energies MDPI

Review

Commercial Small-Scale Horizontal and Vertical Wind Turbines: A Comprehensive Review of Geometry, Materials, Costs and Performance

Antonio Rosato *, **Achille Perrotta** and **Luigi Maffei**

Department of Architecture and Industrial Design, University of Campania Luigi Vanvitelli, Via San Lorenzo 4, 81031 Aversa, Italy; achille.perrotta@unicampania.it (A.P.); luigi.maffei@unicampania.it (L.M.)
* Correspondence: antonio.rosato@unicampania.it

Abstract: The effective exploitation of renewable energy sources is one of the most effective solutions to counter the energy, environmental and economic problems associated with the use of fossil fuels. Small-scale wind turbines (converting wind energy into electric energy with a power output lower than 50 kW) have received tremendous attention over the past few decades thanks to their reduced environmental impact, high efficiency, low maintenance cost, high reliability, wide wind operation range, self-starting capability at low wind speed, limited installation space, reduced dependence on grid-connected power and long transmission lines, low capital costs, as well as the possibility to be installed in some urban settings. However, there are significant challenges and drawbacks associated with this technology from many different perspectives, including the significant discrepancy between theoretical performance data provided by the manufacturers and real field operation, that need to be investigated in greater depth in order to enable a more widespread deployment of small-scale wind turbines. In this review, a complete and updated list of more than 200 commercially available small-scale horizontal and vertical wind turbine models is provided and analysed, detailing the corresponding characteristics in terms of the number and material of blades, start-up wind speed, cut-in wind speed, cut-out wind speed, survival wind speed, maximum power, noise level, rotor diameter, turbine length, tower height, and specific capital cost. In addition, several scientific papers focusing on the experimental assessment of field performance of commercially available small-scale horizontal and vertical wind turbines have been reviewed and the corresponding measured data have been compared with the rated performance derived from the manufacturers' datasheets in order to underline the discrepancies. This review represents an opportunity for the scientific community to have a clear and up-to-date picture of small-scale horizontal as well as vertical wind turbines on the market today, with a precise summary of their geometric, performance, and economic characteristics, which can enable a more accurate and informed choice of the wind turbine to be used depending on the application. It also describes the differences between theoretical and in-situ performance, emphasizing the need for further experimental research and highlighting the direction in which future studies should be directed for more efficient design and use of building-integrated small-scale wind turbines.

Keywords: wind energy; commercial small-scale wind turbines; wind turbine performance; wind turbine cost; wind turbine geometry; wind turbine materials

Citation: Rosato, A.; Perrotta, A.; Maffei, L. Commercial Small-Scale Horizontal and Vertical Wind Turbines: A Comprehensive Review of Geometry, Materials, Costs and Performance. *Energies* **2024**, *17*, 3125. https://doi.org/10.3390/en17133125

Academic Editor: Antonio Segalini

Received: 19 April 2024
Revised: 26 May 2024
Accepted: 19 June 2024
Published: 25 June 2024

1. Introduction

1.1. Background

The use of fossil fuels and the associated release of greenhouse gas emissions has increased due to the world's population growth, and residential buildings account for a significant amount of global energy consumption (according to the International Energy Agency [1]). It is well known that encouraging the use of renewable energy sources is one of the most promising ways to reduce primary energy demand and mitigate climate change; many countries around the world have adopted technologies based on renewable sources to generate clean and inexhaustible energy to fulfil their ever-increasing demands [1,2].

Among the renewable energy resources, the use of wind turbines for converting wind energy into electrical power is rapidly growing in popularity and has received tremendous attention from the scientific community [2–5]. They can be categorized based on the rated output power [6,7]:

- Large-scale wind turbines;
- Medium-scale wind turbines;
- Small-scale wind turbines.

According to the International Commission of Electrotechnics [8], small-scale wind turbines (SWTs) are characterized by an electric output of up to 50 kW; they are referred to as SWTs because they are situated on the "customer" side of the electric meter or at or close to the location where the electric energy they generate will be utilized. They can either be devoted to meeting the on-site load or linked to distribution grids to balance off huge loads and assist grid operation. Usually, they are employed in small-scale commercial, industrial, agricultural, and residential settings; they can also be adopted in hybrid energy systems integrated with additional distributed resources, such as photovoltaics, micro-cogeneration units, batteries, etc. Compared to large-scale and medium-scale implementations of wind energy, little attention has been given to the installations of SWTs in the built environment [3]. However, SWTs are potential low-cost renewable energy devices that could be adopted in urban environments and they are gaining more and more interest mainly thanks to their easy installation, low negative environmental impact, high efficiency, etc. [2–9]. With respect to large-scale and medium-scale wind energy systems, SWTs have numerous advantages, such as less installation space, lower maintenance costs, higher reliability, wider wind operation range, self-starting capability at lower wind speed, reduced dependence on grid-connected power and long transmission lines, lower capital costs, etc.; in addition, SWTs can also be installed at low altitudes in a variety of locations, including rooftops and even in some urban settings, making them a more versatile option for homeowners who may not have a lot of land or a sunny south-facing roof for solar panels [3,9]; therefore, SWTs have the potential to be utilized and integrated into residential urban environments. In comparison with photovoltaic panels, SWTs are noisier, require more regular maintenance (due to their moving parts), are generally characterized by a reduced service life, and need a larger space for their installation, but they are generally more efficient [9].

Despite these advantages, building integrated SWTs also faces significant challenges. In fact, the potential of SWTs is dependent upon several parameters, including wind speed intensity and direction [3,7,9,10]. An SWT operating in real life is exposed to wind that changes direction and speed suddenly; manufacturers' power curves do not account for this transient behaviour, during which the power output will decrease significantly as a result of the SWT attempting to adjust to the new conditions; this could have a substantial impact on the design phase's evaluation of the SWT's performance [3,7,9–11]. As a consequence, obtaining a constant and dependable source of electricity can be challenging in urban locations due to variable wind conditions [3,7,9,10]. One of the main obstacles to the widespread diffusion of SWTs in urban areas is also represented by the challenge of estimating the feasibility of SWTs depending on the local wind resource, which is very site-specific and characterized by a lack of accurate means for its assessment [3,7,9]. Furthermore, the wind flow is hindered by the nearby trees and buildings, which causes turbulence to be created in the flow and a considerable drop in mean wind speed; therefore, in order to obtain the maximum amount of energy per year, the installation site for any SWT on a building needs to be accurately evaluated and this requires a thorough analysis of factors like the mean wind speed's direction, how the building envelope interacts with the wind flow, and the degree of wind turbulence [3,7,9].

1.2. Novelty, Goals and Structure of the Study

Several reviews related to small-scale wind turbines are available in the scientific literature [10–16]. Some of them [12,13] are really dated. In order to comprehend the characteristics of inflowing wind, the turbine performance, and identify knowledge gaps, Anup et al.'s paper [11] reviewed a variety of studies on the operation of wind turbines with an electric output between 5 and 20 kW in built environments; they also looked into the extent to which the International Standard IEC 61400-2:2013 [14] can be applied with reference to urban settings. In order to improve the efficiency, cost-effectiveness and reliability of SWTs, Calautit et al. [10] reviewed their current state, drawbacks and research gaps. This study also examined innovations, developments, and technical aspects allowing for the maximisation of these technologies' performances in uneven scenarios of wind flows and across a broad interval of wind velocities. The paper of Wang et al. [15] looked at SWTs for Internet of Things (IoT) applications, giving a thorough analysis of their state-of-art that included power generation methods as well as wind energy rectifiers; it also discussed applicable generator systems like piezoelectric, electromagnetic, and tribo-electric nanogenerators. Moreover, it provided a detailed review of the most recent research on IoT applications, such as urban environments, transportation, self-powered wind sensing, and intelligent agriculture. Finally, the study identified future research developments and highlighted the potential of interdisciplinary approaches in supporting SWTs application. Different designs of vertical-axis SWTS are presented by Wilberforce et al. [16], with each concept potential evaluated under poor wind quality situations (with wind speeds of 3 m/s, 5 m/s, 7 m/s and 10 m/s), such as those seen in densely populated, suburban, or sparsely forested regions; in addition, several types of materials for small-scale wind turbines were explored. However, all the above-mentioned review papers do not provide a complete and updated list of currently commercially available models of SWTs, nor do they clearly report the detailed characteristics in terms of geometry, materials, rated performance and costs of the analysed SWTs. Finally, they do not analyse the performance of SWTs based on existing in-situ measured data.

In this review, a complete and updated list of currently commercially available small-scale horizontal and vertical wind turbine models is provided and analysed, detailing the corresponding characteristics in terms of number and material of blades, start-up wind speed, cut-in wind speed, cut-out wind speed, survival wind speed, maximum power, noise level, rotor diameter, turbine length, tower height, and specific capital cost. In addition, the scientific papers focusing on the experimental assessment of field performance of commercially available small-scale horizontal and vertical wind turbines are reviewed and the corresponding measured data are compared with the performance characteristics rated by the corresponding manufacturers. In particular, Section 2 describes the main classifications, performance metrics, components and operation of SWTs, Section 3 reports the main characteristics of commercially available pico, micro and mini SWTs, Section 4 analyses the main characteristics of commercial SWTs, Section 5 performs a detailed literature review of the scientific papers available in the literature focusing on the field assessment of SWTs, and Section 6 discusses the comparison between the data measured in the above-mentioned scientific papers and the performance data rated by the SWTs manufacturers.

The main aims of this paper can be summarized as follows:

- Support the development and encourage wider use of small wind turbines in urban settings;
- Create a detailed database including all the main information related to geometry, materials, costs and performance of commercial SWTs;
- Assist researchers, designers, decision-makers and stakeholders in obtaining an accurate picture of the products available on the market and their characteristics in a way that facilitates the selection of the most appropriate technology and model corresponding to the selected area;
- Clarify the state-of-the-art related to up-to-date scientific studies on the experimental analysis of SWT;

- Highlight the differences between field data and rated performance in such a way as to stimulate further scientific research and push manufacturers to provide increasingly detailed and representative information about the real performance of SWTs.

2. Small-Scale Wind Turbines: Main Classifications, Performance Metrics, Components and Operation

According to the International Commission of Electrotechnics [8], SWTs are those characterized by an electric output of up to 50 kW. There are basically two types of SWTs [12,13]:

- Horizontal axis small-scale turbines (HAWTs);
- Vertical axis small-scale wind turbines (VAWTs).

HAWTs have their axis of rotation parallel to the wind stream (i.e., horizontal), whereas VAWTs are characterized by an axis of rotation perpendicular to the wind stream (i.e., vertical). The operation of HAWTs is dependent on wind direction, while VAWTs are omnidirectional (i.e., they operate independently of the wind direction because they can use wind from all directions).

Both HAWTs and VAWTs are characterized by the following main performance characteristics:

- Start-up wind speed v_{up}, i.e., the minimum wind speed required for the blades and the rotor to start spinning (without providing any usable electric power) [17];
- Cut-in wind speed v_{in}, i.e., the speed at which a wind turbine starts generating electricity [18];
- Cut-out wind speed v_{out}, i.e., the maximum wind speed at which the wind turbine is designed to produce usable power [19];
- Rated wind speed v_r, i.e., the wind speed at which the rated power of the wind turbine is reached [20];
- Survival wind speed v_s, i.e., the maximum wind speed, as designated by the manufacturer, at which the wind turbine is designed to survive (not necessarily producing power) without damage to any structural equipment or loss of the ability to function normally [21];
- Rated power output P_{rated}, i.e., the power output at the rated wind speed [20];
- Maximum power output (P_{max}), i.e., the highest power output that the wind turbine can supply [22];
- Thrust coefficient C_T, i.e., the dimensionless number that quantifies the amount of thrust generated by a wind turbine for a given wind speed; it is a measure of how effectively the turbine converts the momentum of the incoming wind into a force that helps rotate the turbine blades;
- Torque coefficient C_Q, i.e., the dimensionless number that quantifies the amount of torque (rotational force) generated by the wind turbine for a given wind speed. It is a measure of how effectively the turbine converts the energy of the incoming wind into rotational energy;
- Power coefficient C_p, i.e., the ratio between the maximum power that is generated by the turbine P_{max} and the kinetic power available in the undisturbed stream (maximum power output that can be theoretically generated by the turbine) P_{wind} [23]:

$$C_p = \frac{P_{max}}{P_{wind}} = \frac{(v_1 + v_2) \cdot \left(v_1^2 - v_2^2\right)}{2 \cdot v_1^3} \quad (1)$$

where v_1 is the wind speed before contact with the wind turbine, and v_2 is the wind speed after contact with the wind turbine [23]. According to Betz's law, the maximum power coefficient C_p theoretically achievable by a wind turbine is 59.3%, meaning that a turbine can extract no more than 59.3% of the kinetic energy contained in a mass of air [24]; this maximum theoretical value refers to an ideal wind turbine, i.e., in the case of no friction, steady and incompressible flow, undisturbed static pressure, infinite blades' number, etc.; in addition, the thermodynamic irreversibility associated to the real operation of wind turbines' components should be taken into account; therefore, the C_p values of existing wind turbines are much lower than the Betz' law limit of 59.3%. According to [25,26], HAWTs are able to achieve larger power outputs than VAWTs within the same flow conditions, but the performances of HAWTs are much more sensitive to the variations of surface conditions, decreasing the power production for higher turbulence levels due to ground-level surface roughness. Lee et al. [27] highlighted that VAWTs can produce power at a relatively lower wind speed with respect to HAWTs (and this is one of the reasons why VAWTs are generally preferred in residential areas), while, when both operate at similar wind speeds, HAWTs are expected to produce more power than VAWTs [27]. In addition, it should be underlined that when there are turbulent flows, which are common in the case of built environments, VAWTs appear to provide more power in comparison to HAWTs [28];

- Tip speed ratio (TSR), defined as follows [29]:

$$TSR = \frac{\omega \cdot R}{v} \tag{2}$$

where ω is the angular velocity of the turbine, R is the rotor radius and v is the wind velocity [29].

The efficiency of a wind turbine is determined by how the individual parts are configured and designed. The main components of HAWTs and VAWTs can be summarized as follows [30]:

- Blades: when wind blows across a wind turbine, the air pressure on one side of the blade drops; this difference in air pressure creates lift and drag; the force of the lift is greater than the drag, which causes the blades to rotate. This is how a wind turbine converts wind energy into electricity;
- Hub: it is the component that holds the blades and connects them to the shaft of the wind turbine;
- Nose cone (or division hood): it is the conically formed forward part of the wind turbine that is intended to reduce aerodynamic drag and control the behaviour of approaching airflow;
- Rotor: this piece includes both the blades and the hub;
- Shaft: it connects the rotor to the generator;
- Generator: it is the system converting mechanical energy into electrical energy (either AC or DC); it is driven by the shaft of the wind turbine; when the rotor of the turbine rotates, it generates electricity;
- Tower (or pole): it supports the wind turbine's nacelle; its height is important taking into account that taller towers allow wind turbines to catch more energy and produce more power since wind speed rises with height;
- Nacelle (or gondola or body): is the "head" of the wind turbine, and it is mounted on top of the tower and contains the shaft and the generator;
- Tail vane: this part serves as a guide for the entire structure, directing the wind turbine's rotor in the direction of stronger and more favourable winds. If the wind direction changes, the tale vane turns the turbine into the wind, maximizing the production of electrical energy;
- Tail boom (or rudder): it connects the tail vane to the nacelle;
- Yaw bearing: it enables the turbine to rotate and react to variations in the wind direction.

There are two fundamental types of HAWTs: downwind and upwind. When the turbine is in operation, the rotor of an upwind HAWT is situated on the upwind side of the turbine. Downwind turbines are HAWTs where the rotor is positioned on the downwind side of the turbine when the wind is blowing. Another typical construction for HAWTs lacks a shaft [30] and the turbine's blades are fastened to a faceplate that is fastened directly to a cylindrical metal "can"; the faceplate and the turbine's blades combined constitute the turbine's rotor. The aforementioned HAWTs are referred to as "direct-drive" HAWTs as the turbine's rotor is fixed to the generator directly. However, a few HAWTs contain a gearbox; it connects a low-speed shaft (connected to the rotor of the turbine) with a high-speed shaft (connected to the generator) allowing to increase the rotational speed and enhance the electricity production. These HAWTs are known as "gear-driven" turbines.

VAWTs significantly differ with respect to HAWTs. In the case of VAWTs:

- The blades are attached to a central vertical shaft; when the blades rotate, the shaft rotates;
- The shaft is linked to the generator installed at the bottom of the shaft.

VAWTs can be divided into two categories, based on their rotor type: they are the Savonius type, which is drag-based, and the Darrieus type, which is lift-based [31,32].

Savonius wind turbines are made up of a certain number of half-cylinders arranged around a vertical shaft in opposition to one another [31]. These rotors operate based on the variance in drag force experienced by blades depending on whether the wind hits the concave or convex side. As wind flows through the structure, it encounters opposite-facing surfaces (one concave and the other convex), resulting in the exertion of two distinct forces (drag and lift) on these surfaces. Enhancements to the power coefficient can be achieved by modifying the blade geometry; the introduction of helical blades, for instance, aims to enhance the power coefficient across various twist angles.

The Darrieus wind turbine, initially patented by G.J.M. Darrieus, featured egg-beater, H-shaped, and V-shaped rotors. However, subsequent developments have led to the creation of various geometries aimed at optimizing both aerodynamic and structural performance, such as helical-shaped or Gorlov rotors [33,34]. Among these, the egg-beater-shaped rotor stands out as the most renowned type of vertical axis wind turbine, characterized by its "C" shaped rotors, giving it the appearance of an egg-beater. Nevertheless, due to the diminishing rotor radius from the centre to the ends, it loses its self-starting capability, making it less favourable in scenarios where self-starting is required. Additionally, this design is not considered appropriate for the generation of electricity in metropolitan areas because of its low torque coefficient and power coefficient. An egg-beater wind turbine's highest coefficient of performance falls between 0.26 and 0.42 [16,35]. The H-shaped rotor is an advancement of the Darrieus egg-beater shape for improving aerodynamic characteristics with the goal of optimized power coefficient. The rotor's blades are straight and have a uniform radius throughout; the number of blades can vary from two to five depending on the wind speed; an H-shaped rotor wind turbine's maximum coefficient of performance falls between 0.25 and 0.35 [36]. In the case of V-shaped rotor (or "Y" or "sunflower") with the two-bladed fixed geometry, each blade is attached to the rotor hub at its root at a fixed angle to the vertical forming a "V" [37]. Helical-shaped (or Gorlov) rotor consists of straight and curved blades that are helically twisted around the rotational axis; a helical-bladed wind turbine's highest coefficient of performance ranges between 0.25 and 0.479, even if it shows notable unsteadiness in the power coefficient over the course of a single turbine revolution [38,39].

Darrieus rotors operate on aerodynamic lift principles, enabling them to rotate at speeds faster than the wind itself. They are commonly employed for power generation due to their high rotational speed. However, they lack self-starting capability and exhibit lower starting torque, making them less reliable in regions with weak prevailing winds [39]. On the other hand, Savonius rotors are drag-based turbines known for their self-starting nature, which allows them to initiate rotation even at stream velocities of 1.0 m/s [40]. The disadvantages of a Savonius rotor mainly involve low efficiency and low power generation [41].

While each type of rotor has advantages and disadvantages of its own, none of them is superior to the other. Hybrid Darrieus–Savonius rotors represent a relatively new and attractive technology and are seen to be particularly promising for small-scale distributed power production. A hybrid Darrieus–Savonius rotor has two conventional rotors (Savonius and Darrieus), where the internal wind turbine is chosen as Savonius and the external wind turbine is chosen as Darrieus to increase the performance [42]. Hybrid Darrieus–Savonius rotors are characterized by power coefficients between 0.204 and 0.400 [43]. The Darrieus–Savonius rotors are engineered to address the drawbacks of both Darrieus and Savonius designs. Specifically, the Darrieus rotor's inability to self-start and its low starting torque are mitigated by attaching a Savonius rotor, which, in contrast, boasts a high starting torque but lower efficiency [3]. As noted by Chong et al. [44], HAWTs prove highly effective in harnessing wind energy for electricity generation. However, they need yaw mechanisms to line themselves correctly with the wind, constant maintenance and transmission repairs, extra costs for strengthening the tower construction to handle the weighty nacelle, as well as increased rotor diameter and number of blades, which can pose risks to surrounding wildlife. Moreover, they are characterized by high noise levels, and optimal power extraction necessitates the rotor facing the wind direction.

On the other hand, Chong et al. [44] underlined that VAWTs are deemed more suitable to be used in urban areas mainly thanks to the fact that they can capture wind from any orientation (they do not require to be positioned into the wind as the HAWTs do and, therefore, they do not need yaw mechanisms); in addition, because their gearbox and generator are located at a lower position, VAWTs can be easily scaled down without sacrificing their efficiency in harnessing wind power; their rotor size can also be adjusted horizontally without impacting their height. Furthermore, VAWTs can be integrated into existing HAWTs' wind farms to integrate the power output. Moreover, the anatomy of VAWTs makes it considerably easier and more efficient to replace and repair gearboxes than it is for HAWTs, thanks to the fact that the gearbox can be accessed at ground level, negating the need for cranes or other big equipment. Finally, as VAWTs can capture wind energy whatever the wind direction is, they do not require a yawing mechanism, which lowers manufacturing and maintenance costs. It should also be underlined that VAWTs are more effective in catching rapidly changing wind, allowing them to be more suitable in urban installations. Lastly, the decreased rotating speed of VAWTs guarantees safer bird flying, while simultaneously producing lower noise levels. Despite VAWTs' usual superiority with respect to HAWTs, VAWTs also exhibit their share of drawbacks. For instance, they often suffer from relatively lower efficiency, as seen in the Savonius rotor design, because the wind hits the rotor blade on both sides (one side counters the direction of the wind, while the other side follows it), partially balancing the wind force that is available. Another limitation of VAWTs is their inability to self-start, exemplified in the Darrieus rotor design. However, site-specific factors and careful planning are essential to minimize the negative impacts of wind energy applications.

The installation of SWTs often requires planning permissions, and the corresponding specific rules and regulations can vary greatly depending on the location [45,46]. In particular, in Italy, the installation and operation of SWTs are regulated by six Legislative Decrees [47–52], one Regional Law [53], one Law Decree [54], one Directive [55], one Interministerial Decree [56], and two Civil Codes [57,58].

The power generated by wind turbines varies from a few watts up to hundreds of megawatts. As mentioned above, SWTs are those characterized by an electric output of up to 50 kW (according to the International Commission of Electrotechnics [8,14]). In particular, according to IEC 61400-2:2013 [8,14], SWTs are usually classified into the three different categories (pico, micro and mini) reported in Table 1 depending on the rated power P_{rated} as well as the rotor swept area A (the plane of wind intersected by the generator, i.e., the area of the circle delineated by the tips of the blades of the wind turbine for HAWTs, and the area determined by multiplying the rotor radius times the rotor height times 3.14 for VAWTs).

Table 1. Small-scale wind turbines (SWTs) classification according to [8,14].

Category	Rated Power P_{rated} (kW)	Rotor Swept Area A (m^2)
Pico wind turbines (PWTs)	$P_{rated} \leq 1$ kW	$A \leq 4.9$ m^2
Micro wind turbines (MCWTs)	1 kW $\leq P_{rated} \leq$ 7 kW	$A \leq 40$ m^2
Mini wind turbines (MNWTs)	7 kW $\leq P_{rated} \leq$ 50 kW	$A \leq 200$ m^2

The classification criteria of SWTs suggested in [8,14] and reported in Table 1 are assumed in this paper.

A different classification of SWTs is provided in Italy by the Gestore dei Servizi Energetici S.p.A. [50,59]. However, according to Araujo et al. [60], alternative classifications of small-scale wind turbines can be recognized worldwide. Table 2 summarizes such alternative classification criteria, specifying the proposed categories of wind turbines, the rated power based on which wind turbines are categorized, the country of application, as well as the rating institution.

Table 2. SWTs classification methods according to [60].

Category	Rated Power P_{rated} (kW)	Country	Rating Institution
Small-scale wind turbines	≤200	USA	American Wind Energy Association
Mini wind turbines	0.3–1	Canada	NRCan/CanWEA
Small-scale wind turbines	≤75	Germany	Bundesverband WindEnergie
Micro wind turbines	≤1.5	UK	Bundesverband WindEnergie
Small-scale wind turbines	1.5–15		RenewableUK
Small-medium wind turbines	15–100		
Small-scale wind turbines	≤100	China	Renewable Energy and Energy Efficiency Partnership
Small-scale wind turbines	≤500	Brazil	National Electric Energy Agency
Micro wind turbines	<75		
Mini wind turbines	75–500		

3. Commercially Available Small-Scale Wind Turbines (SWTs)

In the following sections, all the SWTs available on the worldwide market are described and analysed in detail. In particular, Section 3.1 refers to the pico wind turbines (PWTs), Section 3.2 focuses on the micro wind turbines (MCWTs), and Section 3.3 describes the mini wind turbines (MNWTs). Both horizontal and vertical SWTs are considered. Figure 1 indicates the countries where the SWTs analysed in this study are manufactured; this figure highlights that 30.44% of the selected SWTs are manufactured in the USA, while 52.55% of them are manufactured in Europe.

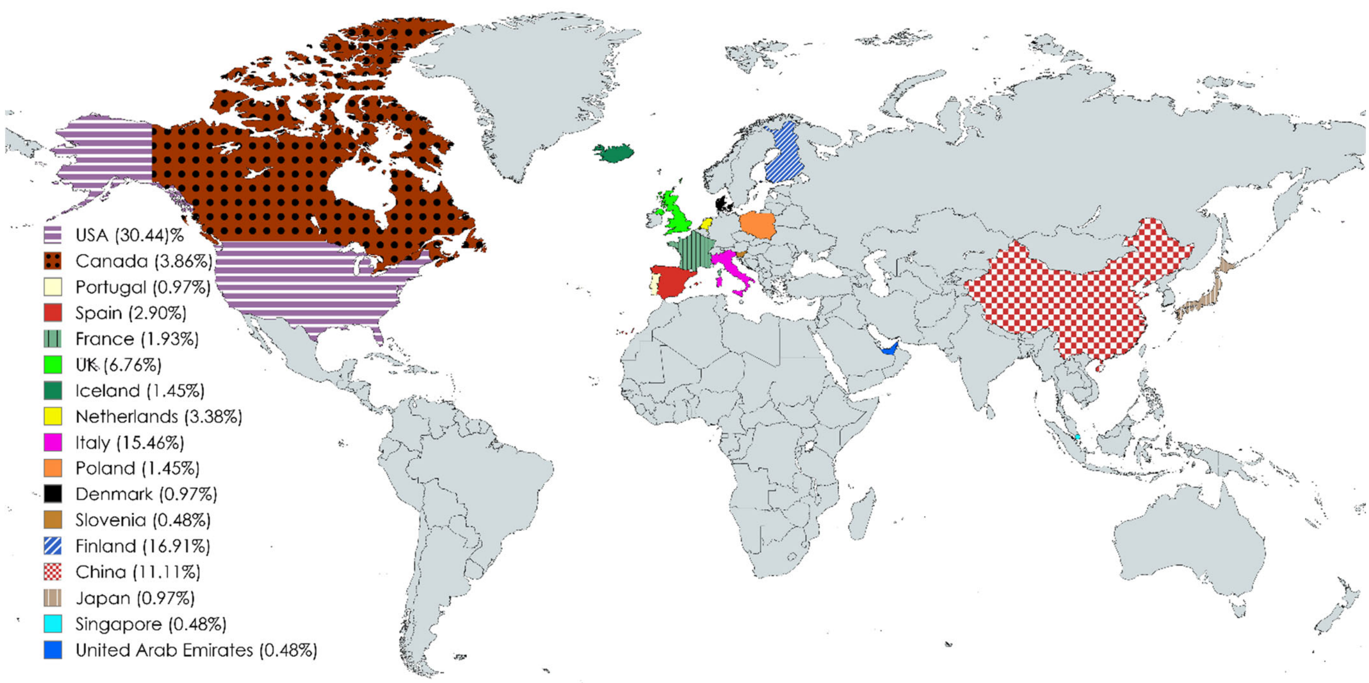

Figure 1. Distribution STWs selected in this study as a function of manufacturing country.

3.1. Commercial Pico Wind Turbines (PWTs)

This section focuses on pico wind turbines (PWTs), i.e., wind turbines with electric output of up to 1.0 kW, commercially available on the market. In particular, Tables 3 and 4 report the manufacturer, model, number of blades, start-up wind speed, cut-in wind speed, cut-off wind speed, survival wind speed, maximum power output (i.e., the maximum electric output according to the power curve provided by the manufacturer), voltage (distinguishing between alternating current (AC) and direct current (DC), rotor diameter, turbine length (i.e., the distance between the nose cone and the tail vane), tower height, capital cost, specific capital cost (i.e., capital cost divided by maximum electric output), material of blades, noise level, maximum capacity of electric battery eventually coupled with the PWT. In particular, Table 3 refers to horizontal axis pico wind turbines (HAPWTs), while Table 4 focuses on vertical axis pico wind turbines (VAPWTs); in the case of VAPWTs, the type (Savonius or Darrieus or hybrid) is also specified. It is worth noting that if one of the characteristics is not specified, the symbol NA (not available) is used.

3.2. Commercial Micro Wind Turbines (MCWTs)

This section focuses on micro wind turbines (MCWTs), with electric output between 1.0 and 7.0 kW, commercially available on the market. Tables 5 and 6 report the manufacturer, model, number of blades, start-up wind speed, cut-in wind speed, cut-off wind speed, survival wind speed, maximum power output (i.e., the maximum electric output according to the power curve provided by the manufacturer), voltage (distinguishing between alternating current (AC) and direct current (DC), rotor diameter, turbine length (i.e., the distance between the nose cone and the tail vane), tower height, capital cost, specific capital cost (i.e., capital cost divided by maximum electric output), material of blades, noise level, maximum capacity of electric battery eventually coupled with the MCWT. In particular, Table 5 refers to horizontal axis micro wind turbines (HAMCWTs), while Table 6 focuses on vertical axis micro wind turbines (VAMCWTs); in the case of VAMCWTs, the type (Savonius or Darrieus or hybrid) is also specified. It is worth noting that if one of the characteristics is not specified, the symbol NA (not available) is used.

3.3. Commercial Mini Wind Turbines (MNWTs)

This section focuses on mini wind turbines (MNWTs), with electric output between 7.0 kW and 50.0 kW, commercially available on the market. Tables 7 and 8 report the manufacturer, model, number of blades, start-up wind speed, cut-in wind speed, cut-off wind speed, survival wind speed, maximum power output (i.e., the maximum electric output according to the power curve provided by the manufacturer), voltage (distinguishing between alternating current (AC) and direct current (DC), rotor diameter, turbine length (i.e., the distance between the nose cone and the tail vane), tower height, capital cost, specific capital cost (i.e., capital cost divided by maximum electric output), material of blades, noise level, maximum capacity of electric battery eventually coupled with the MNWT. In particular, Table 7 refers to horizontal axis micro wind turbines (HAMNWTs), while Table 8 focuses on vertical axis micro wind turbines (VAMNWTs); in the case of VAMNWTs, the type (Savonius or Darrieus or hybrid) is also specified. It is worth noting that if one of the characteristics is not specified, the symbol NA (not available) is used.

Table 3. Main characteristics of commercially available horizontal axis pico wind turbines (HAPWTs).

Manufacturer/Model/Number of Blades	Start-Up/Cut-In/Cut-Out/Survival Wind Speed (m/s)	Maximum Power (W)/Voltage (V)	Rotor Diameter/Turbine Length/Tower Height (m)	Capital Cost (EUR)/Specific Capital Cost (EUR/W)	Materials of Blades	Noise Level	Battery Capacity (Ah)
Aurea Technologies/Shine/3 [61,62]	NA/3.58/12.52/NA	40/5 (DC)	0.6/0.35/0.814	526.11/13.153	Durable injection-moulded PC-ABS + Glass	50 dB	0.012
Marlec Engineering/Rutland 504/6 [63–65]	2.2/3.0/20.60/NA	~72/12 (AC)	0.51/0.439/2.0–6.5	433.23/6.02	Reinforced plastic	NA	150
Force 4/Giga/6 [66,67]	1.03/1.54/13.0/NA	~30/12 (DC)	0.3/0.07/NA	430.40/14.35	Rigid plastic	NA	NA
Texenergy/Infinite Air 18/3 [68]	3.58/5.36/17.43/20.56	27/18 (DC)	0.5/NA/NA	455.95/16.89	NA	NA	NA
WindLily/WindLily/6 [69]	NA/3.13/9.84/NA	23/14.6 (DC)	0.6/0.18/NA	329.99/14.35	NA	NA	NA
Cutting Edge Power/Tailgating/2 [70]	NA/3.13/NA/20.12	15/30 (DC)	0.457/NA/NA	215.15/14.34	NA	NA	NA
Cutting Edge Power/Tailgating/5 [70]	NA/2.24/NA/20.12	15/30 (DC)	0.457/NA/NA	215.15/14.34	NA	NA	NA
WindSoleil/Hiko Hyacinth Z300/6 [71]	2.0/3.0/15.0/40.0	350/12–24 (AC/DC)	1.14/NA/NA	495.0/1.41	Carbon fibre reinforced with plastics	NA	NA
WindSoleil/Hiko Hyacinth X-600CS/5 [72]	2.5/3.0/15.0/45.0	680/24–48 (AC/DC)	1.85/NA/4.0	695.0/1.02	Carbon fibre and nylon	NA	200
KiteX/Wind Catcher/3 [73]	2.0/4.02/15.0/25.0	600/42–45.60 (DC)	4.0/NA/NA	1995.0/3.26	NA	55 dB at 6.00 m/s and a maximum level of 65 dB	NA
KiteX/Wind Catcher Lite/3 [73–75]	2.0/4.02/15.0/22.0	200/19.80–22.80 (DC)	2.05/NA/4.0	1995.0/9.78	NA	55 dB at 6.00 m/s and a maximum level of 65 dB	NA
Nheowind/Nheowind 3D-04/3 [76,77]	2.0/2.5/35.0/50.0	350/25(AC)	1.5/NA/NA	792.36/2.26	Fibreglass composite	35 dB at 12.00 m/s	NA
VEVOR/NA/5 [78]	2.0/NA/NA/50.0	510/12 (DC)	1.19/0.61/NA	157.99/0.31	Nylon fibre	NA	NA
Nieuw bij EDL/OmniLed07/6 [79–81]	NA/NA/NA/45.0	NA/12 (DC)	0.7/0.3/6.0, 8.0, 12.0	NA	Reinforced polyamide PAG	28 dB at 8.00 m/s	14
Nieuw bij EDL/OmniLed035/6 [80,81]	NA/NA/NA/45.0	NA/12 (DC)	0.35/0.15/4.0, 5.0, 6.0	650.0/NA	Reinforced polyamide PAG	28 dB at 8.00 m/s	7.2
Clean Energy Storage Inc./Energy Ball V100/6 [82–84]	2.0/3.0/22.0/40.0	525/230 (DC)	1.1/1.857/8.9–10.9	1607.0/3.06	Fibreglass reinforced polyester	NA	NA
Primus Windpower/Air X Marine Blades standard/3 [85]	3.58/NA/15.65/49.20	450/12–48 (DC)	1.17/0.675/7.6–13.7	1647.64/3.66	Injection moulded composite—Blue + plastic and carbon fibre	NA	NA
Primus Windpower/SilentWind Air X Marine—blue carbon fibre Blades/3 [85]	3.58/NA/15.65/49.2	450/12–48 (DC)	1.17/0.675/7.6–13.7	1903.30/4.23	Hand laminated and carbon fibre	NA	NA
Primus Windpower/Air Breeze Marine Wind Generator—standard black blades/3 [86]	3.13/NA/15.65/40.2	250/12–48 (DC)	1.17/0.675/7.6–13.7	1647.64/6.59	Injection moulded composite	NA	NA
Primus Windpower/Air Max Marine Wind Generator carbon blades/3 [86]	3.13/NA/15.65/40.2	450/12–48 (DC)	1.17/0.675/7.6–13.7	1903.30/4.23	Injection moulded composite—black	NA	NA

Table 3. *Cont.*

Manufacturer/Model/Number of Blades	Start-Up/Cut-In/Cut-Out/Survival Wind Speed (m/s)	Maximum Power (W)/Voltage (V)	Rotor Diameter/Turbine Length/Tower Height (m)	Capital Cost (EUR)/Specific Capital Cost (EUR/W)	Materials of Blades	Noise Level	Battery Capacity (Ah)
AUTOMAXX/Windmill DB-600 Standard/3 [87]	1.0/2.0/14.0/NA	600/12–24 (DC)	1.35/NA/NA	638.00/1.06	Nylon fibre and fibreglass	NA	100
AUTOMAXX/Windmill DB-600 Bluetooth/3 [87]	1.0/2.0/14.0/NA	600/12–24 (DC)	1.35/NA/NA	683.70/1.14	Nylon fibre and fibreglass	NA	100
AUTOMAXX/Windmill DB-400 Standard/3 [88]	1.0/3.0/12.5/NA	400/12 (DC)	1.22/NA/NA	547.0/1.37	Nylon fibre and fibreglass	NA	100
AUTOMAXX/Windmill DB-400 Bluetooth/3 [88]	1.0/3.0/12.5/NA	400/12 (DC)	1.22/NA/NA	592.67/1.48	Nylon fibre and fibreglass	NA	100
WINDANDSOLAR/SKU 500W-BSC/3 [89]	5.36/NA/NA/NA	500/12 (AC/DC)	1.52/NA/6.71	327.22/0.65	Plastic	NA	NA
WINDANDSOLAR/SKU 500W-BSC/5 [89]	2.68/NA/NA/NA	500/12 (AC/DC)	1.52/NA6.71	327.22/0.65	Plastic	NA	NA
WINDANDSOLAR/SKU 500W-BSC/7 [89]	2.68/NA/NA/NA	500/12 (AC/DC)	1.52/NA/6.71	327.22/0.65	Plastic	NA	NA
ATO/WT-800M5/3 [90]	2.5/3.0/14.0/40.0	820/24–48 (AC)	2.2/1.4/NA	830.57/1.01	Fibreglass	NA	NA
ATO/WT-800M5/5 [91]	2.5/3.0/14.0/40.0	820/24–48 (AC)	2.2/1.4/NA	858.07/1.05	Fibreglass	NA	NA
ATO/WT-600M4/3 [91]	2.5/3.0/14.0/40.0	630/24–48 (AC)	1.85/NA/NA	726.93/1.15	Fibreglass	NA	NA
ATO/WT-600M4/5 [91]	2.5/3.0/14.0/40.0	630/24–48 (AC)	1.85/NA/NA	754.43/1.20	Fibreglass	NA	NA
ATO/WT-500M2/3 [92]	2.5/3.0/15.0/40.0	510/24–48 (AC)	1.75/NA/NA	563.35/1.10	Fibreglass	NA	NA
ATO/WT-500M2/5 [92]	2.5/3.0/15.0/40.0	510/24–48 (AC)	1.75/NA/NA	590.85/1.16	Fibreglass	NA	NA
ATO/WT-400M2/3 [93]	2.5/3.0/14.0/40.0	420/24–48 (AC)	1.75/0.83/NA	526.0/1.25	Fibreglass	NA	NA
ATO/WT-400M2/5 [93]	2.5/3.0/14.0/40.0	420/24–48 (AC)	1.75/0.83/NA	553.50/1.27	Fibreglass	NA	NA
ATO/WT-NE-300S5/3 [94]	2.0/3.0/15.0/55.0	310/12–24 (AC)	1.35/0.66/NA	326.72/1.05	Nylon fibre	NA	NA
ATO/WT-NE-300S5/5 [94]	2.0/3.0/15.0/55.0	310/12–24 (AC)	1.35/0.66/NA	359.16/1.16	Nylon fibre	NA	NA
ATO/WT-NE-200S5/3 [95]	2.0/NA/13.0/55.0	220/12–24 (AC)	1.3/0.66/NA	299.22/1.36	Nylon fibre	NA	NA
ATO/WT-NE-200S5/3 [95]	2.0/NA/13.0/55.0	220/12–24 (AC)	1.3/0.66/NA	326.72/1.49	Nylon fibre	NA	NA
ATO/WT-NE-100S5/3 [96]	2.0/3.0/14.0/55.0	130/12–24 (AC)	1.2/0.66/NA	269.20/2.07	Nylon fibre	NA	NA
ATO/WT-NE-100S5/5 [96]	2.0/3.0/14.0/55.0	130/12–24 (AC)	1.2/0.66/NA	296.70/2.28	Nylon fibre	NA	NA
WINDFORCE™/XUNZEL-6000/3 [97,98]	1.0/2.0/NA/50.0	600/12–24 (DC)	1.31/0.85/8.8	1307.90/2.18	PP + Fibreglass	NA	240–480
WINDFORCE™/XUNZEL-6000 MARINE/3 [98,99]	1.0/2.0/NA/50.0	600/12–24 (DC)	1.31/0.85/8.8	1626.37/2.71	PP + Fibreglass	NA	240–480
ISTA BREEZE/i-500/3 [100,101]	2.0/2.3/17.0/NA	~540/12–24 (NA)	1.03/0.5/NA	230.0/0.43	UV-resistant Plastic + 30% glass fibres	40 dB	NA
ISTA BREEZE/i-700/3 [102,103]	2.0/3.0/16.0/NA	~785/12–48 (NA)	1.86/0.9/NA	390.0/0.50	UV-resistant Plastic + 30% glass fibres	40 dB	NA
TESUP/Master X/3 [104,105]	2.0/2.7/20.0/50.0	980/220 (NA)	1.6/0.825/NA	439.58/0.45	Composite Materials and Cast Aluminium	30 dB	NA
Southwest Windpower/Whisper 100/3 [106,107]	2.9/3.4/20.3/55.0	~972/12–48 (DC)	2.1/NA/NA	2230.76/2.30	Carbon fibre composite, fibreglass and epoxy bonding	NA	NA

Table 4. Main characteristics of commercially available vertical axis pico wind turbines (VAPWTs).

Type/Manufacturer/Model/Number of Blades	Start-Up/Cut-In/Cut-Out/Survival Wind Speed (m/s)	Maximum Power (W)/Voltage (V)	Rotor Diameter/Turbine Length/Tower Height (m)	Capital Cost (EUR)/Specific Capital Cost (EUR/W)	Materials of Blades	Noise Level	Battery Capacity (Ah)
Savonius/Leading Edge/LE-v50/3 [108]	NA/5.0/27.0/45.0	86/12–48 (DC)	0.27/0.631/NA	1289.80/15.0	Aluminium alloy	NA	NA
Savonius/Leading Edge/LE-v150/3 [109]	NA/5.0/27.0/NA	200/12–48 (DC)	0.27/1.093/NA	1612.56/8.06	Aluminium alloy	NA	NA
Hybrid/Etneo/DS300/3 External Darrieus + 4 Internal Savonius [110–112]	NA/2.2/15.5/60.0	500/24 (DC)	1.245/1.06/4.0	2950.0/5.90	Anodized Aluminium	50 dB	100, 150, 200
Hybrid/Etneo/DS700/3 External Darrieus + 4 Internal Savonius [113,114]	NA/2.2/15.5/60.0	~830/48 (DC)	1.93/1.811/4–7	6500.0/7.83	Anodized Aluminium	50 dB	NA
Hybrid/IceWind/Njord RW100/3 External Darrieus + 3 Internal Savonius [115]	2.0/2.5/17.0/60.35	~430/NA	1.1/1.5/NA	NA	Stainless Steel and Aluminium	30 dB	NA
Hybrid/IceWind/Njord CW100/3 External Darrieus + 3 Internal Savonius [116]	2.0/2.5/10.0/58.12	~175/12–230 (NA)	1.4/1.5/NA	4800.0/27.43	Stainless Steel and Aluminium	30 dB	NA
Darrieus/Makemu/SMARTWIND SW300_PLUS_3P_110/3 [117]	2.6/NA/NA/NA	300/12–110 (AC)	0.7/1.2/NA	441.0/1.47	NA	40 dB	NA
Darrieus/Makemu/SMARTWIND SW300_PLUS_6P_110/6 [117]	0.9/NA/NA/NA	300/12–110 (AC)	0.7/1.2/NA	482.0/1.61	NA	40 dB	NA
Darrieus/Makemu/SMARTWIND SW400_PLUS_3P_110V/3 [117]	2.4/NA/NA/NA	400/12–110 (AC)	0.7/1.2/NA	491.0/1.23	NA	40 dB	NA
Darrieus/Makemu/SMARTWIND SW400_PLUS_6P_110V/6 [117]	1.2/NA/NA/NA	400/12–110 (AC)	0.7/1.2/NA	532.0/1.33	NA	40 dB	NA
Darrieus/Makemu/SMARTWIND SW500_PLUS_3P_110V/3 [117]	3.2/NA/NA/NA	500/12–110 (AC)	0.7/1.2/NA	541.0/1.08	NA	40 dB	NA
Darrieus/Makemu/SMARTWIND SW500_PLUS_6P_110V/6 [117]	1.06/NA/NA/NA	500/12–110 (AC)	0.7/1.2/NA	582.0/1.16	NA	40 dB	NA
Darrieus/Makemu/DOMUS 500_PLUS_3P_220V/3 [118]	2.4/NA/NA/NA	500/12–220 (AC)	1.3/0.8/NA	491.0/0.98	NA	40 dB	NA
Darrieus/Makemu/DOMUS 500_PLUS_6P_100V/6 [118]	1.2/NA/NA/NA	500/12–100 (AC)	1.3/0.8/NA	622.0/1.24	NA	40 dB	NA
Darrieus/Makemu/DOMUS 750_PLUS_3P_220V/3 [118]	2.8/NA/NA/NA	750/12–220 (AC)	1.3/0.8/NA	781.0/1.04	NA	40 dB	NA
Darrieus/Makemu/DOMUS 750_PLUS_6P_220V/6 [118]	1.4/NA/NA/NA	750/12–220 (AC)	1.3/0.8/NA	792.0/1.06	NA	40 dB	NA
Darrieus/Makemu/DOMUS 1000_PLUS_3P_220V/3 [118]	3.2/NA/NA/NA	1000/12–220 (AC)	1.3/0.8/NA	821.0/0.82	NA	40 dB	NA

Table 4. *Cont.*

Type/Manufacturer/Model/Number of Blades	Start-Up/Cut-In/Cut-Out/Survival Wind Speed (m/s)	Maximum Power (W)/Voltage (V)	Rotor Diameter/Turbine Length/Tower Height (m)	Capital Cost (EUR)/Specific Capital Cost (EUR/W)	Materials of Blades	Noise Level	Battery Capacity (Ah)
Darrieus/Makemu/DOMUS 1000_PLUS_6P_220V/6 [118]	1.6/NA/NA/NA	1000/12–220 (AC)	1.3/0.8/NA	922.0/0.92	NA	40 dB	NA
Darrieus/Makemu/EOLO 1K_PLUS_3P_110V/3 [119]	NA/NA/NA/NA	1000/12–110 (AC)	1.3/1.3/NA	1310.10/1.31	NA	40 dB	NA
Darrieus/Makemu/EOLO 1K_PLUS_6P_110V/6 [119]	1.9/NA/NA/NA	1000/12–110 (AC)	1.3/1.3/NA	1510.20/1.51	NA	40 dB	NA
Darrieus/Maglev/FH-600/3 [120]	1.3/2.5/40.0/45.0	650/12–48 (NA)	0.8/NA/7.0–9.0	655.85/1.01	Aluminium alloy	NA	NA
Savonius/FLTXNY/FS-V-600/2 [121]	1.3/2.5/40.0/45.0	650/12–96 (DC)	0.52/NA/7.0–12.0	710.0/1.09	Glass and Basalt	NA	NA
Darrieus/ATO/X3-100/3 [122]	2.0/NA/NA/50.0	130/12–24 (AC)	0.55/0.75/NA	750.50/5.77	Nylon fibre	NA	NA
Darrieus/ATO/X3-200/3 [123]	2.0/NA/NA/50.0	220/12–24 (AC)	0.55/0.75/NA	835.51/3.80	Nylon fibre	NA	NA
Darrieus/ATO/X3-300/3 [124]	2.0/NA/NA/50.0	310/12–24 (AC)	0.55/0.75/NA	871.15/2.81	Nylon fibre	NA	NA
Darrieus/ATO/X3-400/3 [125]	2.0/NA/NA/50.0	420/12–24 (AC)	0.55/0.75/NA	955.29/2.28	Nylon fibre	NA	NA
Darrieus/ATO/X5-500/3 [126]	2.0/NA/NA/50.0	510/12–48 (AC)	0.65/0.90/NA	1089.47/2.14	Nylon fibre	NA	NA
Darrieus/ATO/X5-600/3 [127]	2.0/NA/NA/50.0	630/12–48 (AC)	0.65/0.90/NA	1199.84/1.91	Nylon fibre	NA	NA
Hybrid/IceWind/Njord RW500/3 External Darrieus + 3 Internal Savonius [128–130]	2.0/2.5/50.0/60.35	900/NA	1.3/2.2/NA	4459.68/4.96	Carbon fibre	30 dB	NA
Savonius/Windside/WS-0,15B/2 [131,132]	2.0/2.5/40.0/60.0	71/12 (DC)	0.34/0.515/10	NA/NA	Aluminium	2–5 dB at 2 m distance	NA
Savonius/Windside/WS-0,15B/2 [131,132]	2.0/2.5/40.0/60.0	132/24 (DC)	0.34/0.515/10	NA/NA	Aluminium	2–5 dB at 2 m distance	NA
Savonius/Windside/WS-0,15Bplus/2 [131,133]	2.0/2.5/50.0/60.0	73/12 (DC)	0.34/0.515/10	NA/NA	Aluminium	2–5 dB at 2 m distance	NA
Savonius/Windside/WS-0,15Bplus/2 [131,133]	2.0/2.5/50.0/60.0	147/12 (DC)	0.34/0.515/10	NA/NA	Aluminium	2–5 dB at 2 m distance	NA
Savonius/Windside/WS-0,30C/2 [134–136]	2.0/2.5/30.0/60.0	94/12 (DC)	0.34/1.03/10	NA/NA	Aluminium	2–5 dB at 2 m distance	NA
Savonius/Windside/WS-0,30C/2 [134–136]	2.0/2.5/30.0/60.0	166/24 (DC)	0.34/1.03/10	NA/NA	Aluminium	2–5 dB at 2 m distance	NA
Savonius/Windside/WS-0,30B/2 [134,135,137]	2.0/2.5/40.0/60.0	97/12 (DC)	0.34/1.03/10	NA/NA	Aluminium	2–5 dB at 2 m distance	NA
Savonius/Windside/WS-0,30B/2 [134,135,137]	2.0/2.5/40.0/60.0	190/24 (DC)	0.34/1.03/10	NA/NA	Aluminium	2–5 dB at 2 m distance	NA

Table 4. *Cont.*

Type/Manufacturer/Model/Number of Blades	Start-Up/Cut-In/Cut-Out/Survival Wind Speed (m/s)	Maximum Power (W)/Voltage (V)	Rotor Diameter/Turbine Length/Tower Height (m)	Capital Cost (EUR)/Specific Capital Cost (EUR/W)	Materials of Blades	Noise Level	Battery Capacity (Ah)
Savonius/Windside/WS-0,30Bplus/2 [134,135,138]	2.0/2.5/50.0/60.0	100/12 (DC)	0.34/1.03/10	NA/NA	Aluminium	2–5 dB at 2 m distance	NA
Savonius/Windside/WS-0,30Bplus/2 [134,135,138]	2.0/2.5/50.0/60.0	192/24 (DC)	0.34/1.03/10	NA/NA	Aluminium	2–5 dB at 2 m distance	NA
Savonius/Windside/WS-0,30A8-08/2 [134,135,139]	2.0/2.5/60.0/60.0	102/12 (DC)	0.34/1.03/10	NA/NA	Aluminium	2–5 dB at 2 m distance	NA
Savonius/Windside/WS-0,30A8-08/2 [134,135,139]	2.0/2.5/60.0/60.0	201/24 (DC)	0.34/1.03/10	NA/NA	Aluminium	2–5 dB at 2 m distance	NA
Savonius/Windside/WS-0,30B-29N/2 [134,135,140]	2.0/2.5/40.0/60.0	190/12 (DC)	0.34/1.03/10	NA/NA	Aluminium	2–5 dB at 2 m distance	NA
Savonius/Windside/WS-0,30B-29N/2 [134,135,140]	2.0/2.5/40.0/60.0	341/24 (DC)	0.34/1.03/10	NA/NA	Aluminium	2–5 dB at 2 m distance	NA
Savonius/Windside/WS-0,30Bplus-29N/2 [134,135,141]	2.0/2.5/50.0/60.0	193/12 (DC)	0.34/1.03/10	NA/NA	Aluminium	2–5 dB at 2 m distance	NA
Savonius/Windside/WS-0,30Bplus-29N/2 [134,135,141]	2.0/2.5/50.0/60.0	377/24 (DC)	0.34/1.03/10	NA/NA	Aluminium	2–5 dB at 2 m distance	NA
Savonius/Windside/WS-2City/2 [142,143]	2.0/2.5/25.0/60.0	225/12 (DC)	1.05/2.0/10	NA/NA	Aluminium	2–5 dB at 2 m distance	NA
Savonius/Windside/WS-2City/2 [142,143]	2.0/2.5/25.0/60.0	270/24 (DC)	1.05/2.0/10	NA/NA	Aluminium	2–5 dB at 2 m distance	NA
Savonius/Windside/WS-2CityG/2 [142,143]	2.0/2.5/30.0/60.0	375/12 (DC)	1.05/2.0/10	NA/NA	Aluminium	2–5 dB at 2 m distance	NA
Savonius/Windside/WS-2CityG/2 [142,144]	2.0/2.5/30.0/60.0	450/24 (DC)	1.05/2.0/10	NA/NA	Aluminium	2–5 dB at 2 m distance	NA
Savonius/Windside/WS-2B-dte08/2 [142,145]	2.0/3.0/40.0/60.0	540/12 (DC)	1.05/2.0/10	NA/NA	Aluminium	2–5 dB at 2 m distance	NA
Savonius/Windside/WS-2B-dte08/2 [142,145]	2.0/3.0/40.0/60.0	792/24 (DC)	1.05/2.0/10	NA/NA	Aluminium	2–5 dB at 2 m distance	NA
Savonius/Windside/WS-2AK/2 [142,146]	2.0/3.0/60.0/60.0	540/12 (DC)	1.05/2.0/10	NA/NA	Aluminium	2–5 dB at 2 m distance	NA
Savonius/Windside/WS-2AK/2 [142,146]	2.0/3.0/60.0/60.0	864/24 (DC)	1.05/2.0/10	NA/NA	Aluminium	2–5 dB at 2 m distance	NA

Table 4. *Cont.*

Type/Manufacturer/Model/Number of Blades	Start-Up/Cut-In/Cut-Out/Survival Wind Speed (m/s)	Maximum Power (W)/Voltage (V)	Rotor Diameter/Turbine Length/Tower Height (m)	Capital Cost (EUR)/Specific Capital Cost (EUR/W)	Materials of Blades	Noise Level	Battery Capacity (Ah)
Savonius/Windside/WS-0,60City/2 [147,148]	2.0/2.5/20.0/60.0	162/12 (DC)	0.34/2.06/10	NA/NA	Aluminium	2–5 dB at 2 m distance	NA
Savonius/Windside/WS-0,60City/2 [147,148]	2.0/2.5/20.0/60.0	259/24 (DC)	0.34/2.06/10	NA/NA	Aluminium	2–5 dB at 2 m distance	NA
Savonius/Windside/WS-0,60A12/2 [147,149]	2.0/2.5/60.0/60.0	198/12 (DC)	0.34/2.06/10	NA/NA	Aluminium	2–5 dB at 2 m distance	NA
Savonius/Windside/WS-0,60A12/2 [147,149]	2.0/2.5/60.0/60.0	384/24 (DC)	0.34/2.06/10	NA/NA	Aluminium	2–5 dB at 2 m distance	NA
Savonius/Windside/WS-4A/2 [150,151]	2.0/2.5/40.0/60.0	540/12 (DC)	1.05/4.0/10	NA/NA	Aluminium	2–5 dB at 2 m distance	NA
Savonius/Windside/WS-4A/2 [150,151]	2.0/2.5/40.0/60.0	630/24 (DC)	1.05/4.0/10	NA/NA	Aluminium	2–5 dB at 2 m distance	NA
Savonius/Windside/WS-4A/2 [150,151]	2.0/2.5/40.0/60.0	900/48 (DC)	1.05/4.0/10	NA/NA	Aluminium	2–5 dB at 2 m distance	NA
Savonius/Windside/WS-4B-dte08/2 [150,152]	2.0/2.5/40.0/60.0	540/12 (DC)	1.05/4.0/10	NA/NA	Aluminium	2–5 dB at 2 m distance	NA
Savonius/Windside/WS-4B-dte08/2 [150,152]	2.0/2.5/40.0/60.0	630/24 (DC)	1.05/4.0/10	NA/NA	Aluminium	2–5 dB at 2 m distance	NA
Savonius/Windside/WS-4B-dte08/2 [150,152]	2.0/2.5/40.0/60.0	900/48 (DC)	1.05/4.0/10	NA/NA	Aluminium	2–5 dB at 2 m distance	NA
Savonius/Flower Turbines/Small Tulip Wind Turbine (Off-Grid)/2 Savonius [153,154]	NA/0.7/14.5/54.0	100/230–240 (AC)	0.55/1.40/0.91–1.83	1469.72/44.70	Thermoplastic	NA	NA
Savonius/Flower Turbines/Medium Tulip Wind Turbine (On-Grid)/2 Savonius [153,155]	NA/0.7/12.0/54.0	500/230–240 (AC)	1.18/2.62/1.0–2.44	11,281.60/22.56	Thermoplastic	NA	NA
Savonius/Flower Turbines/Medium Tulip Wind Turbine (Off-Grid)/2 Savonius [153,156]	NA/0.7/12.0/54.0	500/230–240 (AC)	1.18/2.62/1.0–2.44	9529.44/19.06	Thermoplastic	NA	NA
Savonius/Whirlwind/Whirlwind-500/3 [157]	2.0/4.0/14.0/35.83	550/24–48 (DC)	0.33/0.75/NA	NA	NA	NA	NA

Table 5. Main characteristics of commercially available horizontal axis micro wind turbines (HAMCWTs).

Manufacturer/Model/Number of Blades	Start-Up/Cut-In/Cut-Out/Survival Wind Speed (m/s)	Maximum Power (W)/Voltage (V)	Rotor Diameter/Turbine Length/Tower Height (m)	Capital Cost (EUR)/Specific Capital Cost (EUR/W)	Materials of Blades	Noise Level	Battery Capacity (Ah)
Southwest Windpower/Whisper 200/2 [158]	2.5/3.1/20.3/55.0	1000/12–48 (DC)	2.7/NA/NA	5890.64/5.89	Carbon fibre composite, fibreglass and epoxy bonding	NA	NA
TESUP/Magnum5/3 [159,160]	NA/2.0/19.0/50.0	6050/220 (AC)	2.35/1.55/1.41	1670.0/0.28	Composite Materials and Aluminium	35 dB	NA
Etneo/Pegasus1500/3 [161]	2.0/2.5/18.0/60.0	1800/48–220 (AC)	3.0/2.05/6.0	NA/NA	Fibreglass reinforced nylon	20 dB at 5.00 m/s	NA
Eolienne/Nheowind 3D-50/3 [162,163]	2.5/3.0/35.0/50.0	1500/135 (AC)	2.8/NA/11.0	4125.53/2.75	Fibreglass composite	35 dB at 12.00 m/s	NA
Eolienne/Nheowind 3D-100CP/3 [164]	2.5/3.0/25.0/58.33	1800/230 (AC)	3.0/NA/11.0	NA/NA	Fibreglass composite	35 dB at 12.00 m/s	NA
Eolienne/Nheowind 3D-100/3 [164,165]	2.5/3.0/36.0/50.00	3500/230 (AC)	4.0/NA/11.0	NA/NA	Fibreglass composite and epoxy	35 dB at 12.00 m/s	NA
Vornay Wind/J. Bornay Wind 13+/2 [166–168]	2.0/3.0/30.0/60.0	1500/220 (AC)	2.86/2.04/NA	3728.0/2.49	Fibreglass and carbon fibre	NA	150
Bornay Wind/J. Bornay Wind 25.2+/2 [167–169]	2.0/3.0/30.0/60.0	3500/220 (AC)	4.05/2.61/NA	7197.20/2.10	Fibreglass and carbon fibre	NA	250
Bornay Wind/J. Bornay Wind 25.3+/2 [167,168,170]	2.0/3.0/30.0/60.0	6000/220 (AC)	4.05/3.135/NA	8954.83/1.49	Fibreglass and carbon fibre	NA	550
Clean Energy Storage Inc./Energy Ball V200/5 [171–173]	2.0/3.0/20.5/40.0	2250/230 (AC)	1.98/3.524/12.0–15.0	5113.35/2.27	Fibreglass reinforced polyester	45 dB	NA
Zaphyr/Airdolphin Pro-Model Z-1000-48/3 [174–176]	2.5/3.5/50.0/65.0	2300/50 (DC)	1.8/NA/3.5–9.0	6185.81/2.69	Carbon fibre laminate over solid foam core	NA	420
Zaphyr/Airdolphin Mark-Zero Model Z-1000-24/3 [174–177]	2.5/3.5/50.0/65.0	2300/25 (DC)	1.8/NA/3.5–9.0	5574.74/2.42	Carbon fibre laminate over solid foam core	NA	420
Tumo Int Corporation LTD/Tumo-Int3000/5 [178,179]	2.0/2.5/18.0/50.0	3500/48–220 (DC)	3.0/NA/8.0	4763.49/1.36	Steel	30 dB at 5.00 m/s	NA
ItalSol/Anemos 455/5 [180]	2.0/3.0/15.0/44.44	2800/220–380 or 24–48 (AC/DC)	2.0/1.6/NA	NA/NA	Anodized aluminium	NA	NA
ItalSol/Anemos MWT522/5 [181,182]	2.0/3.0/19.0/44.44	3200/220–380 or 24–48 (AC/DC)	2.0/1.6/NA	NA/NA	Composite FE 1630PW	NA	NA

Table 5. *Cont.*

Manufacturer/Model/Number of Blades	Start-Up/Cut-In/Cut-Out/Survival Wind Speed (m/s)	Maximum Power (W)/Voltage (V)	Rotor Diameter/Turbine Length/Tower Height (m)	Capital Cost (EUR)/Specific Capital Cost (EUR/W)	Materials of Blades	Noise Level	Battery Capacity (Ah)
Tumo Int Corporation LTD/Tumo-Int1000/5 [183]	2.0/2.5/18.0/50.0	1200/24–180 (DC)	1.96/NA/3.0	1391.44/1.16	Fibreglass and nylon	20 dB at 5.00 m/s	NA
Tumo Int Corporation LTD/Tumo-Int1000/3 [184]	2.5/3.13/13.86/40.0	1100/24–48 (DC)	1.96/NA/3.0	1287.54/1.17	Fibreglass and nylon	NA	NA
Bergey Windpower/Excel-1/3 [185,186]	2.5/3.0/54.0/54.0	~1225/12–48 (DC)	2.5/2.1/2.5	9886.97/8.07	Fibreglass	NA	NA
Automaxx/SKU DB-1500/3 [187]	1.0/2.5/32.0/NA	1500/24 (DC)	1.7/NA/6.71	1332.54/0.88	Polypropylene and fibreglass	40 dB	200
Automaxx/SKU DB-1500/3 [187]	1.0/2.5/32.0/NA	1500/48 (DC)	1.7/NA/6.71	1422.74/0.95	Polypropylene and fibreglass	40 dB	200
WINDANDSOLAR/Raptor G4/5 [188]	2.24/2.68/NA/56.0	1600/12–48 (DC)	1.5/NA/NA	764.04/0.48	Carbon fibre composite	NA	NA
WINDANDSOLAR/Raptor G4/7 [189]	2.24/2.68/NA/56.0	1600/12–48 (DC)	1.55/NA/NA	797.0/0.50	Carbon fibre composite	NA	NA
WINDANDSOLAR/Raptor G4/9 [190]	2.24/2.68/NA/56.0	2000/12–48 (DC)	1.57/NA/NA	840.4/0.42	Carbon fibre composite	NA	NA
WINDANDSOLAR/Raptor G4/11 [191]	2.24/2.68/NA/56.0	2000/12–48 (DC)	1.57/NA/NA	1386.2/0.69	Carbon fibre composite	NA	NA
WINDANDSOLAR/Raptor G5/3 [192]	2.24/2.68/NA/56.0	1600/12–48 (DC)	1.78/0.84/NA	819.0/0.51	Carbon fibre composite	NA	NA
WINDANDSOLAR/Raptor G5/5 [192]	2.24/2.68/NA/56.0	1600/12–48 (DC)	1.78/0.84/NA	819.0/0.51	Carbon fibre composite	NA	NA
WINDANDSOLAR/Raptor G5/3 [192]	2.24/2.68/NA/56.0	2000/12–48 (DC)	1.78/0.84/NA	819.0/0.41	Carbon fibre composite	NA	NA
WINDANDSOLAR/Raptor G5/5 [192]	2.24/2.68/NA/56.0	2000/12–48 (DC)	1.78/0.84/NA	819.0/0.41	Carbon fibre composite	NA	NA
WINDANDSOLAR/Falcon 3/3 [193]	NA/NA/NA/42.5	1600/12–48 (DC)	1.57/1.04/NA	851.4/0.53	Aluminium	NA	NA
WINDANDSOLAR/Falcon 3/3 [193]	NA/NA/NA/42.5	2000/12–48 (DC)	2.05/1.30/NA	851.4/0.43	Aluminium	NA	NA
WINDANDSOLAR/Falcon 5/5 [194]	NA/NA/NA/42.5	1600/12–48 (DC)	1.57/1.04/NA	971.4/0.61	Aluminium	NA	NA
WINDANDSOLAR/Falcon 5/5 [194]	NA/NA/NA/42.5	2000/12–48 (DC)	2.05/1.30/NA	971.4/0.49	Aluminium	NA	NA
ATO/WT-1000M5/3 [195]	2.5/3.0/14.0/40.0	~1100/24–48 (AC)	2.4/NA/NA	979.55/0.89	Reinforced fibreglass	NA	NA
ATO/WT-1000M5/5 [195]	2.5/3.0/14.0/40.0	~1100/24–48 (AC)	2.4/NA/NA	1007.05/0.92	Reinforced fibreglass	NA	NA

Table 5. *Cont.*

Manufacturer/Model/Number of Blades	Start-Up/Cut-In/Cut-Out/Survival Wind Speed (m/s)	Maximum Power (W)/Voltage (V)	Rotor Diameter/Turbine Length/Tower Height (m)	Capital Cost (EUR)/Specific Capital Cost (EUR/W)	Materials of Blades	Noise Level	Battery Capacity (Ah)
WINDFORCE™/XUNZEL-15000-48/3 [98,196]	1.0/2.0/34.72/60.0	1500/48 (DC)	1.7/NA/8.8	5784.21/3.86	PP + Fibreglass	NA	240
ISTA BREEZE/i-1000/3 [197,198]	2.0/3.0/16.0/NA	~1150/24–48 (NA)	2.2/1.07/NA	465.0/0.40	UV-resistant Plastic + 30% glass fibres	40 dB	NA
ISTA BREEZE/i-1500 white/3 [199,200]	2.0/2.5/15.0/NA	1600/24–48 (NA)	2.2/1.07/NA	510.0/0.32	UV-resistant Plastic + 30% glass fibres	40 dB	NA
ISTA BREEZE/i-1500 carbon/3 [199,200]	2.0/2.5/15.0/NA	1600/24–48 (NA)	2.2/1.07/NA	570.0/0.36	UV-resistant Plastic + 30% glass fibres	40 dB	NA
ISTA BREEZE/i-1500 white/5 [199,200]	2.0/2.5/15.0/NA	1600/24–48 (NA)	2.2/1.07/NA	580.0/0.36	UV-resistant Plastic + 30% glass fibres	40 dB	NA
ISTA BREEZE/i-1500 carbon/5 [199,200]	2.0/2.5/15.0/NA	1600/24–48 (NA)	2.2/1.07/NA	615.0/0.38	UV-resistant Plastic + 30% glass fibres	40 dB	NA
ISTA BREEZE/i-2000 white/3 [201,202]	2.0/3.0/16.0/NA	~2050/48–350 (NA)	2.25/1.07/NA	550.0/0.27	UV-resistant Plastic + 30% glass fibres	40 dB	NA
ISTA BREEZE/i-2000 carbon/3 [201,202]	2.0/3.0/16.0/NA	~2050/48–350 (NA)	2.25/1.07/NA	610.0/0.30	UV-resistant Plastic + 30% glass fibres	40 dB	NA
ISTA BREEZE/i-2000 white/5 [201,202]	2.0/3.0/16.0/NA	~2050/48–350 (NA)	2.25/1.07/NA	620.0/0.30	UV-resistant Plastic + 30% glass fibres	40 dB	NA
ISTA BREEZE/i-2000 carbon/5 [201,202]	2.0/3.0/16.0/NA	~2050/48–350 (NA)	2.25/1.07/NA	660.0/0.32	UV-resistant Plastic + 30% glass fibres	40 dB	NA
Foshan Ouyad Electronic Co. Ltd./FD3.0-1000/3 [203,204]	2.0/3.0/25.0/35.0	1500/48 (DC)	3.0/NA/6	793.58/0.53	Fibreglass	NA	NA
Bergey Windpower/Excel-6/3 [205]	2.2/2.5/60.0/60.0	~6600/240 (AC)	6.16/4.0/24–49	42,878.90/6.50	NA	47.2 dB	NA
GALAXY GANG Energy House/GG0M6/3 [206]	1.5/3.0/25.0/45.0	~6100/24–48 (NA)	2.03/NA/6.0	1173.88/0.19	Fibreglass	NA	NA
GALAXY GANG Energy House/GG0M3/3 [207]	1.5/4.0/25.0/40.0	~3800/12–48 (NA)	1.68/NA/6.0	414.57/0.11	Nylon	NA	NA
GALAXY GANG Energy House/GG0M3/5 [207]	1.5/4.0/25.0/40.0	~3800/12–48 (NA)	1.50/NA/6.0	414.57/0.11	Nylon	NA	NA
Southwest Windpower/Whisper 500/3 [208]	2.9/3.1/20.3/55.0	3200/12–48 (DC)	4.26/NA/NA	12,941.1/4.04	Carbon fibre composite, fibreglass and epoxy bonding	NA	NA

Table 6. Main characteristics of commercially available vertical axis micro wind turbines (VAMCWTs).

Type/Manufacturer/Model/Number of Blades	Start-Up/Cut-In/Cut-Out/Survival Wind Speed (m/s)	Maximum Power (W)/Voltage (V)	Rotor Diameter/Turbine Length/Tower Height (m)	Capital Cost (EUR)/Specific Capital Cost (EUR/W)	Materials of Blades	Noise Level	Battery Capacity (Ah)
Darrieus/Makemu/EOLO 2K_PLUS_3P_110V/3 [119]	NA/NA/NA/NA	2000/12–110 (AC)	1.3/1.3/NA	1520.10/0.76	NA	40 dB	NA
Darrieus/Makemu/EOLO 2K_PLUS_6P_110V/6 [119]	2.4/NA/NA/NA	2000/12–110 (AC)	1.3/1.3/NA	1720.20/0.86	NA	40 dB	NA
Darrieus/Makemu/EOLO 3K_PLUS_3P_110V/3 [119]	NA/NA/NA/NA	3000/12–110 (AC)	1.3/1.3/NA	1730.10/0.58	NA	40 dB	NA
Darrieus/Makemu/EOLO 3K_PLUS_6P_110V/6 [119]	2.9/NA/NA/NA	3000/12–110 (AC)	1.3/1.3/NA	1930.20/0.64	NA	40 dB	NA
Savonius/KOHILO Wind/Quantum3/6 [209]	NA/1.3/12.0/56.0	3900/NA	2.32/1.07/3.1	NA/NA	NA	38 dB	NA
Hybrid/Etneo/DS1500/3 External Darrieus + 4 Internal Savonius [210]	NA/3.0/15.0/60.0	1500/48–240 (AC)	2.8/2.99/4.0	NA/NA	Anodized Aluminium	40 dB	NA
Hybrid/Etneo/DS3000/3 External Darrieus + 4 Internal Savonius [211,212]	2.0/2.2/14.0/60.0	~3100/45–280 (AC)	4.0/4.16/4.0	17,500.0/5.65	Anodized Aluminium	50 dB	NA
Savonius/FLTXNY/F-Tulips/2 [213]	1.3/2.0/25.0/52.0	1050/12–24 (DC)	0.3537/1.25/NA	NA/NA	Glass and basalt	NA	NA
Darrieus/ENESSERE Srl/Pegasus Wind Turbine/3 [214,215]	2.0/4.0/25.0/39.0	~3800/380–720 (DC)	2.67/3.76/6.0	69,000.0/18.16	Carbon fibre	38 dB	NA
Darrieus/Hipar sp.z.o.o./ECOROTE 2800/4 [216]	1.25/3.0/26.0/NA	3500/230 (AC)	2.2/3.0/9.0	10,600.20/3.03	Aluminium	46 dB at 8.0 m/s	NA
Darrieus/Hipar sp.z.o.o./ECOROTE 1500/4 [217]	1.5/3.0/25.5/NA	2000/230 (AC)	2.2/1.5/9.0	9150.20/4.58	Aluminium	46 dB at 8.0 m/s	NA
Darrieus/Solariss s.r.o./N6A/5 [218]	1.2/3.0/NA/45.0	1200/12–48 (NA)	2.0/2.2/NA	1950.0/1.63	Polyamide + 30% fibreglass	39 dB at 10.0 m/s	100
Darrieus/AEOLOS/Aeolos-V 5/3 [219–221]	1.5/2.0/14.0/52.5	~6300/220 (DC)	4.5/4.8/4.8	13,746.98/2.29	Aluminium	45.0 dB	NA
Darrieus/VWT Power/Quiet Revolution Qr5/3 [222,223]	NA/4.0/16.0/52.5	6500/NA (DC)	3.1/5.0/6.0–18.0	45,937.20/7.10	Carbon fibre	NA	NA
Darrieus/VWT Power/Quiet Revolution Qr 6/3 [224–226]	1.1/1.5/20.0/NA	7000/NA	3.13/5.1/3.0–18.0	61,549.92/8.79	Carbon fibre composite	47–54 dB with 8.0 m/s at 60–25 m distances	NA
Savonius/FLTXNY/FS-1000/2 [227]	1.5/2.0/14.0/40.0	1100/24–48 (AC)	0.67/1.5/7.0–12.0	562.31/0.51	Glass and Basalt	NA	NA
Savonius/FLTXNY/FS-2000/2 [227]	1.5/2.0/14.0/40.0	2200/48–96 (AC)	0.8/2.0/7.0–12.0	684.39/0.33	Glass and Basalt	NA	NA

Table 6. *Cont.*

Type/Manufacturer/Model/Number of Blades	Start-Up/Cut-In/Cut-Out/Survival Wind Speed (m/s)	Maximum Power (W)/Voltage (V)	Rotor Diameter/Turbine Length/Tower Height (m)	Capital Cost (EUR)/Specific Capital Cost (EUR/W)	Materials of Blades	Noise Level	Battery Capacity (Ah)
Hybrid/GALAXY GANG Energy House/GG0X5/3 Darrieus + 9 Savonius [228]	1.5/2.0/25.0/50.0	~5250/24–48 (NA)	0.70/0.95/NA	1247.71/0.24	Nylon	NA	NA
Hybrid/GALAXY GANG Energy House/GG0X3/3 Darrieus + 9 Savonius [228]	3.0/3.0/40.0/45.0	~1900/12–48 (NA)	0.52/0.75/NA	849.35/0.45	Nylon	NA	NA
Hybrid/SMARAAD/SH-3000/5 Darrieus + 9 Savonius [229]	1.0/2.0/15.0/30.0	3200/12–48 (NA)	0.95/1.3/NA	841.79/0.26	Aluminium alloy	NA	NA
Hybrid/SMARAAD/SH-4000/5 Darrieus + 9 Savonius [229]	1.0/2.0/15.0/30.0	4500/12–48 (NA)	0.95/1.4/NA	997.68/0.22	Aluminium alloy	NA	NA
Savonius/Flower Turbines/Large Tulip Wind Turbine (On-Grid)/2 Savonius [155,230]	NA/0.7/12.0/54.0	5390/230–240 (AC)	2.40/5.0/1.0	29,794.13/5.53	Thermoplastic	NA	NA
Savonius/Flower Turbines/Large Tulip Wind Turbine (Off-Grid)/2 Savonius [155,231]	NA/0.7/12.0/54.0	5390/230–240 (AC)	2.40/5.0/1.0	25,608.61/4.75	Thermoplastic	NA	NA

Table 7. Main characteristics of commercially available horizontal axis mini wind turbines (HAMNWTs).

Manufacturer/Model/Number of Blades	Start-Up/Cut-In/Cut-Out/Survival Wind Speed (m/s)	Maximum Power (W)/Voltage (V)	Rotor Diameter/Turbine Length/Tower Height (m)	Capital Cost (EUR)/Specific Capital Cost (EUR/W)	Materials of Blades	Noise Level	Battery Capacity (Ah)
Qingdao Anhua New Energy Equipment Co./Horizontal Axis Wind Turbine with Maglev Generator/3 [232]	2.5/3.0/30.0/60.0	11,000/240–500 (AC)	7.6/NA/12.0	NA/NA	Fibreglass reinforced	65 dB	NA
Bergey Windpower/Excel 10/3 [233,234]	2.24/3.4/59.9/59.9	12,600/220–240 (AC)	7.01/NA/18.0–49.0	29,770.08/2.36	NA	42.9 dB	NA
Bergey Windpower/Excel 15/3 [234,235]	3.13/4.47/59.9/59.9	21,800/230–240 (AC)	9.6/5.21/18.0–49.0	35,139.38/1.60	Carbon fibre	48.5 dB	NA
Ryse Energy/E-10/3 [236,237]	NA/2.0/30.0/70.0	20,000/NA	9.8/NA/15.0–36.0	69,707.41/3.49	Fibreglass	33, 40, 46 dB at 180, 100, 46 m distances	NA
GEATECNO/Gaia-Wind 133-11kW/2 [238,239]	2.5/3.5/10.0/25.0	12,000/400 (NA)	13.0/NA/NA	35,946.90/3.00	NA	20, 40, 60 dB at 100, 60, 30 m distances	NA
InkPV or OEM/FD-30000/3 [240]	3.0/NA/30.0/60.0	33,000/220–380 (DC)	12.0/NA/NA	43,775.18/1.33	Fibreglass	55 dB	NA

Table 8. Main characteristics of commercially available vertical axis Mini wind turbines (VAMNWTs).

Savonius-Darrieus-Hybrid/Manufacturer/Model/Number of Blades	Start-Up/Cut-In/Cut-Out/Survival Wind Speed (m/s)	Maximum Power (W)/Voltage (V)	Rotor Diameter/Turbine Length/Tower Height (m)	Capital Cost (EUR)/Specific Capital Cost (EUR/W)	Materials of Blades	Noise Level	Battery Capacity (Ah)
Darrieus/SISHUINIANHUA/Ruxmy/5 [241]	2.0/NA/NA/45.0	NA/12–24 (NA)	0.90/0.6/NA	568.05/NA	Nylon fibre	NA	NA
Savonius/NA/Wangyongqi/2 [242]	1.5/3.0/NA/40.0	9100/12–220 (AC)	0.47/1.08/7.0–12.0	274.77/0.03	Resin Glass and Basalt	NA	NA
Darrieus/SMJY/SMJY/3 [243]	1.3/2.3/NA/40.0	NA/12–220 (NA)	0.6/0.75/7.0–12.0	2051.0/NA	Fibreglass	NA	NA
Darrieus/Hipar sp.z.o.o./ECOROTE 9800/4 [244]	1.2/3.0/25.5/NA	12,000/230 (AC)	4.3/5.6/9.0	28,588.40/2.38	Aluminium	46 dB at 8.0 m/s	NA
Hybrid/FlexPro/EOL-V/5 External Darrieus + 4 Internal Savonius [245]	3.0/NA/NA/50.0	12,000/380 (NA)	4.5/NA/12.0	21,800.0/1.82	Glass Fibre Reinforced Polymer	NA	NA
Darrieus/Ecolibri Srl/EW01/3 [246]	3.5/5.0/15.0/NA	14,000/380 (NA)	5.7/6.0/10.0	10,000.0/0.71	Composite	NA	NA
Darrieus/AEOLOS/Aeolos-V10/3 [247,248]	1.5/2.5/40.0/52.5	12,000/300–380 (NA)	4.5/4.8/NA	19,057.97/1.59	Aluminium	45 dB	NA
Darrieus/SunSurfs/WT3-10/3 [249]	1.8/NA/8.0/28.0	10,700/360–400 (AC)	9.0/NA/12.0	27,335.54/2.56	NA	63 dB	NA
Darrieus/SunSurfs/WT3-20/3 [250]	1.8/NA/9.0/28.0	21,400/360–400 (AC)	11.0/12.0/12.0	59,600.22/2.79	NA	63 dB	NA
Darrieus/SunSurfs/WT3-30/3 [251]	1.8/2.9/9.0/28.0	32,100/400 (AC)	12.0/12.0/12.0	87,108.01/2.71	NA	65 dB at 5.0 m/s with 10 m distance	NA
Savonius/WINDSIDE/WS-12/2 [252–254]	2.0/2.5/40.0/60.0	25,000/12–48 (DC)	2.0/8.0/10	NA/NA	Aluminium	2–5 dB with 2 m distance	NA
Savonius/TESUP/Hera Wind Pro/2 [104,255]	1.0/2.0/15.0/50.0	7032/220 (NA)	0.40/1.12/NA	1380.0/0.20	Aluminium	35 dB	NA
Savonius/TESUP/Atlas 7/2 [104,256]	1.5/2.0/17.0/50.0	7032/220 (NA)	1.20/1.126/NA	1460.0/0.21	Aluminium	30 dB	NA
Savonius/TESUP/Atlas X7/3–12 [104,257]	1.0/2.0/19.0/50.0	7032/220 (NA)	0.46/1.126/NA	1380.0/0.20	Aluminium	30 dB	NA

4. Analysis of Main Characteristics of Commercial Small-Scale Wind Turbines

Figure 2a–f report the minimum, maximum, average and standard deviation data calculated with reference to the values of the start-up wind speed, the cut-in wind speed, the cut-out wind speed, the survival wind speed, the maximum electric output, the rotor diameter, the turbine length and the specific capital cost derived from Tables 3–8 (in the cases when a parameter is not defined in Tables 3–8, it has been excluded from the calculation). In particular, Figure 2a refers to HAPWTs, Figure 2b corresponds to VAPWTs, Figure 2c is for HAMCWTs, Figure 2d refers to VAMCWTs, Figure 2e corresponds to HAMNWTs and Figure 2f is for VAMNWTs.

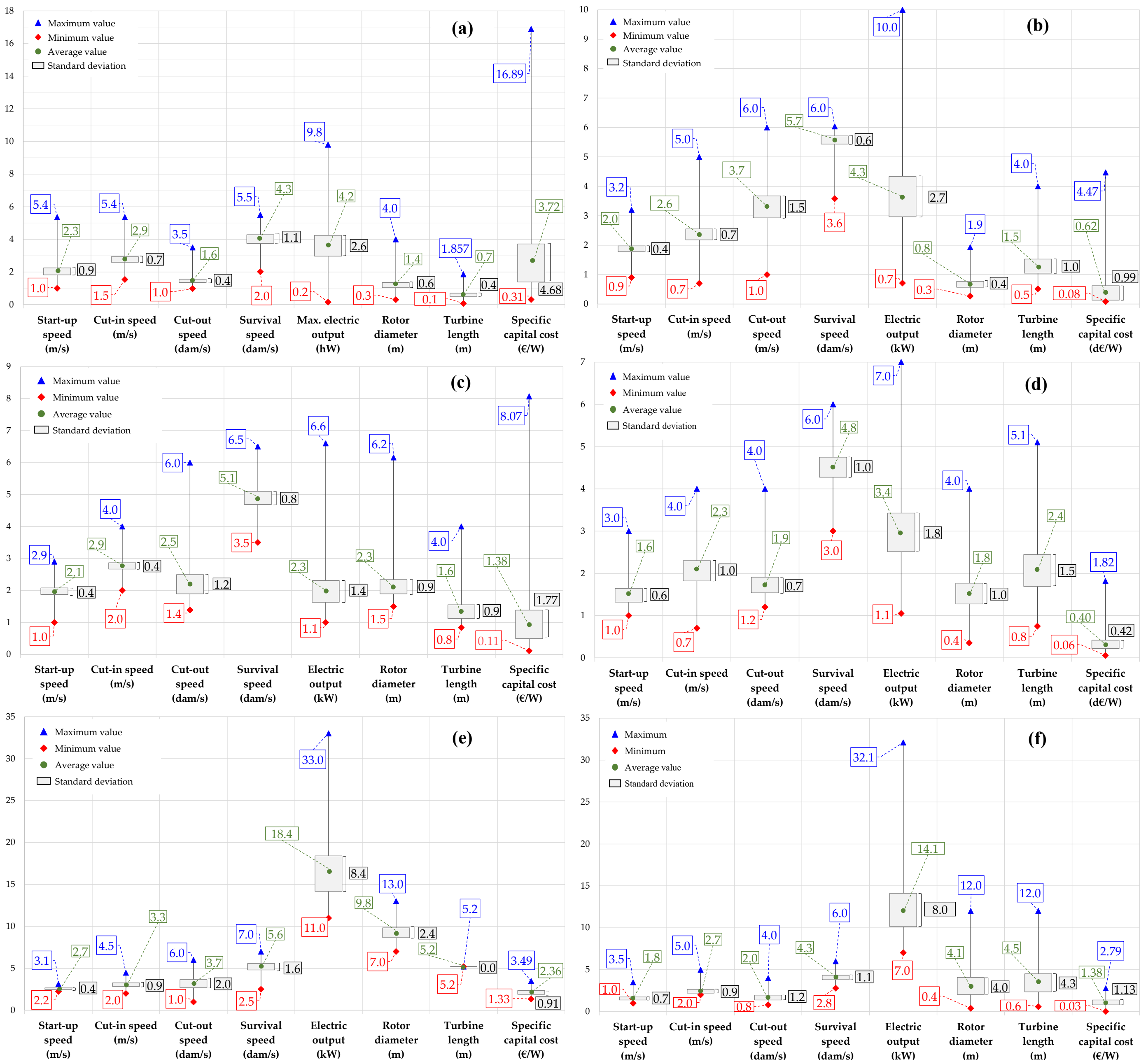

Figure 2. Summary of performance and geometry of SWTs selected in this paper: HAPWTs (**a**), VAPWTs (**b**), HAMCWTs (**c**), VAMCWTs (**d**), HAMNWTs (**e**), and VAMNWTs (**f**).

According to Tables 3–8 and Figure 2a–f, the cut-in wind speed ranges from a minimum of 0.7 m/s (in the cases of VAPWTs and VAMCWTs) up to a maximum of 5.4 m/s (in the case of HAPWTs), while the specific capital cost is between 0.03 EUR/W (for VAMNWTs) and 44.7 EUR/W (for HAPWTs).

Figure 3a–f indicates the blades' material as reported in Tables 3–8. In particular, Figure 3a refers to HAPWTs, Figure 3b corresponds to VAPWTs, Figure 3c is for HAMCWTs, Figure 3d refers to VAMCWTs, Figure 3e corresponds to HAMNWTs and Figure 3f is for VAMNWTs.

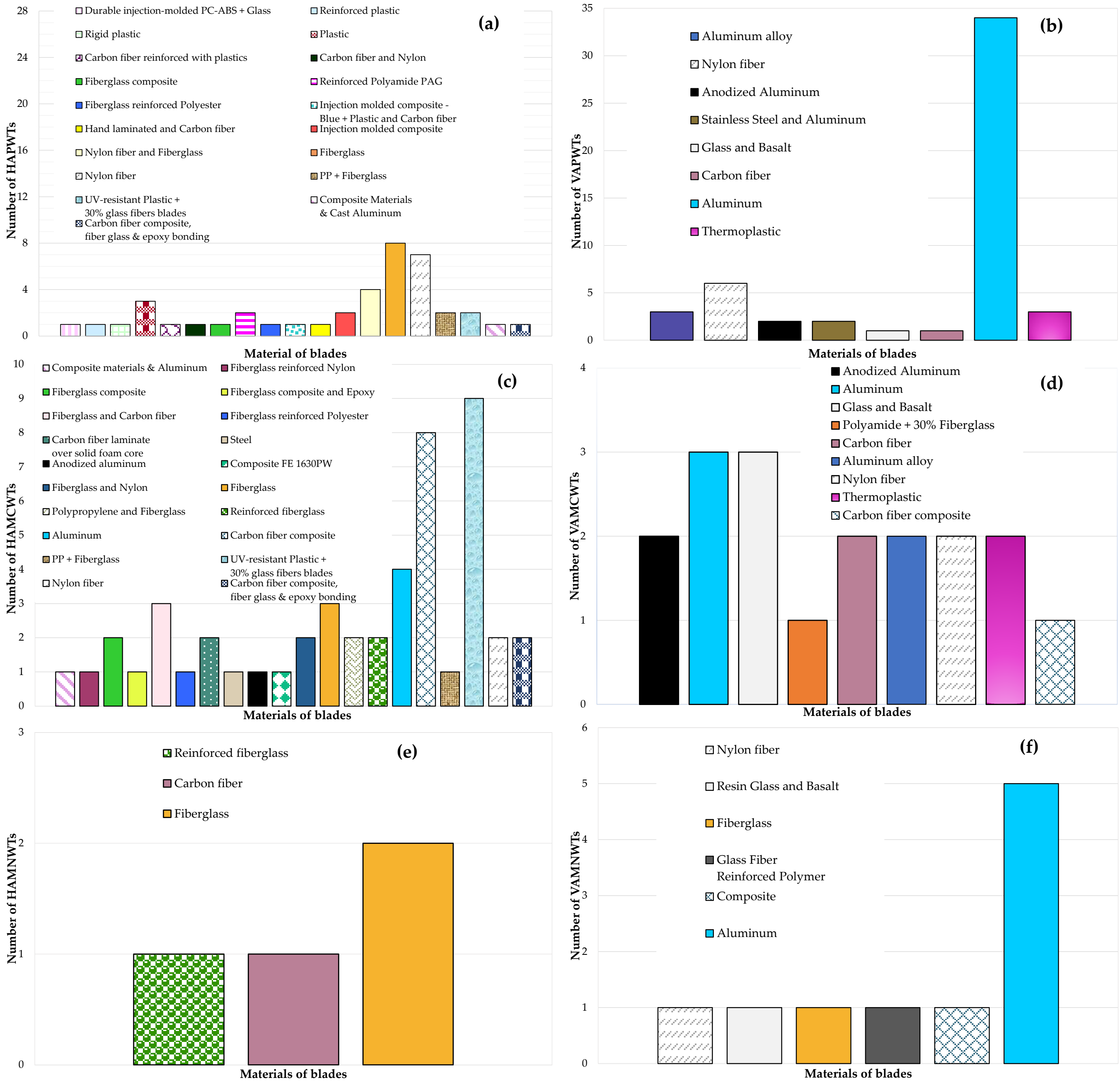

Figure 3. Summary of blades material of SWTs selected in this paper: HAPWTs (**a**), VAPWTs (**b**), HAMCWTs (**c**), VAMCWTs (**d**), HAMNWTs (**e**), and VAMNWTs (**f**).

As reported in Table 3 and Figure 3a, it can be highlighted that fibreglass is the most used material for blade manufacturing, corresponding to 8 out of 47 HAPWTs.

According to Table 4 and Figure 3b, Aluminium is the most used material for blade manufacturing, corresponding to 34 out of 67 VAPWTs.

Table 5 and Figure 3c underline that the combination of UV-resistant plastic with 30% glass fibres is the most used material for blade manufacturing, corresponding to 9 out of 50 HAMCWTs.

Table 6 and Figure 3d indicate that aluminium and the combination of glass with basalt are the most used materials for blade manufacturing, both corresponding to 3 out of 23 VAMCWTs.

According to Table 7 and Figure 3e, fibreglass is the most used material for blade manufacturing, corresponding to two out of six HAMNWTs.

According to Table 8 and Figure 3f, aluminium is the most used material for blade manufacturing, corresponding to 5 out of 14 VAMNWTs.

Tables 3 and 4 also show that:

- In total, 47 out of 114 PWTs models (41.23% of total) are characterized by a horizontal axis;
- In total, 23 HAPWTs (48.94% of total) use direct current (DC), 16 HAPWTs (34.04% of total) use alternating current (AC), and 5 HAPWTs (10.64% of total) can be supplied by both direct current or alternating current;
- HAPWTs have a tower height range of 0.814–13.7 m;
- HAPWTs are characterized by a noise level between 28 dB and 65 dB;
- HAPWTs can have a battery capacity ranging from 0.012 and 480 Ah;
- In total, 41 out of 67 VAPWTs models (61.19% of total) are characterized by Savonius rotors, 21 (31.34% of total) are characterized by Darrieus rotors and 5 (7.47% of total) present a hybrid rotor configuration;
- In total, 39 VAPWTs (58.21% of total) use direct current (DC) and 24 VAPWTs (35.82% of total) use alternating current (AC);
- VAPWTs have a tower height range of 0.91–12.0 m;
- VAPWTs are characterized by a noise level between 2 dB and 50 dB;
- VAPWTs can have a battery capacity ranging between 100 and 200 Ah.

Tables 5 and 6 also highlight that:

- In total, 50 out of 73 MCWTs models (68.49% of total) are characterized by a horizontal axis;
- In total, 24 HAMCWTs (48% of total) use direct current (DC), 12 HAMCWTs (24% of total) use alternating current (AC), and 2 HAMCWTs (4% of total) can be supplied by both direct current or alternating current;
- HAMCWTs have a tower height range of 1.41–49.0 m;
- HAMCWTs are characterized by a noise level between 20 dB and 47.2 dB;
- HAMCWTs can have a battery capacity ranging from 150 to 550 Ah;
- In total, 6 out of 23 VAMCWTs (26.09% of total) are characterized by Savonius rotors, 11 (47.82% of total) are characterized by Darrieus rotors and 6 (26.09% of total) present a hybrid rotor configuration;
- In total, 5 VAMCWTs (21.74% of total) use direct current (DC) and 12 VAMCWTs (52.17% of total) use alternating current;
- VAMCWTs have a tower height range of 1.0–18.0 m;
- VAMCWTs are characterized by a noise level ranging from 38 to 54 dB.

Tables 7 and 8 also show that:

- In total, 6 out of 20 MNWTs (30% of total) are characterized by a horizontal axis;
- One HAMNWTs (16.67% of total) uses direct current (DC), and three HAMNWTs (50% of total) use alternating current;
- HAMNWTs have a tower height range of 12.00–49.00 m;
- HAMNWTs have a noise level ranging from 20 dB to 65 dB;
- In total, 5 out of 14 VAMCWTs (35.71% of total) are characterized by Savonius rotors, 8 (57.14% of total) are characterized by Darrieus rotors and 1 (7.15% of total) presents a hybrid rotor configuration;
- One VAMNWT (7.15% of total) uses direct current (DC), while five VAMNWTs (35.71% of total) use alternating current;

- VAMNWTs have a tower height range of 3.0–18.0 m.

5. Scientific Experimental Studies of Commercial SWTs

Some scientific works investigated the performance of commercially available SWTs in urban areas from an experimental point of view. In this paper, a comprehensive keyword search has been firstly performed on several sources (scientific journal articles, conference papers, scientific books and reports, review studies, etc.); secondly, the relevant articles have been selected and reviewed based on their relevance to the topic of study. In particular, 10 papers [27,28,258–265] focusing on this topic have been found by the authors in the ScienceDirect database [261]. This section describes the above-mentioned papers in order to detail the following aspects:

- The experimentally analysed SWT model;
- The experimental test apparatus and procedure;
- The sensors and related accuracy;
- The experimental results.

Table 9 describes the principal characteristics of the SWTs investigated in the selected 10 scientific papers. In particular, this table reports the type (horizontal or vertical), manufacturer, model, number of blades, start-up, cut-in, cut-out, survival wind speed, maximum power, voltage, rotor diameter, turbine length, tower height, capital cost, specific capital cost, materials of blades, noise level, and battery capacity of the SWTs experimentally investigated in [27,28,258–265]. The papers of Elshazly et al. [263] and Castelli et al. [28] analysed two different SWTs.

This table indicates that only 10 scientific papers experimentally investigated the performance of small-scale wind turbines available on the market (despite the wide range of choices), highlighting that further researches have to be performed with reference to such systems to take this technology one step further; in particular, only two scientific experimental studies have been devoted to vertical axis SWTs, underlining that such kind of wind turbine strongly requires additional attention in the future. In addition, it should be highlighted that the study of Pellegrini et al. [259], Castelli and Benini [28] and Lo Brano et al. [265] have been performed through on-site data acquisition, while the others have been carried out by means of a closed wind tunnel system; therefore, additional field performance analyses should be considered taking into account the local wind resource (which is highly site-specific), the presence of buildings and surrounding trees, the way the building envelope interacts with the direction of the wind and the intensity of the turbulence the turbine encounters, etc.

Table 9. Main characteristics of the SWTs experimentally analysed in [27,28,258–265].

References	Typology/Manufacturer/Model/Number of Blades	Start-Up/Cut-In/Cut-Out/Survival Wind Speed (m/s)	Maximum Power (W)/Voltage (V)	Rotor Diameter/Turbine Length/Tower Height (m)	Capital Cost (EUR)/Specific Capital Cost (EUR/W)	Materials of Blades	Noise Level	Battery Capacity (Ah)
[258]	Horizontal/ItalSol/Anemos 455/5 [180]	2.0/3.0/15.0/44.44	2800/220–380 or 24–48 (AC/DC)	2.0/1.6/NA	NA/NA	Anodized aluminium	NA	NA
[259]	Horizontal/Zaphyr/Airdolphin Mark-Zero Model Z-1000-24/3 [174–177]	2.5/3.5/50.0/65.0	2300/25 (DC)	1.8/NA/3.5–9.0	5574.74/2.42	Carbon fibre laminate over solid foam core	NA	420
[266]	Horizontal/Bergey Windpower/Excel-1/3 [185,186]	2.5/3.0/54.0/54.0	~1225/12–48 (DC)	2.5/2.1/2.5	9886.97/8.07	Fibreglass	NA	NA
[261]	Horizontal/Foshan Ouyad Electronic Co. Ltd./FD3.0-1000/3 [203,204]	2.0/3.0/25.0/35.0	1500/48 (DC)	3.0/NA/6	793.58/0.53	Fibreglass	NA	NA
[262]	Horizontal/Primus Windpower/SilentWind Air X Marine—blue carbon fibre Blades/3 [85]	3.59/NA/15.65/49.2	450/12–48 (DC)	1.17/0.675/7.6–13.7	1903.30/4.23	Hand laminated and carbon fibre	NA	NA
[263]	Horizontal/Clean Energy Storage Inc./Energy Ball V100/6 [82–84]	2.0/3.0/22.0/40.0	525/230 (DC)	1.1/1.857/8.9–10.9	1607.0/3.06	Fibreglass reinforced polyester	NA	NA
[263]	Horizontal/Clean Energy Storage Inc./Energy Ball V200/5 [171–173]	2.0/3.0/20.5/40.0	2250/230 (AC)	1.98/3.524/12.0–15.0	5113.35/2.27	Fibreglass reinforced polyester	45 dB	NA
[27]	Horizontal/WINDFORCE™/XUNZEL-6000/3 [97,98]	1.0/2.0/NA/50.0	600/12–24 (DC)	1.31/0.85/8.8	1307.90/2.18	PP + Fibreglass	NA	240–480
[28]	Vertical (Darrieus)/VWT Power/Quiet Revolution/Qr5/3 [222,223]	NA/4.0/16.0/52.5	6500/NA (DC)	3.1/5.0/6.0–18.0	45,937.20/7.10	Carbon fibre	NA	NA
[28]	Vertical (Savonius)/WINDSIDE/WS-12/2 [252–254]	2.0/2.5/40.0/60.0	25,000/12–48 (DC)	2.0/8.0/10	NA/NA	Aluminium	0.3–5 dB	NA
[264]	Horizontal/Bergey Windpower/Excel-6/3 [205]	2.2/2.5/60.0/60.0	~6600/240 (AC)	6.16/4.0/24–49	42,878.90/6.50	NA	47.2 dB	NA
[265]	Horizontal/Southwest Windpower/Whisper 200/3 [158]	2.5/3.1/20.3/55.0	1000/12–48 (DC)	2.7/NA/NA	5890.64/5.89	Carbon fibre composite, fibreglass and epoxy bonding	NA	NA

5.1. Experimental Study by Eltayesh et al. [258]

The study by Eltayesh et al. [258] analyses the effects of blade number on the performance of a small-scale horizontal-axis micro wind turbine; in particular, the model "Anemos 455" manufactured by the company ItalSol (Arezzo, Italy) [180] is analysed. This study is performed in the Department of Engineering of the University of Perugia (Italy) via an experimental set-up basically consisting of a closed-circuit wind tunnel with a cross-section of 5.7 m × 3.4 m and a maximum achievable air velocity of 47.0 m/s at the test section inlet. Velocity and pressure at the test section inlet are recorded by using two Pitot tubes and a cup anemometer with a maximum error equal to 0.8% of reading.

The experiments are performed by considering three, five and six blades (where five is the number of blades of the commercial version of the wind turbine). The turbine blades have a constant pitch angle and are linked to the hub. The analyses have been carried out at different inlet wind velocities of 6.0, 7.0, and 8.0 m/s to determine the corresponding tip speed ratio (TSR). The power coefficient C_p and the thrust coefficient C_T are derived from the recorded data by means of the following equations:

$$C_p = \frac{V \cdot I}{0.5 \cdot \rho \cdot \pi \cdot R^2 \cdot v^3} \tag{3}$$

$$C_T = \frac{T}{0.5 \cdot \rho \cdot \pi \cdot R^2 \cdot v^3} \tag{4}$$

In the previous equations, I represents the current intensity, V denotes the voltage, v signifies the wind velocity in the wind tunnel, ρ stands for the density of air, T represents the thrust force, and R indicates the radius of the rotor. Current intensity is quantified using current transducers (specifically model MCR-S-1-5 [267]), featuring a maximum error of 2% of the reading. Voltage is acquired through a voltage transducer (model LV 25-P/Sp5 [268]), characterized by an accuracy of 2.0% of the reading. The wind turbine incorporates a three-dimensional load cell (Futek model MAT400 [269]) for a precise measurement of T, with an accuracy of 0.353% of the reading. Furthermore, the turbine's rotational speed is monitored and measured via an optical sensor (model XUB5APBNL2 [270]).

Experimental data indicate that the optimal power coefficient for the three-blade wind turbine surpasses that of configurations employing other numbers of blades, occurring at a tip speed ratio of six, whatever the inlet velocity is. For configurations utilizing five and six blades, the maximum C_T is achieved at a TSR of 3.3, while the highest C_T for the three-blade configuration occurs at TSR = 4. Moreover, the experiments reveal a notable enhancement in C_P when employing three blades compared to five blades. In summary, this investigation emphasizes that (i) higher turbine solidity results in a lower cut-in wind speed, rendering high-solidity turbines suitable for operation in low wind speed conditions, and (ii) an increase in the blade number leads to greater torque but also higher friction losses.

5.2. Experimental Study by Pellegrini et al. [259]

The study by Pellegrini et al. [259] focuses on an extensive analysis (more than 12 months) of a horizontal axis micro wind turbine (model "Airdolphin Mark-Zero Pro" produced by the company Zephyr Corporation (Tokyo, Japan) [174–177]) operated at the outside development centre HEnergia of HERA S.p.A. in Forlì (Italy).

To reduce the effect of barriers, the wind turbine is installed 6 m above the ground. AC voltage and current together with AC power produced are measured; in addition, wind speed and wind direction, solar global irradiation, ambient temperature and humidity, are monitored through a local meteorological station. The measurements of wind velocity are carried out with an accuracy equal to 0.1 m/s or ±1% of reading, while wind direction is evaluated with an accuracy equal to 1% of the measurement range (0–360°).

A total electric energy generation equal to 13.68 kWh is measured with reference to an operating period of 249 h; the measured energy is 29.4 Wh, 6655.0 Wh, 4937.7 Wh and 2194.8 Wh with reference to the wind speed ranges 2.5–3 m/s, 3–4 m/s, 4–5 m/s, and

5–6 m/s, respectively. The highest measured daily electrical energy generation (equal to 1.17 kWh/day, i.e., 8.55% of the total) is obtained on April 1st characterized by a total number of working hours equal to 10.8 h/day, with a mean wind velocity equal to 2.89 m/s and a maximum wind velocity of 15.8 m/s. The authors indicate that, according to the experimental results, the investigated wind turbine is not suitable from an economic point of view in the considered installation site due to the very low annual average wind speed.

5.3. Experimental Study by Kanya and Visser [260]

In the study by Kanya and Visser [260], the performances of a commercially available horizontal axis micro wind turbine (model "Excel-1" manufactured by the company Bergey Windpower (Norman, OK, USA) [185,186]) are measured and compared with a prototype rotor under both ducted and open configurations.

The duct is composed of StyroSpray polymer-coated EPS foam [266]. The duct's 3.3 m exit diameter results in a 1.74 ratio between the rotor and exit areas; the duct length's ratio to the rotor diameter and exit areas is 0.25 and 0.19, respectively. A 1800 W radial flux permanent magnet generator (type GL-PMG-1800, manufactured by the company Ningbo Ginlong Technologies Co., Ltd. (Ningbo, China) [271]) is connected to the rotor. The flow field is generated by a bank of 6–100 hp fans with independent variable speed control. Wind velocity is measured with a single-location sonic anemometer. The prototype rotor is initially tested without a duct in an open rotor configuration; once enough data are collected, the duct is attached to the rotor and the tests are repeated. Then, the duct is removed, and the tests are conducted again in an open prototype rotor configuration. Wind velocity in the tunnel is adjusted in steps of 1 m/s until the generator's maximum rated power output of 1800 W is marginally exceeded.

At 9 m/s, for instance, the model "Excel-1" manufactured by the company Bergey Windpower (Norman, OK, USA) [185,186] generates about 700 W; the open rotor configuration provides about 925 W, while the prototype rotor output increases to about 1880 W with the duct installed. The power coefficient of the open prototype rotor configuration remains fairly constant at 0.4 for wind speeds in the range 5–9 m/s, while the ducted configuration of the prototype rotor generates a power coefficient in the range 0.49–0.52 in the case of the same wind speeds, better than the open rotor configuration. The model "Excel-1" manufactured by the company Bergey Windpower (Norman, OK, USA) [185,186] reaches a maximum power coefficient of about 0.37 at 7 m/s.

5.4. Experimental Study by Hasan et al. [261]

The study by Hasan et al. [261] experimentally evaluates in a laboratory the performance of a commercial micro horizontal axis wind turbine (model "FD3.0-1000" manufactured by the company Foshan Ouyad Electronic Co., Ltd. (Foshan, China) [203,204]) at wind velocities of 4, 5, and 6 m/s.

Nine centrifugal shutter exhaust fans (model DJF-1380 [272]) are employed in the testing; each fan is controlled independently by a control panel, allowing the wind field pattern to be simulated. A generator with a 1 kW permanent magnet synchronization is directly connected to the turbine. On a grid mesh made up of 81 cells, a five-hole probe (AP4K USB system type [273]) with a maximum flow velocity of up to 30 m/s and accuracy ±0.8% of reading is placed. Measurements of voltage and current have an accuracy of ±1% of the reading.

At wind velocities of 4, 5, and 6 m/s, the power coefficient of the investigated wind turbine is 0.253, 0.258, and 0.2588, respectively, at tip speed ratios ranging from 5 to 6; at wind velocities of 4, 5, and 6 m/s, the power output is, respectively, in the ranges 65–89 W, 115–163.9 W and 190–306 W.

5.5. Experimental Study by Singh and Ahmed [262]

This study presents the performance of a horizontal axis pico wind turbine (model "SilentWind Air X Marine" manufactured by the company Primus Windpower (Lakewood, CO, USA) [85]) characterized by a rotor diameter of 1.16 m with three blades. A novel airfoil is also designed, and the operation of a two-bladed rotor with a diameter of 1.26 m is tested in the wind speed range 3–6 m/s. The pitch of the blades is varied by considering three angles equal to 15°, 18° and 20°. The turbines are mounted on a pole with a height of 8.22 m in an open field in front of the ocean at the University of the South Pacific's marine campus.

Data logging is facilitated by a CR1000 Campbell Scientific data logger (Logan, UT, USA) [274], which records average current, voltage and wind speed values at 10 s intervals with a measurement frequency rate of 1 s. Wind speed measurements are conducted using a three-cup A101M anemometer from Vector Instruments [275] capable of measuring wind speeds up to 75 m/s with a resolution equal to 0.1 m/s. A mean temperature equal to 25 °C is also measured.

Comparisons between the power generation of the two-bladed and three-bladed rotors are made possible because of their comparable diameter sizes (1.26 m vs. 1.16 m), rotor solidities (8.27% vs. 8.24%), and suitability for applications characterized by reduced wind speeds. Thanks to its 8.62% longer blades, the two-bladed rotor consistently outperforms the three-bladed rotor in power production, regardless of pitch angle. Furthermore, at any given wind speed, the three-bladed rotor achieves maximum power output at a pitch angle of 18°. However, at this optimal pitch angle, the two-bladed rotor generates more than twice the power of its three-bladed counterpart. The power output of the three-bladed rotor is equal to the one corresponding to the two-bladed rotor only for a pitch angle of 15° up to a wind speed of 4 m/s. The two-bladed rotor begins generating power at cut-in wind speeds of 2.98, 2.34 and 2.38 m/s in the case of pitch angles equal to 15°, 18° and 20°, respectively, while a cut-in wind speed of 3.58 m/s is found in case of the three-bladed rotor. The two-bladed rotor achieves a power coefficient of 0.l, 0.217 and 0.255 at wind speeds of 4, 5 and 6 m/s, respectively, whereas the three-bladed rotor achieves a power coefficient equal to 0.052, 0.112 and 0.15, respectively, at the same wind speeds.

5.6. Experimental Study by Elshazly et al. [263]

The study by E. Elshazly et al. [263] is conducted on the horizontal axis wind turbine named "Energy Ball Wind Turbine" (EBWT). The Home Energy company (Hoofddorp, The Netherlands) [171] developed two versions of this wind turbine: version V100 [82–84] (a pico wind turbine) and version V200 [171–173] (a micro wind turbine). The EBWT V100 wind turbine [82–84] and the EBWT V200 wind turbine [171–173] dimensions are scaled down 1:4, realizing the EBWT V50 wind turbine prototype and the EBWT V25 wind turbine prototype, respectively. Experiments are performed with reference to the EBWT V25 wind turbine prototype.

A small blow-down type wind tunnel, equipped with a fan to change the wind speed, is used to perform the tests. The test section is 2.9 m long and characterized by an inlet diameter of 0.75 m as well as an outlet diameter of 0.50 m. The air velocity is controlled by using a variable resistance switch. The experiments are carried out at different wind speeds (3, 4, 5, 6, and 7 m/s). A high-resolution anemometer located at the wind tunnel's exit around the rotor and a portable anemometer are used to measure wind speed. Both contact and non-contact digital laser tachometers are used to measure the rotor's rotating speed. Six and three-bladed turbines are taken into consideration for each of the three hub angles (20°, 25°, and 30°) that are examined.

The 20° hub angle shows the best performance, while the 30° hub angle is characterized by the lowest power coefficient. The largest power coefficient for the configuration with a 20° twist angle is 0.14. The experimental tests indicate that in the cases of 25° and 30° hub angles, the rotation starts at 6 m/s, while in the case of the 20° hub angle, the rotation starts at 5 m/s. At 7 m/s, the power coefficient of the six-bladed EBWT V25 wind turbine is better than the one corresponding to the three-bladed version. The measured data confirm that the two most important factors to increase the wind turbine efficiency are the number of blades and the blade's twist angle.

5.7. Experimental Study by Lee et al. [27]

The study by Lee et al. [27] investigates and compares the aerodynamic performance of two types of blades, namely the BEMT-blade designed according to the blade element momentum theory (BEMT) and the baseline-blade, a non-twisted and non-tapered type with constant chord length. The horizontal axis pico wind turbine tested in the experiments is the model "XUNZEL-6000" manufactured by the company WINDFORCE™ (Mendaro, Spain) [97,98] (even if the authors do not exactly specify the wind turbine model). The SD8000 airfoil is selected for the turbine blade due to its exceptional lift-to-drag ratio and its capability to achieve higher power coefficients.

Full-scale rotor blade testing is conducted in the wind tunnel at the Architecture and Building Research Institute (ABRI), featuring a test section measuring 36.5 m (length) × 4 m (width) × 2.6 m (height). With two test sections and a closed-circuit design, the ABRI wind tunnel can attain a maximum wind speed of 36.5 m/s. Turbulence intensity stays below 0.35%, while the average flow uniformity is kept lower than 0.37%. Pitot tubes are used to determine wind speed in the free flow at the test section, and pressure transducers are used to calibrate the results. A torque sensor is used to detect mechanical power as a function of rotational speed through the connection of rotor blades.

The DC electronic load module (DCELM), which has three modes (constant-voltage, constant-current, and constant-resistance) is used to mimic different circuit loads; the DCELM modifies the applied loads during generator operation to keep each mode's current, voltage, or resistance constant. In order to stabilize the resulting torque and rotational speed, the constant-voltage mode is used during the experiments. At 8 and 10 wind speeds, the wind tunnel produces tip speed ratios that vary from zero to eight for various rotational velocities.

Results indicate that the BEMT-blade rotor exhibits significantly larger power coefficients compared to the baseline-blade rotor at equivalent wind velocities. Specifically, at 10 m/s, the BEMT-blade rotor achieves the highest power coefficient of 0.469 at a tip speed ratio of 5.61. Additionally, the BEMT-blade rotor exhibits a wider variety of tip speed ratios, which results in greater power coefficients in the range between four and eight; because of the high angles of attack at the blade roots, the related power coefficients are quite low for tip speed ratios less than 3.5. The baseline-blade rotor achieves its largest power coefficient of about 0.3 for a tip speed ratio equal to 5.08; for the baseline-blade rotor, the power coefficient approaches zero when the tip speed ratio is below 2.5.

5.8. Experimental Study of Castelli and Benini [28]

The study of Castelli and Benini [28] describes the performance of the commercial vertical axis small-scale wind turbine model "Qr5" manufactured by the company Quiet Revolution (St.Ives, Cambridgeshire, UK) [222,223] (which is a lift-driven Darrieus-type turbine).

Anemometric measurements are performed in Hortis Square, in the historical centre of Trieste (Italy), where the wind energy potential is quite poor, with the yearly average wind speed equal to about 3.2 m/s; measurements are made at a different site (even if relatively close) with respect to the installation site of the wind turbine as well as without taking into account how the turbine interacts with the building and its surroundings; then, the annual electric energy generation of the wind turbine is evaluated according to the measured wind speeds as well as the performance curves suggested by the corresponding manufacturer.

The "Qr5" turbine produces most of the annual electric energy in the case of high wind speeds (with maximum electric energy generation at about 11.5 m/s). In more detail, its estimated annual electric energy production is equal to 1458 kWh for the "Qr5".

5.9. Experimental Study by Moussa [264]

The study by Moussa [264] uses outdoor experimental measurements on the horizontal axis micro wind turbine model "Excel-6" manufactured by the company Bergey Windpower (Norman, OK, USA) [205] (even if the author does not precisely specify the wind turbine model) to determine its power coefficient.

The wind turbine's voltage and current are monitored, and the associated electrical output is calculated. Concurrently, wind speed is measured by means of a weather station that is situated at the same altitude as the rotor. The power coefficient is estimated by using an experimental setup that includes batteries, a human–machine interface, a power inverter, an inverter load controller, a frequency regulator, a current rectifier, and a number of components for dissipation of power. A meteorological receiver and a wattmeter (Fluke 345 PQ CLAMP METER1 2000A (Washington, DC, USA) [276]) are two examples of sensors used to detect wind physics (speed intensity and direction) as well as the quantity of power generated.

Moussa [264] reports that wind power is governed by a cubic law in relation to wind speed. Furthermore, it is noted that the percentage of power dissipated through cables and electrical inverters appears to be insensitive to both wind speed and turbine rotation speeds. Additionally, experimental values of the power coefficient and tip speed ratio exhibit a relationship that can be modelled by a fourth-degree polynomial function. Finally, a maximum power coefficient of about 0.24 for a tip speed ratio of about 5.4 is experimentally found.

5.10. Experimental Study by Lo Brano et al. [265]

Lo Brano et al. [265] conducted a monitoring campaign in the urban area of Palermo, located in southern Italy, utilizing the horizontal axis pico wind turbine model "Whisper 200" manufactured by the company Southwest Windpower (Fairview, AB, Canada) [158].

Weather conditions are measured using a weather station installed on the roof of a building of the University of Palermo, positioned at a height of 2.7 m, near the wind turbine installation site. A Fluke 189 Multimeter (Perugia, Italy) [277] is used to monitor the voltage across a steady electrical load, while 3 and 4 Ω precision resistances (model RH250 manufactured by the company Vishay (Mansfield, MA, USA) [278]), with an accuracy of ±1% and temperature coefficients of ±50 ppm/°C, are configured in parallel and/or series to calculate the load values. Every minute, data are taken, averaged across thirty samples, and saved twice an hour; a period of three years is covered.

The authors employ both the power curve provided by the manufacturer and the experimental power curve, along with measured wind speeds, to calculate the annual producible energy at a height of 6.0 m. Results indicate that the utilization of the wind turbine in Palermo does not result in a profitable investment, primarily because of the lack of high wind speeds. They suggest positioning the wind turbine at an elevation ranging between 25 m and 30 m in order to enhance energy production and reduce the investment payback period. However, this proposal entails both increased installation costs as well as plant visual impact, factors that require careful consideration.

6. Results and Discussion: Comparison between Experimental and Rated Performance

In this section, the experimental results of the papers previously described are compared with the performance rated by the corresponding manufacturers in order to highlight and assess the discrepancies.

Because the effective power curves are highly impacted by both the morphological characteristics of the ground and the variations of wind speed intensity and associated orientation, it should be underlined that the manufacturer and field performance of SWTs might differ greatly [264,265]. During field operation, SWTs are generally subjected to abrupt changes in wind speed and direction and they have a transition time in which, attempting to adapt to novel conditions, the power energy generation is notably lower; however, power curves issued suggested by manufacturers do not take these variations into account and are defined in very stable and artificial conditions through the use of wind tunnels [265]. Furthermore, because of the extremely turbulent wind patterns found in built environments, SWTs may not perform as well under such complicated conditions as suggested by manufacturers [10]. Moreover, it should be highlighted that the design of roofs, the height of buildings, and the surrounding urban structures may all have a substantial influence on wind acceleration [10,27]; this can make it challenging to provide a consistent and dependable source of energy [10], which will lead to poor performance from SWTs. Differences in the height at which the wind generator's rotor is placed may also potentially be the cause of the discrepancies between manufacturer and field data [265]. Lastly, because it is difficult to obtain high velocities in residential areas, the rated wind speed is typically greater than the field data [261].

Operating SWTs under conditions that differ from those recommended by the manufacturers can lead to significant discrepancies between actual and rated performance; this can cause important consequences with relevant overestimates of SWTs' performance and, therefore, significant effects on the assessment of potential energy, economic, and environmental benefits and overall suitability in the use of such technology. Consequently, manufacturer's data can be used for a preliminary and rough estimate of the SWTs performance; they need field validation that takes into account the actual and real boundary operating conditions in order to perform an accurate and effective assessment.

It has to be underlined that such kind of comparison between rated and field performance is generally not performed in scientific studies generally because the data provided by manufacturers are often not sufficiently detailed or complete to allow accurate and precise comparisons. The results of the comparisons performed in this study can be summarized as follows:

- In the case of five blades, the study by Eltayesh et al. [258] focused on the wind turbine model "Anemos 455" manufactured by ItalSol [180], measured a maximum power coefficient of approximately 0.43, while the manufacturer indicates a C_p higher than 0.45;
- According to the study by Kanya and Visser [260], the open rotor configuration of the wind turbine model "Excel-1" manufactured by the company Bergey Windpower (Norman, OK, USA) [185,186] provides about 1200 W, while the manufacturer suggests a power output of 900 W for the commercial version operating at the same velocity; similarly, the open rotor configuration of this wind turbine exhibits a measured power coefficient of 0.38 with respect to the value of 0.3 indicated by the manufacturer;
- The study of Hasan et al. [261] indicates that the experimental performance of the wind turbine model "FD3.0-1000" manufactured by the company Foshan Ouyad Electronic Co., Ltd. (Foshan, China) [203,204] is significantly reduced in comparison to the performance specified by the manufacturer at wind velocities of 4, 5, and 6 m/s; in particular, the measured power output at 4 m/s is in the range between 65 W and 89 W, while the manufacturer reports a value of about 300 W; the experimental power output at 5 m/s is in the range between 115 W and 163.9 W, while the manufacturer indicates a value of about 400 W; the measured power output at 6 m/s is in the range between 190 W and 306 W, while the manufacturer suggests a value of about 500 W;
- The study by Singh and Ahmed [262] shows a cut-in wind speed of 3.58 m/s for the wind turbine model "SilentWind Air X Marine" manufactured by the company Primus Windpower (Lakewood, CO, USA) [85]; this value is almost equal to the one suggested by the manufacturer. In addition, Singh and Ahmed [262] provide a power output of about 40 W at a wind speed of about 7 m/s, while the manufacturer's power curve reports a value of about 65 W for the same wind velocity;
- Lee et al. [27] investigate the wind turbine model "XUNZEL-6000" manufactured by the company WINDFORCE™ (Mendaro, Spain) [97,98] at 8 and 10 m/s only, even if the manufacturer claims that this wind turbine is characterized by a cut-in wind speed of 2.0 m/s with a survival wind speed of 50 m/s;
- Castelli and Benini [28] indicate that electric energy generation of the wind turbine model "Qr5" manufactured by the company Quiet Revolution (St.Ives, Cambridgeshire, UK) [222,223] starts at about 5.2 m/s, while the cut-in wind speed reported by the manufacturer is 4 m/s; with respect to this point, it should be mentioned that anemometric measurements are made at a different site (even if relatively close) with respect to the installation site of the wind turbine;

- With reference to the wind turbine model "Excel-6" manufactured by the company Bergey Windpower (Norman, OK, USA) [205], Moussa [264] reports a power coefficient ranging from a minimum of about 0.02 up to a maximum of about 0.24 for a tip speed ratio changing between about 2.3 and about 5.4, while the manufacturer indicates values of C_p varying between a minimum of 0.05 up to a maximum of 0.31 in the cases of wind velocity in the range 2.53–18.56 m/s;
- Lo Brano et al. [265] underline that the wind turbine model "Whisper 200" manufactured by the company Southwest Windpower (Fairview, AB, Canada) [158] has a maximum power output of 900 W, while the manufacturer indicates a value of 972 W. The experimental results also show that the real performance of the wind turbine is totally different from the one indicated by the manufacturer. In particular, the authors compare the annual energy production of the wind turbine in an urban area of Palermo (south Italy) calculated via experimental power curves as well as via the power curve issued by the manufacturer; they find significant deviations, underlining rated performance much higher than those corresponding to the field data with deviations ranging from a minimum of −75.5% up to a maximum of −86.6%. The authors attribute this difference to the significant instability of wind speed conditions in the case of the real installation with respect to the operation of the wind turbine established in a wind tunnel; in particular, the field data highlight a significant variability as well as low values of mean wind speed, causing experimental power curves to be much less powerful than the rated one.

7. Conclusions

In this review, a comprehensive and up-to-date analysis of more than 200 commercially available small-scale horizontal and vertical wind turbine models has been provided. They have been mainly classified in terms of rated power output (considering pico, micro and mini wind turbines) as well as distinguished between vertical and horizontal axis wind turbines according to the wind turbine axis position. The characteristics of pico, micro and mini wind turbines with a horizontal or vertical axis have been detailed, encompassing factors such as the number and material of blades, start-up wind speed, cut-in wind speed, cut-out wind speed, survival wind speed, maximum power output, noise level, rotor diameter, turbine length, tower height, and specific capital cost.

The main results of this review can be summarized as follows:

- In total, 114, 73 and 20 pico, micro and mini wind turbines, respectively, are commercially available;
- In total, 47 out of 114 pico wind turbines have a horizontal axis;
- In total, 50 out of 73 micro wind turbines have a horizontal axis;
- In total, 6 out of 20 mini wind turbines have a horizontal axis;
- The minimum, maximum and average cut-in speeds are 1.5 m/s, 5.4 m/s, 2.9 m/s, respectively, with reference to the horizontal axis pico wind turbines;
- The minimum, maximum and average cut-in speeds are 0.7 m/s, 5.0 m/s, 2.6 m/s, respectively, with reference to the vertical axis pico wind turbines;
- The minimum, maximum and average cut-in speeds are 2.0 m/s, 4.0 m/s, 2.9 m/s, respectively, with reference to the horizontal axis micro wind turbines;
- The minimum, maximum and average cut-in speeds are 0.7 m/s, 4.0 m/s, 2.3 m/s, respectively, with reference to the vertical axis micro wind turbines;
- The minimum, maximum and average cut-in speeds are 2.0 m/s, 4.5 m/s, 3.3 m/s, respectively, with reference to the horizontal axis mini wind turbines;
- The minimum, maximum and average cut-in speeds are 2.0 m/s, 5.0 m/s, 2.7 m/s, respectively, with reference to the vertical axis mini wind turbines;
- The minimum, maximum and average specific capital costs are 0.31 EUR/W, 16.89 EUR/W, 3.72 EUR/W, respectively, in the case of the horizontal axis pico wind turbines;
- The minimum, maximum and average specific capital costs are 0.82 EUR/W, 44.70 EUR/W, 6.24 EUR/W, respectively, in the case of the vertical axis pico wind turbines;

- The minimum, maximum and average specific capital costs are 0.11 EUR/W, 8.07 EUR/W, 1.38 EUR/W, respectively, in the case of the horizontal axis micro wind turbines;
- The minimum, maximum and average specific capital costs are 0.58 EUR/W, 18.16 EUR/W, 4.18 EUR/W, respectively, in the case of the vertical axis micro wind turbines;
- The minimum, maximum and average specific capital costs are 1.33 EUR/W, 3.49 EUR/W, 2.36 EUR/W, respectively, in the case of the horizontal axis mini wind turbines;
- The minimum, maximum and average specific capital costs are 0.03 EUR/W, 2.79 EUR/W, 1.38 EUR/W, respectively, in the case of the vertical axis mini wind turbines.

The scientific papers focusing on the experimental assessment of commercial small-scale wind turbines have been reviewed, highlighting that a very limited number of commercial SWTs have been analysed from an experimental point of view and significant differences between rated and field performance can be recognized. Therefore, additional studies are mandatory (mainly with reference to vertical axis small-scale wind turbines) in order to better clarify such differences and fully assess the performance of this technology. In particular, further tests under real operating conditions should be carried out in order to better investigate the effects of site-specific local wind resources, the presence of obstacles (surrounding buildings, trees, etc.), the turbulence level of wind flow, etc. In the future, it would be desirable for manufacturers to provide more accurate and representative data on the actual performance of SWTs, as well as it would be recommended for more detailed comparisons to be conducted in scientific papers between the data provided by manufacturers and those actually measured in the field to effectively clarify the discrepancies.

Author Contributions: Conceptualization, A.R., A.P. and L.M.; methodology, A.R., A.P. and L.M.; software, A.R., A.P. and L.M.; validation, A.R., A.P. and L.M.; formal analysis, A.R., A.P. and L.M.; investigation, A.R., A.P. and L.M.; resources, A.R. and L.M.; data curation, A.R., A.P. and L.M.; writing—original draft preparation, A.R., A.P. and L.M.; writing—review and editing, A.R., A.P. and L.M.; visualization, A.R., A.P. and L.M.; supervision, A.R., A.P. and L.M.; project administration, A.R. and L.M.; funding acquisition, A.R. and L.M. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Data Availability Statement: The raw data supporting the conclusions of this article will be made available by the authors upon request.

Conflicts of Interest: The authors declare no conflicts of interest. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript; or in the decision to publish the results.

Nomenclature

A	Swept area (m^2)
AC	Alternating current (A)
C_p	Power coefficient
C_Q	Torque coefficient
C_T	Thrust coefficient
DC	Direct current (A)
HAMCWTs	Horizontal axis micro wind turbines
HAMNWTs	Horizontal axis mini wind turbines
HAPWTs	Horizontal axis pico wind turbines
HAWTs	Horizontal axis small-scale wind turbines
I	Current (A)
MCWTs	Micro wind turbines
MNWTs	Mini wind turbines
PWTs	Pico wind turbines
P_{max}	Maximum power output (W)
P_{rated}	Rated power output (W)
P_{wind}	Kinetic power (W)

R	Rotor radius (m)
SWTs	Small-scale wind turbines
T	Thrust force (N)
TSR	Tip speed ratio
V	Voltage (V)
v	Wind speed (m/s)
VAMCWTs	Vertical axis micro wind turbines
VAMNWTs	Vertical axis mini wind turbines
VAPWTs	Vertical axis pico wind turbines
VAWTs	Vertical axis small-scale wind turbines
v_{in}	Cut-in wind speed (m/s)
v_{out}	Cut-out wind speed (m/s)
v_r	Rated wind speed (m/s)
v_s	Survival wind speed (m/s)
v_{up}	Start-up wind speed (m/s)
v_1	Wind speed before the contact with the wind turbine (m/s)
v_2	Wind speed after the contact with the wind turbine (m/s)
ρ	Density (kg/m^3)
ω	Angular velocity (rad/s)

References

1. 2021 Global Status Report for Buildings and Construction. Towards a Zero-Emission, Efficient and Resilient Buildings and Construction Sector. Available online: https://globalabc.org/sites/default/files/2021-10/GABC_Buildings-GSR-2021_BOOK.pdf (accessed on 17 April 2024).
2. Chong, W.-T.; Muzammil, W.K.; Wong, K.-H.; Wang, C.-T.; Gwani, M.; Chu, Y.-J.; Poh, S.-C. Cross axis wind turbine: Pushing the limit of wind turbine technology with complementary design. *Appl. Energy* **2017**, *207*, 78–97. [CrossRef]
3. Yang, A.-S.; Su, Y.-M.; Wen, C.-Y.; Juan, Y.-H.; Wang, W.-S.; Cheng, C.-H. Estimation of wind power generation in dense urban area. *Appl. Energy* **2016**, *171*, 213–230. [CrossRef]
4. Tang, X.; Huang, X.; Peng, R.; Liu, X. A Direct Approach of Design Optimization for Small Horizontal Axis Wind Turbine Blades. *Procedia CIRP* **2015**, *36*, 12–16. [CrossRef]
5. Ying, P.; Chen, Y.K.; Xu, Y.G.; Tian, Y. Computational and experimental investigations of an omni-flow wind Turbine. *Appl. Energy* **2015**, *146*, 74–83. [CrossRef]
6. Byrne, R.; Hewitt, N.J.; Griffiths, P.; MacArtain, P. Observed site obstacle impacts on the energy performance of a large-scale urban wind turbine using an electrical energy rose. *Energy Sustain. Dev.* **2018**, *43*, 23–37. [CrossRef]
7. Weekes, S.M.; Tomlin, A.S.; Vosper, S.B.; Skea, A.K.; Gallani, M.L.; Standen, J.J. Long-term wind resource assessment for small and medium-scale turbines using operational forecast data and measure–correlate–predict. *Renew. Energy* **2015**, *81*, 760–769. [CrossRef]
8. European Wind Energy Association. *Wind Energy—The Facts: A Guide to the Technology, Economics and Future of Wind Power*; Routledge: Earthscan, UK, 2009; pp. 1–592.
9. Kalashani, M.B.; Seyedmahmoudian, M.; Mekhilef, S.; Stojcevski, A.; Horan, B. Small-scale wind turbine control in high-speed wind conditions: A review. *Sustain. Energy Technol. Assess.* **2023**, *60*, 103577.
10. Calautit, K.; Johnstone, C. State-of-the-art review of micro to small-scale wind energy harvesting technologies for building integration. *Energy Convers. Manag. X* **2023**, *20*, 100457. [CrossRef]
11. Anup, K.C.; Whale, J.; Urmee, T. Urban wind conditions and small wind turbines in the built environment: A review. *Renew. Energy* **2019**, *131*, 268–283.
12. Kamp, L.M.; Vanheule, L.F.I. Review of the small wind turbine sector in Kenya: Status and bottlenecks for growth. *Renew. Sustain. Energy Rev.* **2015**, *49*, 470–480. [CrossRef]
13. Tummala, A.; Velamati, R.K.; Sinha, D.K.; Indraja, V.; Krishna, V.H. A review on small scale wind turbines. *Renew. Sustain. Energy Rev.* **2016**, *56*, 1351–1371. [CrossRef]
14. *International Standard IEC 61400-2:2013*; Wind Turbines—Part 2: Small Wind Turbines, 3rd ed. International Electrotechnical Commission: Geneva, Switzerland, 2013.
15. Wang, H.; Xiong, B.; Zhang, Z.; Zhang, H.; Azam, A. Small wind turbines and their potential for internet of things applications. *Iscience* **2023**, *26*, 107674. [CrossRef] [PubMed]
16. Wilberforce, T.; Olabi, A.G.; Sayed, E.T.; Alalmi, A.H.; Abdelkareem, M.A. Wind turbine concepts for domestic wind power generation at low wind quality sites. *J. Clean. Prod.* **2023**, *394*, 136137. [CrossRef]
17. International Association of Marine Aids to Navigation and Lighthouse Authorities-IAIA. Available online: https://www.iala-aism.org/wiki/dictionary/index.php/Start-up_wind_speed_(of_a_wind-power_generator) (accessed on 17 April 2024).
18. International Association of Marine Aids to Navigation and Lighthouse Authorities-IAIA. Available online: https://www.iala-aism.org/wiki/dictionary/index.php/Cut-in_wind_speed_(of_a_wind-power_genearator)/es (accessed on 17 April 2024).

19. International Association of Marine Aids to Navigation and Lighthouse Authorities-IAIA. Available online: https://www.iala-aism.org/wiki/dictionary/index.php/Cut-out_wind_speed_(of_a_wind-power_generator) (accessed on 17 April 2024).
20. Sedaghat, A.; Hassanzadeh, A.; Jamali, J.; Mostafaeipour, A.; Chen, W.H. Determination of rated wind speed for maximum annual energy production of variable speed wind turbines. *Appl. Energy* **2017**, *205*, 781–789. [CrossRef]
21. GCE LEVEL Environmental Technology: Energy from the Wind. Available online: https://ccea.org.uk/downloads/docs/Support/Fact%20File:%20AS/2019/Energy%20from%20Wind.pdf (accessed on 17 April 2024).
22. Pande, J.; Nasikkar, P.; Kotecha, K.; Varadarajan, V. A Review of Maximum Power Point Tracking Algorithms for Wind Energy Conversion Systems. *Mar. Sci. Eng.* **2021**, *9*, 1187. [CrossRef]
23. Moyá, J.M. Study of Data of a Wind Farm. Master's Thesis, Department of Management and Engineering, Linköping University in Sweden, Linköpin, Sweden, 25 June 2009.
24. University of Calgary: Energy Education. Available online: https://energyeducation.ca/encyclopedia/Betz_limit (accessed on 17 April 2024).
25. Mendoza, V.; Chaudhari, A.; Goude, A. Performance and wake comparison of horizontal and vertical axis wind turbines under varying surface roughness conditions. *Wind. Energy* **2019**, *22*, 458–472. [CrossRef]
26. Al-Rawajfeh, M.A.; Gomaa, M.R. Comparison between horizontal and vertical axis wind turbine. *Int. J. Appl. Power Eng. (IJAPE)* **2023**, *12*, 13–23. [CrossRef]
27. Lee, M.H.; Shiah, Y.C.; Bai, C.J. Experiments and numerical simulations of the rotor-blade performance for a small-scale horizontal axis wind turbine. *J. Wind. Eng. Ind. Aerodyn.* **2016**, *149*, 17–29. [CrossRef]
28. Castelli, M.R.; Benini, E. Comparison between Lift and Drag-Driven VAWT Concepts on Low-Wind Site AEO. *Int. J. Environ. Ecol. Eng.* **2011**, *5*, 11.
29. Zakaria, A.; Ibrahim, M.S.N. Numerical Performance Evaluation of Savonius Rotors by Flow-driven and Sliding-mesh Approaches. *Int. J. Adv. Trends Comput. Sci. Eng.* **2019**, *8*, 57–61.
30. Kishore, R.A.; Priya, S.; Stewart, C. *Wind Energy Harvesting, Micro-to-Small Scale Turbines*; De Gruyter Textbook: De Gruyter, Germany, 2018; pp. 15–158. Available online: https://books.google.it/books?id=oPZYDwAAQBAJ&printsec=frontcover&hl=it&source=gbs_ge_summary_r&cad=0#v=onepage&q&f=false (accessed on 17 April 2024).
31. Baruah, A.; Patel, B.J.; Ghose, P.; Nayak, P.G.; Rana, B.K. Modelling and numerical analysis of Savonius and Darrieus turbines for small-scale applications. *Mater. Today Proc.* **2023**, in press. [CrossRef]
32. Eltayesh, A.; Castellani, F.; Natili, F.; Burlando, M.; Khedr, A. Aerodynamic upgrades of a Darrieus vertical axis small wind turbine. *Energy Sustain. Dev.* **2023**, *73*, 126–143. [CrossRef]
33. Kharade, V.; Jagtap, K. A Review Study on Vertical axis Wind Turbines (lift and drag type) for Optimizing the Aerodynamic and Structural Performance. *IOSR J. Eng. (IOSR JEN)* **2019**, *3*, 61–65.
34. Gharaati, M.; Xiao, S.; Wei, N.J.; Martínez Tossas, L.A.; Dabiri, J.O.; Yang, D. Large Eddy Simulation of Helical- and Straight-Bladed Vertical Axis Wind Turbines in Boundary Layer Turbulence. *J. Renew. Sustain. Energy* **2022**, *14*, 053301. [CrossRef]
35. Ebrahimpour, M.; Shafaghat, R.; Alamian, R.; Shadloo, M.S. Numerical Investigation of the Savonius Vertical Axis Wind Turbine and Evaluation of the Effect of the Overlap Parameter in Both Horizontal and Vertical Directions on Its Performance. *Symmetry* **2019**, *11*, 821. [CrossRef]
36. Kumar, P.M.; Sivalingam, K.; Narasimalu, S.; Lim, T.C.; Ramakrishna, S.; Wei, H. A Review on the Evolution of Darrieus Vertical Axis Wind Turbine: Small Wind Turbines. *J. Power Energy Eng.* **2019**, *7*, 27–44. [CrossRef]
37. Robotham, A.J. The Aerodynamic Control of the v-Type Vertical Axis Wind Turbine. Ph.D. Thesis, The Open University, Milton Keynes, UK, 22 June 1989.
38. Jayaram, V.; Bavanish, B. Design and analysis of gorlov helical hydro turbine on index of revolution. *Int. J. Hydrogen Energy* **2022**, *47*, 32804–32821. [CrossRef]
39. Moghimi, M.; Hotawej, H. Investigation of Effective Parameters on Gorlov Vertical Axis Wind Turbine. *Fluid Dyn.* **2020**, *55*, 345–363. [CrossRef]
40. Mu, Z.; Tong, G.; Xiao, Z.; Deng, Q.; Feng, F.; Li, Y.; Van Arne, G.V. Study on Aerodynamic Characteristics of a Savonius Wind Turbine with a Modified Blade. *Energies* **2022**, *15*, 6661. [CrossRef]
41. Dewan, A.; Tomar, S.S.; Bishnoi, A.K.; Singh, T.P. Computational fluid dynamics and turbulence modelling in various blades of Savonius turbines for wind and hydro energy: Progress and perspectives. *Ocean Eng.* **2023**, *283*, 115168. [CrossRef]
42. Toptas, E.; Bayrak, M.A.; Boz, T. Vertical axis hybrid wind turbine design. *J. Mechatron. Artif. Intell. Eng.* **2020**, *1*, 33–40. [CrossRef]
43. El-Nenaey, K.M.; Eldrainy, Y.A.; Eissa, A.A.; Kassab, S.Z. Performance Evaluation of Hybrid Vertical Axis Wind Turbine. Available online: https://tfaws.nasa.gov/wp-content/uploads/TFAWS2020-ID-512-El-Nenaey-Paper.pdf (accessed on 17 April 2024).
44. Chong, W.-T.; Wong, K.-H.; Wang, C.T.; Gwani, M.; Chu, Y.-J.; Chia, W.C.; Poh, S.C. Cross-Axis-Wind-Turbine: A Complementary Design to Push the Limit of Wind Turbine Technology. *Energy Procedia* **2017**, *105*, 973–979. [CrossRef]
45. Syngellakis, K.; Carroll, S.; Robinson, P. Small wind power: Introduction to urban small-scale wind in the UK. *ReFocus* **2006**, *7*, 40–45. [CrossRef]
46. PlanningPortal. Planning Permission: Stand-Alone Wind Turbines (UK). Available online: https://www.planningportal.co.uk/permission/common-projects/wind-turbines/planning-permission-stand-alone-wind-turbines (accessed on 17 April 2024).
47. Gazzetta Ufficiale della Repubblica Italiana. Available online: https://energialia.it/wp-content/uploads/2023/03/20110328_071_SO_081.pdf (accessed on 17 April 2024).

48. Bosettiegatti. Available online: https://www.bosettiegatti.eu/info/norme/statali/2003_0387.htm (accessed on 17 April 2024).
49. Ministero Dello Sviluppo Economico. Decreto 18 December 2008. Available online: https://www.camera.it/temiap/temi16/dm%202008-12-18.pdf (accessed on 17 April 2024).
50. GSE. Available online: https://www.gse.it/documenti_site/Documenti%20GSE/Studi%20e%20scenari/Il%20punto%20sull'eolico.pdf (accessed on 17 April 2024).
51. GSE Normative. Available online: https://gse.it/normativa_site/GSE%20Documenti%20normativa/ITALIA_DM_MSE_18_12_2008_SMI.pdf (accessed on 17 April 2024).
52. Gazzetta Ufficiale della Repubblica Italiana. Available online: https://www.aranagenzia.it/attachments/article/12029/20210812_192_SO_031_legge%20108_2021.pdf (accessed on 17 April 2024).
53. Gestore Servizi Energetici GSE. Available online: https://www.gse.it/normativa_site/autorizzazioni_site/Documents/Autorizzazioni%20impianti%20FER.pdf (accessed on 17 April 2024).
54. Testo Coordinato del Decreto-Legge 24 Febbraio 2023. Available online: https://www.ticonsiglio.com/wp-content/uploads/2023/04/testo-coordinato-del-decreto-legge-24-febbraio-2023-n-13.pdf (accessed on 17 April 2024).
55. Ministero dell'Ambiente e della Sicurezza Energetica. Available online: https://www.mase.gov.it/pagina/rete-natura-2000 (accessed on 17 April 2024).
56. Bosettiegatti. Available online: https://www.bosettiegatti.eu/info/norme/statali/1968_1444.htm (accessed on 17 April 2024).
57. BROCARDI. Available online: https://www.brocardi.it/codice-civile/libro-terzo/titolo-ii/capo-ii/sezione-i/art844.html#:~:text=%C3%A8%20applicabile%20unicamente%20alle%20immissioni%20indirette,,non%20quella%20offerta%20dall'art.%202043%20c.c.&text=%C3%A8%20applicabile%20unicamente%20alle,offerta%20dall'art.%202043%20c.c.&text=unicamente%20alle%20immissioni%20indirette,,non%20quella%20offerta%20dall'art (accessed on 17 April 2024).
58. Cassazione Civile Sez. VI Sentenza n. 2319 del 1 Febbraio 2011. Available online: https://www.avvocato.it/massimario-1616/ (accessed on 17 April 2024).
59. Gestore Servizi Energetici GSE. Wind Energy in Italy: Recent Trends. Available online: https://gse.it/media_site/media-gallery_site/Documents/Wind%20energy%20in%20Italy_recent_trends_v5.pdf (accessed on 17 April 2024).
60. Araujo, F.R.P.; Pereira, M.G.; Freitas, M.A.V.; Silva, N.F.; Dantas, E.J.A. Bigger is Not Always Better: Review of Small Wind in Brazil. *Energies* **2021**, *14*, 976. [CrossRef]
61. Shine. Available online: https://shineturbine.com/products/shine-wind-turbine (accessed on 17 April 2024).
62. Indiegogo. Available online: https://www.indiegogo.com/projects/shine-a-wind-turbine-that-fits-in-your-backpack#/ (accessed on 17 April 2024).
63. EcoPowerShop. Available online: https://www.ecopowershop.com/wind-turbines/rutland-504-wind-turbine (accessed on 17 April 2024).
64. Ocean Chandlery. Available online: https://www.oceanchandlery.com/rutland-504-wind-generator.html (accessed on 17 April 2024).
65. BAUHAUS. Available online: https://www.bauhaus.info/windenergie/sunset-windgenerator-wg504/p/21889750 (accessed on 17 April 2024).
66. Bol.com. Available online: https://www.bol.com/nl/nl/p/giga-12v-wind-turbine/9200000112605358/ (accessed on 17 April 2024).
67. Force 4 Chandlery. Available online: https://www.force4.co.uk/item/GIGA/12V-Wind-Turbine-Single/VUM (accessed on 17 April 2024).
68. Tex-Energy. Available online: https://eu.texenergy.com/products/infinite-air-18-portable-off-grid-wind-turbine (accessed on 17 April 2024).
69. World Water Reserve. Available online: https://worldwaterreserve.com/windlily-turbine-review/ (accessed on 17 April 2024).
70. ZORO. Available online: https://www.zoro.com/cutting-edge-power-2023-micro-wind-turbine-portable-generator-for-beach-camping-tailgating-backpacking-stationary-9358548559667/i/G408798520/ (accessed on 17 April 2024).
71. WindSoleil. Available online: https://www.windsoleil.com/new-products/350w-hiko-hyacinth-1224v-wind-turbine-generator-built-in-controller (accessed on 17 April 2024).
72. WindSoleil. Available online: https://www.windsoleil.com/new-products/680w-hiko-city-swallow-x-600cs-1224v-wind-turbine-generator (accessed on 17 April 2024).
73. Stirworld. Available online: https://www.stirworld.com/see-features-kitex-draws-from-looping-kites-to-create-a-portable-wind-turbine-in-denmark (accessed on 7 March 2023).
74. Kite x. Available online: https://kitex.tech/products/wind-catcher-standard-kit-1?variant=48658987188549 (accessed on 17 April 2024).
75. Kite x. Available online: https://kitex.tech/pages/wind-catcher-specifications-power-curve (accessed on 17 April 2024).
76. ORIONAIR. Available online: https://www.orionairsales.co.uk/nheowind-wind-turbine-3d-04-300w-25v-3454-p.asp (accessed on 17 April 2024).
77. WPH. Available online: https://www.wphenerji.com.tr/kucuk-ruzgar-turbinleri/ (accessed on 17 April 2024).
78. VEVOR. Available online: https://www.vevor.it/turbina-eolica-c_10731/generatore-eolica-turbina-500w-12v-con-5-lame-1m-ruota-del-vento-p_010214006301 (accessed on 17 April 2024).
79. Archi EXPO. Available online: https://www.archiexpo.com/prod/omniflow/product-159336-2106619.html (accessed on 17 April 2024).
80. Omniflow. Available online: https://www.omniflow.io/products (accessed on 17 April 2024).
81. Omniflow. Available online: https://www.omniflow.io/downloads (accessed on 17 April 2024).

82. Wind Power Energy Ball. Available online: http://www.optikon.at/sites/default/files/energy_ball_produktbroschuere.pdf (accessed on 17 April 2024).
83. Xprt Energy. Available online: https://www.energy-xprt.com/products/energy-ball-model-v100-and-v200-virtually-silent-wind-turbine-385412 (accessed on 17 April 2024).
84. Eco. Available online: https://www.eco-logisch.nl/Weggestemd-Energy-Ball-V100-1109 (accessed on 17 April 2024).
85. EcoPowerShop.com. Available online: https://www.ecopowershop.com/air-silent-x-marine-wind-turbine (accessed on 17 April 2024).
86. EcoPowerShop.com. Available online: https://www.ecopowershop.com/air-breeze-marine-wind-turbine (accessed on 17 April 2024).
87. AUTOMAXX. Available online: https://automaxxwindmill.com/windmill-600w/ (accessed on 17 April 2024).
88. AUTOMAXX. Available online: https://automaxxwindmill.com/product/automaxx-windmill-400w-wind-turbine/ (accessed on 17 April 2024).
89. WINDANDSOLAR. Available online: https://windandsolar.com/raptor-g4-5-blade-500-watt-basic-wind-turbine (accessed on 17 April 2024).
90. ATO. Available online: https://www.ato.com/800w-wind-turbine (accessed on 17 April 2024).
91. ATO. Available online: https://www.ato.com/600w-wind-turbine (accessed on 17 April 2024).
92. ATO. Available online: https://www.ato.com/500w-wind-turbine (accessed on 17 April 2024).
93. ATO. Available online: https://www.ato.com/400w-wind-turbine (accessed on 17 April 2024).
94. ATO. Available online: https://www.ato.com/300w-wind-turbine (accessed on 17 April 2024).
95. ATO. Available online: https://www.ato.com/200w-wind-turbine (accessed on 17 April 2024).
96. ATO. Available online: https://www.ato.com/100w-wind-turbine (accessed on 17 April 2024).
97. WINDFORCETM. Available online: https://pdf.archiexpo.it/pdf-en/xunzel-applied-solar-wind-energy/windforce-6000ma/149737-278051.html#open1695458 (accessed on 17 April 2024).
98. Truenergy. Available online: https://www.loja.truenergy.pt/products/copia-de-kit-eolico-winforce-6000 (accessed on 17 April 2024).
99. BOOTMANIA. Available online: https://www.bootmania.nl/xunzel-windmolen-windforce600ma-marine-12-24v (accessed on 17 April 2024).
100. Fast Trading LTD. Available online: https://it.istabreeze.store/prodotti/generatore-eolico-istabreeze%C2%AE-i-500-in-12v-o-24v (accessed on 17 April 2024).
101. iSTA BREEZE. Available online: https://www.b2b-istabreeze.com/index.php?route=product/product&product_id=50&search=i-500+Wind+Turbine (accessed on 17 April 2024).
102. Fast Trading LTD. Available online: https://it.istabreeze.store/prodotti/i-700-generatore-eolico (accessed on 17 April 2024).
103. iSTA BREEZE. Available online: https://www.b2b-istabreeze.com/index.php?route=product/product&product_id=53&search=i-700+Wind+Turbine (accessed on 17 April 2024).
104. TESUP. Available online: https://drive.google.com/file/d/1DbrN7FLVS0Cm8GmkhD1pQSdOsg8eIzQi/view (accessed on 17 April 2024).
105. TESUP. Available online: https://www.amazon.it/TESUP-Turbina-eolica-MaestroX-12-24-48V/dp/B096W9MMG1 (accessed on 17 April 2024).
106. Whisper. Available online: https://thesolarstore.com/southwest-windpower-900-watt-whisper-100-wind-generator-12-24-36-or-48-vdc-wo-charge-controller-p-213.html (accessed on 17 April 2024).
107. Whisper. Available online: http://msmelectric.com/montage/catalog/manuals/0040_whisper_100-200_spec.pdf (accessed on 17 April 2024).
108. Leading Edge. Available online: https://www.leadingedgepower.com/le-v50-vertical-axis-wind-turbine-1013843.html (accessed on 17 April 2024).
109. Leading Edge. Available online: https://www.leadingedgepower.com/le-v150-vertical-axis-wind-turbine-1121392.html (accessed on 17 April 2024).
110. Etneo. Available online: https://etneo.com/turbina-ds300/ (accessed on 17 April 2024).
111. Etneo Robotica ed Energia 4.0. Available online: https://etneo.com/prodotto/eolico-verticale-ibrido-300w/ (accessed on 17 April 2024).
112. SEC. Available online: https://www.sec.co.th/product/wind-turbine/ds300 (accessed on 17 April 2024).
113. Etneo. Available online: https://etneo.com/wind-turbine-ds700/?lang=en (accessed on 17 April 2024).
114. Etneo Robotica ed Energia 4.0. Available online: https://etneo.com/prodotto/eolico-verticale-ibrido-700w/ (accessed on 17 April 2024).
115. Icewind IW. Available online: https://icewind.is/wp-content/uploads/2020/08/RW-100-icewind-wind-turbine.pdf (accessed on 17 April 2024).
116. Icewind IW. Available online: https://icewind.is/wp-content/uploads/2020/08/cw-100-Icewind-wind-turbine.pdf (accessed on 17 April 2024).
117. Makemu Green Energy. Available online: https://www.makemu.it/prodotto/generatore-eolico-smartwind/ (accessed on 17 April 2024).
118. Makemu Green Energy. Available online: https://www.makemu.it/prodotto/generatore-eolico-domus/ (accessed on 17 April 2024).
119. Makemu Green Energy. Available online: https://www.makemu.it/prodotto/generatore-eolico-eolo/ (accessed on 17 April 2024).

120. Zotiel. Available online: https://zotiel.com/product/600w-wind-turbine-vertical-12v-24v-48v-maglev-permanent-magnet-wind-generator-with-free-controller-wind-power-48v-600w/ (accessed on 17 April 2024).
121. Zotiel. Available online: https://zotiel.com/product/nl-fltxny-600w-1000w-2000w-vertical-wind-turbine-3-phase-12v-24v-48v-96v-vertical-coreless-wind-generator-green-white-orange-blades-48v-with-mppt-controller-white/ (accessed on 17 April 2024).
122. Inverter. Available online: https://www.inverter.com/100w-vertical-axis-wind-turbine (accessed on 17 April 2024).
123. Inverter. Available online: https://www.inverter.com/200w-vertical-axis-wind-turbine (accessed on 17 April 2024).
124. Inverter. Available online: https://www.inverter.com/300w-vertical-axis-wind-turbine (accessed on 17 April 2024).
125. Inverter. Available online: https://www.inverter.com/400w-vertical-axis-wind-turbine (accessed on 17 April 2024).
126. Inverter. Available online: https://www.inverter.com/500w-vertical-axis-wind-turbine (accessed on 17 April 2024).
127. Inverter. Available online: https://www.inverter.com/600w-vertical-axis-wind-turbine (accessed on 17 April 2024).
128. Icewind IW. Available online: https://icewind.is/wp-content/uploads/2020/08/rw-500-Icewind-wind-turbine.-Mil.pdf (accessed on 17 April 2024).
129. Business AM. Available online: https://fr.businessam.be/icewind-la-start-up-islandaise-qui-veut-dompter-les-vents-extremes/ (accessed on 17 April 2024).
130. Rinnovabili. Available online: https://www.rinnovabili.it/energia/eolico/icewind-mini-eolico-vento-islanda-666/ (accessed on 17 April 2024).
131. Windside. Available online: https://windside.com/products/ws-015/ (accessed on 17 April 2024).
132. ArchiEXPO. Available online: https://pdf.archiexpo.com/pdf/windside/ws-0-15b/88530-358859.html (accessed on 17 April 2024).
133. ArchiEXPO. Available online: https://pdf.archiexpo.com/pdf/windside/ws-0-15-bplus/88530-317397.html (accessed on 17 April 2024).
134. Windside. Available online: https://windside.com/products/ws-030/ (accessed on 17 April 2024).
135. Windside. Available online: https://windside.com/wp-content/uploads/2020/12/143-ws030.pdf (accessed on 17 April 2024).
136. ArchiEXPO. Available online: https://pdf.archiexpo.com/pdf/windside/ws-0-30c/88530-358861.html (accessed on 17 April 2024).
137. ArchiEXPO. Available online: https://pdf.archiexpo.com/pdf/windside/ws-0-30b/88530-358863.html (accessed on 17 April 2024).
138. ArchiEXPO. Available online: https://pdf.archiexpo.com/pdf/windside/ws-0-30b-plus/88530-358865.html (accessed on 17 April 2024).
139. ArchiEXPO. Available online: https://pdf.archiexpo.com/pdf/windside/ws-0-30a8-08/88530-358867.html (accessed on 17 April 2024).
140. ArchiEXPO. Available online: https://pdf.archiexpo.com/pdf/windside/ws-0-308-29/88530-317399.html (accessed on 17 April 2024).
141. Archi.EXPO. Available online: https://pdf.archiexpo.com/pdf/windside/ws-0-308-plus-29n/88530-317400.html (accessed on 17 April 2024).
142. Windside. Available online: https://windside.com/products/ws-2/ (accessed on 17 April 2024).
143. ArchiEXPO. Available online: https://pdf.archiexpo.com/pdf/windside/ws-2-technical-data-sheet/88530-250064.html (accessed on 17 April 2024).
144. ArchiEXPO. Available online: https://pdf.archiexpo.com/pdf/windside/ws-2cityg/88530-358869.html (accessed on 17 April 2024).
145. ArchiEXPO. Available online: https://pdf.archiexpo.com/pdf/windside/ws-2b/88530-358873.html (accessed on 17 April 2024).
146. ArchiEXPO. Available online: https://pdf.archiexpo.com/pdf/windside/ws-2ak/88530-358875.html (accessed on 17 April 2024).
147. Windside. Available online: https://windside.com/products/ws-060/ (accessed on 17 April 2024).
148. ArchiEXPO. Available online: https://pdf.archiexpo.com/pdf/windside/ws-0-60-technical-data-sheet/88530-250063.html (accessed on 17 April 2024).
149. ArchiEXPO. Available online: https://pdf.archiexpo.com/pdf/windside/ws-0-60/88530-317396.html (accessed on 17 April 2024).
150. Windside. Available online: https://windside.com/products/ws-4/ (accessed on 17 April 2024).
151. ArchiEXPO. Available online: https://pdf.archiexpo.com/pdf/windside/ws-4a/88530-391334.html (accessed on 17 April 2024).
152. ArchiEXPO. Available online: https://pdf.archiexpo.com/pdf/windside/ws-4-technical-data-sheet/88530-250065.html (accessed on 17 April 2024).
153. Flower Turbines. Available online: https://www.flowerturbines.com/shop (accessed on 17 April 2024).
154. Flower Turbines. Available online: https://www.flowerturbines.com/small (accessed on 17 April 2024).
155. Flower Turbines. Available online: https://www.flowerturbines.com/medium (accessed on 17 April 2024).
156. Flower Turbines. Available online: https://www.flowerturbines.com/_files/ugd/bd2d84_5714cb8824ba4cd5bbb619817c063716.pdf (accessed on 17 April 2024).
157. Whirlwind Wind Turbine. Available online: https://www.whirlwindwindturbines.eu/en/whirlwind-turbines-specs (accessed on 17 April 2024).
158. N.A.P.S. Solar Store. Available online: https://www.solar-store.com/store/whisper-200-wind-turbine/ (accessed on 17 April 2024).
159. Tesup. Available online: https://www.tesup.de/product-page/magnum-5-windkraftanlage-5kw-12v-24v-48v-Deutschland (accessed on 17 April 2024).
160. Tesup. Available online: https://drive.google.com/file/d/1lSoAM47hA4uERMrflJ-tpXlLmjjHVzff/view (accessed on 17 April 2024).
161. Etneo Robotica ed Industria 4.0. Available online: https://etneo.com/micro-eolico-orizzontale-1500w/ (accessed on 17 April 2024).
162. ORIONAIR. Available online: https://www.orionairsales.co.uk/nheowind-wind-turbine-3d-50-2kw-with-power-one-inverter-3455-p.asp (accessed on 17 April 2024).

163. Nheolis 3D Wind Turbines. Available online: http://savonius-balaton.hupont.hu/91/nheolis-3d-wind-turbines-france (accessed on 17 April 2024).
164. YUMPU. Available online: https://www.yumpu.com/fr/document/read/16844748/fiche-technique-nheowind-3d-100-cp (accessed on 17 April 2024).
165. About Generator. Available online: http://www.aboutgenerator.com/products/nheowind-wind-turbine-generator-3d100_l3BhaWRpk2Jm.html (accessed on 17 April 2024).
166. Marine System. Available online: https://www.emarineinc.com/Bornay-Wind-13-Plus-Wind-Turbine (accessed on 17 April 2024).
167. Manualslib. Available online: https://www.manualslib.com/manual/2329045/Bornay-Wind-13Plus.html?page=9#manual (accessed on 17 April 2024).
168. Bornay. Available online: https://www.bornay.com/en/products/small-wind-turbines/wind-plus-swt (accessed on 17 April 2024).
169. Marine System. Available online: https://www.emarineinc.com/Bornay-Wind-25-2-Plus-Wind-Turbine (accessed on 17 April 2024).
170. Marine System. Available online: https://www.emarineinc.com/Bornay-Wind-25-3-Plus-Wind-Turbine (accessed on 17 April 2024).
171. HomeEnergy. Available online: https://www.homeenergy.nl/energy-ball (accessed on 17 April 2024).
172. HomeEnergy. Available online: https://media.mwps.world/static/2014/10/Energy-Ball-V200-Original-Brochure.pdf (accessed on 17 April 2024).
173. HMPS. Available online: https://www.mwps.world/market/used-wind-turbines-offered/1kw-150kw-wind-turbines/70-x-energy-ball-v-200-domestic-wind-turbines-for-sale/ (accessed on 17 April 2024).
174. Manualslib. Available online: https://www.manualslib.com/manual/846818/Zephyr-Airdolphin-Pro-Z-1000-48.html?page=9#manual (accessed on 17 April 2024).
175. Renugen Renewable Generation. Available online: http://www.renugen.co.uk/zephyr-air-dolphin-pro-1kw-wind-turbine/ (accessed on 17 April 2024).
176. Zephyr Corporation. Available online: https://www.zephyreco.co.jp/en/products/airdolphin_make-zero_pro.jsp (accessed on 17 April 2024).
177. Renugen Renewable Generation. Available online: http://www.renugen.co.uk/zephyr-airdolphin-mark-zero-24v-wind-turbine/ (accessed on 17 April 2024).
178. Manualslib. Available online: https://www.manualslib.com/manual/2423470/Tumo-Int-3000w-5blades.html?page=10#manual (accessed on 17 April 2024).
179. Tumo Int Corporation Ltd. Available online: https://store.tumo-int.com/products/tumo-int-2000w-5blades-wind-turbine-generator-kit-with-wind-boosting-controller-48v#:~:text=Tumo-Int%203000W%205Blades%20Wind%20Turbine%20Generator%20Kit%20with,Kit%20with%20Wind%20Boosting%20Controller%20(48V)%20$4,418.00%20USD (accessed on 17 April 2024).
180. ITALSOL. Available online: https://www.italsolsrl.it/wp-content/uploads/2015/05/Brochure-Mini-Turbina-Anemos.web_.pdf (accessed on 17 April 2024).
181. Eco-Habit. Available online: https://www.eco-habit.it/energie-rinnovabili/mini-eolico/ (accessed on 17 April 2024).
182. AGR Solar Technology. Available online: https://www.agrsolartechnology.com/scheda-tecnica.html (accessed on 17 April 2024).
183. Media Amazon. Available online: https://m.media-amazon.com/images/I/71w2d6DrBUL.pdf (accessed on 17 April 2024).
184. Tumo Int Corporation Ltd. Available online: https://store.tumo-int.com/products/tumo-int-1000w-wind-turbine-generator-kit-with-wind-boosting-controller-24-48v?pr_prod_strat=use_description&pr_rec_id=8eb185ba7&pr_rec_pid=4516369301603&pr_ref_pid=4517174345827&pr_seq=uniform (accessed on 17 April 2024).
185. xprt Energy. Available online: https://www.energy-xprt.com/products/bergey-model-excel-1-residential-wind-turbine-236913 (accessed on 17 April 2024).
186. WATT-U-NEED. Available online: https://www.wattuneed.com/en/wind-turbine/1593-1kw-bergey-excel-wind-turbine-24v-or-48v-charging-models-0712971129535.html (accessed on 17 April 2024).
187. AUTOMAXX. Available online: https://automaxxwindmill.com/product/automaxx-windmill-1500w-wind-turbine-generator-kit-bundle-set/ (accessed on 17 April 2024).
188. WINDANDSOLAR. Available online: https://windandsolar.com/raptor-g4-5-blade-freedom-wind-turbine-generator (accessed on 17 April 2024).
189. WINDANDSOLAR. Available online: https://windandsolar.com/raptor-g4-7-blade-freedom-wind-turbine-generator/ (accessed on 17 April 2024).
190. WINDANDSOLAR. Available online: https://windandsolar.com/raptor-g4-9-blade-freedom-wind-turbine-generator/ (accessed on 17 April 2024).
191. WINDANDSOLAR. Available online: https://windandsolar.com/raptor-g4-11-blade-freedom-wind-turbine-generator/ (accessed on 17 April 2024).
192. WINDANDSOLAR. Available online: https://windandsolar.com/raptor-g5-freedom-wind-turbine-generator/ (accessed on 17 April 2024).
193. WINDANDSOLAR. Available online: https://windandsolar.com/falcon-wind-turbine-generator/ (accessed on 17 April 2024).
194. WINDANDSOLAR. Available online: https://windandsolar.com/falcon-5-blade-wind-turbine-generator/ (accessed on 17 April 2024).
195. ATO. Available online: https://www.ato.com/1000w-wind-turbine-24v48v (accessed on 17 April 2024).

196. Gruppo Coelca. Available online: https://coelca.es/aerogeneradores/371-aerogeneradores-kit-aerogenerador-windforce-15000-24v-automatico-125kwh-mes-xunzel.html (accessed on 17 April 2024).
197. Fast Trading LTD. Available online: https://it.istabreeze.store/prodotti/i-1000-generatore-eolico?variant=31827621871756 (accessed on 17 April 2024).
198. iSTA BREEZE. Available online: https://www.b2b-istabreeze.com/index.php?route=product/product&product_id=54&search=i-1000+Wind+Turbine (accessed on 17 April 2024).
199. Fast Trading LTD. Available online: https://en.istabreeze.store/Products/istabreeze%C2%AE-i-1500-wind-generator?variant=37412300619964 (accessed on 17 April 2024).
200. iSTA BREEZE. Available online: https://www.b2b-istabreeze.com/index.php?route=product/product&product_id=55&search=i-1500+Wind+Turbine (accessed on 17 April 2024).
201. Fast Trading LTD. Available online: https://en.istabreeze.store/Products/wind-generator-istabreeze%C2%AE-i-2000-series?_pos=2&_sid=8e7dd6531&_ss=r (accessed on 17 April 2024).
202. iSTA BREEZE. Available online: https://www.b2b-istabreeze.com/index.php?route=product/product&product_id=56&search=i-2000+Wind+Turbine (accessed on 17 April 2024).
203. Made-in-China. Available online: https://windkings.en.made-in-china.com/product/FMgxqQUbbepo/China-Wind-Turbine-Permanent-Magnet-Generator-FD3-0-1000W-.html (accessed on 17 April 2024).
204. Foshan Ouyad Electronic Co., Ltd. Available online: https://www.ouyad.com/WindTurbine_160.html (accessed on 17 April 2024).
205. WATTUNEED. Available online: https://www.wattuneed.com/en/wind-turbine/1594-6kw-bergey-excel-wind-turbine-230vac-50hz-grid-inertie-0712971129542.html (accessed on 17 April 2024).
206. AliExpress. Available online: https://it.aliexpress.com/item/1005005925430235.html?spm=a2g0o.productlist.main.85.473fqkXeqkXecx&algo_pvid=11d9f4e8-8922-481d-9214-e6958aa17af9&aem_p4p_detail=2023101002495815355295751149280000140460&algo_exp_id=11d9f4e8-8922-481d-9214-e6958aa17af9-42&pdp_npi=4@dis!EUR!2611.91!992.53!!!2697.42!!@211b801b16969313987494819e12b1!12000034876302730!sea!IT!0!AB&curPageLogUid=hc3U8aRmdOdb&search_p4p_id=2023101002495815355295751149280000140460_43#nav-review (accessed on 17 April 2024).
207. AliExpress. Available online: https://it.aliexpress.com/item/1005005581876733.html?spm=a2g0o.detail.1000014.5.33eamCU5mCU5SQ&gps-id=pcDetailBottomMoreOtherSeller&scm=1007.40000.326746.0&scm_id=1007.40000.326746.0&scm-url=1007.40000.326746.0&pvid=82d27bf4-23cd-4b4c-b4b1-1fce44ca6127&_t=gps-id:pcDetailBottomMoreOtherSeller,scm-url:1007.40000.326746.0,pvid:82d27bf4-23cd-4b4c-b4b1-1fce44ca6127,tpp_buckets:668#2846#8108#198&pdp_npi=4@dis!EUR!1090.97!414.57!!!1126.69!!@211b5e2c16969333121597133ea94e!12000033634368582!rec!IT!!AB&search_p4p_id=202310100321521967568764678755760435_0 (accessed on 17 April 2024).
208. N.A.P.S. Solar Store. Available online: https://www.solar-store.com/store/whisper-500-wind-turbine/ (accessed on 17 April 2024).
209. Quantum3. KOHILO Wind. Available online: https://www.linkedin.com/company/kohilo-wind/about/ (accessed on 17 April 2024).
210. SEC. Available online: https://www.sec.co.th/product/wind-turbine/ds1500 (accessed on 17 April 2024).
211. SEC. Available online: https://www.sec.co.th/product/wind-turbine/ds3000 (accessed on 17 April 2024).
212. ETNEO. Available online: https://etneo.com/prodotto/eolico-verticale-ibrido-3000w/ (accessed on 17 April 2024).
213. FLTXNY. Available online: https://www.flytpower.com/tulip-flower-turbine-1000w-vertical-wind-generator-low-rpm-generator-wind-turbine-price-product/ (accessed on 17 April 2024).
214. ENESSERE Srl. Available online: https://www.enessere.com/en/wp-content/uploads/sites/2/2022/10/22.03.24-complete-technical-data-appendix-enessere-pegasus-it_en.pdf (accessed on 17 April 2024).
215. ENESSERE Srl. Available online: https://www.enessere.com/prodotti/pegasus-wind-turbine/#:~:text=Tramite%20il%20suo%20alternatore,%20ENESSERE%20Pegasus%20Wind%20Turbine,ha%20una%20rumorosit%C3%A0%20molto%20bassa%20(circa%2038%20dBA) (accessed on 17 April 2024).
216. Allegro. Available online: https://allegro.pl/oferta/turbina-wiatrowa-pionowa-ecorote-2800w-vawt-wind-12075466783 (accessed on 17 April 2024).
217. Levac Solar. Available online: https://www.levac-solar.com/accueil/4130-eolienne-ecorote-15kw-injection-r%C3%A9seau.html (accessed on 17 April 2024).
218. Solariss. Available online: https://www.solariss.sk/Vertikalna-veterna-turbina-1000w-12-24v-d475.htm?tab=description#anch1 (accessed on 17 April 2024).
219. AEOLOS. Available online: https://www.windturbinestar.com/mini-eolico-verticale-5kw.html (accessed on 17 April 2024).
220. Renugen. Available online: https://store-7wpeis.mybigcommerce.com/aeolos-aeolos-v-5000w-5000w-off-grid-wind-turbine/ (accessed on 17 April 2024).
221. Wind-Turbine-Models. Available online: https://it.wind-turbine-models.com/turbines/1853-aeolos-aeolos-v-5kw (accessed on 17 April 2024).
222. REUK.co.uk. Available online: http://www.reuk.co.uk/wordpress/wind/quiet-revolution-qr5-vawt/ (accessed on 17 April 2024).
223. WIKIPEDIA. Available online: https://en.wikipedia.org/wiki/Quietrevolution_wind_turbine (accessed on 17 April 2024).
224. Renugen. Available online: https://store-7wpeis.mybigcommerce.com/quiet-revolution-qr6-7-5kw-7500-watt-wind-turbine/ (accessed on 17 April 2024).
225. VWT Power. Available online: https://vwtpower.com/ (accessed on 17 April 2024).
226. Quietrevolution. Available online: https://www.quietrevolution.com/products/ (accessed on 17 April 2024).

227. AliExpress. Available online: https://it.aliexpress.com/item/1005005066900234.html?pdp_npi=2@dis!EUR!488,33%E2%82%AC!488,33%E2%82%AC!!!!!@211b813b16854350504741675e3fcd!12000031506951497!btf&_t=pvid:fc384f7b-933a-4d07-bcb1-3f831f498375&afTraceInfo=1005005066900234__pc__pcBridgePPC__xxxxxx__1685435050&spm=a2g0o.ppclist.product.mainProduct&gatewayAdapt=glo2ita (accessed on 17 April 2024).
228. AliExpress. Available online: https://de.aliexpress.com/item/1005005305662736.html (accessed on 17 April 2024).
229. AliExpress. Available online: https://it.aliexpress.com/item/1005005996849233.html?spm=a2g0o.detail.1000014.22.46bc9Dqq9Dqq2L&gps-id=pcDetailBottomMoreOtherSeller&scm=1007.40000.326746.0&scm_id=1007.40000.326746.0&scm-url=1007.40000.326746.0&pvid=1b3a3f4c-cb89-468e-9515-368f1e1e9487&_t=gps-id:pcDetailBottomMoreOtherSeller,scm-url:1007.40000.326746.0,pvid:1b3a3f4c-cb89-468e-9515-368f1e1e9487,tpp_buckets:668#2846#8107#93&pdp_npi=4@dis!EUR!1735.28!832.93!!!13176.00!!@211b61ae16954099862222697ef587!12000035230716541!rec!IT!!AB (accessed on 17 April 2024).
230. Flower Turbines. Available online: https://www.flowerturbines.com/large (accessed on 17 April 2024).
231. Flower Turbines. Available online: https://www.flowerturbines.com/_files/ugd/bd2d84_4f64149dc6ff427389a20d58f3bea131.pdf (accessed on 1 April 2024).
232. About Generator. Available online: http://www.aboutgenerator.com/products/400-30kw-horizontal-axis-wind-turbine-with-maglev-generator_mG9jb2RtlmRm.html (accessed on 17 April 2024).
233. Bergey WindPower. Available online: https://www.bergey.com/products/grid-tied-turbines/excel-10/ (accessed on 17 April 2024).
234. World Wind Energy Association. Generating Electricity at a Lower Cost: New Bergey Excel 15 kW Small Wind Turbine. Available online: https://www.youtube.com/watch?v=F2miqHP6oTk (accessed on 17 April 2024).
235. Bergey WindPower. Available online: https://www.bergey.com/products/grid-tied-turbines/excel-15/ (accessed on 17 April 2024).
236. Renugen. Available online: https://store-7wpeis.mybigcommerce.com/ryse-energy-e-10-10kw-wind-turbine/ (accessed on 17 April 2024).
237. Ryse Energy. Available online: https://www.ryse.energy/10kw-wind-turbines/ (accessed on 17 April 2024).
238. Renugen. Available online: https://store-7wpeis.mybigcommerce.com/gaia-wind-11kw-wind-turbine/ (accessed on 17 April 2024).
239. GEATECNO. Available online: https://www.casaportale.com/download/Brochure_new.pdf (accessed on 17 April 2024).
240. Ink. Available online: https://inkpv.com/product/solar-and-wind-power-system/30kw-wind-turbine/#:~:text=A%2030kw%20wind%20turbine%20price%20is%20$17894%20What,dump%20load,%20inverter,%20battery,%20and%20the%20cable%20accessory (accessed on 17 April 2024).
241. Rotiel. Available online: https://zotiel.com/product/sishuinianhua-8000w-12v-24v-5-blades-vertical-axis-wind-turbines-generator-lantern-motor-kit-for-home-hybrids-streetlight-use-electromagnetic12v/ (accessed on 17 April 2024).
242. Amazon. Available online: https://www.amazon.it/WANGYONGQI-Generatore-Dellasse-Verticale-Controller/dp/B09DGR273H (accessed on 17 April 2024).
243. Amazon. Available online: https://www.amazon.it/SMJY-Generatore-Verticale-Controller-Domestico/dp/B0BCW3TZG5 (accessed on 17 April 2024).
244. Allegro. Available online: https://allegro.pl/oferta/turbina-wiatrowa-pionowa-ecorote-9800w-vawt-wind-12075465499?reco_id=47535662-78e2-11ee-bee5-625354eba5f6&sid=041047f9c36843e364ecb91b45c568a2755aa386fe7e14ee7421a14291fbf951 (accessed on 17 April 2024).
245. Flexpro Industry. Available online: https://www.flexpro-industry.com/e-commerce/it/turbina-eolica-asse-verticale/78-verticale-del-vento-turbina-10kw-10000w.html (accessed on 17 April 2024).
246. Ecolibrì. Available online: https://www.ecolibri.it/it/turbina-eolica/turbina-10kw/ (accessed on 17 April 2024).
247. AEOLOS. Available online: https://www.windturbinestar.com/mini-eolico-verticale-10kw.html (accessed on 17 April 2024).
248. Renugen. Available online: https://www.renugen.co.uk/aeolos-aeolos-v-grid-on-10kw-10kw-wind-turbine/ (accessed on 17 April 2024).
249. SunSurfs. Available online: https://www.attainablehome.com/the-7-best-10kw-home-small-wind-turbines/ (accessed on 1 April 2024).
250. Dworak, P.; Mrozik, A.; Korzelecka-Orkisz, A.; Tański, A.; Formicki, K. Energy Self-Sufficiency of a Salmonids Breeding Facility in the Recirculating Aquaculture System. *Energies* **2023**, *16*, 2565.
251. SunSurfs. Available online: https://sites.google.com/illinois.edu/mini-project-3-gp4/analyze (accessed on 1 April 2024).
252. Windside. Available online: https://windside.com/products/ws-12/ (accessed on 17 April 2024).
253. ArchiEXPO. Available online: https://pdf.archiexpo.com/pdf/windside/ws-12/88530-319009.html (accessed on 17 April 2024).
254. Renugen Renewable Generation. Available online: https://renugen.co.uk/windside-ws-12-25kw-wind-turbine/ (accessed on 17 April 2024).
255. TESUP. Available online: https://www.tesup.it/product-page/turbina-eolica-hera-wind-pro-Italia (accessed on 17 April 2024).
256. TESUP. Available online: https://www.tesup.it/product-page/turbina-eolica-atlas7-Italia (accessed on 17 April 2024).
257. TESUP. Available online: https://www.tesup.it/product-page/turbina-eolica-atlasx7-per-le-case (accessed on 17 April 2024).
258. Eltayesh, A.; Castellani, F.; Burlando, M.; Hanna, M.B.; Huzayyin, A.S.; El-Batsh, H.M.; Bacchetti, M. Experimental and numerical investigation of the effect of blade number on the aerodynamic performance of a small-scale horizontal axis wind turbine. *Alex. Eng. J.* **2021**, *60*, 3931–3944. [CrossRef]
259. Pellegrini, M.; Guzzini, A.; Saccani, C. Experimental measurements of the performance of a micro-wind turbine located in an urban area. *Energy Rep.* **2021**, *7*, 3922–3934. [CrossRef]

260. Kanya, B.; Visser, K.D. Experimental Validation of a Ducted Wind Turbine Design Strategy. *Wind Energy Sci.* **2018**, *3*, 919–928. [CrossRef]
261. Hasan, M.E.; Eltayesh, A.; Awaad, M.I.; El-Batsh, H.M. Experimental Examination for the Electric Power Generation of a Commercial Small-scale Wind Turbine with Modified Aerodynamic Design. *Alex. Eng. J.* **2023**, *64*, 25–39. [CrossRef]
262. Singh, R.K.; Ahmed, M.R. Blade design and performance testing of a small wind turbine rotor for low wind speed applications. *Renew. Energy* **2013**, *50*, 812–819. [CrossRef]
263. Elshazly, E.; Eltayeb, N.; Fatah, A.A.A.; El-Sayed, T.A. Experimental and computational investigation of energy ball wind turbine aerodynamic performance. *Adv. Mech. Eng.* **2019**, *11*, 1687814019879546. [CrossRef]
264. Moussa, M.O. Experimental and numerical performances analysis of a small three blades wind turbine. *Energy* **2020**, *203*, 117807. [CrossRef]
265. Lo Brano, V.; La Rocca, V.; Ciulla, G.; Moreci, E.; Beccali, M. Energy and economic assessment of a small domestic wind turbine in Palermo. In Proceedings of the 16th International Conference on Environment and Electrical Engineering (EEEIC), Florence, Italy, 6–7 June 2016.
266. SPEEDLINER. Available online: https://www.speedliner.com.au/spray-ute-tray-liner/spray-plastic-coating/ (accessed on 17 April 2024).
267. PHOENIX CONTACT. Available online: https://www.phoenixcontact.com/en-us/products/current-transducer-mcr-s-15-ui-dci-2814634 (accessed on 17 April 2024).
268. LEM. Available online: https://www.lem.com/en/product-list/lv-25psp5 (accessed on 17 April 2024).
269. Futek Advanced Technology. INC. Available online: https://www.futek.com/store/multi-axis-sensors/triaxial/triaxial-load-cell-MTA400/FSH04139 (accessed on 17 April 2024).
270. OnlineCOmponents.com. Available online: https://www.onlinecomponents.com/en/datasheet/xub5apbnl2-43924043/ (accessed on 17 April 2024).
271. Made-in-China. Available online: https://ginlong.en.made-in-china.com/product/jqbEQcMdCopn/China-1-8kw-Wind-Turbine-Generator-GL-PMG-1800-.html (accessed on 17 April 2024).
272. Etw Cloud. Available online: https://www.etwinternational.co.uk/1-1-3-shutter-mount-exhaust-fan-125152.html (accessed on 17 April 2024).
273. VISIOTECH. Available online: https://www.visiotechsecurity.com/en/products/xs-nvr4324-ap4k-detail?showall=1#tab=prod_0 (accessed on 17 April 2024).
274. Campbell. Available online: https://www.campbellsci.com/cr1000x (accessed on 17 April 2024).
275. Vector Instruments. Available online: http://www.windspeed.co.uk/ws/index.php?option=displaypage&op=page&Itemid=48 (accessed on 17 April 2024).
276. FLUKE. Available online: https://www.fluke.com/en-us/product/electrical-testing/power-quality/345 (accessed on 17 April 2024).
277. TEST-IT. Available online: https://www.test-italy.it/fluke-189-c2x23230571 (accessed on 17 April 2024).
278. MOUSER ELETRONICS. Available online: https://www.mouser.it/ProductDetail/Vishay-Dale/RH250-4-1?qs=j1ruRH/HY9kzM9vTYqFeYQ== (accessed on 17 April 2024).