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Analysis of characteristics of bladeless turbines in Kazakhstan

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Abstract. This article provides a comprehensive analysis of the characteristics inherent in bladeless wind turbines and elucidates their pivotal role in Kazakhstan as a burgeoning source of renewable energy. The discourse delves into the multifaceted features encapsulated within bladeless wind turbine technology, expounding on their myriad advantages, particularly in the realms of ecology and efficiency. The authors meticulously evaluate the potential applicability of bladeless wind turbines in the specific environmental conditions of Kazakhstan, considering influential factors such as the country's distinctive climate and geography. This scholarly study is strategically designed to foster a profound understanding of the nuanced capabilities intrinsic to this innovative technology within the specific context of Kazakhstan. The overarching objective is to make a meaningful contribution to the broader landscape of sustainable energy development in the region. By probing the intersection of bladeless wind turbine technology and the unique challenges and opportunities presented by Kazakhstan's geographical and climatic attributes, this research seeks to provide valuable insights that can catalyze advancements in the utilization of renewable energy sources. Ultimately, the study aspires to be a catalyst for positive change, steering the trajectory of energy development in Kazakhstan towards a more sustainable and eco-friendly future.

Keywords: *bladeless turbines, alternative energy, vortex wind, wind energy, wind turbine.*

1. Introduction

A comprehensive technical analysis of Vortex Bladeless technology and its potential application in the residential sector of Almaty is currently underway, closely monitored throughout. This analysis includes a correlation study between electricity demand and energy production, aiming to evaluate the practicality and efficiency of integrating Vortex wind turbines into the local energy grid.

The Vortex wind turbine distinguishes itself by harnessing small wind gusts to convert kinetic energy into electricity through a patented alternative to conventional electromagnetic induction [1]. This innovation within the non-solar renewable energy sector is rooted in the concept of resonance, inspired by the studies conducted on the Tacoma Narrows Bridge [2].

The ongoing analysis and monitoring of Vortex equipment are grounded in the real field conditions of Almaty. Power and performance curves will be derived based on the device's generation in September, offering insights into its efficiency and output. Additionally, correlation analysis will be conducted to understand the relationship between energy demand and Vortex generation, considering both overall residential end-users and the specific behavior of Vortex NANO and projected Vortex Tacoma generation at a reference height of 12 meters [3].

Given the wind resources available in Almaty, the introduction of Vortex Bladeless technology aims to incentivize end consumers to align their consumption patterns with wind generation. The Spanish prototype, namely the NANO device, is chosen for its low power and ease of analysis, facilitating a detailed study. Similar analyses from other researchers and simulations are considered in tandem for a comprehensive evaluation [4, 5].

This research initiative seeks to not only advance the understanding of Vortex Bladeless technology but also to promote sustainable choices among consumers by highlighting the potential of wind energy in meeting residential electricity needs.

2. Materials and methods

2.1 Tools and materials

To obtain accurate weather data, an analogue of the Spanish weather station and the Vortex NANO analysis device itself were used, located in the same place, at the same installation height. The following tools were used for technical analysis: SolidWorks software for visualizing the 3D model and flow simulation, Excel for tabulating data and creating graphs, PVGIS for checking data from Almaty [6]. Figures 1 and 2 show the main Spanish devices used for the study.

Figure 1. Vortex NANO device

Figure 2. Weather station

2.2. Research methodology

For the first time, a detailed analysis of the electricity demand of a residential subscriber was conducted, utilizing the load profile that corresponds to their consumption history. This innovative approach involves delimiting the area for analysis, considering factors such as project location and complexity, meteorological conditions, generation analysis, and correlation studies between demand and Vortex turbine generation. The calibration of the device, necessitated by a previous interruption in mast operation, results in the generation of wind turbine data based on expected theoretical characteristics. All data were meticulously gathered through continuous measurements of the Vortex NANO device's generation.

Considering the low roughness at the project site, attempts were made to enhance roughness by installing obstacles around different volumes. However, the analysis of fluid behavior around structures adjacent to the device [7] revealed a tendency towards increased vibrations, leading to the exclusion of introducing structures in close proximity to the device.

This comprehensive study not only incorporates real-world demand patterns but also addresses the practical challenges encountered in enhancing the efficiency of Vortex Bladeless technology. The meticulous calibration process and consideration of environmental factors, including wind patterns and structural interactions, contribute to a thorough understanding of the technology's performance in actual residential settings. The exclusion of certain structures based on fluid dynamics analysis showcases the importance of an interdisciplinary approach in optimizing wind turbine installations, ensuring both efficiency and structural integrity.

2.3. Specifications

The characteristics of the equipment that will be used to analyze Vortex Bladeless in Almaty are a priori presented in Table 1.

The device used is intended for experimental analysis of the technology. The market entry of Vortex Bladeless power rated devices begins with the Spanish Vortex Tacoma and certain forecast technical analyzes will be conducted based on this device.

2.4. Test method

The analysis conducted within the validation methodology plays a crucial role in shaping the presentation and substantiation of the obtained results. Given the pre-experimental nature of the project, the initial testing phase followed a thorough review of literature pertinent to theories supporting emerging technologies. This literature review provided a solid foundation for understanding the theoretical underpinnings and potential challenges associated with the implementation of Vortex Bladeless technology.

Table 1. Technical data sheet Vortex NANO

Nom. power	1 W
Overall height	0.85 m
Oscillation angle	4.5° per side, 9° total
Capacity	3000 mAh
Output voltage	5 V DC current

A critical aspect of the analysis involves the examination of data sourced from a weather station strategically positioned within the project area. This data, coupled with load profiles derived from the residential subscriber's consumption history, will serve as a vital checkpoint for the demand analysis. The resulting power generation data will be intricately linked to the on-site measurements conducted with the Vortex NANO device.

This multifaceted validation methodology not only ensures the accuracy of the data collected but also establishes a robust framework for assessing the viability and effectiveness of Vortex Bladeless technology within the context of the residential sector in Almaty. The triangulation of weather data, load profiles, and on-site measurements enhances the reliability of the findings and contributes to the overall credibility of the analysis.

3. Results and discussion

3.1. Demand analysis

Conducting an energy audit is integral to understanding historical consumption patterns and assessing the suitability of deploying the Vortex Bladeless wind turbine in a residential sector. In Almaty's residential area, a meticulous energy audit was performed to scrutinize consumption readings and consumer behavior. This analysis aims to establish a representative load profile for the sector, recognizing that changes in consumption among other consumers will primarily differ in magnitude rather than behavioral aspects. Figure 3 visually illustrates the average load profile of a residential consumer, derived from the comprehensive energy audit.

The energy audit not only captures historical consumption data but also delves into the intricacies of consumer behavior within the residential sector. This detailed examination contributes to the creation of a load profile that accurately mirrors the typical energy consumption patterns of residents. Such load profiles are essential for evaluating the compatibility and effectiveness of integrating the Vortex Bladeless wind turbine into the existing energy infrastructure, providing valuable insights into how the technology can seamlessly align with the energy demands of the local residential community.

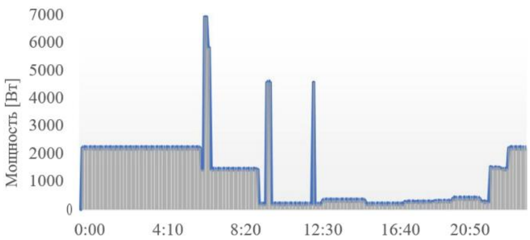

Figure 3. Load profile of residential subscribers

Typical consumption reflects consumption peaks in the morning, at noon and gradually increases at night.

The energy parameters of the end consumer can be seen in Table 2.

Table 2. Energy parameters of a household consumer

Average monthly consumption [kWh]	611
Average daily consumption [kWh]	42

3.2. Technical analysis

The Vortex NANO is a small power generation device whose generation behavior will form the basis for the design of the Tacoma generation, which will serve as a correlation study. Because regardless of the height of the device, the concept and energy conversion are maintained.

3.3. Meteorology of the place

Based on the data received from the weather station, information about the wind resource present at the location was tabulated. To check the data, a mini weather station was installed at the project location to obtain more accurate results and at a specific project altitude. Table 3 shows meteorological data in Almaty.

Table 3. Meteorologistic Almaty data

Parameter	Temp. [°C]	Speed [m/s]	Pressure [mm. rt. Art.]
Average per year	11	4	633
Maximum per year	16	8	764
Minimum per year	6	0.1	764

The wind resource is presented on an atypical assessment day; September 1. This profile allows you to calculate the wind power at a certain base height. An elevation of 4 meters will be selected as the project location and 12 meters for the Tacoma project. Figure 4 shows the average wind profile per day in September.

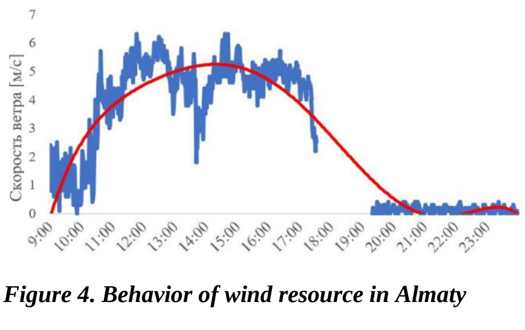

Figure 4. Behavior of wind resource in Almaty

The comprehensive analysis of the average wind resource for the third quarter of the year, determined to be 2.72 m/s, serves as a pivotal metric in evaluating the conversion of kinetic energy to electrical energy and its corresponding power factor (Cp) through the application of Vortex NANO technology. The selection of this specific quarter is strategic, considering its representation of a substantial portion of the annual wind conditions in Almaty.

The assessment of wind resources plays a crucial role in gauging the efficiency and potential of Vortex NANO to harness wind energy for electricity generation. This evaluation involves a meticulous examination of wind speed patterns, considering the unique characteristics of the third quarter. The determination of Cp, the power coefficient, is essential in understanding the effectiveness of the Vortex NANO in converting wind energy into electrical power.

By focusing on the third quarter, the analysis captures seasonal variations and ensures a nuanced understanding of the wind resource dynamics during this period. This information is instrumental in making informed decisions about the feasibility and optimization of Vortex Bladeless technology in harnessing wind energy for sustainable electricity generation in the specific context of Almaty. The insights derived from this evaluation contribute to a comprehensive understanding of the technology's performance and its potential integration into the local energy landscape.

3.4. Performance

The technical analysis conducted in the field utilized the Vortex NANO instrument as a representative device. Extrapolating from the gathered data, predictions were made regarding the generation and behavior of the Vortex Tacoma, accounting for its greater height and power rating of 100 W. In assessing the power of the Vortex NANO, results were obtained through the Hellman average speed calculation, providing a basis for predicting the power output of the Vortex Tacoma at a higher installation height.

The tabulated wind resource for the Vortex NANO was derived from data collected at the experimental site's weather station. Concurrently, the wind resource projection for the Vortex Tacoma's power calculations was based on a 12-meter height using the Hellman calculation method. Table 4 presents a comprehensive overview of the results, showcasing the generation of the Vortex NANO and the forecasted power output of the Vortex Tacoma based on available wind resources.

This comparative analysis not only highlights the performance of the Vortex NANO in real-world conditions but also provides insights into the anticipated capabilities of the Vortex Tacoma at an elevated installation height. Such projections contribute to a holistic understanding of the potential of Vortex Bladeless technology across different scales and installations.

Figures 5 and 6 show the power curve of Vortex NANO and Cp obtained from field analysis. Based on the available wind resource, the output power of the AC device was measured, resulting in a power graph when analyzing a real field with irregularities. Vortex NANO achieves a generation power of 0.9 W in nominal values and starts generating at a speed of 2 ~ 2.5 m/s. The measured NANO device does not reach rated power at higher magnitudes due to a previous mast failure that required repairs and resulted in axial asymmetry of the device. There is a deviation of 2° relative to the vertical, which determines the behavior of the turbine considering the direction of the wind it is exposed to, due to which the turbine has preferred oscillation angles.

Table 4. NANO Forecast and Tacoma Forecast Results

m/s	NANO	m/s	Tacoma
1.5	0.005	3.5	1.09
2	0.04	4	3.26
2.5	0.09	4.5	6.96
3	0.17	5	12.7
3.5	0.28	5.5	19.8
4	0.3	6	29.3
4.5	0.54	6.5	42
5	0.54	7	55.3
5.5	0.77	7.5	71.6
6	0.85	8	87
7	0.84	9	111

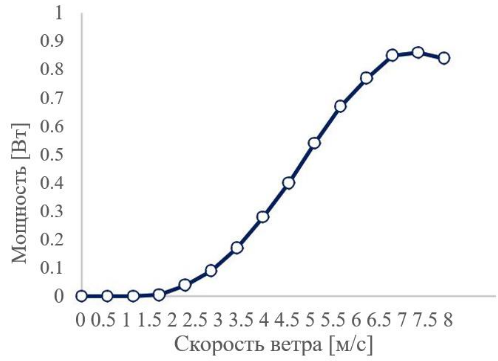

Figure 5. Vortex NANO power curve

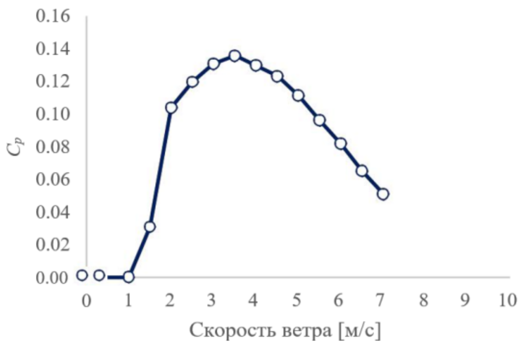

Figure 6. Vortex NANO power factor curve

The power factor of a wind turbine determines how efficiently the device converts wind energy into electrical energy. Based on the energy generated using the energy available at a wind height of 4 meters, a coefficient was calculated. Vortex NANO generates more efficiently at wind speeds of 2-3 m/s, which is an advantage since winds of this magnitude are more likely to occur in residential and urban areas with greater roughness. In this case, Vortex makes the most of the available power based on its performance. The Vortex Tacoma generation forecast will be used for correlation analysis given its attractive power. Figures 7 and 8 show the Tacoma Power and Cp curves.

The Vortex Tacoma device has a performance curve with the same behavior as the NANO, but with a higher generated value, reaching 110 W at reference values of 9 m/s. Cp is based on wind power. The Vortex Tacoma's power factor exhibits a clear bell-like trend, peaking at a conversion efficiency of 7 m/s. The data that will be used in the correlation analysis will be the Tacoma's performance curve and power factor.

3.5. Available power

For the field analysis of Vortex NANO, based on meteorological tables, the available power of the wind resource was calculated at a height of 4 meters for September. The graph shows the Betz limit, which represents the actual wind power under ideal conditions. However, no wind turbine in real field conditions ever reaches this Betz limit. The same calculation is made based on the Tacoma projection. The calculations are organized as follows in Figures 9 and 10.

The wind power available in Almaty at a height of 4 meters reaches 35 W/m^2, the Betz limit, which is 59% of this power, allows the use of approximately 20 W/m^2 in ideal conditions. Given its height, the Vortex NANO wastes all its potential as it is experimental in nature. Vortex Tacoma has the following behavior:

For installation at a height of 12 meters with greater unevenness than on site, energy projection was performed using the Vortex Tacoma height (2.75 meters). The wind power at this altitude reaches 500 W/m^2, the achievable limit under ideal conditions is close to 300 W/m^2. The power of the windmill in nominal mode reaches 110 W, that is, it uses a third of the actual useful energy. The Vortex Tacoma has an efficiency of about 30% under these conditions, while other wind turbines reach values of 20% in ideal conditions at a speed of 9 m/s.

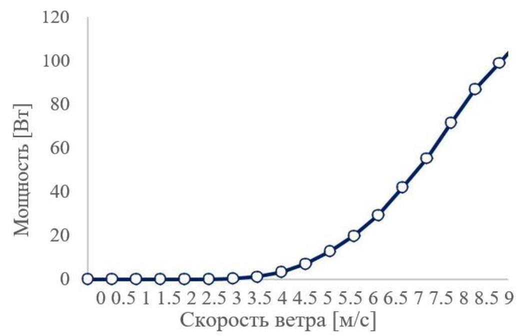

Figure 7. Vortex Tacoma Power Curve

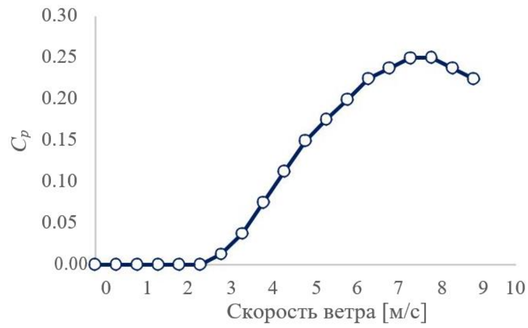

Figure 8. Vortex Tacoma Power Factor Curve

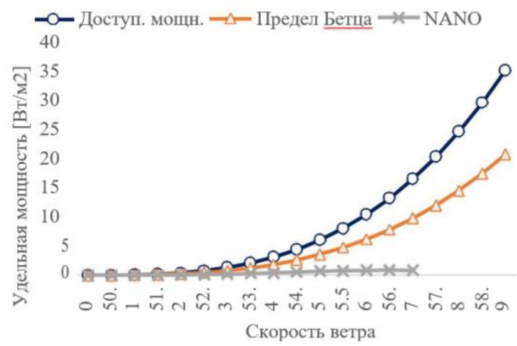

Figure 9. Available power at 4 meters

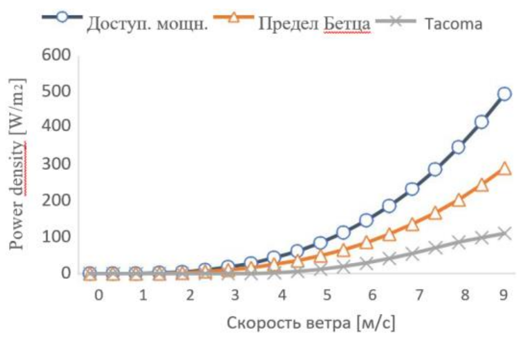

Figure 10. Available power at 12 meters

3.6. Correlation analysis

In-depth correlation analysis was conducted, centering on the demand profile of residential subscribers in Almaty and the energy consumption forecast specifically tailored for the Vortex Tacoma. It is crucial to note that the Vortex NANO, while informative for real-world conditions, possesses a power rating that may not singularly meet the demands of practical energy consumption. Consequently, this correlation analysis delves into the dynamic relationship between consumer demand and the anticipated power generation of the Vortex Tacoma, considering the latter's higher power rating and suitability for real-world applications.

The primary objective of this correlation analysis is to ascertain the extent to which electricity demand from an average consumer, with a monthly consumption of 611 kWh, can be fulfilled by the Vortex Tacoma. Given the analysis's scope, a scenario is considered wherein a single Vortex Tacoma device is employed, excluding the consideration of multiple devices or site-wide installations.

Figure 11 provides a visual representation of the correlation analysis, illustrating the interplay between consumer demand and the projected power generation from the Vortex Tacoma. This correlation elucidates the potential contribution of a single Vortex Tacoma device to meeting the average residential electricity demand. The insights derived from this analysis serve as a foundation for understanding the practical implications of integrating Vortex Bladeless technology into the residential energy landscape in Almaty.

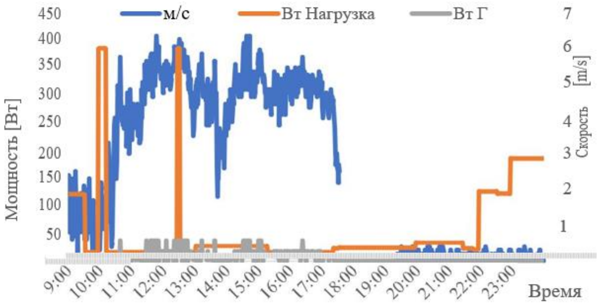

Figure 11. Analysis of demand generation

Where:

• W Load - behavior of final consumer demand in the residential sector.

• W G - Vortex Tacoma device behavior.

• Wind speed [m/s] - the behavior of a typical wind resource in September.

A home subscriber's daily demand according to an energy audit based on its historical consumption is 42 kWh per day, while observing the generation behavior of the projected Vortex Tacoma, it could generate 4.5 kWh per day if wind behavior were typical. It turns out that the percentage of demand that the installed Vortex Tacoma device satisfies is 9.8%. Quite an attractive percentage considering this is one unit installed, if more than one Vortex Tacoma is installed the flow is met at a higher percentage. These results are tied to certain conditions such as the behavior of the wind speed resource in September, a 4 meters height installation and consideration of a Reynolds number low enough to cause the Vortex wind turbine to continue generating electricity continuously throughout the day.

The analysis to determine the amount of demand covered by Vortex during the year will depend on providing an accurate analysis of wind behavior throughout the year. Using meteorological data from Almaty, it was confirmed that the data obtained, given the differences in height and distance, did not include accurate data that could be used to predict the behavior of vortices for an entire year. However, subscriber behavior in the residential sector is typical for the rest of the year, with the exception of the use of new purchased household appliances or any significant change in consumer behavior.

4. Conclusions

After determining the friction coefficient to be 0.1 and interpolating the air density to 1.135 kg/m^3, a graph of the wind power available for Almaty was plotted. As a result, the available power density reaches 35 W/m^2 at a height of 4 meters and 500 W/m^2 at a height of 12 meters, excluding the Betz limit (59.7%). It was found that the Vortex Tacoma device will operate with 30% efficiency at an installation height of 8 meters. Higher efficiency compared to other vertical axis wind turbines which reach 20% under ideal conditions and peak Cp of ~6 m/s. Considering the difference in height and size with the Vortex NANO, the generation and performance figures are lower than the Vortex Tacoma. In general, the performance curve of both devices will have the same trend, but at different wind ranges.

Cp Vortex NANO at its peak reaches a value of 0.14 with an approximate wind resource of 2-3 m/s; however, its maximum generation is achieved at a speed of 7 m/s without reaching the rated power. Residential subscriber-specific coverage of a single Tacoma device is projected to reach 9.8%. Additionally, the Vortex NANO demonstrates competitive performance in moderate wind conditions, making it a suitable option for locations with lower wind speeds.

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Қазақстандағы қалақсыз жел турбиналарын талдау

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Аңдатпа. Бұл мақалада қалақсыз жел турбиналарына тән сипаттамалар жан-жақты талданады және олардың Қазақстандағы жаңартылатын энергияның дамып келе жатқан көзі ретіндегі шешуші рөлі түсіндіріледі. Дискурс қалақсыз жел турбинасы технологиясының ішінде қамтылған көп қырлы мүмкіндіктерді зерттейді, олардың сансыз артықшылықтарын, әсіресе экология мен тиімділік салаларында түсіндіреді. Авторлар елдің ерекше климаты мен географиясы сияқты ықпалды факторларды ескере отырып, Қазақстанның нақты экологиялық жағдайында қалақсыз жел қондырғыларының әлеуетті қолдану мүмкіндігін мұқият бағалайды. Бұл ғылыми зерттеу Қазақстанның нақты контекстінде осы инновациялық технологияға тән нюанстық мүмкіндіктерді терең түсінуге көмектесу үшін стратегиялық тұрғыдан әзірленген. Негізгі мақсат – аймақтағы тұрақты энергетиканы дамытудың кең ландшафтына елеулі үлес қосу. Қалақсыз жел турбиналары технологиясының қиылысуын және Қазақстанның географиялық және климаттық атрибуттары ұсынатын бірегей қиындықтар мен мүмкіндіктерді зерттей отырып, бұл зерттеу жаңартылатын энергия көздерін пайдаланудағы жетістіктерді катализдей алатын құнды түсініктерді беруге тырысады. Сайып келгенде, зерттеу Қазақстандағы энергетиканың даму траекториясын неғұрлым тұрақты және экологиялық таза болашаққа бағыттай отырып, оң өзгерістердің катализаторы болуға ұмтылады.

Негізгі сөздер: *қалақсыз турбиналар, баламалы энергия, құйынды жел, жел энергиясы, жел турбинасы*.

Анализ характеристик безлопастных турбин в Казахстане

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Аннотация. В данной статье представлен всесторонний анализ характеристик, присущих безлопастным ветряным турбинам, и поясняется их ключевая роль в Казахстане как растущем источнике возобновляемой энергии. В докладе рассматриваются многогранные особенности технологии безлопастных ветряных турбин, раскрываются их многочисленные преимущества, особенно в области экологии и эффективности. Авторы тщательно оценивают потенциальную применимость безлопастных ветряных турбин в конкретных экологических условиях Казахстана, принимая во внимание такие влиятельные факторы, как своеобразный климат и географическое положение страны. Это научное исследование стратегически предназначено для содействия глубокому пониманию нюансов возможностей, присущих этой инновационной технологии в конкретном контексте Казахстана. Главной целью является внести значимый вклад в более широкий ландшафт устойчивого энергетического развития в регионе. Изучая взаимосвязь технологии безлопастных ветряных турбин, а также уникальные проблемы и возможности, связанные с географическими и климатическими особенностями Казахстана, данное исследование стремится предоставить ценную информацию, которая может стать катализатором прогресса в использовании возобновляемых источников энергии. В конечном итоге исследование призвано стать катализатором позитивных изменений, направляя траекторию развития энергетики Казахстана в сторону более устойчивого и экологически чистого будущего.

Ключевые слова: *безлопастные турбины, альтернативная энергетика, вихревой поток, ветроэнергетика, ветряная турбина*.

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