



Wind Energy Resource Assessment and Turbine Selection for Nigeria's Coastal Regions

A Comprehensive Feasibility Study

 Presenter: Ms. Fatima Abubakar

 Email: fair@ws-expo.com

 Website: www.nnepie.com

 Venue: Landmark Centre, Lagos, Victoria Island, Nigeria



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01

Research Background and Objectives

Nigeria's Energy Status and Challenges

Critical Power Supply Deficit

Installed capacity stands at 13,000 MW, but only 4,500–5,500 MW is reliably available. Peak demand exceeds 20,000 MW, creating a massive supply gap.

Low Access & Consumption

Over 40% of the population lacks grid access. Per capita consumption is a mere 143 kWh, significantly below the global average, hindering economic growth.

Over-reliance on Fossil Fuels

The energy mix is heavily skewed (86% Natural Gas, 14% Hydropower). Diversification into renewables like wind is urgently needed for sustainability.

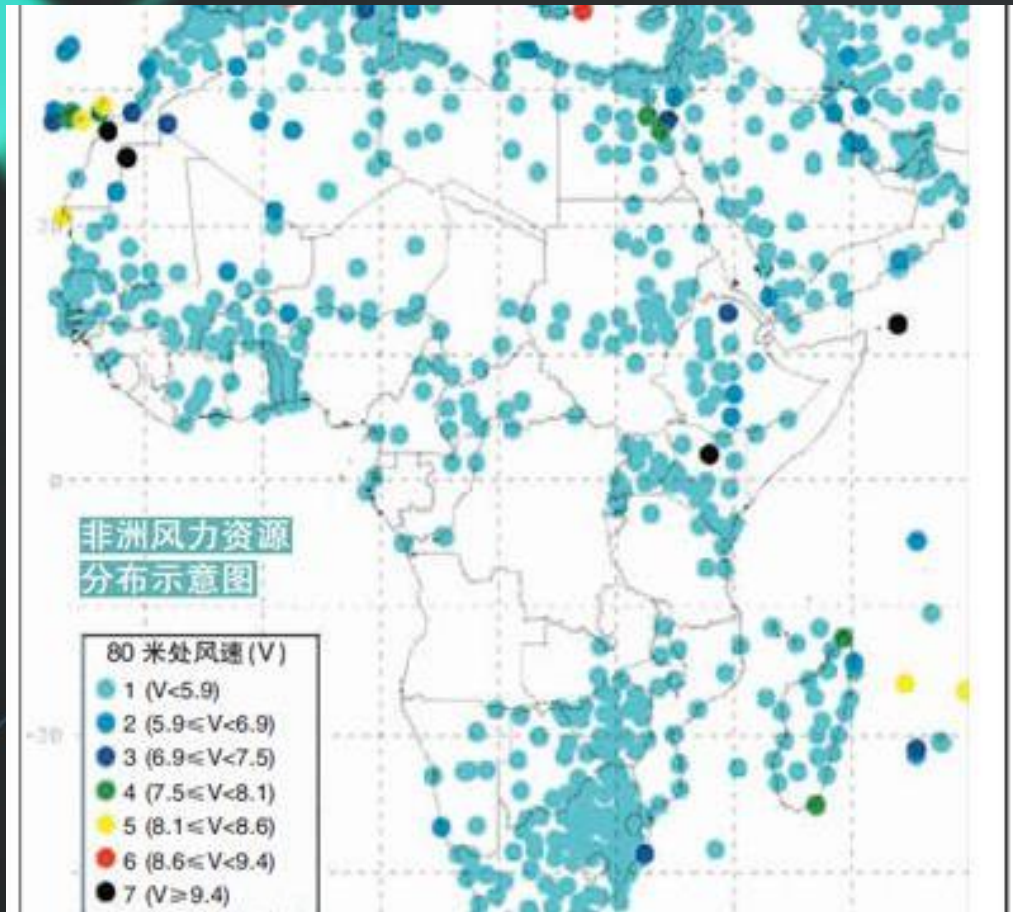
Energy Mix Composition



Electricity Capacity vs Demand (MW)



Global and African Wind Energy Trends



Global Growth & African Potential

The global market is projected to exceed 150 GW by 2025. Africa, though emerging, is set to reach 51.2 GW by 2025, with Nigeria positioned as a key player due to its favorable coastal wind regimes.



2025 Global Projection

150+ GW



2025 Africa Capacity





51.2 GW

Global Wind Energy Additions (GW) 2020-2030






Research Objectives and Scope

Core Objectives

-  **Assess Wind Energy Potential**
Analyze speed, direction, and density characteristics in coastal regions.
-  **Provide Turbine Selection Guidelines**
Recommend appropriate models based on specific wind conditions.
-  **Identify Key Challenges**
Evaluate technical, economic, and regulatory hurdles to development.
-  **Propose Strategic Solutions**
Offer actionable strategies to accelerate wind energy adoption.

Scope of Work

-  **Geographical Focus**
Coastal states: Lagos, Ondo, Delta, Rivers, Bayelsa, Akwa Ibom.
-  **Resource Evaluation**
Comprehensive assessment of both onshore and near-shore wind resources.
-  **Technology Consideration**
Incorporation of the latest turbine technologies from leading global manufacturers.

02

Overview of Nigeria's Wind Energy Resources

National Wind Resource Distribution



Northern Regions (Katsina & Sokoto)

Peak Wind Speed: **Up to 7 m/s**

Characterized by seasonal Harmattan winds, these areas experience the highest wind speeds in the country at 10m height. However, the resource is highly seasonal and may require energy storage solutions for year-round stability.

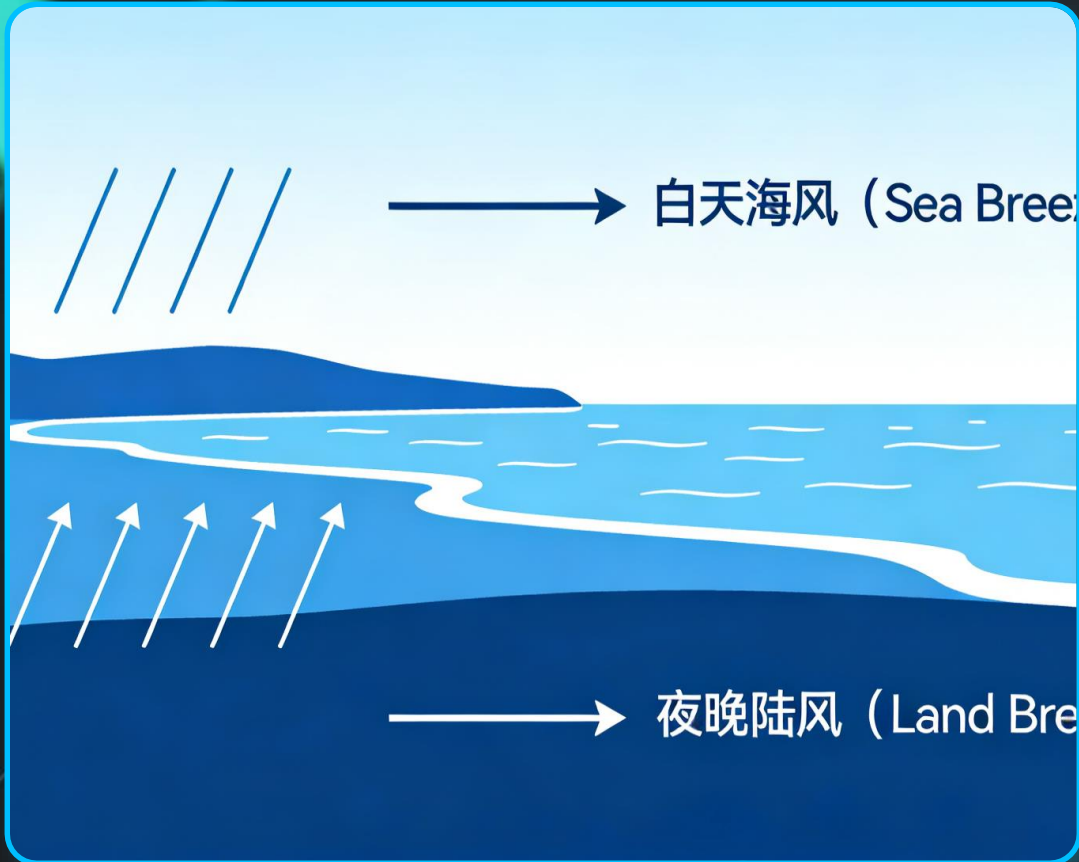


Coastal Regions (Lagos to Akwa Ibom)

Resource Stability: **Highly Consistent**

Driven by the sea breeze effect, this belt offers a stable wind regime throughout the year. Proximity to major load centers (e.g., Lagos) and lower turbulence make it the most commercially viable zone for immediate large-scale wind farm development.

The Uniqueness of Coastal Wind Resources



Stability & Predictability

Driven by the daily sea/land breeze cycle, coastal winds offer a reliable and consistent energy supply compared to inland sites.

Lower Turbulence

Smoother wind flow reduces mechanical stress on turbines, maximizing operational efficiency and extending equipment lifespan.

High Hub Height Potential

Higher wind speeds at elevated heights (e.g., 100m) significantly enhance energy production capabilities.

03

Coastal Wind Resource Assessment Methodology

Technical Methodology & Data Analysis

Key Steps in Wind Resource Assessment



01. Data Collection & Screening

Gather meteorological, satellite, and NWP data to identify promising sites with high wind potential.



02. Field Measurement Campaign

Deploy anemometer towers/LiDAR for ≥ 12 months to collect high-quality wind speed, direction, and turbulence data.



03. Data Processing & Validation

Clean, filter, and validate raw data to remove errors. Perform gap filling and ensure data integrity.



04. Resource Analysis & Modeling

Utilize Weibull distribution and software (WASP/OpenWind) to estimate wind speed distributions and energy yield.



05. Uncertainty Analysis

Quantify uncertainties from measurement errors, data length, and model assumptions to assess risk.



06. Reporting & Mapping

Compile findings into a comprehensive report and generate detailed wind resource maps for the study area.

Data Sources and Collection Methods



Meteorological Stations

Pros: Long historical records, high accuracy at point.

Cons: Limited coverage, low height (10m), unrepresentative.



Remote Sensing (Satellite & LiDAR)

Satellite: Wide spatial coverage for regional mapping.

LiDAR: Measures up to 200m height, ideal for complex/offshore terrain.



NWP Models (Numerical Weather Prediction)

Pros: High-res large area data, simulates complex terrain flow.

Cons: Requires on-site validation, computationally intensive.



On-Site Measurements (Anemometer Towers)

Pros: Gold standard for accuracy, detailed hub height data.

Cons: High cost, time-consuming (1+ year data needed).

Commonly Used Assessment Models & Tools



Weibull Distribution

- ✓ Widely used statistical model for describing wind speed probability distribution. Characterized by shape (k) and scale (c) factors, critical for calculating power density.
- ✓ Essential for estimating wind energy yield from raw data.



WAsP Software

- ✓ Industry-standard tool for wind resource assessment and micro-siting.
- ✓ Developed by Risø DTU Lab, focusing on wind climate and flow modeling.
- ✓ Capable of handling complex terrain and calculating energy production.



OpenWind Platform




- ✓ Flexible platform for detailed wind farm design and feasibility studies.
- ✓ Advanced features for turbine layout optimization and wake effect modeling.
- ✓ Integrates financial analysis for comprehensive project evaluation.

04

Data and Analysis of Nigeria's Coastal Wind Resources

Coastal Wind Speed and Power Density Analysis

Key Findings & Site Analysis


-  **Warri (Koko) – Most Promising**
7.29 m/s | 237.6 W/m² (Class III). Best onshore potential.
-  **Apapa Port – Height Advantage**
Speed increases to 6.44 m/s at 100m hub height.
-  **Offshore Potential – Untapped Gold**
Speeds up to 4x higher than onshore (>500 W/m²).

Commercial Viability

All analyzed regions fall into Class II to III wind sites, making them commercially viable for modern turbine installations.

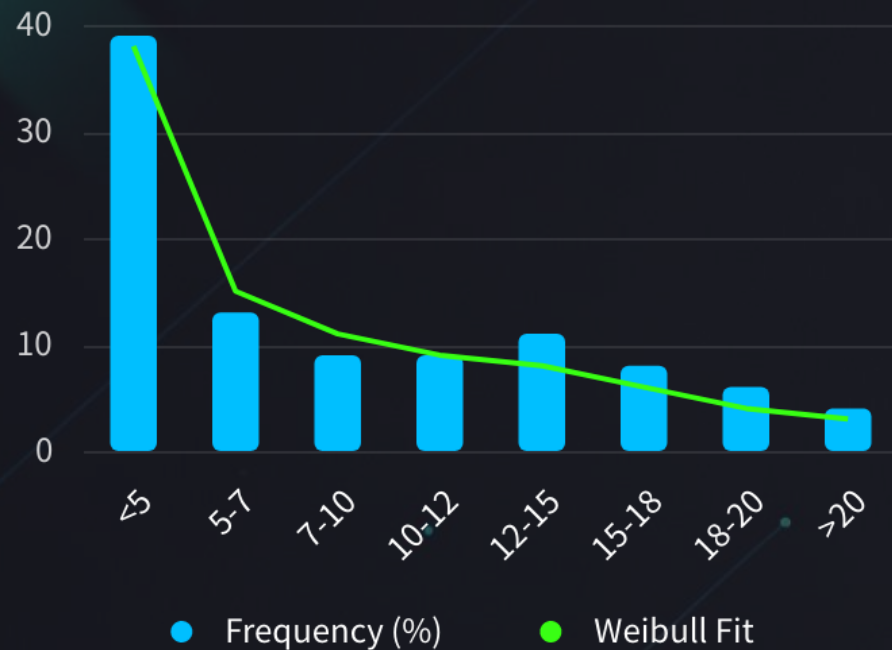
Annual Avg Wind Speed (10m Height)



-  Ibeno (Akwa Ibom) leads with 7.72 m/s, followed closely by Warri. Apapa shows the lowest 10m speed but improves significantly with height.

Wind Speed Frequency Distribution & Weibull Fitting

Lekki Peninsula: Wind Speed Frequency (%)



Weibull Parameters ($k=2.3$, $c=6.8$)

k -value (~ 2) indicates a wide distribution typical of coastal areas. c -value aligns with average wind speed, confirming a good fit.

Frequency Breakdown

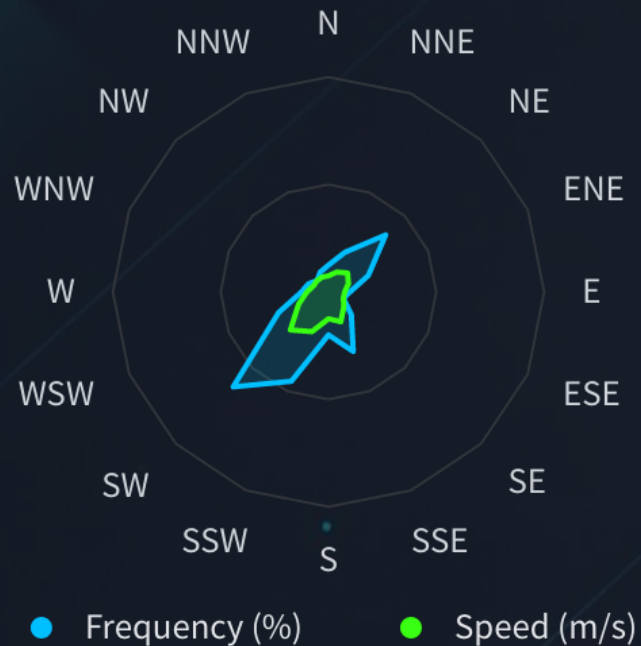
- 39% below 5 m/s (below cut-in)
- 30% between 7-15 m/s (optimal generation)
- 4% above 20 m/s (potential cut-out)

Turbine Selection Strategy

Prioritize turbines with low cut-in speeds and a broad optimal operating range to maximize energy capture.

Wind Rose Diagram Analysis

Niger Delta Wind Rose Data



📍 Dominant Direction: Southwest (SW)

Driven by Atlantic trade winds, this is the primary direction for most of the year with the highest energy potential.

🌀 Secondary: Northeast (NE) Harmattan

Seasonal shift (Dec-Feb) brings drier, persistent winds. Typically lighter but more dusty than SW winds.

🏠 Farm Layout Implications

Turbines should align perpendicular to SW winds. Spacing must account for wake effects to maintain efficiency.

CHAPTER 05

Turbine Selection Technology and Standards

Key Considerations for Turbine Selection

Wind Resource Characteristics

- Match power curve to Weibull distribution (k/c values)
- Select turbines with high turbulence tolerance
- Ensure withstand 50-year extreme wind speeds

Technical Specifications

- Larger rotors optimize energy capture at low speeds
- Align cut-in/rated speeds with site profile
- Taller hub height accesses more consistent winds

Environmental Conditions

- Account for temperature/humidity effects on performance
- Coastal sites need C5-M corrosion resistance
- Design for seismic activity and typhoon loads

Economic Factors

- CAPEX: Turbine cost, installation & balance of plant
- OPEX: Maintenance, access & spare parts
- LCOE: Ultimate measure of economic viability

Supply Chain & Local Content

- Leverage local manufacturing & assembly capabilities
- Assess logistics for transporting large components
- Ensure local maintenance support network

Strategic Decision Making

Turbine selection is a holistic process requiring balance across technical fit, environmental resilience, and economic viability. Success hinges on aligning all these factors to ensure long-term project sustainability.

Special Requirements for Coastal & Offshore Environments



Corrosion Protection

High-grade stainless steel, aluminum, and advanced coatings combat salt spray corrosion.

Typhoon & Extreme Wind Design

Reinforced towers and blades to withstand tropical cyclone gusts and turbulence.

Foundation Design

Monopile (shallow), Jacket (deep), or Floating (very deep) structures for seabed anchoring.

Installation & Maintenance

Requires heavy-lift vessels, weather windows, and remote monitoring for reliability.

Understanding Turbine Technical Specifications

Rated Power

Max output (e.g., 15 MW). Determines peak capacity; critical for high-wind sites.

Rotor Diameter

Swept circle size (e.g., 236m). Larger diameters capture more energy, especially at low speeds.

Cut-in Speed

Min speed to start (e.g., 3 m/s). Lower values mean more generation time at low-wind sites.

Rated Speed

Speed for max power (e.g., 13 m/s). Should align with the site's most frequent high-energy winds.

Cut-out Speed

Shutdown speed (e.g., 25 m/s). Must exceed the site's typical extreme wind speeds for safety.

Hub Height

Height to rotor (e.g., 160 m). Taller hubs access faster winds and reduce turbulence impact.

Power Coefficient (C_p)

Energy conversion efficiency (max ~ 0.59). Higher C_p means a more aerodynamically efficient design.

CHAPTER 06

Major Turbine Manufacturers and Their Products

Overview of Leading Global Manufacturers

Vestas (Denmark)

World's largest manufacturer, renowned for reliability and a broad product range for both onshore and offshore applications.

Siemens Gamesa (EU)

Leader in offshore wind, known for innovative direct-drive turbines and large offshore platforms.

Goldwind (China)

Largest Chinese manufacturer, focused on cost-effective PMDD (permanent magnet direct-drive) technology.

Mingyang (China)

Major player in offshore markets, known for hybrid drive technology and large offshore turbines.

GE Vernova (USA)

Offers diverse turbines with a strong focus on digital solutions and wind farm optimization.

Market Trends

The industry is rapidly shifting towards larger, more efficient offshore turbines and increased integration of AI for predictive maintenance.

Comparison of Mainstream Coastal/Offshore Turbine Models

Manufacturer	Model	Rated Power	Rotor Diam.	Hub Ht.	Key Technology
Vestas	V236-15.0 MW	15.0 MW	236 m	160 m	Gearbox, Large offshore platform
Siemens Gamesa	SG 15-236 DD	15.0 MW	236 m	155 m	Direct Drive, Offshore
Goldwind	GWH252-16MW	16.0 MW	252 m	170 m	PMDD, Ultra-large offshore
Mingyang	MySE 16.0-242	16.0 MW	242 m	166 m	Hybrid Drive, Offshore
GE Vernova	Haliade-X 13 MW	13.0 MW	220 m	150 m	Direct Drive, Offshore

📈 Strategic Analysis for Nigeria

🌸 Onshore Coastal Sites (e.g., Lagos)

Focus on large rotor diameters and low cut-in speeds to capture moderate winds efficiently. Models like Vestas V172-7.2 MW are recommended.

🏗️ High-Potential Offshore Sites

Deploy ultra-large 15-16 MW turbines (Vestas, Siemens Gamesa, Goldwind) for maximum energy capture and lowest LCOE.

Case Study: Vestas V236-15.0 MW Turbine



Key Features & Specifications

- ➡ **Enormous Rotor (236m)**
Covers 43,000 m² (6 soccer fields) with 115.5m blades.
- ⚡ **80 GWh Annual Output**
Powering ~20,000 European households per year.
- 📍 **Versatile & Proven**
Optimized for diverse wind conditions with high reliability.

Why Nigeria?

- 📍 The V236-15.0 MW is ideal for Nigeria's high-potential offshore sites. Its large rotor ensures significant clean energy delivery and a low Levelized Cost of Energy (LCOE), making it a strategic investment for the nation's renewable future.

Case Study: Siemens Gamesa SG 15-236 DD Turbine

Key Features & Innovations

Direct-Drive Technology

Gearbox elimination reduces failure points, cutting maintenance costs and boosting

236m Modular Rotor

Massive platform with modular design for easier transportation and installation of large components.

High Efficiency Design

Optimized aerodynamics and permanent magnet generator ensure maximum energy conversion.

Industrialized Production

Built for serial production and large-scale deployment, driving down overall project costs.

Strategic Fit for Nigeria Overcoming Maintenance Challenges



Nigeria's offshore environment can make access difficult and costly. The turbine's low-maintenance design minimizes the need for frequent trips, ensuring long-term operational

peace of mind.

High reliability is critical for remote offshore projects. The direct-drive system eliminates common failure points, making it a robust solution for Nigeria's ambitious wind energy



Cost-Effective Scalability

As Nigeria scales up its offshore wind capacity, the SG 15-236 DD's industrialized design ensures competitive LCOE (Levelized Cost of Energy).

CHAPTER 07

Challenges and Solutions

Key Challenges for Wind Energy Development in Nigeria

Weak Grid Infrastructure

- Underdeveloped grid unable to handle large power injections.
- High transmission losses (up to 40%).

Financing Barriers

- High upfront costs and perceived risks hinder affordable financing.
- Limited local institutional capacity for project funding.

Policy & Regulatory Uncertainty

- Lack of stable FiTs or PPAs to guarantee investor revenue.
- Lengthy and complex permitting/land acquisition processes.

Technical & Human Capacity Gaps

- Shortage of skilled professionals in assessment, installation & O&M.
- Absence of local manufacturing for turbine components.

Socio-Environmental Considerations

- Potential land use conflicts and need for robust ESIA's.
- Low public awareness of wind energy benefits.

Strategies and Recommendations to Overcome Challenges

Strengthen Grid Infrastructure

- Invest in transmission lines connecting wind-rich regions to load centers.
- Deploy grid-scale storage (batteries, pumped hydro) to manage variability.

Improve Financing Access

- Establish national renewable funds for concessional loans and grants.
- Implement attractive FiTs/auctions to de-risk investments.
- Leverage international climate finance (e.g., Green Climate Fund).

Clarify Policy & Regulation

- Enforce stable frameworks with clear permitting timelines.
- Simplify land acquisition for renewable projects.
- Standardize Power Purchase Agreement (PPA) templates.

Build Technical & Human Capacity

- Launch training programs with universities to develop local workforce.
- Incentivize technology transfer and local manufacturing of components.

Address Socio-Environmental Concerns

- Ensure community engagement and benefit-sharing from projects.
- Conduct transparent ESIA's and public awareness campaigns.

The Importance of International Cooperation & Technology Transfer



Global Partnerships

Nigeria can leapfrog development stages by fostering strong international alliances, building a sustainable, world-class wind energy industry.



Access to Capital

Low-interest loans and grants from IFIs and development banks.



Technology Transfer

Access to latest wind turbine tech & best practices in construction/O&M.



Capacity Building

Joint ventures and training programs develop skilled local workforce.



Knowledge Sharing

Learning from Denmark/Germany/India to avoid pitfalls and adopt proven policies.

08

Conclusions and Recommendations

Key Research Conclusions

Significant Coastal Potential

Regions like Warri and Ibeno are classified as Class II-III wind areas, offering commercially viable resources for modern turbines.

Immense Offshore Opportunity

Offshore resources are far more abundant, with power densities potentially four times higher than onshore, representing a massive untapped source.

Technology Readily Available

Leading global manufacturers offer a wide range of onshore and offshore models well-suited to Nigeria's coastal conditions.

Challenges are Surmountable

Grid, finance, and policy hurdles can be addressed through targeted investments, reforms, and international collaboration.

Strategic Development is Key

Focus first on high-potential sites with good grid access and leverage partnerships to build local capacity.

Recommendations for Future Development



Launch Demonstration Projects

Initiate 1-2 GW-scale onshore wind farms in high-potential coastal states (Delta, Ondo) to build confidence and test grid integration processes.



Accelerate Grid Development

Prioritize a coastal transmission backbone to connect wind-rich areas to major load centers like Lagos and Port Harcourt.



Implement Supportive Policies

Urgently implement clear policies including a competitive auction mechanism and standardized PPAs to attract private investment.



Build Local Capacity

Establish a Nigerian Wind Energy Institute to train professionals and incentivize local manufacturing of turbine components.



Plan for Offshore Wind

Begin pre-feasibility studies in the Gulf of Guinea to position Nigeria as a future leader in African offshore wind development.

Future Outlook

Nigeria stands at the threshold of a renewable energy revolution, harnessing its vast coastal wind resources to transform the nation.



Achieve Energy Security

Significantly reduce reliance on fossil fuels and stabilize power supply for a more resilient nation.



Drive Economic Growth

Create thousands of jobs in manufacturing and construction while attracting billions in foreign investment.



Lead Africa's Green Transition

Position Nigeria as a regional leader in renewable energy technology and expertise across the continent.



Combat Climate Change

Contribute to global goals by reducing emissions and developing a sustainable, low-carbon economy.

Appendix A: Detailed Data Tables

 Table A1: Wind Resource Data for Selected Coastal Sites (10m Height)

Location	Latitude	Longitude	Avg Speed (m/s)	Power Density	Weibull k	Weibull c
Lagos (VI)	6° 27' N	3° 24' E	6.25	171.47	2.1	7.0
Warri (Koko)	5° 50' N	5° 45' E	7.29	237.60	2.4	8.1
Apapa Port	6° 25' N	3° 21' E	4.64	67.51	1.9	5.2
Ibena	4° 34' N	8° 04' E	7.72	344.68	3.29	8.24
Port Harcourt	4° 47' N	7° 00' E	3.31	23.22	3.64	3.43

 Table A2: Wind Speed Frequency Distribution for Lekki Peninsula

Wind Speed Range (m/s)	<5	5-7	7-10	10-12	12-15	15-18	18-20	>20
Frequency (%)	39	13	9	9	11	8	6	4

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Appendix C: Contact Information



Report Prepared by

Ms. Fatima Abubakar



For further inquiries



Email: fair@ws-expo.com



Website: www.nnepie.com



Address: Landmark Centre, Lagos, Victoria Island, Nigeria



Collaboration & Discussion

We welcome discussions and collaboration on the development of Nigeria's wind energy sector.

Whether you are a stakeholder from the public or private sector, we are eager to engage with you to advance Nigeria's wind energy agenda and explore potential opportunities.



Thank You

Thank You for Your Attention

"The future belongs to those who believe in the beauty of their dreams." — Eleanor Roosevelt

Let us dream of a Nigeria powered by the wind.

