Diversifying the Energy Matrix: Implementation of Vertical Axis Wind Turbines in Urban Areas in Argentina

Acosta Darrichón Enzo Juan Ángel [#1], Usinger Kornschuh Federico Agustín [*2]

[#] *Universidad Tecnológica Nacional, 1033 Almafuerte Av., Paraná, 3100, Argentina*

[1] enzoacostadarrichon@alu.frp.utn.edu.ar

[2] federicousingerkornschuh@alu.frp.utn.edu.ar

***Abstract*—In the global shift towards renewable energy, efforts to expedite implementation are underway. Currently, renewable energy constitutes 13.47% of the world's total energy matrix. However, Argentina, despite embracing various renewable energy sources, lags behind in comparison to fossil fuels and nuclear energy. Faced with the overreliance on fossil fuels nationally, a global trend towards deploying low-power wind turbines, operable in winds as low as 2 [m/s], has emerged. This study aims to showcase the viability of integrating Vertical Axis Wind Turbines (VAWTs) in Argentina's urban areas, aiming to diminish fossil fuel usage and enhance wind power generation. The paper begins by providing an overview of the country's energy landscape and its wind energy production capacities. Subsequently, it delves into VAWTs, exploring types and characteristics, followed by examples of commercial products. The advantages and disadvantages of the system are analyzed. The expected contribution is to investigate why VAWTs are a good solution in urban environments to address contemporary climate challenges, promoting a sustainable and environmentally friendly energy solution, applicable at national and international levels.**

Keywords: **Darrieus turbines, Savonius turbines, vertical axis wind turbines (VAWT), wind energy.**

***Resumen*—En el actual cambio global hacia las energías renovables, se busca acelerar su implementación, representando actualmente el 13.47% de la matriz energética mundial. Sin embargo, Argentina, a pesar de adoptar diversas fuentes de energía renovable, se rezaga frente a los combustibles fósiles y la energía nuclear. Frente al excesivo uso de combustibles fósiles a nivel nacional, surge una tendencia global hacia la adopción de aerogeneradores de baja potencia, capaces de operar con vientos de 2 [m/s] o más bajos. Este estudio tiene como objetivo demostrar la viabilidad de integrar Aerogeneradores de Eje Vertical (AEV) en zonas urbanas de Argentina, con la meta de reducir el consumo de combustibles fósiles y aumentar la generación eólica. El documento inicia presentando el panorama energético del país y sus capacidades de producción de energía eólica, para luego explorar los AEV, sus tipos y características, seguido de ejemplos de productos comerciales. Se analizan las ventajas y desventajas del sistema. La contribución esperada es investigar la viabilidad de incorporar AEV en entornos urbanos para abordar desafíos climáticos contemporáneos, promoviendo una solución energética sostenible y amigable con el medio ambiente, aplicable a nivel nacional e internacional.**

Palabras clave: **Aerogeneradores de eje vertical (AEV), energía eólica, Turbinas Darrieus, Turbinas Savonius.**

I. Introduction

Today the world is in the transition to renewable energy, seeking every day to accelerate its implementation. Worldwide, the percentage of renewable energy generated represents 13.47% of the total energy in the global energy matrix [1]. In our particular case, Argentina has implemented various renewable energies but not to the same extent as fossil fuels or nuclear energy, since only 11.33% of derived energy comes from renewable sources [2]. Specifically, if we talk about wind energy, only 8% of energy in Argentina came from wind farms in 2021. Due to the latter, it is expected that by 2035 this 8% will become 23% of the National Energy Matrix (NEM)[3].

In relation to the aforementioned national context and the overuse of fossil fuels, a new trend towards the implementation of low-power wind turbines appears worldwide, capable of operating with minimum winds of 2 [m/s][4]. These turbines are called Vertical Axis Wind Turbines.

This work is related to the United Nations Sustainable Development Goal (SDG) #7 called “Affordable & Clean Energy” [5, p.37]. SDG #7 has 3 targets to be achieved by 2030. The first target establishes that countries must guarantee more modern, low-cost, and good-quality energy [5]. The second one emphasizes the need to increase the use of renewable energies globally in comparison with fossil fuels. The last target focuses on "doubling the overall rate of improvement in energy efficiency"[5, p.37].

The main objective of this work is to demonstrate the feasibility of implementing Vertical Axis Wind Turbines in urban areas in Argentina, allowing to reduce the use of fossil fuels and increase wind generation. To fulfill this objective, it will be necessary to analyze the productive capacities of the country and its regions, to know the different models of Vertical Axis Wind Turbines and analyze the advantages and disadvantages of their installation.

In order to achieve the objective stated above, this work is organized as follows. First, readers will be introduced to the country's energy context and its wind energy production capacity. Secondly, this work will address Vertical Axis Wind Turbines, the different types and their characteristics. Third, some examples of commercial products will be given. Fourth, the advantages and disadvantages of the design to be implemented will be discussed.

The expected contribution of this paper is to explore into the viability of incorporating Vertical Axis Wind Turbines in urban settings to meet contemporary climate challenges. This paper promotes a more sustainable and environmentally-conscious energy solution that can be applied around the country and replicated around the world as well.

II. Wind Patterns and wind energy production capacity across Argentina

As mentioned in the introduction, the expectations of the increase in the use of wind energy are high worldwide. Argentina is a vast territory that has a great diversity of biomes, which can be divided into five regions with different wind characteristics (Fig. 1). These regions are described by Tomás Lugaro [6] in his thesis on the characterization of the Argentine wind and these are:

- Northwest Region
- Central-Northeast Region
- South of Buenos Aires
- Central West Region
- Patagonia Region

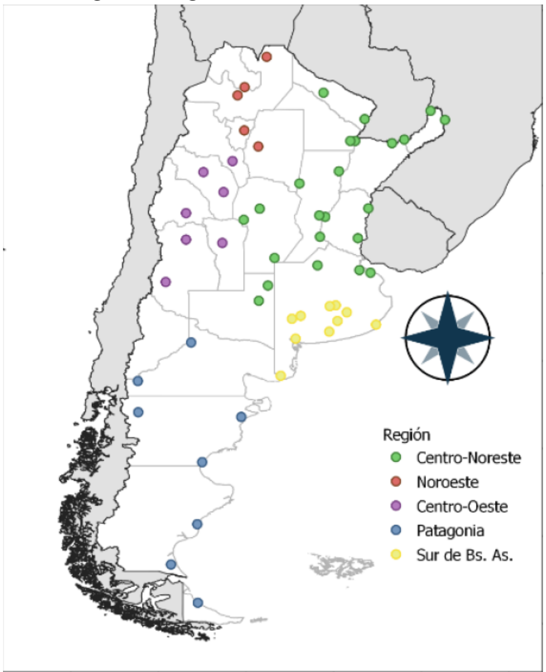


Fig. 1. Map of the biomes of Argentina. [6, p.18]

The first region mentioned is the Northwest. It is made up of the provinces of Salta, Jujuy, Santiago del Estero and Tucumán, where there is an average wind intensity of less than 10 km/h. The second region is the Central-Northeast, which includes Córdoba, the north of Buenos Aires and the entire Littoral region. The average wind intensity in this second region is between 10 and 14 km/h. The third region is the south of Buenos Aires whose average annual wind intensity ranges between 12 and 18 km/h. The fourth region is the Central-West, which covers from Neuquén to La Rioja, where its average wind intensity is around 14 km/h. As for the last region, Patagonia covers the entire southern part of the country, from Rio Negro to Tierra del Fuego, and it has an average wind intensity of 23 km/h [6].

Considering the data just mentioned, it is evident wind speeds remain above 10 km/h or 2.7 m/s most of the year in the different regions of Argentina. This information verifies the feasibility of implementing Vertical Axis Wind Turbines, which will be explored throughout the work.

III. Vertical Axis Wind Turbines

Wind turbines are the modern version of a windmill. They use the power of the wind to generate electricity. These wind turbines are made up of blades, which are attached through an axis to a reduction box. When the wind hits the blades, it causes the rotation of the axis which, through the reduction box, converts the wind into electrical energy.

To carry out the transformation of mechanical energy into electrical energy through the rotation of the axis, there are two types of wind turbines based on their relative orientation. The first type is called Horizontal Axis Wind Turbines (HAWTs). In these turbines, the rotation axis is parallel to the ground and they are characterized by the blades rotating in a direction perpendicular to the wind speed. Vertical Axis Wind Turbines, also known as VAWTs, represent the second type. In this case, the axis of rotation is perpendicular to the ground [7].

VAWTs have a distinctive feature: they do not need yaw systems. This means that they do not require complicated mechanisms to point in a specific direction or prevent blade stress when the rotor changes direction [7].

VAWTs can be installed close to the ground, making them easy to access for maintenance. Unlike HAWTs, in which the conversion systems are located on the towers and support heavy loads, VAWTs have the conversion systems practically at ground level. However, wind speeds are lower compared to those that would be obtained if they were located at higher altitudes. Although the efficiency of VAWTs is lower compared to HAWTs, they are easier to place in urban areas due to their lower noise level and their less dangerous rotation speed [4].

There are two basic designs of vertical axis rotors from which several variants arise. They are the Darrieus turbines and the Savonius turbines.

A. *Darrieus Turbines*

These turbines use the force of elevation of the air by lift. They have great efficiency since the rotor rotates faster than the speed of the wind. However, due to the particular shape of the blades, which are curved, they create a vibration in the shaft and, therefore, a greater wear on their bearings [8]. In general, these turbines need an external power source to be able to start rotating since their particular shape prevents them from starting with low wind speeds [4]. However, once set in motion, they can continue rotating until they obtain a speed faster than that of the wind. Due to the imbalance generated by the particular shape of Darrieus turbines, H-Rotor turbines were created with the same operating principle, but these have straight blades and are not as efficient as the aforementioned [8].

B. *Savonius Turbines*

They are drag turbines, which use aerodynamic resistance, in order to take advantage of the wind's energy. When the wind collides with the blades, it generates enough friction to be able to move them [4], [8]. As the wind pushes the blades, the rotation speed of Savonius turbines is much lower than the speed of wind [8].

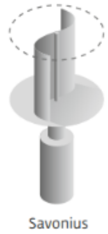
Horizontal Axis	***Vertical Axis of Support***	***Drag Vertical Axis***
		

Fig. 2. Types of wind turbines based on axis orientation. [8]

IV. Commercial products

Currently, the growing need to implement renewable energy has led the market to start producing VAWTs more and more frequently. To exemplify the types of Vertical Axis Turbines seen previously and other more commercial ones, different products available in the market will be described below.

A. Flower Turbines: Medium Tulip Wind Turbine

Fig. 3. Medium Tulip Wind Turbine. [9]

Flower Turbines manufactures Medium Tulip Wind Turbines (Fig. 3). They have two blades which are 2 meters high and 1 meter in diameter. These turbines are around three meters tall. They start operating with winds of 2 to 4 m/s and their maximum wind speed is up to 15 m/s. Although the operating speed is not specified, these turbines generate a power output of 300 to 500 watts [9], [10].

B. CEMI-023 Wind Turbine

Fig. 4. CEMI-023 Wind Turbine. [11]

Figure 4 shows the CEMI-023 Wind Turbine, produced by Coldwind. The dimensions are not specified by the manufacturer. It has a starting speed of 2.01 m/s and an operating speed of 11 m/s, with a maximum speed of 45 m/s. This turbine features four blades and can generate a power output ranging from 3.7KW to 4.2KW [11].

C. Wind Generator EOLO

Fig. 5. Wind generator EOLO. [12]

Makemu Green Energy presents the EOLO Wind Generator, with dimensions of 195 cm × 130 cm × 130 cm. Although it has an initial speed of 1.9 m/s, there is not provided information about EOLO's operating speed or its maximum speed. This turbine is available in power output options of 1KW, 2KW or 3KW, and it can have between three and twelve blades [12].

D. Wind Generator DOMUS

Fig. 6. Wind generator DOMUS. [13]

The Wind Generator Domus, also manufactured by Makemu Green Energy, has dimensions of 115 cm × 130 cm × 65 cm. Similar to the EOLO, it lacks specifications for operating and maximum speeds. This model offers power outputs of 1KW, 750W, or 500W and provides options for three or six blades [13].

E. Wind Generator SMARTWIND

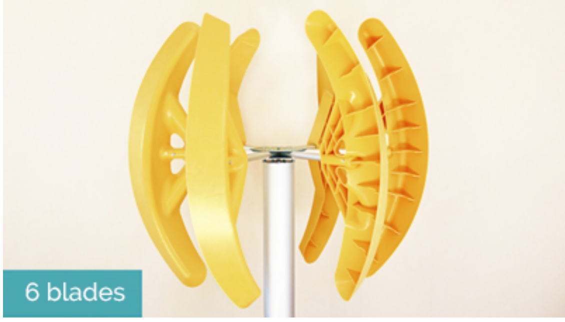


Fig. 7. Wind generator SMARTWIND. [14]

Another offering from Makemu Green Energy is the Wind Generator Smartwind, with dimensions of 130 cm × 80 cm × 85 cm. The starting speed for this turbine is 0.9 m/s, and like the others, it lacks specifications for operating and maximum speeds. It generates power ranging from 300W to 500W and is available with three or six blades [14].

F. Wind Generator NINILADY

Fig. 8. Wind generator of NINILADY. [15]

Lastly, NL produces the Wind Generator Ninilady, which stands at 1.42 meters tall. It has a starting speed of 1.31064 m/s and the operating speed is not specified. The maximum speed is 12.00912 m/s and this turbine generates between 600 and 650 watts of power with its two blades [15].

V. Vertical Axis Wind Turbines 's Advantages and disadvantages

Vertical Axis Wind Turbines represent an interesting alternative to the more common Horizontal Axis Wind Turbines in wind energy generation [4], indicating that VAWT have a series of advantages and disadvantages.

In relation to the VAWTs' advantages, these are:

- Independence of yaw mechanism;
- Ease of maintenance (can be located close to the ground);
- Very low starting speed;
- Ability to be placed anywhere in a building (on top, to the side or below);
- Suitable for placement on irregular terrain, particularly in areas such as plateaus and hilltops

As far as their disadvantages are concerned, they are:

- Lower efficiency compared to HAWT (due to its higher resistance against the vertical axis or due to the lower efficiency of the wings);
- Installation proximity to the ground, leading to reduced operational wind speeds [4]

It can be concluded then that VAWTs are less energy efficient than HAWT. However, VAWTs' ease of installation and the few wind requirements they have for the generation of wind energy make them a highly competitive product and of great importance for the development of wind energy locally and globally.

VI. Conclusion

In conclusion, Vertical Axis Wind Turbines are positioned as one of the most promising alternatives from an energy and environmental point of view for implementation in urban areas of Argentina. Their minimum requirements make them a viable option for practically any region of the country, thus presenting a tangible response to the challenge posed by the United Nations Sustainable Development Goals.

The growing popularity of VAWTs and their attractive design suggest that in the coming years we are likely to see them more frequently in the global market and to be integrated into future constructions. This trend will not only contribute to greater clean energy generation but will also reinforce Argentina's commitment to the transition towards more sustainable energy sources and its independence from fossil fuels.

References

[1] H. Ritchie and M. Roser, "Energy mix," Our World in Data. [Online]. Available: https://ourworldindata.org/energy-mix. Accessed: Apr. 16th, 2023.

[2] H. Ritchie, M. Roser, and P. Rosado, "Renewable Energy," Our World in Data. [Online]. Available: https://ourworldindata.org/renewable-energy#how-much-of-our-primary-energy-comes-from-renewables. Accessed: Apr. 16th, 2023.

[3] GlobalData, "Wind Power Capacity in Argentina and Major Projects," Power Technology. [Online]. Available: https://www.power-technology.com/data-insights/wind-power-in-argentina/#:~:text=According%20to%20GlobalData%2C%20wind%20power,total%20power%20generation%20in%202021. Accessed: Apr. 16th, 2023.

[4] M. Casini, "Small Vertical Axis Wind Turbines for Energy Efficiency of Buildings," *Journal of Clean Energy Technologies*, vol. 4, no. 1, pp. 10, Jan. 2016. Accessed: June. 03rd, 2023. [Online]. Available: http://www.jocet.org/vol4/254-H0020.pdf

[5] NU. CEPAL, "The 2030 Agenda and the Sustainable Development Goals: An opportunity for Latin America and the Caribbean (LC/G.2681-P/Rev.3)," cepal.org. Available: https://www.cepal.org/sites/default/files/events/files/2030_agenda_and_the_sdgs_an_opportunity_for_latin_america_and_the_caribbean.pdf Accessed: April. 16th, 2023.

[6] T. Lúgaro, "Caracterización climática de los vientos en Argentina a partir de datos observados y satelitales," Tesis de Licenciatura, Facultad de Agronomía, Universidad de Buenos Aires, Buenos Aires, Argentina, 2022. [Online]. Available : https://anemoi.net.ar/static/img/Tesis_Lugaro.pdf

[7] A. Eskenazi, J. P. Mela, and J. I. Artola, "Generador Eólico de eje vertical," *Instituto Tecnológico de Buenos Aires*, Abr. 2015. [Online]. Available:

https://ri.itba.edu.ar/server/api/core/bitstreams/23be51e3-a5d6-4f7c-8563-53b361467712/content

[8] B. Medina Warmburg, Ed., "Energía en Lanzarote," Lanzarote: Beatriz Medina Warmburg, 2010. [Online]. Available: https://lanzarotebiosfera.org/wp-content/uploads/2013/05/Energia-en-Lanzarote.pdf ISBN: 978-84-95938-78-7.

[9] Flower Turbines, "Flower Turbines," flowerturbines.com .https://www.flowerturbines.com/product-page/medium-tulip-wind-turbine-on-grid (accessed Jul. 5, 2023)

[10] Flower Turbines, "Frequently asked questions," https://www.flowerturbines.com/faq (accessed Jul. 5, 2023)

[11] Coldwind Vertical Axis Wind Turbine, 12V, 24V, 4200W, 4-Blade Lantern Wind Turbine Motor Kit, Power Charging Wind Turbines for Home Camping, Black 24V, Amazon, https://www.amazon.com/-/es/Coldwind-Generador-turbinas-vertical-campamento/dp/B0975C557W/ref=sr_1_1?keywords=vertical%2Baxis%2Bwind%2Bturbine&qid=1689775134&sr=8-1&th=1 (accessed Jul. 5, 2023)

[12] EOLO Wind Generator, Makemu, https://www.makemu.it/linea-prodotti/eolo/?lang=en (accessed Jul. 5, 2023)

[13] DOMUS Wind Generator, Makemu, https://www.makemu.it/linea-prodotti/domus/?lang=en (accessed Jul. 5, 2023)

[14] SMARTWIND Wind Generator, Makemu, https://www.makemu.it/linea-prodotti/smartwind/?lang=en (accessed Jul. 5, 2023)

[15] NINILADY Vertical Axis Wind Turbine, 600W Permanent Magnet Wind Turbine Generator, 3-Phase, 12V, 24V, 48V, Coreless Wind Power (12V with Controller, White), Amazon, https://www.amazon.com/-/es/NINILADY-Generador-permanente-vertical-controlador/dp/B08MPX83LG/ref=sr_1_3?keywords=vertical%2Baxis%2Bwind%2Bturbine&qid=1689719204&sr=8-3&th=1 (accessed Jul. 5, 2023)

Acosta Darrichón Enzo Juan Ángel is an Electronics Engineering student at UTN FRP: enzoacostadarrichon@alu.frp.utn.edu.ar Usinger Kornschuh Federico Agustín is a Electronics Engineering student at UTN FRP: federicousingerkornschuh@alu.frp.utn.edu.ar .

The present manuscript is part of the research activities in the Inglés II lesson at Universidad Tecnológica Nacional, Facultad Regional Paraná. Students are asked to research into a topic so as to shed light on a topic of their interest within the National Academy of Engineering's Grand Challenges or the United Nations' Sustainable Development Goals frameworks. If sources have not been well paraphrased or credited, it might be due to students' developing intercultural communicative competence rather than a conscious intention to plagiarize a text. Should the reader have any questions regarding this work, please contact Graciela Yugdar Tófalo, Senior Lecturer, at gyugdar@frp.utn.edu.ar