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Research Article

Assessment For Using Wind Power Plant as An Alternative Source of Electrical Energy in School of Technology, Kano State Polytechnic, Nigeria

*Bashir Muhammad Abba[1], Usman Haruna Hussain[2], Mariya Garba Mustapha[3], Anas Mukhtar[4]

[1,2,3,4] Department of Electrical/ Electronic Engineering Technology, Kano State Polytechnic, School of Technology (SOT).

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***Corresponding author:** *Bashir Muhammad Abba*
Department of Electrical/ Electronic Engineering Technology, Kano State Polytechnic, School of Technology (SOT).

Abstract
Renewable energy has been in increasing demand recently due to overstress on nonrenewable resources and their increasing cost. Considering the use of wind power plants as an alternative source of electrical energy in Kano State Polytechnic, several factors should be assessed to determine its feasibility and effectiveness. Assessment of wind speed, direction, and other climatic factors to determine if the site has sufficient and consistent wind resources to generate electricity effectively. Identifying a suitable location within the institution for installing wind turbines is crucial. Factors such as land availability, proximity to power infrastructure, and potential impacts on surrounding areas. Assessing the technical feasibility by evaluating the compatibility of wind power plants with the existing electrical grid infrastructure of the institution. Assessing the economic viability involves evaluating the costs associated with installing, operating, and maintaining wind power plants compared to the potential energy savings and environmental benefits. Stakeholder engagement, such as with the management, staff, and students of Kano State Polytechnic, is vital to establish a maintenance and monitoring plan for the wind power plant to ensure optimal performance and longevity. Regular inspections, repairs, and necessary upgrades should be carried out to maximize efficiency and minimize downtime. By embracing renewable energy technologies, polytechnics can serve as role models for other institutions and inspire a greener future.

Keywords: *Renewable energy, wind power plant, Polytechnic, electricity, assessment, economic, infrastructures, optimal performance, efficiency.*

Introduction:
The kinetic energy in the wind is a promising source of renewable energy with significant potential in many parts of the world. The energy that can be captured by wind turbines is highly dependent on the local average wind speed. Currently, wind energy is the second most important source of renewable energy after water energy [1]. By 2016 global cumulative installed wind capacity surpassed 432 MW [2]. In the past most of wind power plants were installed onshore, but currently offshore plants are becoming more popular. Most modern wind power is generated in the form of electricity by converting the rotation of turbine blades into electrical current by means of an electrical generator. In windmills (a much older technology) wind energy is used to turn mechanical machinery to do physical work, like crushing grain or pumping water. Wind power is used in large scale wind farms for national electrical grids as well as in small individual turbines for providing electricity in isolated locations. Wind energy is abundant, renewable, widely distributed, cleans, and mitigates the greenhouse effect if it is used to replace fossil-fuel-derived electricity.

In industrialized countries, wind energy is deployed mainly for environmental reasons, to replace fossil fuels. In developing countries, especially in rural areas, wind turbines are now used mainly to provide first-time access to strongly-desired modern energy services, such as clean water supply or electric power, to fulfill basic needs. However, the demand for these wind energy services is fairly low, because of abundant availability of wind energy on the earth. Breaking this constraint can set up a virtuous circle of more energy services, lower costs, and more renewable supplies.

This is for two reasons. First, it is because most renewable technologies enjoy large economies of scale larger installations cost less per unit of output than smaller ones, and both provide lower cost energy services if used for more hours each day. Second, many energy services, because they can enable income generating activities, spur a demand for yet more energy services. A key energy development strategy is, therefore, to consolidate the demand for energy services from individual users such as separate house-holds, community establishments (school, water supply, health clinic), and other users. A second strategy is to integrate the provision of energy services with income-generating activities, for example, activities that increase farm productivity (e.g., irrigation), enhance the ability of communities to add value to agricultural goods and market them (grain milling, baking, refrigeration, storage and transport), and generate other marketable products (manufactured and artisanal products) which provide social and economic development gains.[3] Estimates of market potential based on demand-enhancing strategies like the above are a long way from the theoretical resource assessments which opened this section. They provide a rather more relevant and positive perspective on renewable energy implementation, and they make explicit the connection between renewable and human development. [3]

New generation of wind turbines is more reliable than those from 1980's. This is necessary condition if energy production is to play an important role among renewable energy sources. Over the last 30 years, the size of wind turbines increased 7 times, as nominal power increased nearly 14 times. At present, turbines capable of producing over 10 MW of power are being developed. The main reason for continued growth of turbines sizes is to minimize the energy cost per kilowatt-hour. However, it is worth remembering that according to the “square-cube law”, there is a maximum size after the surpassing of which the cost of ever-larger turbines would grow faster than financial gain from the increased size. Apart from expansive wind farms with large-scale turbines, there has been an increase in the area of small wind energy systems, the so-called off-grid or stand-alone systems, unconnected to the grid. The systems produce less than 100 kW energy. Globally the number of manufacturers of small wind energy systems has been growing dynamically. In 2002, number was less 50, whereas in 2015 there were about 250 companies located in 27 countries [4].

Problem Statement/Justification:

The current reliance on conventional electricity sources in the School of Technology at Kano State Polytechnic is leading to several issues, such as frequent power outages, high electricity bills, hike cost of fuel due to subsidy removal and environmental pollution. Therefore, there is a need to assess the feasibility and potential benefits of implementing a wind power plant as an alternative source of electrical energy to address these challenges and promote sustainable energy practices within the institution.

Objective (s) of the study:

The objectives of the study encompass several goals as follows:

(i) To determine the technical and economic feasibility of implementing a wind power plant in the school.
(ii) Quantify the potential electricity generation capacity of a wind power plant in the institution.
(iii) Evaluate the costs associated with implementing a wind power plant compared to the potential benefits.
(iv) Assess the technical aspects of integrating wind power generation into the existing electrical infrastructure of the school.
(v) Investigate the environmental benefits in terms of reducing greenhouse gas emissions and promoting sustainability.

Literature Review:

A literature review of wind power plants involves examining and analyzing existing research and scholarly articles on the subject to gain a comprehensive understanding of the topic. Throughout the years, there has been considerable research conducted in the field of wind energy, specifically in the context of wind power plants.

One of the key areas of investigation in wind power plant is the design and engineering aspects. Numerous studies have focused on optimizing the layout and configuration of wind turbines within a wind farm, considering factors such as wind resource assessment, turbine technology, and spatial planning. These studies aim to enhance the overall efficiency and performance of wind power plants. [5]

Another important area of research in this field is related to the integration of wind power plants into the existing power grid infrastructure. Researchers have evaluated various techniques for grid integration, including control strategies, power management, and grid stability analysis. These studies aim to address the challenges associated with intermittency, variability, and fluctuating output of wind power plants, ensuring a reliable and stable electricity supply.

Furthermore, the wind power plants also encompass environmental and social aspects. Researchers have examined the environmental impact and sustainability of wind energy generation, assessing factors such as noise pollution, effects on wildlife, and land use. Additionally, studies have explored the social acceptance and community engagement related to wind power plant projects, investigating factors that influence public perception, participation, and policy-making

Moreover, the economic and financial analysis of wind power plants has been extensively covered in the literature. Researchers have examined the cost-effectiveness of wind energy generation, considering factors such as capital investment, operational and maintenance costs, and leveled cost of electricity. These studies provide valuable insights into the economic viability and financial feasibility of wind power plant projects.

This also explores policy frameworks, regulations, and market dynamics affecting the development and deployment of wind power plants. Researchers have examined government incentives, support mechanisms, and market structures to promote the growth of wind energy. Additionally, studies have evaluated the barriers and challenges faced by wind power plant developers and proposed policy recommendations to foster a favorable environment for clean energy transition. [6]

Wind power plants – types, working principles, design

Conventionally wind power plants can be classified based on:

a) Power output:

- Micro plant, with the power output up to 100 W, used to power off-grid circuits,
- Small power plants with the power output from 100 W to 100 kW, used to power individual households or small enterprises,
- Large wind power plants with the power output of 100 kW and above, used for producing grid-tied energy,
- Utility-scale more than 1 MW,

b) **Construction size**,

c) rotor axis orientation:

– Horizontal axis (HAWT),
– Vertical axis (VAWT),

d) **Other criteria**:

- Wind energy utilization,
- Rotor speed (low, medium, high)
- Rotor and mast orientation relative to wind direction – upwind and downwind,
- Generator design: gearbox and direct drive. [7]

Principal elements of wind turbine are rotor (blades and hub), drive and control system. The most important element of a turbine are blades because it is those elements that perform the actual energy conversion from kinetic to mechanical energy utilizing the principle of lift force creation on the blade airfoil. Currently horizontal three blades design is the most popular configuration. The three-blade design has proven to be the most energy efficient and the balanced [8]. Fig. 2b shows the effect of the number of blades on the power coefficient for particular tip speed ratio

$$J = \frac{\Omega R}{V}$$

where:
Ω – rotational velocity,
$\mathbf{V_0}$ – wind speed, $\mathbf{R}$ – blade radius

In Fig. 2b, it is easy to see significant increase power coefficient as the configuration changes from one blade to blade. Future increase of the number of blades results in considerably smaller increase in the power coefficient, when friction-related efficiency losses are taken into account. However, three-blade configuration is preferable because it only has 2/3 of the load of two-blade configuration, generating less noise [7].

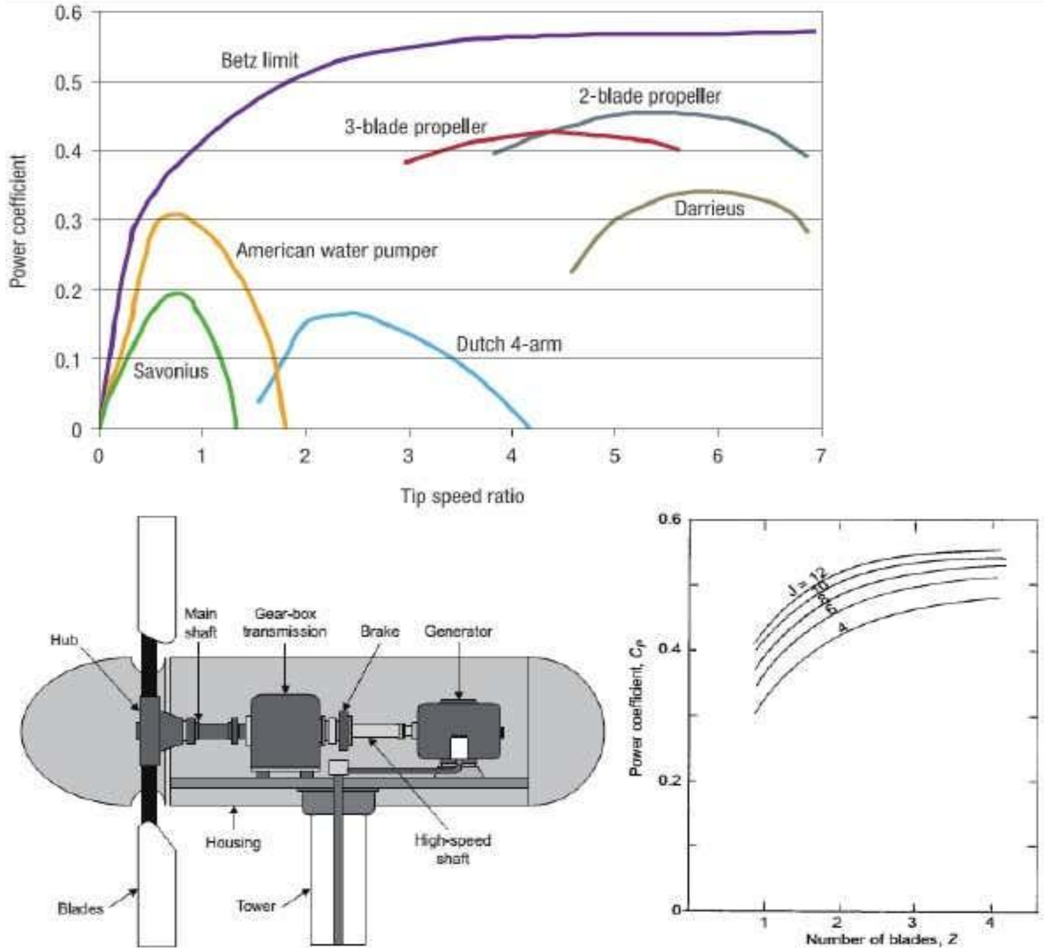

Fig.1: Simplified wind turbine design (a) [4]. The effect of tip speed ratio and number of blades on power coefficient in zero friction conditions (b) [4]

As for axis orientation, VAWTs (Fig. 2e, f) designs being less efficient than HAWT ones, are used mainly for small-scale. A key factor causing lower efficiency of VAWT is that, each blade reaches maximum lift force only in a single point per rotation. Maximum efficiency of wind turbines is indicates by Betz's low, which states at maximum amount of kinetic energy that may be theoretically derived from wind and converted into mechanical energy cannot be greater than 59.3%. Figure 2 illustrates a comparison of power coefficients of several wing plant designs against BETZ's limit. It shows that the only promising solutions are two and three blade constrictions. Is should be noted that currently produced wind turbines do not reach 100% Betz limit, which is why a construction is considered to be well designed if it can reach power coefficient 35-45% [2].

Fig. 2: Wind turbine designs: (a) Darrieus, (b) American water pumper, (c) 2-blade design, (d) Savonius, (e) Dutch 4-arms (g) 3-blade design.

The power generated by wind turbines is expressed by the formula:

$$P = \frac{1}{2}\rho A V^3 C_P$$

P – Rotor generated power, **ρ**– air density, **A** – swept area, described as circle drawn by rotating blades, V^3 – Wind speed, **Cp** – power coefficient.

Figure 3a illustrates relationship between the power generated by the wind turbine and wind speed. At wind speeds less than 5 m/s the turbine generates no power at all. Maximum efficiency is achievable at speed of over 12 m/s.

The main differences in the approaches in wind turbines design are related to:

a) Constant or variable operating speed,
b) Direct drive or gearbox generators,
c) Stall controlled or pitched controlled.

Wind turbine axle rotates at speed of 20 rpm or less. The aim of the gearbox is to increase of rotation speed up to 1200-1800 rpm, a speed that is better suited to generator operation. Changes wind conditions generate highly variable and difficult to predict high forces that place heavy load on the gearbox especially the bearings and the cogs. Some of the constructions utilize epicyclic gearing with planet gears turn around the sung gear, while others utilize worm drives, while manufacturers keep increasing the strength of gear wheels and bearings, gearboxes continue to require frequent servicing due to harsh operating conditions caused by variable wind loads. Gearbox repairs are among the most costly servicing actions. For example, replacing damage gearbox in a large wind turbine generate an expenditure of up to 1 million Euro. Most of large wind turbines are equipped with hydraulic or pneumatic brake disc clamping system. Some of the turbines employ highly efficient braking systems; however, the standard solution is to switch to idle by using pitch change system and the braking system to stop only the rotor and preventing it from rotating freely. [10]

Wind power plants generators and control system

An important part of the wind turbine is the generator converting mechanical energy to electrical. As the rotation speed of the generator increases, its size and weight decrease. The generators contain only one or two bearings, which are put under heavy load. Proper mounting of the generator shaft relative to the gearbox shaft is critical for the correct operation of the entire turbine system. Generators can be divided into three main groups:

a) Induction generators,
b) Permanent magnet generators,
c) Synchronous generators.

In the past synchronous generators, ware rarely due to the necessity to adjust accurately to the frequency the electro energetic network. However, in recent years this type of construction successfully returns in turbines with a direct drive. In large-scale wind turbines, the most commonly used generators are induction generators producing alternating current (AC) of 50-60 Hz. The advantage of using induction generator is their simple construction and certain flexibility in the rotational speed of approximately, which make it possible for the turbine system to adjust to occasional wind gusts. In the course of many years, the design of induction generators has undergone modifications, among which was the implementation of energy-electronic systems called power converters, which allows adjustments in the rotational speed. The power converters also synchronize the generators with the electro energetic grid. Increasingly, utility-scale turbines have begun employing generators with permanent magnets. Permanent magnets used in modern generators designs are made of rare earth metals, which allows for the generation stronger magnetic field. The higher price of such materials is their major disadvantage. Despite the fact, permanent magnets generators are larger and more expensive than induction generators, their offer smaller power loss, increased reliability, and efficiency, even during operation under low load. [11] Nowadays, gearless transmissions are becoming increasingly popular. This trend is related to the fact that, apart from the torque, the transverse and lateral forces are also often relayed to the transmission through the main shaft [1]. Direct-drive generators are starting to be particularly popular in high power turbines at sea. This solution is beneficial due to the elimination of turbine gear servicing on marine farms where this operation can be complicated and time consuming. The lower rotational speed of direct-driven systems also increases the lifespan of the structure. The disadvantage of using direct drives and low speed generators is their resulting greater overall dimensions and hence the weight, which increases the cost of construction. Direct-drive turbines employ two-generator systems for low and high-speed operation. Another solution may be to use a variable speed generator. This, however, has its own disadvantages, because the result will be a variable current that forces the use of an AC-DC-AC converter, which again increases the cost of turbine production. [12]

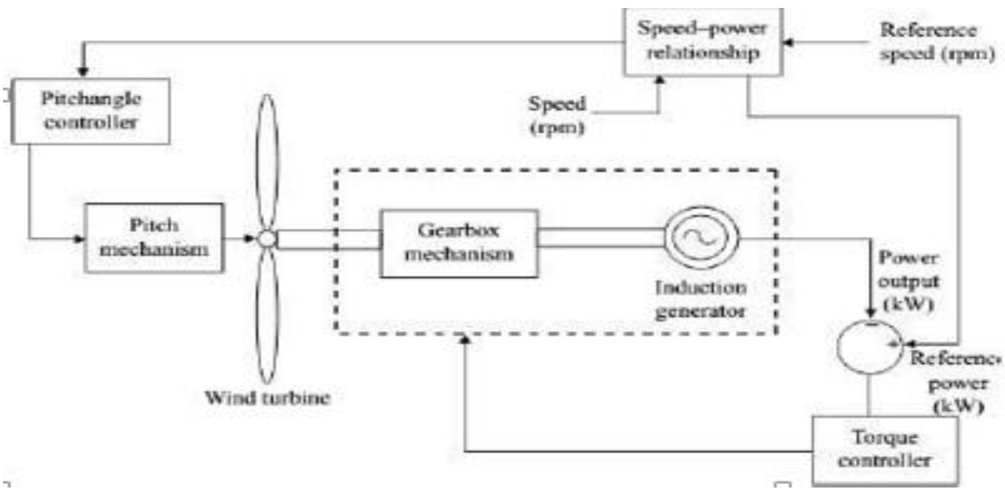

Fig.3: A diagram of a variable-speed wind turbine with adjustable blade pitch [6]

Another important element of the wind turbine design is a control system integrating signals from many of the sensors installed on its components. This system optimizes turbine operation and ensures safety in the event of a malfunction or sudden deterioration of the weather conditions. The control system must continuously control many of the parameters responsible for the efficient operation of the turbine, such as:

a) Positioning the blades in optimal direction relative to the wind,
b) Setting the appropriate pitch of the blades,
c) Starting and stopping,
d) Energy-electronics,
e) Cooling the components,
f) Controlling the de-icing system,
g) Diagnostics. [13]

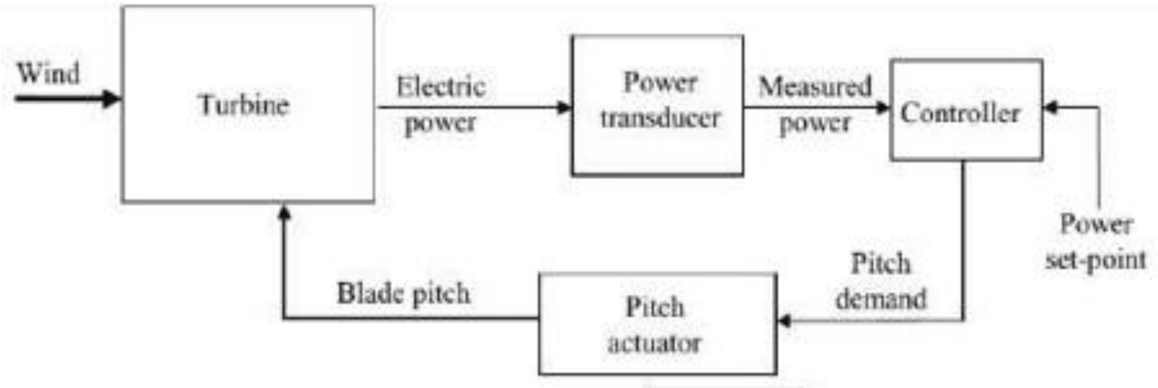

Fig. 4: A control loop for fixed-speed wind turbine with adjustable blade pitch [7]

To set up a wind power plant in Kano State Polytechnic, the following materials and equipment are required:

1. **Wind Turbines**: These are the primary components of a wind power plant, by choosing the appropriate size and quantity based on the expected energy demand. Different types of wind turbines are available, such as horizontal-axis and vertical-axis turbines.
2. **Tower Structures**: These structures provide support and elevation for the wind turbines. They are typically made of steel and need to be strong enough to withstand wind loads. The height of the tower will depend on the wind resource assessment in the area.
3. **Foundation Materials:** Depending on the terrain and soil conditions, it requires appropriate materials for the tower foundations. This may include concrete, rebar, and gravel or crushed stone for the base.
4. **Electrical Infrastructure**: To connect the wind turbines to the power grid or local electrical system, this requires cables, conductors, transformers, and switchgear equipment. These materials enable the transmission and distribution of the generated wind energy.
5. **Control Systems:** Wind power plants require advanced control systems to monitor and regulate the turbines' performance. This includes supervisory control and data acquisition (SCADA) systems, sensors, and communication equipment.
6. **Power Conditioning Equipment:** Use power conditioning equipment such as inverters or power converters to convert the variable output of the wind turbines into stable and usable electricity.
7. **Grid Interconnection Equipment:** If the power plant is connected to the grid, there is need for an equipment to synchronize the wind power plant with the existing electrical network. This includes protective relays, circuit breakers, and other grid interconnection devices.
8. **Meteorological Equipment:** Install weather monitoring instruments to collect data on wind speed, direction, temperature, and other relevant atmospheric conditions. This data helps optimize the wind power plant's performance and predict energy generation.
9. **Maintenance and Safety Equipment:** Stock up on tools, spare parts, and safety equipment required for regular maintenance and repairs. These include safety gear, ladders, safety harnesses, and general maintenance tools.
10. **Miscellaneous Materials:** Depending on the specifications of the wind power plant, other materials may be required, such as access roads, fencing, concrete for transformer pads, and lightning protection systems.

Constructing a wind power plant as an alternative source of electrical energy in Kano State Polytechnic, Nigeria, can yield several expected results:

1. **Renewable Energy Generation:** Building a wind power plant will enable the polytechnic to produce electricity from a clean and renewable energy source. This will help reduce the dependence on traditional fossil fuels and contribute to a more sustainable energy mix.
2. **Cost Savings:** By harnessing the power of wind, the polytechnic can potentially reduce its electricity expenses in the long run. Wind power plants have comparatively low operational and maintenance costs once the initial installation is complete.

3. **Environmental Benefits:** Wind energy is a clean and green source of electricity that produces no greenhouse gas emissions or air pollutants during operation. By adopting wind power, the polytechnic can contribute to reducing carbon dioxide emissions and mitigating environmental impact.
4. **Energy Security and Independence:** Owning a wind power plant provides the polytechnic with greater control over its energy supply. By diversifying the sources of electricity, the institution can reduce vulnerability to disruptions in the power grid and achieve greater energy security.
5. **Academic and Research Opportunities:** The construction of a wind power plant can create educational and research opportunities for students and institution. It can serve as a platform for learning about renewable energy technologies, electrical engineering, and sustainable development. Additionally, students can gain hands-on experience in wind energy system operations and maintenance.
6. **Community Impact:** The establishment of a wind power plant can have a positive impact on the local community. It can serve as an example of sustainable development and renewable energy adoption, inspiring others to consider clean energy solutions. Additionally, surplus electricity generated can potentially be shared with neighboring communities, contributing to their energy needs.

However, it is crucial to evaluate factors such as wind resource availability, site selection, grid integration, and economic feasibility when planning the construction of a wind power plant. Conducting comprehensive studies and engaging relevant stakeholders would ensure the successful implementation of the project.

Conclusion

After conducting a thorough assessment, it can be concluded that implementing a wind power plant as an alternative source of electrical energy in the School of Technology at Kano State Polytechnic in Nigeria would be a viable and beneficial option to Kano State, Nigeria at large, has favorable wind conditions, especially during certain seasons. The region experiences consistent wind patterns, making it suitable for harnessing wind energy. Wind power is a clean and renewable energy source, which aligns with the global need for reducing greenhouse gas emissions and combating climate change. By adopting a wind power plant, School of Technology can contribute to a greener and more sustainable campus.

Although the initial investment for setting up a wind power plant may be significant, the operational costs are relatively low. Once the plant is up and running, it can generate electricity at a lower cost compared to traditional sources, leading to potential long-term savings for the institution. With the integration of a wind power plant on campus, School of Technology can provide hands-on training and research opportunities for students. This would enable them to gain practical experience in renewable energy systems and contribute to the development of the local wind energy sector.

The implementation of a wind power plant would reduce the school's reliance on the national grid and conventional energy sources. This would enhance energy security and ensure a consistent and reliable power supply, even during grid outages, fuel shortage and recent hike price of fuel due to subsidy removal. School of Technology can serve as a role model for other educational institutions and the community at large. By embracing wind energy, they can inspire others to adopt clean energy solutions, thus promoting sustainable development and creating a positive impact on the surrounding community.

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