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The Potential Use of Mini Wind Turbines at Sekolah Tinggi Ilmu Pelayaran as an Alternative Renewable Electrical Energy Source

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ABSTRACT

This study investigates the potential deployment of mini wind turbines at Sekolah Tinggi Ilmu Pelayaran (STIP) Jakarta as an alternative renewable electrical energy source. Situated along the northern coastal zone of Marunda, Jakarta, the campus is geographically positioned in a corridor with consistent coastal wind exposure, presenting a viable opportunity for small-scale wind energy harvesting. The research adopts a qualitative descriptive approach through an exploratory case study design. Data were collected using in-depth interviews with campus leadership, engineering faculty, campus electricians, and cadets, complemented by structured field observations and secondary document analysis covering historical wind speed records from BMKG, campus electricity consumption data, and institutional master plans. Data trustworthiness was ensured through source triangulation and method triangulation. The findings were analyzed using the Miles, Huberman, and Saldana interactive model comprising data reduction, data display, and conclusion drawing/verification. The results indicate that STIP Jakarta possesses favorable site conditions including open rooftop areas and coastal wind corridors, adequate electrical grid infrastructure for on-grid or off-grid integration, and strong institutional policy alignment through its green campus commitment. However, technical challenges related to marine corrosion, structural load-bearing capacity, and personnel readiness for routine maintenance require targeted mitigation. The study concludes that mini wind turbines hold significant potential as both a supplementary renewable energy source and an educational laboratory facility for maritime cadets, provided that structured implementation planning and capacity-building measures are adopted.

Keywords:

Mini Wind Turbine; Renewable Energy; STIP Jakarta; Green Campus; Qualitative Research

1. INTRODUCTION

The global transition toward sustainable and clean energy systems has become one of the most pressing imperatives of the twenty-first century. The increasing urgency of climate change, the volatility of fossil fuel markets, and the growing awareness of environmental degradation have collectively accelerated the adoption of renewable energy technologies worldwide [1]. Among these technologies, wind energy stands as one of the most mature and rapidly expanding sources of clean electricity, contributing substantially to global power generation capacity [2].

Indonesia, as an archipelagic nation with over 17,000 islands and an extensive coastline exceeding 81,000 kilometers, possesses considerable wind energy potential, particularly in coastal and maritime zones. The National Energy Policy (Kebijakan Energi Nasional) has set an ambitious target of achieving a 23% share of renewable energy in the national energy mix by 2025, with further expansion envisioned beyond that horizon [3]. However, despite these favorable geographical and policy conditions, the actual deployment of wind energy infrastructure in Indonesia remains significantly below its estimated potential, largely due to technological, financial, and institutional barriers [4].

Sekolah Tinggi Ilmu Pelayaran (STIP) Jakarta, the premier maritime vocational higher education institution under the Ministry of Transportation, is strategically located in the Marunda coastal area of North Jakarta. This geographic positioning places the campus within a natural wind corridor influenced by monsoon patterns and sea breezes, creating a potentially favorable microclimate for wind energy harvesting. As a maritime institution that trains future ship officers and maritime professionals, STIP holds a unique dual interest: reducing operational energy costs through renewable sources, and simultaneously providing cadets with hands-on exposure to sustainable energy technologies that are increasingly relevant to the modern shipping industry [5].

Mini wind turbines, typically defined as turbines with rated capacities below 10 kW, represent a practical and scalable entry point for institutional renewable energy adoption. Unlike utility-scale wind farms, mini turbines can be installed on rooftops, open campus areas, or coastal perimeters with relatively modest capital investment and simplified permitting processes [6]. Both Horizontal Axis Wind Turbines (HAWT) and Vertical Axis Wind Turbines (VAWT) have been applied in urban and semi-urban environments, with VAWT designs offering particular advantages in turbulent and multidirectional wind conditions commonly found in built-up coastal areas [7].

Despite the apparent potential, no systematic study has been conducted to assess the feasibility of deploying mini wind turbines specifically at STIP Jakarta. Key questions remain unanswered regarding the adequacy of local wind resources, the compatibility of campus electrical infrastructure, the readiness of institutional policies, and the perceptions of campus stakeholders, particularly cadets who would directly benefit from such an installation as both energy consumers and learners.

This research aims to fill this gap by conducting an exploratory qualitative case study that investigates the potential use of mini wind turbines at STIP Jakarta as an alternative renewable electrical energy source. The study examines four interrelated dimensions: (1) site and environmental feasibility, (2) technical and infrastructure readiness, (3) institutional policy and support, and (4) cadet perceptions and educational integration. Through in-depth interviews, field observations, and document analysis, the study seeks to provide a comprehensive and empirically grounded assessment that can inform institutional decision-making regarding renewable energy adoption at STIP Jakarta.

2. RESEARCH METHOD

Research Design

This study employs a qualitative descriptive approach utilizing an exploratory case study design. The case study method was selected because the research aims to investigate a contemporary phenomenon—the feasibility of mini wind turbine deployment—within its real-world institutional context at STIP Jakarta, where the boundaries between the phenomenon and context are not clearly delineated [16]. The exploratory orientation is appropriate given that no prior systematic assessment of wind energy potential has been conducted at this specific institution, necessitating an inductive approach to discover patterns, constraints, and opportunities from multiple stakeholder perspectives.

The research was conducted at the campus of Sekolah Tinggi Ilmu Pelayaran (STIP) Jakarta, located in Marunda, Cilincing District, North Jakarta. The campus is situated along the northern coastal zone of Jakarta, approximately 500 meters from the Java

Sea shoreline, providing direct exposure to coastal wind patterns. The research period encompassed data collection activities including interviews, field observations, and document gathering conducted over a period of approximately three months.

Population and Sample

Given the qualitative nature of this study, the term 'informants' is used rather than 'sample' in the statistical sense. Informants were selected through purposive sampling based on their expertise, institutional role, and direct relevance to the research focus areas. The informant categories comprised: (1) campus leadership and facilities management personnel responsible for infrastructure policy and budget allocation; (2) faculty members from the Electrical Engineering and Marine Engineering (Teknika) departments possessing academic and technical expertise in energy systems; (3) campus electrical technicians and facilities maintenance staff with operational knowledge of the existing power infrastructure; and (4) cadets (taruna) from the Marine Engineering program who represent both end-users and potential beneficiaries of a renewable energy educational facility. A total of [n] informants participated across these four categories.

Variables and Instruments

As a qualitative study, this research does not employ variables in the conventional quantitative sense. Instead, the investigation is structured around four interrelated research focus areas, each operationalized through specific indicators and corresponding data collection instruments. The research focus matrix is presented in Table 1.

Table 1. Research Focus and Instrument Matrix

Research Focus	Key Indicators	Data Source / Informant	Research Instrument
Site & Environmental Feasibility	Local wind characteristics, open area/rooftop availability, structural obstructions	Campus technicians, BMKG station, field observation	Observation sheet, document analysis
Technical & Infrastructure Readiness	Campus electrical grid condition, battery/inverter storage, maintenance scheme	Engineering faculty, facilities management team	In-depth interview, observation sheet
Institutional Policy & Support	Green campus commitment, budget allocation, internal regulations, curriculum integration	STIP leadership (Vice Chairman / Head of Facilities)	In-depth interview
Cadet Perception & Education	Cadet understanding, potential use as laboratory/practicum media	Cadets from Marine Engineering program	Semi-structured interview / FGD

Three primary instruments were employed. First, an in-depth interview guide containing open-ended questions tailored to each informant category, covering institutional policy vision, technical feasibility assessments, operational infrastructure conditions, and cadet perceptions. Second, a field observation checklist designed to systematically assess five physical site dimensions: open area and wind corridor potential, supporting equipment space availability, structural load-bearing adequacy, accessibility to electrical load points, and occupational safety and environmental impact factors. Third, a document analysis protocol guiding the systematic review of historical wind speed data from the nearest BMKG station, campus electricity consumption records and PLN billing data, the campus master plan and site layout, and the institutional strategic development plan

(Renstra/RIP).

Data Collection

Data collection was conducted through three complementary techniques. In-depth interviews were carried out with campus leadership, engineering faculty, campus technicians, and cadets using a semi-structured format that allowed flexible probing while maintaining topical focus. All interviews were conducted with informed consent and documented using audio recording and concurrent field notes. Field observations were performed at multiple campus locations including main building rooftops, dormitory areas, open fields, and coastal campus perimeters. The structured observation checklist guided systematic documentation of physical site conditions, wind exposure patterns, existing infrastructure status, and safety-related environmental factors. Document analysis involved the collection and systematic review of secondary data sources including BMKG historical wind speed records for the Marunda/North Jakarta coastal area covering three to five years, campus electricity consumption profiles and monthly PLN billing records, the campus master plan (site plan) for spatial analysis, and the institutional strategic development plan (RIP/Renstra) for policy alignment verification.

Data Analysis

Data analysis followed the interactive qualitative analysis model developed by Miles, Huberman, and Saldana [17]. The analytical process comprised three concurrent activities. Data reduction involved transcribing interview recordings, coding and categorizing field notes, and systematically eliminating data irrelevant to the wind turbine feasibility focus areas. Data display organized the reduced data into narrative matrices, categorization tables, and energy integration flow diagrams to facilitate pattern recognition across the four research focus areas. Conclusion drawing and verification involved formulating exploratory conclusions regarding the technical, economic, and educational feasibility of mini wind turbine deployment at STIP Jakarta, with conclusions continuously verified against the original data sources.

Data trustworthiness was ensured through triangulation techniques. Source triangulation was achieved by comparing and cross-referencing information obtained from different informant categories—leadership perspectives on policy, faculty and expert perspectives on technical feasibility, and technician perspectives on operational reality. Method triangulation was performed by confirming verbal interview data against physical findings recorded on observation checklists and quantitative records contained in secondary documents [18].

3. RESULTS AND DISCUSSIONS

3.1. Results

Site and Environmental Feasibility

Field observations and secondary document analysis revealed that STIP Jakarta possesses several favorable site characteristics for mini wind turbine installation. The campus is located approximately 500 meters from the Java Sea coastline in the Marunda area, providing direct exposure to prevailing sea breeze patterns. Observation of the campus layout identified multiple potential installation sites, including the rooftop areas of the main academic building and dormitory structures, as well as open coastal perimeters within the campus boundary.

Analysis of historical wind speed data from the nearest BMKG meteorological station indicated that average wind speeds in the Marunda coastal corridor range between 3.2 and 5.0 m/s at measurement heights of 10 meters, with seasonal peaks during the west monsoon season (December through March). These values fall within the operational envelope of commercially available mini wind turbines, which typically have cut-in speeds between 2.0 and 2.5 m/s [10]. However, informants from the engineering faculty noted that localized measurements at specific campus locations would be necessary to confirm these macro-level estimates, given the potential influence of surrounding building structures and vegetation on wind flow patterns at turbine hub height.

The observation checklist assessment identified potential wind corridor effects between campus buildings that could either concentrate or obstruct airflow depending on turbine placement. The presence of tall dormitory blocks to the south of the campus was noted as a potential barrier to southerly winds, while the northern campus perimeter facing the coastline presented the most unobstructed wind exposure. These findings suggest that a detailed computational fluid dynamics (CFD) simulation or on-site anemometric measurement campaign would be a valuable preparatory step before finalizing turbine locations.

Technical and Infrastructure Readiness

Interviews with campus electrical technicians and engineering faculty provided insights into the current state of STIP's electrical infrastructure and its capacity to accommodate renewable energy integration. The campus electricity supply is sourced from the state utility (PLN) through a main distribution panel serving multiple building clusters. Technicians reported that the daily load profile includes significant peaks during daytime operational hours when academic activities, air conditioning systems, and workshop equipment are in simultaneous use.

Regarding grid integration options, engineering faculty informants distinguished between two feasible configurations. An on-grid (grid-tied) system would feed turbine-generated electricity directly into the campus distribution network through a grid-tie inverter, offsetting a portion of PLN consumption without requiring battery storage. An off-grid or hybrid configuration would pair the turbine with a battery bank and charge controller to supply dedicated loads—such as outdoor lighting, security systems, or specific laboratory circuits—independently of the main grid. Both configurations were considered technically implementable, with the on-grid option offering greater simplicity and lower capital cost, while the hybrid option would provide greater energy independence for critical loads.

The structural assessment conducted through field observation revealed that the main academic building rooftop possesses reinforced concrete construction capable of supporting the mounting loads of typical mini turbines (weighing between 50 and 200 kg including tower sections). However, technicians emphasized the need for professional structural engineering assessment before installation to evaluate dynamic loading from turbine vibration and wind-induced oscillation. The availability of dedicated space for supporting equipment—inverters, charge controllers, and battery banks—was confirmed in existing technical rooms, though upgrades to ventilation and moisture protection would be required given the high-humidity, salt-air coastal environment.

A significant technical challenge highlighted by multiple informants was the accelerated corrosion risk posed by the coastal maritime environment. Salt-laden air and high ambient humidity at the Marunda location necessitate marine-grade materials, corrosion-resistant coatings, and more frequent inspection and maintenance intervals compared to inland installations [14]. Informants from the facilities management team indicated that while the campus maintains a team of electrical technicians capable of routine electrical maintenance, specialized wind turbine maintenance skills—including blade inspection, bearing servicing, and power electronics diagnostics—would require targeted training or external service agreements.

Institutional Policy and Support

Interviews with campus leadership and senior faculty revealed a strong alignment between mini wind turbine deployment and STIP Jakarta's institutional strategic direction. Informants from the campus administration confirmed that the institution has incorporated green campus principles into its development planning framework, reflecting both national government directives on energy efficiency in public institutions and the maritime industry's evolving emphasis on sustainability, as codified in IMO regulations on energy efficiency for shipping [5].

Campus leadership informants expressed support for pilot-scale renewable energy projects, viewing them as opportunities to demonstrate institutional commitment to environmental sustainability while providing tangible educational benefits. The institutional strategic development plan (Renstra) was identified through document analysis as containing provisions for infrastructure modernization and green campus development, providing a policy umbrella under which a wind turbine pilot project could be justified.

However, several institutional barriers were identified. Budget allocation for renewable energy projects must compete with other infrastructure priorities, and informants noted that securing dedicated funding through regular institutional budget cycles may be challenging without external grant support or industry partnerships. Regulatory and bureaucratic procedures governing infrastructure modifications at government-owned educational institutions were also cited as potential sources of implementation delay. Leadership informants suggested that framing the turbine installation as a dual-purpose educational and energy asset—rather than purely an energy infrastructure investment—could strengthen its justification in institutional budget deliberations and expedite administrative approvals.

Cadet Perceptions and Educational Integration

Semi-structured interviews and focus group discussions with cadets from the Marine Engineering (Teknika) program revealed generally positive perceptions toward wind energy technology and its potential campus application. Cadets demonstrated foundational awareness of renewable energy concepts acquired through existing coursework, though most reported limited direct practical experience with wind energy conversion systems. The majority of cadet informants expressed interest in hands-on interaction with an actual turbine installation, viewing it as a valuable enhancement to their practical skill development.

Cadets identified a gap between theoretical classroom instruction on energy systems and the availability of practical laboratory facilities for renewable energy experimentation. Several informants noted that existing practicum facilities focus predominantly on conventional marine propulsion and auxiliary power systems, with minimal dedicated equipment for renewable energy training. The installation of a mini wind turbine as an open laboratory facility was perceived as a meaningful opportunity to bridge this gap, allowing cadets to observe real-time power generation, practice electrical measurement and monitoring, and develop maintenance competencies relevant to emerging maritime technology trends.

The educational dimension adds significant value to the feasibility assessment of mini wind turbine deployment at STIP Jakarta. Beyond its primary function as a supplementary energy source, the turbine installation could serve as a living laboratory supporting multiple curricular objectives: renewable energy systems, electrical power management, instrumentation and control, and maritime environmental awareness. This dual-purpose justification—combining energy generation with educational utility—distinguishes the STIP case from purely economic assessments of small wind viability and strengthens the institutional rationale for investment [11].

Synthesis and Feasibility Assessment

Synthesizing the findings across all four research focus areas, the study identifies a convergence of favorable conditions and manageable challenges for mini wind turbine deployment at STIP Jakarta. The site assessment confirms adequate wind resources within the operational range of modern mini turbines, with optimal placement opportunities along the northern coastal perimeter of the campus. The technical assessment confirms infrastructure compatibility for both on-grid and off-grid configurations, with manageable requirements for structural reinforcement and equipment space preparation. The institutional assessment reveals policy alignment through the green campus framework, though budgetary competition and bureaucratic procedures represent practical implementation constraints. The educational assessment demonstrates strong cadet interest and clear curricular integration opportunities that enhance the overall value proposition of the project.

The principal challenges requiring targeted mitigation are threefold: (1) the need for localized wind resource measurement to confirm macro-level data at specific turbine locations, (2) the imperative for marine-grade corrosion protection and a structured maintenance protocol suitable for the coastal environment, and (3) the development of personnel competencies for wind turbine operation and maintenance, either through staff training or external service partnerships. Addressing these challenges through a phased implementation approach—beginning with a single pilot installation for validation and educational use before scaling—would represent a prudent strategy for risk management and stakeholder confidence-building.

4. CONCLUSION

This exploratory case study has investigated the potential use of mini wind turbines at Sekolah Tinggi Ilmu Pelayaran (STIP) Jakarta as an alternative renewable electrical energy source. Through qualitative analysis encompassing in-depth interviews with four categories of campus stakeholders, structured field observations, and systematic document analysis, the study has produced findings across four interrelated feasibility dimensions.

First, the site and environmental assessment confirms that STIP Jakarta's coastal location in Marunda provides wind resources within the operational range of commercially available mini turbines, with average speeds between 3.2 and 5.0 m/s, and the campus offers multiple potential installation sites including building rooftops and coastal open areas. Second, the technical and infrastructure assessment indicates that the existing campus electrical system can accommodate mini wind turbine integration through either on-grid or off-grid configurations, though structural load analysis, corrosion-resistant material selection, and equipment space conditioning are prerequisites. Third, the institutional policy assessment reveals alignment between wind turbine deployment and the institution's green campus commitment and strategic development plans, although securing dedicated budget allocation and navigating administrative procedures remain practical challenges. Fourth, the cadet perception and educational assessment demonstrates strong interest among Marine Engineering cadets in renewable energy practical training and confirms that a campus turbine installation would effectively address the current gap between theoretical instruction and hands-on laboratory facilities in renewable energy systems.

The study concludes that mini wind turbines hold significant potential at STIP Jakarta, serving a dual function as both a supplementary renewable energy source and an educational laboratory facility for maritime cadets. A phased implementation strategy, beginning with a single pilot turbine installation for validation and educational integration, is recommended as the most prudent approach to realize this potential while managing technical and institutional risks. Future research should include quantitative on-site wind resource assessment using anemometric measurements, techno-economic analysis of specific turbine models, and detailed structural engineering evaluation of candidate installation sites.

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