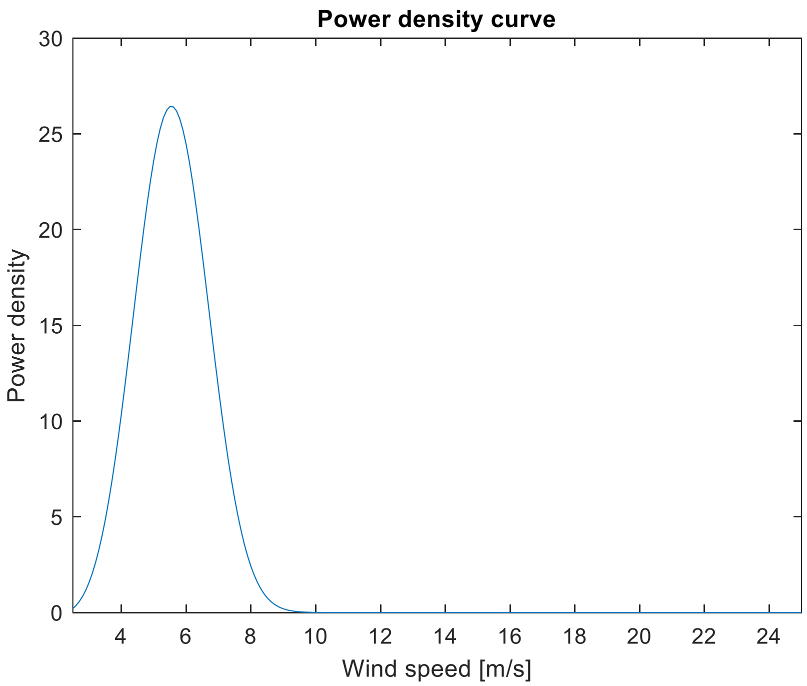
Bornay Wind 13+ wind turbine



$$P_{WG_{avg}} = 122.2965\ [W] \tag{309}$$

$$Energy = 88.053\ [kWh] \tag{310}$$

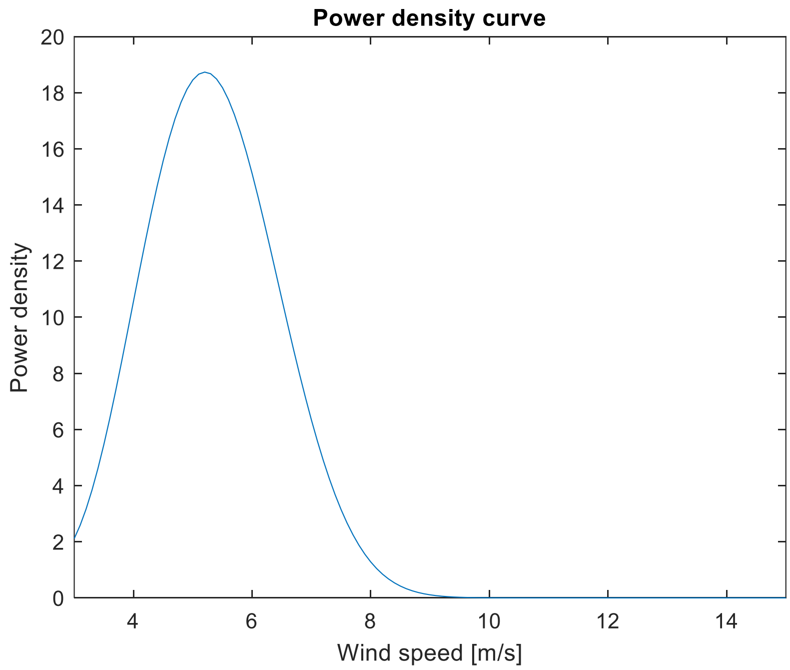
Fortis Passaat 1.4kW wind turbine



$$P_{WG_{avg}} = 74.2343\ [W] \tag{311}$$

$$Energy = 53.449\ [kWh] \tag{312}$$

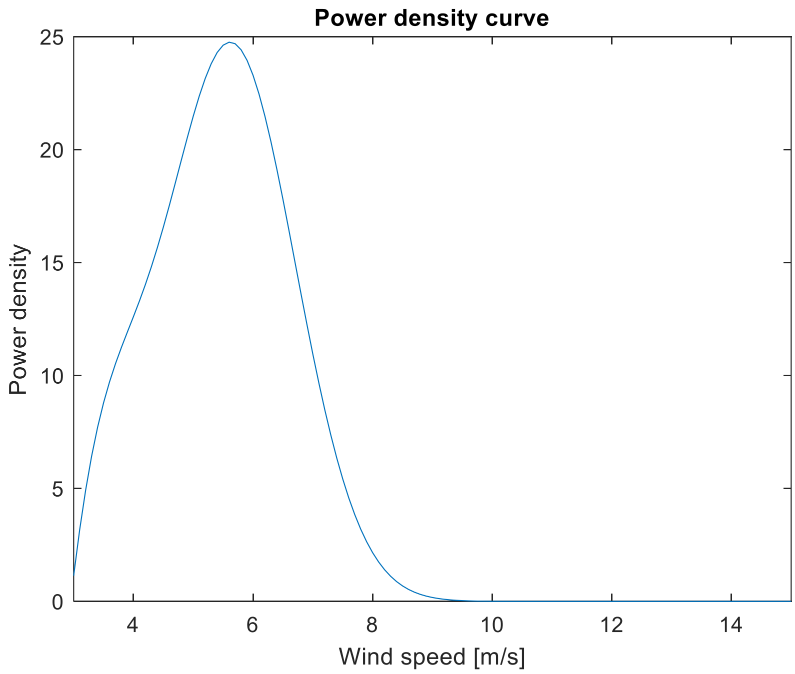
Hi-VAWT DS700



$$P_{WG_{avg}} = 53.2771\ [W] \quad (313)$$

$$Energy = 38.359\ [kWh] \quad (314)$$

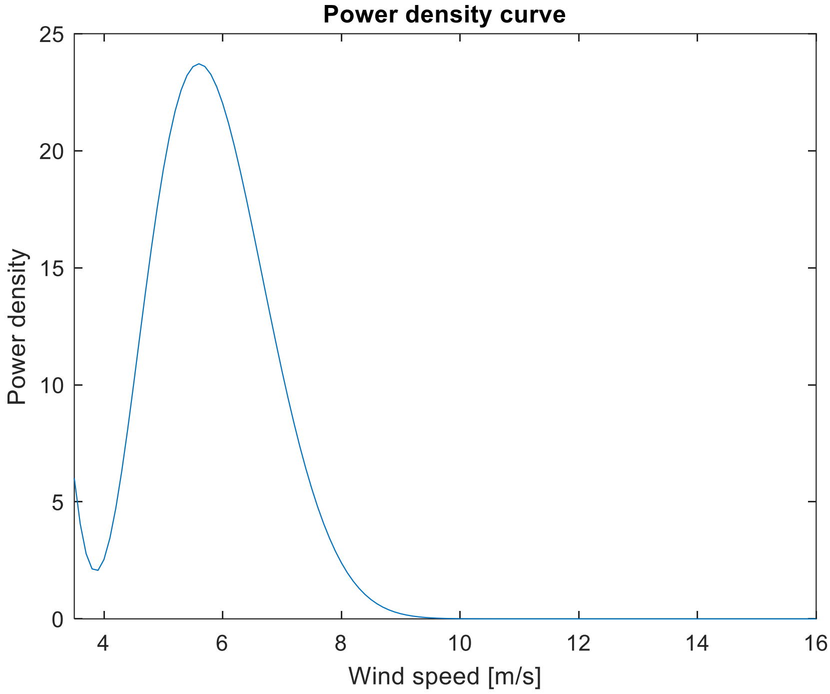
Hi-VAWT DS1500



$$P_{WG_{avg}} = 73.0095\ [W] \quad (315)$$

$$Energy = 52.567\ [kWh] \quad (316)$$

Superwind 1250 wind turbine

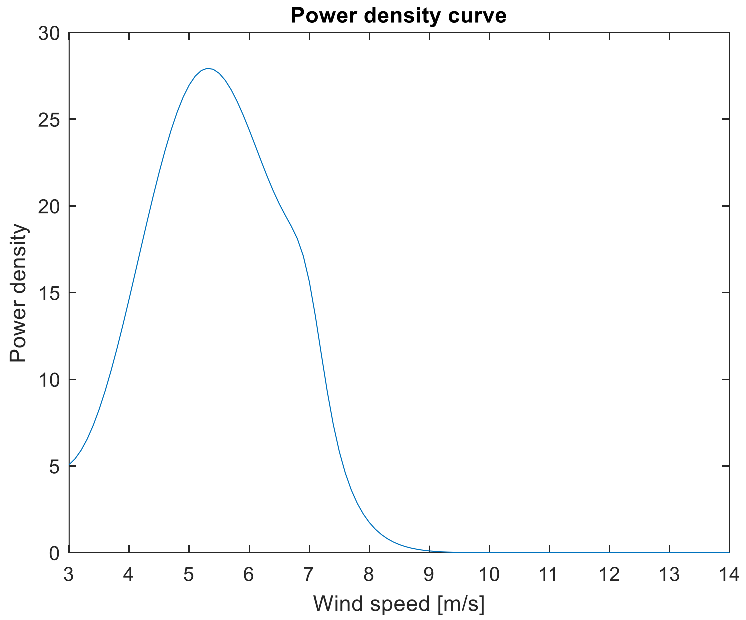


$$P_{WG_{avg}} = 57.9191\ [W] \quad (317)$$

$$Energy = 41.702\ [kWh] \quad (318)$$

December

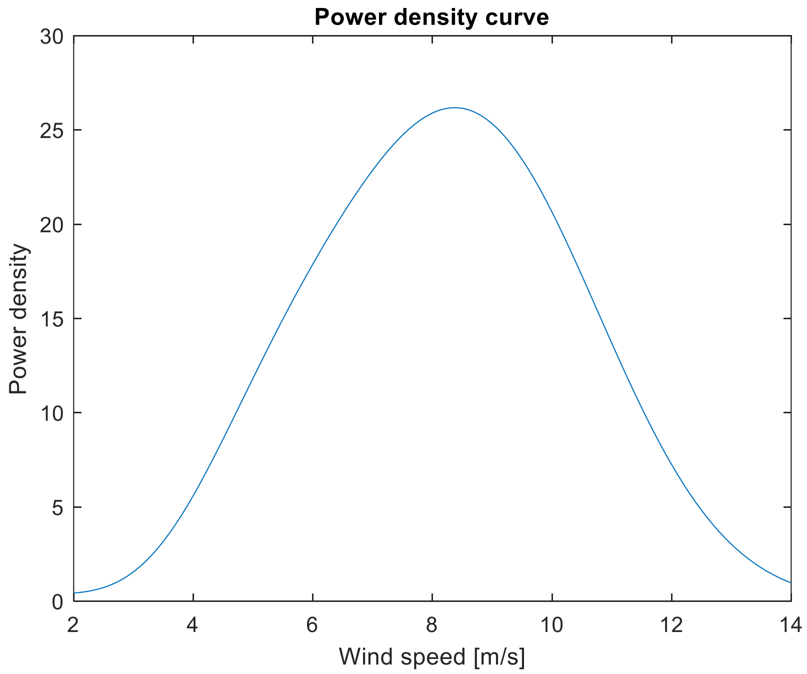
Automaxx 400W wind turbine



$$P_{WG_{avg}} = 232.3624\ [W] \tag{319}$$

$$Energy = 172.88\ [kWh] \tag{320}$$

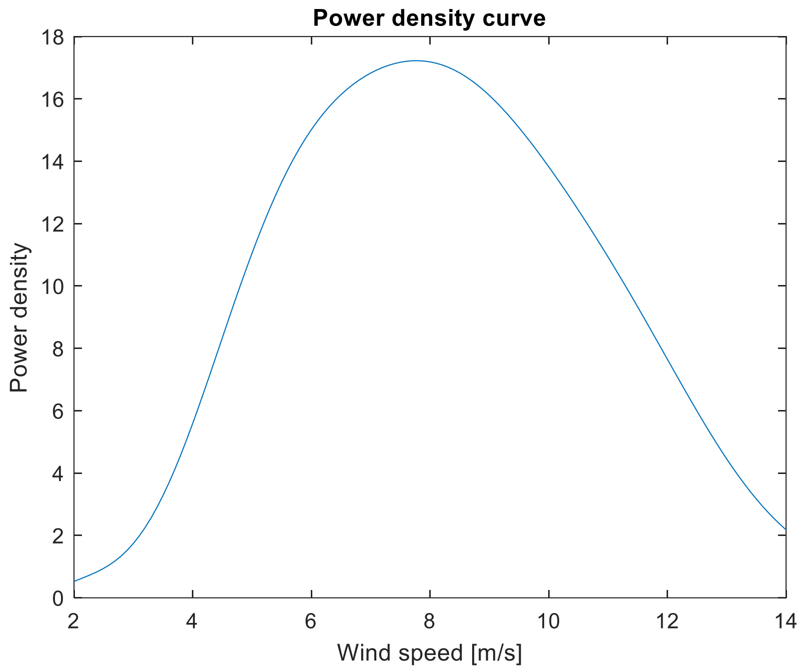
Automaxx 600W (12V) wind turbine



$$P_{WG_{avg}} = 156.4274\ [W] \tag{321}$$

$$Energy = 116.38\ [kWh] \tag{322}$$

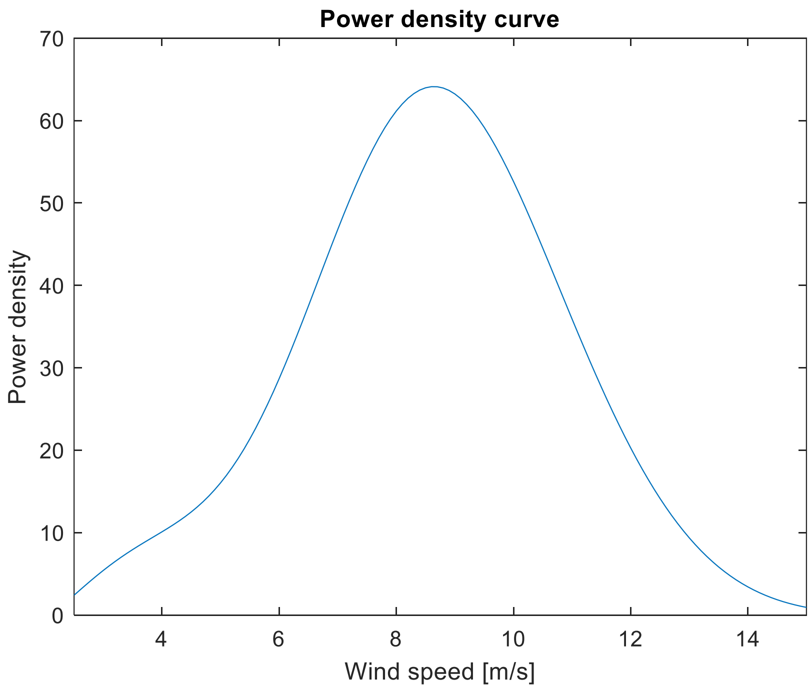
Automaxx 600W wind turbine (24V)



$$P_{WG_{avg}} = 121.9303\ [W] \quad (323)$$

$$Energy = 90.716\ [kWh] \quad (324)$$

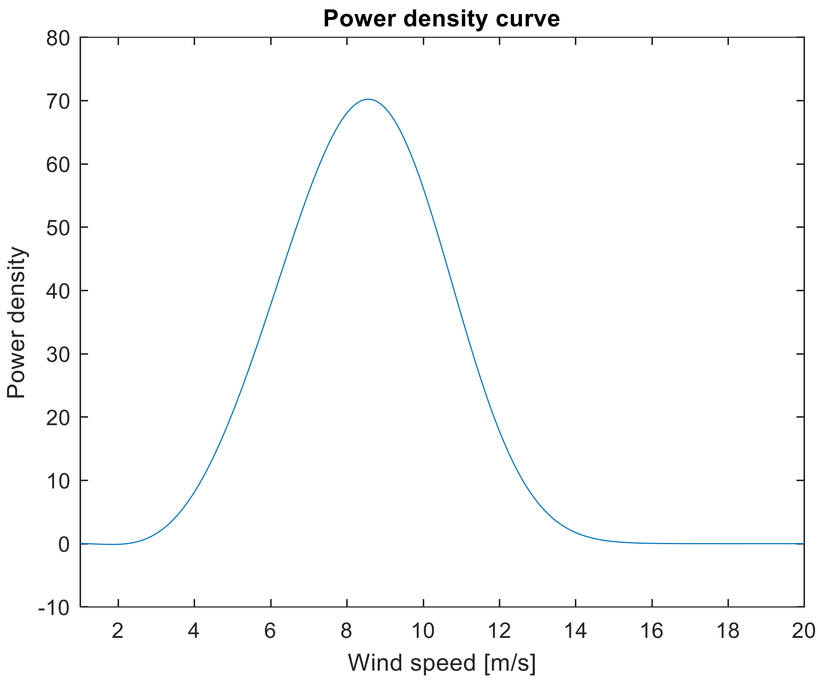
Automaxx 1500W wind turbine



$$P_{WG_{avg}} = 353.2912\ [W] \quad (325)$$

$$Energy = 262.85\ [kWh] \quad (326)$$

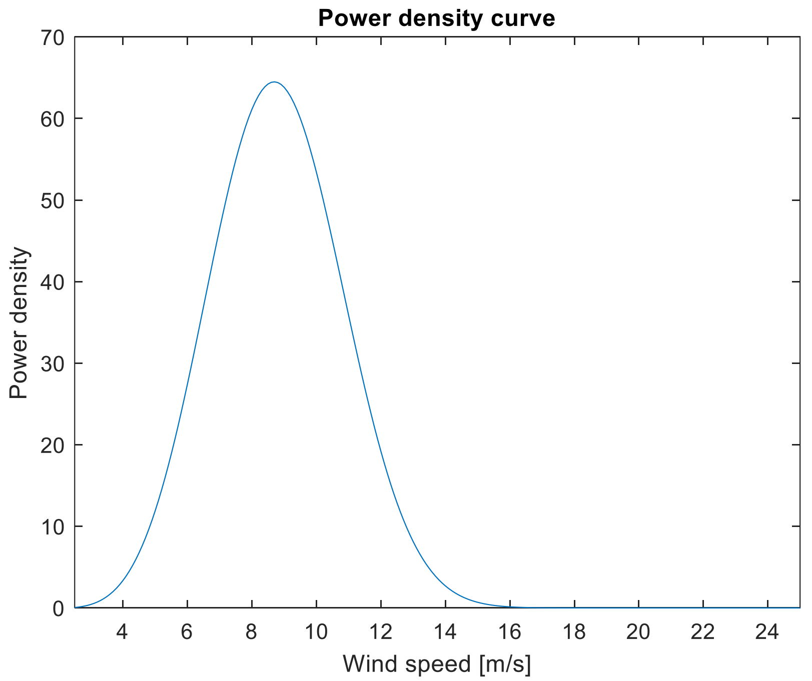
Bornay Wind 13+ wind turbine



$$P_{WG_{avg}} = 379.4378\ [W] \tag{327}$$

$$Energy = 282.30\ [kWh] \tag{328}$$

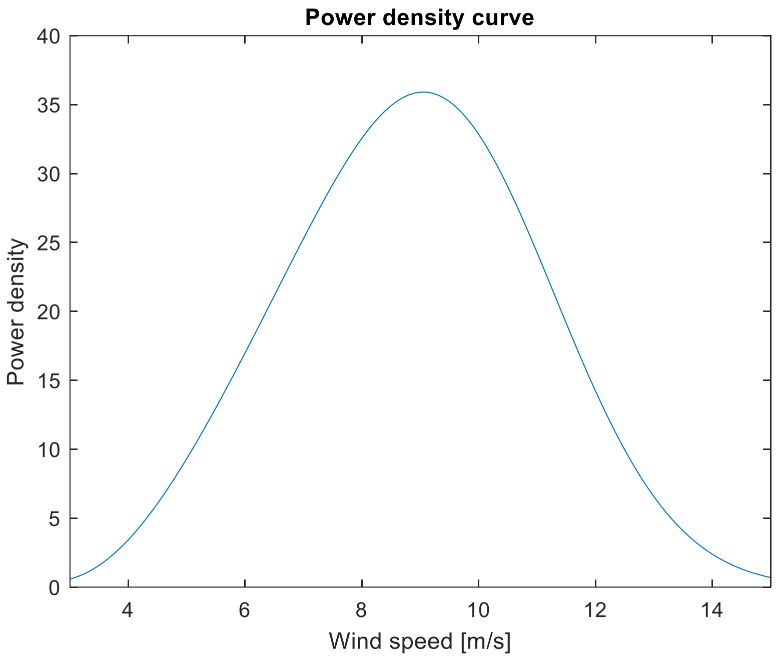
Fortis Passaat 1.4kW wind turbine



$$P_{WG_{avg}} = 334.7921\ [W] \tag{329}$$

$$Energy = 249.09\ [kWh] \tag{330}$$

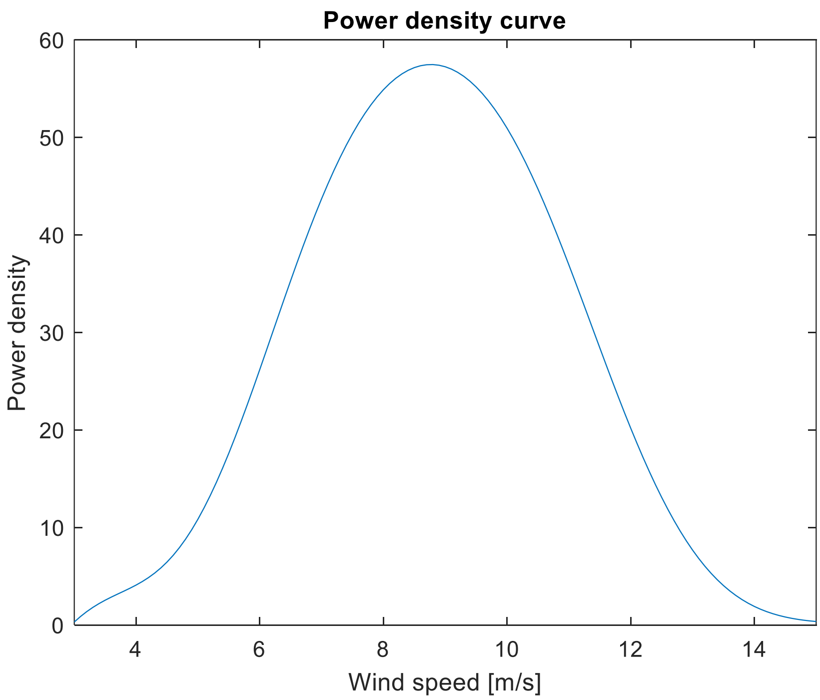
Hi-VAWT DS700



$$P_{WG_{avg}} = 204.6405\ [W] \quad (331)$$

$$Energy = 152.25\ [kWh] \quad (332)$$

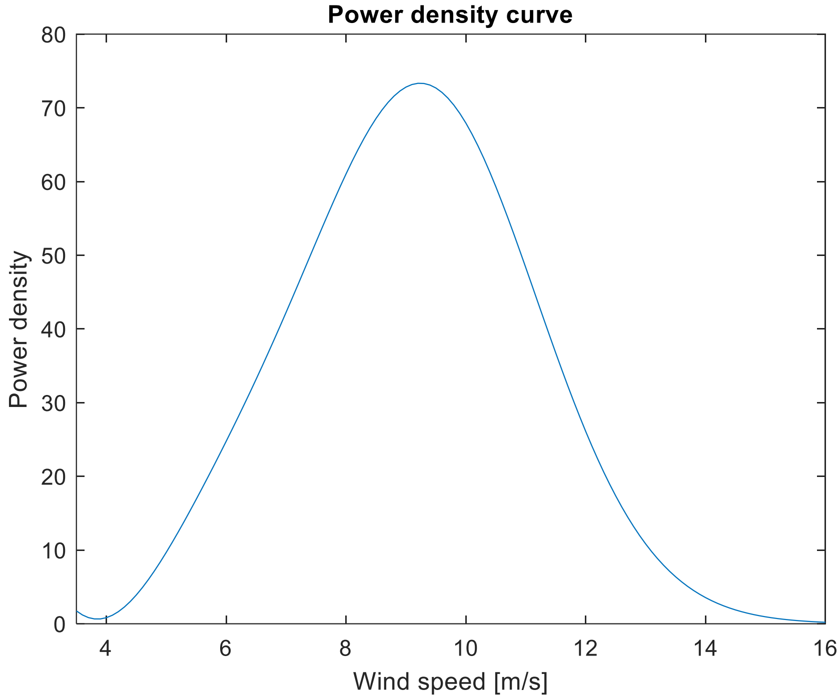
Hi-VAWT DS1500



$$P_{WG_{avg}} = 315.5149\ [W] \quad (333)$$

$$Energy = 234.74\ [kWh] \quad (334)$$

Superwind 1250 wind turbine



$$P_{WG_{avg}} = 369.4599\ [W] \quad (335)$$

$$Energy = 274.88\ [kWh] \quad (336)$$

Annex 4 - Wind forecast from 01/05/2021 to 31/05/2021 from 3 different sources

Date	Hour	Wind Speed [m/s] Aemet	Wind Speed [m/s] The weather channel	Wind Speed [m/s] eltiempo.es
01/05/2021	0:00	0,833	1,111	1,111
01/05/2021	1:00	0,833	1,111	1,111
01/05/2021	2:00	0,556	1,389	1,111
01/05/2021	3:00	0,556	1,389	1,111
01/05/2021	4:00	0,833	1,389	1,111
01/05/2021	5:00	1,389	1,667	1,111
01/05/2021	6:00	1,389	1,944	1,111
01/05/2021	7:00	1,389	1,944	1,111
01/05/2021	8:00	1,667	1,944	1,111
01/05/2021	9:00	1,389	2,500	1,111
01/05/2021	10:00	2,500	2,500	1,111
01/05/2021	11:00	2,778	2,778	1,111
01/05/2021	12:00	3,333	3,333	1,111
01/05/2021	13:00	3,333	3,889	1,111
01/05/2021	14:00	3,611	4,167	1,111
01/05/2021	15:00	3,889	4,167	1,111
01/05/2021	16:00	4,167	4,167	1,111
01/05/2021	17:00	3,889	4,444	1,111
01/05/2021	18:00	3,611	4,444	1,111
01/05/2021	19:00	2,778	3,889	1,944
01/05/2021	20:00	1,389	3,333	3,056
01/05/2021	21:00	1,111	2,500	3,056
01/05/2021	22:00	1,389	1,667	3,056
01/05/2021	23:00	0,833	1,389	1,944
02/05/2021	0:00	0,833	1,389	1,111
02/05/2021	1:00	0,833	1,111	1,111
02/05/2021	2:00	0,833	1,111	1,111
02/05/2021	3:00	1,111	1,111	1,111
02/05/2021	4:00	0,833	1,111	1,111
02/05/2021	5:00	1,389	1,111	1,111
02/05/2021	6:00	1,389	1,111	1,944
02/05/2021	7:00	0,556	1,111	1,944
02/05/2021	8:00	0,278	1,111	1,944
02/05/2021	9:00	0,556	0,833	1,111
02/05/2021	10:00	0,556	0,833	1,111
02/05/2021	11:00	0,833	0,833	1,111
02/05/2021	12:00	0,833	1,944	1,111
02/05/2021	13:00	2,222	2,222	3,056
02/05/2021	14:00	1,944	2,778	3,056
02/05/2021	15:00	1,667	2,778	3,889

02/05/2021	16:00	1,944	3,056	3,889
02/05/2021	17:00	2,222	3,889	3,889
02/05/2021	18:00	2,500	3,889	3,889
02/05/2021	19:00	2,500	3,611	3,889
02/05/2021	20:00	2,500	3,056	3,056
02/05/2021	21:00	1,389	2,222	3,056
02/05/2021	22:00	0,833	1,111	1,944
02/05/2021	23:00	0,833	0,556	1,111
03/05/2021	0:00	0,833	0,833	1,111
03/05/2021	1:00	1,111	0,833	1,111
03/05/2021	2:00	1,111	0,833	1,111
03/05/2021	3:00	1,667	0,833	1,111
03/05/2021	4:00	1,389	1,111	1,111
03/05/2021	5:00	1,111	1,389	1,111
03/05/2021	6:00	1,389	1,389	1,111
03/05/2021	7:00	1,667	1,389	1,944
03/05/2021	8:00	1,389	1,389	1,944
03/05/2021	9:00	0,833	1,111	1,944
03/05/2021	10:00	1,111	1,111	1,944
03/05/2021	11:00	1,389	1,389	1,944
03/05/2021	12:00	1,111	1,944	1,944
03/05/2021	13:00	1,389	2,222	1,944
03/05/2021	14:00	1,944	2,500	1,944
03/05/2021	15:00	2,778	2,222	1,944
03/05/2021	16:00	2,500	2,778	1,944
03/05/2021	17:00	2,500	3,611	1,111
03/05/2021	18:00	2,500	3,333	1,111
03/05/2021	19:00	2,222	2,778	1,111
03/05/2021	20:00	0,833	2,222	1,111
03/05/2021	21:00	2,222	1,667	1,111
03/05/2021	22:00	0,833	0,833	1,111
03/05/2021	23:00	1,667	0,833	1,111
04/05/2021	0:00	1,944	1,111	1,111
04/05/2021	1:00	1,111	1,111	1,111
04/05/2021	2:00	0,556	1,111	1,111
04/05/2021	3:00	0,556	1,389	1,111
04/05/2021	4:00	0,556	1,389	1,111
04/05/2021	5:00	1,389	1,389	1,111
04/05/2021	6:00	1,111	1,389	1,944
04/05/2021	7:00	0,833	1,389	1,944
04/05/2021	8:00	0,278	1,667	1,944
04/05/2021	9:00	0,556	0,833	1,944
04/05/2021	10:00	0,278	0,278	1,111
04/05/2021	11:00	0,556	0,556	1,111
04/05/2021	12:00	0,556	1,389	1,944

04/05/2021	13:00	0,833	2,500	3,056
04/05/2021	14:00	3,056	3,333	3,889
04/05/2021	15:00	3,611	3,889	3,889
04/05/2021	16:00	4,167	3,889	3,889
04/05/2021	17:00	3,333	3,889	3,889
04/05/2021	18:00	2,778	3,889	3,889
04/05/2021	19:00	2,778	2,778	3,056
04/05/2021	20:00	1,944	2,222	3,056
04/05/2021	21:00	0,833	1,389	1,944
04/05/2021	22:00	0,278	0,556	1,944
04/05/2021	23:00	0,278	0,833	1,111
05/05/2021	0:00	1,667	1,944	1,944
05/05/2021	1:00	1,667	2,222	1,944
05/05/2021	2:00	2,500	2,222	1,944
05/05/2021	3:00	2,500	2,222	1,944
05/05/2021	4:00	2,500	2,500	1,944
05/05/2021	5:00	3,889	2,500	1,944
05/05/2021	6:00	2,778	2,500	1,944
05/05/2021	7:00	1,667	2,222	1,944
05/05/2021	8:00	1,111	1,667	1,944
05/05/2021	9:00	1,111	1,667	1,944
05/05/2021	10:00	0,556	1,667	1,111
05/05/2021	11:00	1,111	1,667	1,111
05/05/2021	12:00	0,833	1,667	1,111
05/05/2021	13:00	1,944	2,222	1,944
05/05/2021	14:00	1,667	2,500	1,944
05/05/2021	15:00	1,389	2,222	3,056
05/05/2021	16:00	2,778	2,500	3,056
05/05/2021	17:00	1,944	2,778	3,056
05/05/2021	18:00	1,944	3,056	3,056
05/05/2021	19:00	1,944	2,500	1,944
05/05/2021	20:00	1,389	1,944	1,111
05/05/2021	21:00	1,111	1,111	1,111
05/05/2021	22:00	0,556	0,278	1,111
05/05/2021	23:00	0,556	0,556	1,111
06/05/2021	0:00	0,833	2,222	1,111
06/05/2021	1:00	1,111	1,944	1,111
06/05/2021	2:00	1,111	1,667	1,944
06/05/2021	3:00	0,556	1,667	1,944
06/05/2021	4:00	0,556	1,667	1,944
06/05/2021	5:00	0,278	1,667	1,944
06/05/2021	6:00	0,833	1,667	1,944
06/05/2021	7:00	0,556	1,667	1,944
06/05/2021	8:00	1,111	1,667	1,944
06/05/2021	9:00	0,833	2,500	1,944

06/05/2021	10:00	1,667	3,056	1,111
06/05/2021	11:00	1,389	3,333	1,111
06/05/2021	12:00	3,611	4,167	1,944
06/05/2021	13:00	4,722	4,722	3,056
06/05/2021	14:00	4,444	4,722	3,889
06/05/2021	15:00	4,444	4,444	3,889
06/05/2021	16:00	4,444	3,889	5,000
06/05/2021	17:00	3,889	3,611	5,000
06/05/2021	18:00	3,333	3,333	3,889
06/05/2021	19:00	2,500	2,778	3,056
06/05/2021	20:00	0,833	2,778	3,056
06/05/2021	21:00	0,556	3,056	1,944
06/05/2021	22:00	1,111	3,333	1,111
06/05/2021	23:00	1,111	3,056	1,111
07/05/2021	0:00	0,833	1,389	1,111
07/05/2021	1:00	1,111	1,389	1,111
07/05/2021	2:00	1,111	1,389	1,111
07/05/2021	3:00	1,111	1,389	1,111
07/05/2021	4:00	1,111	1,389	1,944
07/05/2021	5:00	0,833	1,389	1,944
07/05/2021	6:00	0,833	1,389	1,944
07/05/2021	7:00	0,833	1,389	1,944
07/05/2021	8:00	0,833	1,389	1,944
07/05/2021	9:00	0,278	1,111	1,111
07/05/2021	10:00	0,833	0,833	1,111
07/05/2021	11:00	1,944	0,833	1,111
07/05/2021	12:00	1,944	1,667	1,944
07/05/2021	13:00	1,944	2,222	3,056
07/05/2021	14:00	2,500	3,056	3,889
07/05/2021	15:00	2,500	3,333	3,889
07/05/2021	16:00	2,778	3,333	3,889
07/05/2021	17:00	3,333	3,889	3,889
07/05/2021	18:00	2,778	3,889	3,889
07/05/2021	19:00	2,500	3,056	3,056
07/05/2021	20:00	1,944	2,222	3,056
07/05/2021	21:00	1,111	1,389	1,944
07/05/2021	22:00	0,278	0,833	1,111
07/05/2021	23:00	1,111	0,556	1,111
08/05/2021	0:00	0,278	0,556	1,111
08/05/2021	1:00	0,278	0,833	1,111
08/05/2021	2:00	1,389	1,111	1,944
08/05/2021	3:00	1,389	1,667	1,944
08/05/2021	4:00	1,389	1,389	1,944
08/05/2021	5:00	1,389	1,667	1,944
08/05/2021	6:00	1,667	1,667	1,944

08/05/2021	7:00	1,667	2,222	1,944
08/05/2021	8:00	1,944	3,056	3,056
08/05/2021	9:00	1,389	3,889	3,056
08/05/2021	10:00	1,667	3,889	3,056
08/05/2021	11:00	3,333	3,611	3,056
08/05/2021	12:00	4,444	3,889	3,056
08/05/2021	13:00	4,444	4,167	3,889
08/05/2021	14:00	4,444	4,444	3,889
08/05/2021	15:00	3,889	4,444	3,889
08/05/2021	16:00	5,000	3,889	3,889
08/05/2021	17:00	2,778	3,611	3,889
08/05/2021	18:00	2,500	3,333	3,056
08/05/2021	19:00	2,500	2,778	3,056
08/05/2021	20:00	2,222	2,222	3,056
08/05/2021	21:00	2,500	1,944	1,944
08/05/2021	22:00	2,222	1,389	1,944
08/05/2021	23:00	1,944	1,389	1,944
09/05/2021	0:00	1,389	1,111	1,944
09/05/2021	1:00	0,556	1,389	1,944
09/05/2021	2:00	1,667	2,222	1,944
09/05/2021	3:00	1,389	2,778	1,944
09/05/2021	4:00	2,222	2,778	1,944
09/05/2021	5:00	2,500	3,056	1,944
09/05/2021	6:00	2,500	3,333	3,056
09/05/2021	7:00	1,944	3,056	3,056
09/05/2021	8:00	2,500	3,056	3,056
09/05/2021	9:00	1,389	3,333	3,889
09/05/2021	10:00	1,944	3,889	3,889
09/05/2021	11:00	1,389	4,167	3,889
09/05/2021	12:00	4,722	4,167	5,000
09/05/2021	13:00	5,278	5,278	5,000
09/05/2021	14:00	4,167	5,278	5,000
09/05/2021	15:00	4,167	4,722	3,889
09/05/2021	16:00	6,667	5,278	5,000
09/05/2021	17:00	6,389	4,167	5,000
09/05/2021	18:00	5,000	4,167	5,000
09/05/2021	19:00	3,056	4,167	3,889
09/05/2021	20:00	2,500	4,444	3,889
09/05/2021	21:00	8,333	3,611	3,889
09/05/2021	22:00	3,333	2,500	3,056
09/05/2021	23:00	1,111	1,389	1,944
10/05/2021	0:00	1,944	1,667	1,944
10/05/2021	1:00	1,389	1,389	1,944
10/05/2021	2:00	1,667	1,667	1,944
10/05/2021	3:00	0,833	1,667	1,944

10/05/2021	4:00	0,833	1,944	1,944
10/05/2021	5:00	1,111	2,222	1,944
10/05/2021	6:00	1,667	2,500	1,944
10/05/2021	7:00	1,389	2,500	3,056
10/05/2021	8:00	0,833	2,778	3,056
10/05/2021	9:00	1,389	3,333	3,056
10/05/2021	10:00	2,500	3,889	3,056
10/05/2021	11:00	4,167	4,167	3,889
10/05/2021	12:00	4,722	4,167	3,889
10/05/2021	13:00	5,000	4,444	3,889
10/05/2021	14:00	5,000	4,444	3,889
10/05/2021	15:00	4,722	3,889	3,056
10/05/2021	16:00	3,889	3,056	3,056
10/05/2021	17:00	3,056	2,500	1,944
10/05/2021	18:00	2,222	2,500	3,056
10/05/2021	19:00	3,333	3,056	3,056
10/05/2021	20:00	5,556	3,056	3,889
10/05/2021	21:00	1,944	2,778	3,056
10/05/2021	22:00	2,500	2,500	3,056
10/05/2021	23:00	5,000	2,222	3,056
11/05/2021	0:00	0,833	3,333	3,056
11/05/2021	1:00	1,111	3,611	3,889
11/05/2021	2:00	1,667	3,611	3,889
11/05/2021	3:00	2,222	3,056	3,889
11/05/2021	4:00	3,056	2,778	3,056
11/05/2021	5:00	2,222	3,056	3,056
11/05/2021	6:00	1,667	3,056	3,056
11/05/2021	7:00	1,667	2,778	3,056
11/05/2021	8:00	1,944	2,500	3,056
11/05/2021	9:00	3,333	2,778	3,056
11/05/2021	10:00	5,278	3,611	3,889
11/05/2021	11:00	5,556	3,889	3,889
11/05/2021	12:00	4,722	4,444	5,000
11/05/2021	13:00	4,722	5,000	5,000
11/05/2021	14:00	4,444	5,000	6,111
11/05/2021	15:00	5,556	4,722	6,111
11/05/2021	16:00	5,000	3,889	5,000
11/05/2021	17:00	4,167	3,889	3,889
11/05/2021	18:00	3,611	3,611	3,889
11/05/2021	19:00	3,056	2,778	3,056
11/05/2021	20:00	2,778	2,500	3,056
11/05/2021	21:00	0,833	1,389	1,944
11/05/2021	22:00	1,111	0,833	1,111
11/05/2021	23:00	1,389	1,111	1,111
12/05/2021	0:00	0,833	1,389	1,111

12/05/2021	1:00	1,389	1,667	1,944
12/05/2021	2:00	1,667	2,222	3,056
12/05/2021	3:00	2,222	2,778	3,056
12/05/2021	4:00	1,944	3,611	3,889
12/05/2021	5:00	2,222	4,444	3,889
12/05/2021	6:00	2,222	5,000	3,889
12/05/2021	7:00	3,333	5,000	3,889
12/05/2021	8:00	3,333	5,278	5,000
12/05/2021	9:00	5,556	5,000	5,000
12/05/2021	10:00	6,944	5,833	5,000
12/05/2021	11:00	6,111	5,556	5,000
12/05/2021	12:00	5,833	5,278	6,111
12/05/2021	13:00	4,722	6,389	6,111
12/05/2021	14:00	2,500	7,222	6,944
12/05/2021	15:00	5,278	6,944	6,944
12/05/2021	16:00	6,389	6,944	8,056
12/05/2021	17:00	6,111	7,500	8,056
12/05/2021	18:00	6,389	6,944	6,944
12/05/2021	19:00	5,833	6,111	6,111
12/05/2021	20:00	4,722	5,556	6,111
12/05/2021	21:00	3,056	4,167	3,889
12/05/2021	22:00	2,222	3,333	3,056
12/05/2021	23:00	1,667	2,222	3,056
13/05/2021	0:00	1,667	2,222	3,056
13/05/2021	1:00	1,389	1,944	3,056
13/05/2021	2:00	1,389	1,389	1,944
13/05/2021	3:00	0,833	1,389	1,944
13/05/2021	4:00	0,833	1,667	1,944
13/05/2021	5:00	1,111	2,222	1,944
13/05/2021	6:00	1,111	2,222	1,944
13/05/2021	7:00	1,667	1,944	1,944
13/05/2021	8:00	1,389	2,500	1,944
13/05/2021	9:00	2,222	2,222	3,056
13/05/2021	10:00	1,944	2,778	3,056
13/05/2021	11:00	2,778	2,778	3,056
13/05/2021	12:00	3,333	3,333	3,056
13/05/2021	13:00	3,611	3,611	3,056
13/05/2021	14:00	0,833	3,611	3,056
13/05/2021	15:00	2,778	3,056	3,056
13/05/2021	16:00	1,667	2,500	3,056
13/05/2021	17:00	2,222	2,778	3,056
13/05/2021	18:00	0,833	3,611	3,889
13/05/2021	19:00	2,222	4,167	3,889
13/05/2021	20:00	5,000	4,722	3,889
13/05/2021	21:00	5,556	3,889	3,889

13/05/2021	22:00	5,833	3,889	3,889
13/05/2021	23:00	4,444	4,167	3,889
14/05/2021	0:00	3,056	3,611	3,889
14/05/2021	1:00	2,778	3,333	3,889
14/05/2021	2:00	3,056	3,611	3,889
14/05/2021	3:00	2,500	3,333	3,889
14/05/2021	4:00	2,222	3,056	3,889
14/05/2021	5:00	2,500	3,333	3,889
14/05/2021	6:00	1,389	3,333	3,056
14/05/2021	7:00	2,222	3,056	3,056
14/05/2021	8:00	1,667	3,889	3,889
14/05/2021	9:00	3,056	3,611	3,889
14/05/2021	10:00	2,778	3,611	3,889
14/05/2021	11:00	3,333	4,167	3,889
14/05/2021	12:00	4,167	4,444	5,000
14/05/2021	13:00	2,500	4,167	5,000
14/05/2021	14:00	4,444	4,722	5,000
14/05/2021	15:00	3,611	4,167	5,000
14/05/2021	16:00	3,056	3,611	5,000
14/05/2021	17:00	2,222	3,611	3,889
14/05/2021	18:00	1,944	3,333	3,889
14/05/2021	19:00	1,111	2,778	3,056
14/05/2021	20:00	0,833	2,500	3,056
14/05/2021	21:00	0,556	1,667	1,944
14/05/2021	22:00	1,111	1,111	1,944
14/05/2021	23:00	1,667	1,111	1,111
15/05/2021	0:00	1,111	0,833	1,111
15/05/2021	1:00	1,111	1,111	1,111
15/05/2021	2:00	1,389	1,111	1,111
15/05/2021	3:00	1,389	1,389	1,111
15/05/2021	4:00	1,389	1,111	1,944
15/05/2021	5:00	1,111	1,111	1,944
15/05/2021	6:00	1,111	1,111	1,944
15/05/2021	7:00	1,111	1,389	1,944
15/05/2021	8:00	1,389	1,944	1,944
15/05/2021	9:00	0,556	1,944	1,944
15/05/2021	10:00	0,556	1,944	1,944
15/05/2021	11:00	1,111	2,778	1,944
15/05/2021	12:00	0,833	2,500	1,944
15/05/2021	13:00	1,389	2,500	1,944
15/05/2021	14:00	1,667	3,333	1,944
15/05/2021	15:00	2,500	3,333	3,056
15/05/2021	16:00	2,500	3,333	3,056
15/05/2021	17:00	3,056	3,056	3,889
15/05/2021	18:00	1,389	2,222	3,056

15/05/2021	19:00	1,111	1,667	3,056
15/05/2021	20:00	0,556	1,667	3,056
15/05/2021	21:00	0,278	1,111	1,944
15/05/2021	22:00	0,556	1,111	1,111
15/05/2021	23:00	0,556	0,833	1,111
16/05/2021	0:00	1,111	0,556	1,111
16/05/2021	1:00	0,556	0,833	1,111
16/05/2021	2:00	0,833	0,833	1,111
16/05/2021	3:00	0,833	0,556	1,111
16/05/2021	4:00	0,556	0,556	1,111
16/05/2021	5:00	0,556	0,833	1,111
16/05/2021	6:00	0,833	0,833	1,111
16/05/2021	7:00	1,111	1,111	1,111
16/05/2021	8:00	0,833	1,667	1,944
16/05/2021	9:00	2,222	1,944	1,944
16/05/2021	10:00	3,611	1,944	1,944
16/05/2021	11:00	2,222	2,222	1,944
16/05/2021	12:00	2,222	2,222	3,056
16/05/2021	13:00	1,667	2,500	3,056
16/05/2021	14:00	2,222	3,611	3,889
16/05/2021	15:00	1,944	3,056	3,889
16/05/2021	16:00	2,222	3,056	3,889
16/05/2021	17:00	1,944	3,056	3,889
16/05/2021	18:00	1,944	2,778	3,889
16/05/2021	19:00	2,222	2,778	3,889
16/05/2021	20:00	1,667	3,333	3,889
16/05/2021	21:00	1,389	2,500	3,056
16/05/2021	22:00	1,667	1,944	3,056
16/05/2021	23:00	1,944	1,667	1,944
17/05/2021	0:00	1,667	1,944	3,056
17/05/2021	1:00	1,667	1,944	3,056
17/05/2021	2:00	1,389	2,222	3,056
17/05/2021	3:00	1,667	1,944	3,056
17/05/2021	4:00	1,667	1,944	3,056
17/05/2021	5:00	1,667	2,222	3,056
17/05/2021	6:00	1,667	1,944	1,944
17/05/2021	7:00	1,667	1,667	1,944
17/05/2021	8:00	1,389	1,944	1,944
17/05/2021	9:00	1,389	1,944	3,056
17/05/2021	10:00	3,889	2,778	3,056
17/05/2021	11:00	4,167	3,611	3,889
17/05/2021	12:00	4,444	3,611	5,000
17/05/2021	13:00	4,722	4,167	5,000
17/05/2021	14:00	4,722	4,722	5,000
17/05/2021	15:00	4,444	4,444	5,000

17/05/2021	16:00	4,167	3,889	5,000
17/05/2021	17:00	3,611	3,889	3,889
17/05/2021	18:00	3,056	3,889	3,889
17/05/2021	19:00	3,056	3,333	3,889
17/05/2021	20:00	2,500	3,056	3,889
17/05/2021	21:00	1,944	1,667	3,056
17/05/2021	22:00	0,833	0,833	1,111
17/05/2021	23:00	0,833	0,278	1,111
18/05/2021	0:00	0,556	0,278	1,111
18/05/2021	1:00	0,833	0,833	1,111
18/05/2021	2:00	1,389	1,111	1,111
18/05/2021	3:00	1,389	0,833	1,111
18/05/2021	4:00	1,389	1,111	1,111
18/05/2021	5:00	1,389	1,389	1,111
18/05/2021	6:00	1,667	1,111	1,111
18/05/2021	7:00	1,389	0,833	1,111
18/05/2021	8:00	1,111	1,111	1,111
18/05/2021	9:00	1,389	0,833	1,111
18/05/2021	10:00	2,500	1,389	1,111
18/05/2021	11:00	2,222	2,222	1,944
18/05/2021	12:00	1,389	1,944	3,056
18/05/2021	13:00	2,500	2,500	3,889
18/05/2021	14:00	3,056	4,167	3,889
18/05/2021	15:00	2,778	3,889	3,889
18/05/2021	16:00	1,389	3,056	3,889
18/05/2021	17:00	1,667	3,056	3,056
18/05/2021	18:00	1,389	2,778	3,056
18/05/2021	19:00	1,944	3,056	3,056
18/05/2021	20:00	2,222	3,611	3,056
18/05/2021	21:00	1,944	3,056	3,056
18/05/2021	22:00	1,667	2,222	1,944
18/05/2021	23:00	2,222	1,667	1,111
19/05/2021	0:00	1,667	1,111	1,111
19/05/2021	1:00	1,667	1,111	1,111
19/05/2021	2:00	1,667	1,389	1,111
19/05/2021	3:00	1,389	0,833	1,111
19/05/2021	4:00	2,500	1,389	1,111
19/05/2021	5:00	1,667	1,389	1,944
19/05/2021	6:00	0,556	1,111	1,944
19/05/2021	7:00	0,833	1,389	1,944
19/05/2021	8:00	0,833	1,667	1,944
19/05/2021	9:00	1,667	2,222	1,944
19/05/2021	10:00	2,222	3,056	3,056
19/05/2021	11:00	2,500	3,611	3,056
19/05/2021	12:00	3,611	3,889	3,889

19/05/2021	13:00	3,889	4,167	5,000
19/05/2021	14:00	3,889	5,000	5,000
19/05/2021	15:00	3,611	4,444	5,000
19/05/2021	16:00	3,333	4,167	5,000
19/05/2021	17:00	3,056	4,167	3,889
19/05/2021	18:00	3,056	3,889	3,889
19/05/2021	19:00	2,500	3,333	3,889
19/05/2021	20:00	1,944	3,056	3,056
19/05/2021	21:00	1,667	1,944	3,056
19/05/2021	22:00	0,556	1,111	1,111
19/05/2021	23:00	0,556	0,556	1,111
20/05/2021	0:00	1,111	0,556	1,111
20/05/2021	1:00	1,389	1,111	1,111
20/05/2021	2:00	1,667	1,389	1,944
20/05/2021	3:00	1,667	1,389	1,944
20/05/2021	4:00	1,667	1,667	1,944
20/05/2021	5:00	1,389	1,944	1,944
20/05/2021	6:00	1,667	1,667	1,944
20/05/2021	7:00	1,667	1,667	1,944
20/05/2021	8:00	1,667	1,944	1,944
20/05/2021	9:00	1,667	1,944	1,944
20/05/2021	10:00	2,222	1,944	1,944
20/05/2021	11:00	1,944	1,944	1,944
20/05/2021	12:00	1,111	1,667	1,944
20/05/2021	13:00	0,278	1,389	1,944
20/05/2021	14:00	1,667	2,500	3,056
20/05/2021	15:00	3,056	2,778	3,056
20/05/2021	16:00	3,056	3,056	3,056
20/05/2021	17:00	3,056	3,333	3,056
20/05/2021	18:00	3,056	3,611	3,056
20/05/2021	19:00	3,056	2,778	3,056
20/05/2021	20:00	2,778	2,778	3,056
20/05/2021	21:00	1,667	1,667	1,944
20/05/2021	22:00	1,111	1,389	1,111
20/05/2021	23:00	1,111	0,556	1,111
21/05/2021	0:00	0,833	1,111	1,111
21/05/2021	1:00	1,389	0,833	1,111
21/05/2021	2:00	1,667	1,389	1,111
21/05/2021	3:00	1,389	1,389	1,111
21/05/2021	4:00	1,389	1,111	1,111
21/05/2021	5:00	1,667	1,389	1,111
21/05/2021	6:00	1,389	1,389	1,111
21/05/2021	7:00	0,833	0,556	1,111
21/05/2021	8:00	0,556	0,278	1,111
21/05/2021	9:00	0,556	0,000	1,111

21/05/2021	10:00	1,944	1,389	1,111
21/05/2021	11:00	2,500	2,778	3,056
21/05/2021	12:00	3,333	3,889	3,889
21/05/2021	13:00	4,167	5,000	5,000
21/05/2021	14:00	5,556	6,111	5,000
21/05/2021	15:00	4,444	4,167	3,056
21/05/2021	16:00	2,778	2,500	1,944
21/05/2021	17:00	1,389	1,111	1,944
21/05/2021	18:00	1,389	1,111	1,944
21/05/2021	19:00	1,667	1,389	1,944
21/05/2021	20:00	1,944	1,389	1,944
21/05/2021	21:00	1,944	1,389	1,111
21/05/2021	22:00	1,667	1,667	1,944
21/05/2021	23:00	1,944	1,667	1,944
22/05/2021	0:00	1,111	0,833	0,833
22/05/2021	1:00	1,111	1,111	1,389
22/05/2021	2:00	0,833	1,111	1,389
22/05/2021	3:00	1,389	1,111	1,389
22/05/2021	4:00	0,556	1,111	1,389
22/05/2021	5:00	1,111	1,111	1,389
22/05/2021	6:00	0,833	0,833	1,389
22/05/2021	7:00	1,111	0,833	1,389
22/05/2021	8:00	1,111	1,667	1,389
22/05/2021	9:00	1,667	1,389	1,667
22/05/2021	10:00	4,444	2,222	2,222
22/05/2021	11:00	4,444	2,778	2,778
22/05/2021	12:00	4,722	2,778	3,333
22/05/2021	13:00	4,167	3,056	3,611
22/05/2021	14:00	4,444	3,611	3,889
22/05/2021	15:00	4,722	3,611	3,889
22/05/2021	16:00	4,444	3,056	3,889
22/05/2021	17:00	4,444	3,333	3,611
22/05/2021	18:00	3,889	3,056	3,333
22/05/2021	19:00	3,056	2,222	2,778
22/05/2021	20:00	2,500	2,500	2,500
22/05/2021	21:00	1,667	1,389	1,944
22/05/2021	22:00	0,833	0,833	1,667
22/05/2021	23:00	0,556	0,556	1,111
23/05/2021	0:00	1,111	0,833	0,833
23/05/2021	1:00	1,111	0,833	1,111
23/05/2021	2:00	0,833	1,389	1,389
23/05/2021	3:00	0,833	1,389	1,667
23/05/2021	4:00	1,111	1,389	1,667
23/05/2021	5:00	1,389	1,667	1,667
23/05/2021	6:00	1,389	1,389	1,667

23/05/2021	7:00	1,111	1,389	1,667
23/05/2021	8:00	1,111	1,667	1,944
23/05/2021	9:00	1,111	1,111	1,667
23/05/2021	10:00	0,833	1,111	1,389
23/05/2021	11:00	0,278	1,111	1,111
23/05/2021	12:00	0,278	1,389	1,667
23/05/2021	13:00	1,667	1,944	2,500
23/05/2021	14:00	0,833	2,778	3,333
23/05/2021	15:00	0,556	3,056	3,611
23/05/2021	16:00	2,778	3,333	3,889
23/05/2021	17:00	2,500	3,611	4,167
23/05/2021	18:00	2,222	3,333	4,167
23/05/2021	19:00	2,500	3,333	3,889
23/05/2021	20:00	2,500	3,333	3,611
23/05/2021	21:00	2,222	2,222	2,500
23/05/2021	22:00	0,833	0,833	1,389
23/05/2021	23:00	0,278	0,556	0,833
24/05/2021	0:00	0,556	1,389	1,111
24/05/2021	1:00	0,278	1,667	1,667
24/05/2021	2:00	1,111	1,667	1,944
24/05/2021	3:00	1,389	1,667	2,222
24/05/2021	4:00	1,389	1,667	2,222
24/05/2021	5:00	1,667	2,222	2,222
24/05/2021	6:00	1,667	2,222	2,222
24/05/2021	7:00	1,111	2,222	2,222
24/05/2021	8:00	1,667	2,500	2,222
24/05/2021	9:00	1,944	2,500	2,500
24/05/2021	10:00	1,389	2,500	2,778
24/05/2021	11:00	1,667	3,056	3,333
24/05/2021	12:00	5,833	3,333	4,167
24/05/2021	13:00	5,556	3,611	4,722
24/05/2021	14:00	6,111	4,167	5,000
24/05/2021	15:00	6,944	4,167	5,000
24/05/2021	16:00	6,667	4,444	5,000
24/05/2021	17:00	6,667	4,444	4,722
24/05/2021	18:00	6,389	4,167	4,722
24/05/2021	19:00	6,389	3,889	4,722
24/05/2021	20:00	5,278	4,444	4,444
24/05/2021	21:00	4,444	3,611	3,889
24/05/2021	22:00	2,778	2,778	3,056
24/05/2021	23:00	2,500	2,222	2,500
25/05/2021	0:00	2,222	2,222	3,611
25/05/2021	1:00	2,222	2,222	2,500
25/05/2021	2:00	1,944	2,222	2,500
25/05/2021	3:00	1,389	1,944	2,222

25/05/2021	4:00	1,667	1,667	2,222
25/05/2021	5:00	1,389	1,667	1,944
25/05/2021	6:00	1,111	1,389	1,944
25/05/2021	7:00	0,556	1,389	1,667
25/05/2021	8:00	1,389	1,389	1,667
25/05/2021	9:00	1,944	1,667	1,944
25/05/2021	10:00	2,500	2,500	2,222
25/05/2021	11:00	2,778	2,778	2,778
25/05/2021	12:00	2,778	2,778	3,333
25/05/2021	13:00	3,333	3,333	3,889
25/05/2021	14:00	3,056	3,889	4,167
25/05/2021	15:00	3,333	3,611	4,167
25/05/2021	16:00	2,778	3,333	3,889
25/05/2021	17:00	2,500	3,333	3,889
25/05/2021	18:00	2,778	3,333	3,611
25/05/2021	19:00	2,222	3,056	3,333
25/05/2021	20:00	1,667	2,778	3,056
25/05/2021	21:00	1,389	1,944	2,222
25/05/2021	22:00	0,833	1,111	1,111
25/05/2021	23:00	0,833	0,556	0,556
26/05/2021	0:00	0,556	0,278	0,833
26/05/2021	1:00	0,833	0,833	1,111
26/05/2021	2:00	1,111	1,111	1,389
26/05/2021	3:00	1,111	1,111	1,389
26/05/2021	4:00	1,389	1,111	1,389
26/05/2021	5:00	1,389	1,389	1,389
26/05/2021	6:00	1,389	0,833	1,389
26/05/2021	7:00	1,389	1,111	1,389
26/05/2021	8:00	1,111	1,389	1,667
26/05/2021	9:00	1,111	0,833	1,667
26/05/2021	10:00	1,111	0,833	1,389
26/05/2021	11:00	1,111	1,389	1,389
26/05/2021	12:00	1,667	1,944	1,944
26/05/2021	13:00	1,944	2,500	2,778
26/05/2021	14:00	1,667	3,333	3,333
26/05/2021	15:00	1,667	3,611	3,611
26/05/2021	16:00	2,500	3,333	3,611
26/05/2021	17:00	2,222	3,611	3,611
26/05/2021	18:00	2,778	3,611	3,611
26/05/2021	19:00	2,500	3,333	3,333
26/05/2021	20:00	2,500	3,056	3,056
26/05/2021	21:00	1,944	2,222	2,500
26/05/2021	22:00	0,556	1,389	1,389
26/05/2021	23:00	0,278	0,556	0,833
27/05/2021	0:00	0,556	0,833	1,111

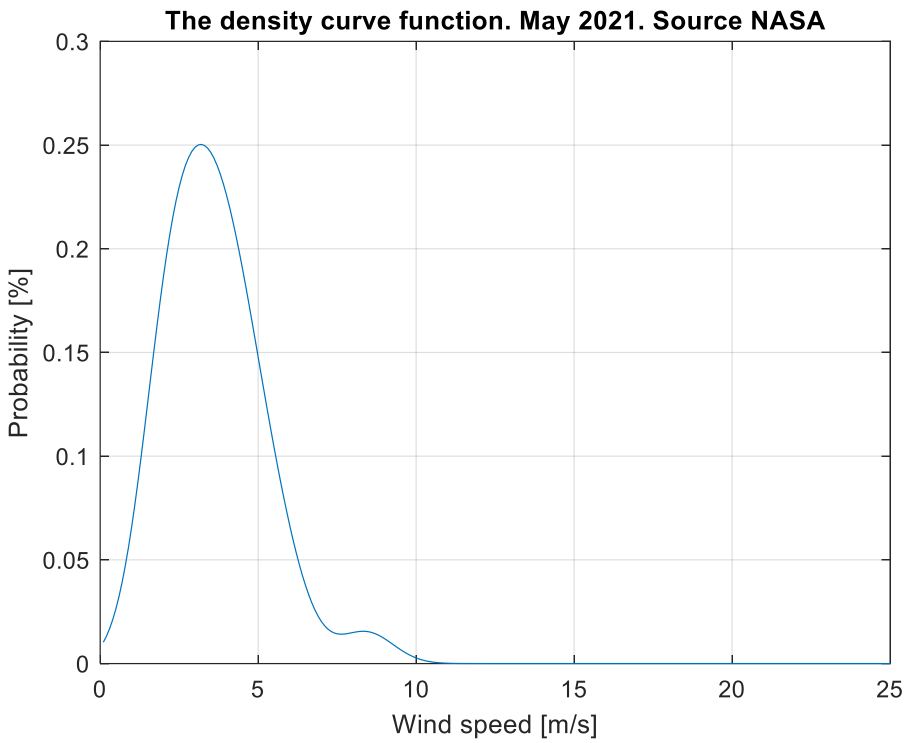
27/05/2021	1:00	0,833	0,556	1,111
27/05/2021	2:00	1,389	0,833	1,111
27/05/2021	3:00	1,389	0,833	0,833
27/05/2021	4:00	1,389	0,833	0,833
27/05/2021	5:00	1,389	0,833	0,556
27/05/2021	6:00	1,389	0,833	0,556
27/05/2021	7:00	1,111	1,111	0,278
27/05/2021	8:00	0,833	1,389	0,278
27/05/2021	9:00	1,667	1,389	0,556
27/05/2021	10:00	2,222	1,667	1,111
27/05/2021	11:00	2,222	1,944	1,944
27/05/2021	12:00	1,944	2,222	2,778
27/05/2021	13:00	2,222	3,056	3,333
27/05/2021	14:00	2,500	3,611	3,889
27/05/2021	15:00	2,500	3,889	4,167
27/05/2021	16:00	2,778	3,889	3,889
27/05/2021	17:00	3,611	4,167	3,611
27/05/2021	18:00	3,611	4,167	3,333
27/05/2021	19:00	3,056	3,611	2,778
27/05/2021	20:00	2,222	3,056	1,944
27/05/2021	21:00	0,833	2,222	1,389
27/05/2021	22:00	1,944	1,389	1,389
27/05/2021	23:00	2,222	0,833	1,111
28/05/2021	0:00	1,944	1,111	0,833
28/05/2021	1:00	1,389	1,111	1,111
28/05/2021	2:00	0,833	1,111	1,389
28/05/2021	3:00	0,833	0,833	1,389
28/05/2021	4:00	0,278	0,833	1,111
28/05/2021	5:00	0,278	0,556	1,111
28/05/2021	6:00	0,833	0,556	1,111
28/05/2021	7:00	1,111	0,833	1,389
28/05/2021	8:00	1,111	0,833	1,389
28/05/2021	9:00	0,833	0,833	1,111
28/05/2021	10:00	1,111	0,833	1,111
28/05/2021	11:00	0,833	1,111	0,833
28/05/2021	12:00	0,833	1,389	1,389
28/05/2021	13:00	2,778	1,944	2,500
28/05/2021	14:00	3,333	2,500	2,778
28/05/2021	15:00	2,778	2,778	3,056
28/05/2021	16:00	1,944	2,778	3,056
28/05/2021	17:00	1,111	2,778	2,778
28/05/2021	18:00	0,556	3,056	2,778
28/05/2021	19:00	0,278	2,778	2,778
28/05/2021	20:00	1,667	2,778	2,500
28/05/2021	21:00	3,611	1,667	1,944

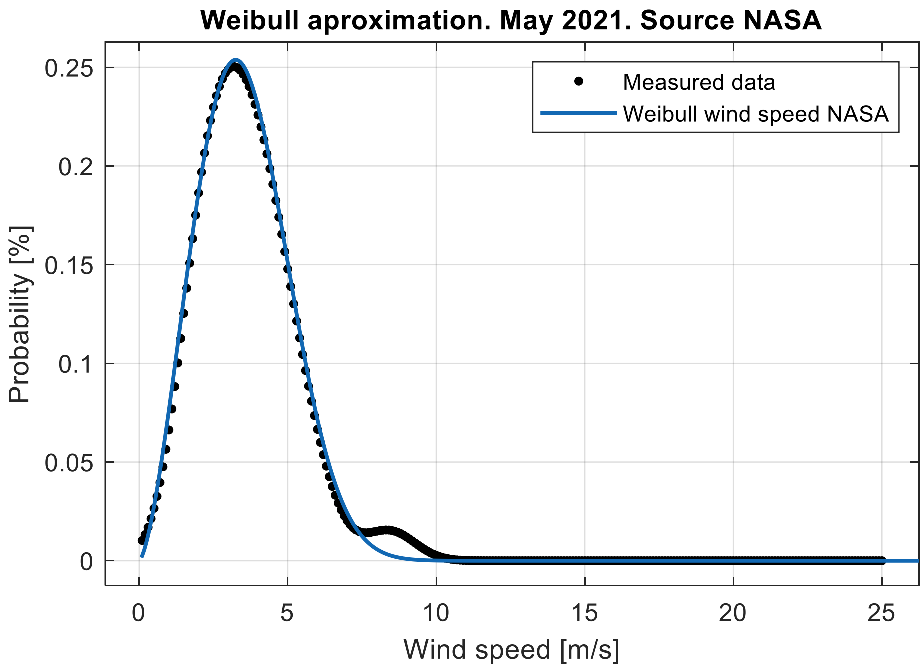
28/05/2021	22:00	3,056	1,389	1,389
28/05/2021	23:00	1,389	0,833	0,833
29/05/2021	0:00	2,500	0,833	0,000
29/05/2021	1:00	0,833	1,111	0,278
29/05/2021	2:00	0,833	0,833	0,556
29/05/2021	3:00	1,111	0,556	1,111
29/05/2021	4:00	1,111	0,556	1,111
29/05/2021	5:00	0,833	0,556	1,111
29/05/2021	6:00	1,389	0,833	1,111
29/05/2021	7:00	1,389	0,556	1,111
29/05/2021	8:00	1,111	0,833	1,389
29/05/2021	9:00	0,833	0,833	1,389
29/05/2021	10:00	1,389	1,389	1,944
29/05/2021	11:00	2,500	2,222	2,222
29/05/2021	12:00	3,056	2,222	2,778
29/05/2021	13:00	3,333	2,778	3,333
29/05/2021	14:00	3,611	3,333	3,611
29/05/2021	15:00	3,056	3,611	3,889
29/05/2021	16:00	3,056	3,333	3,889
29/05/2021	17:00	2,500	3,611	3,889
29/05/2021	18:00	2,500	3,611	3,611
29/05/2021	19:00	2,222	3,333	3,611
29/05/2021	20:00	1,667	3,056	3,333
29/05/2021	21:00	2,778	2,222	2,778
29/05/2021	22:00	1,667	1,389	1,667
29/05/2021	23:00	0,833	0,833	1,111
30/05/2021	0:00	0,556	0,833	1,111
30/05/2021	1:00	1,389	0,833	1,111
30/05/2021	2:00	0,833	0,833	1,111
30/05/2021	3:00	0,278	1,111	1,111
30/05/2021	4:00	1,111	0,833	1,111
30/05/2021	5:00	1,389	0,833	1,389
30/05/2021	6:00	1,111	0,833	1,389
30/05/2021	7:00	1,111	0,833	1,111
30/05/2021	8:00	0,278	0,833	1,111
30/05/2021	9:00	0,556	0,556	1,111
30/05/2021	10:00	0,556	0,833	1,111
30/05/2021	11:00	0,556	1,389	1,111
30/05/2021	12:00	1,111	1,667	1,667
30/05/2021	13:00	2,778	2,500	2,500
30/05/2021	14:00	2,500	3,333	3,056
30/05/2021	15:00	2,500	3,611	3,333
30/05/2021	16:00	2,778	3,611	3,611
30/05/2021	17:00	2,500	3,611	3,889
30/05/2021	18:00	2,222	3,611	3,611

30/05/2021	19:00	1,944	3,056	3,333
30/05/2021	20:00	2,500	2,500	2,778
30/05/2021	21:00	1,944	1,667	2,222
30/05/2021	22:00	1,667	1,111	1,111
30/05/2021	23:00	0,833	0,278	0,556
31/05/2021	0:00	0,556	0,556	0,833
31/05/2021	1:00	0,556	0,556	0,833
31/05/2021	2:00	0,556	0,556	1,111
31/05/2021	3:00	0,556	0,556	1,111
31/05/2021	4:00	0,278	0,556	1,111
31/05/2021	5:00	0,556	0,833	1,111
31/05/2021	6:00	1,111	0,833	1,389
31/05/2021	7:00	1,389	0,833	1,389
31/05/2021	8:00	1,389	1,111	1,389
31/05/2021	9:00	1,389	0,833	1,667
31/05/2021	10:00	1,389	1,111	1,667
31/05/2021	11:00	1,667	1,389	1,667
31/05/2021	12:00	1,944	1,944	2,222
31/05/2021	13:00	2,222	2,500	3,056
31/05/2021	14:00	3,056	3,333	3,611
31/05/2021	15:00	3,889	3,611	3,889
31/05/2021	16:00	4,167	3,889	4,167
31/05/2021	17:00	4,444	4,167	4,167
31/05/2021	18:00	4,444	4,167	3,889
31/05/2021	19:00	4,444	3,611	3,333
31/05/2021	20:00	4,444	2,778	2,778
31/05/2021	21:00	4,444	2,500	2,222
31/05/2021	22:00	3,611	1,667	1,389
31/05/2021	23:00	1,111	1,111	1,111

Annex 5 – Weibull parameters for wind speed data for the month of May 2021

Weibull parameters. Source NASA. Daily average data (Real data)

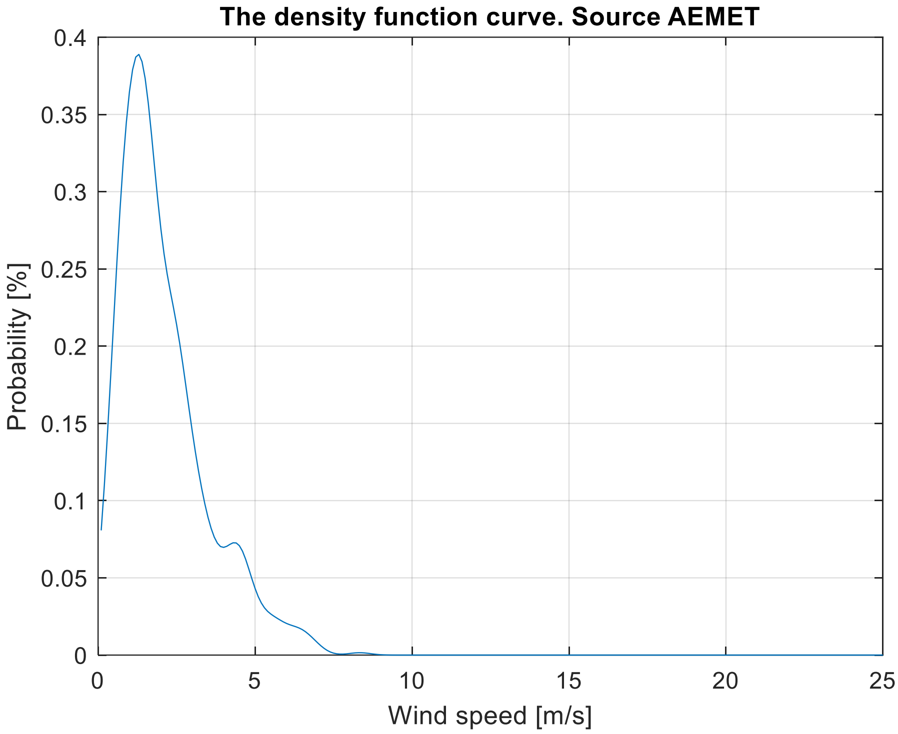


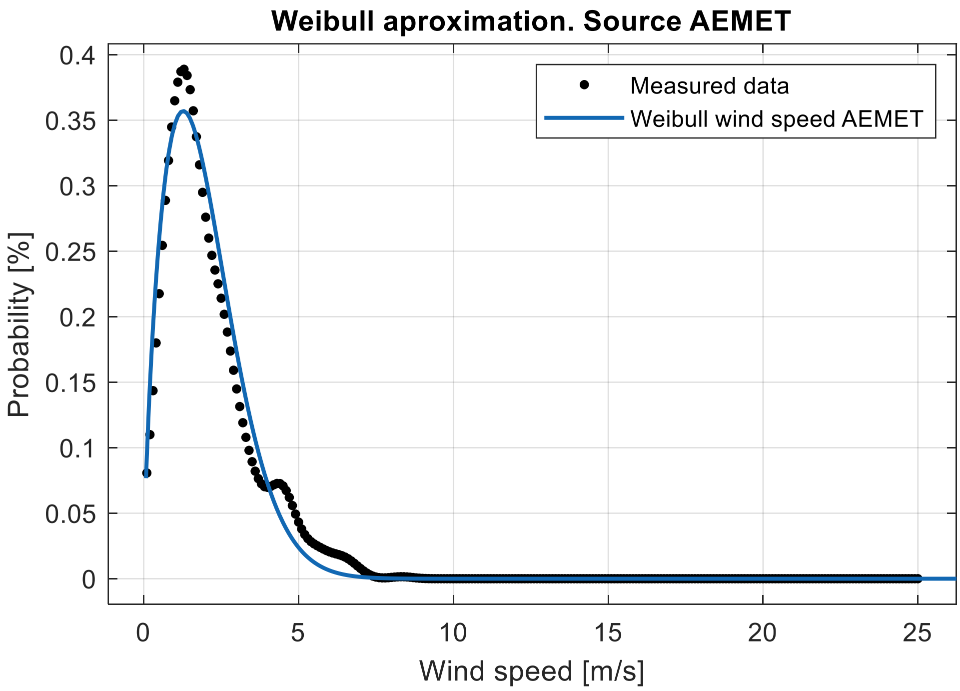


$$a = 0.03145 \quad (337)$$

$$b = 2.503 \quad (338)$$

Weibull parameters. Source AEMET

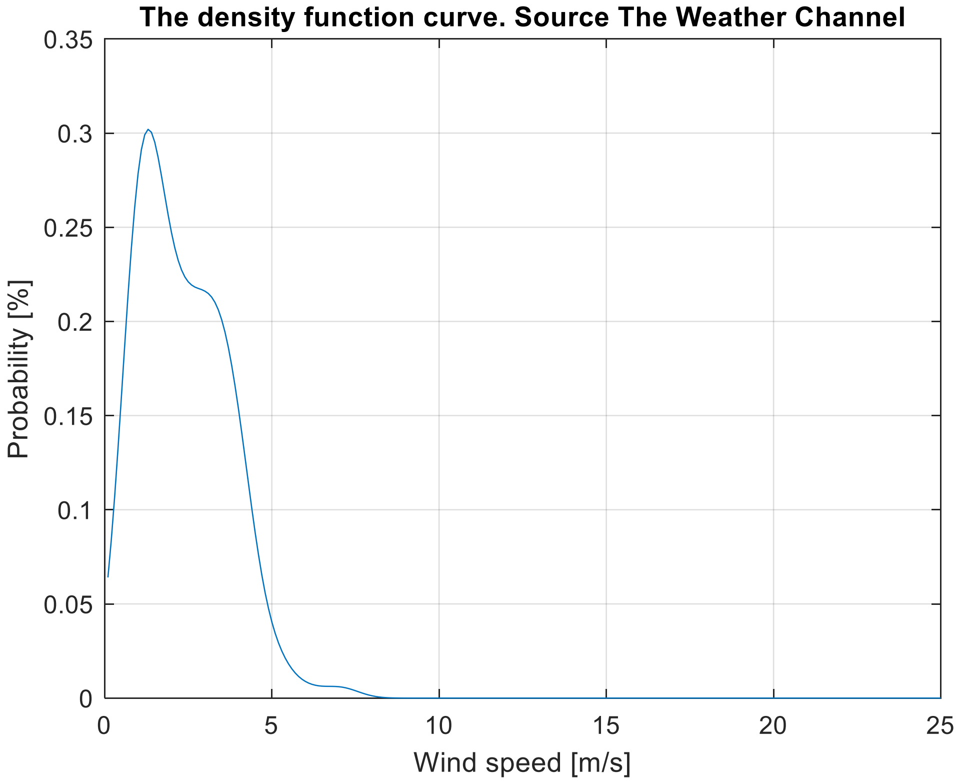


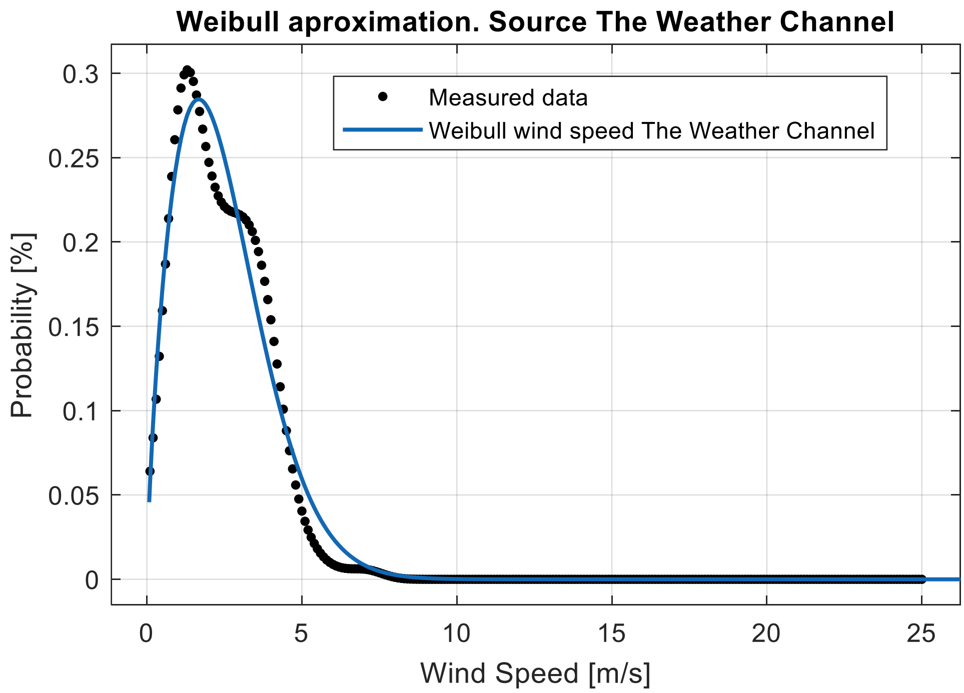


$$a = 0.2697 \quad (339)$$

$$b = 1.683 \quad (340)$$

Weibull parameters. Source The Weather Channel

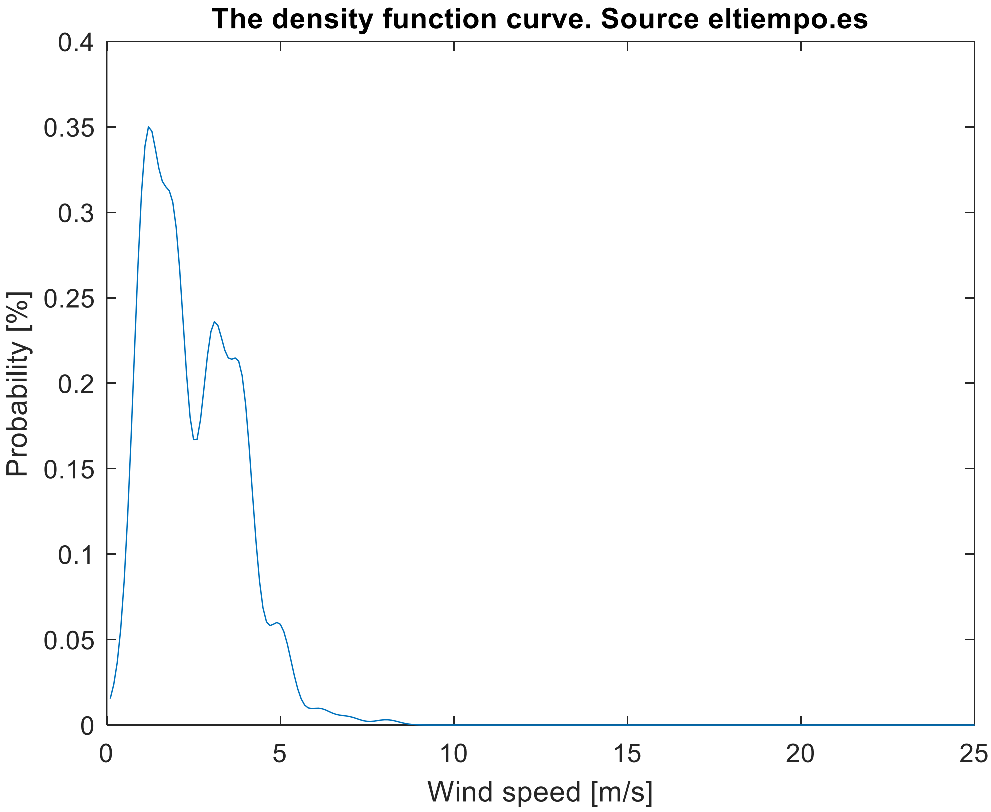


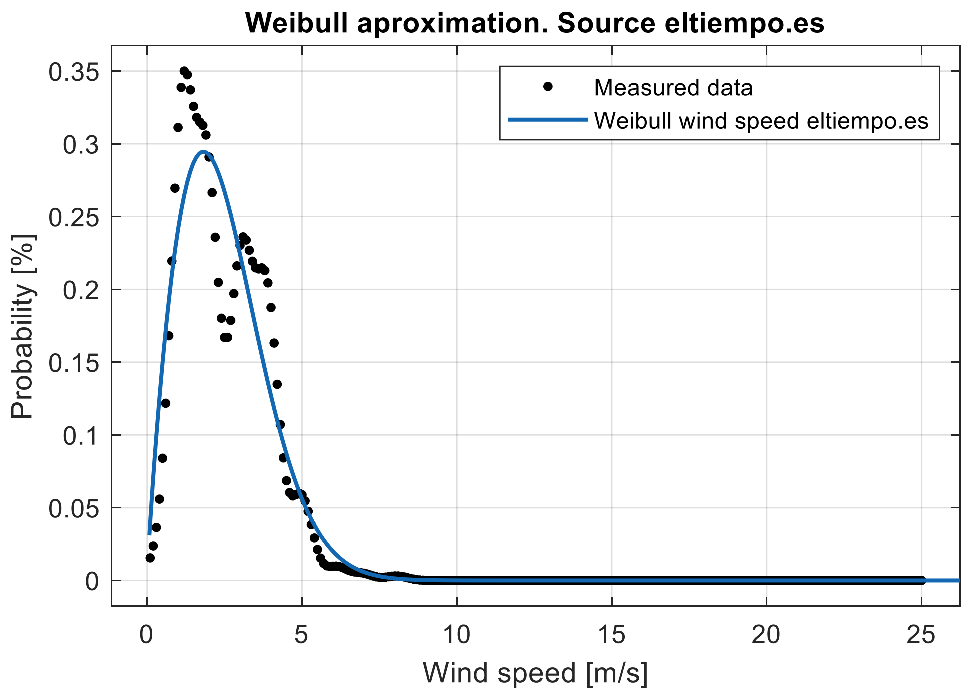


$$a = 0.1736 \tag{341}$$

$$b = 1.722 \tag{342}$$

Weibull parameters. Source eltiempo.es





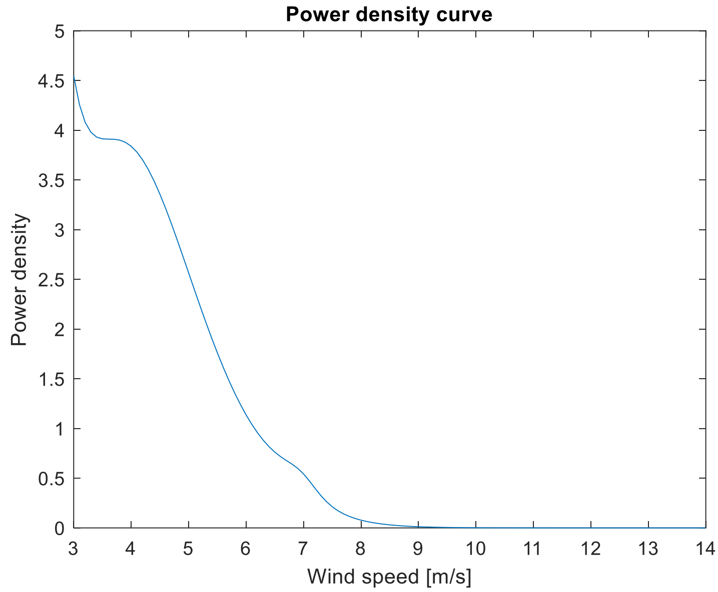
$$a = 0.152 \tag{343}$$

$$b = 1.847 \tag{344}$$

Annex 6 – Energy produced in May 2021

Automaxx 400W wind turbine

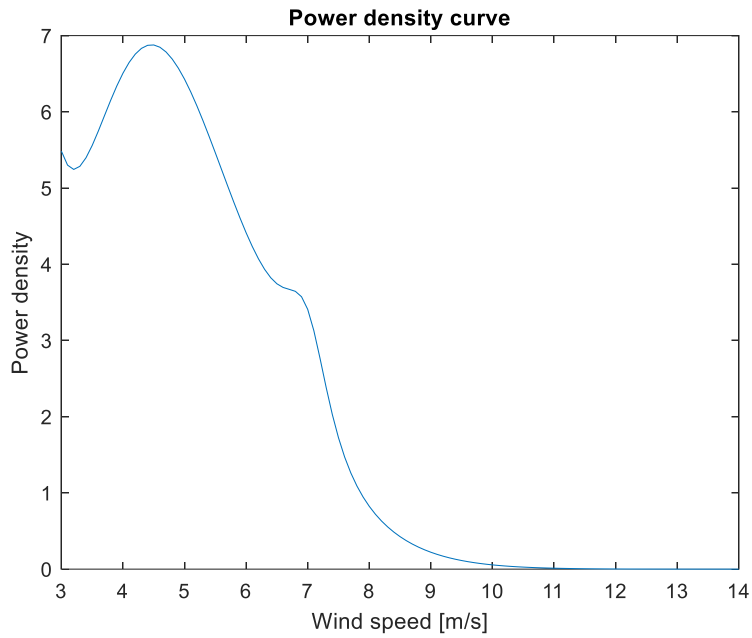
Source AEMET



$$P_{WG_{avg}} = 10.1753\ [W] \quad (345)$$

$$Energy = 7.5705\ [kWh] \quad (346)$$

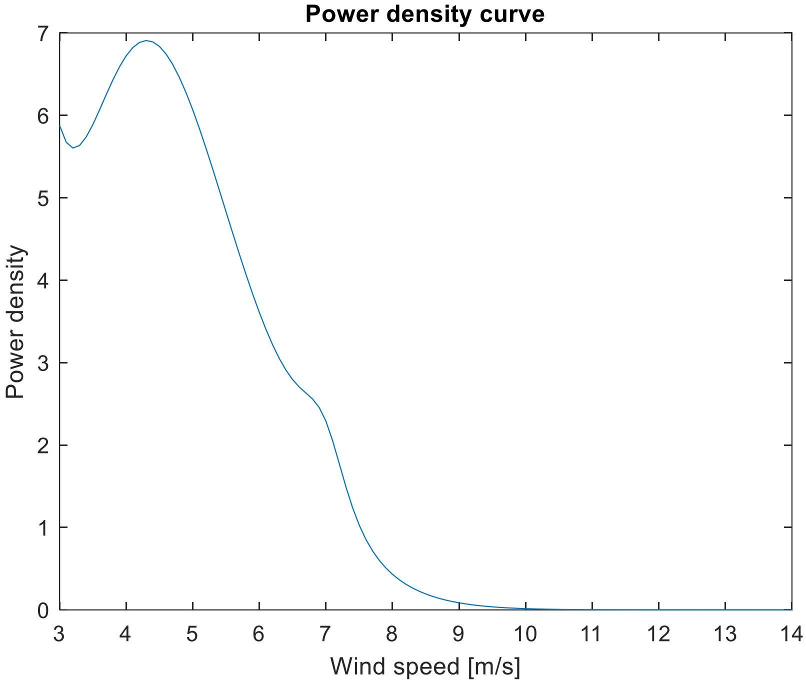
Source The Weather Channel



$$P_{WG_{avg}} = 24.2189\ [W] \quad (347)$$

$$Energy = 18.019\ [kWh] \quad (348)$$

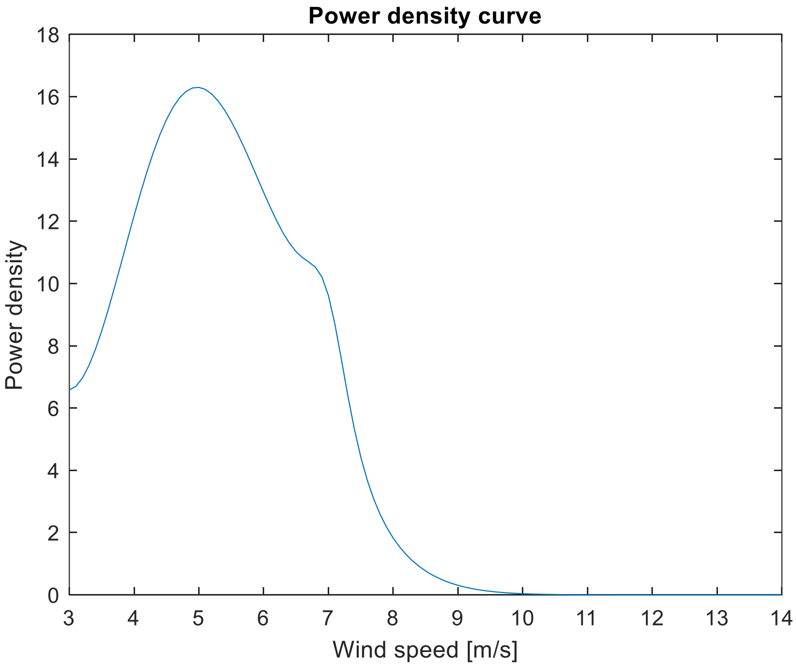
Source eltiempo.es



$$P_{WG_{avg}} = 21.8302\ [W] \quad (349)$$

$$Energy = 16.242\ [kWh] \quad (350)$$

Source NASA (Real wind speed data)

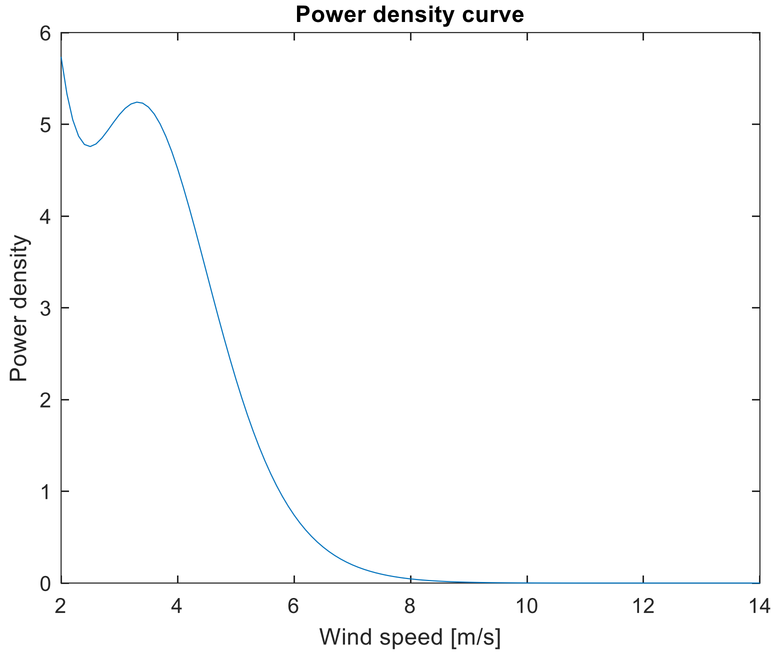


$$P_{WG_{avg}} = 55.8580\ [W] \quad (351)$$

$$Energy = 41.558\ [kWh] \quad (352)$$

Automaxx 600W wind turbine (12V)

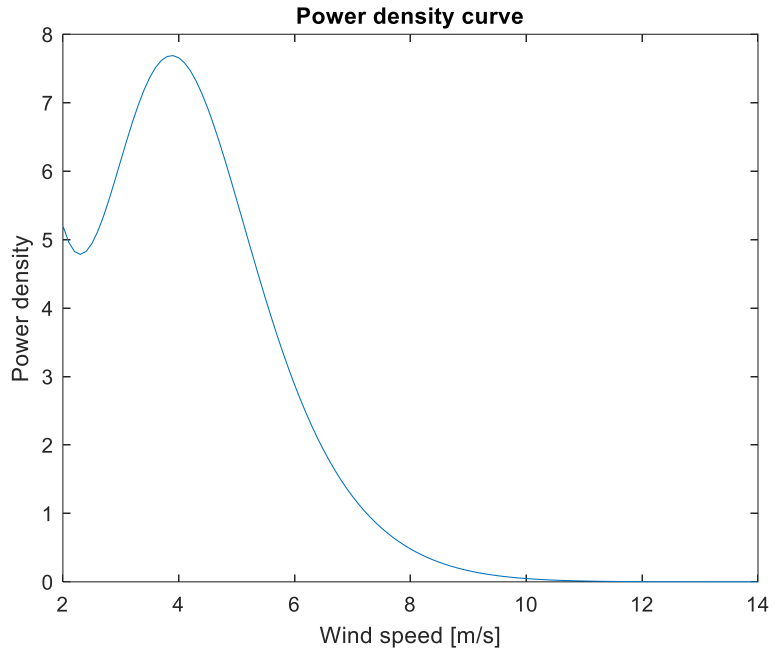
Source AEMET



$$P_{WG_{avg}} = 15.3480\ [W] \tag{353}$$

$$Energy = 11.419\ [kWh] \tag{354}$$

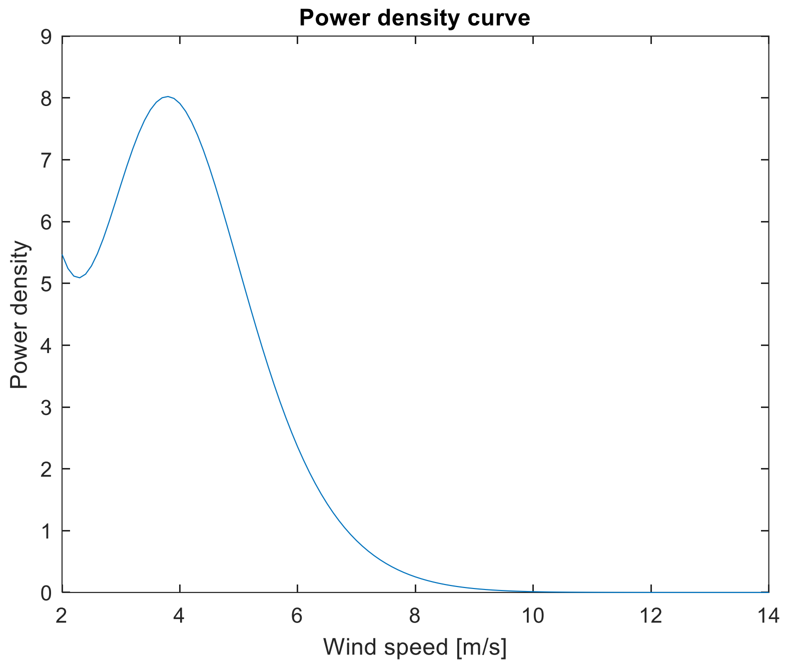
Source The Weather Channel



$$P_{WG_{avg}} = 26.5974[W] \tag{355}$$

$$Energy = 19.788\ [kWh] \tag{356}$$

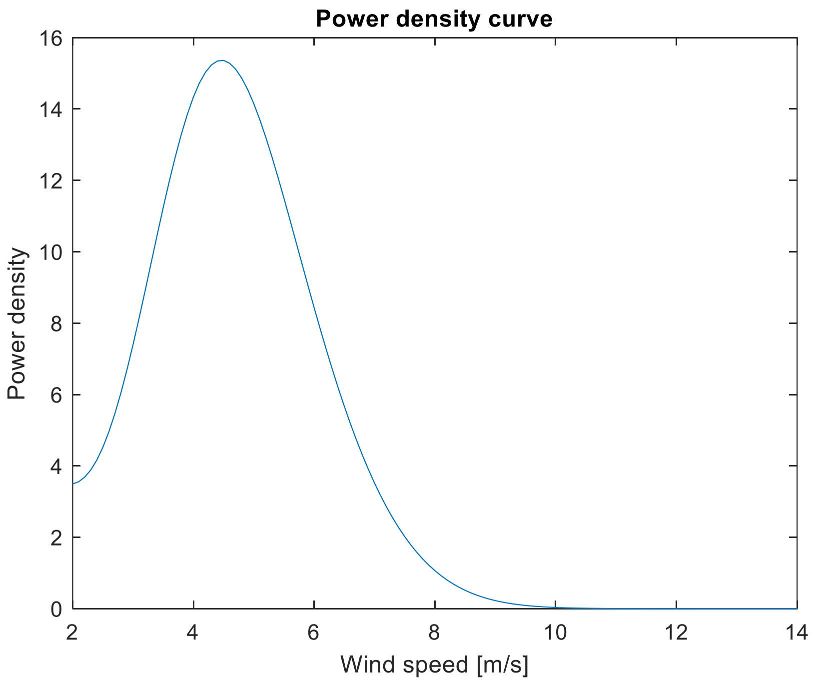
Source eltiempo.es



$$P_{WG_{avg}} = 25.8098\ [W] \tag{357}$$

$$Energy = 19.203\ [kWh] \tag{358}$$

Source NASA (Real wind speed data)

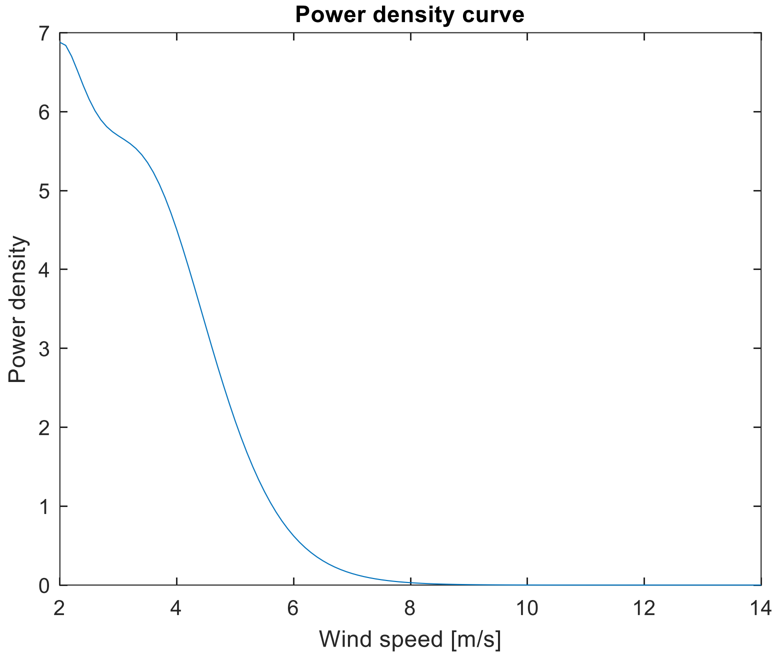


$$P_{WG_{avg}} = 50.9139\ [W] \tag{359}$$

$$Energy = 37.88\ [kWh] \tag{360}$$

Automaxx 600W wind turbine (24V)

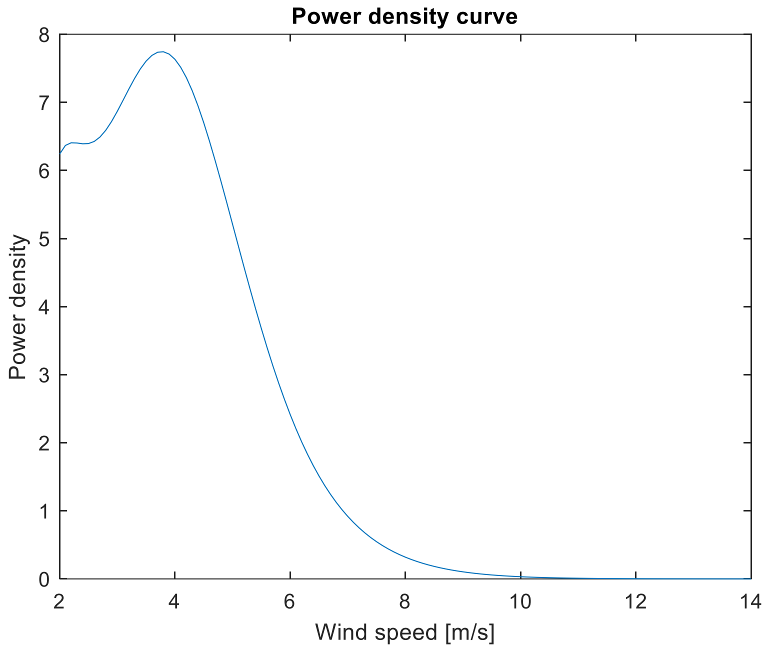
Source AEMET



$$P_{WG_{avg}} = 16.4396\ [W] \tag{361}$$

$$Energy = 12.231\ [kWh] \tag{362}$$

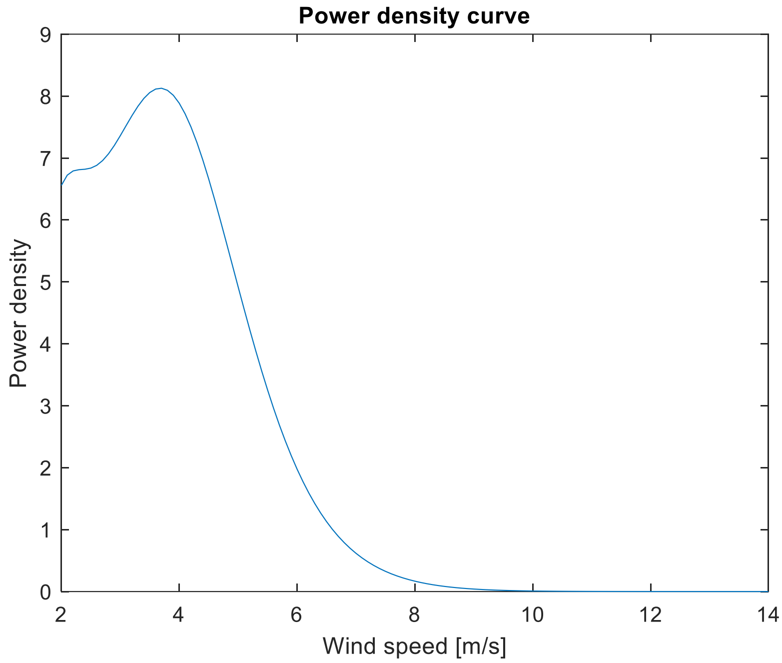
Source The Weather Channel



$$P_{WG_{avg}} = 26.7026\ [W] \tag{363}$$

$$Energy = 19.867\ [kWh] \tag{364}$$

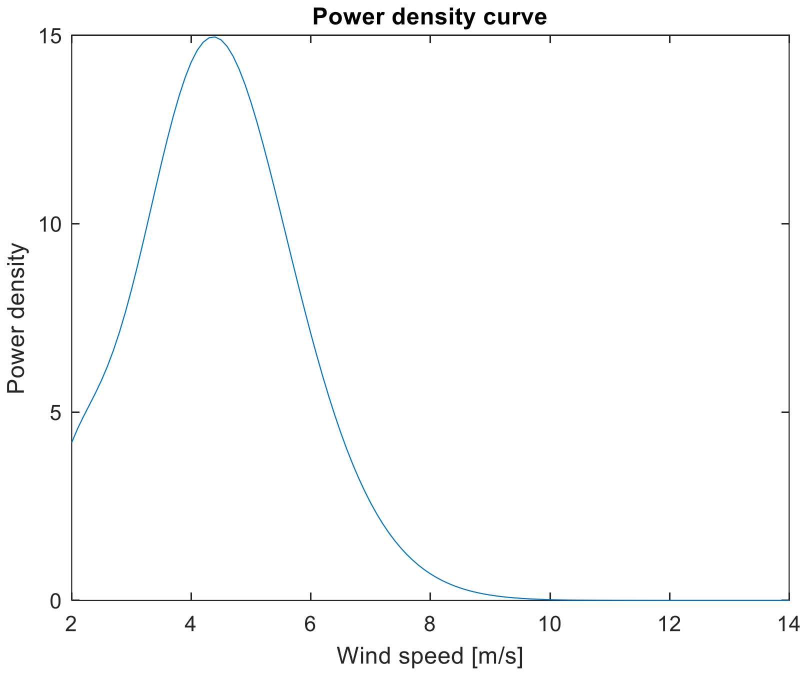
Source eltiempo.es



$$P_{WG_{avg}} = 26.3555\ [W] \tag{365}$$

$$Energy = 19.609\ [kWh] \tag{366}$$

Source NASA (Real wind speed data)

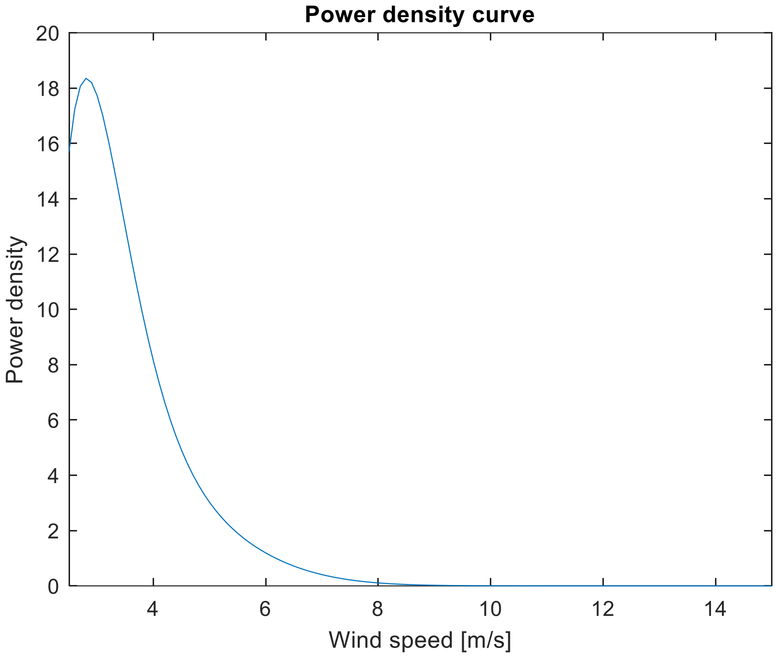


$$P_{WG_{avg}} = 48.6771\ [W] \tag{367}$$

$$Energy = 36.216\ [kWh] \tag{368}$$

Automaxx 1500W wind turbine

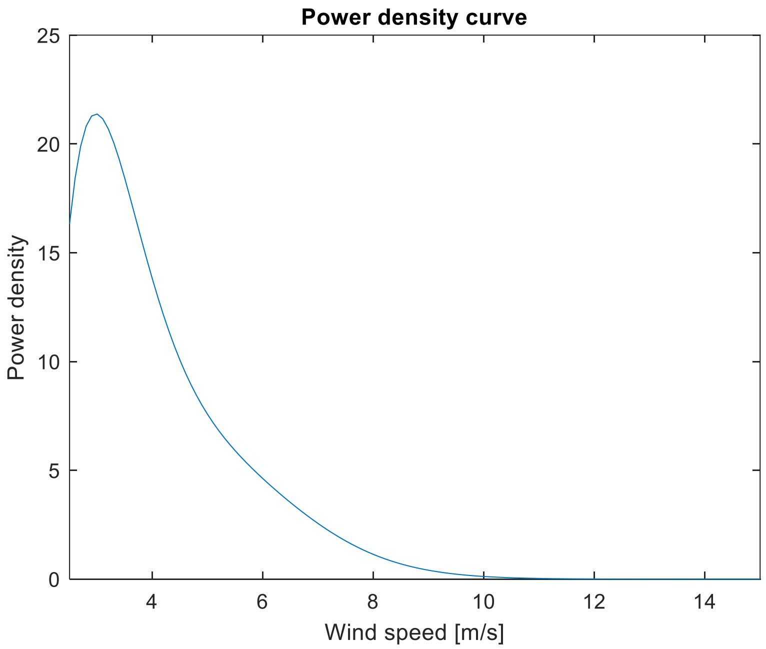
Source AEMET



$$P_{WG_{avg}} = 29.9805\ [W] \tag{369}$$

$$Energy = 22.305\ [kWh] \tag{370}$$

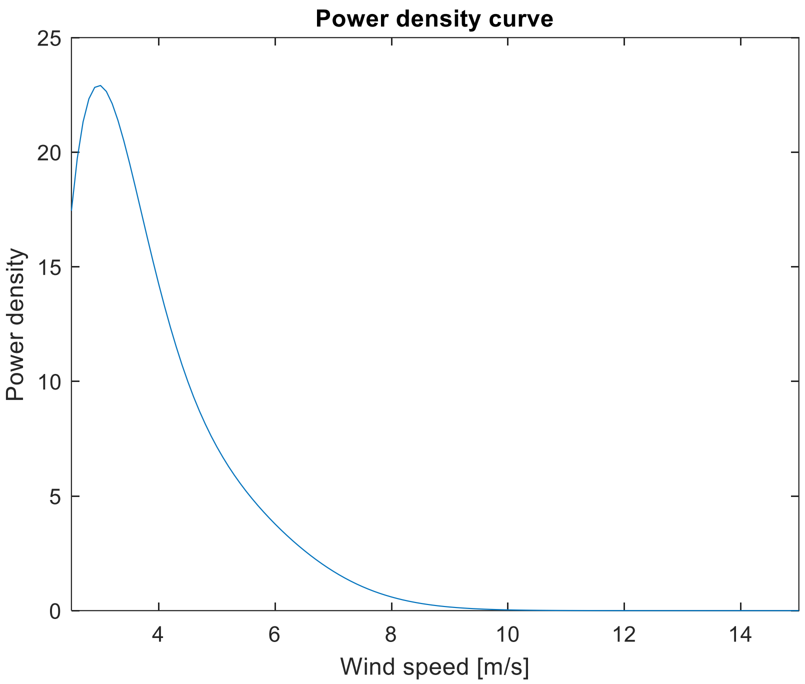
Source The Weather Channel



$$P_{WG_{avg}} = 50.6829\ [W] \tag{371}$$

$$Energy = 37.708\ [kWh] \tag{372}$$

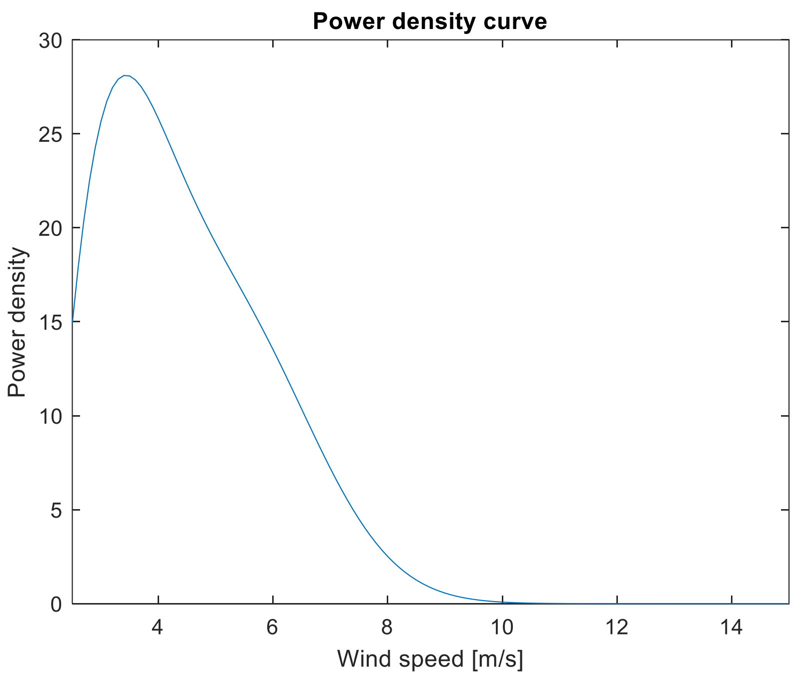
Source eltiempo.es



$$P_{WG_{avg}} = 49.5722\ [W] \tag{373}$$

$$Energy = 36.882\ [kWh] \tag{374}$$

Source NASA (Real wind speed data)

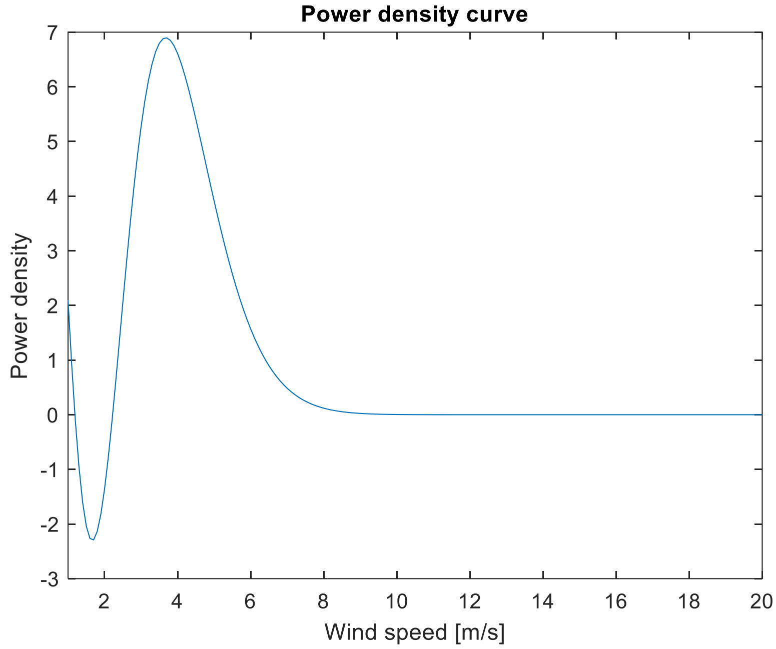


$$P_{WG_{avg}} = 93.2089\ [W] \tag{375}$$

$$Energy = 69.347\ [kWh] \tag{376}$$

Bornay Wind 13+ wind turbine

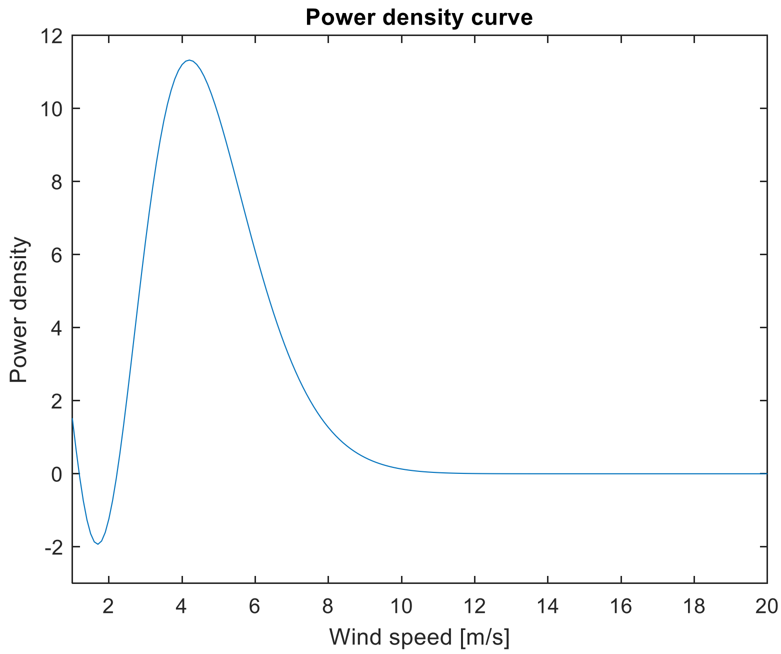
Source AEMET



$$P_{WG_{avg}} = 16.5852\ [W] \quad (377)$$

$$Energy = 12.339\ [kWh] \quad (378)$$

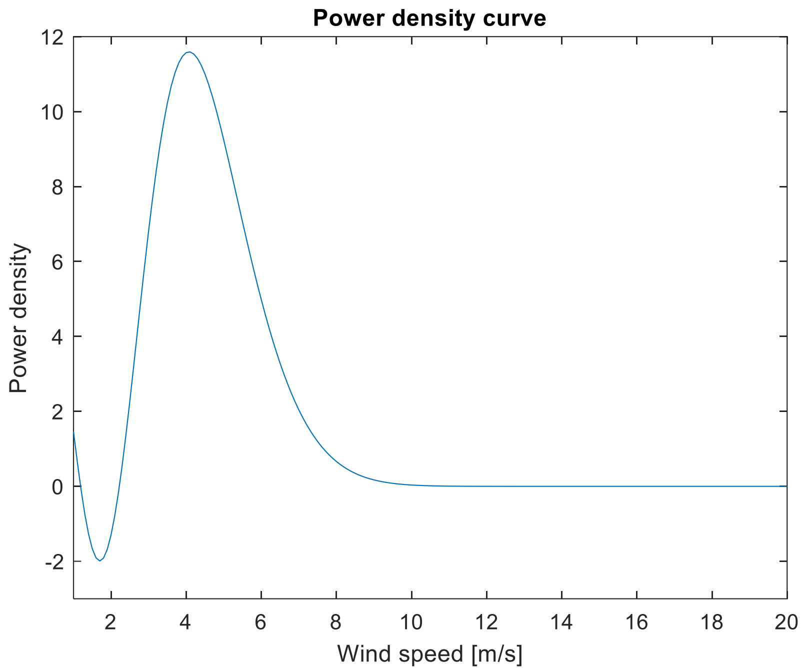
Source The Weather Channel



$$P_{WG_{avg}} = 37.1076\ [W] \quad (379)$$

$$Energy = 27.608\ [kWh] \quad (380)$$

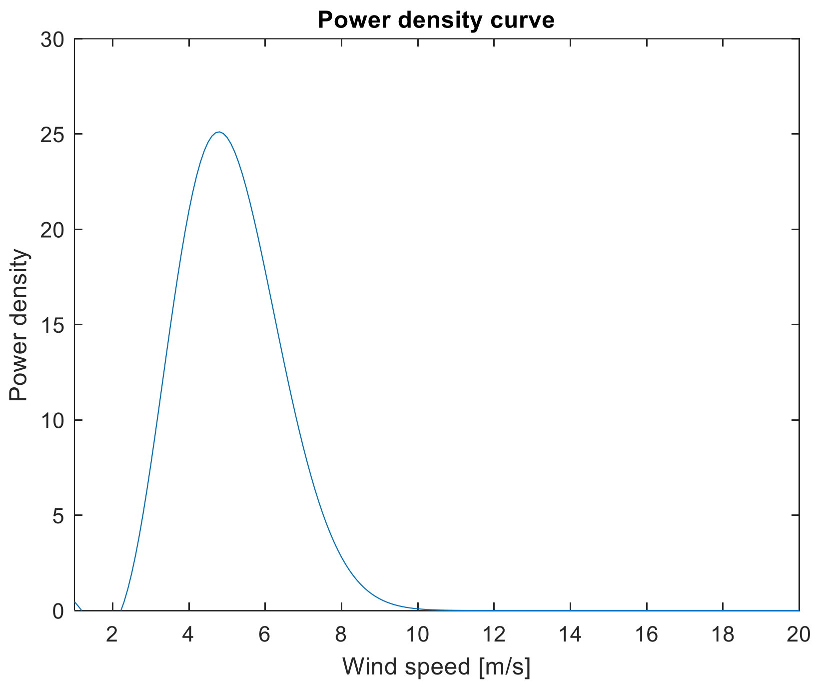
Source eltiempo.es



$$P_{WG_{avg}} = 34.2259\ [W] \tag{381}$$

$$Energy = 25.464\ [kWh] \tag{382}$$

Source NASA (Real wind speed data)

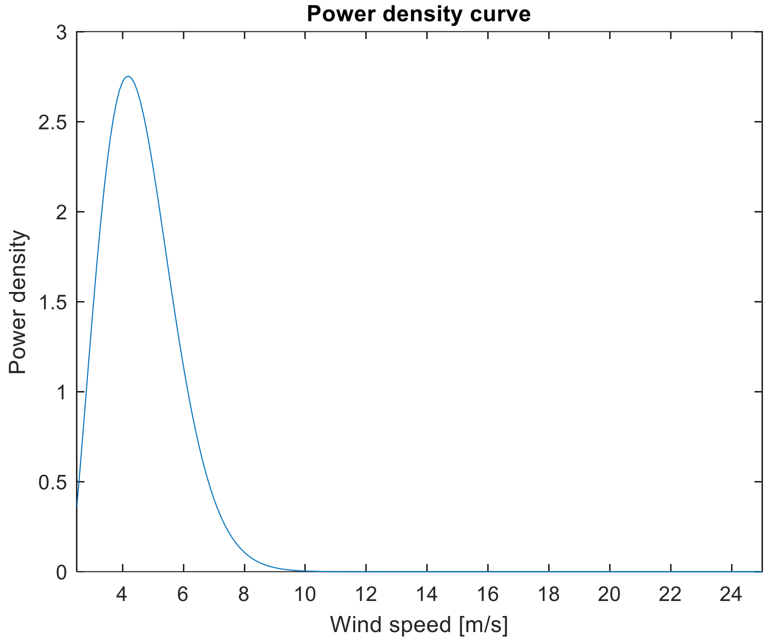


$$P_{WG_{avg}} = 82.5253\ [W] \tag{383}$$

$$Energy = 61.399\ [kWh] \tag{384}$$

Fortis Passaat 1.4kW wind turbine

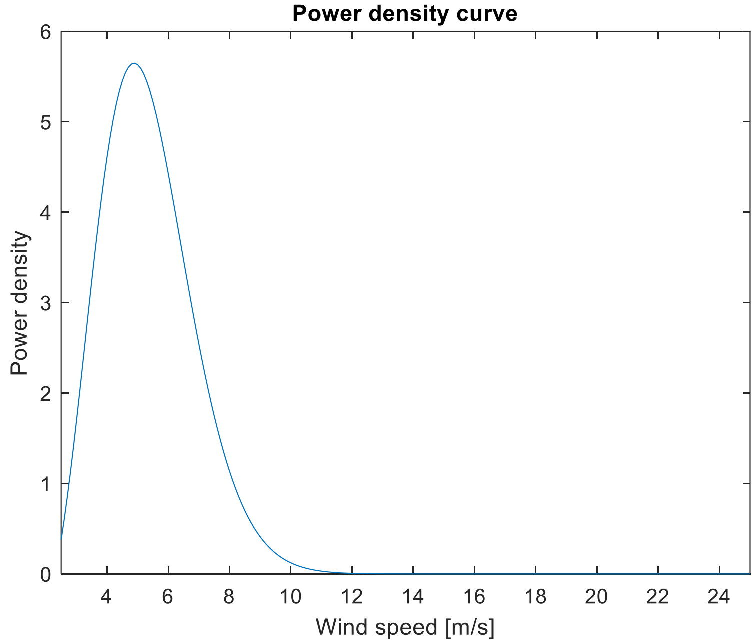
Source AEMET



$$P_{WG_{avg}} = 7.9601\ [W] \quad (385)$$

$$Energy = 5.9223\ [kWh] \quad (386)$$

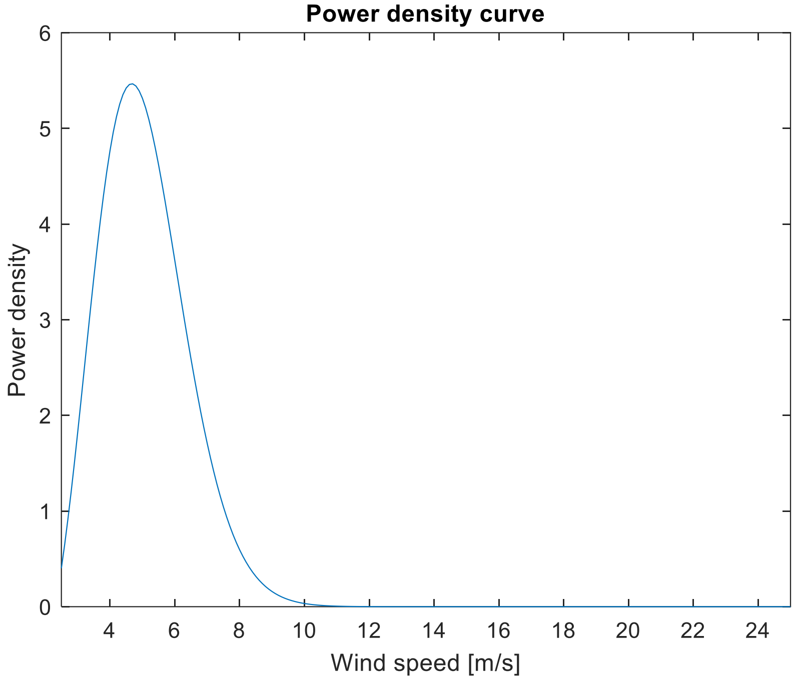
Source The Weather Channel



$$P_{WG_{avg}} = 20.5163\ [W] \quad (387)$$

$$Energy = 15.264\ [kWh] \quad (388)$$

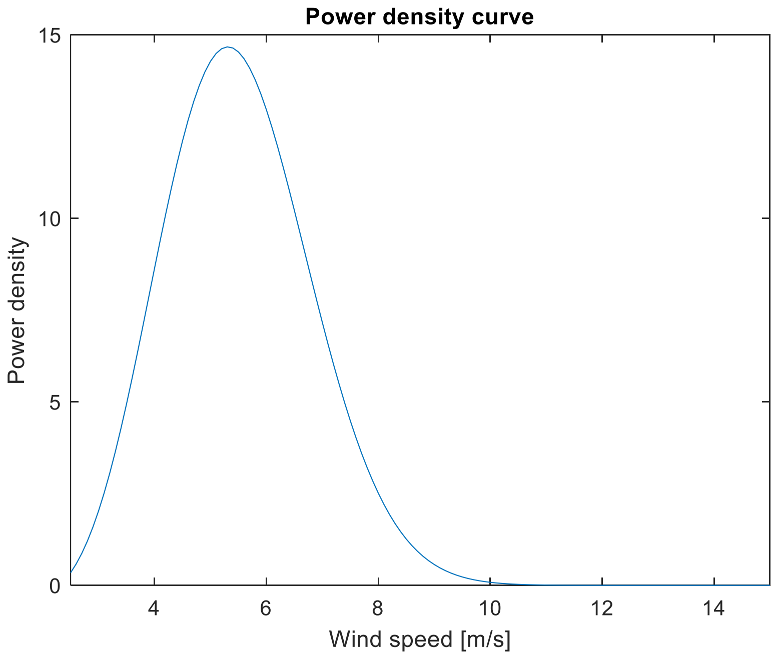
Source eltiempo.es



$$P_{WG_{avg}} = 17.9119\ [W] \tag{389}$$

$$Energy = 13.326\ [kWh] \tag{390}$$

Source NASA (Real wind speed data)

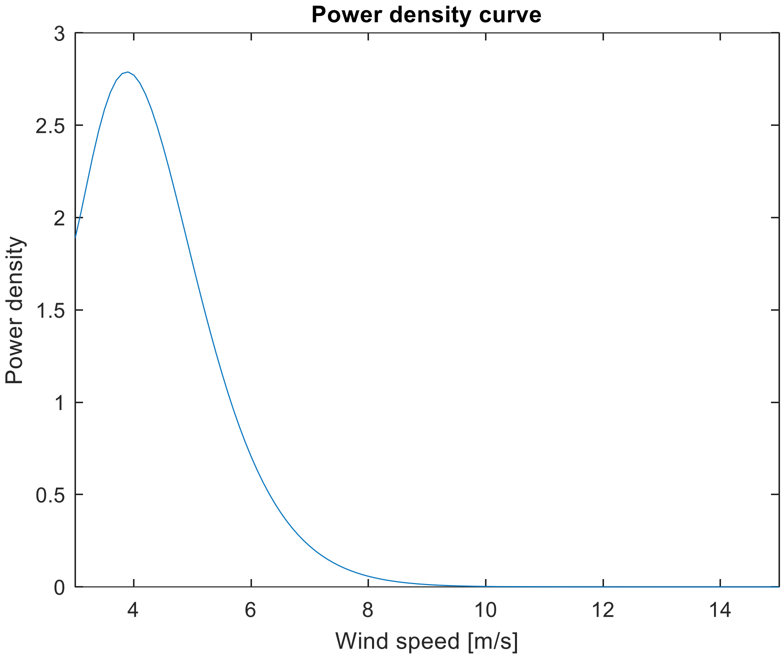


$$P_{WG_{avg}} = 48.1482\ [W] \tag{391}$$

$$Energy = 35.822\ [kWh] \tag{392}$$

Hi-VAWT DS700

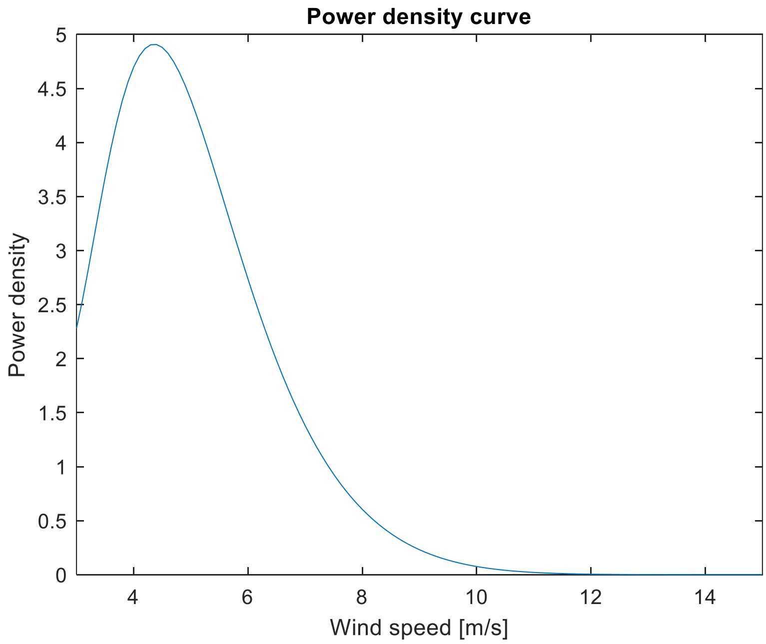
Source AEMET



$$P_{WG_{avg}} = 6.6007\ [W] \tag{393}$$

$$Energy = 4.9109\ [kWh] \tag{394}$$

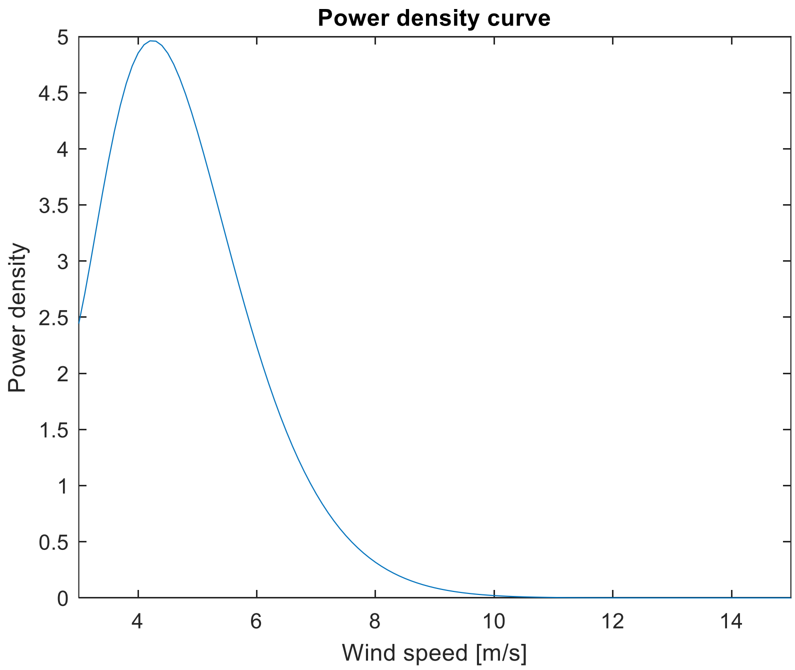
Source The Weather Channel



$$P_{WG_{avg}} = 15.5062\ [W] \tag{395}$$

$$Energy = 11.537\ [kWh] \tag{396}$$

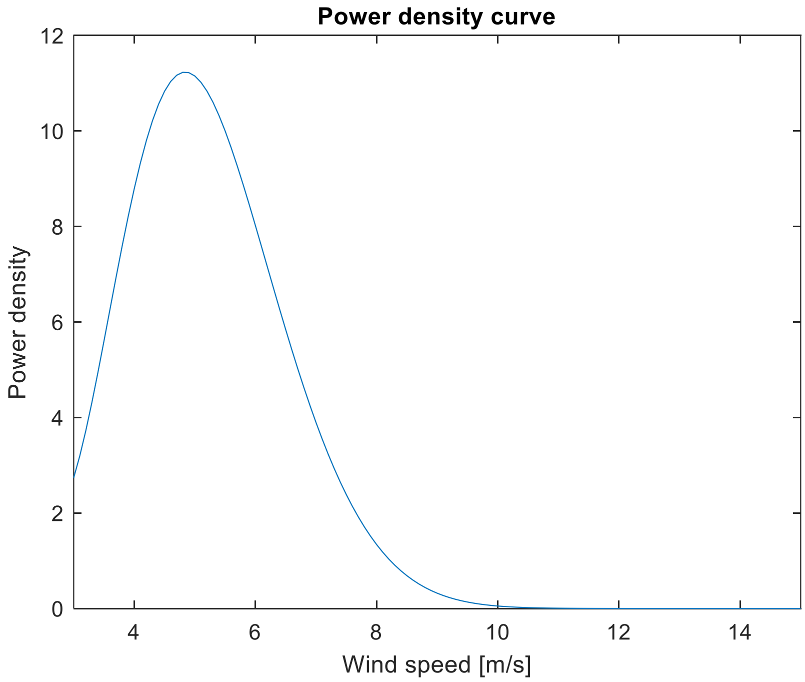
Source eltiempo.es



$$P_{WG_{avg}} = 14.0520\ [W] \tag{397}$$

$$Energy = 10.455\ [kWh] \tag{398}$$

Source NASA (Real wind speed data)

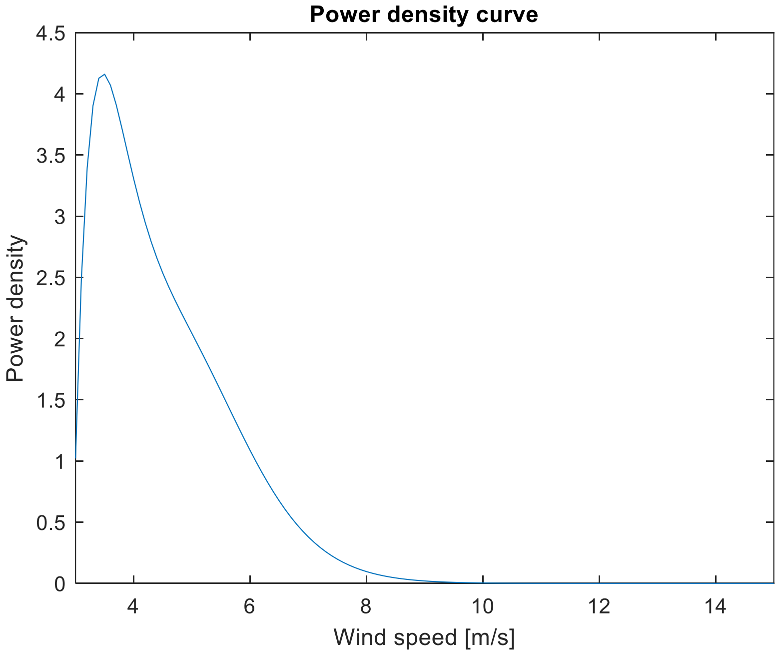


$$P_{WG_{avg}} = 35.2942\ [W] \tag{399}$$

$$Energy = 26.259\ [kWh] \tag{400}$$

Hi-VAWT DS1500

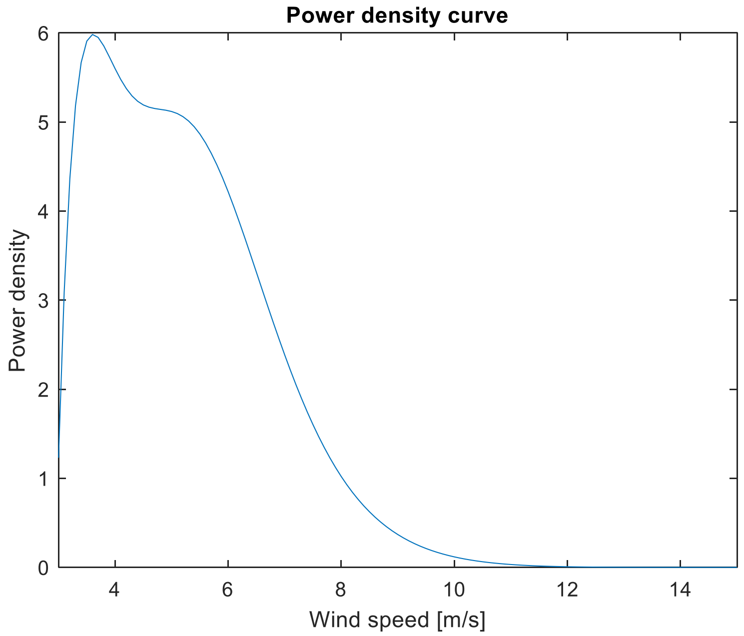
Source AEMET



$$P_{WG_{avg}} = 8.6574\ [W] \tag{401}$$

$$Energy = 6.4411\ [kWh] \tag{402}$$

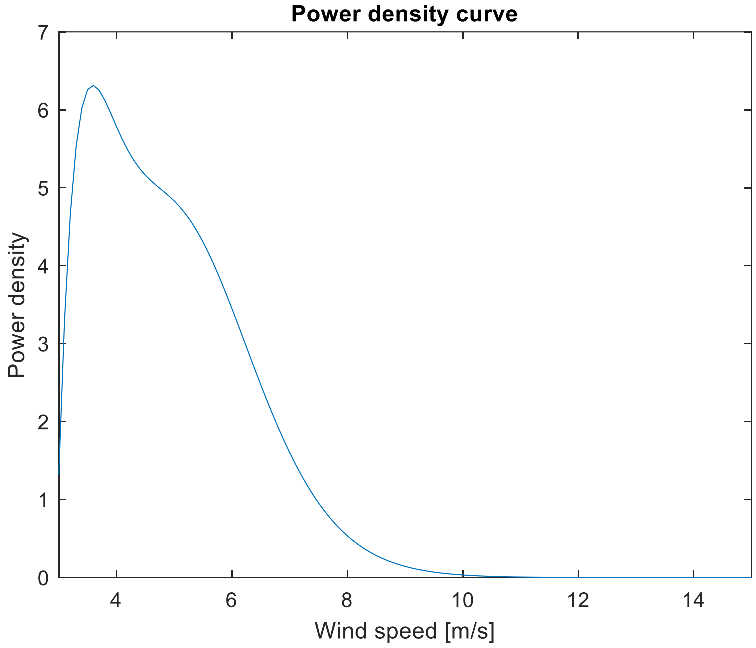
Source The Weather Channel



$$P_{WG_{avg}} = 21.0655\ [W] \tag{403}$$

$$Energy = 15.673\ [kWh] \tag{404}$$

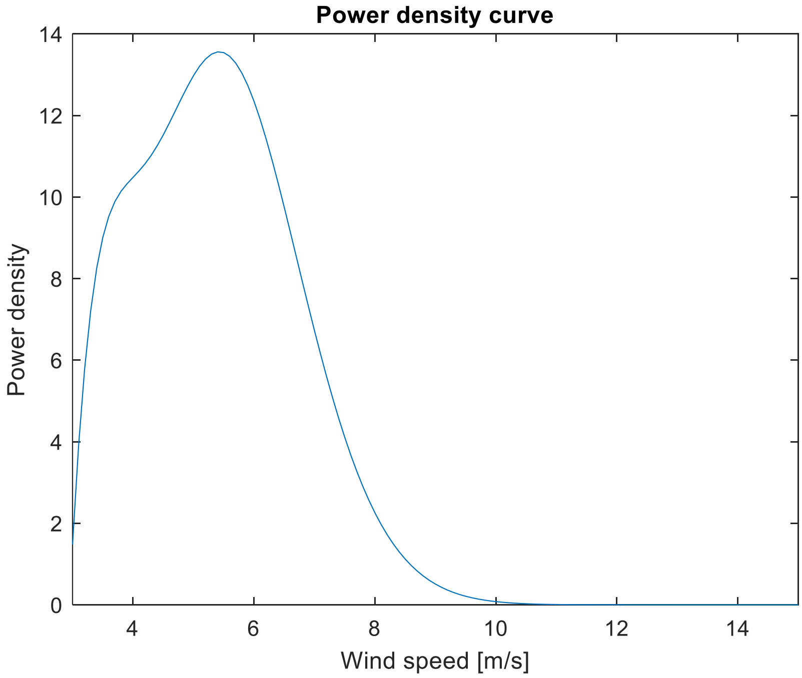
Source eltiempo.es



$$P_{WG_{avg}} = 18.7376\ [W] \tag{405}$$

$$Energy = 13.941 [kWh] \tag{406}$$

Source NASA (Real wind speed data)

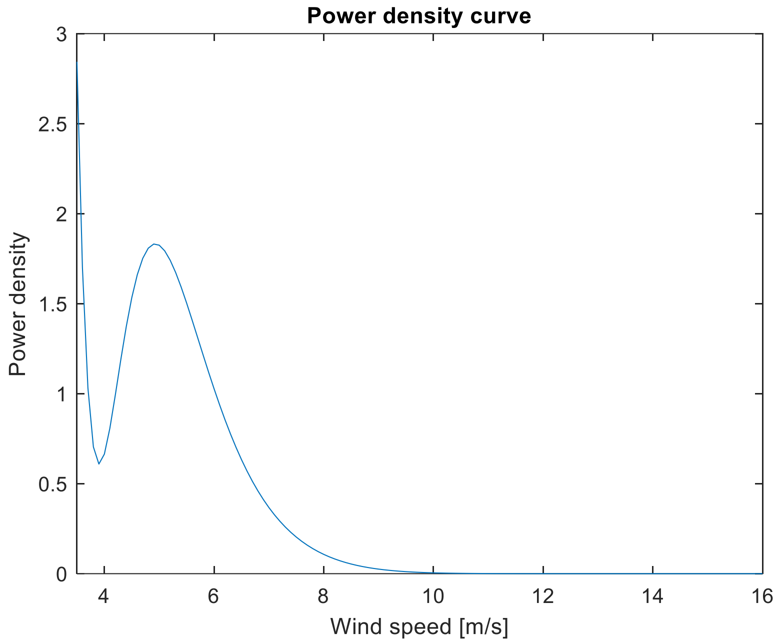


$$P_{WG_{avg}} = 48.2490\ [W] \tag{407}$$

$$Energy = 35.897\ [kWh] \tag{408}$$

Superwind 1250 wind turbine

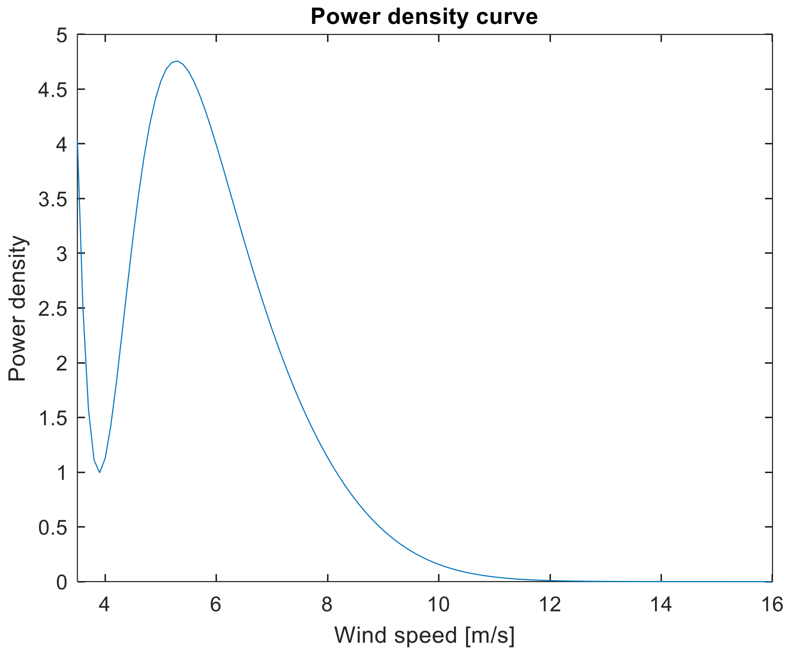
Source AEMET



$$P_{WG_{avg}} = 4.4204\ [W] \tag{409}$$

$$Energy = 3.2888\ [kWh] \tag{410}$$

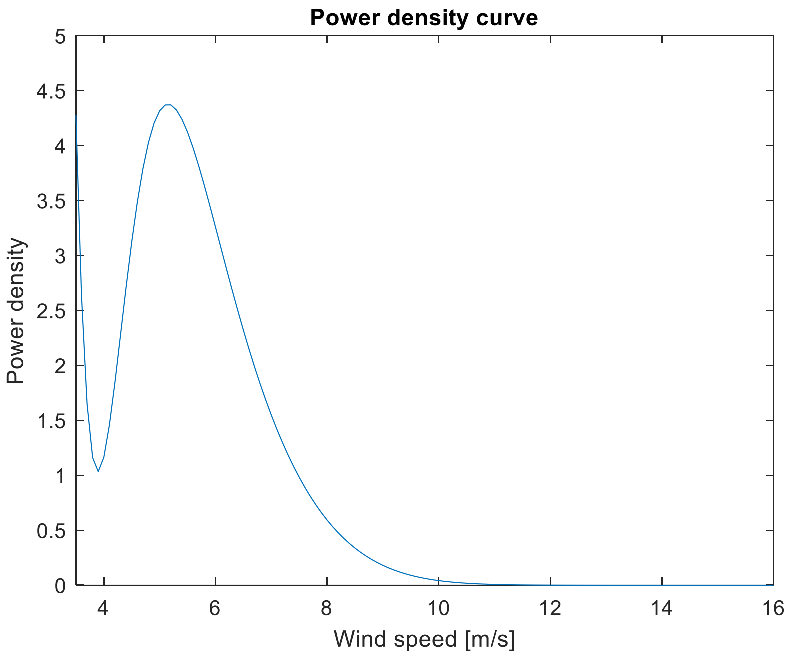
Source The Weather Channel



$$P_{WG_{avg}} = 14.3974\ [W] \tag{411}$$

$$Energy = 10.712\ [kWh] \tag{412}$$

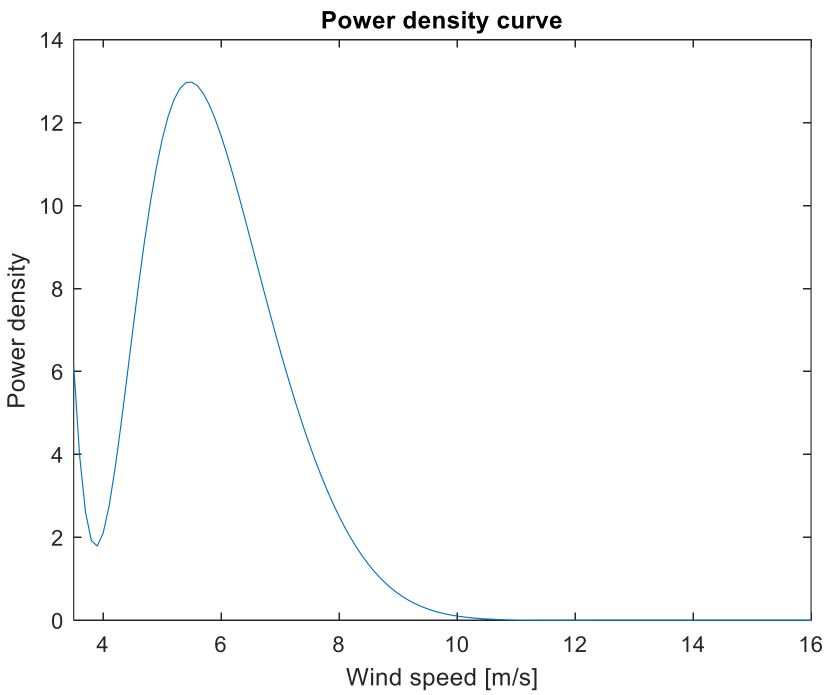
Source eltiempo.es



$$P_{WG_{avg}} = 11.7412\ [W] \quad (413)$$

$$Energy = 8.7354[kWh] \quad (414)$$

Source NASA (Real wind speed data)



$$P_{WG_{avg}} = 36.1040\ [W] \quad (415)$$

$$Energy = 26.861\ [kWh] \quad (416)$$

Annex 7 - Legislation and regulations

International and European legislation

- Directive 2001/77/EC of the European Parliament and of the Council of 27 September 2001 on the promotion of electricity produced from renewable energy sources in the internal electricity market
- Energy for the Future: Renewable Sources of Energy. White Paper for a Community Strategy and Action Plan. COM (97) 599 final, 26 November 1997
- Kyoto Protocol to the United Nations Framework Convention on Climate Change, 11 December 1999.
- Directive 2004/101/EC of the European Parliament and of the Council of 27 October 2004 amending Directive 2003/87/EC establishing a scheme for greenhouse gas emission allowance trading within the Community, in respect of the Kyoto Protocol's project mechanisms
- COM(2005) 265 final. Green paper on energy efficiency or doing more with less. European Commission.
- COM(2005) 627 final, December 2005. Communication from the Commission on support for electricity from renewable energy sources.

National legislation

- Royal Decree-Law 3/2006, of 24 February, which modifies the mechanism for matching bids for the sale and purchase of energy submitted simultaneously to the daily and intraday production market by parties in the electricity sector belonging to the same business group (BOE no. 53, 03/03/2006).
- Law 1/2005, of 9 March 2005, regulating the greenhouse gas emission allowance trading scheme (BOE no. 59, 10/03/05).
- Royal Decree 2392/2004, of 30 December 2004, establishing the electricity tariff for 2005 (BOE no. 315, 31/12/04).
- Royal Decree 436/2004, of 12 March 2004, establishing the methodology for updating and systematising the legal and economic regime for electricity production activity under the special regime (BOE no. 75, 27/03/04).
- Royal Decree 1432/2002, of 27 December 2002, establishing the methodology for the approval or modification of the average or reference electricity tariff (BOE no. 313, 31/12/02).
- Law 6/2001, of 8 May 2001, modifying Royal Legislative Decree 1302/1986, of 28 June 1986, on Environmental Impact Assessment (BOE no. 111, 09/05/01).
- Royal Decree 1955/2000, of 1 December 2000, regulating the activities of transmission, distribution, commercialisation, supply and authorisation procedures for electricity installations (BOE no. 310, 27/12/00).
- Law 54/1997, of 27 November 1997, on the Electricity Sector (BOE no. 285, 28/11/97).
- Order of 5 September 1985, establishing administrative and technical standards for the operation and connection to electricity networks of hydroelectric power stations of up to 5000 kVA and self-generation power stations (BOE no. 219, 12/09/85).
- Decree 584/1972, of 24 February 1972, on Aeronautical Easements (BOE nº 69, 21/03/1972).

Regional administrations

Basque Country

- Decree 104/2002, of 14 May 2002, definitively approving the Territorial Plan for the Wind Energy Sector in the Basque Country (BOPV no. 105, 05/06/02).
- Decree 115/2002, of 28 May 2002, regulating the procedure for the authorisation of wind farms in the Basque Country (BOPV no. 108, 10/06/02).

Annex 8 – Simulations in Homer Pro. Analysis of generation and consumption

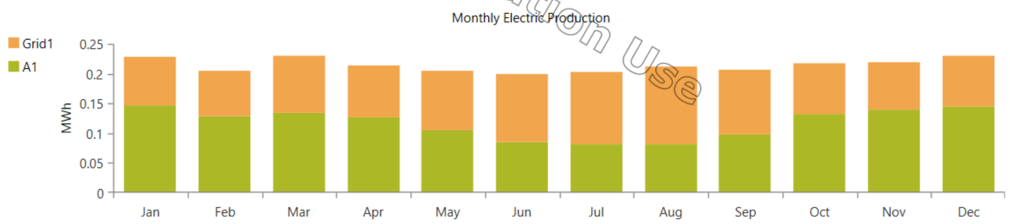
Automaxx 400W wind turbine

Production	kWh/yr	%
Automaxx 400W	1,407	54.8
Grid Purchases	1,160	45.2
Total	2,568	100

Consumption	kWh/yr	%
AC Primary Load	2,289	89.1
DC Primary Load	0	0
Deferrable Load	0	0
Grid Sales	279	10.9
Total	2,568	100

Quantity	kWh/yr	%
Excess Electricity	0	0
Unmet Electric Load	0	0
Capacity Shortage	0	0

Quantity	Value	Units
Renewable Fraction	54.8	%
Max. Renew. Penetration	100	%



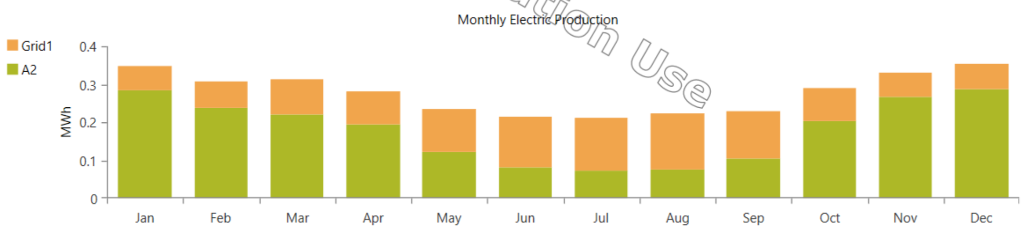
Automaxx 600W (12V) wind turbine

Production	kWh/yr	%
Automaxx 600W 12V	2,142	64.2
Grid Purchases	1,193	35.8
Total	3,335	100

Consumption	kWh/yr	%
AC Primary Load	2,288	68.6
DC Primary Load	0	0
Deferrable Load	0	0
Grid Sales	1,047	31.4
Total	3,335	100

Quantity	kWh/yr	%
Excess Electricity	0	0
Unmet Electric Load	0	0
Capacity Shortage	0	0

Quantity	Value	Units
Renewable Fraction	64.2	%
Max. Renew. Penetration	100	%



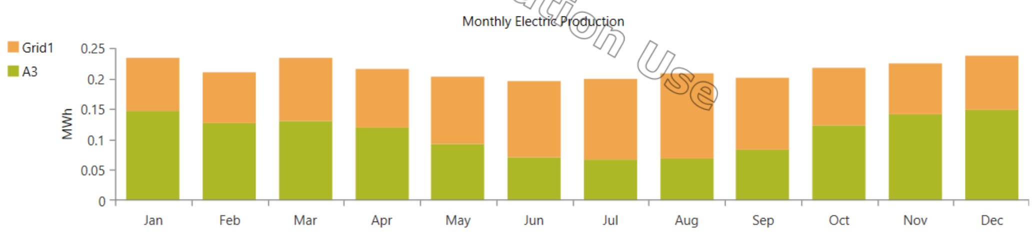
Automaxx 600W (24V) wind turbine

Production	kWh/yr	%
Automaxx 600W 24V	1,320	51.2
Grid Purchases	1,257	48.8
Total	2,577	100

Consumption	kWh/yr	%
AC Primary Load	2,288	88.8
DC Primary Load	0	0
Deferrable Load	0	0
Grid Sales	289	11.2
Total	2,577	100

Quantity	kWh/yr	%
Excess Electricity	0	0
Unmet Electric Load	0	0
Capacity Shortage	0	0

Quantity	Value	Units
Renewable Fraction	51.2	%
Max. Renew. Penetration	100	%



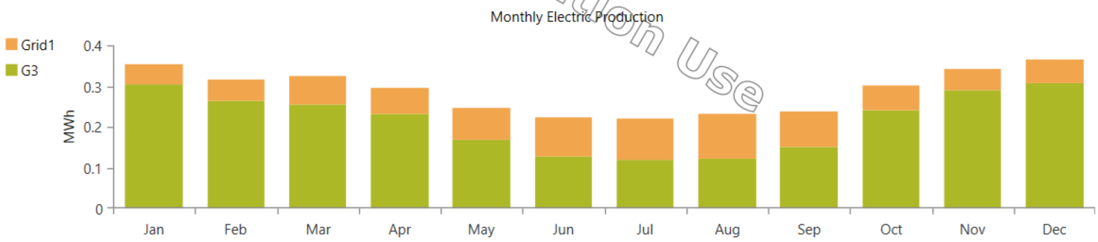
Automaxx 1500W wind turbine

Production	kWh/yr	%
Generic 3 kW	2,575	74.5
Grid Purchases	882	25.5
Total	3,457	100

Consumption	kWh/yr	%
AC Primary Load	2,288	66.2
DC Primary Load	0	0
Deferrable Load	0	0
Grid Sales	1,169	33.8
Total	3,457	100

Quantity	kWh/yr	%
Excess Electricity	0	0
Unmet Electric Load	0	0
Capacity Shortage	0	0

Quantity	Value	Units
Renewable Fraction	74.5	%
Max. Renew. Penetration	100	%



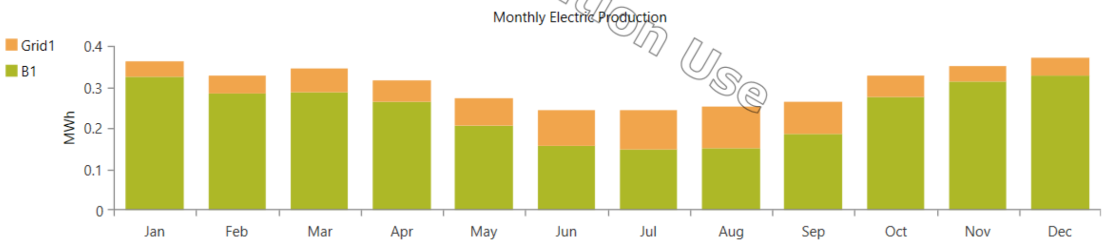
Bornay Wind 13+ wind turbine

Production	kWh/yr	%
Bornay Wind 13+	2,922	79.6
Grid Purchases	751	20.4
Total	3,672	100

Consumption	kWh/yr	%
AC Primary Load	2,288	62.3
DC Primary Load	0	0
Deferrable Load	0	0
Grid Sales	1,384	37.7
Total	3,672	100

Quantity	kWh/yr	%
Excess Electricity	0	0
Unmet Electric Load	0	0
Capacity Shortage	0	0

Quantity	Value	Units
Renewable Fraction	79.6	%
Max. Renew. Penetration	100	%



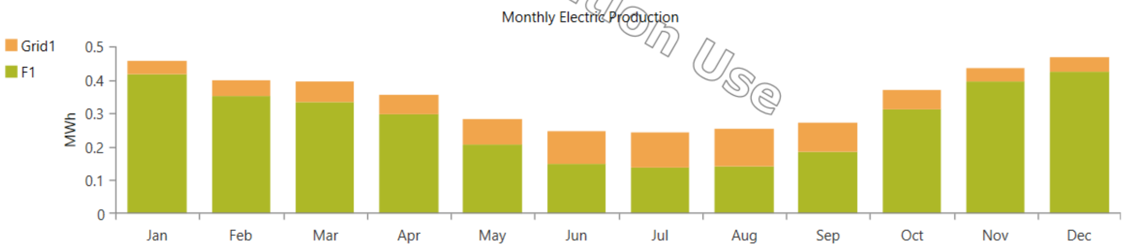
Fortis Passaat 1.4kW wind turbine

Production	kWh/yr	%
Fortis Passaat 1.4kW	3,347	80.1
Grid Purchases	829	19.9
Total	4,176	100

Consumption	kWh/yr	%
AC Primary Load	2,288	54.8
DC Primary Load	0	0
Deferrable Load	0	0
Grid Sales	1,888	45.2
Total	4,176	100

Quantity	kWh/yr	%
Excess Electricity	0	0
Unmet Electric Load	0	0
Capacity Shortage	0	0

Quantity	Value	Units
Renewable Fraction	80.1	%
Max. Renew. Penetration	100	%



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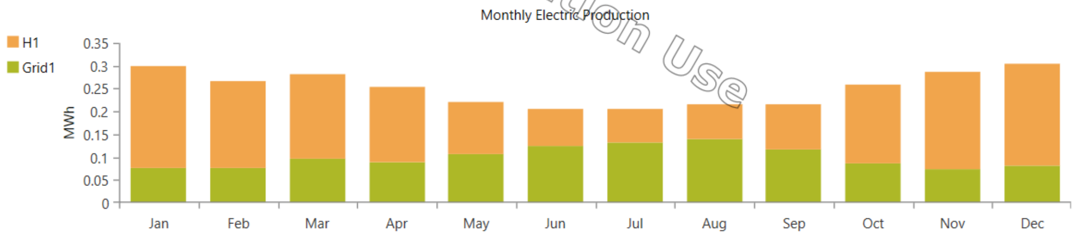
Hi-VAWT DS700 wind turbine

Production	kWh/yr	%
Hi-VAWT DS700	1,808	60.1
Grid Purchases	1,201	39.9
Total	3,010	100

Consumption	kWh/yr	%
AC Primary Load	2,288	76.0
DC Primary Load	0	0
Deferrable Load	0	0
Grid Sales	722	24.0
Total	3,010	100

Quantity	kWh/yr	%
Excess Electricity	0	0
Unmet Electric Load	0	0
Capacity Shortage	0	0

Quantity	Value	Units
Renewable Fraction	60.1	%
Max. Renew. Penetration	100	%



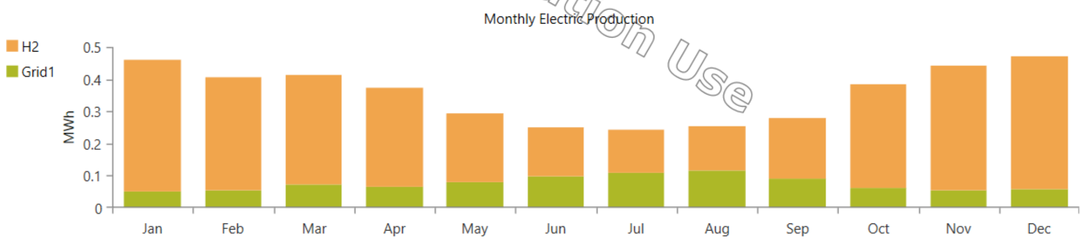
Hi-VAWT DS1500 wind turbine

Production	kWh/yr	%
Hi-VAWT DS1500	3,357	78.6
Grid Purchases	912	21.4
Total	4,268	100

Consumption	kWh/yr	%
AC Primary Load	2,288	53.6
DC Primary Load	0	0
Deferrable Load	0	0
Grid Sales	1,980	46.4
Total	4,268	100

Quantity	kWh/yr	%
Excess Electricity	0	0
Unmet Electric Load	0	0
Capacity Shortage	0	0

Quantity	Value	Units
Renewable Fraction	78.6	%
Max. Renew. Penetration	100	%



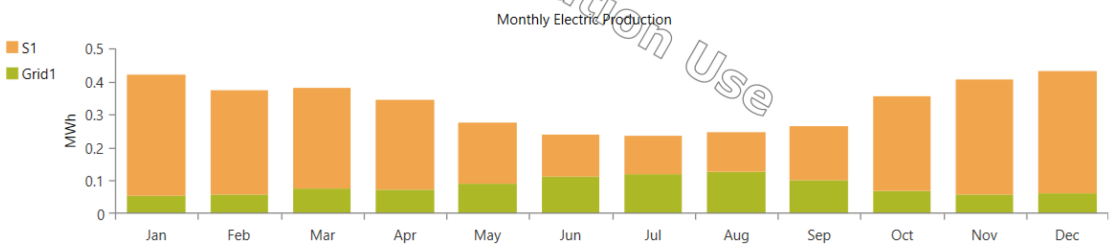
Superwind 1250 wind turbine

Production	kWh/yr	%
Superwind 1250	2,968	74.8
Grid Purchases	999	25.2
Total	3,968	100

Consumption	kWh/yr	%
AC Primary Load	2,289	57.7
DC Primary Load	0	0
Deferrable Load	0	0
Grid Sales	1,679	42.3
Total	3,968	100

Quantity	kWh/yr	%
Excess Electricity	0	0
Unmet Electric Load	0	0
Capacity Shortage	0	0

Quantity	Value	Units
Renewable Fraction	74.8	%
Max. Renew. Penetration	100	%



Annex 9 – Simulations in Homer Pro. Energy purchased to the grid

Automaxx 400W wind turbine

Month	Energy purchased [kWh]	Energy sold [kWh]	Net Energy purchased [kWh]	Energy charge [€]	Demand Charge [€]
January	82	35	46	11,53	2,95
February	76	34	42	10,97	2,34
March	95	31	64	14,83	3,41
April	87	25	62	13,76	2,85
May	99	15	84	16,35	3,13
June	114	10	105	19,55	2,83
July	122	10	112	21,14	3,41
August	129	11	119	22,48	3,08
September	109	15	94	18,02	2,83
October	84	26	58	12,78	2,78
November	79	33	46	11,26	3,1
December	84	35	49	12,53	2,85
Annual	1160	279	881	185,19	35,55

Automaxx 600W (12V) wind turbine

Month	Energy purchased [kWh]	Energy sold [kWh]	Net Energy purchased [kWh]	Energy charge [€]	Demand Charge [€]
January	65	157	-92	-1,07	3,19
February	69	135	-66	0,8	2,52
March	93	113	-20	4,29	3,41
April	89	92	-3	4,83	2,94
May	113	44	69	13,16	3,13
June	133	24	108	19,95	2,82
July	141	19	122	22,25	3,49
August	149	22	127	23,67	3,25
September	123	37	86	16,25	3,06
October	86	98	-12	3,76	2,87
November	65	145	-80	-0,9	3,32
December	67	160	-93	-1,56	2,64
Annual	1193	1,047	146	105,46	36,65

Automaxx 600W (24V) wind turbine

Month	Energy purchased [kWh]	Energy sold [kWh]	Net Energy purchased [kWh]	Energy charge [€]	Demand Charge [€]
January	86	41	45	11,03	3,08
February	82	38	44	11,03	2,37
March	103	34	69	15,29	3,32
April	96	25	71	14,7	2,84
May	110	12	98	18,56	3,05
June	125	6	118	21,89	2,74
July	131	6	125	23,25	3,4
August	139	7	132	24,63	3,1
September	118	11	108	20,27	2,92
October	94	27	67	14,12	2,78
November	83	37	46	10,6	3,19
December	89	43	47	11,63	2,85
Annual	1257	289	968	197	35,64

Automaxx 1500W wind turbine

Month	Energy purchased [kWh]	Energy sold [kWh]	Net Energy purchased [kWh]	Energy charge [€]	Demand Charge [€]
January	51	163	-112	-2,79	2,93
February	54	146	-92	-0,6	2,26
March	70	126	-56	1,45	3,17
April	64	105	-41	1,73	2,66
May	78	56	22	7,59	3,13
June	95	33	62	13,11	2,56
July	102	28	74	14,91	3,21
August	109	29	79	16,41	2,96
September	88	48	40	10,26	2,79
October	61	110	-49	€ 1	2,59
November	52	155	-103	-2,05	3,06
December	57	170	-113	-2,26	2,85
Annual	882	1,169	-287	58,7	34,16

Bornay Wind 13+ wind turbine

Month	Energy purchased [kWh]	Energy sold [kWh]	Net Energy purchased [kWh]	Energy charge [€]	Demand Charge [€]
January	36	170	-134	-4,01	2,59
February	42	156	-113	-2,01	2,19
March	58	145	-88	-0,5	3,34
April	52	127	-75	-0,4	2,81
May	68	82	-14	3,75	3,07
June	86	53	32	8,56	2,74
July	95	49	45	10,78	3,39
August	100	50	50	11,96	2,95
September	79	73	6	5,98	2,58
October	51	136	-85	-1,6	2,77
November	40	165	-125	-3,36	2,82
December	43	177	-133	-3,41	2,54
Annual	751	1384	-633	25,69	33,77

Fortis Passaat 1.4kW wind turbine

Month	Energy purchased [kWh]	Energy sold [kWh]	Net Energy purchased [kWh]	Energy charge [€]	Demand Charge [€]
January	39	265	-226	-7,69	2,68
February	45	226	-181	-5,79	2,26
March	63	197	-134	-3,21	3,38
April	58	166	-108	-2,23	2,91
May	78	94	-16	3,88	3,11
June	97	57	39	9,49	2,79
July	106	51	56	12,06	3,45
August	112	52	60	13,26	3,06
September	89	81	8	6,19	2,65
October	57	178	-121	-3,39	2,83
November	41	248	-207	-7,04	2,89
December	44	272	-229	-7,78	2,6
Annual	829	1888	-1059	7,75	34,6

Hi-VAWT DS700 wind turbine

Month	Energy purchased [kWh]	Energy sold [kWh]	Net Energy purchased [kWh]	Energy charge [€]	Demand Charge [€]
January	76	108	-32	2,96	3,08
February	76	95	-19	3,93	2,42
March	97	81	16	8,19	3,41
April	90	64	26	8,37	2,89
May	108	30	78	14,87	3,13
June	125	15	111	20,42	2,82
July	133	13	120	22,25	3,45
August	141	14	126	23,65	3,15
September	117	25	91	17,21	2,95
October	86	68	18	7,45	2,83
November	74	99	-25	3,09	3,21
December	80	110	-31	3,45	2,85
Annual	1201	722	480	135,84	36,19

Hi-VAWT DS1500 wind turbine

Month	Energy purchased [kWh]	Energy sold [kWh]	Net Energy purchased [kWh]	Energy charge [€]	Demand Charge [€]
January	52	269	-217	-7,31	2,75
February	55	234	-179	-4,93	2,31
March	71	214	-142	-3,21	3,41
April	64	182	-118	-2,75	2,88
May	80	103	-23	3,54	3,13
June	99	59	40	9,54	2,82
July	109	52	57	12,2	3,45
August	115	54	61	13,37	3,06
September	91	88	3	5,7	2,72
October	62	194	-132	-4,24	2,83
November	54	255	-202	-6,86	2,97
December	60	276	-216	-7,22	2,85
Annual	912	1,98	-1069	7,81	35,18

Superwind 1250 wind turbine

Month	Energy purchased [kWh]	Energy sold [kWh]	Net Energy purchased [kWh]	Energy charge [€]	Demand Charge [€]
January	55	230	-175	-5,78	2,89
February	59	201	-142	-3,51	2,42
March	78	182	-104	-1,35	3,41
April	71	155	-84	-1,01	2,96
May	91	85	5	5,82	3,13
June	111	50	61	12,58	2,83
July	120	42	78	15,21	3,49
August	127	45	83	16,59	3,16
September	102	73	29	8,54	2,85
October	69	163	-94	-2,32	2,88
November	56	218	-162	-5,44	3,1
December	61	237	-176	-5,64	2,85
Annual	999	1679	-680	33,68	35,96

Annex 10 – Wind turbines – Specifications.

Automaxx 400W wind turbine

Model	400 Watt Turbine
Rated speed	28 mph / 12.5 m/s
Rated power	400 watts
*Output Voltage	0-15V
Cut-in wind speed	6.7 mph / 3 m/s
**Survival wind speed	112 mph / 50 m/s
Rotor diameter	4 ft / 1.22 m
Number of Blades	3
Blade material	Plastic steel
Suggested battery capacity	>50 A/Hr

Automaxx 600W wind turbine

<table>
<tr><td rowspan="10">Wind Turbine</td><td>Model</td><td>600 Watts Wind Turbine</td></tr>
<tr><td>Rated speed</td><td>28 mph / 12.5 m/s</td></tr>
<tr><td>Rated power</td><td>600 watts</td></tr>
<tr><td>*Voltage with MPPT</td><td>12 volts or 24 volts</td></tr>
<tr><td>Rotor diameter</td><td>4.3 ft / 1.31 m</td></tr>
<tr><td>Cut-in wind speed</td><td>4.47 mph / 2 m/s</td></tr>
<tr><td>**Survival wind speed</td><td>112 mph / 50 m/s</td></tr>
<tr><td>Number of blades</td><td>3</td></tr>
<tr><td>Blade material</td><td>fiber glass + plastic steel</td></tr>
<tr><td>Suggested battery capacity</td><td>>100 A/HR</td></tr>
</table>

Automaxx 1500W wind turbine

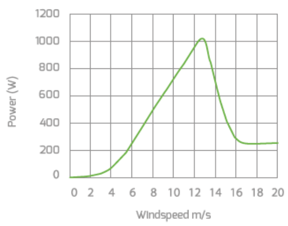
Wind Turbine	Model	1500 Watts Wind Turbine	
	Rated speed	31.3 mph / 14 m/s	
	Rated power	1500 watts	
	Voltage with MPPT	24 volts	48 volts
	Start-up Wind Speed	>2.24 mph / >1 m/s	
	Cut-in wind speed	5.59 mph / 2.5 m/s	
	Survival wind speed	112 mph / 50 m/s	
	Rotor Diameter	5.6 ft / 1.7 m	
	Number of blades	3	
	Blade material	Glass fiber + PP	
	Suggested battery capacity	>200 A / Hr	

Wind 13+ wind turbine

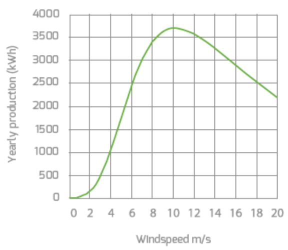
13+

Number of blades	2
Diameter	2,65 m
Material	Fiberglass / carbon
Direction of rotation	Counterclockwise
Control system	1) Electronic regulator 2) Passive because of tilt
Electrical specifications	
Alternator	Three phases permanent magnet
Magnets	Neodymium
Nominal power	1000 W
Nominal voltage	220 Vac
RPM	@ 450
Controllers	Regulator MPPT Wind+ Multivoltage: 12, 24, 48 Vdc Intensity: Max. 125 Amp Type of battery: Flooded, AGM, Gel Lithium Interface Wind+ Direct water pumping AC or DC Telecom Grid connection
Windspeed	
Operating range	2 -30 m/s
For turn on	3 m/s
For nominal power	12 m/s
For automatic braking	14 m/s
Survival	60 m/s
Physical characteristics	
Wind turbine weight	41 kg
Regulator weight	30 kg
Packing Dimensions - weight	50 x 77 x 57 cm - 68 Kg 153 x 27 x 7 cm - 7 Kg
Total	0,22 m³ - 65 Kg
Warranty	3 years

Performance



Energy



WIND+

Fortis Passaat 1.4kW wind turbine

FORTIS
WIND ENERGY
GREAT IN SMALL TURBINES

Technical Specifications

Max. output	1400Watt
Output @ 11m/sec	900Watt
Wind speed:	
cut in	2.5 m/sec.
rated	16 m/sec.
survival	60 m/sec.
Rotor blades:	
number	3
diameter	3.12 m
area	7.64m²
airfoil	E387
tip speed ratio	6.9
material	glass-fibre reinforced epoxy
Generator:	
type	Brushless permanent 12-pole
RPM operation range	180 - 775
voltage	24V- 350VDC standard
	other voltages on request
frequency	0-70 Hz
Other:	
gearbox	none
braking mechanism	none
rotor speed control	Inclined hinged vane
output control	voltage control with dump load
rectifiers	built inside controller
hub type	rigid
yaw system	tail vane
rotor position	Upwind rotor with fixed pitch
tower	guyed steel tubular (height: 12 - 24m)
tower	free standing tube mast (height: 12 - 18m)
Head weight	75 kg

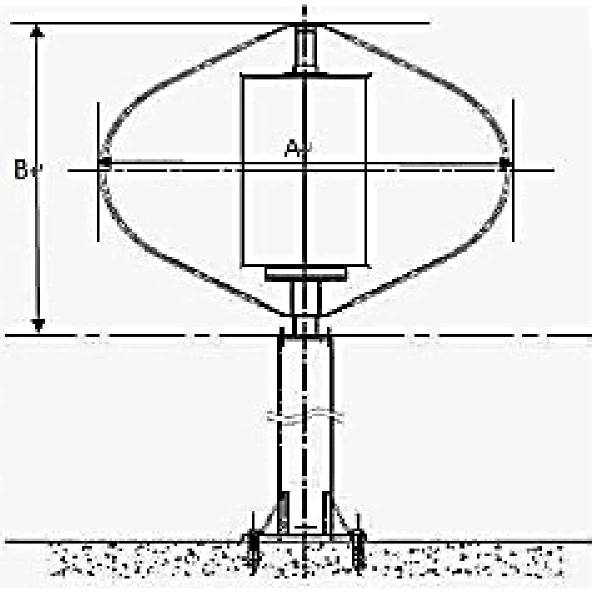
Hi-VAWT DS700 wind turbine

HIVAWT VERTICAL AXIS SMALL WIND TURBINE MODEL NO.: DS700

PRODUCT SPECIFICATION

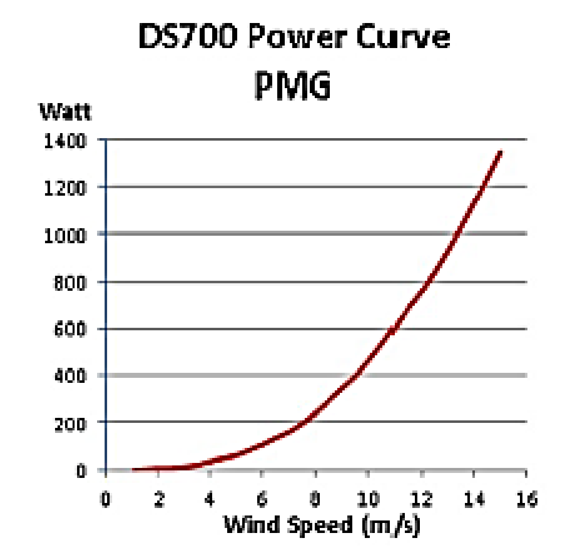
General Specification			
Rated Power	700w	Rated wind speed	12 m/s
Rated rpm	405 rpm	Cut-in wind speed	<3m/s
Cut-out	15m/s	Survivor wind speed	60m/s

Wind turbine specification	
Rotor Diameter(A)	1.93m
Total Height (B)	1.66m
Tower Height (Option)	3 meter height minimum recommended
Turbine Weight	60kg
External Darrieus	3 blades
Internal Savonius	2 layer
Blades material	Anodized Aluminum
Rotor Axis material	Anodized Aluminum



Generator Specification	
Type	AC, 3phase, Synchronism PMG
Rated power	700W
Brake system	
Automatic	Over speed short circuit brake control
Manual	Electronic Switch Type
System Operation Conditions	
Ambient Temperature	-10~40°C
Ambient Humidity	95% max.

Power Curve



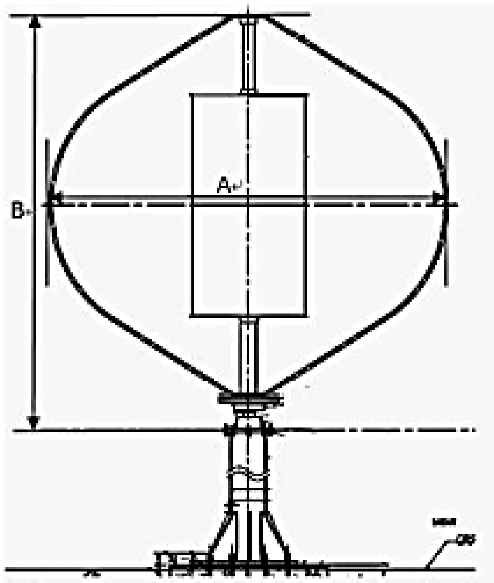
Hi-VAWT DS1500 wind turbine

HIVAWT **Vertical Axis Wind Turbine Power System**
Model: DS1500

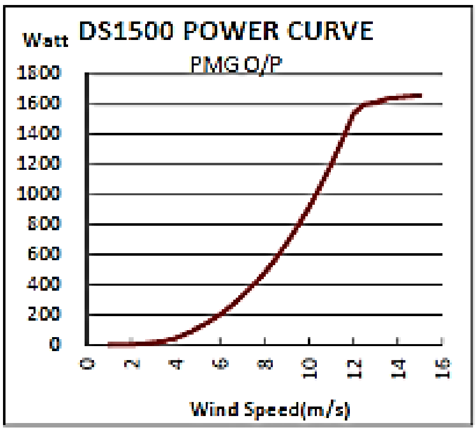
RODUCT SPECIFICATIONS

General Specifications			
Rated Power	1.5kW	Rated Wind Speed	12 m/s
Rated Speed	274 rpm	Cut in Wind Speed	<3 m/s
Cut out Wind Speed	15 m/s	Survival Wind Speed	60 m/s (At Parking)

Dimensions/Weight	
Rotor Diameter (A)	2.80m
Total Height (B)	2.94m
Tower Height (Option)	4 m (minimum)
Turbine Weight	380kg w/o tower
Rotor Specifications	
External Darrieus	3 blades
Internal Savonius	2 layers
Blades Material	Anodized aluminum
Rotor Axis Material	Galvanized steel SS400
Generator Specifications	
Generator Type	AC, 3phase Synchronism PMG
Rated Output	1.5kW
Braking System	
Automatic	Automatic dump-load and 3-phase short circuit braking system
Manual	Electronic brake and Mechanical brake
System Operation Conditions	
Ambient Temperature	-10~40℃
Ambient Humidity	95% max.



Power Curve

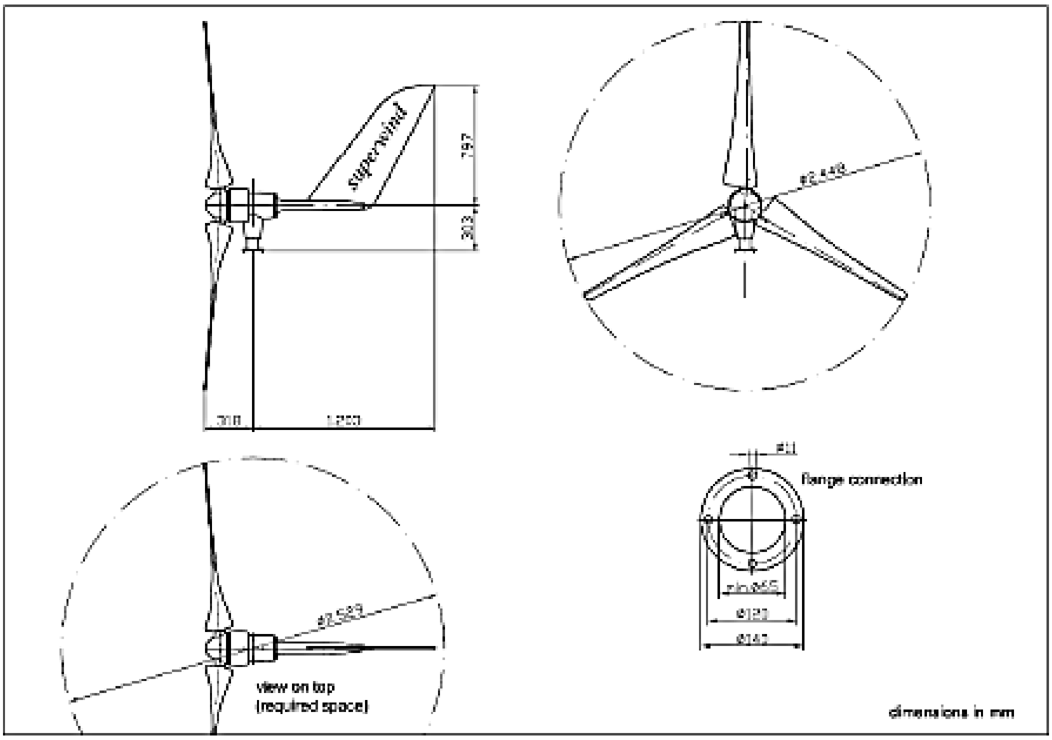


Superwind 1250 wind turbine

superwind

3. Technical specifications

3.1 Main dimensions



3.2 Technical data

Nominal power	1250 W
Nominal wind speed	11.5 meters per second (22.35 Knots)
Cut in wind speed	3.5 meters per second (6.8 knots)
Cut off wind speed	None
Rotor diameter	2.40 m
Number of blades	3
Blade material	Glass and carbon fiber reinforced plastics
Rotor speed	300 – 600 rpm
Generator	Permanent magnet, 3-phase Neodymium magnets
Nominal voltage	24 VDC or 48 VDC
Speed regulation	Rotor blade pitch
Power regulation	Rotor blade pitch
Brake 1	Generator short-circuit
Brake 2	Disc brake
Weight	45 kg
Rotor thrust (operation)	190 N
Rotor thrust (extreme wind speed)	1700 N