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Date: October 17, 2025

Subject: A Review of Commercially Available Vertical Axis Wind Turbines

Introduction

To investigate the breadth of current commercial Vertical Axis Wind Turbine technology, we compiled a list of 33 VAWTs using "Commercial Small-Scale Horizontal and Vertical Wind Turbines: A Comprehensive Review of Geometry, Materials, Costs and Performance" [1], as well as a list of the most commercially successful VAWTs from Perplexity, an Artificial Intelligence software. We did a broad investigation into the basic designs and parameters of each of these turbines. From these designs, we evaluated one design of each common type of Vertical-Axis Wind Turbine (Darrieus: Helical or Eggbeater or H-type, Savonius: Tulip or standard). We decided which of the designs to evaluate by how much documentation is given, how commercially successful the design appears to be, and how common the design is in the broader sphere of commercially available VAWTs.

There are 5 designs we studied more in depth: The Quiet Revolution Qr6, (**Figure 1**), The Wind Harvester 4.0 (**Figure 2**), The Tulip (**Figure 4**), The DS3000 (**Figure 5**), The UGE 4k (**Figure 8**). Technological information and considerations of where these designs have succeeded, as well as their limitations are detailed in the memo below.

1. Quiet Revolution Qr6 Vertical Axis Wind Turbine

Figure 1. Quiet Revolution Qr6 Vertical Axis Wind Turbine static (left) and in motion (right) [48]

The Quiet Revolution 7.5kW Qr6 Vertical Axis Wind Turbine (**Figure 1**) is a helical 3-bladed Darrieus-type turbine designed for urban environments. Manufactured by VWT Power Limited in the UK, the Qr6 has a cut-in speed of 3m/s, a high wind cut-out speed around 20m/s, and a low wind cut-out speed of 2.0m/s [48]. The turbine measures 5.5m in height and 3.1m in diameter, giving it a swept area of about 16m², and weighs roughly 1,650kg including its mast and base [50]. It can be roof-mounted on a 6m tilt-down mast or ground-mounted on 15m or 18m masts, making it adaptable for urban or rural settings [49]. The mast itself is modular, making installation and maintenance simpler and less expensive by allowing the turbine to be tilted down or partially disassembled [49]. The Qr6 uses aero-elastic carbon-fiber composite blades which serve to absorb vibration [50]. The Qr6 has an operating temperature range of -30°C to 55°C, sells for around $44,684 USD, and has an expected design life of 30+ years [49].

Key features of the Qr6 provide useful insights for a future VAWT design. The helical blades could be explored to optimize torque smoothness and improve energy capture, the aero-elastic composite blades merit further study to assess how certain materials can reduce vibration and mitigate structural stress, and the modular mast warrants consideration for simplifying installation and maintenance while lowering costs. Additionally, the inclusion of a programmable controller highlights the potential benefits of active control and automated protection for safe and efficient operation across variable wind conditions.

2. Wind Harvester 4.0

Another type of VAWT which is often seen in commercial technology is the H-type or straight bladed VAWT. An emerging company that produces H-type VAWTs is “Wind Harvest”, based in Sacramento, California [65]. The company caters to wind farms, rather than urban designs. However, the design is a good demonstration of what’s currently available and who these designs target. One of their designs, the “Wind Harvester 4.0” (**Figure 2**) is available for order now, to be delivered in 2026.

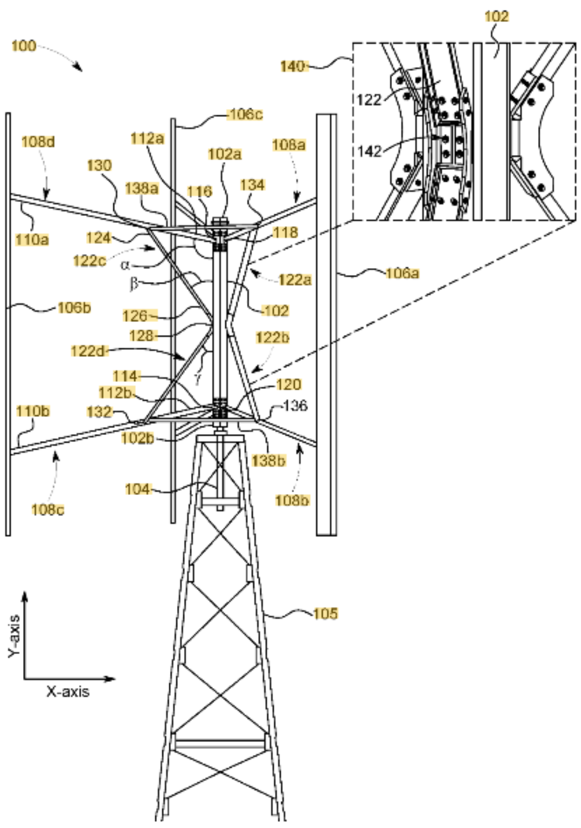

Figure 2. Wind Harvester 4.0 [66]

The Wind Harvester 4.0 is made of galvanized steel and aluminum for the base and blade extruded aircraft aluminum for the blades. The turbine has a 13m rotor diameter, three 13m blades, and a total minimum height of 17.5m (**Figure 2**). It requires maintenance and part replacement every 15-20 years. The ideal power generated from the smallest size of Wind Harvester is 70kW. The rated speed is 11m/s, the cut-in speed is 5m/s, the cut-out speed is 25m/s, and the survival wind speed is 60m/s. At 6m/s, around the average wind speed in urban environments, provides a capacity factor of 29.5%, this would provide 181 MWh/year/turbine [65].

A model of the rated (maximum) power based on wind speed for the current model, the former model, and the current model when coupled with other wind turbines (Figure 3) provides further insight into the Electric Power the Wind Harvester 4.0 is capable of producing. A feature of many VAWTs often highlighted in commercial applications, this being one of them, is the vortex effect, in which

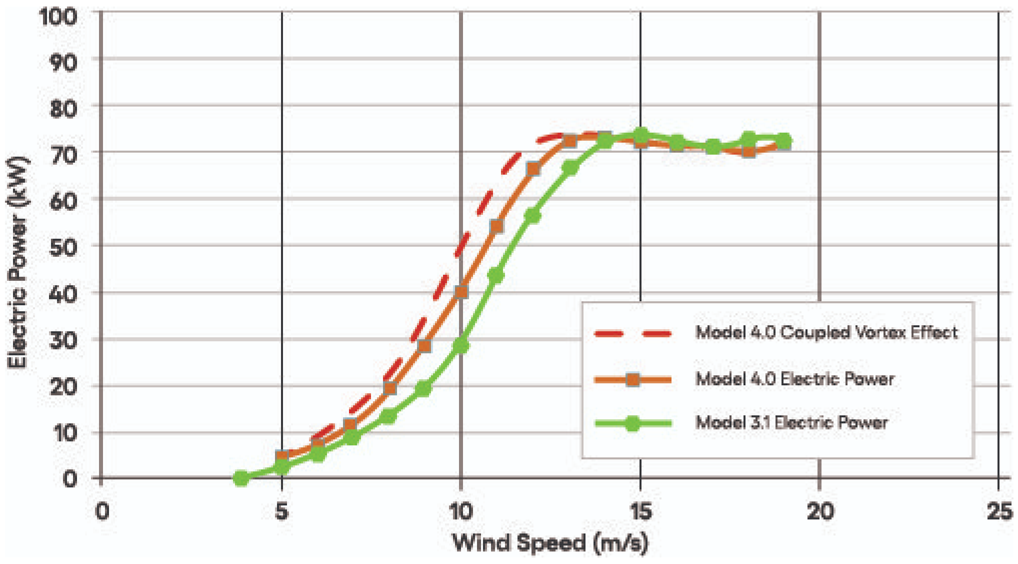

Figure 3. Wind Speed and Electric Power relationship for Wind Harvester [65]

The Wind Harvester has some special design features, mainly focused on durability, that attempt to fill some of the holes in VAWT technology thus far [66]. They have patented the use of braces to eliminate the need for cables, hinge blade connections, and a hexagonal center axis for easier connection to blades. This design may not handle the highly turbulent winds in urban areas as successfully as other designs nor is it directly applicable to rooftop applications at this scale.

3. Tulip Vertical Axis Wind Turbine

Figure 4. Tulip Vertical Axis Wind Turbine side view (left) and top view (right) [52]

The Flower Turbines 500W Medium Tulip Vertical Axis Wind Turbine (**Figure 4**) is a compact, Savonius-type turbine designed for residential and small-scale commercial applications [52]. The Tulip has a cut-in speed of 0.7m/s, a max survival speed of 54m/s, and the cut-out speed is regulated by an electrical brake system [51]. It is approximately 3m tall with 2m high and two 1.18m wide thermoplastic blades. The turbine converts mechanical energy to electricity through a permanent magnet generator connected to a battery and inverter system, supporting both off-grid and on-grid configurations. Its lightweight design of 227.25kg and modular pole system, which can tilt down for maintenance, make it adaptable to a variety of installation sites, including rooftops that can safely support its weight and ground-based concrete foundations. The Tulip has an operating temperature range of -15°C to 50°C, sells for around $9,349.26 USD, and has an expected design life of 40 years with yearly maintenance [51].

Several features of the Flower Turbine provide insights for a future VAWT design. Related to the compact "tulip" shape of the VAWT, its "Bouquet Effect" enhances the performance of neighboring turbines, with closely positioned units producing more total energy than the same turbines separated, suggesting that turbine interactions could be leveraged to improve array efficiency [52]. This also highlights the factor of how a turbine's design can influence airflow patterns, which may be important when considering placement on rooftops and constrained environments. The modular pole system merits consideration for simplifying installation and maintenance, similar to the Qr6's mast design. The use of thermoplastic blades warrants further study, as the material is uncommon for VAWTs and may offer advantages in performance, flexibility, or durability.

4. DS3000W

Figure 5. DS3000W Model [68]

The DS3000W (**Figure 5**) is a hybrid wind turbine with a rated power at 3kW, it consists of an outer "egg-beater" darrieus and an inner 2-layered Savonius . The Darrieus has 3 blades and each Savonius has 2 blades. The DS3000W is made by Etneo Italia srl, located in Novara, Italy. The applications this model is marketed towards are single-family homes, wind farms, parking lots, and radio towers. The start-up speed for this model is 2.0m/s, the cut-in speed is 2.2m/s, the cut-out speed is 14.0m/s, and the survival wind speed is 60m/s. The DS3000W is made of anodized aluminum, has a rotor diameter of 4m, Darrieus blade length of 4.16m, and a tower height of 4m, not including the turbine itself. It has operating temperatures between 20 and 40°C. This turbine costs 17,500 Euros, which is around $20,500 [67,68].

The company additionally provides expected annual power production. They indicate a yearly energy output ranging from 2,851kWh at 5m/s to 8,945 kWh at 8m/s. The lower end of this range is around 0.25% the yearly power production of a 60,000 sq. ft. college building. This is higher than the expected yearly power production rate, see "Ideal and Realistic Power Output from a VAWT" section. The rated power of 3kW occurs at 12m/s, though while mounted on a rooftop in an urban area, it would generally be operating at lower wind speeds around the 5m/s range. An efficiency curve is shown below, demonstrating the efficiency of the wind turbine at different wind speeds (**Figure 6**) [67,68].

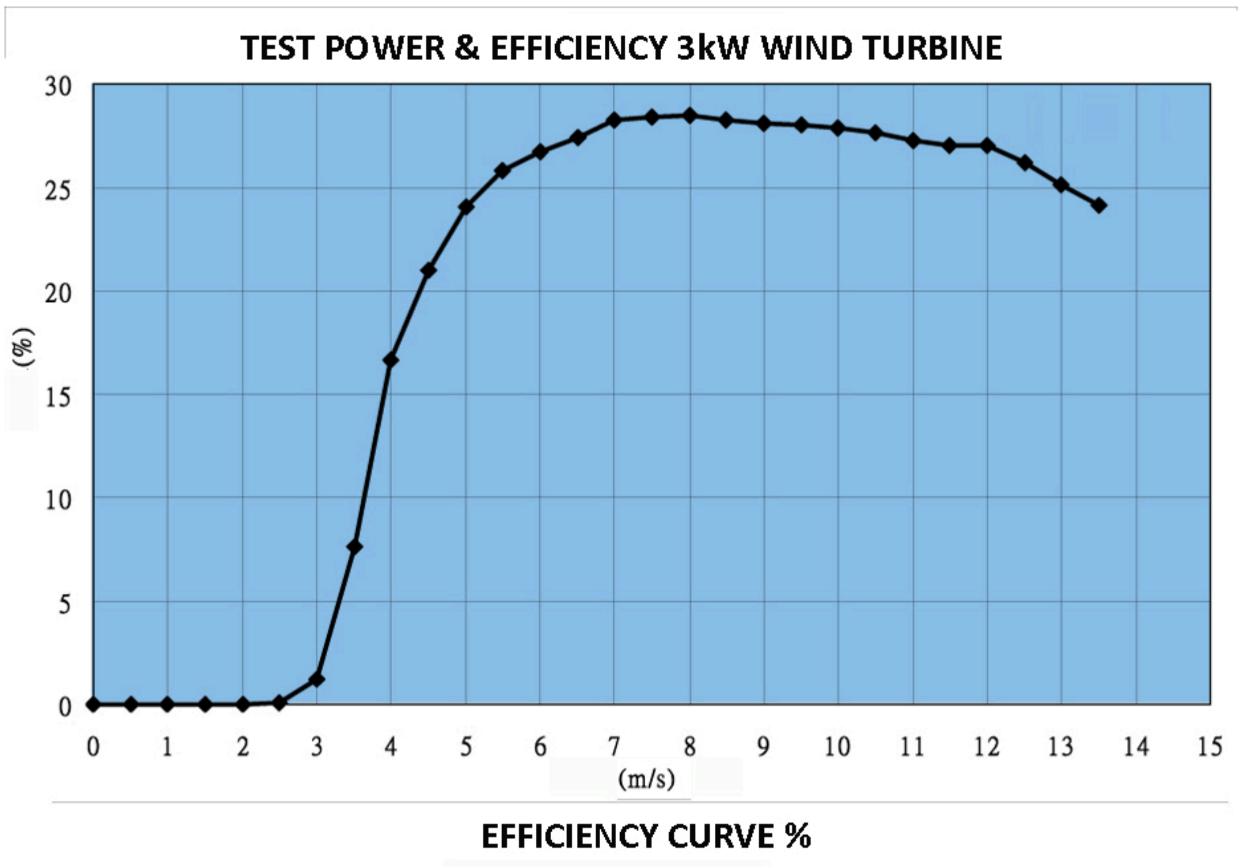

Figure 6. Efficiency Curve for DS3000W.

The hybrid design of the ds3000 provides it with the capability to capture low wind speeds via the Savonius element, and higher wind speeds via the Darrieus element [68]. The Savonius segment has blades facing in all 4 cardinal directions to capture wind from all those directions (**Figure 7**). The design additionally boasts strong connections for the darrius blades via connecting brackets (**Figure 7**).

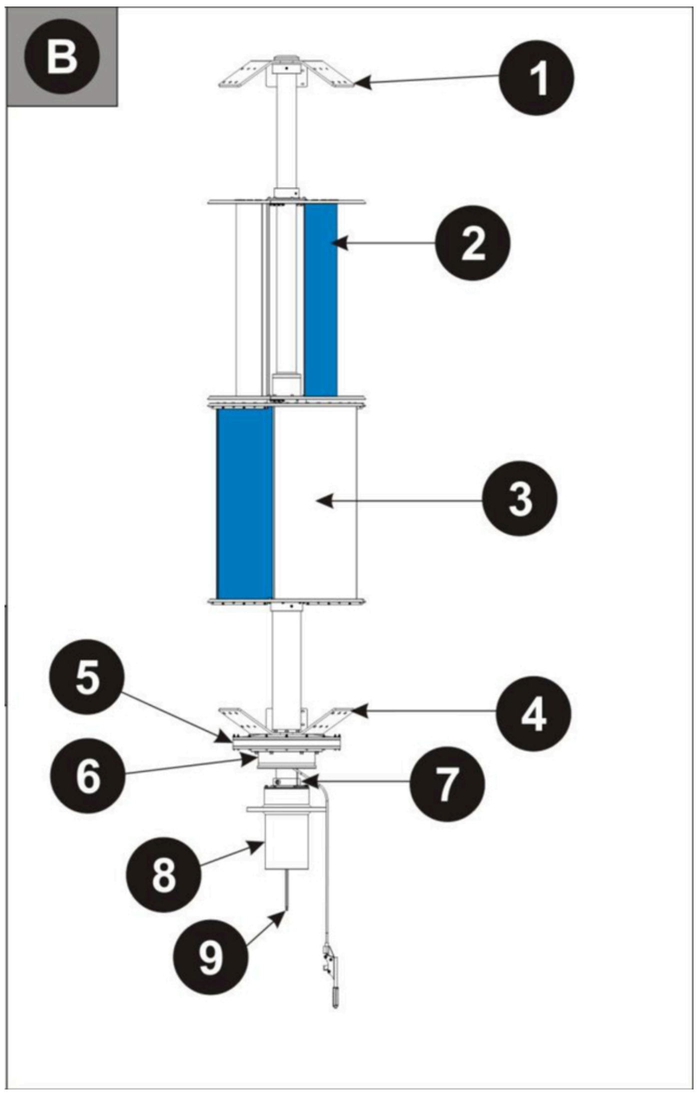

Figure 7. 1 and 4 are where the darrius blades connect into the center pole. 2 and 3 illustrate the directions the Savonius blades face.

The ds3000 was chosen for in depth investigation because it is ICC (International Code Council) certified and boasts of being commercially available, with installations all over the world. It was actually the first vertical axis wind turbine to be ICC certified in the US in 2019. An additional reason this design was chosen is because hybrids are one of the more promising options in small wind power [40]. The concept of a hybrid is combining a Savonius and Darrieus turbine into one, there are many different hybrid models using different sizes and types of each design, this is one successful example representing a wide range of hybrids.

5. Urban Green Energy 4K

Figure 8. Urban Green Energy 4K Vertical Axis Wind Turbine [63]

The UGE-4K Vertical Axis Wind Turbine (**Figure 8**) is a helical-bladed Darrieus-type model developed by Urban Green Energy (UGE) for distributed and urban wind generation. The turbine is no longer in production following the sale and rebranding of UGE's wind division as V-Air Wind [61]. It stands approximately 4.6m tall with a 3.1m rotor diameter, giving a swept area of about $14.1m^2$, and weighs roughly 461kg [64]. The UGE-4K's cut-in wind speed is 3.5m/s, rated wind speed is 12m/s, cut-out is 25m/s, and survival speed is 60m/s, with an operating temperature range of −20°C to 50°C [64]. The turbine features a permanent magnet direct-drive generator and a patented Dual-Axis Technology (DAT) system, which distributes loads more evenly across the rotor and tower, suggesting that exploring similar load management approaches could improve structural stability and longevity in a future VAWT design [63].

Conclusion

Through this review of existing commercial VAWT designs, several trends and opportunities for improvement have been identified. The next steps include further investigation of patents related to promising design features such as aero-elastic composite blades for vibration reduction, hybrid configurations for broader wind-speed performance, and load-distribution systems like UGE's Dual-Axis Technology (DAT) for enhanced structural stability. Modular mast or pole systems that simplify installation and maintenance will also be explored. Concurrently, the concept generation phase of the design process will begin.

It is important to consider common commercial VAWT designs when determining how to ideate upon them. There are benefits and drawbacks to different VAWT designs. There needs to be further improvements to the capability of VAWTs to fulfill the need for harnessing wind energy in urban areas.

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