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Project report

Mini-eolic approach for energy generation

Subject

Energetic Systems

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Abstract. In this report it is characterized the mini-eolic approach for wind power generation. One speaks of mini eolic approach, when the rotor surface area goes up to max. 200m^2 or the rated power moves in a range between 5 kW to 75 kW. The aspects to take into consideration for installing a facility are described, such as the air density, the wind speed and the rotor surface. The energy yield pro year is taken into consideration to aim a rentable installation for a local and mostly private use for this kind of approach.

Keywords. Mini-Eolic, Betz coefficient, Weibull & Rayleigh, Horizontal- & vertical axis wind turbines, energy yield, power curve

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0. Foreword

From the last century human kind has been starting to be aware of the natural impact he is having on Earth, due to the exponential growth of its population and accelerated mobility behavior. The efforts, nevertheless, to neutralize or reduce the impact of the lately irrational actions is now a reality that a fraction of this generation is concerning about, and it is crucial for the sustainability of the future planet, that more people, countries and continents feel alluded on this matter.

Since the mid 1990´s the world has shown its concern about the raising temperatures on Earth, seeing us humans and our actions as the cause of it. With the early Kyoto protocol (1997) and lately Paris Agreement (2015/2016) we went a step forward to approach the problem. There is consciousness that the way of producing the energy through fossil fuels or nuclear is no longer viable, speaking of sustainability and the amount of CO2-emissions that are produced.

Renewable non-polluting resources are the future for the energy generation field, where technologies and constellations of implementation evolve according to the exiting demand. Hydro, solar, eolic, geothermal and bioenergy production are the strongest candidates to contribute to the 2°C –limitation until 2050 (Paris agreement) and beyond.

On one hand political decisions can help to give humanity a direction or indicators on how one shall behave, but on the other hand the obstinacy of the individuals is the most challenging part of the problem. Today any effort on reducing or avoiding greenhouse gases emissions counts for the global purposes of this and next generations.

1. Introduction

In this paper it is aimed to represent the approach for the use of mini eolic devices for energy generation. For the classification of mini eolic there are diverse definitions or aspects taken into consideration by different entities on this field. Therefore we need to specify the cases in which this approach should be implemented in terms of efficacy and cost effectiveness.

Being wind power generation one of the most growing fields in renewable energies beside to solar energy and the more long implemented hydro-production, one can observe from its development in the last years, that it also has a potential of growth for future generations. Therefore one can expect from an expanding field of technology a diversity of ways to implement and use it, depending on the intended energy yield.

Today we find wind power in several dimensions and therefore in power ratings, rather in wind parks (on- and off-shore) for greater production on the MW or GW range or also as mini or micro-turbines for less dimensional scale projects (around the kW range) for both on-grid and off-grid applications.

In terms of reliability, the economic aspects have to be taken in consideration in order to aim the return of investment over the time. This paper will give a short overview of the basic tools out of the tool-box for implementing wind energy generation.

2. Generalities of wind power production

Wind turbines use the speed of the wind mass flow to convert it into electricity. The speed of the wind is used as the source of the kinetic energy to turn the blades of a rotor. The shaft connected to the rotor then turns a generator which transforms the mechanical energy into electricity.

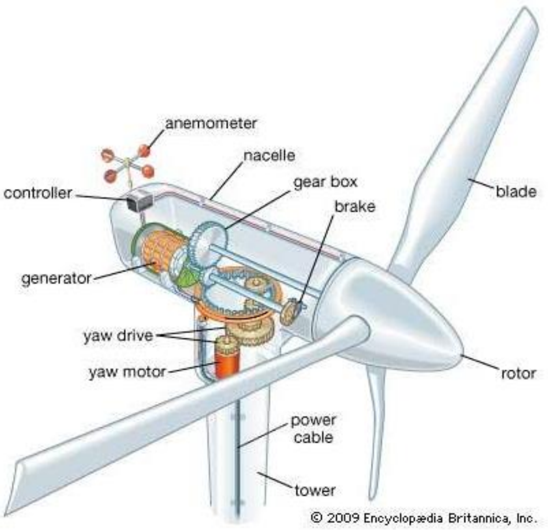

Figure 1Components in a horizontal axis wind turbine (HAWT) [10]

An overview of the technical components can be appreciated in Figure 1. Remark that the structure in a vertical axis wind turbine (VAWT) would be similar. The mast supports the rotor, usually equipped with three blades, and the nacelle which contains the generator and electrical and mechanical components.

The **air density**, the **rotor area** and the **wind speed** play an important role for the amount of energy that can be transferred to the rotor. In a second background also turbulences, temperature changes, irregularities of the area and technical instabilities (among other aspects) influence the power output of the system.

For this section it is intended to give an overview of the three important aspects for wind energy generation.

2.1 Air density

Let consider the air as fluid that is passing through the swept area of the blades of a wind turbine at wind speed. The air density is a conserved unit once considering the dynamical function of the system before and after the rotor area. Described by the conservation of mass of a closed system, one can make this statement, remembering that the air density is considered as a fluid. Furthermore it is defined as the mass per unit volume of earth's atmosphere, and using the ideal gas formula, one could write:

$$\rho = \frac{m}{V} = \frac{mP}{nRT} \quad (1)$$

ρ- Air density [g/cm^3]
P- Pressure [hPa][atm]
m- Mass [g]
V- Volume [cm^3]

n- Number of moles [mol]
T- Absolute temperature [K]
R- Gas constant of air

For example the standard value for the dry air density is ρ_{dryair}= 1.275 kg/m^3 at a temperature of 0°C or 273.15 K and an atmospheric pressure 100 kPa. The point is that (1) shows the dependence of the air density to the atmospheric pressure and temperature. These are parameters that will depend on the location of the wind turbine and that should be considered. [6]

2.2 Rotor area

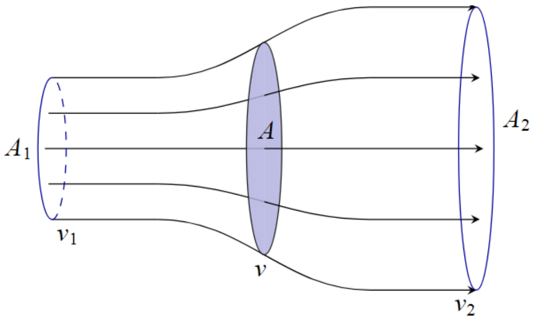

Figure 2 Schematic of fluid flow through a disk-shaped actuator [9]

The power output of a wind turbine depends strongly on the rotor area, which catches the wind. Indeed this aspect is used to define the category of the turbines power scale by some of the regulating instances of this field, for example the IEC (see section 3).The area is defined as the area of a disk:

$$A = \pi r^2 \tag{2}$$

and the wind power as a moving fluid in a cylinder with cross sectional area A and v_1 as the wind speed [m/s] (see Figure 2) and ρ the air density:

$$P_{wind} = \frac{1}{2}\rho \cdot A \cdot {v_1}^3 \tag{3}$$

Furthermore this characteristic defines a part of the maximum theoretical efficiency for a wind turbine of this type in general. Albert Betz´s[1] law states that the maximal amount of winds kinetic energy that can be converted into mechanical energy by a wind tower is **η_{Betz}=59,3%**; or as it is applied in calculations, as the power coefficient **$c_{p.\,Betz}$=0.593**.

$$c_p = \frac{P}{P_{wind}} \tag{4}$$

This he characterized by calculating the ratio of the wind power (3) and the power of the eolic flow according to Betz´s law (5) in the unperturbed case.

$$P = \frac{1}{2}\rho \cdot A \cdot {v_1}^3 \cdot 4a(1-a)^2 \tag{5}$$

Being a the coefficient of interference equal to a = $(v_1 - v_m)/v_1$ and v_m as the average wind speed. [4]

With the calculated value of **c_p** for general cases, the maximum power is given by:

$$P_{max} = c_p \frac{1}{2}\rho \cdot A \cdot {v_1}^3 \tag{6}$$

[1] **Albert Betz** (25 December 1885 – 16 April 1968) was a german physicist and a pioneer of wind turbine technology.

Furthermore one shall consider the rotational losses described by Schmidt (that should be added to the Betz power coefficient, Figure 3). Behind a wind turbine, the wind is not only slowed down but also affected by a swirl: the so-called spin effect. The rotational losses increase with the generated torque..[3]

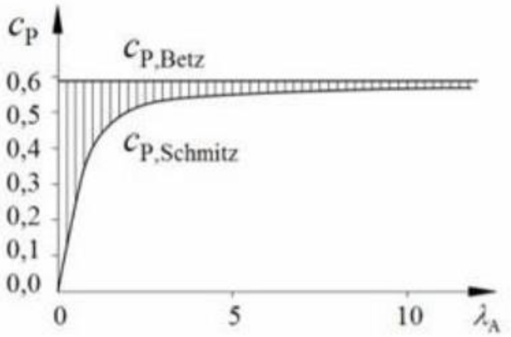

Figure 3 The marked area represent additional losses in power due to the rotational losses [3]

The swirl effect represents a loss, since it reduces the efficiency and creates turbulence in the downstream flow of the system.

Summing up and concerning other aspects, such as the technical limitations for example:

- the aerodynamically shape of the blades
- the resistance coefficient at the incidence of the wind into the blades c_R; cap. 4 [3]
- the rotational-speed value due to the number of blades implemented λ_{outl}; cap. 4 [3]
- the capacity of the imbedded electrical generator

among others, define more and more correction factors directly and indirectly to the possible power output of a wind turbine. One could then extend (6) for example with the following equation, concerning the factoring of the mechanical efficiency (η_m) and of the electrical generators efficiency (η_g):

$$P_g = c_p \frac{1}{2} \rho \cdot A \cdot {v_1}^3 \cdot \eta_g \cdot \eta_m \qquad [4] - (6.1)$$

For instance one could get more into detail about the aspects above; nevertheless it is intended to give a general overview of the characteristics off wind power production in this section.

2.3 Wind speed

The most essential aspect and from which depends a good functioning and rentable system, is the observation of the wind speed at the site where the turbine is planned to be applied. As a matter of fact wind is the most variable factor of the system, since it varies in intensity, direction and density. HAWT turbines today have specific systems imbedded in the towers to optimize the angles of incidence of the wind into the rotor area and the blades themselves with electrical motors, and increase or maintain the efficiency.

Furthermore it is shown in (6) that the wind velocity influences with a significant magnitude the maximum power, since it goes into the calculation with its cubic amount. Knowing that the behavior of wind might be turbulent or laminar, depending on the distance to the ground and also concerning possible obstacles in the site, is a key point for the installation of a turbine.

In Figure 4 is an overview of the meaning of the laminar and turbulent wind flow. On the left it is appreciable that the flow lines are mostly constant in their direction and close to parallel to the next line of flow at high distances. In the cases after a house, trees or of some irregularities on the ground we find more curved flow lines mostly whirling due to the irregularities and state that this places should be avoided for installing a turbine.

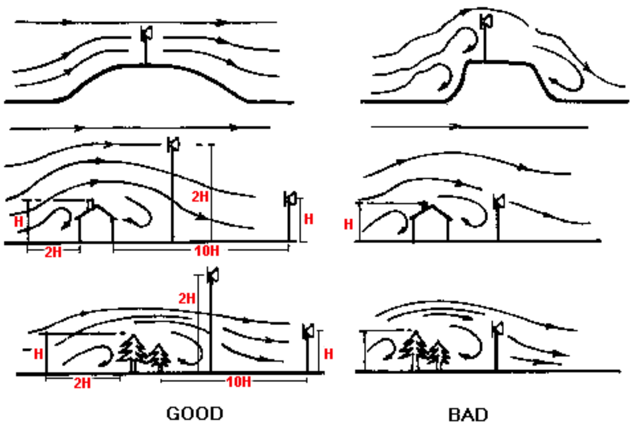

Figure 4 Wind behavior sketch in 3 different surroundings

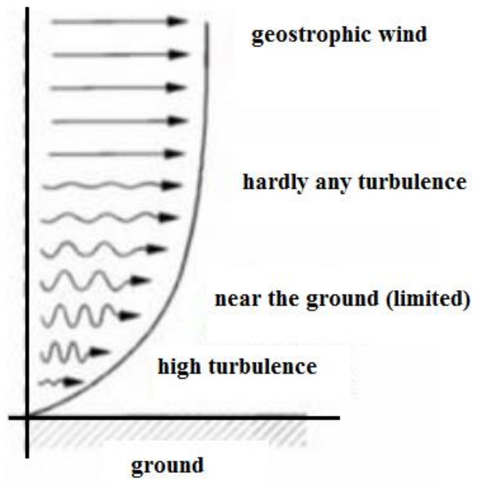

Figure 5 The wind on high sites from the ground is characterized by a laminar flow, which reduces any turbulent behavior and results in a higher rate of power output [3]

Now, since this aspect plays such an important role, how can it be stated that the system is efficient or rentable for the application of a wind turbine?

For this matter in the wind energy sector it has to be approached with statistical tools, which concerns the observation of the winds velocity frequencies over the time. This way one can estimate important relations between the real power output depending on the velocities and, with that, the very critical aspect of the investments efficacy.

The statistical method is given by the Weibull[2] continuous probability distribution, which records the frequency of the various velocities (in form of histograms). The statistical equation is given as follow:

$$p(v) = \frac{k}{A} \cdot (\frac{v}{A})^{k-1} \cdot e^{-(\frac{v}{A})^k} \tag{7}$$

$p(v)$	-distribution density
k	-shape factor that indicates the form of the distribution. k assumes a value of 1 to 3
A	-Scale factor in [m/s]; is a measure of the time series characterizing the wind speed, and is in a certain ratio to the average wind speed of the distribution.

For the case of simplification the Rayleigh form is used, so that there is only one variable parameter (A, fixing k=2), instead of two variable parameters (k and A).

$$p(v) \ = \frac{2v}{A^2} \cdot e^{-(\frac{v}{A})^2} \tag{8}$$

An example of a Weibull and Rayleigh curve is given in the next figure.

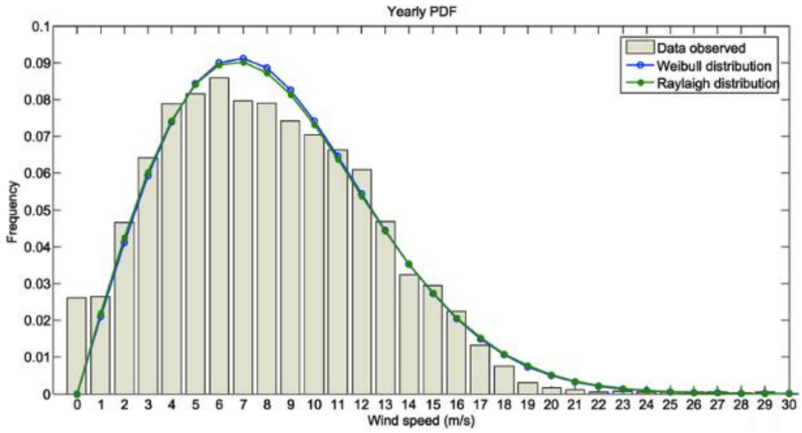

Figure 6 Example of a Weibull distribution curve and the case of the Rayleigh distribution for k=2 [8]

Nevertheless the k values define the shape for different scenarios of implementation. For k=1 are considered very variable polar wind areas and k=3 is used for less changing strong, high and constant trade winds[3].

Furthermore if one derives the Weibull approximation function, one can appreciate the distribution function, which describes the probable percentage of presences of a certain wind speed. This one will also expand or shrink depending on the shape and scale factors. For calculations, as such as the energy yield per year, this approximation curve is preferred

[2] **Ernst Hjalmar Waloddi Weibull** (18 June 1887 – 12 October 1979) was a Swedish engineer, scientist, and mathematician.

[3] The **trade winds** are the prevailing pattern of easterly surface winds found in the tropics, within the lower portion of the Earth's atmosphere, in the lower section of the troposphere near the Earth's equator.

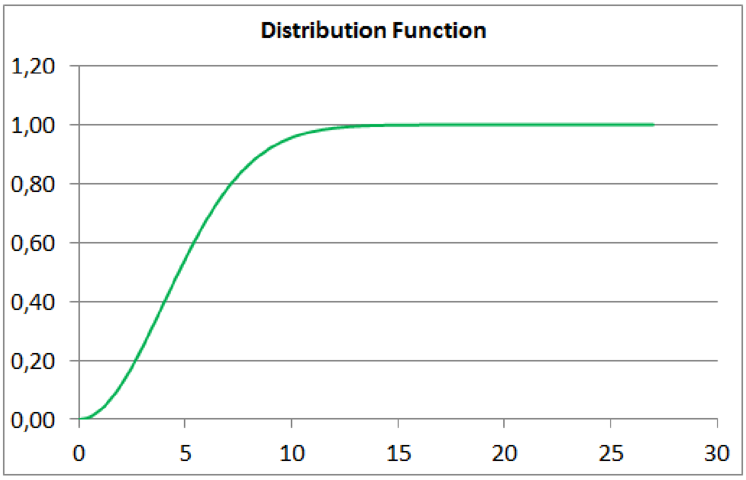

Figure 7 Example of a distribution function; from the overview calculations for wind speed parameters (see Appendix)

A distribution function could look like the following example, where the y-axis is the percentage and the x-axis the wind speed.

A solution on the curve represents the percentage of the total power that can be achieved at a certain velocity. Furthermore one can also identify up to what speed it is possible to deliver 100% (=1) of the rated power; the so called rated wind speed.

These measurements of the wind speed and its direction can be done at least in 3 ways: mechanically (with a cup anemometer with a vane), with ultrasonics, or with laser-based devices.

Also online tools could be taken into consideration for a first rough analysis. For example from the global wind atlas as part of an international collaboration with the Danish DTU Wind Energy under the following link (**https://www.globalwindatlas.info/**) which provides an overview of global recorded wind speeds at different heights. Using this tool should be for a rough and not an accurate application.

Going a bit farther, concerning this aspect of the wind speed, feasibility studies and wind site assessment are the basis for the financial decision to use a wind turbine. Since even a miscalculation of 3% of the speed can lead into a loss of seven digit economic figures, according to the assessment company of wind measurement Ammonit (Berlin, Germany; http://www.ammonit.com), at a wind farm level. The same consequences could show up also in mini eolic projects, with proportional losses to the dimension of the investment.

As for every sector which needs accurate data, it is important to give attention to the measurement devices, also in terms of reliability. Three technologies that are used nowadays are:

- Mechanical sensors (cup anemometer with a vane)
- Ultrasonic sensors (sonic anemometer)
- Laser-based devices (laser Doppler velocimetry) [10]

Figure 8 Tower facility for collecting wind data

.The international regulations on how to measure the wind speed can be found in the IEC 61400-12.

3. Mini Eolic Approach

The question of which installations are small wind turbines cannot be clearly answered as different actors use different definitions. The attached table gives an overview of these different definitions and the delimitations of the different entities and sources. [2]

Table 1 Definition of small/mini wind turbines; (translated table from source) [2]

Criteria in	Property		Groups		
IEC 61400-2 Norm*	Rotor surface	to 200m²	*Wind turbines – Part 2: Requirements for small wind turbines		
EEG Erneuerbare-Energien-Gesetz *engl. Renewable Energy Law*	Rated capacitiy	to 50kW	–	–	–
BWE Bundesverband Windenergie *- engl. Federal Wind Energy Association*	Rated capacitiy	to 100kW	Performance class 1: Mikro: to 5kW	Performance class 2: Mini: 5-30kW	Performance class 3: Medium: 30 – 100kW
BWEA British Wind Energy Association	Rated capacitiy	100kW	Micro: 0 – 1,5kW	Small: 1,5 – 15kW	Medium: 15 – 100kW
EWEA European Wind Energy Association	Rated capacitiy	100kW	Pico: 0 – 1kW	Micro: 1 – 7kW	Mini: 7 – 50kW Midi: 50 – 100kW
DWEA Distributed Wind Energy Association	Rotor surface	200m² / 1000m²	Small (to 200m² i.e about max. 50kW)	Medium (201-1000m² i.e about max. 500kW)	–
IWES Fraunhofer-Institut für Windenergie und Energiesystemtechnik	Rotor surface & Rated capacitiy	to 200m² max. 50kW	Categorie XXS: 1,5kW, max.	Categorie XS: 10kW, max. 40m²	Categorie S: 75kW max.200m²
BVKW* Bundesverband Kleinwindanlagen *- engl. Federal Association for small wind turbines*	Rotor surface	to 200m²	Mikro: 0 – 1,5kW, max. 6m²	Small: 1,5 – 6kW	According to Norm: 200m²
AWEA American Wind Energy Association	Rated capacitiy	100kW	Island: 0 – 0,9kW	Home: 1 – 10kW	Business: 11 – 100kW

Basically for defining a mini-eolic turbine there are two delimitations: the **rotor surface** and the **rated power**. The International Electro-technical Commission (standard IEC 61400-2) as an international entity has more “power” in meaning and defines the mini eolic up to the size of a rotor surface of 200m^2.

As it was presented in section 2, there is a dependence of the rated power to the surface area of the rotor and farther, to the wind speed. Either way, this means that there are no exact values for defining where the mini eolic branch of wind energy production stops in terms of rated power, since it is possible to produce with a 200 m^2 rotor surface an roughly estimation of 50kW to 75kW. But from this various definitions one can derive a rated power range for the mini-eolic in a general sense and one states that:

One speaks of mini eolic approach, when the **rotor surface area** goes up to **max. 200m^2** or the **rated power** moves in a **range between 5 kW to 75kW.**

With this information one can start considering more concrete examples of wind turbines, since we look now into the specific market and also its application areas.

To get more into the practice it is intended to identify the possible uses and expectations of a concrete example that could be rather of 7 kW or a 50kW turbine.

Either way there are some aspects aside that should be taken firstly into consideration before implementing wind generation:

- Characterization of the area
  - Character of wind and air
  - Topography of the area; meaning potential obstacles for the air flow
  - Statics and dynamics of the subsoil and system
  - Status of the infrastructure for; transport, construction, grid connectivity
- The type of the turbine and its wind power curve
- Implementation of the system Off or On-Grid

3.1 Types and sites: HAWT vs VAWT

Figure 9 Example mini eolic implementation; Horizontal and Vertical AWT [1]

In this section it is aimed to present a breve overview of aspects between horizontal axis and vertical axis wind turbine and their possible application sites.

In Figure 9 are shown several applications rather on the rooftop of a building, in the backyard of houses or farms or in front of a business. One can say the use is mostly locally and for private use. And depending on the location, one can also identify the different constellations of wind turbines applied.

Considering the aspects to be taken into account for the installation of a turbine in section 2, it is important to decide whether to apply a vertical or a horizontal turbine. Mostly the space and the wind statistic will define the suitable choice. Anyhow, speaking of power coefficients we saw that the highest capacity factor of a HAWT lays around $c_{p\text{-HAWT}}$ of 0,593 (59%), meanwhile the VAWT is nearly as capable with a $c_{p\text{-VAWT}}$ of 0,56 (56%) [3]

Other characteristics are the size and the height of the platform, which will depend on the topography of the place. Furthermore there is also the ergonomically aspect which concerns the perception of the humans near the structures. The rotational movement and passing thru of the wind is not completely noiseless. These turbines are also characterized by the decibels that they can generate at different wind speeds, and as sceptic as it might sound, the shadows that this wind turbines produce could affect psychologically the people around the devices, due to the frequent on/off effect of the light; for example thru the window of a house.

One can also trivially mention that the structural features characterize these two technologies. The orientation of the axis defines directly the influence of forces as gravity or inertia on the blades. On one hand the horizontal axis is subject to a constant change of the force of inertia, meanwhile the gravitational keeps constant. This causes an alternating load in the structure, which follows to a systematic fatigue. On the other hand the vertical axis is subject to a constant (rather, less changing in comparison) gravitational and inertial force in all directions, which causes a more or less more stable rotation and with that, less fatigue. From this point the longevity of the VAWT is greater than the HAWT.

Furthermore the maintenance works into the generator, could be an important aspect to remark. Since the generator on a HAWT is located at the height of the rotor, it is necessary for the worker to ascend all the way up to the tower, in order to make the reparation works. In VAWTs instead, thanks to its orientation it is possible to locate the generator at more accessible levels, if it is not already embedded at ground level.

Figure 10 contents other aspects for the comparison of these two technologies. The image is taken from a wind turbine distributor and installer; Aeleos wind turbine:

Number	Performance	Horizontal axis	Vertical axis
1	Power generation efficiency	50% - 60%	Above 70%
2	Electromagnetic interference	YES	NO
3	Steering mechanism of the wind	YES	NO
4	Gear box	Above 10KW:YES	NO
5	Blade rotation space	Quite large	Quite small
6	Wind-resistance capability	Weak	Strong (it can resist the typhoon up to 12-14 class)
7	Noise	5-60dB	0-10dB
8	Starting wind speed	High (2.5-5m/s)	Low (1.5-3m/s)
9	Ground projection effects on human beings	Dizziness	No effect
10	Failure rate	High	Low
11	Maintenance	Complicated	Convenient
12	Rotating speed	High	Low
13	Effect on birds	Great	Small
14	Cable stranding problem	YES	NO
15	Power curve	Depressed	Full

Figure 10 HAWT vs VAWT [1]

3.2 On-grid and off-grid application

Whether the system is connected to a local utility grid or not can have an impact on what type of wind turbine is right for the intended location.

3.2.1 On-Grid

A home or facility that is currently connected to a locally provided power source is considered "on-grid." In this scenario a power conditioning unit (inverter) makes the turbine output electrically compatible with the utility that is installed. Wind turbines are connected to the electricity network via a transformer located at the base of the mast**Fehler! Verweisquelle konnte nicht gefunden werden.**. The electricity produced is generally stepped up to the voltage of the network, and then it passes through a delivery substation before being fed into the electrical transport network.

In an on-grid station the turbine works in tandem with the electric utility to power the house or facility. At the absence of wind, the utility supplies the electricity. In the case of the presence of wind, the wind turbine will produce the electricity. When the generator produces more energy than it is needed in the facility, the electricity meter can “spin backwards”, meaning that one is “selling” electricity back to the utility.

An on-grid system can be practical if the following conditions exist [10]:

- The area has an average annual wind speed of at least 4.5m/s
- Utility-supplied electricity is expensive in the area
- The utility’s requirements for connecting the system to its grid are not prohibitively expensive

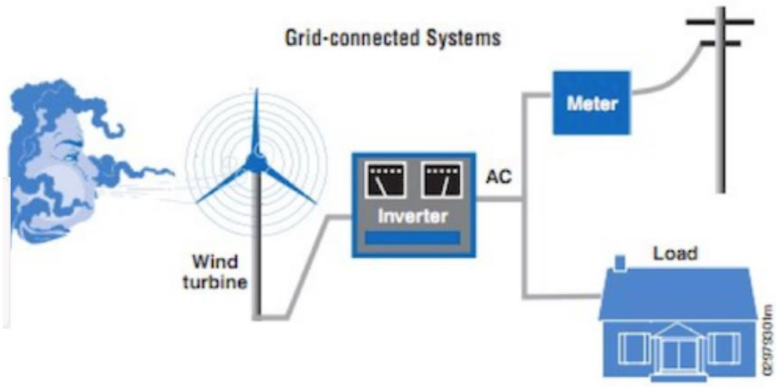

Figure 11 On-grid representation of a wind turbine connected to the network and a house/facility [10]

3.2.2 Off-Grid

Systems not connected to a local utility supplier are known as “off-grid” systems. This means that the facilities´ energy is completely depended on the energy production of the turbines. In these cases a possible constellation of implementation could be a hybrid system that uses both a wind turbine and solar photovoltaic panels, as an example. This situation could be common in places that are far from an electricity network, where battery modules are used instead as the energy bank of the system. This proposal makes sense when the wind is not constant in the site but with good sun incidence. That way the devices can complement each other, while they are not able to operate due to the weather conditions. Due to the alternating nature of peak operating times hybrid systems are ideal for producing consistent power. In case of emergency, off-grid systems normally have an engine-generator on hand.

An off-grid hybrid system may be practical if:

- The applied area has an annual average wind speed of at least 9 mph (4.0m/s)
- A grid connection is not available or can only be made through an expensive extension
- The user aims to gain energy independence from the utility in the area [10]

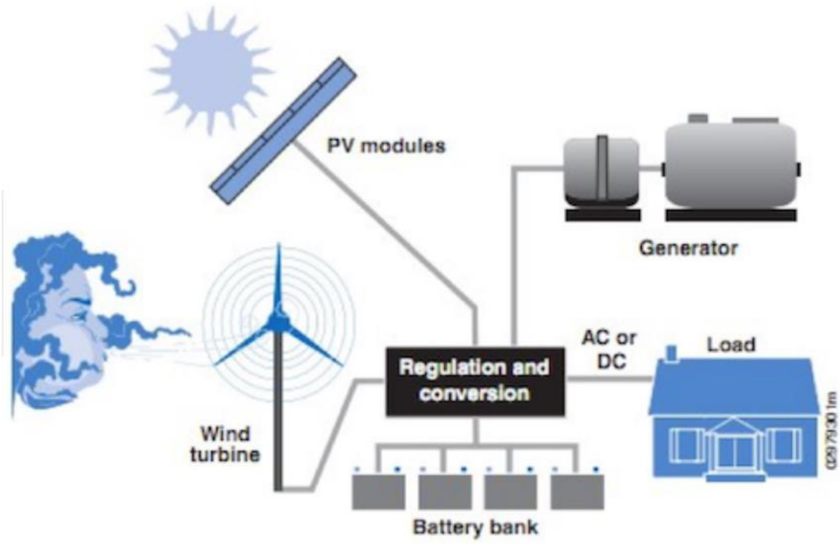

Figure 12 Hybrid power systems combine multiple sources to deliver non-intermittent electric power [10]

Again, rather on grid or off grid implementation of the wind energy will rely mostly on the users interest and also on the conditions of the placement. How much energy a user is consuming should be known and with this information he can consider proper selection of technology, as we will see in the next section.

4. Energy yield per year and power curve for investment

To characterize a rentable application of a wind turbine, it is necessary to know the possible **energy yield** of it, in order to identify, whether the technology, the size, or its power output are the proper ones to deliver the needed amount of electricity. To determine this, there are two essential tools: one is the wind statistic (see section 2) and the other the power curve.

The power curve should be given by the supplier of the wind turbine in the data sheet, which describes the possible power output at different wind speeds. Also in this curve one can identify the so called regulations speeds, which are the **cut-in** (means: from which speed, is the rotor able to start producing power) and the **cut-off** (means: where the rotor breaks/shuts down for a higher wind speed, in order to protect the station) . Furthermore one can find the **rated wind speed** which shows the minimum value of the speed that needs the station to deliver the rated power.

Note that the data given in the power curve should be measured and this is regulated in IEC 61400-12-1:2017: “Wind energy generation systems - part 12-1: Power performance measurements of electricity producing wind turbines”. There is the possibility to take a model to illustrate a power curved (see Figure 13), but this would deliver theoretical values, which at the end are not useful. The ideal scenario would be to measure right on the intended location at more or less the height of the mast. The measurements should be of the average wind speeds of a time gap equal to10 min. This value will represent a point in the measurements chart. Experts recommend the measurement of the winds characteristics to take at least 6 months.

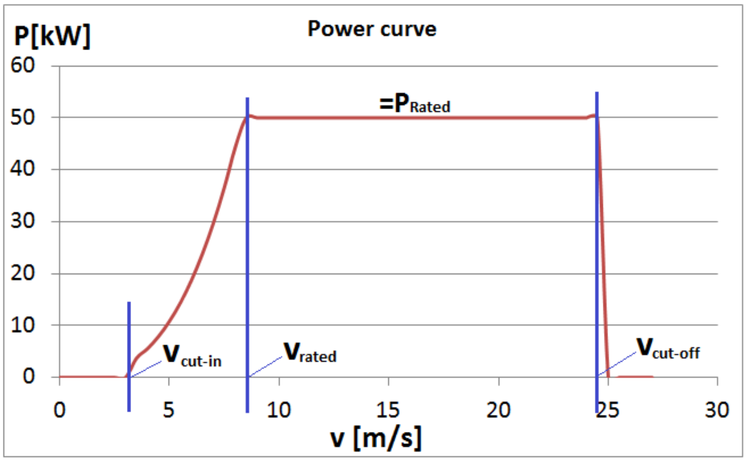

Figure 13 Model of a power curve for 50kW power rated wind turbine

Combining the power curve and the wind statistic leads us to the total amount of energy that a turbine can deliver in a year (= 365 days for each 24 hours):

$$E_{annual} = 365 \cdot 24 \cdot \Sigma P_{regulated} \qquad [Wh] \qquad (9)$$

where $P_{regulated}$ is given by the maximum power P_{max} (6) multiplied by its probability of presence from the Weibull wind statistic. Note that the capacity factor is also contemplated in this formula as well. The following figure shows an example of an energy yield curve:

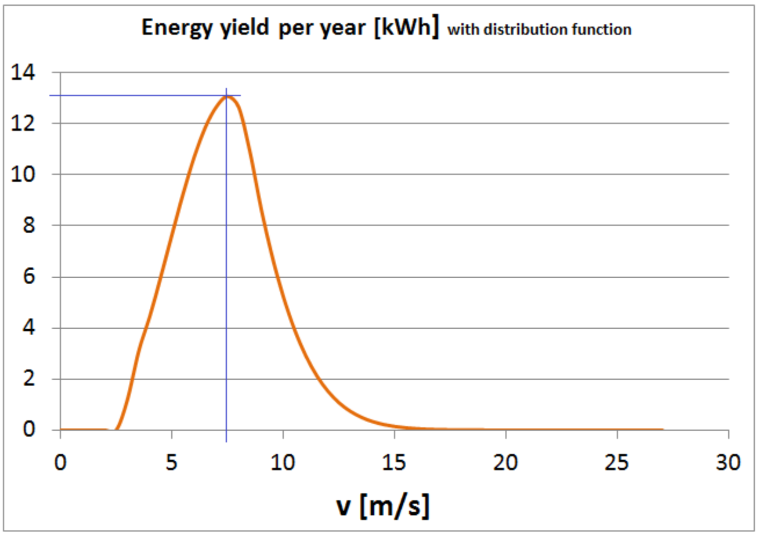

Figure 14 Energy curve per year; the blue lines remark the peak of energy produced at a certain wind speed

Moving a step forward there are two other interesting parameters that can be estimated, such as the annual efficiency (10) and the operating hours (11)

$$\eta_{annual} = \frac{E_{annual}}{365 \cdot 24 \cdot P_{Rated}} \qquad [-] \qquad (10)$$

a dimensionless quantity, which gives the theoretical percent of hours that the wind turbine must runs at full load to produce the annual yield.

$$t_{operating} = \frac{E_{annual}}{P_{rated}} \qquad [h] \qquad (11)$$

The operating hours give the expected number of hours of a year, on which the wind turbine produces electricity. The total hours per year are 8'760 hours.

4.1 Financial point of view

The great question: how much cost a wind turbine or how rentable will it be over the time?

First of all, one needs to put the right turbine at the right place. In the sections above are described a few basic tools of the tool-box for wind generation power implementation, that can be helpful to make a first self-analyze, before contacting any provider. Furthermore one can also assume if the region one is planning to put a tower is windy or not. If there is no wind one can always consider other options for renewable energy production.

Second of all, it is truth that implementing a wind turbine for private interests can be an investment of a few thousand of euros/dollars or pounds. Of course it will depend on the intended output, which is connected to a chain of factors that could influence the price of the station. Certainly, the return of investment will not happen in a year and maybe not in the next 5 years. Much greater it is a **longer term investment**, since wind turbines are produced to live between 20-25 years and deliver the rated power over this time.

And third of all, one shall consider the installation costs, transport and very important the maintenance works over the time. Starting with a 5 kW turbine one could count with 5000-9000 Euro for a starting estimation, depending on the supplier, the quality and installation cost, plus others. The same estimation for a 50 kW-turbine can, which could cost between 50.000 Euro to 80.000 Euro or more.

There is Chinese quality, German quality, UK-Quality, US-Quality and so on. It is difficult to confirm an specific value for this turbines, but since we considered a range for this mini eolic approach from 5kW to 75kW, one estimates according to a superficial overview of different prices that the investment could lay between 5.000 Euro to 120.000, noting that one can pay always more.

5. Conclusion

For the mini eolic approach, one shall consider several characteristics, in order to make the investment rentable and also in order to be able to gain the energy required. Using statistical methods, international standards measurement handbooks and knowing the kind of wind on the site, are essential aspects to let maximize the capacity of a turbine.

In the paper one defined the range of use and the dimensions for a mini eolic approach, and with that also the sites of implementations by giving some examples. Most of them are concerning the private use, rather for business, farms, schools or houses. Furthermore after illustrating the characteristics of the wind speed, the air density and the rotor area, there is an overview of technologies implemented such as the horizontal and vertical axis wind turbines.

One would like to remark the possibilities of networks, which are the on-grid and off-grid. With this one can contemplate also the possibility of implementing hybrid networks by using various technologies as different resources for the grid, f.e. a wind and sun combination as sources.

About the financial aspect: since the market is pretty trendy nowadays there exist several constellations on how to resort on wind energy. Important is to identify the aspects that one should be aware of once it gets to the point of investment.

Fact is that knowing the characteristics of the sites is the main property of these technologies. And also the very crucial fact of the annual energy yield, since with this one can tell if the wind tower is capable of covering the necessities.

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7. Appendix

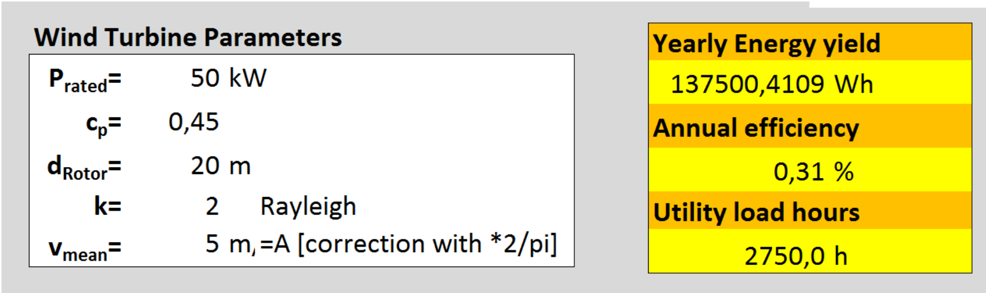
Exceled- Program: to understand the wind turbines characterization parameters and energy yield per year. The formulas implemented <u>do not</u> represent a real case, but the theoretical scenario

<u>This should be meassured!</u>

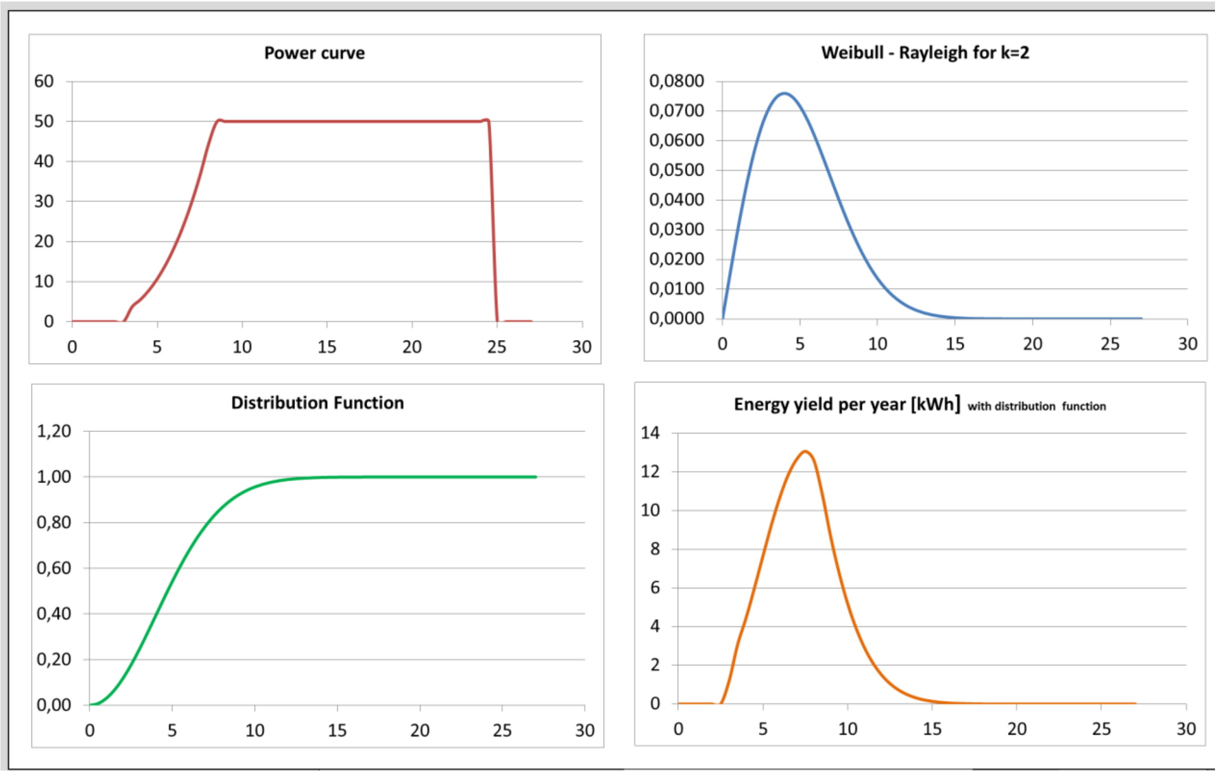
Wind speed [m/s]	Weibull	Distribution Function		Power [kW]	Power with c_p [kW]	After Regulation [kW]	Energy yield per year [Wh]	Energy yield per year [kWh] with distribution function
0	0,0000	0,00		0,0	0	0	0	0
0,5	0,0156	0,01		0,0	0,0	0	0	0
1	0,0304	0,03		0,2	0,1	0	0	0
1,5	0,0439	0,07		0,6	0,3	0	0	0
2	0,0554	0,12		1,5	0,7	0	0	0
2,5	0,0645	0,18		3,0	1,4	0	0	0
3	0,0710	0,25		5,2	2,3	0,0	0	1
3,5	0,0748	0,32		8,3	3,7	3,7	2433,652314	3
4	0,0760	0,40		12,3	5,5	5,5	3690,304536	4
4,5	0,0748	0,47		17,5	7,9	7,9	5172,330909	6
5	0,0716	0,54		24,1	10,8	10,8	6790,603723	8
5,5	0,0668	0,61		32,0	14,4	14,4	8430,423063	9
6	0,0608	0,68		41,6	18,7	18,7	9966,713458	11
6,5	0,0542	0,73		52,8	23,8	23,8	11280,4617	12
7	0,0472	0,79		66,0	29,7	29,7	12273,55025	13
7,5	0,0402	0,83		81,2	36,5	36,5	12879,70194	13
8	0,0337	0,87		98,5	44,3	44,3	13070,17913	13
8,5	0,0276	0,90		118,2	53,2	50,0	12085,95557	11
9	0,0222	0,92		140,3	63,1	50,0	9721,23957	9
9,5	0,0175	0,94		165,0	74,2	50,0	7673,578303	7
10	0,0136	0,96		192,4	86,6	50,0	5946,311133	5
10,5	0,0103	0,97		222,8	100,2	50,0	4524,685024	4
11	0,0077	0,98		256,1	115,3	50,0	3381,592567	3
11,5	0,0057	0,98		292,7	131,7	50,0	2482,756317	2
12	0,0041	0,99		332,5	149,6	50,0	1791,031729	2
12,5	0,0029	0,99		375,8	169,1	50,0	1269,684867	1
13	0,0020	1,00		422,8	190,2	50,0	884,6496245	1
13,5	0,0014	1,00		473,4	213,0	50,0	605,8733456	1
14	0,0009	1,00		528,0	237,6	50,0	407,9194049	0
14,5	0,0006	1,00		586,6	264,0	50,0	270,0167474	0
15	0,0004	1,00		649,4	292,2	50,0	175,7391195	0
15,5	0,0003	1,00		716,6	322,5	50,0	112,4712421	0
16	0,0002	1,00		788,2	354,7	50,0	70,78487998	0
16,5	0,0001	1,00		864,4	389,0	50,0	43,81202271	0
17	0,0001	1,00		945,4	425,4	50,0	26,67013672	0
17,5	0,0000	1,00		1031,3	464,1	50,0	15,96832813	0
18	0,0000	1,00		1122,2	505,0	50,0	9,404097039	0
18,5	0,0000	1,00		1218,3	548,3	50,0	5,447755911	0
19	0,0000	1,00		1319,8	593,9	50,0	3,104409093	0
19,5	0,0000	1,00		1426,8	642,1	50,0	1,740273508	0
20	0,0000	1,00		1539,4	692,7	50,0	0,95972888	0
20,5	0,0000	1,00		1657,7	746,0	50,0	0,520698369	0
21	0,0000	1,00		1782,0	801,9	50,0	0,277935203	0
21,5	0,0000	1,00		1912,4	860,6	50,0	0,145959628	0
22	0,0000	1,00		2048,9	922,0	50,0	0,075416281	0
22,5	0,0000	1,00		2191,8	986,3	50,0	0,038339921	0
23	0,0000	1,00		2341,2	1053,5	50,0	0,019177894	0
23,5	0,0000	1,00		2497,2	1123,8	50,0	0,009438944	0
24	0,0000	1,00		2660,0	1197,02	50,0	0,004571171	0
24,5	0,0000	1,00		2829,8	1273,4	50,0	0,002178317	0
25	0,0000	1,00		3006,6	1353,0	0,0	0	0
25,5	0,0000	1,00		3190,6	1435,78	0,0	0	0
26	0,0000	1,00		3382,0	1521,9	0,0	0	0
26,5	0,0000	1,00		3580,9	1611,4	0,0	0	0
27	0,0000	1,00		3787,5	1704,35	0,0	0	0
Σ	1,00						137500,4109	137,9

x0,5 (so we can define the probability at between the 0,5 value)

Appendix; Figure 1 Table of wind speeds, Weibull values, power yield and energy yield



Appendix; Figure 2 Example for a 50kW rated power wind turbine



Appendix; Figure 3 Graphical overview for the example

8. Notes for the author

Metrologic devices

Mechanical sensors, for instance, use moving parts and still connect to data recording devices. The uses spinning cups for wind speed and a vane for vector changes. These physically move with changes in the wind and give accurate readings of speed and direction.

Ultrasonic sensors function without moving parts. On a typical sonic anemometer, a transducer sends a pulse of ultrasonic sound from a 'north' facing side of the sensor. A microprocessor measures the time it takes to travel to a 'South' transducer. The wind speed is calculated from the time it takes the ultrasound to travel to the opposite transducer. Measurement times are affected by the wind speed and direction blowing along the line between the transducers. Without moving parts, measurement is said to be immediate and precise.

In the cases above, the instruments are small enough to mount on a nacelle. Larger, ground-mounted sonic instruments, however, can take the place of a met tower and measure wind speed and direction at several elevations.

This latter device, also called a sonic wind profiler or a sodar (sound detection and ranging) unit, detects wind speeds and directions at several levels up to about 300 m. The unit is said to work unattended to capture accurate wind data at turbine heights in any weather and location. one model runs on as little as 7 W from a battery recharged by a solar panel, and it can be relocated by one man with a truck. Readings from these devices look like anemometry results and so need no expert analysis. Users can often access data in real time from a computer over a satellite wind data service.

Sodar uses short-wavelength sound waves to measure the Doppler shift of emitted sound and calculate wind speeds. Sodar units are reported have performed well in tests. Laser-based wind sensors use laser Doppler velocimetry – an optical remote-sensing technique similar to Doppler radar – to measure minute frequency changes of light reflected by microscopic air particles moving with the wind which precisely determines wind speed and direction. One laser wind sensor mounts atop the turbine nacelle (pointing through the rotor) to measure real-time horizontal and vertical wind speed and directions in front of the turbine. This sensor looks out to 300 m ahead of the turbine to measure wind speed and direction as it approaches the turbine blades. It transmits that data to the controls in time (20 sec of lead time for a 35-mph wind) to reorient the turbine. The system is comprised of a base laser and a remote lens. The base unit, housed in a separate assembly, can be mounted inside the turbine's nacelle. The remote lens mounts atop the nacelle. According to one report, reacting to oncoming wind before it reaches a turbine improves power production by about 10%.