Current Trends in Wind Energy Development in Uganda: A Comprehensive Review

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ABSTRACT

Uganda faces a severe energy deficit, with only 25.3% of its population having access to the national grid, making biomass dominate the energy mix. Wind energy presents a viable renewable option, given the estimated potential of 1,000 MW in the northeast and east regions. However, harnessing this potential into actual on-ground capacity has remained stalemated. This review synthesizes what is known of Uganda's wind energy landscape with a view to identifying why the progress stalled and charts a clear way forward. We analyzed the country's wind resource availability, compared global technology trends with local applicability, and examined the policy structure and institutional setup in place. Importantly, the paper provides an integrated analysis of historical project case studies: the canceled Rupa and Tororo efforts, the unsuccessful Karamoja wind-driven water-pumping initiative, and the slow-moving 120 MW Karamoja wind farm to pull out across-the-board lessons. The findings reveal that development is hindered by a cyclic barrier: developers are discouraged by a lack of bankable and site-specific wind data, while a lack of investment prevents such data from being collected. Projects also fail when business models neglect operations, maintenance, and community involvement. In conclusion, unlocking Uganda's wind potential requires a twin-track approach: 1) targeted public funding for detailed wind mapping to de-risk private capital, and 2) making projects commercially viable and engaging local communities. This review provides policymakers, developers, and researchers with solid evidence to inform Uganda's sustainable energy transition.

Keywords: Wind Energy, Uganda, Project Failure Analysis, Renewable Energy Policy, Energy Transition, Sustainable Development.

1 Introduction

The energy challenges Uganda faces make it one of the most energy-deficient countries. According to the energy statistics provided by the Uganda Bureau of Statistics (UBOS), as of 2024, only 25.3% of the Ugandan population was connected to the national grid, while less than 5% of rural households accessed it, with only 3.8% of the Ugandan population discovered using clean energy and technology for cooking [1]. The energy sector's fuel mix mainly relies on biomass energy, with over 88% of the total energy consumption derived from wood and charcoal. As of June 2025, hydropower generates around 82.1% of Uganda's electricity [2]. These energy dynamics make the Uganda energy sector more prone to environmental concerns, such as deforestation due to the reliance on wood energy. Despite the environmental concerns associated with the current energy dynamics, the most appropriate way for Uganda to improve energy security is for the Ugandan energy sector to focus on the development of renewable energy technologies such as wind energy. Wind energy is now being considered a viable option for addressing the power gaps in Uganda, mainly for off-grid and rural electrification in areas where extending the grid is not justifiable. The wind resource for the country is mainly found along the northeastern and eastern parts of Uganda, which include the Karamoja sub-region, Mount Elgon, and the Lake Victoria Basin. The average wind speed measured ranges between 4 and 6 m/s at 50-meter hub heights [3]. This speed is ideal for the installation of wind turbines of small to medium capacity. The policy environment of Uganda, including the country's Renewable Energy Policy (2007), has placed concrete emphasis on the development of wind resources to increase the contribution of renewable sources to the country's energy base and to support the country's commitment to achieving universal access to electricity by 2030 [4].

Globally, the growth of the wind industry has been revolutionary, with installed capacity reaching 743 GW in 2020 due to the technological advancement of the sector, which has seen a reduction in costs [5], [6]. However, the emergence of utility-scale wind power in Uganda has been in its infancy due to a series of daunting challenges, such as high capital expenses and a lack of technical capacity and information on site-specific wind resources.

While the policy documents and associated reports have recognized Uganda's wind potential and challenges that come with it, a real analytical gap has remained. Much of the existing literature isolates technical potential, policy analysis, and project case studies into separate strands, lacking a unified assessment that ties these pieces together to explain why the sector stalls and how to move forward with a clear plan. This review bridges this gap by providing an in-depth, integrated

assessment of the state of Ugandan wind power. This assessment examines wind potential in Uganda, tech trends, and existing policy structures, opportunities, and challenges, with a focus on lessons that have been accumulated from failed attempts as well as new initiatives. With this information brought together, this article moves from presenting problems to presenting a strategic blueprint to harness Ugandan wind power. The aim is to provide some direction to policymakers, project developers, and researchers in this journey towards sustainable energy in this region.

2 Wind Potential in Uganda

Uganda has vast potential for wind power, particularly in the northeast and east, where satisfactory wind speed would make it suitable to utilize wind power. The Uganda Renewable Energy Policy (2007) conservatively estimates that Uganda's potential for wind power is approximately 1,000 megawatts (MW), which, when harnessed to capacity, would be significant to Uganda's energy supply. The regions with the greatest potential for wind energy utilization are Mount Elgon, the Karamoja plateau, and the Lake Victoria basin. The regions have average wind speeds ranging from 4 to 6 m/s at an altitude of 10 meters above ground level, which is sufficient for the installation of small- to medium-sized wind turbines [4]. The Karamoja region, for example, is a possible location for wind power exploitation since it experiences relatively flat ground and open vegetation cover, which results in relatively high and uniform wind speeds. Apart from the northeast corners, the Lake Victoria basin is also apparently a good location for decentralized, off-grid use of wind power. The basin enjoys moderate wind speeds that are appropriate for decentralized wind turbines to provide power to off-grid rural communities.

The government of Uganda, along with its international partners, has carried out an initial assessment of wind resources to identify potential sites for wind energy development. This effort has reinforced the need for thorough research to accurately estimate Uganda's wind power potential. With effective investment, supportive policies, and capacity-building efforts, the wind energy sector could significantly help address Uganda's electricity shortfall and contribute to sustainable development.

3 Current Trends in Wind Turbine Technology

Wind turbine technology has significantly emerged in recent years, driven by the world's ambition for cleaner energy and the need to improve efficiency, reduce costs, and boost reliability. These tendencies are reshaping the future of wind energy, not only in industrialized countries but also in developing countries like Uganda, where wind energy is being taken seriously and exploited as a renewable energy source. One of the most pronounced trends is the development of larger and more efficient turbines. Wind turbines are now capable of producing more power due to larger rotor diameters and taller towers, which allow them to harness stronger and more stable winds at higher altitudes. For instance, onshore turbine rotor diameters have increased from an average of 80 meters in 2010 to over 130 meters in 2023, and the sizes of turbines have increased from 2-3 MW to 5-6 MW for onshore machines and up to 15 MW for offshore machines [6], [7].

The second prevailing trend is the use of cutting-edge materials and design innovations to boost turbine efficiency and lifespan. Lightweight composite materials such as carbon fibers are being employed to create longer and more durable blades, while advanced control systems and sensors enable real-time monitoring and optimization of turbine performance. These technologies not only maximize energy production but also reduce maintenance expenses and extend the life of wind turbines [8]. In addition, the integration of digital technologies such as artificial intelligence (AI) and the Internet of Things (IoT) is revolutionizing wind farm management. AI algorithms are being applied to predict wind patterns, tune the performance of turbines, and predict faults before they lead to costly downtime [7].

In Uganda, the application of these advanced technologies is still in its infancy, but growing interest in small wind turbines for rural electrification and off-grid applications is being observed. Currently, there are no installed wind turbines in Uganda being utilized to produce electricity. Only windmills exist, of which most of them are not operating because of a lack of maintenance, vandalism, among others[9].

Literature shows that wind energy resources in Uganda are sufficient for small-scale electricity generation, particularly in the 2.5 kV to 10 kV range, suitable for rural areas, small-scale industries, as well as for special applications, such as water pumping, mainly in the Karamoja region[9].

Furthermore, international partnerships and financing agreements are playing a significant role in facilitating the transfer of wind turbine technology to Uganda. For example, the Karamoja wind farm of 120MW onshore wind power project, which is currently at the permitting stage and was

expected to be commissioned in 2025 in Northern Uganda by AMEA Power, shows a very great trend in wind energy development [10].

4 Policy and Institutional Framework

Significant progress has been made toward formulating a policy framework and institutional support mechanism for renewable energy, including wind power development. This is according to the Renewable Energy Policy (2007) whose aim is to increase the share of renewable energy in Uganda's energy mix as well as reduce dependency on traditional biomass and fossil fuel. The policy states wind energy as one of the major sources of renewable energy that can provide energy security and sustainable development of the country. There must be proper resource appraisal, capacity building, and facilitation of public-private partnerships in attempting to utilize wind power, in line with the policy [4]. Augmented to this is the National Energy Policy 2002, which outlines a more holistic development plan for the energy sector, part of which is renewable energy technology development. The policy aims at the development of an enabling environment for private investment in renewable energy projects, one of which is wind power [11].

Institutional support for the development of wind power is mainly offered by the Uganda Electricity Regulatory Authority (ERA), whose mission is to regulate the electricity market, licensing, and tariff-setting for the renewable energy projects. ERA plays a vital role in making wind energy schemes economically viable and aligned with the nation's energy policy. Besides, the lead ministry for developing the energy policy and that of wind power is the Ministry of Energy and Mineral Development (MEMD). MEMD has been in the vanguard of conducting wind resource mapping and developing pilot projects.

In addition, international cooperation and funding agreements have promoted Uganda's wind power development. For instance, the Scaling Up Renewable Energy Program (SREP), funded by the World Bank, has provided financing as well as technical support to renewable energy projects, such as wind energy projects. Similarly, the African Development Bank (AfDB) has supported Uganda's renewable energy sector with a capacity development program and grants to institutions such as off-grid solutions and rural electrification [3], [12]. All of these partnerships have helped in their own way in bridging some of the technical and financial challenges to utilizing wind power in Uganda.

While all of this is going on, plenty of issues still need to be addressed regarding harnessing the wind energy of Uganda. These include, for instance, additional research into the wind resources, the high upfront cost of installing the wind turbines, and minimal technology expertise in working with wind power technology. Although today's climate policy and institutionally supported arrangements present a very strong basis in handling such challenges as well as accessing Uganda's wind potential, continued government assistance, foreign donor support, and private sector participation, wind energy can make considerable contributions towards Uganda's transition into a green economy.

5 Opportunities and Challenges

5.1 Challenges to Wind Energy Deployment

Despite the large wind resource potential in Uganda, various interconnected challenges constrain this resource from being exploited. Firstly, the relatively high capital costs involved in the installation of a wind energy plant remain an important setback. This is because large-scale projects require major capital outlays for the construction of wind turbines and the necessary support infrastructure, which would remain an important concern for Uganda, given other major development initiatives to undertake [4]. Further, the major lack of accurate wind resource information limits optimal investment decision-making and location choices. Despite the promising potential offered by areas such as Karamoja and Mount Elgon, the discontinuation of projects such as wind resource measurement posts (as mentioned in **Section 6**) illustrates the sensitivities associated with the collection of wind resource information, given the various uncertainties involved, and creates a potential drawback for investors seeking critical bankable information to de-risk involved projects [3]. Additionally, the major lack of Ugandan capacity and knowledge with regard to the design, implementation, operation, and management associated with the installations of wind turbines may compromise the potential efficiency of involved projects, which would also contribute to increased costs [12]. Lastly, the intermittent nature of wind sources also complicates the integration process, with the major national grid facing a limited transmission capacity and major losses [13].

5.2 Strategic Opportunities for Development

On the other hand, a convergence of strategic elements puts wind energy on the map as a potential future energy source for Uganda. This strategic context benefits from a supporting policy framework, which has been shaped by the Renewable Energy Policy in 2007 and the National Energy Policy in 2002. These policies lay a strategic foundation for the energy mix diversification with renewable energy sources, including wind energy. The presence of access to climate finance and development funds provides an added strategic benefit. The World Bank's Scaling Up Renewable Energy Program (SREP) has shown the way to finance and technical assistance for renewable energy projects [5], [12]. In addition, Public-Private Partnerships (PPPs) have emerged as a strategic way to access private funds and technical know-how, while managing public risk, as demonstrated by the presence of foreign developers in large projects [3].

At a decentralized level, the small-scale or distributed wind energy systems directly offer a prospect for rural electricity. These schemes are capable of offering clean electricity to off-grid and deprived areas of electricity access. This helps stimulate economic development at the local level [14]. Finally, and notably, the universal need for responding to the challenge of climate change has increased the availability of green finance options.

5.3 Synthesis: Navigating the Path

The future of wind power in Uganda will largely depend on exploiting these opportunities for the benefit of the country by providing definitive solutions to some of the key challenges. A positive move will depend on informed government and donor investments in definitive wind resources mapping to minimize risk for independent investors. With the help of overseas collaboration for funding of projects related to a clean environment, the future of wind power will form a major component of a stable future related to the use of energy.

6 Synthesis and Critical Lessons from Project Case Studies

There have been several wind power projects in Uganda, which provide us with useful information about Uganda's potential, challenges, and viability of wind energy. The case studies in **Table 1** represent the success achieved to date and also serve as a point of reference for future projects.

Table 1: Summary and Analysis of Wind Energy Projects in Uganda

Project Name	**Capacity**	**Coordinate**	**Date of Commissioning**	**Status**	**Key success/failure factors**	**Primary funding/Developer**
Rupa Wind Power Plant	20 MW	2°34'59.98"N, 34°40'0.02"E	December, 2023[15]	Cancelled [16]	**Failure factors**: Lack of wind resource data; Budget constraint due to cancellation of the development partner (AfDB).	Senok Wind Uganda Limited (Developer); AfDB (Financing)
Tororo Wind Power Project	Up to 100 MW[9]	0°38'30.00"N, 34°10'25.00"E	December, 2022	Cancelled (inferred June 2024)[17]	**Failure factors:** Failure to meet the financial guarantees, which risked license cancellation.	Xsabo Wind Technologies Limited (Developer); Xsabo funding (0ne-third); Private funding (two-third)
Karamoja Water-Pumping Wind Mills [18]	N/A (Mechanical Water Pumping)-43 installed	N/A	N/A	Only 7 are functioning, while the rest are abandoned or vandalized.	**Failure factors**: Lack of maintenance, security measures, and community migration	Government of Uganda, OXFAM, United Nations Development Programme (UNDP).
Karamoja Onshore-Wind Farm	120 MW[10]	2°39'38.16"N, 34°34'8.04"E	Planned (2025)	Permitting	N/A	AMEA Power (Developer)

From the project history documented in **Table 1**, a crucial systemic barrier to the development of wind power in Uganda is found to be the absence of bankability and site-specific resource information, and the trouble of fulfilling pre-licensing financial conditions. The license cancellation of the 20 MW Rupa Wind Power Plant is a direct consequence of budgetary constraints due to the absence of a crucial development partner (AfDB) for wind measurement masts. Such a case warrants a disturbing pattern of a 'valley of death' in the pre-commercialization stage, where projects are abandoned not due to technical unviability but due to the absence of basic information required to transit projects from the planning to implementation phases. In a similar pattern of events, the non-fulfillment of a project's financial guarantees has culminated in a

presumed license cancellation of the Tororo Wind Power Project. Such developments reveal that even a project at an advanced stage of technical development fails to survive at the 'valley of death' of capital commitment.

In contrast to ambitions for utility-scale projects, however, the situation of Karamoja Water-Pumping Windmills is a sobering reminder of the dangers of standalone, donor-funded projects. When considering that not more than 7 of 43 installed projects are currently operational owing to a lack of maintenance and community disconnection, a situation that cannot and should not be attributed to failures of wind technology, one is struck by a fundamental principle of utilizing such renewable energy sources for development purposes. When such projects are implemented as discrete hardware solutions to development challenges that do not involve operations and maintenance as part of their design and do not embed such developments within a program of development that is concerned with livelihood and water management, for instance, such projects are bound to be technologically obsolete.

Notwithstanding these well-documented challenges, the Karamoja Onshore-Wind Farm, with a projected capacity of 120 MW, remains the most prominent evidence of wind power potential in Uganda. Its first stage advancement to the permitting process, under the development umbrella of an international independent power producer (AMEA Power), represented a milestone in the adoption of a commercially driven paradigm. Yet the project's failure to adhere to its planned commissioning schedule for the year 2025 and the lack of any public update to date (as of 2026) provides a very significant data point in and of itself. This lack of feedback suggests that it is probably struggling with certain unseen challenges, potentially but not necessarily confined to financing hurdles, power purchase agreement negotiations, and/or various other delays. This process again reflects the ever-present paradigmatic crisis in Uganda's energy development landscape: namely, the lack of a clear and easily tractable, real-time project development process. Thus, the Karamoja project has come to represent not merely the hope brought to the landscape by private finance but also those unseen challenges facing even the most promising projects. Its stalled development path is merely additional evidence to support the argument that while securing developers to build projects on land and sea remains the first step forward, it must not and should not represent the final step in creating a more transparent and agile development path from permitting to project realization.

These case studies, therefore, demonstrate the potential of wind power towards Uganda's energy crisis, particularly for rural and underdeveloped areas. They also call for the need for the contribution of government policy, foreign investment, and people's participation towards the successful installation and operation of wind power projects. Finally, these case studies justify the challenges and opportunities presented in **Section 5**.

7 Conclusion

This review examines the opportunities as well as challenges facing the development of wind energy in Uganda. Indeed, the wind potential of Uganda has been estimated at 1,000 MW, mainly found in the areas of Karamoja, Mount Elgon, and the Lake Victoria basin. However, the development of the sector is still in a pre-commercial stage due to a series of canceled projects.

From the results, it is clear that the major barriers are systemic in nature. Firstly, the existence of a significant data gap, evidenced by the abandonment of wind monitoring schemes, is a major investment barrier in a self-reinforcing cycle where the lack of data increases perceived risk, discouraging funding required for data gathering. Secondly, the existence of unsustainable project schemes is evidenced by the almost total abandonment of the donor-sponsored wind-powered water-pumping schemes, which clearly demonstrate that the implementation of hardware without an investment framework for sustainability is destined for failure. Thirdly, the challenge in ensuring fulfillment of the financing guarantees for commercial-scale schemes suggests there are systemic barriers to the formulation of bankable investments and contracting for the purchasing power in the energy sector in Uganda.

To break through the vicious cycle, a drastic intervention is required. A proposed list of strategic priorities is as follows:

Innovative Public Investments: The government, together with the help of development partners, should invest in and pursue a comprehensive, high-resolution mapping assessment of the country’s wind resources. This is an essential public good, which will form an integral part of a bankable project pipeline amenable to private investors.

Shift in Model for Project Development: In the coming initiatives for project development, there needs to be a shift away from the isolated or “donor” model of development. In the case of distributed systems in the power sector, the development of projects needs to take into account the

total cost of ownership in the concerned regions. In the case of larger projects in the power sector, the PPP models need to be improved.

Improved Transparency and Tracking: The development of a publicly accessible "dashboard" to track licensed energy projects from the permitting stage to operation will significantly promote more transparency and facilitate learning from the successes and setbacks.

Through the adoption of this comprehensive approach, which combines core information sources with efficient project models, Uganda can harness its considerable wind potential as a bedrock of a secure, diverse, and clean energy sector. This is crucial, not just for meeting Uganda's energy needs, but also in serving to promote rural development, as well as the further progression of Uganda towards conformity to sustainable development principles internationally, in respect of, particularly, SDG7 – Affordable and Clean Energy.

Credit authorship contribution

James Odur: Conceptualization, methodology, investigation, writing original draft, resources, analysis, visualization, review, and editing. **Cosmas Ngozichukwu Anyanwu**: Conceptualization, analysis, review, and editing.

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Data Availability Statement

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Conflict of Interest

The authors declare that there is no conflict of interest.

Disclaimer

The opinions and views expressed in this paper are those of the authors and should not be ascribed to the official policy or position of any affiliated organization.

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